

CLEAPSS

Supporting practical science & technology

- in schools and colleges

HAZCARDS

2007 edition

ABOUT HAZCARDS

These Hazcards will be known as the 2007 edition. Previous editions of Hazcards must be discarded.

The cards give information for teachers and technicians about hazards with chemicals in school science. They include all the changes that had been made in previous editions and all their amendments.

This edition covers **more chemicals and procedures**. However, the numbering of cards has remained essentially the same, with extra cards being referenced as, for example, 4A and 4B; this has led to some reorganisation so **please look carefully at the index** if you have difficulty finding information for a chemical.

Keeping up to date

This will always be a problem with *Hazcards* for two reasons.

- 1 The law regularly changes. The HSE continually reviews the hazards of chemicals. Changes to the hazard information on chemicals is likely to increase in the future as the *REACH (Registration, Evaluation and Authorisation of CHemicals) Regulations* from Europe come into force. There will be wholesale changes (even to symbols) when the *Globally Harmonised System of Classification and Labelling of Chemicals (GHS)* is adopted.
- 2 When CLEAPSS hears of useful modifications to established practical work, new materials available to schools or new procedures, this information will be added to the relevant *Hazcards*.

We suggest that you print any changed Hazcards from the most-recent version on our Science Publications CD-ROM to keep your copy / copies of Hazcards up to date in the future.

Changes to *Hazcards* will be announced in the *Bulletin* newsletter and documented in PS 35. You will be able to download the most-current version of PS 35 from the ‘members-only’ area of the CLEAPSS web site or you may request a paper copy via the CLEAPSS **Helpline**.

It is expected that many employers will continue to use the content of these cards as the basis of risk assessments required by the *Control of Substances Hazardous to Health Regulations* 2002 and the *Management of Health and Safety at Work Regulations* 1999. While every effort has been made to describe good experimental practice, the use of *Hazcards* can be no substitute for proper training, good laboratory discipline and common sense.

Index

An index of chemicals and procedures is provided on the pink cards.

Please use this first to find information on a particular chemical before contacting CLEAPSS at:

The Gardiner Building, Brunel Science Park, Uxbridge UB8 3PQ.

Tel: 01895 251496, *Fax:* 01895 814372, *E-mail:* science@cleapss.org.uk, *Web site:* www.cleapss.org.uk.

The spelling of sulfur

In 1994, the British Standards Institution announced that it would adopt the spelling of sulfur and sulfate etc with an ‘f’ not a ‘ph’ since there was no etymological justification for using a ‘ph’ and to continue doing so left the United Kingdom almost unique in the developed world.

Acknowledgements

This new edition of *Hazcards* obviously draws heavily on the previous editions, the sources for which were too numerous to mention. It should be particularly emphasised that *Hazcards* in their present form would not exist without the assistance of the HSE, technicians, teachers and local-authority advisers who have commented on drafts, completed questionnaires and sent details of accidents and near accidents. Our thanks go to all who helped.

Explanation of layout: Front

Chemical names	The names use the terminology in <i>Signs, Symbols & Systematics</i> , Association for Science Education, 2000, ISBN 0863573126. Other, and perhaps more familiar, names have been included on the cards and in the index. However, the use of correct terminology may, for some chemicals, become cumbersome, especially with organic compounds. For these chemicals, and where space is limited, the more familiar name may be used, eg, methyl benzoate for methyl benzenecarboxylate.
Hazard category	<p>Categories and symbols are those required by the <i>Chemicals (Hazard Information and Packaging for Supply) Regulations</i> 2002, amended 2005. Not all substances are included in the <i>Approved Supply List</i>. For these other chemicals, a supplier is required to pass on to consumers any hazard information it has. Naturally, suppliers differ in their sources of guidance and CLEAPSS has to reach a compromise in deciding the hazard categories to use. A fuller explanation of hazard categories is in section 7 of the <i>Handbook</i>. This edition includes the Risk Phrases associated with the chemicals; a full list of these is on Risk phrase card R.</p> <p>Hazard information is also found on <i>Safety Data Sheets</i> which the supplier must send to you. However, hazard data for chemicals from suppliers, although useful, do not take into account how much of a chemical is used or how a chemical is used. These safety data sheets are not risk assessments.</p>
Dangerous with:	Advice is taken from the <i>Laboratory Handbook of Reactive Chemical Hazards</i> , L Bretherick, Butterworths and from the ASE Safeguards in Science Committee. Where dangers are pointed out, this does not mean that an activity is automatically banned. In some cases, a model risk assessment is provided on the reverse of the card, eg, sodium reacting with water, which means that, with care, the procedure can be carried out. In other cases, more detailed risk assessments than can be provided on <i>Hazcards</i> are required. Some are on the <i>Science Publications CD-ROM</i> as <i>Supplementary Risk Assessments</i> . (Recently-produced <i>Supplementary Risk Assessments</i> are on the members-only section of the CLEAPSS web site.) Other risk assessments are in documents kept at CLEAPSS and you should request a <i>Special Risk Assessment</i> based on this information by contacting us via the Helpline .

Workplace Exposure Limits (WELs)	<p>WELs are given in <i>Guidance Note EH40</i>, HSE, 2005, ISBN 0717629775. The limits are updated regularly in the light of new information and research. A WEL is the maximum concentration to which employees may be exposed by inhalation (averaged over a certain time span); two periods are given: long term (LTCL: 8 hours) and short term (STCL: 15 minutes). Where the notation 'Sk' is included, this indicates the possibility of significant uptake through the skin. The WEL value does not represent a distinction between levels that are unsafe or safe and exposure should be kept well below any relevant WEL. See <i>Handbook</i> 7.9.</p> <p>The maximum quantity of chemicals to be used in the open laboratory and guidance on the need for ventilation or the use of a fume cupboard are given on <i>Hazcards</i>. This information has been produced as a result of calculations to establish that WELs will not be exceeded, or even approached, in a normal size of laboratory (with a total volume of around 240 m³ and 15 pairs of students working in it).</p>
Flash point	<p>This is the lowest temperature at which a chemical gives off vapour in such a concentration that, when the vapour combines with air near the surface of the liquid or solid, a flammable mixture is formed. (This is not the same as the auto-ignition temperature.) Flash point is used in the storage classification of flammable chemicals. Flammable chemicals are defined as having a flash point higher than 21 °C but less than 55 °C but, although they carry the R10 risk phrase, there is no hazard label. We recommend that chemicals with a flash point of less than 32 °C are stored in the flammables cabinet. Also, if there is room, others could go in as well.</p>
Emergency	<p>The Emergency card E is based on the immediate remedial measures found in the <i>Handbook</i> section 5.2. If there is any information specific to a particular chemical, it is provided on the relevant <i>Hazcard</i>.</p>
Store	<p>The storage group and any extra information are provided on the <i>Hazcard</i>. See the <i>Handbook</i> section 7.3 for further information. In particular, look at Table 7.2 since this is where the storage codes are explained. PLEASE READ IT AND BE FAMILIAR WITH IT.</p>
Disposal	<p>Codes are given which are explained on the Waste card W. PLEASE READ THIS AND BE FAMILIAR WITH IT. Extra specific information may also be given on the individual <i>Hazcards</i>. Also consult section 7.5 of the <i>Handbook</i> for a full explanation of the problems of disposal.</p>

Explanation of layout: Back

Activity	Model risk assessments for standard secondary school science activities for students up to A level or equivalent. These are listed in the index.
User	<p>The recommended level implies that pupils of that year and above may normally carry out the procedure. This is only a guide. A teacher might consider that some pupils are not responsible enough to do the activity despite the recommendation on <i>Hazcards</i> that it is suitable for pupils of their age. Alternatively, a teacher may feel that slightly-younger pupils are sufficiently responsible to proceed with an activity which is generally recommended for older pupils. It is important that such a departure from a <i>Hazard</i> recommendation is justified by the agreement of other members of the department and by the approval of the Head of Science or Senior Teacher. 'TT' indicates that a procedure should only be carried out by a teacher or technician.</p> <p>Another issue is that some activities, specifically designed for older students, become incorporated into schemes of work for younger age groups. After a considered review of the procedure of the activity, use by younger pupils may indeed be possible. A recent example is the use of 'Slime' which is now an activity for all age groups when it was originally used to illustrate cross-linking between polymers.</p> <p>Terms such as "close supervision" have been dropped. Supervision of practical work by teaching staff is an obvious and necessary part of teaching - to improve technical expertise, emphasise teaching points and observe any lapses in safety by the student.</p>
Control measures	These emphasise the basic safety equipment to be used during the procedure. Other required strategies may also be included.
Experiment- al points	<p>This section includes recommended techniques and maximum quantities that must be used in laboratory operations. Where a substance produces irritant or toxic fumes, the recommended maximum quantities are based on information derived from HSE <i>Guidance Note EH40</i>, which describes either the maximum permissible levels of chemicals in the atmosphere of the workplace or levels at which current information suggests there will be no damage to health. Details of any alterations to these levels or any additional information will be given in the <i>CLEAPSS Bulletin</i>. Should further advice, including special risk assessments, be required, contact CLEAPSS:</p> <p>The Gardiner Building, Brunel Science Park, Uxbridge UB8 3PQ. <i>Tel:</i> 01895 251496, <i>Fax:</i> 01895 814372, <i>E-mail:</i> science@cleapss.org.uk.</p>

Risk assessment

The *Management & COSHH Regulations* require that, before model risk assessments are adopted for use in a particular workplace, the need for modification to suit the local conditions must be considered, eg, size of rooms and their ventilation, class size and pupil behaviour, the apparatus available etc. In other words, risk assessments need to be ‘customised’. More information can be found in guide L196, *Managing Risk Assessment in Science*.

A risk assessment should not be regarded as permanent. It needs to be reviewed whenever:

- 1 experience, eg, an accident or near-accident, suggests that it is inadequate,
- 2 an instruction is received from the employer (most likely in local-authority schools) or a warning is published by CLEAPSS or the Association for Science Education,
- 3 conditions change - different apparatus, larger or more-unruly classes, pupils with special educational needs or for whom English is not the first language, less-experienced teachers, a new technician, etc,
- 4 the course as a whole is being reviewed.

It is sensible if the opportunity for discussion of risk assessments is a regular item on the agenda of science department meetings. Problems can then be reported and risk assessments amended if necessary. Technicians and part-time staff should be present at least for this item. However, other items on the agenda may also have health & safety implications.

DO NOT ATTEMPT ANY ACTIVITY MENTIONED IN A BOX UNLESS YOU ARE QUITE SURE YOU UNDERSTAND IT AND THE ASSOCIATED RISKS.

What to do when faced with an incident

Science staff should be prepared to carry out *immediate remedial measures* while waiting for a first aider to arrive. Keep the casualty as still as possible. Look out for signs of shock (due to loss of blood or other body fluids) or of unconsciousness and make the situation safe.

The remedial measures, reproduced on the reverse of this card, can be used for common laboratory accidents in conjunction with the relevant *Hazcard* which may provide extra information. It is recommended that the list of remedial measures (see section 5.2 of the *Handbook*) is displayed on the wall of each laboratory. **A copy of this card should accompany chemicals requested by teaching staff.** The use of all immediate remedial measures should be included in the department's health & safety policy. All staff in the science department, including science technicians and teaching assistants, should be able to carry out these remedial measures; speed is of the essence. Immediate remedial measures are relatively simple and can be taught in school. In addition, there should be brief drills, held at least annually, to remind staff of them. *Safe and Exciting Science*, ASE, 1999, ISBN 0863572952, is useful for staff training on internal CPD courses.

First aid

This should be left to personnel designated in the school's health & safety policy and who have received special training. The *First-Aid Regulations* do **not** require there to be a qualified first-aider among science staff.

Who else to contact?

Send a pupil to bring help, eg, to control the class or call a first aider. For serious accidents, there may be a need to contact the casualty's guardians or relatives. The first aider should do this using the school procedure.

Other emergencies

Spill emergency

Wear goggles and chemical-resistant gloves. Fence off the area and, if any fumes are causing distress, consider evacuation; see below. If the substance is **HIGHLY FLAMMABLE**, switch off all sources of ignition. Ventilate the area of the spill. Do **not** put other teachers, technicians or pupils at risk. For liquid spills, evaluate the amount spilt and the degree of hazard. Paper towels may suffice but, for larger or more hazardous spills, add the mineral absorbent in your laboratory and summon help. For further advice on dealing with the mineral absorbent and its subsequent treatment, consult section 7.7 of the *Handbook* and, if necessary, phone the **CLEAPSS Helpline**. In extreme cases, call the fire brigade, asking for the Chemical Incident Unit.

Gas or vapour released

If inhalation of the gas begins to cause distress, evacuation procedures must be initiated. If the vapour is **EXTREMELY** or **HIGHLY FLAMMABLE**, switch off all sources of ignition. If possible open all windows before you leave but this is **not** a priority. If necessary, phone the **CLEAPSS Helpline**. For a large release, the fire brigade may need to be called, asking for the Chemical Incident Unit.

Immediate remedial measures

Act quickly

Chemicals in the eye	Immediately wash the eye with gently-running water for at least 10 minutes, <i>and for much longer in the case of alkalis</i> (unless very dilute). Hold back the eyelids to rinse underneath. Contact lenses must be removed. If the first aider has any concerns, send for an ambulance (and, for alkalis, ensure irrigation is continued during the journey).
Chemicals in the mouth	Even if swallowed, do no more than wash out the casualty's mouth. Do not induce vomiting. Sips of water may help cool the throat and help keep the airway open. If the first aider has concerns after treatment, seek medical help.
Chemicals on clothes	If the chemical is flammable (R10, R11 or R12), extinguish all flames. Remove contaminated clothing immediately and wash the contaminated area. Take steps to ventilate the area of the spill. If necessary, take contaminated clothing outside.
Chemical splashes on the skin	Brush off any solids. Wash the skin for 5 minutes or until all traces of the chemical have disappeared. (If immediately available, for phenol, rinse with glycerol and, for bromine, use sodium thiosulfate solution.) Remove clothing as necessary. If the chemical adheres to the skin, wash gently with soap. For chemical burns, irrigate for 20 minutes. If the first aider has concerns after treatment, especially if blistering occurs, seek medical help.
Toxic gas	If more than a sniff is inhaled, sit the casualty down in uncontaminated air. Explain to the first aider that chlorine, bromine, iodine, nitrogen dioxide and sulfur dioxide can have a delayed-action effect. If the first aider has concerns after treatment, seek medical help.
Hair on fire	Smother with a fire blanket, thick cloth or coat, whatever is close to hand.
Clothing on fire	Stop, drop and roll. This means stop the casualty moving around and make her/him lie down on the floor. Then either roll the casualty to smother the flames or, with the flames on top, cover with a fire blanket, thick cloth or coat, whatever is close to hand.
Burns	Cool under gently-running water for 10 minutes or until heat is no longer felt. Call a first aider if there are concerns.
Electric shock	Taking care for your own safety, break contact by switching off or pulling out the plug. If it is necessary to move the casualty with the power still on, use a wooden broom handle or window pole or wear rubber gloves. Call a first aider.
Severe cuts	Lower the casualty to the floor. Raise the wound as high as possible. If feasible, ask the casualty to apply pressure on or as close to the cut as possible, using fingers, a pad of cloth or, better, a sterile dressing (adding further layers as necessary). If the casualty is unable to do so, apply pressure yourself, protecting your skin and clothes from contamination by blood if possible. Leave any embedded large bodies and press around them.
Asthma attack, anaphylactic shock etc	Follow the school's agreed procedures. Vulnerable pupils will have been trained in what to do. Help them to access their medication. In the case of anaphylactic shock, those at risk will have access to an <i>Epipen</i> which allows adrenaline to be injected into the thigh through clothing. Seek medical help.
Fainting	Lie the casualty down on the floor and raise the legs.

R Risk Phrases

R1	Explosive when dry	R25	Toxic if swallowed
R2	Risk of explosion by shock, friction, fire or other sources of ignition	R26	Very toxic by inhalation
R3	Extreme risk of explosion by shock, friction, fire or other sources of ignition	R27	Very toxic in contact with skin
R4	Forms very sensitive explosive metallic compounds	R28	Very toxic if swallowed
R5	Heating may cause an explosion	R29	Contact with water liberates toxic gas
R6	Explosive with or without contact with air	R30	Can become highly flammable in use
R7	May cause fire	R31	Contact with acids liberates toxic gas
R8	Contact with combustible material may cause fire	R32	Contact with acids liberates very toxic gas
R9	Explosive when mixed with combustible material	R33	Danger of cumulative effects
R10	Flammable	R34	Causes burns
R11	Highly flammable	R35	Causes severe burns
R12	Extremely flammable	R36	Irritating to eyes
R14	Reacts violently with water	R37	Irritating to respiratory system
R15	Contact with water liberates extremely flammable gases	R38	Irritating to skin
R16	Explosive when mixed with oxidising substances	R39	Danger of very serious irreversible effects
R17	Spontaneously flammable in air	R40	Limited evidence of a carcinogenic effect
R18	In use, may form flammable/explosive vapour-air mixture	R41	Risk of serious damage to eyes
R19	May form explosive peroxides	R42	May cause sensitisation by inhalation
R20	Harmful by inhalation	R43	May cause sensitisation by skin contact
R21	Harmful in contact with skin	R44	Risk of explosion if heated under confinement
R22	Harmful if swallowed	R45	May cause cancer
R23	Toxic by inhalation	R46	May cause heritable genetic damage
R24	Toxic in contact with skin	R48	Danger of serious damage to health by prolonged exposure
		R49	May cause cancer by inhalation
		R50	Very toxic to aquatic organisms
		R51	Toxic to aquatic organisms

R52	Harmful to aquatic organisms
R53	May cause long-term adverse effects in the aquatic environment
R54	Toxic to flora
R55	Toxic to fauna
R56	Toxic to soil organisms
R57	Toxic to bees
R58	May cause long-term adverse effects in the environment
R59	Dangerous for the ozone layer
R60	May impair fertility
R61	May cause harm to the unborn child
R62	Possible risk of impaired fertility
R63	Possible risk of harm to the unborn child
R64	May cause harm to breast-fed babies
R65	Harmful: may cause lung damage if swallowed
R66	Repeated exposure may cause skin dryness or cracking
R67	Vapours may cause drowsiness and dizziness
R68	Possible risk of irreversible effects

Risk phrases 13 and 47 are **not** currently used.

Combination of risks

R14/15	Reacts violently with water, liberating extremely flammable gases
R15/29	Contact with water liberates toxic, extremely flammable gases
R20/21	Harmful by inhalation and in contact with skin
R20/21/22	Harmful by inhalation, in contact with skin and if swallowed
R20/22	Harmful by inhalation and if swallowed
R21/22	Harmful in contact with skin and if swallowed
R23/24	Toxic by inhalation and in contact with skin
R23/24/25	Toxic by inhalation, in contact with skin and if swallowed
R23/25	Toxic by inhalation and if swallowed
R24/25	Toxic in contact with skin and if swallowed
R26/27	Very toxic by inhalation and in contact with skin
R26/27/28	Very toxic by inhalation, in contact with skin and if swallowed
R26/28	Very toxic by inhalation and if swallowed
R27/28	Very toxic in contact with skin and if swallowed
R36/37	Irritating to eyes and respiratory system
R36/37/38	Irritating to eyes, respiratory system and skin
R36/38	Irritating to eyes and skin
R37/38	Irritating to respiratory system and skin
R39/23	Toxic: danger of very serious irreversible effects through inhalation
R39/23/24	Toxic: danger of very serious irreversible effects through inhalation and in contact with skin

R39/23/24/25	Toxic: danger of very serious irreversible effects through inhalation, in contact with skin and if swallowed	R48/20/21	Harmful: danger of serious damage to health by prolonged exposure through inhalation and in contact with skin
R39/23/25	Toxic: danger of very serious irreversible effects through inhalation and if swallowed	R48/20/21/22	Harmful: danger of serious damage to health by prolonged exposure through inhalation, in contact with skin and if swallowed
R39/24	Toxic: danger of very serious irreversible effects in contact with skin	R48/20/22	Harmful: danger of serious damage to health by prolonged exposure through inhalation and if swallowed
R39/24/25	Toxic: danger of very serious irreversible effects in contact with skin and if swallowed	R48/21	Harmful: danger of serious damage to health by prolonged exposure in contact with skin
R39/25	Toxic: danger of very serious irreversible effects if swallowed	R48/21/22	Harmful: danger of serious damage to health by prolonged exposure in contact with skin and if swallowed
R39/26	Very Toxic: danger of very serious irreversible effects through inhalation	R48/22	Harmful: danger of serious damage to health by prolonged exposure if swallowed
R39/26/27	Very Toxic: danger of very serious irreversible effects through inhalation and in contact with skin	R48/23	Toxic: danger of serious damage to health by prolonged exposure through inhalation
R39/26/27/28	Very Toxic: danger of very serious irreversible effects through inhalation, in contact with skin and if swallowed	R48/23/24	Toxic: danger of serious damage to health by prolonged exposure through inhalation and in contact with skin
R39/26/28	Very Toxic: danger of very serious irreversible effects through inhalation and if swallowed	R48/23/24/25	Toxic: danger of serious damage to health by prolonged exposure through inhalation, in contact with skin and if swallowed
R39/27	Very Toxic: danger of very serious irreversible effects in contact with skin	R48/23/25	Toxic: danger of serious damage to health by prolonged exposure through inhalation and if swallowed
R39/27/28	Very Toxic: danger of very serious irreversible effects in contact with skin and if swallowed	R48/24	Toxic: danger of serious damage to health by prolonged exposure in contact with skin
R39/28	Very Toxic: danger of very serious irreversible effects if swallowed	R48/24/25	Toxic: danger of serious damage to health by prolonged exposure in contact with skin and if swallowed
R42/43	May cause sensitisation by inhalation and skin contact		
R48/20	Harmful: danger of serious damage to health by prolonged exposure through inhalation		

R48/25	Toxic: danger of serious damage to health by prolonged exposure if swallowed	R68/20/21/22	Harmful: possible risk of irreversible effects through inhalation, in contact with skin and if swallowed
R50/53	Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment	R68/20/22	Harmful: possible risk of irreversible effects through inhalation and if swallowed
R51/53	Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment	R68/21	Harmful: possible risk of irreversible effects in contact with skin
R52/53	Harmful to aquatic organisms, may cause long-term adverse effects in the aquatic environment	R68/21/22	Harmful: possible risk of irreversible effects in contact with skin and if swallowed
R68/20	Harmful: possible risk of irreversible effects through inhalation	R68/22	Harmful: possible risk of irreversible effects if swallowed
R68/20/21	Harmful: possible risk of irreversible effects through inhalation and in contact with skin		

W Chemical waste from school and college laboratories

The codes W1, W2 etc, will be found on relevant *Hazcards*. Any exceptions, other disposal methods or extra instructions to the basic procedures will be highlighted on the relevant *Hazcard* as **Wspec**. A more-detailed discussion can be found in section 7.5 of the CLEAPSS *Laboratory Handbook* 2005 version or later. If in doubt, contact the CLEAPSS **Helpline** on 01895 251496 for further advice.

W1 Unwanted hazardous chemicals in bottles

Unwanted hazardous chemicals (ie, those carrying a hazard warning symbol) should be stored for removal by a Registered Waste Carrier; contact details can be found in guidance leaflet PS5 on the CLEAPSS *Science Publications CD-ROM*. Technicians do not have time (nor possibly the resources and/or experience) to deal with the disposal of large quantities of chemicals in several bottles.

W2 General laboratory waste - Waste can sometimes be bulked together but store the following in separate, labelled containers before removal by a Registered Waste Carrier.

Mercury metal and compounds of mercury, including broken mercury thermometers and the collected waste from a mercury spill.

Cadmium metal and compounds of cadmium.

Waste organohalogens; do not mix with hydrocarbons.

Water-insoluble flammable liquids and other organic waste; do not mix with organohalogens.

Oxidising compounds insoluble in water. Explosive compounds insoluble in water.

Toxic, Irritant or Harmful compounds insoluble in water, dilute acids and alkalis.

W3 It is possible to recycle the material for further use with little effort.

W4 Extremely and highly flammable, corrosive, harmful and irritant substances which react with alkalis. Add slowly to 1 mol dm⁻³ sodium carbonate solution. Heat may be produced. The resulting solution should be tested for alkalinity with litmus solution and, when just alkaline, poured down a foul-water drain with further dilution.

W5 Extremely and highly flammable, corrosive, harmful and irritant substances which react with acids. Add slowly to 1 mol dm⁻³ ethanoic acid solution. Heat may be produced. The resulting solution should be tested for acidity with litmus solution and, when just acidic, poured down a foul-water drain with further dilution.

W6 Burn, evaporate or vent the material in a working fume cupboard or out in the open if safe to do so.

W7	Dilute in water to below the concentration in the right-hand column. Solutions should be poured down a foul-water drain with further dilution. See relevant <i>Hazcards</i> for more information.	
T+	Very toxic (R26, R27, R28) and soluble in water.	0.1% (w/v)
T	Toxic (Category 1 or 2 carcinogen, R45 or R49; Category 1 or 2 mutagen, R46; Category 1 or 2 toxic for reproduction, R60 or R61) and soluble in water.	0.1% (w/v)
T	Toxic (R23, R24, R25) and soluble in water.	1% (w/v)
Xn	Harmful (Sensitising, R42 or R43; Category 3 carcinogen, R40; Category 3 mutagen, R68; Category 3 toxic for reproduction, R62 or R63) and soluble in water.	1% (w/v)
Xn	Harmful (R20, R21, R22) and soluble in water.	10% (w/v)
C	Corrosive (R34, R35) and soluble in water.	1% (w/v)
Xi	Irritant (R42, R43 sensitising) and soluble in water.	1% (w/v)
Xi	Irritant (R36, R37, R38) and soluble in water.	10% (w/v)
F	Highly flammable (R11), Extremely flammable (R12), and Flammable (R10) and soluble in water.	5% (w/v)
Ox	Oxidising agent (R8) and soluble in water.	5% (w/v)
-	Low-hazard waste soluble in water.	No limit

W8	Solid substances, which are low hazard, can be placed in normal refuse. For solid chemicals with hazard warnings, their concentrations must be below the level stipulated in the right-hand column. There must be no attempt to dilute deliberately the chemical with, for example, sand. However, for example, filter paper (1 g) containing less than 0.25 g of copper(II) oxide (Xn) can be placed in the waste. No flammable chemicals or oxidising chemicals should be placed in the waste.	
T+	Very toxic (R26, R27, R28).	0.1% (w/w)
T	Toxic (Category 1 or 2 carcinogen, R45 or R49; Category 1 or 2 mutagen, R46; Category 1 or 2 toxic for reproduction, R60 or R61).	0.1% (w/w)
T	Toxic (R23, R24, R25).	3% (w/w)
Xn	Harmful (Sensitising, R42 or R43; Category 3 carcinogen, R40; Category 3 mutagen, R68; Category 3 toxic for reproduction, R62 or R63).	25% (w/w)
Xn	Harmful (R20, R21, R22).	25% (w/w)
C	Corrosive (R34, R35).	1% (w/w)
Xi	Irritant (R42, R43 sensitising).	1% (w/w)
Xi	Irritant (R36, 37, 38).	20% (w/w)
-	Low-hazard waste.	No limit

Hazard index

Use this index to identify the location of information on specific chemicals and activities involving them.

Chemicals that are prohibited by law

There are very few chemicals that are banned nationally and these are indicated on the index cards by a '**B**' and also emphasised by being in **bold** print. They include benzene and any mixture containing more than 0.1% by mass of benzene, eg, petrol. Other banned substances include various aromatic amines; see *Hazard 4A*.

Chemicals that are not recommended

Chemicals that are not recommended or are not suitable for general use in schools are indicated on the index cards by '**NR**' and also emphasised by being in **bold** print.

It may still be possible to use such chemicals under certain circumstances if teachers have contacted CLEAPSS and received a special risk assessment describing the precise conditions in which the chemicals can be used, with great care.

Chemical or activity	Hazard	Chemical or activity	Hazard
Acenaphthene	3C, 46	Adhesives	28, 99
Acetaldehyde	34	Adipoyl chloride	41
Acetamide	35	L-Adrenaline	3C
Acetanilide	35	Alanine	38C
Acetic acid	38A	Alcohols	40A, 40B, 84A, 84B, 84C
Acetic anhydride	39	Aldehyde reactions	30, 34, 83
Acetone	85	Aldehyde test	87
Acetonitrile	13B	Aldehydes	34, 63, 83
Acetophenone	85	Alginate gels	95C
Acetyl chloride	41	Aliphatic hydrocarbons	45A, 45B, 45C
Acetylcholine chloride	3C	Alizarin stains	32
diacetyl-dioxime	53	Alkali metal / butanol reaction	84B
Acetylene	45C	Alkaline pyrogallate	12
o-acetylsalicylic acid	52	Alkene reactions	45C
Acid anhydrides, preparation	75	Alkenes	15B
Acid blue 40	32	Alkylation	2A
Acid chlorides and their preparation	41, 74, 96B	Allotropes of phosphorus	73A
Acid rain, simulation	92	Alloys, analysis	47A, 67
Acids acting on iron	55A	Alum and its preparation	2B
Acridine orange	32	Aluminium	1
Acrylamide	NR, 35	Aluminium acetate	2B
Acrylic cement	28, 99	Aluminium activation	62
Acrylic, preparation	43B	Aluminium ammonium sulfate(VI)	2B
Acrylics	71	Aluminium bromide	2A
Activated carbon	21	Aluminium chloride and its preparation	2A
Activating aluminium	1	Aluminium chloride-6-water	2A
Acylation	2A	Aluminium ethanoate	2B
Adenosine triphosphate	72	Aluminium halides, hydrolysis	2A

Chemical or activity	Hazard	Chemical or activity	Hazard
Aluminium nitrate(V)	2B	<i>p</i> -aminobenzoic acid	13A
Aluminium oxide	2B	4-aminobiphenyl	B, 4A
Aluminium potassium sulfate(VI)	2B	1-aminobutane	3A
Aluminium salt solutions	2B	Aminoethane	3A
Aluminium sulfate(VI)	2B	1,2-diaminoethane	3B
Aluminium, activating	1	Aminoethanoic acid	38C
Aluminium / halogen reactions	1	1,6-diaminohexane	3B
Aluminium / mercury(II) salts reaction	62	4-aminophenol	70
Aluminon	32	3-aminophthalhydrazide	4B
AMG	33	880 Ammonia	6
Amide reactions	13B	Ammonia & amines / ethanoyl chloride reactions	41
Amidosulfonic acid	98B	Ammonia gas and its preparation	5
Amine groups, detection	35	Ammonia gas, dissolving	5
Amines, aliphatic	3A, 3B	Ammonia gas, testing for	5
Amines, aromatic	4A, 4B	Ammonia in water, testing for	62
Amines, aromatic: diazotisation	93	Ammonia solution	6
Amines, heterocyclic	4C	Ammonia, oxidation	5
Amines, physiologically active	3C	Ammonia / hydrogen chloride reaction	5
Amines, preparation and reactions	3A	Ammoniacal copper(I) chloride	45C
Amino acid chromatograms	66	Ammoniacal silver nitrate(V)	6, 45C, 87
Amino acids	38C	Ammonium acetate	9B
Aminoacetic acid	38C	Ammonium alum	2B
Aminobenzene	4A	triammonium aurine tricarboxylate	32
3-aminobenzene-1,2-dicarboxylic hydrazide	4B	Ammonium bromide	9B
4-aminobenzenecarboxylic acid	13A	Ammonium carbonate	9A
4-aminobenzenesulfonic acid	4B	Ammonium chlorate(VII)	NR
3-aminobenzoic acid	4A	Ammonium chloride	9A, 68, 93
4-aminobenzoic acid	13A	Ammonium dichromate(VI)	7

Chemical or activity	Hazard	Chemical or activity	Hazard
Ammonium dihydrogenphosphate(V)	72	Ammonium vanadate(V)	9B
Ammonium ethanedioate	36A	Amphibian heart inhibition / stimulation	3C
Ammonium ethanoate	9B	Ampoules, opening	15A, 86
diammonium hydrogenphosphate(V)	72	<i>iso</i> -amyl acetate	43B
Ammonium hydroxide	6	<i>n</i> -amyl acetate	43B
Ammonium iodide	9B	Amyl acetate	50, 105
Ammonium ions test	95A	<i>iso</i> -amyl alcohol	84C
diammonium iron(II) sulfate(VI)	55B	<i>n</i> -amyl alcohol	84C
Ammonium iron(III) citrate	79	Amyl ethanoate	50, 105
Ammonium iron(III) sulfate(VI)	55C, 68	Amylase	33
Ammonium metavanadate	9B	Amylglucosidase	33
Ammonium molybdate(VI)	9A	Amylose	40C
Ammonium nickel(II) sulfate(VI)	65B	Anaesthetising <i>Drosophila</i>	42
Ammonium nitrate(V)	8	Anhydrous aluminium bromide	2A
Ammonium nitrite, preparation	93	Anhydrous aluminium chloride	2A
Ammonium oxalate	36A	Anhydrous calcium chloride	19A
Ammonium peroxodisulfate(VI)	8	Anhydrous copper(II) sulfate(VI)	27C
Ammonium persulfate	8	Anhydrous iron(II) chloride	55B
Ammonium phosphate(V)	72	Anhydrous iron(III) chloride	55C
Ammonium polytrioxovanadate	9B	Anhydrous magnesium sulfate(VI)	98B
Ammonium purpurate	32	Anhydrous sodium carbonate	95A
Ammonium salt, preparation	6	Anhydrous sodium ethanoate (acetate)	38A
Ammonium salts	8, 9A, 9B	Anhydrous sodium sulfate(VI)	98B
Ammonium salts (oxidising agents)	8	Aniline	4A
Ammonium sodium hydrogenphosphate(V)	72	Aniline blue	32
Ammonium sulfate(VI) and its preparation	9B, 68	Anilinium salts	4A
Ammonium sulfide	51	<i>o</i> -dianisidine	4A
Ammonium thiocyanate	9B	Anisole	2A, 42

Chemical or activity	Hazard	Chemical or activity	Hazard
Anodised aluminium	32	Barium nitrate(V)	11
Antifebrin	35	Barium peroxide	11
Antifreeze investigations	37	Barium sulfate(VI)	10B
Anti-fungal agent	52	Barking dog demonstration	68
Antimony	73B	Barlow's wheel	61
Antimony trichloride	73B	Barytes	10B
Antimony(III) chloride	73B	Basic copper carbonate	26
Aqua Regia	47A, 67	Basic fuchsin	32
Arginine	38C, 62, 89	Basic nickel(II) carbonate	65A
Aromatic amines, diazotisation	93	Basic magnesium carbonate	59B
Aromatic hydrocarbons	46	Batteries	65A
Aromatic nitro compounds	4A	Bell jar & phosphorus demonstration	73A
Aromatic ring reactions	42, 46	Belousov-Zhabotinski reaction	80
Arsenic and its compounds	NR, 73B	Benedict's solution	27C, 34, 40C, 91
Asbestos	NR	Benzaldehyde	34, 83
Ascorbic acid	38C	Benzamide	13B
Asparagine	38C	Benzene	B, 45A, 46
Aspartic acid	38C	Benzene-1,2,3-triol	12
Aspirin and its preparation	52	Benzene-1,2-dicarboxylic acid	13A
ATP	72	Benzene-1,2-dicarboxylic acid anhydride	13B
Azo dyes	4A, 4B, 93	Benzene-1,2-diol	12
Barium	10A	Benzene-1,3,5-triol	12
Barium carbonate	10A	Benzene-1,3-diol	12
Barium chloride	10A	Benzene-1,4-dicarboxylic acid	13A
Barium chromate(VI)	10B	Benzene-1,4-diol	12
Barium diphenylamine sulfonate	10B	Benzene diols and triols	12
Barium ferrate(VI), preparation	55C	Benzenecarbaldehyde	83
Barium hydroxide	10B	Benzenecarbonitrile	13B

Chemical or activity	Hazard	Chemical or activity	Hazard
Benzenecarbonyl chloride	13B	Black powder	82
di(benzenecarbonyl) peroxide	NR, 29	Bleach	89
Benzenecarboxamide	13B	Bleaching	22A, 22B
Benzenecarboxylic acid	13A	Bleaching powder	17
Benzenecarboxylic acid derivatives	13B	Bleaching, analysis of	89
Benzenesulfonic acid	31	Blood, carbon monoxide reaction	21
Benzidine	B, 4A	Blowpipe reductions	21, 26, 56
Benzocaine	4B	Blue dextran	32
2-hydroxy benzoic acid	52	Blue flash reaction	50
Benzoic acid and its preparation	13A, 40B	Blue John	19A
Benzonitrile	13B	Blueprints	79
Benzophenone	85	Boiling points of ideal mixtures	84A
Benzoyl chloride	13B	Boracic acid	14, 56
Benzoyl peroxide	NR, 29	Borax	14
dibenzoyl peroxide	NR, 29	Borax bead test	14
Benzyl alcohol	40B	Boric acid	14, 56
Benzyl chloride	44A	Boron compounds	14
Beryllium and its compounds	NR	Brady's reagent and its preparation	30
Bial's test	12	Brass / nitric acid reaction	67
Bile salts	95C	Bromate / bromide clock reaction	80
Bio-diesel, preparation	40B	Bromination	46
Biphenyl-4,4'-diamine	B, 4A	Bromine	15A, 71
Bis[bis(carboxy)amino]ethane (disodium salt)	3B	Bromine solvent	45B, 99, 100, 103, 106
Bismuth	73B	Bromine water and ethene	103
Bismuth trichloride	73B	Bromine water and its preparation	15B, 80
Bismuth(III) chloride	73B	Bromine, dissolving in cyclohexane	45B
Bismuth(III) nitrate(V)	73B	Bromine / aluminium reaction	1
Bismuth(III) oxychloride	73B	Bromine / metal reactions	15A

Chemical or activity	Hazard	Chemical or activity	Hazard
Bromine / methanoic acid reaction	38A	Burning sodium	88
Bromine / organics reactions	15A	Burning substances in oxygen	69
Bromine / sodium thiosulfate reaction	95C	Burning sulfur	96A
2-bromo-2-methyl propane	44B	Burning sulfur in chlorine	96B
Bromoalkanes	44B	Burning <i>Volasil</i> 244	106
2-bromobutane	44B	Burning wood with a nitrate(V)	82
1-bromobutane and its preparation	44B	Burning zinc	107
1,2-dibromoethane	NR, 103	Butan-1-ol	84B
Bromoethane and its preparation	44B	Butan-2-ol	84B
Bromomethane	NR	Butan-2-one	85
Bromophenol blue	32	Butanal	83
Bromothymol blue	32	Butane	45A
Brown ring test	82	<i>n</i> -butane	45A
Buffer solutions	9B, 13B, 14, 36C, 72	Butane-1,4-dioic acid	36B
Bunsen burners	20, 45A	Butanedioic acid	36B
Burning aluminium in chlorine	2A	Butanedione dioxime	53
Burning calcium	16	Butanoic acid	38B
Burning candles / nightlights	45B	<i>iso</i> -butanol	84B
Burning fuels	45A, 45B, 45C	Butanol / alkali metal reaction	84B
Burning hydrocarbons	45A, 45B, 45C	Butanols	84B
Burning hydrogen	48	Butanone	85
Burning magnesium in carbon dioxide	20	<i>cis</i> -butenedioic acid	36B
Burning magnesium ribbon	59A	<i>trans</i> -butenedioic acid	36B
Burning metals in chlorine	1, 22A, 73A, 76, 88	<i>n</i> -butyl acetate	43B
Burning paper money	40A	<i>n</i> -butyl alcohol	84B
Burning phosphorus	73A	<i>sec</i> -butyl alcohol	84B
Burning potassium	76	<i>tert</i> -butyl alcohol	84B
Burning propanols	84A	<i>iso</i> -butyl alcohol	84B

Chemical or activity	Hazard
dibutyl benzene-1,2-dicarboxylate	64
<i>n</i> -butyl bromide	44B
<i>sec</i> -butyl bromide	44B
<i>tert</i> -butyl bromide	44B
<i>n</i> -butyl chloride	44A
<i>sec</i> -butyl chloride	44A
<i>tert</i> -butyl chloride	44A
Butyl ethanoate	43B
<i>n</i> -butyl iodide	44B
dibutyl phthalate	64
Butylamine	3A
Butyraldehyde	83
<i>n</i> -butyric acid	38B
Cadmium	NR, 61
Cadmium salts	NR, 62
Caesium chloride	47B
Caffeine	3C, 103
Caffeine extraction	28, 84A, 104
Calcite	19B
Calcium	16
Calcium carbide	19B
Calcium carbonate and its heating	19B
Calcium chlorate(I)	17
Calcium chloride	19A, 47B
Calcium chromate(VI)	19B
Calcium dicarbide	19B, 45C
Calcium dihydrogenphosphate(V)	72
Calcium fluoride	19A

Chemical or activity	Hazard
Calcium hydroxide	18
Calcium hypochlorite	17
Calcium nitrate(V)	19A
Calcium orthophosphate	72
Calcium oxide and its preparation	18
Calcium phosphate(V)	72
Calcium phosphide	19B
Calcium salts	19A, 19B
Calcium sulfate(VI)	19B
Calcium / chlorine reaction	16
Calcium / water reaction	16
Calomel	62
Candles, burning	45B
Cannizzaro's reaction	83
Carbamide	35
Carbohydrates and tests for	40C
Carbohydrazide mixture	33
Carbolic acid	70
Carbon	21
Carbon blocks	21, 56
Carbon dioxide and its preparation	20
Carbon dioxide, testing for	10B, 18
Carbon dioxide / hot carbon reaction	20
Carbon disulfide	NR, 20
Carbon monoxide and its preparation	21, 38A
Carbon monoxide, use for reduction	21
Carbon tetrachloride	100
Carbonyl group test	30

Chemical or activity	Hazard	Chemical or activity	Hazard
Carbonyl group, reactions	85	Chemiluminescence reactions	4B
<i>Carbosorb</i>	91	Chemosin	33
bis[bis(carboxy)amino]ethane	3B	Chloric(VII) acid	NR
Carmine	32	Chloride concentrations in urine	87, 95C
Cassiterite	102	Chlorine and its preparation	17, 22A, 27A, 47A, 60, 73A, 73B, 76, 81, 88, 89
Castner-Kellner cell	61	Chlorine water and its preparation	22B, 89, 92
Catalase	33	Chlorine, burning metals	22A
Catalytic action of oxides	77	Chlorine, testing for	17
Catalytic cracking	45B	Chlorine / aluminium reaction	1
Catalytic oxidation of ammonia	5	Chlorine / calcium reaction	16
Catechol	12	Chlorine / hydrogen reaction	22A
Caustic potash	91	Chlorine / iodine reaction	54A
Caustic soda	91	Chlorine / sodium reaction	88
CDA	40A	Chlorine / sulfur reaction	96B
Cell division, arresting	3C	2-chloro-2-methylpropane and its hydrolysis	44A
<i>Celluclast</i>	33	Chloroacetic acid	38C
Cellulase	33	dichloroacetic acid	38C
Cellulose	6, 40C	trichloroacetic acid	38C
Cellulose ethanoate and its preparation	39, 40C	Chloroalkanes	44A
Cellulose, stain for	24	Chlorobenzene	4A, 23, 44A
<i>Celluzyme</i>	33	1,4-dichlorobenzene	3C, 23
Cement / mortar, making	18	1,2-dichlorobenzene	23
Ceramic wool	86	<i>o</i> -dichlorobenzene	23
Cerrusite	56	<i>p</i> -dichlorobenzene	23
Cetyl alcohol	84C	1-chlorobutane	44A
Chalk	19B	2-chlorobutane	44A
Charcoal	21, 56	1,2-dichloroethane	NR, 103
Chemical gardens	95B		

Chemical or activity	Hazard	Chemical or activity	Hazard
1,1,1-trichloroethane	103	dichromate(VI) oxidation of propanols	84A
Chloroethane	NR	dichromate(VI) test papers	92
Chloroethanoic acid	38C	dichromate(VI) titrations	4A
dichloroethanoic acid	38C	Chromatography, locating reagents	4A, 66
trichloroethanoic acid	38C	Chromatography of amino acids	38C, 66
tetrachloroethene	54B, 99	Chromatography of sugars	4A, 4C
trichloroethene	99	Chromatography solvents	84B, 85, 103
Chloroethene	NR	Chrome alum crystals	24
tetrachloroethylene	99	Chromic acid	NR, 24, 78
trichloroethylene	99	Chromium	24
Chloroform	104	Chromium complexes	24
dichloromethane	28, 84A, 99	Chromium trioxide	24
tetrachloromethane	100	Chromium(II) ethanoate	24
trichloromethane	104	Chromium(II) salts	24
tetrachloromethane, alternative	45B	Chromium(III) chloride	24
dichloromethane, ethoxyethane alternative	42	Chromium(III) nitrate(V)	24
trichloromethane / propanone reaction	104	Chromium(III) oxide	24
Chloromethylbenzene	44A	Chromium(III) potassium sulfate(VI)	24
2,6-dichlorophenolindophenol	32	Chromium(III) salts	24
Chlorophyll extraction from leaves	40A, 85	Chromium(VI) compounds / H ₂ O ₂ reaction	50
Chlorophyll, action spectrum	64	Chromium(VI) oxide	24
1-chloropropane	44A	Chromosomes at metaphase	23
Chloro-substituted ethanoic acids	38C	Chromyl(VI) chloride, preparation	78
Chlorosulfonic acid	NR	Cigarette smoking machines	3C
Chlor-zinc-iodine	24	Cinnabar	62
Cholesteryl benzoate and its preparation	4C, 13B	<i>trans</i> -cinnamic acid	13A
Chrom-acetic fixative	24	Cis / trans isomersim	36B
dichromate(VI) oxidation of butanols	84B	Citric acid	36C

Chemical or activity	Hazard	Chemical or activity	Hazard
Cleaning agents	84A	Copper pyrites	26
Cleaning glassware	24, 67, 78, 81	Copper salts	27A, 27B, 27C
Clock reactions	8, 80, 95B	Copper(I) chloride	27A
Coal, distillation	21	Copper(I) chloride / iodide, preparation	27A
Cobalt	25	dicopper(I) ethynediide	45C
Cobalt complexes and their preparation	25	Copper(I) iodide	27A
Cobalt(II) carbonate	25	Copper(I) oxide and its preparation	26
Cobalt(II) chloride	25, 86, 96B	Copper(II) carbonate	26, 27C
Cobalt(II) reactions	25	Copper(II) carbonate hydroxide	26
Cobalt(II) thiocyanate	25	Copper(II) chloride	27A, 47B
Cochineal	32	Copper(II) chromate(VI)	27B
Colchicine	NR, 3C	Copper(II) complexes	27C
Colchicine, alternative	23	Copper(II) ethanoate and its preparation	27B
Cole's modification of Millon's reagent	62	Copper(II) ions, reduction	34
Completely denatured alcohol	40A	Copper(II) nitrate(V)	27B
Complex equilibria	55B, 55C	Copper(II) oxide	26, 27C, 77
Complex ion formation	6	Copper(II) oxide, reduction	26, 45A, 48, 107
Condensation reactions	34, 83	Copper(II) oxide, reduction by hydrogen	48
Condensation reactions of aldehydes	83	Copper(II) oxide, reduction by zinc	107
Conductivity of naphthalene	46	Copper(II) sulfate(VI), acidified solution	61
Congo red	32	Copper(II) sulfate(VI), anhydrous	27C
Contact process	23, 38B, 46, 52, 84C, 97	Copper(II) sulfate(VI), crystals	27C
Copper	26	Copper(II) sulfate(VI), preparation	27C
Copper acetate	27B	Copper(II) sulfate(VI)-5-water	27C
Copper carbonate	26	Copper(II) sulfate(VI) / sulfuric(VI) acid reaction	98A
Copper complexes, preparation	27A	Copper(II) sulfide	26
Copper halides	27A	Copper / nitric acid reaction	67
Copper oxide / magnesium reaction	59A	Copper / sulfur reaction	96A

Chemical or activity	Hazard
Copper / sulfuric(VI) acid reaction	98A
Cotton blue	32
Cracked gas	15B
Cracking hydrocarbons	45B
Cresol red	32
Cresols	70
Crude oil	B, 45A
Crystal growing	24, 27C, 36C, 55B
Crystal violet	32
Crystallisation	2B, 13A, 24, 27B, 27C, 38A, 46, 49, 55B, 56, 60, 64, 78, 96A, 106, 108B
Crystallisation investigations	2B
Crystallisation of alum	2B
Crystallisation of naphthalene	46
Crystals of copper(II) ethanoate	27B
Crystals of lead	56
Crystals of sulfur	96A, 106
Crystals of zinc sulfate(VI)	108B
Cupric acetate	27B
Cupric carbonate	26
Cupric chloride	27A
Cupric chromate	27B
Cupric nitrate	27B
Cupric oxide	26
Cuprous chloride	27A
Cuprous iodide	27A
Cuprous oxide	26
Cutin, stain for	24

Chemical or activity	Hazard
Cyanides	NR
Cyclohexane	28, 45B, 47B, 54B, 100, 103
Cyclohexane, ethoxyethane alternative	42
Cyclohexanol and its dehydration	72, 84C
Cyclohexanone	85
Cyclohexene and its preparation	45C, 84C
Cysteine	38C
Cystine	38C
DCPIP	32, 38C
Decanedioyl dichloride	41
Decomposing polyacrylates into monomers	43B
Degreasing agent	84A
Dehydration of methanoic acid	38A
Depolarising simple cells	78
Descaling procedures	98B
Desiccants	19A, 25, 75, 86, 98A, 98B
Detergent, preparation	31
Devarda's alloy	1
Developing photographs	12
Dextrin	40C
Dextrose	40C
Di(benzenecarbonyl) peroxide	NR, 29
Di(dodecanoyl) peroxide	29, 43B
Diacetyl-dioxime	53
1,2-diaminoethane	3B
1,6-diaminohexane	3B
Diammonium hydrogenphosphate(V)	72
Diammonium iron(II) sulfate(VI)	55B

Chemical or activity	Hazard	Chemical or activity	Hazard
o-dianisidine	B, 4A	Diffusion demonstrations	15A
Diastase	33	Diffusion in liquids	81
Diazine green	32	Diffusion of gases	68
Diazonium salts / phenol reaction	70	1,2-dihydroxyanthraquinone	32
Diazonium solution	4B	1,2-dihydroxybenzene	12
Diazotisation	4A, 4B, 70, 93	1,3-dihydroxybenzene	12
Di(benzenecarbonyl) peroxide	NR, 29	1,4-dihydroxybenzene	12
Dibenzoyl peroxide	NR, 29	2,3-dihydroxybutanedioic acid	36C
1,2-dibromoethane	NR, 103	2,2-dihydroxy-1,3-indanedione	66
Dibutyl benzene-1,2-dicarboxylate	64	Dilauryl peroxide	29
Dibutyl phthalate	64	Di-lead(II) lead(IV) oxide	56
Dichloroacetic acid	38C	Diluting sulfuric(VI) acid	98A
1,2-dichlorobenzene	23	3,3'-dimethoxybiphenyl-4,4'-diamine	B, 4A
1,4-dichlorobenzene	3C, 23	Dimethyl sulfate(VI)	NR
o-dichlorobenzene	23	<i>N,N</i> -dimethylaniline	4B
<i>p</i> -dichlorobenzene	23	Dimethylbenzene, including all isomers	2A, 46
1,2-dichloroethane	NR, 103	3,3'-dimethylbiphenyl-4,4'-diamine	B, 4A
Dichloroethanoic acid	38C	Dimethylglyoxime	53
Dichloromethane	28, 84A, 99	<i>N,N</i> -dimethylphenylamine	4B
Dichloromethane, ethoxyethane alternative	42	2,4-dinitrobromobenzene	NR
2,6-dichlorophenolindophenol	32	2,4-dinitrochlorobenzene	NR
Dichromate(VI) oxidation of butanols	84B	2,4-dinitrofluorobenzene	NR
Dichromate(VI) oxidation of propanols	84A	Dinitrogen monoxide and its preparation	8, 68
Dichromate(VI) test papers	92	Dinitrogen tetroxide	68
Dichromate(VI) titrations	4A	2,4-dinitrophenylhydrazine	30
Dicopper(I) ethynediide	45C	Dipentene	45C
Diethyl ether	42	D-(+)-dipentene	45C
Diethyl sulfate(VI)	NR	Diphenylamine	4A

Chemical or activity	Hazard	Chemical or activity	Hazard
Diphenylamine indicator	4A	Distillation of coal	21
Diphenylamine-4-sulfonic acid, salts	4A	Distillation, fractional	45A
1,2-diphenylethane-1,2-diol	14	Distribution coefficient	36B, 100, 103, 106
1,2-diphenylethanedione (benzil)	14	Disulfur dichloride and its preparation	96B
Diphenylmethanone	85	Dithioamide	35
Diphenylthiocarbazone	32	Dithizone	28, 32
Diphosphine	19B	Dodecanoic acid	38B
Diphosphorus pentaoxide	75	di(dodecanoyl) peroxide	29, 43B
Dipotassium disulfate(IV)	92	Dodecylbenzenesulfonic acid	31
Dipotassium hydrogenphosphate(V)	72	<i>Drosophila</i> , anaesthetising	42
Dipotassium peroxodisulfate(VI)	95B	<i>Drosophila</i> , medium	52
Direct dye 28	32	Dry ice and its preparation	20
Direct red 23	32	<i>Dry-Chlor</i>	89
Disilver ethynediide	45C	Drying agents	19A, 25, 75, 86, 98A, 98B
Disinfectants	89	Drying gases	19A
Disodium disulfate(IV)	92	Drying glassware	85
Disodium hydrogen orthophosphate	72	Dutch metal	22A
Disodium hydrogenphosphate(V)	72	Dyeing fabrics	32
Disodium peroxodisulfate(VI)	95B	Dyes	4B, 32
Disodium tetraborate	14	Dyes, indicators and stains	32
Disperse yellow 7	32	Earthworms, extraction from soil	63, 81
Displacement reactions	47B, 108B	EDTA and its titrations	3B
Disposal of oxidising agents	92	Electrically-conducting polymers	4C
Disposal of potassium	84B	Electrolysis of copper salts	27A, 27B
Disposal of sodium	88	Electrolysis of halide salt solutions	47B
Dissolved oxygen, test for	80, 95B	Electrolysis of magnesium sulfate(VI)	59B
Distillation	43B	Electrolysis of molten lead salts	57A
Distillation extractions	28	Electrolysis of molten salts	108A

Chemical or activity	Hazard	Chemical or activity	Hazard
Electrolysis of potassium chromate(VI)	27B	Ethanal tetramer	34
Electrolysis of salt solutions	47B	Ethanal / sulfur dioxide reaction	34
Electrolysis of sodium chloride	22A, 47B	Ethanamide and its preparation	13B, 35
Electrolysis of sodium sulfate(VI)	98B	Ethane	45A
Electrolysis of sulfuric(VI) acid	98A	Ethane-1,2-diamine	3B
Electrolysis of zinc bromide	108A	Ethane-1,2-diol	37, 71
Electrophoresis	3C	Ethanedioate / iron complexes	55B, 55C
Electrophoresis, gel: stains	3C	Ethanedioic acid and its salts	36A
Electrostatic charge, effect of	100	Ethanenitrile	13B
Electrostatic fields, attraction to	99	Ethanoic acid	38A
Electrostatic fields, deflection by	104	Ethanoic acid / phosphorus pentachloride reaction	38A
Endothermic reactions	8, 9A, 9B, 36C, 47B, 96B	Ethanoic acid, 100%, lack of acidity	39
Engine oil, viscosity	37, 45B	Ethanoic acid / sodium reaction	38A
Engine oils, unused	37	Ethanoic anhydride	39
Enthalpy changes	91	Ethanol	40A, 88
Enthalpy of mixing	43A	Ethanol gun	40A
Enzymes and their inhibition	33	Ethanol oxidation	78
Eosin	32	Ethanol, 70%	63
Epinephrine	3C	Ethanol, authority to purchase	40A
Epsom salts	59B	Ethanol / sodium reaction	88
Equilibrium mixtures	43A	Ethanoyl chloride	41
Eriochrome black	32	Ethanoyl chloride / ammonia & amines reactions	41
Esters and their preparation	13A, 36A, 38A, 38B, 39, 43A, 43B, 52, 64, 84A, 84B	2-ethanoylbenzenecarboxylic acid	52
Etching	8, 67	Ethanoylbenzoic acid	52
Etching solutions	55C	Ethene and bromine water	103
Ethanal	34	Ethene and its preparation	40A, 45C
Ethanal solution	23	Ether	42
		Etherising <i>Drosophila</i>	42

Chemical or activity	Hazard	Chemical or activity	Hazard
Ethidium bromide	NR, 3C	Expanded polystyrene	71
Ethoxyethane	42	Exploding film canisters	36C
Ethyl 3-phenylpropenoate	64	Exploding tin	45A
Ethyl 4-aminobenzenecarboxylate	4B	Explosions, hydrogen / air / oxygen	48
Ethyl 4-aminobenzoate	4A, 4B	Extracting caffeine	28, 84A, 104
Ethyl benzenecarboxylate	64	Extracting earthworms from soil	63, 81
Ethyl acetate	43A	Extracting organics with ethoxyethane	42
Ethyl benzoate	13A, 64	Extracting soil organisms	23, 63, 81
Ethyl bromide	44B	Extraction of limonene	45C
Ethyl carbamate	NR	Extraction using solvents	28
Ethyl chloride	NR	Fabric dyeing	32
Ethyl cinnamate	64	Fehling's solution	27C, 34, 91
Ethyl ethanoate	43A, 54B, 85, 103, 104	Fermentation	40C
diethyl ether	42	Ferrate(VI) compounds	55C
Ethyl iodide	44B	Ferric alum	55C
diethyl sulfate(VI)	NR	Ferric chloride	55C
Ethylamine	3A	Ferric nitrate	55C
Ethylene	45C	Ferric oxide	55A
Ethylene diamine tetraacetic acid	3B	Ferric sulfate	55C
Ethylene dibromide	103	Ferrosoferric oxide	55A
Ethylene dichloride	103	Ferrous ammonium sulfate	55B
Ethylene glycol	37	Ferrous chloride	55B
triethylene glycol	37	Ferrous oxide	55A
Ethylenediamine	3B	Ferrous sulfate	55B
Ethyne and its preparation	19B, 45C	Ferrous sulfide	55A
Ethyne, reactions	45C	Ferroxyl indicator	79
Euthanasia of animals	42	Filter fume cupboards, efficiency tests	99
Evaporation investigations	40A, 42	Finkelstein reaction	44B, 85

Chemical or activity	Hazard	Chemical or activity	Hazard
Fire writing	82	Galena	56
Fixatives	24, 63	Gas analysis	12
Flame tests	10A, 19A, 47B	Gas-drying agent	19A
Flame-retarding solution	14	Gaseous equilibrium	68
Fluorescein	32	Gatenby's fluid, alternative	24
Fluoride / iron complexes	55B, 55C	Gel electrophoresis, stains	3C
Fluorine	NR	Gentian violet	32
Fluorspar	19A	Gibberellic acid	38C
Formaldehyde	63	Glass pigment	65A
Formalin	63	Glass, making	14, 56, 108B
Formalin, alternatives to	37	Glassware, cleaning	24, 67, 78, 81
Formic acid	38A	Glassware, drying	85
Formula of a compound	10A	Glauber's salt	98B
Fountain experiment	5, 49, 97	Glazes	65A
Fractional distillation	45A	D-Glucose	40C
Freezing mixture	20	Glucose isomerase	33
Freezing water with ethoxyethane	42	D-Glucose-1-phosphate (dipotassium salt)	40C
Friedel-Crafts reaction	2A	Glutamic acid	38C
Frog heart inhibition / stimulation	3C	Glutamine	38C
D-Fructose	40C	Glycerine	37, 45B, 46
Fuels	3B, 40A, 40B, 45A, 45B, 45C, 84A, 84B, 84C	Glycerol	37, 45B, 46
Fumaric acid	36B	Glycine	38C
Fume cupboard (filter) efficiency tests	99	Gram's stain	32
Fuming nitric acid	67	Graphite	21
Fuming nitric acid / sawdust reaction	67	Grignard reagents	23
Functional group identification	13A	Group I nitrates, heating	82
Fusion test	88	Group I salts	47B
D-Galactose	40C	Group IV halides	99

Chemical or activity	Hazard	Chemical or activity	Hazard
Group V elements and compounds	73B	Heating highly-flammable liquids	40A, 40B
Growing crystals	24, 27C, 36C, 55B	Heating hydrated copper(II) sulfate(VI)	27C
Gun-cotton	40C	Heating hydrogen iodide	49
Gunpowder	82	Heating iodates and bromates	80
Gypsum	19B	Heating iodine	54A
Haematite	55A	Heating iron(II) carbonate	55A
Halide salts	47B	Heating lead sulfide	56
Halide test	87	Heating lead(II) nitrate(V)	57A
Halides	19A	Heating lithium	58
Halite	47B	Heating lithium nitrate(V)	58
Halogen identification	106	Heating magnesium compounds	59B
Halogenated ethanes	103	Heating mercury	61
Halogenoalkanes	44A, 44B	Heating mercury(II) compounds	62
trihalophenols	70	Heating nickel(II) carbonate	65A
Hand warmers	38A	Heating nickel(II) nitrate(V)	65B
Harcourt Esson reaction	50	Heating nitrates	19A
Harlow's solutions	92	Heating ores	26
Heart action inhibition / stimulation	3C	Heating plastics	71
Heat of reaction	58	Heating potassium chlorate(V)	77
Heat of solution	8, 47B	Heating potassium manganate(VII)	81
Heating aluminium compounds	2A, 2B	Heating propanols	84A
Heating ammonium compounds	8, 9A	Heating zinc compounds	108A, 108B
Heating calcium carbonate	19B	Heptan-1-ol	84C
Heating carbohydrates	40C	Heptane	45A
Heating cobalt(II) carbonate	25	<i>n</i> -heptane	45A
Heating copper(II) compounds	27A, 27B	Heptanol	84C
Heating ethanedioic acid	36A	<i>n</i> -heptyl alcohol	84C
Heating Group I nitrates	82	Hex-1-ene	45C

Chemical or activity	Hazard	Chemical or activity	Hazard
Hexadecan-1-ol	46, 84C	Hydrated cobalt chloride	25
Hexadecanoic acid	38B, 46	Hydrated copper acetate	27B
Hexamethylene	34	Hydrated copper sulfate	27C
Hexamethylenediamine	3B	Hydrated cupric acetate	27B
Hexamethylenetetramine	3B	Hydrated cupric chloride	27A
Hexamine	3B	Hydrated cupric nitrate	27B
Hexan-1-ol	84C	Hydrated ferric compounds	55C
Hexane	45A	Hydrated ferrous compounds	55B
<i>n</i> -hexane	45A	Hydrated lead acetate	57B
Hexane-1,6-diamine	3B	Hydrated magnesium nitrate	59B
Hexanedioyl chloride	41	Hydrated sodium acetate	38A
Hexanoic acid	38B	Hydrated sodium sulfate	98B
Hexanol	84C	Hydrated stannous chloride	102
Hexene	45C	Hydrated strontium chloride	19A
<i>n</i> -hexoic acid	38B	Hydrated strontium hydroxide	18
<i>n</i> -hexyl alcohol	84C	Hydrated zinc nitrate	108A
<i>n</i> -hexylene	45C	Hydrated zinc sulfate	108B
HHSNNA	32	Hydrazine hydrate and its salts	NR, 53
Histidine	38C	Hydriodic acid	47A
Hoffman bromination reaction	3A, 35	Hydrobromic acid	47A
Hoffman voltameter	59B, 98A	Hydrocarbons, aliphatic	45A, 45B, 45C
Hollow-prism activities	64	Hydrocarbons, aromatic	46
Hormone rooting powders / gels	38C	Hydrocarbons, burning	45A, 45B, 45C
Howling jelly-baby demonstration	77	Hydrocarbons, cracking	45B
Humidity, test for	25	Hydrocarbons, saturated	45A, 45B
Hydrated aluminium chloride	2A	Hydrocarbons, unsaturated	45C
Hydrated calcium chloride	19A	Hydrocarbons, unsaturated: test for	45B
Hydrated calcium sulfate	19B	Hydrochloric acid	47A

Chemical or activity	Hazard
Hydrochloric acid / pot. manganate(VII) reaction	47A
Hydrofluoric acid	NR
Hydrogen and its preparation	26, 48, 55A, 107
Hydrogen bond energy	43A
Hydrogen bonds, strength measurement	85, 104
Hydrogen bromide	49
Hydrogen chloride and its preparation	49, 55B
Hydrogen chloride, dissolving	49
Hydrogen chloride / ammonia reaction	5
Hydrogen cyanide	NR
Hydrogen halides and their preparation	49, 72
Hydrogen halides, tests for	49
Hydrogen iodide and its heating	49
Hydrogen peroxide	50, 69
Hydrogen peroxide decomposition	33
Hydrogen peroxide / chromium(VI) reaction	50
Hydrogen peroxide / iodide reaction	50
Hydrogen peroxide / tartrate reaction	25
Hydrogen sulfide and its preparation	51
Hydrogen / air / oxygen explosions	48
Hydrogen / chlorine reaction	22A
Hydrohalic acids	47A, 81
Hydroiodic acid	47A
Hydrolysis of aluminium halides	2A
Hydrolysis of benzoate esters	64
Hydrolysis of benzonitrile	13B
Hydrolysis of ethanamide	35
Hydrolysis of group IV halides	99

Chemical or activity	Hazard
Hydrolysis of halogenoalkanes	44A, 44B
Hydrolysis of lipids	91
Hydrolysis of organohalogens	23
Hydrolysis of starch	40C
Hydrolysis of tin(IV) chloride	102
Hydroquinone	12
Hydroxyammonium chloride	53, 68
Hydroxyammonium / iron(III) ions reaction	53
Hydroxyammonium salts	53
Hydroxyammonium sulfate(VI)	53
1,2-dihydroxyanthraquinone	32
1,2,3-trihydroxybenzene	12
1,3,5-trihydroxybenzene	12
2-hydroxybenzenecarboxylic acid	52
2-hydroxybenzoic acid	52
2-hydroxybutanedioic acid	36C
2,3-dihydroxybutanedioic acid	36C
2,2-dihydroxy-1,3-indanedione	66
Hydroxyl group tests	74
Hydroxylamine hydrochloride	53
Hydroxylammonium chloride	53
Hydroxylammonium sulfate	53
2-hydroxypropane-1,2,3-tricarboxylic acid	36C
2-hydroxypropanoic acid	38C
Hypo	95C
IAA	38C
IBA	38C
IDA	40A

Chemical or activity	Hazard	Chemical or activity	Hazard
IMS	40A	Iodine / aluminium reaction	1
1,2,3-indanetrione hydrate	66	Iodine / chlorine reaction	54A
Indicators	32	Iodine / mercury reaction	61
Indicators, use with ammonia solution	6	Iodine / propanone reaction	54B, 85
Indigo carmine	32, 90	Iodine / sodium thiosulfate reaction	95C
Indigo reduction prior to dyeing	90	Iodine / zinc reaction	107
Indol-3-ylbutanoic acid	38C	Iodoalkanes	44B
Indol-3-ylethanoic acid	38C	1-iodobutane and its preparation	44B
Indoleacetic acid	38C	Iodoethane and its preparation	44B
Indolebutyric acid	38C	Iodoform	104
Indolylacetic acid	38C	Iodoform test	54A, 54B, 104
Indolylbutyric acid	38C	triiodomethane and its preparation	104
Industrial denatured alcohol	40A	Iodomethane	NR
Industrial methylated spirits	40A	Iodopropanone	54B
Inhibition of enzymes	33	1-iodopropane	44B
Inhibitors of polymerisation	12	Iodopropane	85
Inhibitors, removal	43B	Iron alum	55B
Invertase	33	Iron and its compounds	55A
Invisible ink	25	Iron powder / filings	55A, 55B, 55C
Iodates and bromates, heating	80	Iron(II) ammonium sulfate(VI)	55B
Iodide / hydrogen peroxide reaction	50	Iron(II) carbonate decomposition / heating	55A
Iodine	54A	Iron(II) carbonate saccharated	55A
Iodine number	45C	Iron(II) chloride and its preparation	49, 55B
Iodine reaction with alkalis and metals	54A	Iron(II) chloride, anhydrous	55B
Iodine solution and its preparation	54B	Iron(II) disulfide	55A
Iodine solvent	106	Iron(II) iron(III) oxide	55A
Iodine value	28	Iron(II) oxide and its preparation	55A
Iodine, partition coefficient	106	Iron(II) salts	55B

Chemical or activity	Hazard	Chemical or activity	Hazard
Iron(II) sulfate(VI)	55B, 68, 82	Lamp black	21
Iron(II) sulfide	51, 55A	Landolt clock reaction	80
Iron(III) ammonium sulfate(VI)	55C, 68	Laughing gas	68
Iron(III) chloride	55C, 79	Lauric acid	38B
Iron(III) chloride, anhydrous: preparation	55C	Lauroyl peroxide	29
Iron(III) nitrate(V)	55C	dilauroyl peroxide	29
Iron(III) oxide	55A, 55C	Lead	56
Iron(III) oxide, reduction with hydrogen	55A	Lead acetate	57B
Iron(III) salts	55C	Lead alkyls	NR
Iron(III) sulfate(VI)	55C	Lead crystals	56
Iron(III) / hydroxyammonium ions reaction	53	Lead dioxide	56
Iron / acids reaction	55A	Lead halides	57A
Iron / sulfur reaction	55A, 96A	Lead monoxide	56
Iron / thiocyanate complexes	95A	Lead oxide / ores, reduction	56
Isomerism	36B	Lead pigments, painting with	57B
cis / trans isomers	36B	Lead salts	56, 57A, 57B
Janus green b	32	Lead sulfide, heating	56
Kaowool	86	Lead(II) bromide	57A
Kerosene	45B	Lead(II) carbonate	56
Ketone reactions	85	Lead(II) chloride	47B, 57A
Ketone reduction	14	Lead(II) chromate(VI) and its preparation	57B
Ketones	85	Lead(II) ethanoate	57B
Kipp's apparatus	20, 51	Lead(II) iodide	57A
Lactase	33	di-lead(II) lead(IV) oxide	56
Lactic acid	38C	Lead(II) nitrate(V) and its heating	57A, 57B, 68
Lactophenol	38C	Lead(II) oxide	56
D-Lactose	40C	Lead(II) oxide reduction	21
Lactozym	33	Lead(II) sulfate(VI)	57A

Chemical or activity	Hazard	Chemical or activity	Hazard
Lead(II) sulfide	56	Lithium hydroxide	91
Lead(IV) chloride and its preparation	57A	Lithium nitrate(V) and its heating	58
Lead(IV) oxide and its preparation	56	Lithium tetrahydridoaluminate	NR
Lead, melting	56	Lithium, heating	58
Lead, test for in water	28	Lithium / hydrochloric acid reaction	58
Leatherjackets, extracting from soil	23	Lithium / water reaction	58
isoleucine	38C	Litmus	32
Leucine	38C	Liver, source of catalase	33
Lighting hydrogen at a jet	48	Locating agents in chromatography	4A, 66
Lignin test	12	LPG	45A
Limestone	19B	Luminol	4B
Limewater and its preparation	18	Lysine	38C
Limonene	45C	Macerating woody tissue	92
Limonene, extraction of	28	Magenta	32
Lipase	33	Magnesia	59B
Lipase investigations	95C	Magnesium carbonate and its heating	59B
Lipid hydrolysis	91	Magnesium carbonate hydroxide	59B
<i>Lipolase</i>	33	Magnesium chlorate(VII)	NR, 59B
Liquid crystals and their preparation	4C, 13B	Magnesium chloride	59B
Liquid detergent, making	31	Magnesium nitrate(V) and its heating	59B
Liquid nitrogen	68	Magnesium oxide	59B
Liquid paraffin	37, 45B, 46	Magnesium perchlorate	59B
Liquid petroleum gas	45A	Magnesium ribbon and its burning	59A
Litharge	56	Magnesium silicide	59A
Lithium	58	Magnesium sulfate(VI)	59B, 98A, 98B
Lithium aluminium hydride	NR	Magnesium, turnings or powder	48, 59A
Lithium carbonate	58	Magnesium / acid reaction	59A
Lithium chloride	47B	Magnesium / carbon dioxide reaction	20

Chemical or activity	Hazard	Chemical or activity	Hazard
Magnesium / copper oxide reaction	59A	Medicinal paraffin	37, 45B, 46
Magnesium / silica reaction	59A	MEK	85
Magnesium / steam reaction	59A	Melting sulfur	96A
Magnesium / sulfur dioxide reaction	97	Melting-point determinations	37, 45B, 46, 64, 106
Magnetism	55A	Mercuric chloride	62
Magnetite	55A	Mercuric nitrate	62
Making cement / mortar	18	Mercuric oxide	62
Making glass	56, 108B	Mercuric sulfate	62
Making liquid detergent	31	Mercuric sulfide	62
Making soap	91	Mercuric salts	33, 62
Malachite	26	Mercurous chloride	62
Malachite green	32	Mercurous oxide	62
Maleic acid	36B	Mercurous salts	62
Malic acid	36C	Mercury	61
Malonic acid	36B	Mercury alkyls	NR
D-Maltose	40C	Mercury(I) chloride	62
Manganese and its compounds	60	Mercury(I) oxide	62
Manganese dioxide	50, 60	Mercury(II) chloride	62
Manganese test	95A	Mercury(II) nitrate(V) and its heating	62
Manganese(II) chloride	60	Mercury(II) oxide and its heating	61, 62
Manganese(II) sulfate(VI)	60	Mercury(II) salts / aluminium reaction	62
Manganese(IV) oxide	60, 69, 77, 81	Mercury(II) sulfate(VI)	62
Manometers, mercury	61	Mercury(II) sulfide	62
Marble chips	18, 19B	Mercury, heating	61
Marsh gas	45A	Mercury / iodine reaction	61
Massicot	56	Metal etching solution	8
<i>Maxiren</i>	33	Metal oxides, reduction	21
May-Grunwald stain	32	Metal / bromine reactions	15A

Chemical or activity	Hazard	Chemical or activity	Hazard
Metaldehyde fuel	34	Methyl phenyl ether	42
Metals / nitric acid reaction	67	Methyl red	32
Methanal	63, 70	Methyl salicylate	52
Methane	45A	dimethyl sulfate(VI)	NR
Methanoic acid	38A	Methyl violet	32
Methanol	40B	Methylamine	3A
Methenamine	3B	<i>N,N</i> -dimethylaniline	4B
Methionine	38C	dimethylbenzene	2A
Methoxybenzene	2A, 42, 46	Methylbenzene	2A, 46, 54B
3,3'-dimethoxybiphenyl-4,4'-diamine	B, 4A	dimethylbenzene (all isomers)	46
Methyl 2-hydroxybenzenecarboxylate	52	Methylbenzene (dry), as solvent	49
Methyl 2-hydroxybenzoate	52	3,3'-dimethylbiphenyl-4,4'-diamine	B, 4A
Methyl 2-methylpropenoate	29, 43B	3-methylbutan-1-ol	84C
Methyl 3-nitrobenzenecarboxylate	64	2-methylbutan-2-ol	44A
Methyl 3-nitrobenzoate	13A, 64	3-methylbutyl ethanoate	43B, 105
Methyl 4-hydroxybenzenecarboxylate	52	Methylene blue	32
Methyl 4-hydroxybenzoate	52, 70	Methylene dichloride	28
Methyl acetate	43A	dimethylglyoxime	53
Methyl alcohol	40B	Methylphenols	70
Methyl benzenecarboxylate	64	<i>N,N</i> -dimethylphenylamine	4B
Methyl benzoate	46, 64	2-methylpropan-1-ol	84B
Methyl blue	32	2-methylpropan-2-ol	76, 84B
Methyl chloroform	103	Microcosmic salt and bead test	72
Methyl ethanoate	43A	Middleton's test	88, 107
Methyl ethyl ketone	85	Millon's reagent	62
Methyl green	32	Mineral wool	86
Methyl methacrylate	29, 43B	Mineralised methylated spirits	40A
Methyl orange and its preparation	4B, 32, 93	Model steam engine fuel	3B, 34

Chemical or activity	Hazard	Chemical or activity	Hazard
Molisch's test	40C	Navashin's fluid	24
Monastral blue, preparation	13B	Nessler's reagent	62
Money, paper burning	40A	Neutral red	32
Monobasic acids	38B	<i>Neutrase</i>	33
Monoclinic sulfur and its preparation	46, 96A, 106	NiCad batteries	61
Mortar	18	Nickel	65A
Motor oil, viscosity	37, 45B	Nickel complexes, preparation	65B
Motor oils, unused	37	Nickel salts, testing for	53
Mountants	38C	Nickel(II) carbonate (basic) and its heating	65A
Movement of immiscible liquids in water	4A	Nickel(II) chloride	65B
Movement of ions	27B	Nickel(II) nitrate(V)	65B
Murexide	32	Nickel(II) oxide	NR, 65A
Muriate of potash	47B	Nickel(II) salts	65B
Mustard, English, ready-made	63	Nickel(II) sulfate(VI) and its preparation	65B
NAA	38C	Nickel-based batteries	65A
Nansa acid	31	Nicotine	3C
Naphthalen-1-amine	B, 4A	Nightlights, burning	45B
Naphthalen-1-ol	70	Nigrosin	32
Naphthalen-2-amine	B, 4A	Ninhydrin	66
Naphthalen-2-ol	4B, 70	Nipagin	52
Naphthalene	46, 84C	Nital	67
Naphthols	70	Nitrate test	1, 82
Naphthylacetic acid	38C	Nitrate(V) / sugar reaction	82
1-naphthylamine	B, 4A	Nitrates, heating	19A
2-naphthylamine	B, 4A	Nitrating mixture	67
Naphthylethanoic acid	38C	Nitration	64
Natural gas	45A	Nitration of aromatic rings	46
Natural red 4	32	Nitration of phenol	70

Chemical or activity	Hazard	Chemical or activity	Hazard
Nitric(V) acid and its decomposition	67	Nitrosoamines	B
Nitric(V) acid, fuming	67	Nitrosonaphthalenes	B
Nitric(V) acid, fuming / sawdust reaction	67	Nitrosophenols	B (some), NR
Nitric(V) acid / metals reaction	67	Nitrotoluenes	NR
Nitric(III) acid, preparation	93	Nitrous acid, preparation	93
Nitric oxide	68	Nitrous oxide and its preparation	8, 68
Nitro aromatic compounds	4A	<i>Novoshape</i>	33
Nitrobenzene	NR, 4A	Nucleic acid staining	3C
3-nitrobenzenecarboxylic acid & its preparation	4A, 13A	Nylon	71
3-nitrobenzoic acid and its preparation	4A, 13A	Nylon 'rope' demo / preparation	3B, 41, 100, 103, 106
2,4-dinitrobromobenzene	NR	Oct-1-ene	45C
2,4-dinitrochlorobenzene	NR	<i>cis</i> -octadec-9-enoic acid	38B
2,4-dinitrofluorobenzene	NR	Octadecan-1-ol	46
Nitrocellulose	40C	Octadecanoic acid	38B, 46
Nitrogen and its oxides	68	Octamethylcyclotetrasiloxane	106
Nitrogen dioxide	5, 68	Octan-1-ol	84C
Nitrogen dioxide from ammonia	5	Octan-2-ol	84C
Nitrogen monoxide and its preparation	68	Octanol	84C
dinitrogen monoxide and its preparation	8, 68	1-octene	45C
Nitrogen peroxide	68	Octenes, preparation	84C
dinitrogen tetroxide	68	<i>iso</i> -octyl alcohol	84C
Nitrogen triiodide	NR, 6	<i>n</i> -octyl alcohol	84C
Nitrogen, liquid	68	Oil of wintergreen	52
Nitrogen, preparation	68, 93	Oil, for baths	37, 45B, 46
Nitromethylbenzenes	NR	Oil-drop investigation	42
Nitronaphthalenes	B	Oleic acid	38B
2,4,6-trinitrophenol	NR, 70	Oleum	NR
2,4-dinitrophenylhydrazine	30	<i>Opresol</i>	37, 63

Chemical or activity	Hazard	Chemical or activity	Hazard
Orange 2	4B	Oxygen production in photosynthesis	90
Oranges, extraction of limonene	45C	Oxygen, absorbing	12
Orcein	32	Oxygen, preparation	50, 60, 69, 77, 94
Ores	26	Paint stripper	28
Organic 'unknowns'	13A	Painting with lead pigments	57B
Organic peroxides	29	Palmitic acid	38B
Organic substances, extraction	42	Palmityl alcohol	84C
Organohalogen hydrolysis	23	Pancreatin	33
Orthophosphoric acid	72	Paracetamol preparation	70
Oscillating reactions	80	Paraffin	45B
Osmic acid	NR	Paraffin oil	37, 45B, 46
Osmium(VIII) oxide	NR	Paraffin wax	45B
Ovens, use of mercury thermometers	61	Paraffin, liquid / medicinal	37, 45B, 46
Oxalic acid	36A	Partition coefficient / constant / function	36B, 100, 103, 106
Oxidation of ammonia	5		
Oxidation of butanols	84B	Patton and Reeder's indicator	32
Oxidation of ethanol	40A, 78	Pectinase	33
Oxidation of methanol	40B	Pectinesterase	33
Oxidation of phenylmethanol	40B	<i>Pectinex</i>	33
Oxidation of propanols	84A	Pemanganate Value test	81
Oxidation reactions of aldehydes	83	Pentan-1-ol	84C
Oxides, catalytic action	77	Pentane	45A
Oxidising agents, disposal	92	<i>n</i> -pentane	45A
Oxidising halides	15B	Pentanoic acid	38B
Oximes, preparation	53	Pentanol	84C
Oxygen	69	D-(+)-dipentene	45C
Oxygen in water, test for	80, 95B	Pentose test	12
Oxygen mixture	77	Pentyl acetate	43B, 50, 105

Chemical or activity	Hazard	Chemical or activity	Hazard
Pentyl ethanoate	43B, 50, 105	Phenyl bromide	23
Pepsin	33	Phenyl chloride	23
Percentage available chlorine	17	Phenyl cyanide	13B
Perchloric acid	NR	Phenyl salicylate	46, 52
Perchloroethylene	99	Phenyl-2-hydroxybenzenecarboxylate	52
Periodicity of chlorides	100	Phenyl-2-hydroxybenzoate	52
Perkin's mauve	4A	Phenylacetylene	71
Permanganate Value test on water	81	Phenylalanine	38C
Peroxide test for ethers	42	Phenylamine	4A
Peroxides, organic	29	diphenylamine	4A
Peroxodisulfate(VI) / iodide clock reaction	8	diphenylamine indicator	4A
Perspex cement	28, 99	diphenylamine-4-sulfonic acid, salts	4A
Perspex, preparation	43B	Phenylammonium chloride	4A
Petrol	B	<i>N</i> -phenylethanamide and its preparation	35, 39
Petroleum ether / spirits	45A, 85	1,2-diphenylethane-1,2-diol	14
pH 4 buffer	13B	1,2-diphenylethanedione (benzil)	14
pH 7 buffer	9B	Phenylethanone	85
pH 9.2 buffer	14	Phenylethene	29, 71
pH of soil	10B	Phenylethene, bromination	71
Phenol and its preparation	31, 63, 70, 88	Phenylethene, inhibitor removal	71
Phenol red	32	Phenylethyne and its preparation	71
Phenol / diazonium salts reaction	70	Phenylhydrazine	30
Phenol / sodium reaction	88	Phenylmethanol	40B
Phenol-indo-2,6-dichlorophenol	32	diphenylmethanone	85
Phenolphthalein and its preparation	13B, 32, 70, 79	<i>trans</i> -3-phenylprop-2-enoic acid	13A
Phenyl amides, preparation	41	2,3,5-triphenyltetrazolium chloride	4C
Phenyl benzenecarboxylate	64	Phenylthiocarbamide	35
Phenyl benzoate	46, 64	diphenylthiocarbazon	32

Chemical or activity	Hazard	Chemical or activity	Hazard
N-phenylthiourea	35	Photosynthesis, indicator for	90
Philosopher's wool	107	Phthalic acid	13A
Phloroglucinol	12	Phthalic anhydride	13B, 70
Phosgene	NR	Picric acid	NR, 70
Phosphate test and reagent	9A	PIDCP	32
diphosphine	19B	Pigments	65A
Phosphine, preparation	19B	Plant hormones	38C
Phosphoric(V) acid and its salts	72, 82	Plant pigments, extraction	40A
Phosphoric(V) oxide	72	Plaster casts	19B
Phosphorus	73A	Plaster of Paris	19B
Phosphorus chlorides / water reaction	74	Plastic sulfur	96A
Phosphorus pentachloride	74	Plastics, identification and pyrolysis	71
Phosphorus pentachloride / ethanoic acid reaction	38A	Plateau's spherule	4A
diphosphorus pentaoxide	75	Plating	65B
Phosphorus pentoxide	75	Polyacrylates, decomposing	43B
Phosphorus trichloride	74	Polybasic organic acids and salts	36A, 36B, 36C
Phosphorus(III) chloride	74	Polycarbonates	71
Phosphorus(V) chloride	74	Polylactic acid	38C
Phosphorus(V) oxide	75	Polymerisation	29, 34, 35
Phosphorus, allotropes	73A	Polymerisation of acrylamide	35
Phosphorus, burning	73A	Polymers, electrically-conducting	4C
Phosphorus, cutting	73A	Polyols	37
Phosphorus, red	73A	Polyphenylethene	71
Phosphorus, white	73A	Polypropene	71
Phosphorus, yellow	73A	Polypropylene	71
Phosphorylase	33	Polystyrene	71
Photochemical reaction of ferricyanide	79	Polystyrene, expanded: hot-wire cutting	71
Photographic developing	12	Polytetrafluoroethene	71

Chemical or activity	Hazard	Chemical or activity	Hazard
Polyurethane	71	Potassium ferrocyanide	79
Polyvinyl alcohol	14	Potassium fluoride	95A
Polyvinyl chloride	71	Potassium halides / sulfuric(VI) acid reaction	98A
Potassium	76	Potassium hexacyanoferrate(II)	79
Potassium amide	NR	Potassium hexacyanoferrate(III)	79
Potassium bicarbonate	95C	Potassium hydrogen oxalate	36A
Potassium bisethanedioate	36A	Potassium hydrogen phthalate	13B
Potassium bisulfite	92	Potassium hydrogen-benzene-1,2-dicarboxylate	13B
Potassium bromate(V)	80	Potassium hydrogen-benzene-1,2-dioate	13B
Potassium bromide	47B, 80	Potassium hydrogencarbonate	95C
Potassium carbonate	95A	Potassium hydrogenethanedioate	36A
Potassium chlorate(V) and its heating	60, 77	Potassium hydrogenethanedioate-1-ethanedioic acid	36A
Potassium chlorate(V), solubility investigations	77	dipotassium hydrogenphosphate(V)	72
Potassium chlorate(VII)	77	Potassium hydrogensulfate(IV)	92
Potassium chloride	8, 47B	Potassium hydrogensulfite	92
Potassium chromate(VI)	57B, 78	Potassium hydroxide	91
Potassium chromium(III) sulfate(VI), preparation	78	Potassium iodate(V)	80
Potassium cyanide	NR, 95B	Potassium iodide	47B, 50, 69
Potassium dichromate(VI)	10B, 50, 78, 92, 97	Potassium iodide solution	54B
Potassium dichromate(VI) titrations	10B	Potassium ions test	95A
Potassium dichromate(VI), test papers	78	Potassium manganate(VII) and its heating	50, 81
Potassium dihydrogenphosphate(V)	72	Potassium manganate(VII), preparation	60, 81
Potassium dioxide	94	Potassium manganate(VII) / hydrochloric acid reaction	47A
Potassium disulfate(IV)	92	Potassium manganate(VII) / propane-1,2,3-triol reaction	37
dipotassium disulfate(IV)	92	Potassium manganate(VII) / hydrohalic acids reaction	81
Potassium disulfite	92	Potassium metabisulfite	92
Potassium ethanedioate	36A	Potassium nitrate(III)	93
Potassium ferricyanide	79	Potassium nitrate(V)	82

Chemical or activity	Hazard	Chemical or activity	Hazard
Potassium nitrite	93	Powdered roll sulfur	96A
Potassium orthophosphate	72	Precipitation of barium carbonate	10A
Potassium oxalate	36A	Precipitation of barium chromate(VI)	10B
Potassium perchlorate	77	Precipitation reactions	6, 10A, 10B, 19A, 19B, 27C, 51, 60, 73B, 78, 79, 108A, 108B
Potassium permanganate and its heating	50, 81	Precipitation, quantitative	10A, 10B
Potassium permanganate, preparation	60, 81	<i>Presept</i>	89
Potassium permanganate / hydrochloric acid reaction	47A	Preservatives and preserving specimens	37, 63, 84A
Potassium permanganate / hydrohalic acids reaction	81	Prism, hollow: use of	64
Potassium permanganate / propane-1,2,3-triol reaction	37	Proline	38C
dipotassium peroxodisulfate(VI)	95B	Propan-1-ol	84A
Potassium persulfate	95B	Propan-1-ol + sodium chloride	28
Potassium phosphate(V)	72	Propan-1-ol, caffeine extraction	3C
Potassium salts	78, 79, 80, 81, 82, 95A, 95B, 95C	Propan-2-ol	84A
Potassium sodium 2,3-dihydroxybutanedioate	36C	Propanal	34, 83
Potassium sodium tartrate	25, 36C	Propane	45A
Potassium sulfate(IV)	92	Propane-1,2,3-triol	37, 45B, 46
Potassium sulfate(VI)	98B	Propane-1,2,3-triol / potassium manganate(VII) reaction	37
Potassium sulfide	51	Propane-1,2-diol	37
Potassium sulfite	92	Propanedioic acid	36B
Potassium superoxide	94	Propanoic acid	38B
Potassium tetroxalate	36A	<i>iso</i> - propanol	84A
Potassium thiocyanate	87, 95C	<i>n</i> - propanol	84A
Potassium, burning	76	Propanols and their heating	84A
Potassium, cutting	76	Propanols / sodium reaction	84A
Potassium, disposal	84B	Propanone	54B, 85
Potassium / alcohols reaction	76	Propanone / iodine reaction	54B, 85
Potassium / butanol reaction	84B	Propanone / trichloromethane reaction	104
Potassium / water reaction	76		

Chemical or activity	Hazard	Chemical or activity	Hazard
Propenamide	NR, 35	Pyroxylin	40C
Propionaldehyde	83	Pyrrole	4C
Propionic acid	38B	Quicklime	18
<i>n</i> -propyl acetate	43B	Quinol	12
iso propyl alcohol	84A	Radioactive compounds	47B, 101, 105
Propyl alcohol	84A	Radon	101
<i>n</i> -propyl chloride	44A	Radon-220 generators	101
Propyl ethanoate	43B	Raoult's law, negative deviation	43A, 85, 104
<i>n</i> -propyl iodide	44B	Rate of reaction / particle size	19B
Propylene glycol	37	Recycling silver	87
Propylene phenoxetol	37, 63	Red lead	56
Protactinium generators	105	Red phosphorus	73A
Protease	33	Redox equilibria	55C
Protein testing	62	Redox reactions	77, 80
Prussian blue	79	Reducing agents	83, 90
PTC / PTU	35	Reducing sugar tests	27C, 40C, 91
PTFE	71	Reducing sugars	83
Purification of naphthalene	46	Reduction of aromatic nitro compounds	4A
Purple meths	40A	Reduction of copper(II) ions	34
PV (Permanganate Value), testing water	81	Reduction of copper(II) oxide	26, 45A, 48, 107
PVA	14	Reduction of copper(II) oxide by zinc	107
PVC	71	Reduction of iron(III) oxide with hydrogen	55A
Pyridine	4C	Reduction of ketones	14
Pyrites	55A	Reduction of lead(II) oxide / ores	21, 56
Pyrocatechol	12	Reduction of metal oxides	21
Pyrogallate, alkaline	12	Reduction of 3-nitrobenzoic acid	4A
Pyrogallol	12	Reduction using carbon monoxide	21
Pyrolusite	60	Reductions using blowpipes	21, 26, 56

Chemical or activity	Hazard	Chemical or activity	Hazard
Refluxing	99	Saponification of esters	43A, 43B
Regenerating cellulose	6	Saponification of oils	91
<i>Rennilase</i>	33	Saturated hydrocarbons	45A, 45B
Rennin / rennet	33	Schotten-Baumann reactions	13B, 41
Resins and their preparation	13B, 35, 63, 70	Schulze's solution	24
Resins, preparation from urea	35	Sebacoyl chloride	41
Resorcinol	12	Selenium and its compounds	NR
Respiratory activity in tissues	4C	Sensitised paper	87
Rhombic sulfur	96A	Separating funnel, use	28
Rochelle salt, crystals	36C	Serine	38C
Rock salt	47B	Silica	86
<i>Rocksil</i>	86	Silica gel	25, 86
Root tips, metaphase	23	Silicon and its compounds	86
Rooting powders / gels	38C	Silicon(IV) oxide	86
Rosaniline	32	Silicon tetrachloride and its preparation	86
Rubeanic acid	35	Silicon tetrachloride / water reaction	86
Rubidium chloride	47B	Silver	87
Rust, detecting	79	Silver bromide	87
Rusting investigations	55A	Silver chloride	87
Sakaguchi test	62, 89	disilver ethynediide	45C
Sal ammoniac	9A	Silver fulminate	6
Salicylic acid	52	Silver iodide	87
Saliva, source of amylase	33	Silver mirror test	87
Saliva, use of	40C	Silver mirrors, preparing	83
Salol	46, 52	Silver nitrate(V)	44A, 44B, 87
Sand	86	Silver nitrate(V), ammoniacal	6, 87
Sandell's solution	27C, 34, 40C	Silver, recycling	87
Saponification of benzoate esters	64	Siphon cylinders	20

Chemical or activity	Hazard	Chemical or activity	Hazard
Slaked lime	18	Sodium cobaltinitrite	95A
Slime and its preparation	14	Sodium cyanide	NR, 95B
Smelling salts	9A	Sodium dichloroisocyanurate	22B, 89
Smith's fixative	24	Sodium dichromate(VI)	78
Smoking machines	3C	Sodium dihydrogenphosphate(V)	72
Soap	95C	Sodium disulfate(IV)	92
Soap, making	91	disodium disulfate(IV)	92
Soda lime	91	Sodium disulfite	92
Sodamide	NR	Sodium dithionite	90
Sodium	88	Sodium dodecyl sulfate(VI)	95C
Sodium acetate	38A	Sodium ethanedioate	36A
Sodium alginate	95C	Sodium ethanoate	38A
Sodium amalgam	61	Sodium fluoride	95A
Sodium amide	NR	Sodium formate	38A, 95C
Sodium azide	95B	Sodium halides / sulfuric(VI) acid reaction	98A
Sodium bicarbonate	95C	Sodium hexanitrocobaltate(III)	95A
Sodium bismuthate(V)	95A	disodium hydrogen orthophosphate	72
Sodium bisulfate	98B	Sodium hydrogencarbonate	95C
Sodium bisulfite	92	disodium hydrogenphosphate(V)	72
Sodium borohydride	14	Sodium hydrogensulfate(IV)	92
Sodium bromide	47B	Sodium hydrogensulfate(VI)	98B
Sodium carbonate	95A	Sodium hydrogensulfite	83, 92
Sodium carbonate-hydrogencarbonate	95C	Sodium hydrosulfite	90
Sodium chlorate(I)	89	Sodium hydroxide	91
Sodium chlorate(V)	77	Sodium hypochlorite	89
Sodium chloride	47B	Sodium iodide	47B, 85
Sodium chromate(VI)	78	Sodium lauryl sulfate	95C
Sodium citrate	36C, 79	Sodium metabisulfite	83, 92

Chemical or activity	Hazard	Chemical or activity	Hazard
Sodium methanoate	38A	Sodium thiosulfate	95C
Sodium nitrate(III)	68, 93	Sodium thiosulfate / acid reaction	95C
Sodium nitrate(V)	82	Sodium thiosulfate / bromine reaction	95C
Sodium nitrite	68, 93	Sodium thiosulfate / iodine reaction	95C
Sodium octadec-9-enoate	95C	Sodium, burning	88
Sodium octadecanoate	95C	Sodium, cutting	88
Sodium oleate	95C	Sodium / butanol reaction	84B
Sodium orthophosphate	72	Sodium / chlorine reaction	88
Sodium oxalate	36A	Sodium / ethanoic acid reaction	38A
Sodium perborate	14	Sodium / ethanol reaction	40A, 88
Sodium peroxide	94	Sodium / methanol reaction	40B
Sodium peroxoborate	14	Sodium / phenol reaction	88
disodium peroxodisulfate(VI)	95B	Sodium / propanols reaction	84A
Sodium persulfate	95B	Sodium / water reaction	88
Sodium phosphate(V)	72	Soil organisms, extracting	23, 63, 81
Sodium salts	88, 89, 92, 93, 94, 95A, 95B, 95C	Soil, pH	10B
Sodium sesquicarbonate	95C	Solid fuels	3B, 34
Sodium silicate solution	95B	Solid sulfuric acid	98B
Sodium stearate	95C	Solochrome black	32
Sodium sulfate(IV)	92	Solubility investigations	77
Sodium sulfate(VI)	98B	Solubility product	18
Sodium sulfide	51	Solvent extraction	28, 99
Sodium sulfite	92	Solvent green 1	32
Sodium tauroglycocholate	95C	Solvent, for bromine	45B
Sodium tetraborate	14	Solvents	42, 104, 106
disodium tetraborate	14	Solvents for chromatography	84B
Sodium tetrahydridoborate(III)	14	Solvents for iodine	54B
Sodium thiocyanate	95C	Solvents, cyclohexane	45B


Chemical or activity	Hazard	Chemical or activity	Hazard
Solvents, hydrocarbons	45A	Sucrose	40C
Soylent green	32A	Sucrose / nitrate(V) reaction	82
Spirit blue	32	Sucrose / sulfuric(VI) acid reaction	98A
Spirit burners	40A, 40B, 45A, 84A, 84B, 84C	Sudan black stain	24
Spirometers, carbon dioxide removal	91	Sudan dyes	32
Stainless-steel sinks	55B, 55C	Sudan III stain	24
Stains	30, 32, 38C	Sugar	40C
Standard solutions	13B	Sugar / nitrate(V) reaction	82
Stannic chloride	102	Sugar / sulfuric(VI) acid reaction	98A
Stannic iodide	102	Sugars, chromatography	4C
Stannic oxide	102	Sulfamic acid	98B
Stannous chloride	102	Sulfanilic acid	4A, 4B
Stannous oxide	102	Sulfate(VI) test	10A, 11
Stannous sulfate	102	Sulfates	98B
Starch	40C	Sulfite test	92
Steam engine fuel	3B, 34	Sulfur	96A
Stearic acid	38B	Sulfur chlorides	96B
Strontium	16	Sulfur crystals	96A, 106
Strontium chloride	19A, 47B	Sulfur dichloride oxide	96B
Strontium hydroxide	18	disulfur dichloride, and its preparation	96B
Strontium nitrate(V)	19A	Sulfur dioxide and its preparation	83, 92, 97
Strontium salts	19A, 19B	Sulfur dioxide, test for	97
Styrene	29, 71	Sulfur dioxide / aldehyde reaction	83
Suberin, stain for	24	Sulfur dioxide / ethanal reaction	34
Sublimation	2A, 54A	Sulfur dioxide / magnesium reaction	97
Sublimation of ammonium chloride	9A	Sulfur monochloride	96B
Sublimation of benzoic acid	13A	Sulfur, burning	96A
Succinic acid	36B	Sulfur, burning in chlorine	96B

Chemical or activity	Hazard	Chemical or activity	Hazard
Sulfur, dissolving	46	Test papers	25
Sulfur, melting	96A	Test papers, potassium dichromate(VI)	78
Sulfur, monoclinic	96A, 106	Tetrachloroethene	54B, 99
Sulfur, monoclinic: preparation	46	Tetrachloroethylene	54B, 99
Sulfur, powdered roll	96A	Tetrachloromethane	100
Sulfur, rhombic	96A	Tetrachloromethane, alternative	45B
Sulfur / copper reaction	96A	Tetrazolium chloride	4C
Sulfur / iron reaction	55A, 96A	Thallium and its compounds	NR
Sulfur / zinc reaction	96A, 107	Thermite reaction	11
Sulfuric(VI) acid	98A	Thermite reaction mixtures	1
Sulfuric(VI) acid / copper reaction	98A	Thermite reaction starter	37
Sulfuric(VI) acid / sucrose reaction	98A	Thermometers	61
Sulfuric(VI) acid, diluting	98A	Thiocyanate complexes	95C
Sulfuric(VI) acid / copper(II) sulfate(VI) reaction	98A	Thiocyanate / iron complexes	55B, 55C, 95A
Sulfuric(VI) acid / halides reaction	98A	Thiocyanates indicator	95C
Sulfuric(VI) acid / <i>Volasil 244</i> reaction	106	Thiokol rubber	103
Sulfur dichloride oxide	96B	Thionyl chloride	96B
Summer fuel	45A	Thiooxamide	35
Super-cooling	52	dithioxamide	35
<i>Superwool 607</i>	86	Thorium(IV) carbonate	101
Surgical spirits	40A	Thorium(IV) hydroxide	101
Synthetic crude oil	45A	Thorium(IV) nitrate(V)	101
Tartaric acid	36C	Thorium(IV) oxide	101
Tartrate / hydrogen peroxide reaction	25	Thoron generators	101
Taste-testing papers	35	Threonine	38C
Tellurium and its compounds	NR	Thymol blue	32
Terephthalic acid	13A	Tin and its compounds	102
<i>Termamyl</i>	33	Tin(II) chloride and its preparation	102

Chemical or activity	Hazard	Chemical or activity	Hazard
Tin(II) nitrate(V)	NR, 102	<i>Triton Kaowool</i>	86
Tin(II) oxide	102	Trypsin	33
Tin(II) sulfate(VI)	102	Tryptophan	38C, 62
Tin(IV) chloride and its preparation / hydrolysis	102	TTC	4C
Tin(IV) iodide and its preparation	28, 99, 102	Turkey red oil, preparation	31
Tin(IV) oxide and its preparation	102	Turpentine substitute	45B
Titration 10B, 17, 36A, 45C, 54A & B, 80, 81, 87, 95A		Tyrosine	38C
Titration with thiosulfate	54A & B	Universal indicator	32
Titration, potassium dichromate(VI)	10B	Unsaturated hydrocarbons	45C
o-tolidine	B, 4A	Unsaturated hydrocarbons, test for	45B
Tollen's reagent	6, 87	Unsaturated oils	28
Toluene	46	Unsaturation test	15B
Toluidine blue	32	Unsaturation; quantitative test	45C
Triammonium aurine tricarboxylate	32	Uranium(IV) oxide	105
Trichloroacetic acid	38C	Uranyl(VI) ethanoate	105
1,1,1-trichloroethane	103	Uranyl(VI) magnesium ethanoate	105
Trichloroethanoic acid	38C	Uranyl(VI) nitrate(V)	105
Trichloroethene	99	Uranyl(VI) zinc ethanoate	105
Trichloroethylene	99	Urea	35, 63
Trichloromethane	104	Urease	33
Trichloromethane / propanone reaction	104	Urine, chloride concentrations	87, 95C
Triethylene glycol	37	<i>n</i> -valeric acid	38B
Trihalophenols	70	Valine	38C
1,2,3-trihydroxybenzene	12	Vanadium oxidation states	9B
1,3,5-trihydroxybenzene	12	Vegetable oils	80
Triiodomethane and its preparation	104	Verdigris	27B
2,4,6-trinitrophenol	NR, 70	Vinyl chloride	NR
2,3,5-triphenyltetrazolium chloride	4C	Viscosity investigations	37




Chemical or activity	Hazard	Chemical or activity	Hazard
Viscosity of engine oil	45B	Woody tissue, macerating	92
<i>Viscozyme</i>	33	Xenylamine	B, 4A
Vitamin C	38C	Xylenes	46
<i>Volasil 244</i> , burning	106	Xylenol orange	32
<i>Volasil 244</i> / sulfuric(VI) acid reaction	106	Yeast	33
<i>Volasil / Volasil 244</i>	54B, 106	Yellow lead	56
Volcano experiment	7	Yellow phosphorus	73A
Volhard's method	87, 95C	Zinc	107
Washing soda	95A	Zinc blende	108B
Water glass	95B	Zinc bromide	108A
Water, test for	25	Zinc carbonate and its heating	108B
Water-insoluble dyes	4B	Zinc chloride	108A
Water-purification tablets	22B, 89	Zinc chloride, anhydrous	57A
Water-soluble dyes	4B	Zinc chromate(VI)	NR, 108A
Wax, paraffin	45B	Zinc nitrate(V), heating	108A
White phosphorus	73A	Zinc oxide and its heating	56, 108B
White spirit	45B	Zinc sulfate(VI) crystals	108B
Wij's solution and its preparation	28, 45C, 54A	Zinc sulfide	108B
Winkler's method for oxygen analysis	80, 95B	Zinc, granulated	48
Winter fuel	45A	Zinc, reduction of copper(II) oxide	107
Wood alcohol	40B	Zinc / iodine reaction	107
Wood blocks	21, 56	Zinc / sulfur reaction	96A, 107
Wood's metal	73B		

1 Aluminium metal

Aluminium foil		Al
Low hazard	-	Dangerous with: HALOGENS. Violent reactions occur. MERCURY or MERCURY COMPOUNDS (including solutions). Rapid oxidation of aluminium occurs which may cause ignition. STRONG ACIDS AND ALKALIS. Hydrogen is formed.
Store: Gln	Disposal: W3 or W8	
Aluminium powder		Al
Highly flammable		R15: Contact with water liberates highly flammable gases. R10: Flammable. WEL (mg m⁻³): 4 (LTEL), 12 (STEL). Dangerous with: ORGANOHALOGENS. Violent reactions occur. ALCOHOLS. Violent reactions occur after a lengthy induction period. HALOGENS. Violent reactions occur. MERCURY or MERCURY COMPOUNDS (including solutions). Rapid oxidation of aluminium occurs which may cause ignition. METAL OXIDES, NITRATES(V), CHLORATES AND OTHER SOLID OXIDISING AGENTS. Explosive mixtures are formed. STRONG ACIDS and ALKALIS. Hydrogen is formed. SULFUR. Violent and explosive reactions occur. WATER. Hydrogen formed under very hot conditions. Surface forms an oxide which reduces activity. Although difficult to ignite, the powder burns vigorously and is difficult to extinguish. Powdered aluminium is particularly dangerous if blown into a Bunsen-burner flame. Extinguish fires by smothering with sand.
Store: FW	Disposal: W1, W2, Wspec Wspec: Add 10 g to 1 litre of 2 mol dm ⁻³ hydrochloric acid in a 2 litre beaker or a bucket, ensuring that the solution remains acidic. Leave the solution in a fume cupboard for an hour. Dispose of the solution down a foul-water drain, diluting it with a bucket of water.	

Activity	User	Control measures	Experimental points
Addition of acid or alkali to the metal	Y7	Wear eye protection. Do not use powder. Have ready a small beaker of cold water.	Place aluminium foil, eg, 15 x 15 mm, in a test tube, one-quarter full of 1 mol dm ⁻³ hydrochloric acid or 0.4 mol dm ⁻³ sodium hydroxide. Reaction is delayed but then proceeds exothermically and rapidly, producing hydrogen. Place test tube in cold water to slow down the reaction.
Activating metal using copper(II) chloride	Y9	Wear eye protection.	Place a drop of 0.5 mol dm ⁻³ copper(II) chloride solution on a piece of foil or aluminium sheet. The addition of 1 mol dm ⁻³ hydrochloric acid causes an instant reaction on that part of the foil. In addition, teachers should consider demonstrating activation with mercury(II) chloride (see below) which is more pronounced.
Devarda's alloy test for nitrates(V)	Y9	Wear eye protection.	Add 2 cm ³ of suspected nitrate(V) to 5 cm ³ of 1 mol dm ⁻³ sodium hydroxide solution. Add a little Devarda's alloy (contains aluminium, copper and zinc) and warm. Test for ammonia gas.
Reaction with chlorine	Y12	Wear eye protection. Use a fume cupboard.	See <i>Handbook</i> 13.3. See <i>Hazcard</i> 2A.
Reaction with bromine	TT	Wear goggles or a face shield. Wear chemical-resistant gloves. Use a fume cupboard.	Add aluminium foil to 1 cm ³ of bromine in a borosilicate boiling tube. The reaction is very exothermic. When cool, place the boiling tube in a large container of water to dispose of the aluminium bromide.
Reaction with iodine	TT	Wear eye protection. Use a fume cupboard.	Grind 2 g of iodine to a powder. Mix with 0.5 g of aluminium powder and place the mixture on a heat-proof mat in the fume cupboard. No reaction occurs until a drop of water (with a little detergent to assist wetting) is added when, after a delay, fumes are emitted (mostly iodine). Disposal: of iodine, W6.
Thermite reaction mixtures	TT	Wear goggles or a face shield. Do not use copper oxides, chromium(VI) oxide, lead oxides or manganese(IV) oxide in the mixture with aluminium.	If necessary, dry the components individually before mixing; do not heat the mixture itself . See also <i>Handbook</i> 13.4 or L195, <i>Safer Chemicals, Safer Reactions</i> . Metal oxides safe to mix with aluminium are iron(III) oxide, chromium(III) oxide, manganese(II) dimanganese(IV) oxide. Use in the ratio 1:3 by weight of aluminium powder to metal oxide up to no more than 20 g. See <i>Hazcard</i> 11 for details of the initiators and the reaction. Disposal: unused or unreacted thermite mixture, Wspec.
Activating aluminium foil using mercury(II) chloride	TT	Wear eye protection. Do not use aluminium powder.	Place drops of 0.1 mol dm ⁻³ mercury(II) chloride solution on a cotton bud and wipe it over the surface of the aluminium foil. Once the exothermic reaction is complete, the activated aluminium will react with dilute acids and even with water. Disposal: cotton buds, W2.

2A Aluminium compounds: chlorides and bromide



Aluminium chloride-6-water		Hydrated aluminium chloride	$\text{AlCl}_3 \cdot 6\text{H}_2\text{O}$
Irritant		R36/38: Irritating to eyes and skin. Solutions equal to or stronger than 0.8 mol dm^{-3} should be labelled IRRITANT. WEL (mg m^{-3}): 2 (LTEL), 6 (STEL).	
Store: Gln It can absorb water from the atmosphere to give an acidic solution.		Disposal: W1, W7 W7: Solution should be diluted to less than 0.4 mol dm^{-3} .	
Aluminium chloride		Anhydrous aluminium chloride	AlCl_3
Corrosive		R34: Causes burns. Dangerous with: WATER. The reaction is vigorous, exothermic and releases hydrochloric acid fumes/aerosols. WEL (mg m^{-3}): 2 (LTEL), 6 (STEL).	
Aluminium bromide		Anhydrous aluminium bromide	AlBr_3
Corrosive		R34: Causes burns. R22: Harmful if swallowed. Dangerous with: WATER. The reaction is vigorous, exothermic and releases hydrobromic acid fumes/aerosols. WEL (mg m^{-3}): 2 (LTEL), 6 (STEL).	
Store: CW Keep inside another container with soda lime. Pressure may build up in a closed container due to a slow reaction with water absorbed from the atmosphere. Cover with a cloth and open cautiously. The solid should be yellow so any white material is aluminium hydroxide or oxide. Dispose of the white solid as in the next column.		Disposal: W1, W4 W4: Add the solid in small amounts to 1 mol dm^{-3} sodium carbonate solution in a fume cupboard. Wait until the reaction is finished before adding more. Pour the slurry down a foul-water drain.	

2A Aluminium compounds: chlorides and bromide

Model risk assessments

Activity	User	Control measures	Experimental points
Heating hydrated aluminium chloride	Y9	Wear eye protection.	Use 0.5 g per group unless the heating is carried out in a fume cupboard. Aluminium chloride produces hydrogen chloride gas.
Sublimation of anhydrous compounds	Y12	Wear eye protection.	Use 0.5 g of anhydrous aluminium chloride in a boiling tube with a mineral-wool plug inserted at the mouth. Only heat the bottom of the boiling tube.
Hydrolysis of the anhydrous chloride or bromide	Y12	Wear eye protection.	Add 1 g of powdered anhydrous aluminium chloride or bromide to 100 cm ³ of water in a 250 cm ³ beaker. There may be a long induction period if the sample is old.
Preparation of aluminium chloride	Y12	Wear eye protection. Use a fume cupboard. All apparatus must be dry.	Use wide-bore tubing to prevent blockages; use a wide-necked receiver. The reaction tube must be horizontal so that the hot aluminium does not roll into the collection vessel (see <i>Handbook</i> 13.4).
Friedel-Crafts reaction (Alkylation)	Y12	Wear goggles. Use a fume cupboard. Do not use procedures involving benzene.	Alternatives to benzene include methylbenzene, dimethylbenzenes and methoxybenzene (anisole) (IRRITANT). Evolved hydrogen chloride gas can be absorbed in a water trap if a fume cupboard is not available (<i>Handbook</i> 13.7).
Friedel-Crafts reaction (Acylation)	Y12	Wear goggles. Use a fume cupboard. Do not use procedures involving benzene.	Although it is a catalyst, the amount of aluminium chloride needs to be just in excess of the amount of hydrocarbon present. The reaction usually produces a single product instead of a mixture of products as in alkylation. Alternatives to benzene include methylbenzene, dimethylbenzenes and methoxybenzene (anisole) (IRRITANT). Evolved hydrogen chloride gas can be absorbed by a water trap if a fume cupboard is not available (<i>Handbook</i> 13.7).

2B Aluminium compounds: except chlorides and bromide







Aluminium nitrate(V)-9-water			$\text{Al}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$
Oxidising		R8: Contact with combustible material may cause fire. R36/38: Irritating to eyes and skin. Solutions equal to or stronger than 0.5 mol dm^{-3} should be labelled IRRITANT. WEL (mg m^{-3}): 2 (LTEL), 6 (STEL).	
Irritant			
Store: Ox It can absorb water from the atmosphere to give an acidic solution.		Disposal: W1, W7 W7: Solutions should be diluted to less than 0.2 mol dm^{-3} .	

Aluminium ammonium sulfate(VI)-12-water ; ammonium alum; $\text{AlNH}_4(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$	Low hazard	Store: Gln	Disposal: W7, W8
Aluminium ethanoate ; aluminium acetate; $\text{Al}(\text{CH}_3\text{COO})_3$			Disposal: W8
Aluminium oxide ; Al_2O_3			Disposal: W8
Aluminium potassium sulfate(VI)-12-water ; alum; $\text{AlK}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$			Disposal: W7, W8
Aluminium sulfate(VI)-16-water ; aluminium sulfate(VI); $\text{Al}_2(\text{SO}_4)_3 \cdot 16\text{H}_2\text{O}$			Disposal: W7, W8

2B Aluminium compounds: except chlorides and bromide**Model risk assessments**

Activity	User	Control measures	Experimental points
Use of aluminium salt solutions	Y7	Wear eye protection.	Use 0.1 mol dm ⁻³ aluminium sulfate(VI) or nitrate(V) solution. Solutions of aluminium compounds are acidic (0.1 mol dm ⁻³ solution is pH 3).
Crystallisation of alum	Y7	Wear eye protection.	See also <i>Recipe card</i> 3. Solutions of aluminium compounds are acidic (about pH 3). Alum is very soluble at high temperatures (94 g in 100 g of water at 80 °C) but much less so at room temperature (12 g in 100 g of water at 20 °C).
Preparation of alum	Y9	Wear goggles.	The procedure involves dissolving 1 g of aluminium foil in 25 cm ³ of 1 mol dm ⁻³ potassium hydroxide (CORROSIVE). After filtering, 1 mol dm ⁻³ sulfuric(VI) acid is added (about 25 cm ³) until the precipitate of aluminium hydroxide dissolves. The solution is boiled and the saturated solution is allowed to crystallise. Disposal: crystals, W3.
Heating hydrated aluminium nitrate(V) and sulfate(VI)	Y9	Wear eye protection.	Use 0.5 g per group unless the heating is carried out in a fume cupboard. Aluminium nitrate(V) produces nitrogen dioxide (TOXIC). Aluminium sulfate(VI) and alum produce sulfur trioxide (CORROSIVE). Disposal: glass test tubes with residue, W8.





3A Amines: aliphatic monosubstituted

Methylamine (40% solution)		<chem>CH3NH2</chem>
Extremely flammable		<p>R12: Extremely flammable. R20/22: Harmful by inhalation and if swallowed. R34: Causes burns.</p> <p>Solutions equal to or stronger than 1.2 mol dm^{-3} should be labelled CORROSIVE. Solutions equal to or stronger than 0.6 mol dm^{-3} but weaker than 1.2 mol dm^{-3} should be labelled IRRITANT.</p> <p>WEL (mg m^{-3}): 13 (LTEL), 39 (STEL). Flash point: -19 °C.</p>
Corrosive		
Ethylamine (70% solution)		<chem>C2H5NH2</chem>
Highly flammable		<p>R11: Highly flammable. R21/22: Harmful in contact with skin and if swallowed. R34: Causes burns.</p> <p>Solutions equal to or stronger than 2.2 mol dm^{-3} should be labelled CORROSIVE. Solutions equal to or stronger than 1.1 mol dm^{-3} but weaker than 2.2 mol dm^{-3} should be labelled IRRITANT.</p> <p>WEL (mg m^{-3}): 3.8 (LTEL), 11 (STEL). Flash point: -10 °C.</p> <p>The anhydrous liquid, which boils at 17 °C, is not suitable for schools.</p>
Corrosive		
1-aminobutane		<chem>C4H9NH2</chem>
Highly flammable		<p>R11: Highly flammable. R20/21/22: Harmful by inhalation, in contact with skin and if swallowed. R35: Causes severe burns. R50: Very toxic to aquatic organisms.</p> <p>WEL (mg m^{-3}): 15 (LTEL), 45 (STEL). Flash point: -12 °C.</p>
Corrosive		
Store: FL The screw top on the bottle needs to be checked for leaks and deterioration. Wipe away any white solid (usually the chloride) from the outside of the bottle.		Disposal: W1, W5 W5: Use a fume cupboard.
Emergencies: see standard procedures on <i>Hazard E</i>, BUT ALSO:		
If chemical is splashed into the eyes:		Flood the eye with gently-running tap water until a first-aider arrives. Unless the solution is very dilute, send the affected person to hospital and ensure that irrigation is continued during the journey.

3A Amines: aliphatic monosubstituted**Model risk assessments**

Activity	User	Control measures	Experimental points
Reactions of amines	Y12	Wear goggles. Windows must be open. Use a fume cupboard for dispensing the liquid.	The odour from these chemicals is not pleasant. Butylamine is often the preferred amine for such work. Students could be supplied with stoppered test tubes containing the required drops of amine. They can then be used on the open bench in a well-ventilated laboratory.
Hoffman bromination reaction	Y12	Wear goggles. Use a fume cupboard. Wear chemical-resistant gloves.	Use 3 drops of bromine to about 0.1 g of ethanamide. Add 2 cm ³ of 1 mol dm ⁻³ sodium hydroxide (CORROSIVE). On boiling, the fishy smell of the alkaline gas methylamine (EXTREMELY FLAMMABLE and CORROSIVE) can be detected. Smell with care.
Preparation of amines from the chloride salts	Y12	Wear goggles. Use a fume cupboard.	Add 1 g of methylammonium chloride (IRRITANT) or ethylammonium chloride (LOW HAZARD) to 5 cm ³ of 2 mol dm ⁻³ sodium hydroxide solution. Boil gently and test the gas for alkalinity and flammability. The fishy smells of the alkaline gases methylamine (EXTREMELY FLAMMABLE & CORROSIVE) and ethylamine (EXTREMELY FLAMMABLE & CORROSIVE) can be detected. Smell with care.
Reaction with ethanoyl chloride	Y12	Wear goggles. Use a fume cupboard.	To 1 cm ³ of the concentrated methylamine or ethylamine solution, or butylamine, add ethanoyl chloride drop by drop.
Reaction with sodium nitrate(III)	Y12	Wear eye protection.	To 1 g of methylammonium chloride (IRRITANT) or ethylammonium chloride (LOW HAZARD), add 5 cm ³ of water to dissolve the salt and a few crystals of sodium nitrate(III). Nitrogen is evolved.
Reaction with copper(II) sulfate(VI)	Y12	Wear goggles. Use a fume cupboard.	Add butylamine or a 2 mol dm ⁻³ solution of either methylamine or ethylamine to 5 cm ³ of 0.1 mol dm ⁻³ copper(II) sulfate(VI) solution.








3B Amines: aliphatic polysubstituted

Hexane-1,6-diamine	1,6-diaminohexane; hexamethylenediamine		$\text{NH}_2(\text{CH}_2)_6\text{NH}_2$
Corrosive		R21/22: Harmful in contact with skin and if swallowed. R34: Causes burns. R37: Irritating to respiratory system. Solutions equal to or stronger than 1 mol dm^{-3} should be labelled CORROSIVE. Solutions equal to or stronger than 0.5 mol dm^{-3} but weaker than 1 mol dm^{-3} should be labelled IRRITANT. Flash point: 81°C .	
Store: CS There have been reports of suppliers delivering samples which were black. These should be returned. The screw top on the bottle needs to be checked for leaks and deterioration. Remove any white solid (usually the chloride) from the outside of the bottle.			Disposal: W1, W5 W5: Use a fume cupboard.
Ethane-1,2-diamine	1,2-diaminoethane; ethylenediamine		$\text{CH}_2\text{NH}_2\text{CH}_2\text{NH}_2$
Corrosive		R10: Flammable. R21/22: Harmful in contact with skin and if swallowed. R42/43: May cause sensitisation by inhalation and skin contact. R34: Causes burns. Solutions equal to or stronger than 1.7 mol dm^{-3} should be labelled CORROSIVE. Solutions equal to or stronger than 0.1 mol dm^{-3} but weaker than 1.7 mol dm^{-3} should be labelled IRRITANT. Flash point: 34°C .	
Store: CLb Fresh samples which are black should be returned to the supplier. Check the screw top on the bottle for leaks and deterioration. Remove any white solid (usually the chloride) from the outside of the bottle. Samples may absorb water during storage. Sometimes supplied in an aqueous solution.			Disposal: W1, W5 W5: Use a fume cupboard.
Hexamine	Methenamine; hexamethylene tetramine		$(\text{CH}_2)_6\text{N}_4$
Highly flammable Harmful	 	R11: Highly flammable. R42/43: May cause sensitisation by inhalation and skin contact. Flash point: 250°C .	
Store: FS Keep it dry. Store in a desiccator.			Disposal: W1, W6 (Burn it.)
bis[bis(carboxymethyl)amino]ethane (disodium salt), ethylene diamine tetraacetic acid (disodium salt), EDTA		Low hazard	Store: Gln Disposal: W8
Emergencies: see standard procedures on <i>Hazard E</i>, BUT ALSO:			
If chemical is splashed into the eyes:	Flood the eye with gently-running tap water until a first-aider arrives. Unless the solution is very dilute, send the affected person to hospital and ensure that irrigation is continued during the journey.		

3B Amines: aliphatic polysubstituted**Model risk assessments**

Activity	User	Control measures	Experimental points
EDTA titrations	Y7	Wear eye protection.	Use 0.1 or 0.05 mol dm ⁻³ solutions. See <i>Recipe card</i> 68 for details on standardisation.
Hexamine as a fuel	Y9	Wear eye protection. Consider wearing gloves.	There have been reports of a tablet 'spitting' when it burns. This appears to be due to water, absorbed by the chemical. Some suppliers have now started selling wax-coated tablets, which seem to avoid the problem, although we still suggest storing in a desiccator. Pupils should be supplied with what they will use and not allowed access to a larger supply.
Nylon 'rope' investigation for pupils	Y9	Wear goggles. Wear gloves if the nylon is handled. Do not use organohalogen solvents.	See <i>Recipe card</i> 45. Use no more than 5 cm ³ each of the solutions prepared. Disposal: nylon, W8.
Using hexamine as a fuel for model steam engines	Y9	Wear eye protection. Wear nitrile gloves. Liquid fuels must not be used.	An exploding tablet is less of an issue under a steam engine than when comparing fuels.
Using ethane-1,2-diamine solutions	Y12	Wear eye protection.	Dilute solutions (ie, less than or equal to 0.1 mol dm ⁻³) may be used out of a fume cupboard.
Nylon 'rope' demonstration	TT	Wear goggles or a face shield. Wear gloves if the nylon is handled. Do not use organohalogen solvents.	As a demonstration: See <i>Recipe card</i> 45. Use a solution of 2.2 g hexane-1,6-diamine in 50 cm ³ water for the aqueous layer (LOW HAZARD) and 1.5 g decanedioyl chloride or hexanedioyl chloride in 50 cm ³ cyclohexane for the hydrocarbon layer (HIGHLY FLAMMABLE). The hydrocarbon solution is poured slowly onto the aqueous layer down a glass rod. The nylon forms at the interface and can be pulled out with forceps. Disposal: nylon, W8.

3C Amines: physiologically-active compounds

Acetylcholine chloride		<chem>C7H16NO2Cl</chem>
Irritant		R36/37/38: Irritating to eyes, respiratory system and skin.
Store: GOrg		Disposal: W7
L-adrenaline; epinephrine		<chem>C9H13NO3</chem>
Toxic		R23/24/25: Toxic by inhalation, in contact with skin and if swallowed.
Store: Cold		Disposal: W7 W7: Up to 1 g of the material can be dissolved in 100 cm ³ of water before disposal down a foul-water drain.
Caffeine		<chem>C8H10N4O2</chem>
Harmful		R22: Harmful if swallowed.
Store: GOrg		Disposal: W1, W2
Colchicine		<chem>C22H25NO6</chem>
Very toxic		R26/28: Very toxic by inhalation and if swallowed.
Nicotine		<chem>C10H14N2</chem>
Very toxic Dangerous for the environment	 	Very toxic in contact with skin. R25: Toxic if swallowed. R27: R51/53: Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. WEL (mg m⁻³): 0.5 (LTEL) 1.5 (STEL) (Sk).
Ethidium bromide		<chem>C21H20N3Br</chem>
Toxic		R22: Harmful if swallowed. R26: Very toxic by inhalation. R36/37/38: Irritating to eyes, respiratory system and skin. R68: Possible risk of irreversible effects.
Store: T		Disposal: W1



3C Amines: physiologically-active compounds



Model risk assessments

Activity	User	Control measures	Experimental points
Caffeine drinks	Y9	-	For more detail of experiments on students, see <i>Handbook</i> , 11.8.1.
Extraction of caffeine from tea	Y9	Wear eye protection.	See <i>Hazcard 28</i> . See also Guide L195, <i>Safer Chemicals, Safer Reactions</i> for the use of propan-1-ol saturated with sodium chloride in place of any organohalogens used to extract the caffeine.
Inhibition of heart action	Y9	-	Use a solution of 1 g of acetylcholine in 1000 cm ³ of water for amphibian heart investigations.
Stimulation of heart action	Y9	-	Use a solution of 1 g of adrenaline in 1000 cm ³ of water for amphibian heart investigations.
Nucleic acid stains in gel electrophoresis	Y9	Ethidium bromide is unsuitable for school use.	The procedure also requires exposure to uv-radiation. Safer dyes are used in electrophoresis kits sold by educational suppliers.
Arresting cell division to see chromosomes	TT	Wear eye protection. Colchicine is unsuitable for school use.	Some texts have suggested colchicine but 1,4-dichlorobenzene or acenaphthene are more suitable for procedures in schools.
Smoking machine demonstration	TT	Use a fume cupboard. Wear gloves when dismantling the equipment to show tar absorption on cotton wool.	Apart from a no-smoking policy in schools, smoking cigarettes in public buildings is no longer permitted. However, the anti-smoking legislation permits the use of a smoking machine in schools in England, Wales and Northern Ireland as part of health education. Pupils may talk to parents about this activity and some parents may be concerned about exposure to cigarette smoke. Senior management should be informed about this activity and how important and relevant it is. See <i>Bulletins 115 & 129</i> for a discussion and Guide L195, <i>Safer Chemicals, Safer Reactions</i> for details of the procedure.

4A Amines: aromatic non-substituted rings

See also 4B

Phenylamine and its salts (eg, chloride)		Aniline/aminobenzene and its salts	$C_6H_5NH_2$
Toxic		R40: Limited evidence of a carcinogenic effect. Category 3 carcinogen. R68: Possible risk of irreversible effects. Category 3 mutagen. R23/24/25: Toxic by inhalation, in contact with skin and if swallowed. R48/23/24/25: Toxic: danger of serious damage to health by prolonged exposure through inhalation, in contact with skin and if swallowed. R41: Risk of serious damage to eyes. R43: May cause sensitisation by skin contact. R50: Very toxic to aquatic organisms. WEL ($mg\ m^{-3}$): 4 (LTEL), 12 (STEL). Flash point: 70 °C.	
Dangerous for the environment			
Store: T When pure, phenylamine is colourless but it goes dark on storage. It can only be purified by distillation (usually at reduced pressure). For most school chemistry, the dark liquid is suitable.		Disposal: W1, W5 W5: Use 100 cm^3 of 1 $mol\ dm^{-3}$ ethanoic acid per 1 cm^3 or 1 g of phenylamine.	

Diphenylamine		$(C_6H_5)_2NH$
Toxic		R23/24/25: Toxic by inhalation, in contact with skin and if swallowed. R33: Danger of cumulative effects. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. WEL ($mg\ m^{-3}$): 10 (STEL); 20 (STEL). Flash point: 153 °C.
Dangerous for the environment		
Store: T		Disposal: W1, W5 (Use 100 cm^3 of 1 $mol\ dm^{-3}$ ethanoic acid per 1 cm^3 of the amine.)

4-aminobiphenyl ; xenylamine; $C_6H_5C_6H_4NH_2$ 3,3'-dimethoxybiphenyl-4,4'-diamine ; o-dianisidine 3,3'-dimethylbiphenyl-4,4'-diamine ; o-tolidine Biphenyl-4,4-diamine ; benzidine Naphthalen-1-amine ; 1-naphthylamine and naphthalen-2-amine ; 2-naphthylamine, $C_{10}H_7NH_2$	These are banned compounds	Storage: (pending disposal) T	Disposal: W1
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4A Amines: aromatic non-substituted rings

Model risk assessments

Activity	User	Control measures	Experimental points
Preparation of Perkin's mauve	Y10	Wear eye protection.	Dissolve a tiny crystal of sodium dichromate(VI) in 1 cm ³ of water. Place 0.1 cm ³ of phenylamine in a test tube and add 1 cm ³ of 0.5 mol dm ⁻³ sulfuric(VI) acid. Place this in a bath of boiling hot water and add 0.2 cm ³ of the sodium dichromate(VI) solution. Replenish the hot water after 15 minutes. Leave for a day and look for the mauve solution above the settled solid. Disposal: W7, dissolve in a minimum of 100 cm ³ of water per activity.
Small-scale reactions of phenylamine	Y12	Wear eye protection and gloves. Use a fume cupboard for dispensing the liquid.	Use no more than 5 drops on a test-tube scale, especially with nitration. Ethyl 4-aminobenzoate may be used as a less-hazardous substitute. See Guide L195, <i>Safer Chemicals, Safer Reactions</i> .
Diazotisation	Y12	Wear eye protection and gloves. Use a fume cupboard. Do not isolate dry diazonium salts.	Solid phenylammonium chloride is easier to transfer and may be used in place of phenylamine to avoid the use of a fume cupboard. A safer alternative is sulfanilic acid or ethyl 4-aminobenzoate may be used; see Guide L195.
Preparation of azo dyes	Y12	Wear eye protection. Wear disposable nitrile gloves. Some dyes are suspect carcinogens.	Check that diazotisation is complete by testing for excess nitrous acid (starch/iodide paper) before proceeding to the next reaction step. A safer alternative to phenylamine is sulfanilic acid or ethyl 4-aminobenzoate (see Guide L195). Disposal: W7; add dyes to a bucket of water per activity.
Locating agent in chromatography of sugars	Y12	Wear disposable nitrile gloves. Wear eye protection.	The teacher or technician should make up the solution. This consists of 0.9 cm ³ of phenylamine and 1.6 g of phthalic acid in 48 cm ³ of butan-1-ol, 48 cm ³ of ethoxyethane and 4 cm ³ of water. See <i>Handbook</i> 11.1.
Reducing aromatic nitro compounds	Y12	Wear goggles. Use a fume cupboard. Avoid nitrobenzene (VERY TOXIC).	Reducing 3-nitrobenzoic acid to 3-aminobenzoic acid is a safer approach than reducing nitrobenzene (TOXIC); see Guide L195, <i>Safer Chemicals, Safer Reactions</i> .
Making up diphenylamine indicator	TT	Wear goggles or a face shield. Wear chemical-resistant gloves.	Used in dichromate(VI) titrations (colourless to blue violet). A 1% (w/v) solution in concentrated sulfuric(VI) acid is used. It is safer to buy diphenylamine-4-sulfonic acid (sodium salt) and make up a 0.25% (w/v) solution in water.
The movement of immiscible liquids in water	TT	Wear eye protection. Wear chemical-resistant gloves.	Chlorobenzene (density: 1.1 g cm ⁻³) is a safer substitute. Dissolve sodium chloride in water to obtain a suitable density. Also applicable to demonstrations of Plateau's spherule.

4B Amines: aromatic polysubstituted



See also 4A


3-aminobenzene-1,2-dicarboxylic hydrazide		3-aminophthalhydrazide; luminol	$C_8H_7N_3O_2$
Irritant		R36/37/38: Irritating to eyes, respiratory system and skin.	
Store: GOrg		Disposal: W1, W7 W7: Up to 10 g of the material can be dissolved in 100 cm ³ of water before disposal down a foul-water drain.	
Ethyl 4-aminobenzenecarboxylate		Benzocaine; ethyl 4-aminobenzoate	$NH_2C_4H_4COOC_2H_5$
Irritant		R43: May cause sensitisation by skin contact.	
Store: GOrg		Disposal: W1, W2, W5	
4-aminobenzenesulfonic acid		Sulfanilic acid	$(H_2N)C_6H_4SO_3H$
Irritant		R36/38: Irritating to eyes and skin. R43: May cause sensitisation by skin contact.	
Store: GOrg		Disposal: W1, W7 W7: Up to 10 g of the material can be dissolved in 100 cm ³ of water before disposal down a foul-water drain.	
N,N-dimethylphenylamine		N,N-dimethylaniline	$C_6H_5N(CH_3)_2$
Toxic		R40: Limited evidence of a carcinogenic effect. Category 3 carcinogen. R23/24/25: Toxic by inhalation, in contact with skin and if swallowed. R51/53: Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. Flash point: 62 °C. WEL (mg m⁻³): 25 (LTEL), 50 (STEL) (Sk).	
Dangerous for the environment			
Store: T		Disposal: W1	

4B Amines: aromatic polysubstituted**Model risk assessments**

Activity	User	Control measures	Experimental points
Chemiluminescence reactions	Y9	Wear eye protection.	These are light-emitting reactions using luminol. The technician or teacher could make the solutions just before the lesson begins. Details can be found in <i>Recipe Card 16</i> .
Using azo dyes of ethyl 4-amino-benzoate	Y12	Wear eye protection. Wear disposable nitrile gloves.	See L195, <i>Safer Chemicals, Safer Reactions</i> . This can be used as a safer alternative to phenylamine.
Using azo dyes of sulfanilic acid	Y12	Wear eye protection. Wear disposable nitrile gloves.	With sulfanilic acid, the following can be used to prepare water-soluble dyes. The dyes are thought to be less hazardous than water-insoluble dyes. Reagent A: Equal volumes of 0.5% (w/v) sodium nitrate(III) solution and 0.5% (w/v) sulfanilic acid. The diazonium solution is stable at room temperature. Reagent B: 4% (w/v) solution of the naphthalen-2-ol in ethanol. To 1 cm ³ of reagent B, add 3 drops of reagent A followed by 3 drops of 2 mol dm ⁻³ sodium hydroxide solution (CORROSIVE) The dye is called orange II. If <i>N,N</i> -dimethylphenylamine is used in place of naphthalen-2-ol, methyl orange solution is formed.



4C Amines: heterocyclic

Pyridine			<chem>C5H5N</chem>
Highly flammable		R11: Highly flammable. R20/21/22: Harmful by inhalation, in contact with skin and if swallowed. Flash point: 17 °C. WEL (mg m⁻³): 16 (LTEL), 33 (STEL).	
Harmful			
Store: FL		Disposal: W1, W2 W2: Store in a separate container before disposal.	

Pyrrole			<chem>C4H4NH</chem>
Toxic		R10: Flammable. R20: Harmful by inhalation. R25: Toxic if swallowed. R41: Risk of serious damage to eyes. Flash point: 39 °C.	
Store: FL If there is not enough room in the flammables cabinet, this chemical can be stored with general organic chemicals (GOrg).		Disposal: W1, W2 W2: Store in a separate container before disposal.	

2,3,5-triphenyltetrazolium chloride; tetrazolium chloride; TTC	Low hazard	Store: GOrg	Disposal: W1, W7
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Activity	User	Control measures	Experimental points
Respiratory activity in tissues	Y10	-	A 1% (w/v) aqueous solution of 2,3,5-triphenyltetrazolium chloride is used. Details can be found in <i>Experimental Work In Biology, Combined Edition</i> , D G Mackean, John Murray, 1983 or www.biology-resources.com/biology-experiments2.html <i>Germination & Tropisms</i> 16.
Preparation of cholesteryl benzoate (a liquid crystal)	Y12	Wear eye protection. Wear disposable nitrile gloves. Use a fume cupboard.	Dissolve 1 g of cholesterol in 3 cm ³ of pyridine in a 50 cm ³ conical flask. Add 0.4 cm ³ of benzoyl chloride. Heat on a steam bath for 10 minutes. Cool the flask. Add 15 cm ³ of methanol. Collect the solid cholesteryl benzoate by suction filtration. It can be recrystallised from 15 cm ³ of ethyl ethanoate (cool in an ice-bath). The 'liquid crystal' phase of cholesteryl benzoate can be seen by placing 0.1 g of the compound on the end of a microscope slide and heating the sample by holding the slide with a pair of tongs above a small burner. The solid moves through a cloudy liquid phase before it goes clear. On cooling, the liquid goes cloudy before solidifying.
Chromatographic separation of sugars	Y12	Wear eye protection. Wear disposable nitrile gloves. Use a fume cupboard.	Pyridine is often in solvents used to separate components of complex mixtures by chromatography. Separation of sugars on paper can be obtained by using ethyl ethanoate, pyridine and water in the ratio of 8:2:1.
Electrically-conducting polymers	Y12	Wear eye protection. Wear disposable nitrile gloves. Use a fume cupboard.	The details of the preparation of poly(pyrrole) are in Activity PR6 of the <i>Activities and Assessment Pack</i> , Salters Advanced Chemistry, pp 127-129, Second edition, 2000, Heinemann ISBN 0435631217. Also in the T & T Guide ISBN 0435631225.

Toxic		R10: Flammable. R23: Toxic by inhalation. R34: Causes burns. R50: Very toxic to aquatic organisms.
Dangerous for the environment		WEL (mg m⁻³): 18 (LTEL), 25 (STEL). Ammonia has a very distinctive pungent odour which is detected at about 3.5 mg m ⁻³ . This level is lower than the specified WEL. However, the vapour at higher concentrations is very irritating to the eyes and lungs; breathing these levels of ammonia can lead to severe poisoning. A fume cupboard (especially a recirculatory filter model) must be efficient when using this gas.

The substance is dangerous with:	CHLORINE, BROMINE, IODINE. Under some conditions explosive products are formed. MERCURY. Explosive solid formed on prolonged contact. OXYGEN. Explosions can occur. SILVER SALTS. Explosive compounds formed under certain conditions.
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Emergencies: see standard procedures on *Hazard E*, BUT ALSO:

If released into the laboratory:	Consider evacuation. Open windows and doors wide.
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Store: Situ Gas cylinders are not recommended. Prepare the gas in situ. Ammonia gas combines with hydrogen chloride gas to produce a white powder which may be found on bottles in the chemical store. This shows that ventilation may be poor or the necks of bottles are not being wiped properly before being put back after use.	Disposal: W6
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5 Ammonia gas

Model risk assessments

Activity	User	Control measures	Experimental points
Testing for the gas	Y7	Wear goggles.	Pupils should warm gently no more than 0.5 g of an ammonium salt with 1 mol dm ⁻³ sodium hydroxide solution and be taught how to smell the gas safely.
Preparation of ammonia gas	TT	Wear eye protection. Use a fume cupboard.	Normal preparation: Heat the concentrated solution. (2.1 cm ³ of fresh '880' solution produces 1 litre of gas.) May also be prepared by heating a mixture of calcium hydroxide (20 g) and ammonium chloride (10 g) with water. This will give about 5 litres of gas. See <i>Handbook</i> 13.3. Dry the gas with soda lime or calcium oxide, taking care to avoid blockages in the drying tube. Do not reuse the drying agent. However, ammonia does not need drying for the Fountain experiment.
Reaction with hydrogen chloride	TT	Wear eye protection.	Fill gas jars with each gas in a fume cupboard. A jar of hydrogen chloride can be placed over ammonia and the gas-jar lids removed in the open laboratory.
Dissolving the gas in water	TT	Wear eye protection.	Pass the gas into an inverted funnel with the rim just touching the water surface. This prevents sucking back (see <i>Handbook</i> 13.3).
Fountain experiment	TT	Wear eye protection. Use safety screens. Use a fume cupboard to prepare the gas.	Use a thick-walled, borosilicate, round-bottomed flask or a Büchner flask. (The pressure reduction could implode a weak flask.) Apparatus may then be moved to the laboratory bench once the flask is full of ammonia. See <i>Handbook</i> 13.3.
Catalytic oxidation of ammonia gas	TT	Wear goggles or a face shield. Use a fume cupboard.	a) Blow air over concentrated ammonia in a 250 cm ³ conical flask . A glowing platinum coil is suspended in the flask. Gases in the flask may be removed by syringe and bubbled through water to test for nitrate(V) ions. b) Air is passed through 6 mol dm ⁻³ ammonia solution, through a tube containing heated platinised Kaowool, through an empty test tube and finally into a large flask to collect nitrogen dioxide. This procedure must be practised before demonstration. c) Blow oxygen from a cylinder over concentrated ammonia solution in a beaker . A hot platinum coil, suspended over the beaker, continues to glow. There will be small explosions.

The concentrated (35% w/w) solution is also called '880' ammonia. It is also called ammonium hydroxide.

Corrosive		R34: Causes burns. R50: Very toxic to aquatic organisms. Solutions stronger than or equal to 6 mol dm ⁻³ should be labelled CORROSIVE. Solutions stronger than or equal to 3 mol dm ⁻³ but weaker than 6 mol dm ⁻³ should be labelled IRRITANT. If swallowed, causes severe internal damage.
Dangerous for the environment		WEL (mg m⁻³): 18 (LTEL), 25 (STEL). For hazard details of ammonia gas which is diffusing from the solution, see <i>Hazard 5</i> . Solutions equal to or stronger than 14 mol dm ⁻³ are very toxic to the aquatic environment. The concentration of commercially available 35% (w/w) ammonia is 18 mol dm ⁻³ and it has a specific gravity of 0.880, hence '880' ammonia.

The substance is dangerous with:	CHLORINE, BROMINE, IODINE. Under some conditions explosive products are formed. MERCURY. Explosive solid is formed on prolonged contact. OXYGEN. Explosions can occur. SILVER SALTS. Explosive compounds are formed under certain conditions.
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Emergencies: see standard procedures on *Hazard E*, BUT ALSO:

If solution / vapour affects the eyes:	Flood the eye with gently-running tap water until a first aider arrives. Unless the solution is very dilute, send the affected person to hospital and ensure that irrigation is continued during the journey. Take steps to ventilate the area.
If spilt in the laboratory:	Consider evacuation if people are badly affected. If possible, open all windows and outside doors. Wear eye protection, gloves and rubber boots if the spill is large (see <i>Handbook 7.7</i>). For a large spill, the fire brigade may need to be called, asking for the Chemical Incident Unit.

Store: CLb Pressure builds up in containers of concentrated solution on hot days. In hot weather, open bottles cautiously, particularly new ones, wearing a face shield. Store in as cool a place as possible at low level. Ensure containers are tightly closed. The gas is responsible for white deposits on bottles. The solution has a limited shelf life, possibly as short as 5 years depending on the storage conditions.	Disposal: W1, W5 or W7 W5: Use a fume cupboard. W7: Solutions should be diluted to less than 0.5 mol dm ⁻³ .
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Keep the use of the solution under strict control. It has been stolen and used in criminal offences.

Activity	User	Control measures	Experimental points
Use of the solution	Y7	Wear eye protection.	Ammonia solution is often called ammonium hydroxide solution as it acts as a weak base. For precipitation reactions, solutions need not be stronger than 0.5 mol dm^{-3} .
Reaction with indicators	Y7	Wear eye protection.	Solutions need not be stronger than 0.1 mol dm^{-3} . This solution will not keep over several weeks.
Formation of salts and exothermic nature of reaction	Y7	Wear eye protection.	Solutions need not be stronger than 2 mol dm^{-3} . Beware of the evolution of ammonia gas. The room should be well ventilated. Take into account the ability and discipline of the pupils because some pupils may be tempted to inhale the gas. See also <i>Hazard</i> 9B.
Formation of complex ions	Y7	Wear eye protection.	Solutions need not be stronger than 2 mol dm^{-3} . Beware of the evolution of ammonia gas. The room should be well ventilated. Use a fume cupboard if the solution is to be warmed.
Preparation of ammonium sulfate(VI)	Y9	-	See <i>Hazard</i> 9B.
Regenerating cellulose	Y9	Wear eye protection. Use a fume cupboard to prepare the solution. Open wide all windows.	Dissolve 0.5 g of basic copper(II) carbonate in 25 cm^3 of 10 mol dm^{-3} ammonia solution to make the cellulose solvent.
Making Tollen's reagent [ammoniacal silver nitrate(V)]	Y12	Wear eye protection. Use a new, clean test tube and discard the solution within half an hour of preparation by washing it down a sink followed by a large amount of water.	Silver oxide, precipitated from silver nitrate(V) solution by sodium hydroxide solution, is re-dissolved in 1 mol dm^{-3} ammonia solution. Make on a test-tube scale only and do not heat the solution directly; use a bath of hot water. (Explosive silver fulminate forms on standing.) Do not dispose of the solution in a 'silver-residues' bottle.
Preparation of ammonia gas	TT	Wear eye protection. Use a fume cupboard.	See <i>Hazard</i> 5.
Preparing nitrogen triiodide	TT	The supplementary risk assessment for this demonstration (SRA 15) is available on the CLEAPSS members-only web site and <i>Science Publications CD-ROM</i> (2008 onwards).	

Very toxic		R2: Risk of explosion by shock, friction, fire or other sources of ignition. R8: Contact with combustible material may cause fire. R45: May cause cancer. Category 2 carcinogen.
Explosive		R46: May cause heritable genetic damage. Category 2 mutagen. R60: May impair fertility. R61: May cause harm to the unborn child. Category 2 teratogen. R26: Very toxic by inhalation. R25: Toxic if swallowed. R48/23: Toxic: danger of serious damage to health by prolonged exposure through inhalation. R21: Harmful in contact with skin. R34: Causes burns. R42/43: May cause sensitisation by inhalation and skin contact. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.
Dangerous for the environment		Solutions equal to or stronger than 0.2 mol dm^{-3} should be labelled VERY TOXIC. Solutions equal to or stronger than $0.003 \text{ mol dm}^{-3}$ but weaker than 0.2 mol dm^{-3} are TOXIC. WEL (mg m^{-3}): 0.05 (LTEL), 0.15 (STEL) as chromium.





The substance is dangerous with:	ALUMINIUM, MAGNESIUM, CARBON, SULFUR, PHOSPHORUS, COMBUSTIBLE MATERIALS, including ORGANIC SUBSTANCES. The reactions are violent and may become explosive. Never heat this substance in a confined space. Never mix it with powdered aluminium or with magnesium.
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Store: FS	Disposal: W1, Wspec Wspec: In a fume cupboard, add 10 g of sodium metabisulfite to 10 g of solid dissolved in 250 cm^3 of 1 mol dm^{-3} sulfuric(VI) acid. Pour the solution into a bucket of water and pour this down a foul-water drain.
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Activity	User	Control measures	Experimental points
Decomposition on a small scale	Y12	Wear eye protection. Wear gloves when dispensing.	Heat no more than 1 g in a borosilicate boiling tube with a mineral-wool plug inserted at the mouth. Do not mix with powdered metals. Further details are in L195, <i>Safer Chemicals, Safer Reactions</i> .
Volcano experiment	TT	Wear goggles or a face shield. Wear chemical-resistant gloves when dispensing. Use a fume cupboard. Do not mix with powdered metals as suggested in some publications.	Place a heap no wider than 50 mm diameter on a heat-resistant mat and heat the edge of the pile with a Bunsen-burner flame directed downwards. Alternatively, a 3 cm length of wooden splint, previously soaked in ethanol, can be inserted into the heap and ignited. There may be dichromate dust in the residue after the reaction, so wear chemical-resistant gloves when sweeping up the residue [which is chromium(III) oxide (LOW HAZARD)] into a plastic bag. Place this in the refuse. A quantitative approach (suggested by SSERC) can be performed using a conical flask fitted with a dust trap such as mineral wool (<i>Handbook</i> 13.2). This can also be carried out on a smaller scale; see above.

8

Ammonium salts: oxidising agents


Ammonium nitrate(V)		NH ₄ NO ₃
Oxidising		<p>R8: Contact with combustible material may cause fire. R9: Explosive when mixed with combustible material.</p> <p>Dangerous with: ALUMINIUM, MAGNESIUM, SODIUM, POTASSIUM, CARBON, SULFUR, PHOSPHORUS. Explosive mixtures are formed which are sensitive to movement.</p> <p>POTASSIUM MANGANATE(VII). The mixture explodes spontaneously after a while. ETHANOIC ACID and other organic compounds. Unstable explosive mixtures are formed.</p> <p>Do not allow the salt to become contaminated with organic matter and do not grind it.</p>
Store: Ox		<p>Disposal: W1, W7</p> <p>W7: Solutions should be diluted to less than 0.5 mol dm⁻³.</p>
Ammonium peroxodisulfate(VI)		(NH ₄) ₂ S ₂ O ₈
Oxidising		<p>R8: Contact with combustible material may cause fire. R22: Harmful if swallowed. R36/37/38: Irritating to eyes, respiratory system and skin. R42/43: May cause sensitisation by inhalation and skin contact.</p> <p>Solutions equal to or stronger than 0.05 mol dm⁻³ should be labelled IRRITANT.</p> <p>Dangerous with: powdered ALUMINIUM, ZINC: Explosive reactions occur. POTASSIUM CHLORATE(VII), POTASSIUM MANGANATE(VII): Explosive mixtures are formed.</p> <p>HEAT: If heated strongly, it will explode.</p> <p>WEL (mg m⁻³): 1 (LTEL), 3 (STEL).</p>
Irritant		
Dangerous for the environment		
Store: Ox Pressure can build up in bottles.		<p>Disposal: W1, W7, Wspec</p> <p>W7: Solutions should be diluted to less than 0.2 mol dm⁻³.</p> <p>Wspec: Dissolve 5 g of solid in 100 cm³ of water and add 2 g of sodium metabisulfite. Pour the solution down a foul-water drain.</p>


Activity	User	Control measures	Experimental points
Heat of solution	Y9	Wear eye protection. Consider the use of potassium chloride.	When ammonium nitrate(V) dissolves in water, there is a drop in temperature (ie, an endothermic reaction). Potassium chloride is a safer alternative and can be used from Y7. Do not attempt to re-crystallise the salt, once it has been dissolved, by directly heating the solution. If recovery is essential, allow the water to evaporate in a dust-free environment.
Metal-etching solution	Y9	Wear eye protection.	Follow instructions provided by the manufacturer describing the amount of ammonium peroxodisulfate(VI) to be used. It is used as an alternative to iron(III) chloride solution.
Clock reaction	Y9	Wear eye protection.	The peroxodisulfate(VI)/iodide clock reaction is a useful alternative to, and less complicated than, the hydrogen peroxide/iodide reaction because acid ions do not have to be present. The reaction is very susceptible to catalysis by transition metal ions [especially copper(II) ions], so equipment must be clean. See <i>Recipe Card 18</i> .
Preparation of dinitrogen monoxide	TT	Wear eye protection. Use safety screens. Avoid direct heating of ammonium nitrate(V).	Consult methods described on <i>Hazard 68</i> , <i>Recipe Card 26</i> or in <i>Handbook 13.3</i> . If the traditional preparation is required, heat a mixture of 13 g of powdered ammonium sulfate(VI) and 20 g of potassium nitrate(V) carefully. Stop heating if brown fumes are seen.
Heating ammonium nitrate(V)	TT	Wear eye protection. Use safety screens.	Heat no more than 1 g of the pure salt in a test tube. Discontinue heating if brown fumes are seen.


9A Ammonium salts: other (1)

Ammonium sulfide has been moved to *Hazard* 51.

Ammonium salts must not be mixed or ground with potassium chlorate(V) or manganate(VII) because explosive mixtures can be formed.

Ammonium carbonate-1-water		Smelling salts	$(\text{NH}_4)_2\text{CO}_3 \cdot \text{H}_2\text{O}$
Harmful		R22: Harmful if swallowed. Solutions equal to or stronger than 2 mol dm^{-3} should be labelled HARMFUL.	
Store: Gln The solid decomposes to ammonia and carbon dioxide. The top must be on firmly.		Disposal: W1, W7 W7: Solution should be diluted to less than 0.9 mol dm^{-3} .	

Ammonium chloride		Sal ammoniac	NH_4Cl
Harmful		R22: Harmful if swallowed. R36: Irritating to eyes. Solutions stronger than or equal to 1.8 mol dm^{-3} should be labelled HARMFUL. WEL (mg m^{-3}): 10 (LEL), 20 (STEL).	
Store: Gln		Disposal: W1, W7 W7: Solution should be diluted to less than 1.8 mol dm^{-3} .	

Ammonium molybdate(VI)-4-water			$(\text{NH}_4)_6\text{Mo}_7\text{O}_{24} \cdot 4\text{H}_2\text{O}$
Harmful		R20/21/22: Harmful by inhalation, in contact with skin and if swallowed. Solutions equal to or stronger than 0.2 mol dm^{-3} should be labelled HARMFUL. WEL (mg m^{-3}): 5 (LEL), 10 (STEL).	
Store: Gln		Disposal: W1, W7 W7: Solution should be diluted to less than 0.08 mol dm^{-3} .	


9A Ammonium salts: other (1)


Model risk assessments

Activity	User	Control measures	Experimental points
Heating ammonium carbonate	Y7	Wear eye protection. The room must be well ventilated.	Ammonium carbonate even decomposes at room temperature, releasing water vapour, carbon dioxide and ammonia gas. Pupils must not inhale the gas. Use no more than 1 g per group.
Sublimation of ammonium chloride	Y7	Wear eye protection.	Use 1 g of ammonium chloride in a test tube plugged with mineral wool to prevent the dust being inhaled. The lighter, faster-moving, ammonia molecules diffuse through the plug and can be detected with moist red litmus paper.
Endothermic reaction	Y7	Wear eye protection.	Mix 2 g of solid ammonium chloride with 2 g of barium hydroxide. If the procedure is scaled up 10 times for a demonstration, temperatures can fall at least 20 °C. Y12 and 13 can investigate this reaction quantitatively. Disposal: Place the solution in a bucket of water and pour the liquid down a foul-water drain.
Carrying out the phosphate test	Y9	Wear eye protection.	Acidify the test solution (about 0.5 cm ³) with 1 mol dm ⁻³ nitric(V) acid (CORROSIVE) and add 2-3 cm ³ of ammonium molybdate solution (see below). A yellow precipitate indicates the presence of a phosphate.
Preparing the phosphate test reagent	Y12	Wear goggles. Use a fume cupboard.	Dissolve 4 g of ammonium molybdate in 4 cm ³ of '880' ammonia and 6 cm ³ of water. Add 12 g of ammonium nitrate(V) and dilute to 100 cm ³ . This alkaline solution keeps better than acidic solutions.

9B Ammonium salts: other (2)

Ammonium salts must not be mixed or ground with potassium chlorate(V) or manganate(VII) because explosive mixtures can be formed.

Ammonium thiocyanate		NH ₄ SCN
Harmful		R20/21/22: Harmful by inhalation, in contact with skin and if swallowed. R32: Contact with acids liberates very toxic gas. R52/53: Harmful to aquatic organisms, may cause long-term adverse effects in the aquatic environment. Solutions equal to or stronger than 3 mol dm ⁻³ should be labelled HARMFUL. Dangerous with: CONCENTRATED ACIDS or HOT DILUTE ACIDS: A very toxic gas (carbonyl sulfide) is liberated.
Store: Gln		Disposal: W1, W7 W7: Solution should be diluted to less than 1.3 mol dm ⁻³ .





Ammonium vanadate(V)		Ammonium metavanadate; ammonium polytrioxovanadate	NH ₄ VO ₃
Toxic		R20: Harmful by inhalation. R25: Toxic if swallowed. R36/37: Irritating to eyes and respiratory system. Solutions equal to or stronger than 2 mol dm ⁻³ should be labelled TOXIC. Solutions equal to or stronger than 0.2 mol dm ⁻³ but weaker than 2 mol dm ⁻³ should be labelled HARMFUL. Solutions weaker than 0.2 mol dm ⁻³ are LOW HAZARD.	
Store: T		Disposal: W1, W7 W7: Solutions should be diluted to less than 0.2 mol dm ⁻³ .	

Ammonium bromide; NH ₄ Br	Low hazard	Store: Gln	Disposal: W1, W7
Ammonium ethanoate; ammonium acetate; NH ₄ CH ₃ COO			
Ammonium iodide; NH ₄ I			
Ammonium sulfate(VI); (NH ₄) ₂ SO ₄			

9B Ammonium salts: other (2)**Model risk assessments**

Activity	User	Control measures	Experimental points
pH 7 buffer	Y7	Wear eye protection.	Uses ammonium ethanoate. See <i>Recipe Cards</i> .
Endothermic reaction	Y9	Wear eye protection.	Mix 1 g of ammonium thiocyanate and 3 g of solid barium hydroxide, measuring the temperature drop. Water on the side of the test tube will freeze. Disposal: Wash contents away with plenty of water.
Preparation of ammonium sulfate(VI)	Y9	Wear eye protection. Do not allow students to boil the solution to dryness. The room must be well ventilated.	Published methods use burettes and pipettes which are unnecessary and complicate the procedure. An excess of 1 mol dm^{-3} ammonia solution is added to 1 mol dm^{-3} sulfuric(VI) acid (use pH indicator paper or pH probe to check this). The mixture is then boiled to remove the excess ammonia. However, do not boil to dryness as this will lead to the decomposition of ammonium sulfate(VI) and the production of toxic and corrosive vapours. The solubility of ammonium sulfate(VI) is 75 g in 100 cm^3 of water.
Vanadium oxidation states	Y12	Wear eye protection. Wear splash-protection gloves when preparing the solution.	Use a 0.1 mol dm^{-3} solution of ammonium vanadate(V), prepared by the technician before the investigation begins. See <i>Recipe card 71</i> . Reduction to the vanadium(II) state is possible in zinc/acid solutions. There is no need for amalgam if zinc dust is used. Disposal: These dilute solutions can be poured down a foul-water drain with further dilution.



10A Barium metal, barium carbonate and chloride


Barium metal			Ba
Highly flammable		R14/15: Reacts violently with water liberating extremely flammable gases. R22: Harmful if swallowed.	
Harmful		WEL (mg m⁻³): 0.5 (LTEL), 1.5 (STEL). If dry, the metal can be impact sensitive.	
Store: FW It is sometimes supplied under argon. Once open, store under liquid paraffin.		Disposal: W1, W5, Wspec W5: Cut up to 10 g of barium metal into several smaller pieces. Add the pieces, one at a time, to 250 cm ³ of 1 mol dm ⁻³ ethanoic acid. When all the pieces have been added, dilute to 1 litre and pour the solution down a foul-water drain. Wspec: Place small pieces in propan-2-ol and leave until the barium has dissolved. Add the solution to water and pour the waste down a foul-water drain.	
Barium carbonate			BaCO ₃
Harmful		R22: Harmful if swallowed. WEL (mg m⁻³): 0.5 (LTEL), 1.5 (STEL) as barium.	
Store: Gln		Disposal: W1, W5 W5: Use no more than 100 g of barium carbonate per litre of 1 mol dm ⁻³ ethanoic acid.	
Barium chloride-2-water			BaCl ₂ ·2H ₂ O
Toxic		R25: Toxic if swallowed. R20: Harmful by inhalation. Solutions equal to or stronger than 1 mol dm ⁻³ should be labelled TOXIC. Solutions equal to or stronger than 0.1 mol dm ⁻³ but weaker than 1 mol dm ⁻³ should be labelled HARMFUL. WEL (mg m⁻³): 0.5 (LTEL) 1.5 (STEL) as barium.	
Store: T		Disposal: W1, W7, Wspec W7: Dilute to 0.05 mol dm ⁻³ before pouring the solution down a foul-water drain. Wspec: Dissolve in water, add sodium or magnesium sulfate(VI) solution to precipitate barium sulfate(VI). Filter off the barium sulfate(VI) for disposal in normal refuse. Pour the filtrate down a foul-water drain.	


10A Barium metal, barium carbonate and chloride**Model risk assessments**

Activity	User	Control measures	Experimental points
Testing for sulfates(VI)	Y7	Wear eye protection.	Use a 0.1 mol dm^{-3} solution of barium chloride.
Flame test	Y7	Wear eye protection.	Dip a clean nichrome wire into a 0.4 mol dm^{-3} barium chloride solution, shake gently and place it into a hot Bunsen-burner flame. A green flame appears for an instant. The solid can also be used in place of the solution and gives a longer-lasting flame but its use leads to messy benches.
Quantitative precipitation of barium carbonate	Y9	Wear eye protection.	<p>A 1 mol dm^{-3} solution of sodium carbonate (2 to 7 cm^3) is added to 5 cm^3 of hot 1 mol dm^{-3} barium chloride solution (TOXIC) in a series of test tubes. The height of the heavy barium carbonate precipitate in the test tube is measured. If this is done on a class basis, the precipitates will need to be collected for treatment before disposal.</p> <p>1 mol dm^{-3} potassium chromate(VI) (TOXIC) can be used in place of sodium carbonate. The colour of the supernatant liquid changes as excess chromate(VI) ions is added. Disposal is more complicated for barium chromate so a demonstration would be more convenient.</p>
Formula of the hydrated chloride	Y9	Wear eye protection.	The boiling point of anhydrous barium chloride is 1560°C . This is much higher than the temperature of the Bunsen-burner flame, so the amount of toxic material in the atmosphere is negligible. Roast the hydrated chloride until all the water is lost. Allow the hot apparatus to cool before reweighing.
Addition of metal to water and dilute acids	Y12	Wear eye protection.	<p>Barium metal is difficult to cut into smaller pieces. Hold the metal in a vice and use a junior hacksaw carefully. The activity is better done as a teacher demonstration using a 250 cm^3 beaker, half-filled with cold water or dilute (1 mol dm^{-3}) hydrochloric acid. With water, the resulting alkaline solution will be irritant. The solution will absorb carbon dioxide and turn cloudy.</p> <p>There is little reaction with dilute sulfuric(VI) acid.</p>

10B Barium chromate(VI), diphenylamine sulfonate, hydroxide & sulfate(VI)

Barium chromate(VI)		BaCrO ₄
Harmful		R20/22: Harmful by inhalation and if swallowed. R38: Irritating to skin. R43: May cause sensitisation by skin contact. WEL (mg m⁻³): 0.05 (LTEL), 0.15 (STEL) as chromium. Barium chromate(VI) is not listed as a carcinogen by the HSE.
Oxidising		
Store: Ox		Disposal: W1, W2

Barium diphenylamine sulfonate		(C ₆ H ₅ NHC ₆ H ₄ SO ₃) ₂ Ba
Harmful		R20/22: Harmful by inhalation and if swallowed. WEL (mg m⁻³): 0.5 (LTEL), 1.5 (STEL) as barium.
Store: Gln		Disposal: W1



Barium hydroxide-8-water		Ba(OH) ₂ ·8H ₂ O
Corrosive		R20/22: Harmful by inhalation and if swallowed. R34: Causes burns. WEL (mg m⁻³): 0.5 (LTEL), 1.5 (STEL) as barium.
Store: CS		Disposal: W1, W5 W5: Use no more than 100 g of barium hydroxide per litre of 1 mol dm ⁻³ ethanoic acid.



Barium sulfate(VI); barium sulfate; barytes; BaSO ₄	Low hazard	Store: Gln	Disposal: W8
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10B Barium chromate(VI), diph. sulfonate, hydroxide & sulfate(VI) Model risk assessments

Activity	User	Control measures	Experimental points
pH of soil using barium sulfate(VI)	Y7	-	Dispose of barium sulfate(VI) and soil in the normal refuse.
Precipitation of barium chromate(VI)	Y9	Wear eye protection. Wear disposable nitrile gloves.	Use 0.1 mol dm^{-3} solutions of a soluble barium salt and potassium chromate(VI) solution. Although not classified as a carcinogen, treat the solid barium chromate(VI) carefully.
Test for carbon dioxide using barium hydroxide	Y12	Wear eye protection.	Barium hydroxide is slightly soluble in water ($4 \text{ g in } 100 \text{ cm}^3$) and is very sensitive to carbon dioxide. In fact it immediately goes cloudy (barium carbonate) when exposed to the atmosphere. All fresh solutions, which will be alkaline and may irritate a sensitive skin, must be protected with a soda lime guard tube. Distilled water should be boiled to remove carbon dioxide before being added to barium hydroxide.
Potassium dichromate(VI) titrations	Y12	Wear eye protection.	A 0.2% (w/v) solution of barium diphenylamine sulfonate is used as an indicator. The colour change is colourless to blue violet. It is safer to use the barium (or the sodium) salt than to prepare a 1% (w/v) diphenylamine solution in concentrated sulfuric(VI) acid. The concentration of potassium dichromate(VI) solution should be 0.02 mol dm^{-3} (TOXIC), see <i>Hazard 78</i> . Disposal: W7 Pour unused indicator down a foul-water drain. (For unwanted potassium dichromate(VI) solution, see <i>Hazard 78</i> .)
Quantitative precipitation of barium chromate(VI)	TT	Wear eye protection. Wear chemical-resistant gloves.	$2 \text{ to } 7 \text{ cm}^3$ of a 1 mol dm^{-3} solution of potassium chromate (TOXIC) is added to 5 cm^3 of hot 1 mol dm^{-3} barium chloride (TOXIC) in a series of test tubes. The height of the barium bromate precipitate in the test tube is measured. If performed by a whole class, sodium carbonate solution is a useful substitute for potassium chromate(VI) (see <i>Hazard 10A</i>). Disposal: W2.








11 Barium nitrate(V) and peroxide

Barium nitrate(V)		Ba(NO ₃) ₂
Oxidising		R8: Contact with combustible material may cause fire. R20/22: Harmful by inhalation and if swallowed. All solutions are LOW HAZARD.
Harmful		Dangerous with: POWDERED METALS, eg, aluminium. Readily ignites and is extremely sensitive to friction or impact. WEL (mg m⁻³): 0.5 (LTEL), 1.5 (STEL) as barium.
Store: Ox		Disposal: W1, W7, Wspec W7: Dilute to 0.2 mol dm ⁻³ before pouring the solution down a foul-water drain. Wspec: Dissolve in water, add 1 mol dm ⁻³ sodium or magnesium sulfate(VI) solution to precipitate barium sulfate(VI). Filter off the barium sulfate(VI) for disposal in normal refuse. Pour the filtrate down a foul-water drain.

Barium peroxide		BaO ₂
Oxidising		R8: Contact with combustible material may cause fire. R20/22: Harmful by inhalation and if swallowed. Barium peroxide causes serious internal damage when swallowed due to the release of oxygen.
Harmful		Dangerous with: COMBUSTIBLE MATERIAL including ORGANIC SUBSTANCES. Violent or explosive reactions occur. May ignite spontaneously, particularly if damp. ETHANOIC ACID and ETHANOIC ANHYDRIDE. Explosions occur. HYDROGEN SULFIDE. The gas can ignite. WATER. Vigorous reaction occurs forming a corrosive solution. WEL (mg m⁻³): 0.5 (LTEL), 1.5 (STEL) as barium.
Store: Ox		Disposal: W1, Wspec Wspec: Add no more than 5 g to 1 litre of 1 mol dm ⁻³ sulfuric(VI) acid in a beaker. Leave it stirring overnight. Decant the liquid down a foul-water drain with plenty of water. The solid [barium sulfate(VI)] can go in the normal refuse.





Activity	User	Control measures	Experimental points
Testing for sulfates(VI)	Y7	Wear eye protection.	All solutions of barium nitrate(V) are LOW HAZARD as compared with barium chloride. A 0.1 mol dm^{-3} solution is suitable for most purposes. However, it is not possible to prepare solutions of barium nitrate(V) stronger than 0.3 mol dm^{-3} . Barium chloride would have to be used instead.
Heating barium nitrate(V)	Y9	Wear eye protection.	Use no more than 1-2 g. Oxygen is produced. Brown fumes (nitrogen dioxide) may be observed only if heating is prolonged. Disposal: When cool, the test tubes should be soaked in water and placed in the sharps bin.
Thermite reaction	TT	Wear goggles or a face shield. Use safety screens. Pupils must be positioned towards the back of the room and wearing eye protection. Protect the bench with hardboard or heat-proof mats. Do not use a fume cupboard to carry out this reaction. Do not carry out this procedure outdoors. The room must be well ventilated.	See <i>Hazard</i> 1 for details of the thermite mixture. Initiator: Mix carefully 1.7 g barium peroxide or 2 g of barium nitrate(V) with 0.2 g magnesium powder without using any metal tools. See <i>Hazard</i> 37 for an alternative initiator. Procedure: The reaction can be performed in a fireclay crucible set in dry sand in a large bucket or directly in dry Kaolin. (Fill a 500 cm^3 beaker with Kaolin and shape a 'crucible' in the powder by inserting a boiling tube to a depth of 5 cm.) Make a depression about 4 mm deep in the thermite mixture with a spatula or test tube and fill with the initiator. Insert a magnesium ribbon fuse through the initiator mixture so that it extends well into the thermite mixture. Light the magnesium with a Bunsen burner. White-hot particles are sometimes ejected onto the heat-proof mats and possibly the floor. See <i>Handbook</i> 13.4. The reaction can also be performed under water. See L195, <i>Safer Chemicals, Safer Reactions</i> .

12 Benzene diols and triols

Benzene-1,2-diol	1,2-dihydroxybenzene; catechol; pyrocatechol		(HO) ₂ C ₆ H ₄
Harmful		R21/22: Harmful in contact with skin and if swallowed. R36/38: Irritating to eyes and skin. WEL (mg m⁻³): 23 (LTEL) 69 (STEL).	
Benzene-1,3-diol	1,3-dihydroxybenzene; resorcinol		(HO) ₂ C ₆ H ₄
Harmful		R22: Harmful if swallowed. R36/38: Irritating to eyes and skin. R50: Very toxic to aquatic organisms. WEL (mg m⁻³): 46 (LTEL) 92 (STEL) (Sk).	
Dangerous for the environment			
Benzene-1,4-diol	1,4-dihydroxybenzene; quinol, hydroquinone		(HO) ₂ C ₆ H ₄
Harmful		R40: Limited evidence of a carcinogenic effect. Category 3 carcinogen. R68: Possible risk of irreversible effects. Category 3 mutagen. R22: Harmful if swallowed. R41: Risk of serious damage to eyes. R43: May cause sensitisation by skin contact. R50: Very toxic to aquatic organisms.	
Dangerous for the environment		WEL (mg m⁻³): 0.5 (LTEL), 1.5 (STEL).	
Benzene-1,2,3-triol	1,2,3-trihydroxybenzene; pyrogallol		(HO) ₃ C ₆ H ₃
Harmful		R68: Possible risk of irreversible effects. Category 3 mutagen. R20/21/22: Harmful by inhalation, in contact with skin and if swallowed. R52/53: Harmful to aquatic organisms, may cause long-term adverse effects in the aquatic environment.	
Benzene-1,3,5-triol	1,3,5-trihydroxybenzene; phloroglucinol		(HO) ₃ C ₆ H ₃
Irritant		R36/37/38: Irritating to eyes, respiratory system and skin.	
All these substances are dangerous with: CONCENTRATED NITRIC(V) ACID. A vigorous reaction occurs.			
For all these substances, Store: GOrg		For all these substances, Disposal: W1, W4	

Activity	User	Control measures	Experimental points
Absorbing oxygen	Y9	Wear eye protection.	A solution of benzene-1,2,3-triol (pyrogallol) in very concentrated (often saturated) sodium or potassium hydroxide solution (CORROSIVE) has often been used for gas analysis. This solution is very hazardous to prepare and handle. Avoid using this solution if possible. See <i>Recipe Card</i> 64 about making up pyrogallol in saturated sodium hydrogencarbonate solution instead. If the use of a stronger alkali is unavoidable, the solution should be made up by a teacher or technician. When oxygen is being absorbed, the solution goes dark brown. Note that there is still oxygen-absorbing capacity even when the solution is quite dark. Use citric acid solution to remove stains caused by pyrogallol.
Test for pentoses (Bial's test)	Y9	Wear eye protection. No naked flames in the immediate vicinity.	This solution contains 3 g of benzene-1,3-diol in 100 cm ³ of 95% ethanol solution (HIGHLY FLAMMABLE) to which 20 drops of iron(III) chloride are added.
Developing black & white photographs	Y9	Wear eye protection.	Diluted quinol/hydroquinone solutions are supplied for developing procedures in photography. Solutions from suppliers will have further dilution details and safety information. Disposal: W7
Test for lignin	Y12	Wear eye protection.	A solution containing 5% of benzene-1,3,5-triol in ethanol (HIGHLY FLAMMABLE) followed by concentrated hydrochloric acid (CORROSIVE) is used. Use the minimum volume of each reagent on a microscope slide to carry out the test. Draw wax pencil lines on the slide to restrict the spread of the liquids.
Inhibitors	Y12	Wear eye protection. Wear chemical-resistant gloves.	Monomers, such as phenylethene, contain these substances to stop the monomer polymerising during storage. They are removed by 'washing' the monomer with 1 mol dm ⁻³ sodium hydroxide solution (CORROSIVE). This should be supervised by experienced teachers of chemistry.


13A Benzenecarboxylic acid and other aromatic acids


Benzenecarboxylic acid		Benzoic acid	$\text{C}_6\text{H}_5\text{COOH}$
Harmful		R22: Harmful if swallowed. R36: Irritating to eyes. Flash point: 121 °C.	
Store: GOrg		Disposal: W1, W4	
3-nitrobenzenecarboxylic acid		3-nitrobenzoic acid	$\text{NO}_2\text{C}_6\text{H}_4\text{COOH}$
Harmful		R40: Limited evidence of a carcinogenic effect. Category 3 carcinogen. R22: Harmful if swallowed. R36/37/38: Irritating to eyes, respiratory system and skin.	
Store: GOrg		Disposal: W1, W2 or W4 W4: Add no more than 10 g of the substance to 1 litre of 1 mol dm ⁻³ sodium carbonate solution. Pour the solution down a foul-water drain.	
Benzene-1,2-dicarboxylic acid		Phthalic acid	$\text{C}_6\text{H}_4(\text{COOH})_2$
Toxic		R61: May cause harm to the unborn child. Category 2 teratogen. R62: Possible risk of impaired fertility.	
Store: T		Disposal: W1, W2	
trans-3-phenylprop-2-enoic acid		trans-cinnamic acid	$\text{C}_6\text{H}_5\text{CHCHCOOH}$
Benzene-1,4-dicarboxylic acid		Terephthalic acid	$\text{C}_6\text{H}_4(\text{COOH})_2$
Irritant		R36/37/38: Irritating to eyes, respiratory system and skin.	
Store: GOrg		Disposal: W1, W4	
4-aminobenzenecarboxylic acid; 4-aminobenzoic acid; <i>p</i> -aminobenzoic acid; $\text{NH}_2\text{C}_6\text{H}_4\text{COOH}$		Low hazard	Store: GOrg
			Disposal: W1, W8


13A Benzenecarboxylic acid and other aromatic acids**Model risk assessments**

Activity	User	Control measures	Experimental points
Crystallisation	Y7	Wear eye protection.	The solubility of benzoic acid in water increases dramatically on heating. Use 0.1 g of benzoic acid and 5 cm ³ of water in a boiling tube heated in boiling water, remove and cool. Record the temperature at which crystals form. The procedure may be repeated with two further additions of water in 5 cm ³ amounts. The vapour is slightly irritating.
Sublimation	Y7	Wear eye protection.	Use no more than 0.5 g of benzoic acid in a test tube. On warming and cooling, long needle-shaped crystals of benzoic acid reform at the cooler parts of the test tube.
Formation of esters	Y12	Wear eye protection.	A semi-micro scale activity using 2 g of benzoic acid dissolved in 8 cm ³ of ethanol (HIGHLY FLAMMABLE) to which 1 cm ³ of concentrated sulfuric(VI) acid (CORROSIVE) is added: it produces ethyl benzoate after refluxing. Other aromatic acids can be used.
Preparation of 3-nitrobenzoic acid	Y12	Wear goggles.	Schools may have methyl 3-nitrobenzoate (formed by the nitration of methyl benzoate). The acid can be prepared by warming the solution with 2 mol dm ⁻³ sodium hydroxide. See L195, <i>Safer Chemicals, Safer Reactions</i> .
Identifying functional groups in organic 'unknowns'	Y12	Wear eye protection.	Terephthalic acid, <i>trans</i> -cinnamic acid, phthalic acid and 4-aminobenzoic acid contain two functional groups and are useful as unknowns in analysis.

13B Benzenecarboxylic acid derivatives

Benzenecarbonyl chloride		Benzoyl chloride	$\text{C}_6\text{H}_5\text{COCl}$
Corrosive		<p>R34: Causes burns. Flash point: 72 °C.</p> <p>This substance is lachrymatory, ie, it brings tears to the eyes. It reacts with water from the atmosphere to produce hydrogen chloride gas.</p> <p>If spilt in the laboratory: Wear eye protection and disposable nitrile gloves. Ventilate the area as much as possible. Consider evacuation. Cover with mineral absorbent. Clear up into a bucket and take it to a fume cupboard. Treat with a large excess of water and leave to hydrolyse. Treat as a corrosive spill (<i>Handbook 7.7</i>).</p>	
Store: CLa Store in another container containing soda lime.		Disposal: W1, W4 W4: Use a fume cupboard. Add the material in small amounts.	

Benzenecarbonitrile		Benzonitrile; phenyl cyanide	$\text{C}_6\text{H}_5\text{CN}$
Benzenecarboxamide		Benzamide	$\text{C}_6\text{H}_5\text{CONH}_2$
Harmful		<p>R21/22: Harmful in contact with skin and if swallowed.</p> <p>Flash point: 85 °C.</p>	
Store: GOrg		Disposal: W1, W2	



Benzene-1,2-dicarboxylic acid anhydride		Phthalic anhydride	$\text{C}_8\text{H}_4\text{O}_3$
Harmful		<p>R22: Harmful if swallowed. R37/38: Irritating to respiratory system and skin.</p> <p>R41: Risk of serious damage to eyes. R42/43: May cause sensitisation by inhalation and skin contact. WEL (mg m⁻³): 4 (LTEL), 12 (STEL). Flash point: 152 °C.</p>	
Store: GOrg		Disposal: W1, W2	



Potassium hydrogen-benzene-1,2-dicarboxylate; potassium hydrogen phthalate; potassium hydrogen-benzene-1,2-dioate; $\text{KHC}_8\text{H}_4\text{O}_4$	Low hazard	Store: Gln	Disposal: W1, W7
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13B Benzenecarboxylic acid derivatives**Model risk assessments**

Activity	User	Control measures	Experimental points
pH 4 buffer	Y7	Wear eye protection.	0.1 mol dm ⁻³ potassium hydrogen phthalate is the standard pH 4 buffer.
Standard solutions	Y9	Wear eye protection.	As supplied, potassium hydrogen phthalate is a very pure and stable chemical. It is used as the primary standard against which the concentrations of alkaline solutions are measured. See <i>Recipe Cards</i> .
Reactions of benzoyl chloride	Y12	Wear goggles. Use a fume cupboard. Wear disposable nitrile gloves.	Use no more than 1 cm ³ of concentrated ammonia or amine. Fumes of ammonium chloride are produced as well. This is not a good preparative method for amides.
Schotten-Baumann reactions	Y12	Wear goggles. Use a fume cupboard for certain procedures.	The Schotten-Baumann reaction prepares good yields of substituted amides or esters. Mix reagents, eg, phenol or phenylamine, 2 mol dm ⁻³ sodium hydroxide solution (CORROSIVE) and benzoyl chloride in a fume cupboard and stopper the container; it can then be taken from the fume cupboard. Some solid forms around the droplets of benzoyl chloride; any such solid must be broken up with a glass rod in a fume cupboard to avoid fumes. Filtering can be done in a well-ventilated laboratory.
Preparation of cholesteryl benzoate	Y12	Wear goggles. Use a fume cupboard.	0.4 cm ³ of benzoyl chloride is added to a solution of 1 g of cholesterol in 3 cm ³ of pyridine. See Nuffield Advanced Chemistry students book, 3 rd edition, 1994, ISBN 0582233461. The product is a liquid crystal.
Reactions of amides	Y12	Wear eye protection.	Reactions on a test-tube scale can be carried out on benzamide. It is an alternative to ethanamide.
Hydrolysis of benzonitrile	Y12	Wear eye protection.	Benzonitrile is less volatile and safer than ethanenitrile (acetonitrile) (HARMFUL). Reflux 1 cm ³ of benzonitrile with 20 cm ³ of 2 mol dm ⁻³ sodium hydroxide solution (CORROSIVE) for 30 minutes. Transfer to an open flask, boil to remove dissolved ammonia, cool and add concentrated hydrochloric acid (CORROSIVE) dropwise to precipitate benzoic acid.
Preparation of resins	Y12	Use a fume cupboard. Wear goggles.	Heat phthalic anhydride with ethane-1,2-diol to 180 °C in an oil bath. The apparatus takes some time to cool and should be suitably labelled.
Preparation of phenolphthalein	TT	Wear eye protection.	Use amounts no larger than 0.5 g of phthalic anhydride, 0.5 g phenol with 1 drop of concentrated sulfuric(VI) acid (CORROSIVE).
Preparation of Menastral blue	TT	Wear goggles. Use a fume cupboard.	1 g of phthalic anhydride, 1.5 g of carbamide, 0.2 g of copper(II) chloride and 0.005 g of ammonium molybdate are heated in a crucible.

14 Boron compounds

Sodium tetrahydridoborate(III)		Sodium borohydride	NaBH ₄
Highly flammable		R15: Contact with water liberates highly flammable gases. R25: Toxic if swallowed. R34: Causes burns. Dangerous with: ACIDS and ALKALIS, both concentrated and dilute; explosions are well documented.	
Toxic			
Store: FW Hydrogen is evolved if the solid becomes wet.		Disposal: W1, Wspec Wspec: Add the solid in 0.5 g amounts to water in a fume cupboard. Wait for the reaction to finish before adding the next amount.	

Sodium peroxoborate-4-water		Sodium perborate	NaBO ₃ ·4H ₂ O
Oxidising		R8: Contact with combustible material may cause fire. R36: Irritating to eyes.	
Irritant			
Store: Ox		Disposal: W1, W7 W7: It is not very soluble in water. Dissolve 20 g of solid in 1 litre of water before pouring down a foul-water drain.	




Boric acid (boracic acid) H ₃ BO ₃	Low hazard	Dangerous with: POTASSIUM and ETHANOIC ANHYDRIDE. Vigorous reactions occur when heated.	Store: Gln	Disposal: W1, W7
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Disodium tetraborate-10-water; sodium tetraborate; borax; Na ₂ B ₄ O ₇ ·10H ₂ O	Low hazard	Store: Gln	Disposal: W1, W7
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Activity	User	Control measures	Experimental points
Making solutions of boric acid	Y7	-	The crystalline form of the acid is easier to dissolve and does not raise a dust. The solution is a very weak acid (pH 5).
Sodium tetra-borate solutions	Y7	-	A 0.1 mol dm^{-3} solution of sodium tetraborate is an excellent 9.2 pH buffer solution. See Guide R35 <i>pH Measurement</i> .
Making 'glass' with lead(II) oxide and zinc oxide	Y7	Wear eye protection. Take care to avoid raising dust of lead(II) oxide.	A recipe for glass is 6.5 g lead(II) oxide, 3.5 g boric acid and 0.5 g zinc oxide. Tiny grains of transition element oxides (except nickel(II) oxide) can be added to provide colour. Allow time for the crucible to cool before handling further. The apparatus used to make this glass should be immersed in 50 cm^3 1 mol dm^{-3} nitric(V) acid for cleaning. Disposal: W2. Dissolve the glass in 1 mol dm^{-3} nitric(V) acid and dilute to 1 litre before pouring down a foul-water drain.
Making 'slime'	Y7	Wear eye protection.	See <i>Recipe Card</i> 59 and <i>Bulletin</i> 129. Samples of slime should not be taken home. PVA glue contains polyvinyl alcohol and acetate; results depend on the ratio of one to the other.
Borax bead test	Y7	Wear eye protection.	Make a clear bead by fusing a small quantity of borax onto a loop of nichrome wire in a Bunsen-burner flame. After the bead has been formed, coat it with a dry sample of the material to be tested and reintroduce the bead into the burner flame. Observe the colour of the bead.
Flame-retarding solution	Y7	Wear eye protection.	Flame-proofing solution can be made by dissolving 30 g of sodium tetraborate and 25 g of boric acid in 500 cm^3 of water.
Reduction of a ketone to an alcohol	Y12	Wear eye protection.	There should be no sources of ignition in the vicinity. Add 0.7 g of 1,2-diphenylethanedione (benzil) (LOW HAZARD) to 7 cm^3 of 95% (V/V) aqueous ethanol (HIGHLY FLAMMABLE) in a conical flask. Warm to dissolve, cool, add 0.15 g of sodium tetrahydridoborate(III) and allow to stand for 10 minutes. Add 1 cm^3 of water, heat to boiling and filter off the crystals of 1,2-diphenylethane-1,2-diol (LOW HAZARD) on cooling. (<i>Revised Nuffield Advanced Science: Chemistry, Students Book 1</i> , 2 nd edition, Longman, 1984, ISBN 0582353610, p 391.)

15A Bromine liquid (See also 15B)

Br₂(l)

Very toxic		R26: Very toxic by inhalation. R35: Causes severe burns. R50: Very toxic to aquatic organisms. Solutions equal to or stronger than 0.3 mol dm ⁻³ (1.6% v/v) should be labelled VERY TOXIC and CORROSIVE. Solutions equal to or stronger than 0.06 mol dm ⁻³ (0.3% v/v) should be labelled TOXIC and IRRITANT. Solutions equal to or stronger than 0.006 mol dm ⁻³ (0.03% v/v) but weaker than 0.06 mol dm ⁻³ should be labelled HARMFUL.
Corrosive		
Dangerous for the environment		Inhalation of bromine by pupils or staff with known breathing difficulties such as asthma may exacerbate these pre-existing conditions. Effects of exposure can be delayed for some hours. If in doubt, seek medical attention. WEL (mg m⁻³): 0.66 (LTEL), 1.3 (STEL). Wherever bromine liquid is used or stored, have at least 500 cm³ of 1 mol dm⁻³ sodium thiosulfate solution available in a suitable container. This does <i>not</i> apply to bromine water, which, for most purposes, is much safer.

The substance is dangerous with:	POTASSIUM, SODIUM, ALUMINIUM, MAGNESIUM, MERCURY. Violent reactions occur. AMMONIA solution (concentrated). Violent reaction occurs and an explosive product is formed. ALCOHOLS, ETHERS and other organic compounds. Violent reactions occur.
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Emergencies: see standard procedures on *Hazard E*, BUT ALSO:

If spilt on the skin or clothes:	Treat the affected area with 1 mol dm ⁻³ sodium thiosulfate solution before flooding with water. Do not delay treatment if thiosulfate is not readily available; in this case immediately flood with water, as for other splashes or burns.
If spilt in the laboratory:	If less than 0.2 cm ³ (eg, a few drops), add hydrated sodium carbonate (solid) or sodium thiosulfate solution. If more than this, evacuate pupils, open all windows, switch on fans etc and close the door. After 1 hour, if safe, enter and treat area of spill. For larger spills, call the fire brigade, asking for the Chemical Incident Unit.

Store: Spec Fumes accelerate the corrosion of metal in cupboards. Keep liquid bromine bottle inside a closed container with soda lime present which should be renewed regularly. This can be stored on shelves in a secure store. Purchase small quantities (100 cm ³ or less). Check condition of the caps regularly. Keep ampoules in their protective packing with other corrosives. Take only the required number of ampoules into a class.	Disposal: W1, W4 W4: In a fume cupboard, add the liquid, 1 cm ³ at a time, with stirring, to 1 litre of 1 mol dm ⁻³ sodium carbonate solution in a 2 litre, glass beaker. Add no more than 40 cm ³ before pouring down a foul-water drain.
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15A Bromine liquid

Model risk assessments

Inhalation of bromine by pupils or staff with known breathing difficulties such as asthma may exacerbate these pre-existing conditions. Effects of exposure can be delayed for some hours. If in doubt, seek medical attention.



Activity	User	Control measures	Experimental points
Addition of bromine to organic chemicals	Y12	Wear goggles. Use a fume cupboard. Wear chemical-resistant gloves.	Use a 1-5% bromine solution in cyclohexane, tetrachloroethene or <i>Volasil</i> . The reactions produce heat. Add reagents to each other in small amounts and use colour changes to indicate when the reaction is complete. Do not attempt to pass ethene gas through non-aqueous bromine solution; the product [1,2-dibromoethane (TOXIC)] is a carcinogen.
Transfer of liquid bromine	TT	Wear goggles or a face shield. Wear chemical-resistant gloves. Use a fume cupboard.	Use a plastic teat pipette. Hold the teat with the finger tips at the base of the teat. Do not wrap your hand around the teat, heat from the hand or inadvertent pressure can cause the bromine to squirt out.
Opening ampoules	TT	Wear goggles or a face shield. Wear chemical-resistant gloves. Use a fume cupboard.	For most purposes, it is safer to crush an ampoule under water or break it open where it is required, eg, over a beaker. To open an ampoule, scratch its neck with a good glass knife, clamp the ampoule upright and use pliers to snap off the neck. Beware of sharp glass.
Diffusion demonstration of bromine into air	TT	Wear eye protection. Wear chemical-resistant gloves.	1 cm ³ of liquid bromine produces about 480 cm ³ of vapour at room temperature. Measure the volume of the gas jars and use the relevant volume of liquid bromine to vaporise. Use nitrogen dioxide for a safer alternative; see L195, <i>Safer Chemicals, Safer Reactions</i> .
Diffusion demonstration within enclosed apparatus (eg, Nuffield Physics)	TT	Wear goggles or a face shield. Wear chemical-resistant gloves. Use safety screens.	Make sure the rubber tube fits well onto the stopcock tube. Replace the rubber tube after every activity and replace the rubber bung frequently. Vaseline should be used to grease the stopcock. As bromine is fully enclosed within the apparatus, it may be used in an open lab with good ventilation. Clean the apparatus in a fume cupboard by placing it in 0.25 mol dm ⁻³ sodium carbonate solution. See L195, <i>Safer Chemicals, Safer Reactions</i> for an alternative procedure.
Reaction with aluminium and tin	TT	Wear goggles or a face shield. Wear chemical-resistant gloves. Use a fume cupboard.	Add some tin or aluminium foil to 1 cm ³ of bromine in a borosilicate boiling tube. The reaction is very exothermic. When cool, place the boiling tube in a container of water. See SRA 04 for more details.
Reaction with iron	TT	Wear goggles or a face shield. Wear chemical-resistant gloves. Use a fume cupboard.	Place 1 cm ³ of bromine in a boiling tube. Insert iron wool to the middle of the boiling tube. Heat the iron strongly before warming the bromine. See <i>Handbook 13 Metals</i> .


For emergencies, see *Hazard E* as well as more detailed information which may be on this *Hazard*.

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15B Bromine water (See also 15A)

Br₂(aq)

For solutions equal to or greater than 0.06 mol dm ⁻³ (ie, a 0.3% v/v solution)		
Toxic		R26: Very toxic by inhalation. R36: Irritating to eyes. WEL (mg m⁻³): 0.66 (LTEL), 1.3 (STEL).
Irritant		The solubility of bromine in water is 4 g, ie, 1.25 cm ³ , in 100 g of water at room temperature. This concentration is 0.25 mol dm ⁻³ .

Solutions equal to or stronger than 0.006 mol dm ⁻³ (0.03% v/v) but weaker than 0.06 mol dm ⁻³ should be labelled HARMFUL. These include a 0.02 mol dm ⁻³ solution [ie, 0.1% (v/v)] which is made by dissolving 1 cm ³ of bromine liquid in 1 litre of water.		
Harmful		R20: Harmful by inhalation. R21: Harmful in contact with skin. R22: Harmful if swallowed. R36: Irritating to eyes. WEL (mg m⁻³): 0.66 (LTEL), 2.0 (STEL).

The substance is dangerous with:	POTASSIUM, SODIUM, ALUMINIUM, MAGNESIUM, MERCURY. Violent reactions may occur. AMMONIA solution (concentrated). Violent reaction occurs and an explosive product may be formed.
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Emergencies: see standard procedures on *Hazard E*, BUT ALSO:

If spilt in the laboratory:	Much will depend on the volume and concentration of the spilt liquid. Consider using just a cloth (wear chemical-resistant gloves) or mineral absorbent. Do not put yourself at risk.
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Store: Gln The top must be securely closed.	Disposal: W4 W4: Use a fume cupboard.
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15B Bromine water

Model risk assessments

Activity	User	Control measures	Experimental points
Use of bromine water	Y7	Wear eye protection.	Use a 0.02 mol dm^{-3} (ie, 0.1% v/v) solution of bromine water. Add cyclohexane to emphasise the colour changes if oxidising a halide to a halogen. See Guide L195, <i>Safer Chemicals, Safer Reactions</i> . Volasil or ethyl ethanoate could also be used.
Bromine water as a test for unsaturation	Y9	Wear eye protection.	Use 0.005 to 0.01 mol dm^{-3} solutions, (ie, 0.025 to 0.05% v/v), otherwise a colour change may not be observed (usually there is very little alkene in a test tube of 'cracked' gas). Add 1 cm^3 of solution to a test tube of 'cracked' gas or 1 cm^3 of liquid alkenes. With ethene, only a very small amount of 1,2-dibromoethane (TOXIC) is formed because the solution is already diluted and other, less hazardous, products are formed as well. See also PS67-01 for a safer alternative.
Preparation of bromine water	TT	Wear goggles or a face shield. Wear chemical-resistant gloves Use a fume cupboard.	Make up a 0.02 mol dm^{-3} solution (as below). For most purposes, this can be diluted further. 1. Add 1 cm^3 of bromine to 500 cm^3 of water in a 1 litre beaker. Add a stirrer bar and place on a magnetic stirrer to dissolve the bromine. This can take some time. Dilute to 1 litre with water. Alternatively, an ampoule can be crushed (see <i>Hazard 15A</i>) under 500 cm^3 of water and this is diluted to 1 litre. The solution must be decanted so that no glass is present. 2. Dissolve 4.76 g of potassium bromide in 66 cm^3 of water, add 14 cm^3 of 10% available chlorine sodium chlorate(I) solution and 20 cm^3 of 2 mol dm^{-3} hydrochloric acid. Dilute to 1 litre. 3. Add 1.12 g of potassium bromate(V), 12 g of potassium bromide and 14 cm^3 of 2 mol dm^{-3} hydrochloric acid into a 1 litre jug or measuring cylinder. Add water to 1 litre and pour into a labelled bottle. This will make a 0.02 mol dm^{-3} solution of bromine water.

16 Calcium and strontium

Calcium			Ca
Highly flammable		<p>R15: Contact with water liberates highly flammable gases.</p> <p>Dangerous with: WATER, ACIDS. Hydrogen is formed which may ignite from the heat of reaction under certain circumstances.</p> <p>SULFUR. An explosive reaction occurs.</p> <p>HYDROXIDES and CARBONATES of SODIUM, POTASSIUM and other ALKALI METALS. Reactions may be explosive.</p> <p>The metal is difficult to ignite but burns vigorously when lit and is difficult to extinguish. Small fires are best extinguished by smothering with dry sand.</p>	
Store: FW A white oxide layer may form on the turnings.		Disposal: W1, W5 W5: Use a fume cupboard with no sources of ignition present.	

Strontium			Sr
Highly flammable		R11: Highly flammable. R14: Reacts violently with water. R38: Irritating to skin.	
Irritant			
Store: FW It is sometimes supplied under argon. Once opened, it can be stored dry in an air-tight container or stored under liquid paraffin as with barium.		Disposal: W1, W5 W5: Use a fume cupboard with no sources of ignition present.	

Emergencies: see standard procedures on *Hazard E*, BUT ALSO:




If particles enter the eyes:	Flood the eye with gently-running tap water until a first aider arrives. Send the casualty to hospital and ensure that irrigation is continued during the journey.
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Activity	User	Control measures	Experimental points
Reaction of calcium with water	Y7	Wear eye protection.	Hydrogen is evolved. The resulting solution will be alkaline and irritating to the skin. If a test tube is a quarter-filled with water, the amount of calcium added must be limited because frothing can occur. Alternatively, use a tall-form beaker, at least half-filled with water, and collect hydrogen for identification in test tubes, via a small inverted funnel. This reaction is not suitable for the preparation of hydrogen.
Reaction of calcium with dilute acids	Y7	Wear eye protection.	If a test tube is a quarter-filled with 0.4 mol dm^{-3} hydrochloric acid, the amount of calcium added must be limited to 1 to 3 granules or a turning at a time. There is very little reaction with dilute sulfuric(VI) acid because the calcium is coated with calcium sulfate(VI) which is only slightly soluble in water.
Reaction of strontium with water and dilute acids	TT	Wear eye protection.	Hydrogen is evolved.
Burning calcium	TT	Wear eye protection. Must be carried out behind safety screens because there is much sputtering of white-hot particles.	The metal is very difficult to ignite. Use fresh turnings which are easier to ignite than granules. It is usually necessary to wrap the sample partially in ceramic paper in order to ignite the calcium easily and this makes sputtering more likely. Apply heat directly from a supported Bunsen burner or, better still, a portable flame torch suitable for kitchen use. See L195, <i>Safer Chemicals, Safer Reactions</i> .
Action of chlorine on calcium	TT	Wear eye protection. Use a fume cupboard. Not to be done in a gas jar.	Chlorine should be passed over calcium in a combustion tube which is gradually heated to a high temperature.

17 Calcium chlorate(I)



Also known as calcium hypochlorite and bleaching powder.

Oxidising		R8: Contact with combustible material may cause fire. R22: Harmful if swallowed. R34: Causes burns. R31: Contact with acids liberates toxic gas. R50: Very toxic to aquatic organisms.
Corrosive		WEL (mg m⁻³): 1.5 (LTEL), 2.9 (STEL) ie, chlorine. Liberates chlorine gas gradually. Use as a source of chlorine. Technical grade contains 35% chlorine.
Dangerous for the environment		

The substance is dangerous with:	ACIDS. A toxic gas, chlorine, is liberated. CONCENTRATED SULFURIC(VI) ACID. A dangerous reaction occurs. AMMONIUM SALTS. Explosive products are formed. METHANOL, ETHANOL, PROPANE-1,2,3-TRIOL, many other ORGANIC SUBSTANCES and SULFUR. Dangerous reactions occur. RUST. Self-accelerating decomposition is catalysed.
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Emergencies: see standard procedures on *Hazard E*, BUT ALSO:



If dust or suspension contaminates the eyes:	Flood the eye with gently-running tap water until a first aider arrives. Unless the suspension is very dilute, send the affected person to hospital and ensure that irrigation is continued during the journey.
If spilt in the laboratory:	Scoop up as much of any solid as possible into a dry bucket. Flood the area with water and clear up. Rinse the area of the spill and any cloth or mop thoroughly. It is essential to ensure that no significant impregnation occurs of wood, cloth or other combustible material.

Store: Ox The potential available chlorine decreases gradually once the bottle is opened. Old samples should be tested for their chlorine content. Old stock may become explosive, especially if contaminated with traces of metal.	Disposal: W1, Wspec Wspec: Add no more than 10 g to 1 litre of water and pour the suspension down a foul-water drain. If the sample has a low chlorine content, then more can be added.
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Activity	User	Control measures	Experimental points
Testing for chlorine	Y9	Wear eye protection. Make sure the room is well ventilated. Take care to avoid raising dust.	Use no more than 0.2 g of calcium chlorate(I) per test tube. Add about 2 cm ³ of 1 mol dm ⁻³ hydrochloric acid and test for chlorine with moist blue litmus paper. Avoid directly inhaling the gas. Once a colour change on the paper is observed, the mixture can be washed down a foul-water drain with plenty of water.
% available chlorine	Y11	Wear eye protection.	One method involves adding 2 g of potassium iodide to 50 cm ³ of 2 mol dm ⁻³ hydrochloric acid. Add 1 g of calcium chlorate(I) slowly, with stirring, to liberate iodine. Titrate 10 cm ³ portions against 0.1 mol dm ⁻³ sodium thiosulfate solution using starch as the indicator near the endpoint.
Large-scale preparation of chlorine	TT	Wear eye protection. Use a fume cupboard.	This procedure can be used as an alternative to adding concentrated hydrochloric acid to potassium manganate(VII). Drop 5 mol dm ⁻³ hydrochloric acid onto calcium chlorate(I) which has been covered with water or, better still, sodium chlorate(I) solution. This method has the advantage of being easily controlled. See <i>Hazcard</i> 89 for further details.

18 Calcium oxide; calcium and strontium hydroxide

Calcium oxide		Quicklime	CaO
Corrosive		<p>R34: Causes burns. R41: Risk of serious damage to eyes.</p> <p>Dangerous with: WATER. The reaction with water is vigorous and generates heat. Dust may be ejected and enter the eyes. Under some conditions, the rise in temperature is sufficient to ignite combustible material.</p> <p>WEL (mg m⁻³): 2 (LEL), 6 (STEL).</p>	
<p>Store: CS</p> <p>The solid reacts with carbon dioxide from the atmosphere. Once the container is opened, the substance deteriorates rapidly so that very old samples may not give expected results.</p>		<p>Disposal: W1, WSpec</p> <p>Wspec: Add the solid to 1 litre of water in small amounts. Wait until the reaction is finished before more is added. Now treat as calcium hydroxide waste.</p>	


Calcium hydroxide		Slaked lime	Ca(OH) ₂
Irritant		<p>R41: Risk of serious damage to eyes.</p> <p>WEL (mg m⁻³): 5 (LEL), 15 (STEL).</p>	
Strontium hydroxide-8-water		Hydrated strontium hydroxide	Sr(OH) ₂ ·8H ₂ O
Corrosive		<p>R34: Causes burns.</p>	
<p>Store: Gln</p> <p>The solid reacts with carbon dioxide from the atmosphere. Once the container is opened, the substance rapidly deteriorates so that very old samples may not give the expected results.</p>			Disposal: W1, W5


Emergencies: see standard procedures on *Hazard E*, BUT ALSO:



If dust or solution contaminates the eyes:	Flood the eye with gently-running tap water until a first aider arrives. Unless the solution is very dilute (eg, limewater), send the affected person to hospital and ensure that irrigation is continued during the journey.
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Activity	User	Control measures	Experimental points
Testing for carbon dioxide with limewater (blowing into limewater)	Y7	Wear eye protection.	Using guidance from the HSE, calcium hydroxide solution (limewater) does not require a hazard warning, even though it has a pH of 12.4. Blowing into the solution, however, has caused accidents. Students may blow too hard and splashes enter the eye. Students may suck rather than blow, ingesting the solution. Application of immediate remedial measures should quickly remedy the situation. There have been no reports of permanent damage to the health of students.
Preparation of calcium oxide from calcium carbonate	Y7	Wear goggles.	Direct a Bunsen-burner flame onto a marble chip for at least 10 minutes, making sure it glows (limelight) during the heating. Allow the heated 'chip' to cool to room temperature before testing it with water.
Reaction (slaking) of calcium oxide with water	Y7	Wear goggles.	Add the solid in small amounts at a time (< 5 g) to water. Never add water to the finely-divided solid but adding water to a large lump is permissible.
Making mortar and cement	Y7	Wear eye protection. Wear disposable nitrile gloves.	Warn pupils not to raise dust with calcium hydroxide and breathe it in. The mixture may become very messy and contaminate the hands which should be washed immediately after use. It is advisable to wear gloves and to emphasise that those in the building industry should also wear gloves to avoid dermatitis. A typical mortar mix is 1:2:8, cement, calcium hydroxide and sand but amounts can be varied. Disposal: W8.
Solubility of calcium hydroxide (solubility product)	Y12	Wear eye protection.	A saturated solution of calcium hydroxide can be filtered and titrated against 0.05 mol dm ⁻³ hydrochloric acid. The concentration of calcium hydroxide decreases as the temperature rises. Other Group 2 hydroxides, such as strontium hydroxide, can be investigated.
Preparation of limewater	TT	Wear eye protection.	Use 5 g calcium oxide or hydroxide to make 2 litres of limewater. If calcium oxide is used, slake it carefully with water as above before adding to the main volume of water. Limewater should always be tested before use by students. See <i>Recipe Card</i> 15. Label limewater IRRITANT.

19A Calcium and strontium salts (1)

Anhydrous calcium chloride		CaCl_2
Calcium chloride-6-water	Hydrated calcium chloride	$\text{CaCl}_2 \cdot 6\text{H}_2\text{O}$
Strontium chloride-6-water	Hydrated strontium chloride	$\text{SrCl}_2 \cdot 6\text{H}_2\text{O}$
Irritant		R36: Irritating to eyes. Solutions, prepared from calcium or strontium chloride-6-water, equal to or stronger than 1.0 mol dm^{-3} , should be labelled IRRITANT. Dangerous with: WATER; anhydrous calcium chloride can cause water to boil.
Store: Gln These compounds absorb water from the atmosphere.	Disposal: W1, W7 W7: Dissolve no more than 100 g in small amounts in 1 litre of water. Heat will be evolved. Pour the solution down a foul-water drain.	

Calcium fluoride		Blue John; fluorspar	CaF_2
Irritant		R20/22: Harmful by inhalation and if swallowed. R36/37/38: Irritating to eyes, respiratory system and skin. WEL (mg m^{-3}): 2.5 (LTEL), 7.5 (STEL) as fluoride. Dangerous with: CONCENTRATED ACIDS. Hydrogen fluoride (VERY TOXIC & CORROSIVE) is produced.	
Store: Gln	Disposal: W1, W2		







Calcium nitrate(V)-4-water		Ca(NO ₃) ₂ ·4H ₂ O
Strontium nitrate(V)-4-water		Sr(NO ₃) ₂ ·4H ₂ O
Oxidising Irritant	 	R8: Contact with combustible material may cause fire. R36: Irritating to eyes. Solutions equal to or stronger than 0.8 mol dm ⁻³ should be labelled IRRITANT.
Store: Ox These compounds absorb water from the atmosphere.		Disposal: W1, W7 W7: Dilute to 0.2 mol dm ⁻³ before pouring down a foul-water drain.

19A Calcium and strontium salts (1)

Model risk assessments

Activity	User	Control measures	Experimental points
Precipitation of calcium salts	Y7	Wear eye protection.	Use a 0.4 mol dm ⁻³ calcium chloride-6-water solution.
Flame test for calcium and strontium	Y7	Wear eye protection.	Use the hydrated chloride or a 2 mol dm ⁻³ solution of the chloride. The solid is placed on a clean nichrome wire with a small loop at the end. Alternatively, the wire or a wooden splint is dipped into the solutions.
Calcium chloride as a gas-drying agent and desiccant	Y7	Wear eye protection. Gloves should be worn if large amounts are used.	Use loosely-packed granules of the anhydrous salt in a U-tube or drying tube. Gases can also be dried by passing them through saturated calcium chloride solution. Calcium chloride should not be used for drying ammonia. Check that gases can flow through the solid, otherwise there will be a build up of pressure. Do not reuse the same solid to dry another gas.
Precipitation of calcium fluoride	Y7	Wear eye protection.	Use a 0.4 mol dm ⁻³ solution of sodium fluoride with a calcium salt and the precipitate forms slowly.
Using nitrate(V) solutions	Y7	Wear eye protection.	0.4 mol dm ⁻³ calcium or strontium nitrate(V) solutions are suitable for most reactions.
Heating hydrated calcium nitrate(V) and strontium nitrate(V)	Y9	Wear goggles. Consider the use of a mineral-wool plug to retain the solid in the test tube.	Use no more than 0.5 g per group. More solid may be heated if the procedure is carried out in a fume cupboard. The materials produced on heating calcium nitrate(V) are water, nitrogen dioxide and oxygen. With strontium nitrate(V), oxygen is released but further decomposition is only possible after prolonged heating. As the water boils off, there may be solids ejected out of the test tube.

19B Calcium and strontium salts (2)



Calcium chromate(VI)-2-water			<chem>CaCrO4.2H2O</chem>
Toxic		R45: May cause cancer. Category 2 carcinogen. R22: Harmful if swallowed. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. WEL (mg m⁻³): 0.05 (LTEL), 0.15 (STEL) as chromium.	
Dangerous for the environment			
Store: T Do not dry and store.		Disposal: W1, W7 W7: 1 g should be dissolved in 1 litre of water before pouring down a foul-water drain.	
Calcium dicarbide	Calcium carbide		<chem>CaC2</chem>
Highly flammable		R15: Contact with water liberates highly flammable gases. Dangerous with: WATER. Ethyne is produced.	
Store: FW If the solid is white (calcium hydroxide), then it is deteriorating. Examine tins of calcium dicarbide regularly for signs of rust.		Disposal: W1, Wspec Wspec: Add the solid to water in small amounts in a fume cupboard. Wait until the reaction is finished before more is added. Pour down a foul-water drain.	
Calcium phosphide			<chem>Ca3P2</chem>
Highly flammable Toxic Dangerous for the environment	  	R15/29: Contact with water liberates toxic, extremely flammable gases. R28: Very toxic if swallowed. R50: Very toxic to aquatic organisms. Dangerous with: WATER. Phosphine is liberated which ignites in air because of the diphosphine content.	
Store: FW		Disposal: W1, Wspec Wspec: Add the solid to water in small amounts in a fume cupboard. Wait until the reaction is finished before more is added. Pour down a foul-water drain.	
Calcium carbonate; chalk; limestone; marble chips; calcite; <chem>CaCO3</chem> Calcium sulfate(VI)-0.5-water; calcium sulfate; plaster of Paris; <chem>CaSO4.0.5H2O</chem> Calcium sulfate(VI)-2-water; hydrated calcium sulfate; gypsum; <chem>CaSO4.2H2O</chem>			Low hazard Store: Gln Disposal: W8

19B Calcium and strontium salts (2)

Model risk assessments



Activity	User	Control measures	Experimental points
Heating calcium carbonate	Y7	Wear goggles.	Decomposition takes place at the same temperature as the Bunsen-burner flame. The depth of limewater in the collection tube should be no more than 10 mm. Remove the collection tube immediately to avoid suck back of liquid during cooling.
Addition of dilute acid to calcium carbonate	Y7	Wear eye protection. Avoid powdered calcium carbonate which gives too vigorous a reaction.	Use marble chips with a dilute acid. If showing the presence of carbonates is all that is required, 0.4 mol dm ⁻³ hydrochloric acid should be used. 2 mol dm ⁻³ acid is used if carbon dioxide needs to be tested or collected. To illustrate rate of reaction with particle size, sieve out marble chips of different dimensions. Dilute sulfuric(VI) acid does not work well because the carbonate becomes coated with calcium sulfate(VI).
Making plaster casts	Y7	Wear eye protection. Use bench protection. Do not make casts of any parts of the human body.	Mixed plaster gives out heat. Encased body parts may become trapped and will then be burned which, in extreme cases, has resulted in amputations. See PS72. A ratio of 3:2 plaster of Paris : water by mass makes a suspension that will solidify in the hour. It will be very messy!
Precipitation of calcium chromate(VI)	Y9	Wear eye protection. Keep masses and volumes of materials as low as possible.	Use 0.1 mol dm ⁻³ solutions of potassium chromate(VI) and calcium nitrate(V). Attempts must not be made to isolate calcium chromate after it has been precipitated. Disposal: The compounds should be poured down a foul-water drain with plenty of water.
Small-scale preparation of ethyne	Y12	Wear eye protection.	Use 2 or 3 small pieces of calcium dicarbide in a test tube and add 2 to 3 drops of water at a time, collecting ethyne in a test tube over water. Large-scale preparations are not necessary.
Preparation of phosphine	TT	Wear goggles or a face shield. Use a fume cupboard.	Place a small lump of calcium phosphide in a small evaporating basin. Squirt a small amount of water from a wash bottle onto it. A vigorous reaction takes place and phosphine spontaneously bursts into flames, because of the presence of diphosphine. Phosphine is EXTREMELY FLAMMABLE & VERY TOXIC but is destroyed in the fire, forming phosphorus(V) oxide and water. Disposal: The solutions should be poured down a foul-water drain with plenty of water.

20 Carbon dioxide and disulfide

Carbon dioxide gas			CO ₂
Low hazard	-	It is an asphyxiant, lowering the oxygen content of the air. WEL (mg m⁻³): 9000 (LTEL), 27000 (STEL).	
Store: Cyl Cylinders should be placed in an upright position or in a trolley. The regulator should always be on the cylinder so it is kept ready for use. A cylinder will be heavy. Cylinders should not be kept ready for use in the same area as the flammables cupboard. See <i>Handbook</i> 9.9.		Disposal: Gas, W6 Empty cylinders should be refilled. If this is impossible, take them to the local recycling depot or W1.	
Carbon dioxide solid		Dry ice	CO ₂
Low hazard	-	Solid carbon dioxide can cause serious frostbite; always handle it with tongs or thermal gloves. It is an asphyxiant, lowering the oxygen content of the air. WEL (mg m⁻³): 9150 (LTEL), 27400 (STEL).	
Store: Solid carbon dioxide must be bought or made fresh. Large amounts can be stored for a few days in an insulated box which must not be sealed. The box should be placed in a large room.			Disposal: W6
Carbon disulfide			CS ₂
Highly flammable		R11: Highly flammable. R63: Possible risk of harm to the unborn child. Category 3 teratogen. R48/23: Toxic: danger of serious damage to health by prolonged exposure through inhalation. R62: Possible risk of impaired fertility. R36/38: Irritating to eyes and skin. Flash point: -30 °C. Dangerous with: RUST; it may ignite the vapour. ZINC and other powdered metals; violent reaction. PHOSPHORUS; the solution is highly dangerous. NITROGEN OXIDE; an explosion may occur. WEL (mg m⁻³): 32 (LTEL), 96 (STEL) (Sk).	
Toxic			
Store: FL		Disposal: W1, W6 W6: Use a fume cupboard with no sources of ignition.	

Activity	User	Control measures	Experimental points
Using Bunsen burners	Y7	Room must be ventilated.	If rooms are not ventilated while natural gas is being burnt in Bunsen burners, there is a rise in the concentration of carbon dioxide and carbon monoxide and a loss of oxygen.
Preparation of the gas	Y7	Wear eye protection.	For the action of dilute hydrochloric acid on excess calcium carbonate, use marble chips, not powdered calcium carbonate (which gives too vigorous a reaction). 42 cm^3 of 2 mol dm^{-3} hydrochloric acid is sufficient to produce 1 litre of gas. Kipp's apparatus could be used.
Fire extinguisher simulations	Y7	Wear eye protection (goggles if liquids are squirted).	Carbon dioxide is used (generated with 1 mol dm^{-3} ethanoic acid and sodium hydrogencarbonate).
Burning magnesium in carbon dioxide	Y9	Wear eye protection.	Pupils should shield their eyes from the bright magnesium flame.
Reaction of carbon dioxide with hot carbon	TT	The room should be well ventilated.	Start the flow of carbon dioxide before the silica tube is heated strongly. Carbon monoxide could explode if air were not flushed from the apparatus before the charcoal is heated. Collect gases over water in gas jars and apply a lighted splint to burn (and destroy) toxic carbon monoxide.
Using carbon disulfide	TT	Any procedure involving this chemical requires a special risk assessment. An application should be made to CLEAPSS.	
Preparation of dry ice	TT	Wear eye protection. Wear thermal gloves.	A special ('siphon') cylinder has to be used with the required attachment. Do not wear rubber gloves. See <i>Handbook</i> 11.2.
Making very cold liquids	TT	Wear eye protection. Wear thermal gloves. Use a fume cupboard.	Putting solid carbon dioxide in ethanol or propanone cools these liquids to -76°C . There must be no sources of ignition present in the fume cupboard. Add solid carbon dioxide to the liquid, using small pieces added one at a time.
Dry-ice demonstrations	TT	Wear eye protection. Wear thermal gloves. Ventilate the room.	Solid carbon dioxide must not be placed in a sealed container. Do not allow pupils to handle the solid. Dry ice can be added to hot water to see the water-vapour effect. Adding soap solution forms bubbles and foams. 1 g of solid dry ice will inflate a balloon to a diameter up to 10 cm. It can be added to universal indicator solution which produces colour changes, or to make a suitable kettle whistle!

21 Carbon monoxide and carbon



Carbon monoxide		CO
Extremely flammable		R12: Extremely flammable. R61: May cause harm to the unborn child. Category 1 teratogen. R23: Toxic by inhalation. R48/23: Toxic: danger of serious damage to health by prolonged exposure through inhalation. This gas has no taste or smell. 0.01% in air can cause headaches. It is the product of incomplete combustion of fuels in industrial heating boilers. Forms explosive mixtures with air above a 12% concentration. The gas is <i>not</i> absorbed by filters in recirculatory fume cupboards. Flash point: -191 °C. WEL (mg m⁻³): 35 (LTEL), 232 (STEL).
Toxic		
Store: Situ Cylinders should not be used. Small volumes can be made in situ.		Disposal: W6

Carbon	Activated carbon; charcoal: graphite; lamp black		C
Low hazard	-	Sometimes supplied as a very fine powder. Dangerous with: OXYGEN: Finely-divided carbon is a fire hazard. Used, hot carbon blocks can cause fires when stacked. WEL (mg m⁻³): 3.5 (LTEL), 7 (STEL). If dust is spilt in laboratories: Wear a dust mask (FFP1 grade) for a large spill. Sweep up slowly as much as possible, so as not raise airborne particles. Finally wash the area.	
Store: Gln	Disposal: W8		

Activity	User	Control measures	Experimental points
Reduction of metal oxides with carbon powder or blocks	Y7	Wear eye protection. Tie long hair back. The room should be well ventilated. After use, cool carbon blocks in air. Store in an air-tight metal container eg, a biscuit tin. Do not cool carbon blocks in cold water.	Metal oxides can be heated with powdered carbon in a crucible or bottle top. To stop re-oxidation, another bottle top can be placed on top and 'tied' together with nichrome wire. Blowpipe method: To reduce the amount blown into the air, mix the oxide with a little water to dampen it before placing the paste on the carbon block. Rubber tubing can be connected to the blowpipe. Alternatively, make a depression in a piece of soft wood with an old screwdriver and, using the blowpipe, char it before adding damp metal oxide. Wood blocks can be doused in water.
Decolourising charcoal	Y7	Wear eye protection.	Emphasise that only very small amounts are required to absorb dyes or indicators. It may need to be distributed by the supervisor.
Carbon monoxide test	Y9	Wear eye protection.	Ignite carbon monoxide with a lighted splint. It burns with a blue flame.
Distillation of coal	Y9	Wear eye protection. Wear disposable nitrile gloves. The room should be well ventilated.	Watch carefully those children with known breathing difficulties. Burn off the gases from this reaction. Be aware of suck back from the side-arm test tube once the heating stops. See <i>Handbook</i> 13.2 for more details and a diagram of the apparatus.
Preparation of carbon monoxide	Y12	Wear eye protection. Wear disposable nitrile gloves.	Drip 2 cm ³ of concentrated sulfuric(VI) acid onto 0.5 g sodium methanoate. Warm very gently. Larger volumes should be prepared by the teacher/technician using a ducted fume cupboard.
Reaction of carbon monoxide with blood	Y12	Wear eye protection. Wear disposable nitrile gloves. Use a ducted fume cupboard.	Prepare gas as above but adapt the method so that it may be passed through animal blood. Alternatively, adapt the procedure by using a syringe as in <i>School Science Review</i> , 54, 1972 p303. For hygiene and blood spills, consult <i>Handbook</i> 14.13.
Reduction using carbon monoxide	TT	Wear eye protection. Use safety screens. Use a ducted fume cupboard.	This involves a larger-scale preparation of the gas. Methanoic acid is dripped onto concentrated sulfuric(VI) acid. The heat evolved is enough to initiate the reaction. The gas is passed over heated lead(II) oxide and through limewater. Unreacted carbon monoxide can be passed to a working, ducted fume cupboard or through an open window. See <i>Handbook</i> 13.

22A Chlorine (See also 22B)

Cl₂(g)

Toxic		R23: Toxic by inhalation. R36/37/38: Irritating to eyes, respiratory system and skin. R50: Very toxic to aquatic organisms. WEL (mg m⁻³): 1.5 (STEL).
Dangerous for the environment		

The substance is dangerous with:	HYDROGEN. Attempts to explode mixtures of chlorine and hydrogen are very hazardous because many are initiated prematurely by sunlight or light from fluorescent tubes. ETHOXYETHANE (ether) and other organic liquids. These can ignite on contact. AMMONIA, AMMONIUM COMPOUNDS. Explosive nitrogen trichloride may be formed. ALUMINIUM, MAGNESIUM, IRON FILINGS, MERCURY. These metals (and many others) may ignite.
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Emergencies: see standard procedures on *Hazard E*, BUT ALSO:

If released in the laboratory:	Evacuate the laboratory if over 1 litre of gas is released. Open a few outside windows, shut off all services and leave with all doors and internal windows closed. Keep watch on pupils with known breathing problems, eg, asthma.
If chemical is inhaled:	Medical attention may be needed, even if there are no initial symptoms. Inhalation of chlorine by pupils or staff with known breathing difficulties such as asthma may exacerbate these pre-existing conditions. Effects of exposure can be delayed for several hours.

Store: Situ Large cylinders should not be used in schools and colleges because school fume cupboards cannot cope with a large release of chlorine. Small volumes should be made as and when required.	Disposal: W6
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22A Chlorine

Model risk assessments

Inhalation of chlorine by pupils or staff with known breathing difficulties such as asthma may exacerbate these pre-existing conditions. Effects of exposure can be delayed for several hours.

Activity	User	Control measures	Experimental points
Test-tube preparation	Y9	Wear eye protection. Use a fume cupboard. Be aware of any asthmatics.	Use 1 cm ³ of sodium chlorate(I) solution [5% (w/v) available chlorine] with 0.5 mol dm ⁻³ hydrochloric acid. Adding the reaction mixture to sodium carbonate solution will quench the reaction. See also <i>Hazard</i> 60 for alternative procedures.
Bleaching action	Y9	Wear eye protection. There must be good ventilation. Be aware of any asthmatics.	Moist blue litmus turns red and is then bleached. Flowers and coloured cloth can also be bleached. Electrolysis of dilute sodium chloride solutions produces enough chlorine to detect with moist blue litmus paper.
Large-scale preparation	Y12	Wear goggles. Use a fume cupboard. Be aware of any asthmatics.	For the safest method, see <i>Hazard</i> 89 and <i>Handbook</i> 13.3. See also <i>Hazard</i> 47A for an alternative procedure.
Reaction with hydrogen	TT	Wear goggles. Use a fume cupboard. Asthmatics should take care.	Hydrogen may be burned in a gas jar of chlorine in a fume cupboard if proper precautions are taken in lighting the hydrogen jet in air first (attach jet to flexible tubing). Experiments where the gases are pre-mixed and initiated by light are usually considered unsafe because accidents have occurred despite all precautions. However, a version in <i>Classical Chemical Demonstrations</i> has so far not caused problems.
Burning metals in chlorine	TT	Wear goggles. Use a fume cupboard. Asthmatics should take care.	Reactions are very exothermic. The usual method is to heat sodium or magnesium metal (avoid powders) on a deflagrating spoon and plunge it into a gas jar of chlorine. Unfortunately, the iron in the spoon reacts as well giving brown fumes of iron(III) chloride. See L195, <i>Safer Chemicals</i> , <i>Safer Procedures</i> for an alternative method for sodium which produces 'white' sodium chloride. A leaf of Dutch metal (copper/zinc alloy) needs no such heating. Disposal: When cool and in the fume cupboard, add water to the gas jars. Take care with sodium, because all of it may not have reacted with the chlorine. See <i>Handbook</i> 13.4 for other metals.
Using small cylinders	TT	Any procedure involving small cylinder (lecture bottles) requires a special risk assessment. An application should be made to CLEAPSS.	

For emergencies, see *Hazard* E as well as more detailed information which may be on this *Hazard*.

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22B Chlorine water (See also 22A)

Cl₂(aq)

Low hazard	-	Saturated chlorine water is about 0.08 mol dm ⁻³ (ie, a 0.6% (w/v) solution). The solution itself is LOW HAZARD but chlorine gas escapes so a HARMFUL label would be prudent. Super-saturated solutions are possible when even more gas escapes.
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Emergencies: see standard procedures on *Hazard E*, BUT ALSO:

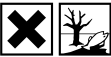
If spilt in the laboratory:	Open a few outside windows, shut off all services and leave with all doors and internal windows closed. Keep watch on pupils with known breathing problems, eg, asthma. Do not enter the room for 1 hour. Even then, enter cautiously. Do not put yourself at risk.
If chemical is inhaled:	Inhaling the gas above chlorine water can produce distress. Medical attention may be needed even if there are no initial symptoms. Inhalation of chlorine by pupils or staff with known breathing difficulties such as asthma may exacerbate these pre-existing conditions. Effects of exposure can be delayed for some hours.

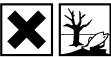
Store: Gln The solution does not keep more than a few days.	Disposal: W7 W7: Pour the solution down a foul-water drain with more water.
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Inhalation of chlorine by pupils or staff with known breathing difficulties such as asthma may exacerbate these pre-existing conditions. Effects of exposure can be delayed for several hours.


Activity	User	Control measures	Experimental points
Use of chlorine water	Y7	Wear eye protection. The room must be well ventilated. Be aware of any asthmatics.	A 0.04 mol dm^{-3} solution [ie, a saturated solution diluted by half - about 0.3% (w/v) solution] can be added to solutions of bromides, iodides and iron(II) compounds.
Bleaching action	Y9	Wear eye protection. The room must be well ventilated. Be aware of any asthmatics.	Blue litmus and most other dyes are bleached. Flowers and coloured cloth can also be bleached in the solution.
Preparation of chlorine water	TT	Wear eye protection. Use a fume cupboard. Asthmatics should take care.	See <i>Recipe Card 28</i> . A further method is to use tablets of sodium dichloroisocyanurate (OXIDISING; HARMFUL), used as water purifiers. To make a 0.5% chlorine solution, add 3 g of the salt to 100 cm^3 of water. When the solution is clear, add 100 cm^3 of 1 mol dm^{-3} hydrochloric acid.

23 Chlorobenzene and related compounds

Chlorobenzene		Phenyl chloride	C_6H_5Cl
Harmful Dangerous for the environment		R10: Flammable. R20: Harmful by inhalation. R51/53: Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. WEL (mg m⁻³): 23 (LTEL), 70 (STEL). Flash point: 23 °C.	
Store: FL			Disposal: W1, W2

Bromobenzene		Phenyl bromide	C_6H_5Br
Irritant Dangerous for the environment		R10: Flammable. R38: Irritating to skin. R51/53: Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. Flash point: 51 °C.	
Store: FL If there is not enough room in the flammables cabinet, this chemical can be stored with GOrg.			Disposal: W1, W2



1,2-dichlorobenzene		o-dichlorobenzene	$C_6H_4Cl_2$
Harmful Dangerous for the environment		R22: Harmful if swallowed. R36/37/38: Irritating to eyes, respiratory system and skin. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. WEL (mg m⁻³): 153 (LTEL), 306 (STEL). Flash point: 67 °C.	
Store: GOrg			Disposal: W1, W2



1,4-dichlorobenzene		p-dichlorobenzene	$C_6H_4Cl_2$
Harmful Dangerous for the environment		R40: Limited evidence of a carcinogenic effect. Category 3 carcinogen. R36: Irritating to eyes. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. WEL (mg m⁻³): 153 (LTEL), 306 (STEL).	
Store: GOrg			Disposal: W1, W2




Activity	User	Control measures	Experimental points
Cooling curves	Y7	Wear eye protection.	Use 1,4-dichlorobenzene (MPt: 53 °C). The substance provides an excellent example of a cooling curve. Use a boiling tube plugged with mineral wool to stop the vapour escaping. See L195, <i>Safer Chemicals, Safer Reactions</i> . Disposal: W3
Hydrolysis of organo-halogen compounds	Y12	Wear eye protection.	Suitable for use in 1 cm ³ amounts. These must be heated in a boiling water bath. See also <i>Hazcards</i> 44A and B. Disposal: W7 (With these small volumes, use lots of detergent to ensure emulsification before pouring down a foul-water drain.)
Organisms; extraction from soil	Y12	Wear eye protection. Wear chemical-resistant gloves.	1,2-dichlorobenzene is occasionally used. Dilute ethanal solution is an alternative for raising leatherjackets. (Worms can be brought to the surface using a solution of English mustard; see <i>Hazard</i> 63.)
Pre-treatment of root tips to arrest chromosomes at metaphase	Y12	Wear eye protection. Wear chemical-resistant gloves.	Use 1,4-dichlorobenzene as an alternative to colchicine. Shake 5 g of 1,4-dichlorobenzene with 500 cm ³ distilled water at 60 °C in a fume cupboard. Leave for several hours at about 60 °C (eg, in a water bath) and filter the solution. Cool and soak root tips for 4 - 6 hours in an aerated solution. Rinse the root tips before handling them.
Grignard reagents	Y12	Wear eye protection.	Careful preparation is required. Bromobenzene and ethoxyethane must be dried overnight with anhydrous calcium chloride. Flasks must be dried in an oven before the investigation. All flames must be extinguished. Reflux equipment must have a guard containing anhydrous calcium chloride.

24 Chromium and its compounds

For dichromates & chromates, see *Hazardcard 78*.

Chromium(III) chloride-6-water		$\text{CrCl}_3 \cdot 6\text{H}_2\text{O}$
Harmful		R22: Harmful if swallowed. R36/38: Irritating to eyes and skin. Solutions equal to or stronger than 1 mol dm^{-3} should be labelled HARMFUL. WEL (mg m^{-3}): 0.5 (LTEL), 1.5 (STEL) as chromium.
Chromium(III) potassium sulfate(VI)-12-water		$\text{CrK}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$
Irritant		R36/38: Irritating to eyes and skin. All solutions are LOW HAZARD. WEL (mg m^{-3}): 0.5 (LTEL), 1.5 (STEL) as chromium.
Store: Gln They absorb water from the atmosphere.		Disposal: W1, W7 (Dilute to less than 0.2 mol dm^{-3} .)






Chromium(III) nitrate(V)-9-water		$\text{Cr}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$
Oxidising Irritant	 	R8: Contact with combustible material may cause fire. R36/38: Irritating to eyes and skin. Solutions equal to or stronger than 0.5 mol dm^{-3} should be labelled IRRITANT. WEL (mg m^{-3}): 0.5 (LTEL), 1.5 (STEL) as chromium.
Store: Ox It absorbs water from the atmosphere.		Disposal: W1, W7 (Dilute to less than 0.1 mol dm^{-3} .)

Chromium(VI) oxide	Chromium trioxide		CrO_3
Oxidising		R9: Explosive when mixed with combustible material. R45: May cause cancer. Category 1 carcinogen. R46: May cause heritable genetic damage. Category 2 mutagen. R62: Possible risk of impaired fertility. Category 3 teratogen. R26: Very toxic by inhalation. R24/25: Toxic in contact with skin and if swallowed. R48/23: Toxic: danger of serious damage to health by prolonged exposure through inhalation. R35: Causes severe burns. R42/43: May cause sensitisation by inhalation and skin contact. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. Dangerous with: ALL ORGANIC COMPOUNDS. Violent reactions can occur. WEL (mg m^{-3}): 0.05 (LTEL), 0.15 (STEL) as chromium.	
Very toxic			
Dangerous for the environment			
Store: CS		Disposal: W1	

Chromium metal; Cr Chromium(III) oxide; Cr_2O_3	Low hazard	Store: Gln	Disposal: W8
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Activity	User	Control measures	Experimental points
Growing chrome alum crystals	Y7	Wear eye protection.	A saturated solution (22 g in 100 cm ³ of water) may irritate the skin; its pH is less than 7. Do not warm the solution to speed up dissolving.
Using chromium(III) salts	Y9	Wear eye protection.	The colours of the solutions vary according to the ligands attached. The violet $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$ ion in solution changes colour on warming. The hydroxide of chromium dissolves in excess sodium hydroxide solution.
Chromium metal reactions	Y9	Wear eye protection.	Chromium metal will react slowly with both 2 mol dm ⁻³ hydrochloric acid and 1 mol dm ⁻³ sulfuric(VI) acid.
Chromium(II) salt preparation	Y12	Wear eye protection.	Chromium(II) salts are unstable in water and air, being oxidised to chromium(III). Only chromium(II) ethanoate is stable for some hours.
Preparation of chromium complexes	Y12	Wear eye protection. Use a fume cupboard if appropriate. Wear gloves if appropriate.	The hazards of individual complexes are not well known. Control measures will depend upon the nature of the ligand. There is no reason why these investigations should not be carried out on a small scale by responsible students.
Using Gatenby's fluid	Y12	Wear eye protection. Wear chemical-resistant gloves. Solution prepared by teacher or technician before use.	A possibly safer alternative is Smith's fixative. Solution A: 1% potassium chromate(VI). Solution B: 200 cm ³ 40% methanal and 50 cm ³ glacial ethanoic acid in 1 litre distilled water. Mix equal volumes of A and B just before use.
Staining tissues for suberin, cutin and cellulose	Y12	Avoid use of stains with chromium(VI) oxide. Use Schulze's solution (chlor-zinc-iodine), Sudan black or Sudan III. Solution should be prepared by the teacher or technician before use.	Schulze's solution stains cellulose, suberin and cutin yellow-brown. See <i>Recipe card 12</i> for details. Sudan black stains all fatty tissue including suberin and cutin. Use a saturated solution in 70% ethanol. Sudan III is good for root endodermis. Use a saturated solution in 50 parts propanone, 3 parts ethanol and 1 part water.
Using fixatives	-	Avoid use.	Applies to chrom-acetic fixative and Navashin's fluid.
Using 'chromic acid' for cleaning glassware	-	Avoid use.	Proprietary detergents are just as effective and far safer.






25 Cobalt and its compounds

Cobalt		Co
Harmful		R42/43: May cause sensitisation by inhalation or skin contact. R53: may cause long-term effects in the aquatic environment. WEL (mg m⁻³): 0.1 (LTEL), 0.3 (STEL).
Store: Gln	Disposal:	W1
Cobalt(II) chloride-6-water		Hydrated cobalt chloride
		CoCl ₂ ·6H ₂ O
Toxic		R49: May cause cancer by inhalation. Category 2 carcinogen by inhalation. (This risk is, however, minimal because the substance is not inhaled in normal school use.) R22: Harmful if swallowed. R42/43: May cause sensitisation by inhalation and skin contact. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. Those who have a known sensitisation to metals should not handle the material directly. Solid or solutions equal to or stronger than 0.15 mol dm ⁻³ may cause sensitisation by inhalation or skin contact. All solutions equal to or stronger than 0.0015 mol dm ⁻³ should be labelled TOXIC. Solutions less than 0.0015 mol dm ⁻³ are LOW HAZARD. WEL (mg m⁻³): 0.1 (LTEL), 0.3 (STEL).
Dangerous for the environment		
Store: T	Disposal:	W1, W7 W7: Dilute the solution to less than 0.004 mol dm ⁻³ before pouring down a foul-water drain.
Cobalt(II) thiocyanate (hydrated)		Co(SCN) ₂ ·xH ₂ O
Harmful		R43: May cause sensitisation by skin contact. R68: Possible risk of irreversible effects. WEL (mg m⁻³): 0.1 (LTEL), 0.3 (STEL). Solutions equal to or stronger than 0.004 mol dm ⁻³ should be labelled HARMFUL.
Store: Gln	Disposal:	W1, W7 W7: Dilute the solution to less than 0.04 mol dm ⁻³ before pouring down a foul-water drain.
Cobalt(II) carbonate		CoCO ₃
Harmful		R40: Limited evidence of a carcinogenic effect. Category 3 carcinogen. R43: May cause sensitisation by skin contact. WEL (mg m⁻³): 0.1 (LTEL), 0.3 (STEL).
Store: Gln	Disposal:	W1

For emergencies, see *Hazard* E as well as more detailed information which may be on this *Hazard*.




Activity	User	Control measures	Experimental points
Silica gel containing traces of cobalt chloride.	Y7	Wear eye protection. Those with known skin allergies should wear gloves.	There is no reason to stop using self-indicating silica gel. The risk of inhaling any cobalt ions is extremely low. The concentration of cobalt ions is less than 0.5% by mass.
Testing for water and humidity	Y7	Wear eye protection. Pupils with known skin allergies should wear disposable nitrile gloves. Papers should not be placed on the face. Wash the hands after handling the papers.	Handle cobalt chloride papers as little as possible. The papers may be placed on the skin if necessary but pupils should be made to wash the area tested on completion of the activity. As soon as a colour change has been observed, the paper must be removed from the skin. A 0.1 mol dm^{-3} solution can be used to prepare the paper which, after drying in an oven, must be kept in a desiccator with dry silica gel. Cobalt thiocyanate appears to be less hazardous to use. However, its toxicological properties are less well defined.
Use of invisible ink	Y7	Wear eye protection. Pupils with known skin allergies should wear disposable nitrile gloves.	Use 0.01 mol dm^{-3} cobalt chloride solution. The 'letter' is better dried in an oven or drying cabinet. The use of a Bunsen-burner flame may be quicker but the paper catches fire.
Reactions of cobalt(II) ions	Y7	Wear eye protection.	Use a 0.1 mol dm^{-3} solution.
Catalyst for the hydrogen peroxide/tartrate reaction	Y9	Wear eye protection. Use a 400 cm^3 beaker for the amounts quoted to cope with the froth.	Dissolve 2 g of potassium sodium tartrate (LOW HAZARD) in 50 cm^3 of water at 80°C . Add 10 cm^3 of 20 'vol' hydrogen peroxide solution. Add a few crystals of cobalt(II) chloride-2-water. The reaction turns green and then back to mauve.
Heating cobalt carbonate	Y9	Wear eye protection. Pupils with known skin allergies should wear-nitrile gloves.	Use a mineral wool plug in the mouth of the test tube to stop cobalt(II) oxide escaping.
Preparation of cobalt complexes	Y12	Wear eye protection.	The particular hazards of individual complexes are not well known. If sensible precautions are followed such as the wearing of gloves and use of fume cupboards when using toxic or corrosive ligands (eg, concentrated ammonia solution), then there is no reason why these investigations should not be carried out on a small scale by responsible students.



26 Copper metal, copper oxides, carbonate and sulfide

Copper(I) oxide		Cuprous oxide	Cu ₂ O
Harmful		R22: Harmful if swallowed. R50: Very toxic to aquatic organisms. R53: May cause long-term adverse effects in the aquatic environment. Dangerous with: ALUMINIUM, MAGNESIUM: Explosive mixtures are formed.	
Dangerous for the environment			
Store: Gln		Disposal: W1, W5 W5: React no more than 24 g in 1 litre of warm 1 mol dm ⁻³ ethanoic acid before pouring the solution and the fine copper precipitate down a foul-water drain. This disposal procedure should be kept to a minimum.	
Copper(II) oxide		Cupric oxide	CuO
Harmful		R22: Harmful if swallowed. R50: Very toxic to aquatic organisms. R53: May cause long-term adverse effects in the aquatic environment. Dangerous with: ALUMINIUM, MAGNESIUM: Explosive mixtures are formed.	
Dangerous for the environment			
Store: Gln		Disposal: W1, W5 W5: React no more than 24 g in 1 litre of warm 1 mol dm ⁻³ ethanoic acid before pouring down a foul-water drain. This procedure should be kept to a minimum.	
Copper(II) carbonate hydroxide		Basic copper carbonate; cupric carbonate; malachite	CuCO ₃ .Cu(OH) ₂
Harmful		R22: Harmful if swallowed.	
Store: Gln		Disposal: W1, W5 W5: React no more than 60 g in 1 litre of warm 1 mol dm ⁻³ ethanoic acid before pouring down a foul-water drain. This procedure should be kept to a minimum.	
Copper metal; Cu Copper(II) sulfide; copper pyrites; CuS		Low hazard	Store: Gln Disposal: W2, W8

Activity	User	Control measures	Experimental points
Heating carbonate or sulfide ores	Y7	Wear eye protection. Avoid raising dust if using powders.	Rocks can spit when heated, so use small amounts, eg, 1 cm ³ in volume. Copper pyrites will produce sulfur dioxide (TOXIC) when heated.
Copper(I) oxide preparation	Y7	Wear eye protection.	Hot Benedict's solution reacts with glucose to form the red precipitate of copper(I) oxide. Avoid Fehling's solution which is more hazardous.
Reduction of the oxide(II) using carbon (crucible)	Y9	Wear eye protection. Ventilate the room well.	To observe copper, lift the hot crucible with suitable tongs and pour the contents into cold water; grains of copper will be seen. A bottle-top, with the plastic insert removed, can be used instead of a crucible and, when hot, this can be dropped directly into cold water.
Reduction of the oxide(II) using carbon (blow-pipe)	Y9	Wear eye protection. Ventilate the room well. Tie back long hair.	To reduce the amount of copper(II) oxide blown into the air, mix it with a little water and place the paste on the carbon block. Rubber tubing can be connected to the blowpipe; this keeps the face away from the flame. Disinfect rubber tubing in sodium chlorate(I) (<i>Milton</i>) after use. See <i>Hazard</i> 21.
Reduction of the oxide(II) using methane	Y9	Wear eye protection. Tie back long hair. Teacher should supervise the lighting of methane from the combustion tube.	Methane is passed over hot copper(II) oxide. The gas should not be lit until 10 seconds have passed once the natural gas has been turned on, to allow all the air to be flushed out. When the reaction is complete, keep the gas passing through the apparatus until the reaction vessel has reached room temperature. The flame burning at the exit of the combustion tube should be about 5 cm high. See <i>Handbook</i> 13.3.
Reduction of the oxide(II) with zinc powder	Y9	Wear eye protection.	Mix no more than 1 g of zinc powder with 1 g of copper(II) oxide on heat-resistant paper (see L195, <i>Safer Chemicals, Safer Procedures</i>) or on a prepared bottle top (remove the plastic insert).
Reduction of the oxide(II) using hydrogen	TT	Wear goggles or a face shield. Use safety screens.	Large-scale demonstrations have been known to explode. There is a small-scale version in Guide L195, <i>Safer Chemicals, Safer Reactions</i> and a commercial kit available. See <i>Hazard</i> 48.
Reduction of the oxide(II) using magnesium	TT	Wear goggles or a face shield. Use safety screens. Do not go back to a seemingly-failed reaction.	See <i>Handbook</i> 13.4. There can be a considerable delay before the violent reaction takes place. If the reaction fails to ignite; turn the gas off using the emergency switch or isolation valve.

27A Copper salts: chlorides and iodide








Copper(I) chloride		Cuprous chloride	CuCl
Harmful		R22: Harmful if swallowed. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.	
Dangerous for the environment			
Copper(I) iodide		Cuprous iodide	CuI
Dangerous for the environment		R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.	
Store: Gln When exposed to air, the top layer oxidises and the colour of the solid turns blue.		Disposal: W1	

Copper(II) chloride-2-water		Hydrated cupric chloride	CuCl ₂ ·2H ₂ O
Harmful		R22: Harmful if swallowed. R36/38: Irritating to eyes and skin. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. Some suppliers label this compound TOXIC. Solutions equal to or stronger than 1.4 mol dm ⁻³ should be labelled HARMFUL. Dangerous with: If heated strongly, brown anhydrous copper(II) chloride decomposes to copper(I) chloride and chlorine (a toxic gas).	
Dangerous for the environment			
Store: Gln		Disposal: W7 or Wspec Wspec: Dilute to less than 0.5 mol dm ⁻³ . This disposal procedure should be kept to a minimum.	

27A Copper salts: chlorides and iodide**Model risk assessments**

Activity	User	Control measures	Experimental points
General use	Y7	Wear eye protection.	Use solutions with concentrations less than 1.4 mol dm^{-3} .
Electrolysis of copper(II) chloride solution	Y9	Wear eye protection. The room should be ventilated.	The amount of chlorine produced should not cause a risk to health. Adjust the current to less than 0.5 A and stop the activity once the presence of chlorine has been confirmed, eg, by bleaching moist blue litmus paper. Pupils should not be encouraged to inhale the gases directly. Pupils or staff with asthma should take particular care. If there is no copper chloride available, add together equal volumes of 0.2 mol dm^{-3} barium chloride and copper sulfate(VI), boil to coagulate the precipitate and leave for several hours. Decant the copper(II) chloride solution. See <i>Hazard</i> 22A.
Preparation of copper(I) iodide	Y9	Wear eye protection.	Add 1 cm^3 of 0.1 mol dm^{-3} copper(II) sulfate(VI) solution to 1 cm^3 of 1 mol dm^{-3} potassium iodide solution. Iodine is produced. Add 0.1 mol dm^{-3} sodium thiosulfate solution dropwise until the solution is pale yellow. Add 1 drop of starch solution. Continue adding the sodium thiosulfate solution until the blue colour is removed. Filter off the solid.
Heating anhydrous copper(II) chloride	Y12	Wear eye protection. Use a fume cupboard.	Chlorine is produced. This can be a good method of producing small volumes of dry chlorine. Copper(II) chloride first needs to be gently warmed in an evaporating basin to remove water. Anhydrous copper(II) chloride is brown.
Preparation of copper(I) chloride	Y12	Wear eye protection. Use a fume cupboard.	Place about 1.5 g of copper turnings and 1 g of copper(II) chloride-2-water in a boiling tube and then add to the mixture about 4 cm^3 of concentrated hydrochloric acid (CORROSIVE). Heat the boiling tube in a beaker of boiling water for about 10 minutes and pour the mixture into about 75 cm^3 of cold distilled water in a small beaker. Filter the precipitate of copper(I) chloride.
Preparation of copper complexes	Y12	Wear eye protection.	The particular hazards of individual complexes are not well known. If sensible precautions are followed, such as the wearing of gloves and use of fume cupboards when using toxic or corrosive ligands (eg, concentrated ammonia solution), then there is no reason why these investigations should not be carried out on a small scale by responsible students.



27B Copper salts: chromate(VI), ethanoate and nitrate(V)



Copper(II) chromate(VI)		Cupric chromate	$\text{CuCrO}_4 \cdot x\text{H}_2\text{O}$
Oxidising Toxic Corrosive Dangerous for the environment	   	R8: Contact with combustible material may cause fire. R49: May cause cancer by inhalation. Category 2 carcinogen. R25: Toxic if swallowed. R35: Causes severe burns. R43: May cause sensitisation by skin contact. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. WEL (mg m^{-3}): 0.05 (LTEL), 0.15 (STEL) as chromium. Use only for the migration of ions demonstration.	
Store: Situ Prepare only what is needed and keep it damp.		Disposal: W1, W2	
Copper(II) ethanoate-1-water		Hydrated copper acetate; hydrated cupric acetate; verdigris	$\text{Cu}(\text{CH}_3\text{COO})_2 \cdot \text{H}_2\text{O}$
Harmful		R22: Harmful if swallowed. R41: Risk of serious damage to eyes. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. All <i>solutions</i> are low hazard.	
Dangerous for the environment			
Store: Gln		Disposal: W1, W7 W7: Dilute to less than 0.3 mol dm^{-3} or dissolve 60 g in 1 litre of water. This disposal procedure should be kept to a minimum.	
Copper(II) nitrate(V)-3-water		Hydrated cupric nitrate	$\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$
Harmful		R22: Harmful if swallowed. R36/38: Irritating to eyes and skin. Solutions equal to or stronger than 1 mol dm^{-3} should be labelled HARMFUL.	
Store: Gln The substance absorbs water from the atmosphere.		Disposal: W1, W7 W7: Dilute to less than 0.4 mol dm^{-3} or dissolve 90 g in 1 litre of water. This disposal procedure should be kept to a minimum.	

27B Copper salts: chromate(VI), ethanoate and nitrate(V)**Model risk assessments**

Activity	User	Control measures	Experimental points
General use of copper(II) nitrate(V) and ethanoate	Y7	-	The solubility of copper(II) ethanoate is 8 g per 100 cm ³ of solution at room temperature. The tiny crystals are quite attractive. 0.1 mol dm ⁻³ solutions are suitable for most purposes.
Preparing copper ethanoate	Y9	Wear eye protection.	Add 1 g portions of copper carbonate (an excess) to 15 cm ³ of 1 mol dm ⁻³ ethanoic acid in a hot water bath. Filter before leaving the solution to evaporate. Do not heat to dryness.
Heating copper(II) nitrate(V)	Y9	Wear eye protection. Do not inhale the gas.	Nitrogen dioxide is formed. For 15 groups performing this activity in the open laboratory, use 0.3 g of hydrated copper nitrate(V) per group. A fume cupboard should be used for larger amounts.
Movement of copper and chromate(VI) ions (small-scale)	TT	Wear goggles or a face shield. Wear chemical-resistant gloves.	Mix equal volumes of 1 mol dm ⁻³ solutions of copper(II) sulfate(VI) and potassium chromate(VI). Using a pipette, place a little of the slurry on filter paper which has been dampened with sodium chloride solution and wrapped around a microscope slide. Crocodile clips, connected to a DC source are placed at either end of the slide. After some minutes blue and yellow colours will separate from the spot, demonstrating the attraction of the ions towards the electrodes.
Movement of copper and chromate(VI) ions (large-scale)	TT	Wear goggles or a face shield. Wear chemical-resistant gloves.	Mix 100 cm ³ of 1 mol dm ⁻³ copper(II) sulfate(VI) solution and 1 mol dm ⁻³ potassium chromate(VI) solution. Filter and wash the precipitate with distilled water. Dissolve it in a minimum quantity of 2 mol dm ⁻³ hydrochloric acid and then dissolve as much carbamide (urea) as possible, to increase its density. Fill one third of a wide U-tube with 2 mol dm ⁻³ hydrochloric acid and run the copper(II) chromate solution very slowly into the bottom of the U-tube with a pipette to form a lower layer. Place carbon electrodes into the acid layers and electrolyse using a 20 V DC source. The blue aqueous copper ions should migrate to the cathode and the yellow chromate ions migrate to the anode.

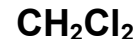
27C Copper salts: sulfates(VI)

Copper(II) sulfate(VI)		Anhydrous copper sulfate	CuSO ₄
Harmful		R22: Harmful if swallowed. R36/38: Irritating to eyes and skin. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. Dangerous with: WATER: much heat is produced.	
Dangerous for the environment			
Store: Gln May turn blue as it absorbs water from the atmosphere. Dry in a hot oven.		Disposal: W7 W7: Dissolve 64 g in 1 litre of water before pouring the solution down a foul-water drain. This disposal procedure should be kept to a minimum.	


Copper(II) sulfate(VI)-5-water		Hydrated copper sulfate	CuSO ₄ .5H ₂ O
Harmful		R22: Harmful if swallowed. R36/38: Irritating to eyes and skin. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. Solutions equal to or stronger than 1 mol dm ⁻³ should be labelled HARMFUL.	
Dangerous for the environment			
Store: Gln		Disposal: W3, W7 W3: Crystals made by students can be used for solutions. W7: Dilute to less than 0.4 mol dm ⁻³ or dissolve 100 g in 1 litre of water before pouring the solution down a foul-water drain. This disposal procedure should be kept to a minimum.	

Activity	User	Control measures	Experimental points
General use	Y7	-	Use solutions less than 1 mol dm^{-3} if suitable. For precipitation reactions, 0.1 mol dm^{-3} is suitable.
Crystal growing	Y7	Wear eye protection. Pupils should not take crystals home.	It is dangerous for young children to drink this brightly-coloured liquid. Other suitable salts for making crystals are aluminium potassium sulfate(VI)-12-water, sodium chloride, sodium potassium tartrate, magnesium sulfate(VI)-5-water and iron(II) sulfate(VI)-7-water. Disposal: W3.
Heating hydrated copper(II) sulfate(VI)	Y7	Wear eye protection.	Use no more than 5 g in a test tube. Stop heating when a red colouration develops in the white residue. Further decomposition produces sulfur trioxide (CORROSIVE). If water is collected, beware of suck back. If not enough water is added to the cold residue, heat is evolved which may cause the test tube to crack. See <i>Handbook</i> 13.4.
Copper(II) sulfate(VI) preparation	Y7	Wear eye protection. Take care with hot equipment. Pupils should not take any crystals home. If copper(II) oxide is used, the solution must be heated to ensure the reaction is complete. To avoid the need for heating, copper(II) carbonate may be substituted for copper(II) oxide.	Excess copper(II) oxide is added to dilute sulfuric(VI) acid which must be heated. This can be done in a boiling tube placed in a boiling water bath. Keep the volume of acid as low as practically possible, eg, 15 cm^3 . The use of 1.2 to 1.4 mol dm^{-3} sulfuric(VI) acid (IRRITANT), rather than 1 mol dm^{-3} acid, produces a near-saturated solution of copper(II) sulfate(VI). Crystals may even appear during the lesson. If white fumes of sulfur trioxide (CORROSIVE) are seen during heating, stop the process immediately. Copper(II) sulfate(VI) solutions must never be heated to dryness because decomposition produces white fumes. See <i>Handbook</i> 13.4.
Benedict's solution	Y7	Wear eye protection.	See <i>Recipe Card</i> 8 for details of the preparation. It is used as a test for reducing sugars. This solution does not work well with aldehydes.
Sandell's solution	Y7	Wear eye protection.	Mix 400 cm^3 of 0.8 mol dm^{-3} sodium hydroxide solution (CORROSIVE) with 400 cm^3 of 0.03 mol dm^{-3} copper(II) sulfate(VI) solution. Add 11.2 g of EDTA (sodium salt) and stir well. The solution does keep and should be labelled IRRITANT. It can be used in place of Fehling's solution.
Fehling's solution	Y9	Wear goggles.	See <i>Recipe Card</i> 25 for details of the preparation. If testing for reducing sugars, use Benedict's solution.

28 Dichloromethane






Also known as methylene dichloride.




Harmful	 <p>R40: Limited evidence of a carcinogenic effect. Category 3 carcinogen. WEL (mg m⁻³): 350 (LTEL), 1060 (STEL). The HSE is reviewing this substance. It can be absorbed through the skin. It decreases the skin which can lead to secondary inflammation. Inhalation and ingestion may cause respiratory tract irritation and central nervous system depression characterised by headache, nausea, vomiting, dizziness and drowsiness. Repeated exposure may cause liver damage. It is present in paint strippers.</p>
The substance is dangerous with:	AIR, METHANOL. It becomes flammable in air if heated above room temperature. If methanol is present, the mixture is flammable at room temperature. ALUMINIUM, MAGNESIUM. Violent reactions can occur. SODIUM, POTASSIUM, LITHIUM. Explosive reactions can occur. CONCENTRATED NITRIC(V) ACID. It may dissolve explosively and the solution can be detonated.
Store: GOrg	Disposal: W1, W2, W6 W6: This should be limited to 25 cm ³ .



Activity	User	Control measures	Experimental points
Adhesives and acrylic cements	Y9	Wear eye protection. Wear disposable nitrile gloves if skin is sensitive.	If applied to areas greater than 500 cm ² , local exhaust ventilation must be used or the work should be done outdoors. Work 1 m from any source of ignition. Pupils should be made aware of the widespread use of dichloromethane in adhesives and paint stripper and how harmful it can be to inhale the fumes. See also <i>Hazard</i> 98B.
Detection of lead in water	Y9	Wear eye protection. Prepare the solution in a fume cupboard. Use the solution in a well-ventilated laboratory.	Originally, 1,1,1-trichloroethane was the solvent for dithizone. Now prepare a solution of dithizone in dichloromethane, methylbenzene or butyl ethanoate. See note below about the use of separating funnels. Dispense solutions of dichloromethane from a fume cupboard.
Extraction of chemicals from aqueous media	Y12	Wear eye protection. It is better to try a hydrocarbon-extracting agent such as cyclohexane before deciding to use dichloromethane. Distillation should be carried out in a fume cupboard or a well-ventilated area.	Eg, caffeine or limonene. Pupils should be instructed in the correct use of separating funnels during the shaking of the liquids. Increases of pressure when using separating funnels with volatile solvents can blow out stoppers and taps, spraying solvent over the user. The distillation should be carried out using a beaker of hot water, rather than using a Bunsen-burner flame. Used dichloromethane can be dried with anhydrous sodium sulfate(VI), redistilled and reused. Do not redistill dichloromethane if it has been mixed with other solvents. See L195, <i>Safer Chemicals</i> , <i>Safer Reactions</i> for the use of propan-1-ol saturated with sodium chloride as an alternative solvent.
Iodine value	Y12	Wear eye protection.	Used to classify unsaturated oils. It amplifies the presence of iodine when using Wij's solution. Use 1 cm ³ per titration.
Tin(IV) iodide preparation	Y12	Wear eye protection. Use a fume cupboard.	Originally, 1,1,1-trichloroethane was the solvent for this reaction. The boiling point is lower, so completion may be slower.

29 Di(dodecanoyl) peroxide and other organic peroxides

Di(dodecanoyl) peroxide		Dilauroyl peroxide; lauroyl peroxide	$(\text{CH}_3(\text{CH}_2)_{10}\text{CO})_2\text{O}_2$
Oxidising		<p>R7: May cause fire. Flash point: 110 °C. Dangerous with: HEAVY METAL SALTS, ACIDS, ALKALIS, REDUCING AGENTS and COMBUSTIBLE MATERIALS. The reaction can cause fire. HEAT: Self-accelerating decomposition sets in at 49 °C.</p>	
Store: Ox Do not store with other organic substances.		Disposal: W1, Wspec Wspec Use no more than 10 g per 1 litre of 2 mol dm ⁻³ sodium hydroxide. Allow to stand for 2 days before washing down a foul-water drain, diluting further.	
Dibenzoyl peroxide		Benzoyl peroxide; di(benzenecarbonyl) peroxide	$(\text{C}_6\text{H}_5\text{CO})_2\text{O}_2$
Explosive		<p>R2: Risk of explosion by shock, friction, fire or other source of ignition. R36: Irritating to eyes. R43: May cause sensitisation by skin contact. WEL (mg m⁻³): 5 (LTEL), 15 (STEL). Flash point: 41 °C. Dangerous with: HEAVY METAL SALTS, ACIDS, ALKALIS, REDUCING AGENTS and COMBUSTIBLE MATERIALS. The reaction can cause fire.</p>	
Irritant		<p>Explodes upon heating strongly. Di(dodecanoyl) peroxide is a safer alternative. Used for initiating free radical polymerisation. Do not grind or subject the chemical to shock or friction.</p>	
Store: Ox Schools should not use this compound, so storage is prior to disposal. Do not store with other organic substances.		Disposal: W1	


Activity	User	Control measures	Experimental points
Dibenzoyl peroxide must not be substituted for di(dodecanoyl) peroxide.			
Polymerisation of phenylethene (styrene)	Y12	Wear eye protection. Use a fume cupboard.	Use about 0.8 g of di(dodecanoyl) peroxide in 25 cm ³ phenylethene. It is best refluxed in a hot water bath until the liquid becomes highly viscous. Pour into ethanol to precipitate the polymer. Wash apparatus in propanone as soon as possible.
Polymerisation of methyl 2-methylpropenoate (methyl methacrylate)	Y12	Wear eye protection. Use a fume cupboard. Wear chemical-resistant gloves.	The monomer is highly flammable and has a highly irritant vapour. Add no more than 1% of di(dodecanoyl) peroxide to the monomer. Care must be taken if there are sources of ignition in the vicinity. Heat with hot water or use an electric heating mantle and carefully control the amount of heat supplied. A reflux condenser should be attached to the flask.


2,4-dinitrophenylhydrazine		Brady's reagent	(NO ₂) ₂ C ₆ H ₃ NHNH ₂
Explosive		<p>R2: Risk of explosion by shock, friction, fire or other source of ignition. R26/27/28: Very toxic by inhalation, in contact with skin and if swallowed. R33: Danger of cumulative effects. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.</p> <p>Skin is stained yellow on contact which may be followed by dermatitis.</p> <p>Dangerous with: OXIDISING AGENTS, METAL OXIDES, eg, lead(IV) oxide. Vigorous or explosive reactions may occur.</p>	
Toxic			
Dangerous for the environment			
<p>Store: GOrg</p> <p>2,4-dinitrophenylhydrazine must be kept damp at all times. It is a good idea to keep the bottle of damp solid inside a larger container with some water in it. (Label both bottle and container!) If the chemical may have become dry, open the bottle slowly to avoid a sudden shock.</p>			<p>Disposal: W1</p>

Phenylhydrazine			C ₆ H ₅ NHNH ₂
Toxic		R45: May cause cancer. Category 2 carcinogen. R68: Possible risk of irreversible effects. Category 3 mutagen. R23/24/25: Toxic by inhalation, in contact with skin and if swallowed. R48/23/24/25: Toxic: danger of serious damage to health by prolonged exposure through inhalation, in contact with skin and if swallowed. R36/38: Irritating to eyes and skin. R43: May cause sensitisation by skin contact. R50: Very toxic to aquatic organisms.	
Dangerous for the environment			
Store: T Schools should not use this compound, so storage is prior to disposal.			Disposal: W1

Activity	User	Control measures	Experimental points
Identification of carbonyl compounds using Brady's reagent	Y12	Wear eye protection. Wear gloves during the dispensing of Brady's reagent and filling of melting-point tubes. Work on a very small scale.	One method uses a few drops of the carbonyl compound dissolved in as little methanol as possible. 5 cm ³ of Brady's reagent is added. The precipitate is filtered by suction, washed with more methanol and allowed to dry before measuring the melting point. Carbohydrates also react with Brady's reagent. Schools often report this activity not working. The carbonyl compounds (especially aldehydes) should not be so old that air oxidation has taken place. It is also wise to prepare the Brady's reagent as and when required; do not store the solution for long periods of time. Disposal: For these 'test-tube amounts', dispose of solid residues in the waste and filtrates down a foul-water drain, accompanied with plenty of water.
Preparation of Brady's reagent	TT	Wear eye protection. Wear chemical-resistant gloves.	See <i>Recipe Card</i> 21. There are two methods given. Make the minimum quantity required. The version using phosphoric(V) acid appears safer to use. Protect the bench from stains. The solution does not keep over months so it is better to make a fresh batch each year. Disposal: Dilute the solution in a full bucket of water and pour the contents down a foul-water drain, accompanied by plenty of water.

31 Dodecylbenzenesulfonic acid and other sulfonic acids

Dodecylbenzenesulfonic acid		Nansa acid	$C_{18}H_{29}SO_2OH$
Corrosive		R34: Causes burns. R22: Harmful if swallowed. R41: Risk of serious damage to eyes. The substance is viscous and not easy to pour. It could adhere to the skin and take some time to wash off with water.	
Store: CLa		Disposal: W1, W2 or W4 W4: Use this method if amounts are less than 25 cm ³ .	

Benzenesulfonic acid			$C_6H_5SO_3H$
Corrosive		R34: Causes burns. R22: Harmful if swallowed. Solutions equal to or greater than 0.6 mol dm ⁻³ should be labelled CORROSIVE. Solutions equal to or greater than 0.3 mol dm ⁻³ but less than 0.6 mol dm ⁻³ should be labelled IRRITANT.	
Store: CLa		Disposal: W1, W4	

Activity	User	Control measures	Experimental points
Pouring dodecyl-benzene-sulfonic acid	Y9	Wear goggles. Wear disposable nitrile gloves.	Because of its viscous nature, it might be better to provide some pupils with prepared volumes in beakers. Use a sink when pouring the contents of the bottle into a beaker or measuring cylinder. Pouring into a measuring cylinder is difficult and the liquid takes some time to settle. Small adjustments to volumes are difficult to make.
Making a liquid detergent using dodecyl-benzene-sulfonic acid	Y9	Wear goggles. Wear disposable nitrile gloves.	As the density of the acid is about 1.05 g cm^{-3} , weighing the beaker before and after pouring would give an approximate volume and necessary adjustments to the volumes of the other reagents can then be made. Uses 4 mol dm^{-3} sodium hydroxide solution (CORROSIVE).
Preparation of Turkey red oil (a detergent)	Y12	Wear goggles. Wear chemical-resistant gloves.	Because water will be added to the mixture, use as little of the reagents as possible, eg, 5 drops of castor oil and 3 drops of the concentrated acid. After the reaction, add 5 cm^3 of cold water.
Preparation of phenol from benzene-sulfonic acid	TT	This procedure involves mixing 5 g of sodium hydroxide with 1 g of water and heating this to 250°C before mixing in 3 g of benzene-sulfonic acid. It will require a special risk assessment; consult CLEAPSS.	

32 Dyes, indicators and stains

Dyes are not very pure, especially very old samples. Sometimes a filler [eg, sodium sulfate(VI)] is included. Little is known about health hazards, so try not to raise / inhale dust. Even low-hazard substances should be used with caution. Students will use dilute solutions.


Solids		
Toxic	Congo red (Direct dye 28)	R45: May cause cancer (Category 2 carcinogen). R63: Possible risk of harm to the unborn child (Category 3 teratogen).
Toxic	Methyl orange	R25: Toxic if swallowed.
Harmful	Acridine orange, Methyl red, Sudan I and II	R40: Limited evidence of a carcinogenic effect (Category 3 carcinogen).
Harmful Dangerous for the environment	Malachite green (solvent green 1)	R22: Harmful if swallowed. R41: Risk of serious damage to eyes. R63: Possible risk of harm to the unborn child. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.
Harmful	Crystal violet (Methyl violet; Gentian violet) (Gram's stain), Magenta (basic fuchsin), May-Grunwald stain, Methylene blue, Rosaniline.	R20/21/22: Harmful by inhalation, in contact with skin and if swallowed.
Irritant	Alizarin red S, Aluminon (triammonium aurine tricarboxylate), Aniline blue (spirit blue, cotton blue), Cresol red, Direct red 23, Disperse yellow 7, Dithizone (diphenylthiocarbazone), Eosin, Eriochrome black (Solochrome black), HHSNNA (Patton and Reeder's indicator), Indigo, Methyl green, Procion dyes, Resazurin, Sudan IV, Xylene cyanol FF.	R36/37/38: Irritating to eyes, respiratory system and skin.
Low hazard	Acid blue 40, Alizarin (1,2-dihydroxyanthraquinone), Blue dextran, Brilliant yellow, Bromocresol green, Bromophenol blue, Bromothymol blue, Carmine (cochineal, natural red 4), 2,6-dichlorophenolindophenol (DCPIP, phenol-indo-2,6-dichlorophenol, PIDCP), Diazine green (Janus green b), (dichloro) Fluorescein, Indigo carmine, Litmus, Methyl blue, Murexide (ammonium purpurate), Neutral red, Nigrosin, Orcein, Phenol red, Phenolphthalein, Rhodizonic acid, Soylent green, Sudan black, Sudan III, Thymol blue, Thymolphthalein, Toluidine blue, Xylenol orange.	
Solutions	Most aqueous solutions of dyes are less than 1% by mass so the solutions are low hazard (except Congo red). Otherwise, the hazard will reflect the nature of the solvent; eg, carmine and orcein dissolved in ethanoic acid are CORROSIVE and if the content of ethanol is greater than 25% (v/v), the solution should be labelled HIGHLY FLAMMABLE. Universal indicator is sold in various formulations; most are HIGHLY FLAMMABLE, some are also HARMFUL. See <i>Recipe Card 36</i> .	
Store: GOrg: (for solids and low-hazard solutions) FL: (for solutions containing more than 25% ethanol as a solvent)		Disposal of small amounts: Solids: W1 1% solutions: W7 (Congo red solution: Dilute to 0.1%).


For emergencies, see *Hazard E* as well as more detailed information which may be on this *Hazard*.

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Activity	User	Control measures	Experimental points
Use of stains etc	-	-	Much will depend on the solvent that is used to dissolve or dilute the dye. See <i>Recipe Cards</i> , <i>Handbook</i> 20.3 or contact CLEAPSS for more information.
General use of dilute solutions	Y7	Wear eye protection.	Solutions are normally less than 1% (w/v) and so are low hazard, unless the solvent is ethanol. See 'Making solutions' below.
Dyeing fabrics	Y7	Wear eye protection. Gloves and aprons may be required.	Use tongs to dip fabric into the dye bath. Do not handle the wet material unless gloves are worn. Beware of spills on clothing. It is difficult to remove stains!
Anodised aluminium	Y9	Wear eye protection.	Use water-soluble dyes. The dye solutions (eg, alizarin) have to be hot. Handle the anodised aluminium foil with tongs.
Preparation of methyl orange	Y12	Wear eye protection. Wear disposable nitrile gloves.	Dissolve 1 g of sulfanilic acid (HARMFUL by all three routes) and 0.25 g of sodium carbonate in 100 cm ³ of ice cold water. Add dropwise 0.5 g of sodium nitrite dissolved in 2 cm ³ of cold water and stir, keeping the temperature below 5°C. Add 0.5 cm ³ of dimethylphenylamine (TOXIC by all three routes) dissolved in 0.5 cm ³ of ethanoic acid.
Making solutions of dyes, indicators & stains	TT	Wear eye protection. Wear disposable nitrile gloves. Use a fume cupboard. Students should not prepare solutions.	Dye containers should be opened in a working fume cupboard. The solid should be weighed out with the fume cupboard switched off. Any aqueous solution containing more than 25% by volume of ethanol should be labelled HIGHLY FLAMMABLE. These solutions should be stored in the flammables cupboard. Directions for technicians when making some common stains and indicators can be found on <i>Recipe Cards</i> .
Use of Congo red	TT	Use of this material will require a special risk assessment. Consult CLEAPSS. All solutions above 0.1% should be labelled TOXIC.	




33 Enzymes

Powders		
Harmful 	Amylase (including diastase and <i>Termamyl</i>), Amylglucosidase (AMG), Carbohydrase mix (including <i>Viscozyme</i>), Catalase, Cellulase (including <i>Celluclast</i> and <i>Celluzyme</i>), Chemosin (including <i>Maxiren</i>), Glucose isomerase, Invertase, Lactase (including <i>Lactozym</i>), Lipase (including <i>Lipolase</i>), Pancreatin, Pectinase (including <i>Pectinex</i>), Pectinesterase (including <i>Novoshape</i>), Pepsin, Phosphorylase, Protease (including <i>Neutrase</i>), Rennilase, Trypsin, Urease.	R36: Irritating to eyes. R41: Risk of serious damage to eyes, R42: May cause sensitisation by inhalation.
Low hazard	Yeast; Enzymes in rennin (rennet).	-
Store: Cold		Disposal of small amounts (10 g): Add the material to 1 litre of water in a bucket and pour this down a foul-water drain.

Solutions equal to or stronger than 1% (w/v)		
Irritant 	Amylase (including diastase and <i>Termamyl</i>), Amylglucosidase (AMG), Carbohydrase mix (including <i>Viscozyme</i>), Catalase, Cellulase (including <i>Celluclast</i> and <i>Celluzyme</i>), Chemosin (including <i>Maxiren</i>), Glucose isomerase, Invertase, Lactase (including <i>Lactozym</i>), Lipase (including <i>Lipolase</i>), Pancreatin, Pectinase (including <i>Pectinex</i>), Pectin esterase (including <i>Novoshape</i>), Pepsin, Phosphorylase, Protease (including <i>Neutrase</i>), Rennilase, Trypsin, Urease.	R37/38: Irritating to eyes and skin. R41: Risk of serious damage to eyes, R43: May cause sensitisation by skin contact.
Low hazard	Yeast; Enzymes in rennin (rennet).	-
Solutions less than 1% (w/v) are low hazard.		
Store: Cold Solutions of enzymes should not be allowed to dry out.		Disposal: W7 W7: Make a 1% or less (w/v) solution and pour this down a foul-water drain.






Activity	User	Control measures	Experimental points
Saliva as a source of amylase	Y7	Ensure good hygiene.	A potential (if unlikely) source of infection. Pupils should supply and dispose of their own saliva after an investigation by rinsing it down a sink and placing the equipment in bleach. See <i>Handbook</i> 14.4.3 Disposal: All contaminated glassware should be immersed in a sodium chlorate(I) solution (1000 ppm) for at least 15 minutes. Ordinary gloves will provide adequate protection.
Experiments on catalase with hydrogen peroxide (small-scale)	Y9	Wear eye protection.	Use 20 'vol' (or lower) hydrogen peroxide; much will depend on the technique used. A yeast suspension or very small piece of liver provides a convenient source of this enzyme. Small amounts of any organic material used as a source of enzyme should not be poured down a sink; it should be collected, wrapped in paper and placed in the waste.
Experiments on catalase with hydrogen peroxide (large-scale)	TT	Wear eye protection.	Use a large-volume, tall-form beaker or 500 cm ³ measuring cylinder and limit the amount of 20 'vol' hydrogen peroxide solution to retain the froth of bubbles that forms. Do not use blood in an open vessel (danger of infective aerosol formation); rather use shop-bought liver or commercial catalase if yeast is inappropriate.
Making solutions	Y12	Wear eye protection. Consider wearing gloves. Use a fume cupboard.	To avoid raising dust, open the bottle in a working fume cupboard. Switch off the fume cupboard to carry out the weighing. This should stop particles being inhaled. Make up enough of the strongest solution so that others may be prepared by dilution.
Enzyme inhibition	Y12	Wear eye protection.	It is recommended that dilute solutions of potassium cyanide are not used. If they <i>have</i> to be used, ready-made dilute solutions can be bought. Pupils should not make up cyanide solutions. Teachers and/or technicians should be experienced in using these solutions. Heavy-metal alternatives such as mercuric salts are available for these investigations.

34 Ethanal and its tetramer

Ethanal		Acetaldehyde	CH ₃ CHO
Extremely flammable		R12: Extremely flammable. R40: Limited evidence of a carcinogenic effect. Category 3 carcinogen. R36/37: Irritating to eyes and respiratory system. Dangerous with: SULFURIC(VI) ACID AND OTHER ACIDS. Violent polymerisation reactions may occur. SILVER NITRATE(V) SOLUTION. Explosive products are formed. WEL (mg m⁻³): 37 (LTEL), 92 (STEL). Flash point: -38 °C.	
Harmful			
Store: FL Ethanal has been known to spontaneously boil away during storage and on opening. It should only be opened in a fume cupboard. Cool in an ice bath before opening the bottle. Ethanal oxidises to ethanoic acid during storage.			Disposal: W7 W7: Add 10 cm ³ to 1 litre of water before pouring down a foul-water drain.
Ethanal tetramer		Metaldehyde	(CH ₃ CHO) ₄
Harmful		R10: Flammable. R20/22: Harmful by inhalation and if swallowed. Hexamethylene is possibly a safer solid fuel.	
Store: FS			Disposal: W1, W6 W6: Burn it in a fume cupboard.


Activity	User	Control measures	Experimental points
Metaldehyde fuel	Y9	Wear eye protection.	Pupils should be supplied with what they will use and not allowed access to a larger supply. If used with a model steam engine, only the teacher should use it. Hexamethylene is possibly a safer solid fuel.
Reducing copper(II) ions	Y9	Wear eye protection.	Ethanal reduces Fehling's solution (see <i>Recipe Card 25</i>) when placed in boiling water. Benedict's solution does not work as well. However, Sandell's solution works in hot water and should be considered as a safer alternative. See <i>Hazcard 27C</i> .
Test-tube reactions of aldehydes	Y12	Wear eye protection.	Investigations can be carried out on a small scale using 3 or 4 drops of ethanal with 1 cm ³ of acidified potassium dichromate(VI) or potassium manganate(VII) solutions (see <i>Recipe Cards 53 & 56</i>). Warming should be carried out in a beaker of hot water. However, because of the ease of air oxidation of ethanal and loss by evaporation, consider using propanal as an alternative. Silver mirror test: See <i>Hazcard 87</i> .
Addition of sulfur dioxide	Y12	Wear eye protection. Use a fume cupboard.	Prepare saturated sodium hydrogensulfite solution by passing sulfur dioxide through saturated sodium metabisulfite solution. Use 3-5 drops of ethanal to 2 cm ³ of the saturated solution, apply a stopper and shake carefully. Leave for 1-2 hours. Benzaldehyde produces more reliable results.
Condensation reactions	Y12	Wear eye protection. Wear disposable nitrile gloves.	See <i>Hazcard 30</i> . Benzaldehyde and propanal produce more reliable results.
Polymerisation	Y12	Wear goggles for all these procedures. Use a fume cupboard. Wear disposable nitrile gloves.	Trimer: The reaction is highly exothermic. Cool 10 drops of ethanal in ice/salt mixture before 1 drop of concentrated sulfuric(VI) acid is added. Stir carefully. Metaldehyde (Tetramer): Dry hydrogen chloride gas is passed through 1 cm ³ of ethanal dissolved in 2 cm ³ of ethoxyethane. Resin: Add 5 mol dm ⁻³ sodium hydroxide solution dropwise to 1 cm ³ of ethanal until the brown resin forms.




35 Ethanamide and other amides

Ethanamide		Acetamide	CH_3CONH_2
Harmful		R40: Limited evidence of a carcinogenic effect. Category 3 carcinogen. Dangerous with: SODIUM or CALCIUM CHLORATE(I). An explosive product is formed. SODIUM NITRITE. An explosion can occur on heating.	
Store: GOrg		Disposal: W7 W7: Dissolve 10 g in 1 litre of water before pouring down a foul-water drain.	
Thiooxamide		Dithioxamide; rubeanic acid	$\text{H}_2\text{NCSCSNH}_2$
Harmful		R22: Harmful if swallowed. R36/37/38: Irritating to eyes, respiratory system and skin.	
N-phenylethanamide		Acetanilide; Antifebrin	$\text{C}_6\text{H}_5\text{NHCOCH}_3$
Harmful		R22: Harmful if swallowed.	
Store: GOrg		Disposal: W1, W2	
Propenamide		Acrylamide	$\text{CH}_2\text{CHCONH}_2$
Toxic		R45: May cause cancer. Category 2 carcinogen. R46: May cause heritable genetic damage. Category 2 mutagen. R62: Possible risk of impaired fertility. Category 2 teratogen. R25: Toxic if swallowed. R48/23/24/25: Toxic: danger of serious damage to health by prolonged exposure through inhalation, in contact with skin and if swallowed. R20/21: Harmful by inhalation and in contact with skin. R36/38: Irritating to eyes and skin. R43: May cause sensitisation by skin contact. WEL (mg m⁻³): 0.3 (LTEL), 0.9 (STEL).	
Phenylthiocarbamide		N-phenylthiourea; PTC; PTU	$\text{C}_6\text{H}_5\text{NHCSNH}_2$
Very toxic		R28: Very toxic if swallowed.	
Store: T		Disposal: W1	
Carbamide; urea; $\text{CO}(\text{NH}_2)_2$		Low hazard	Store: GOrg Disposal: W7

Activity	User	Control measures	Experimental points
PTC-tasting experiments	Y7	-	Papers containing the chemical may be purchased or made by the technician; see <i>Recipe Card</i> 47. Despite its toxicity, only a very small amount of the chemical is on the papers. See <i>Handbook</i> 15.13.
Preparation of resins with urea	Y9	Wear eye protection. Use a fume cupboard. Wear disposable nitrile gloves.	Do not use methods involving hydrochloric acid. Dissolve 5 g of urea in 10 cm ³ of methanal in a polystyrene cup. Add 5 cm ³ of 1 mol dm ⁻³ sulfuric(VI) acid and stir. Leave in a fume cupboard until solid forms. The reaction gives out heat and methanal vapour. Wear gloves when extracting the white resin from the cup. Disposal: of resin - W8.
Preparation of ethanamide	Y12	Wear eye protection. Use a fume cupboard Wear eye protection. Use a fume cupboard.	Reacting ethanoic acid and ammonium carbonate: If a reflux condenser is used, the reaction may be carried out in the laboratory with good ventilation. Reacting ethanoyl chloride and ammonia: Fumes of ammonium chloride are produced as well. This is not a good preparative method.
Hydrolysis of ethanamide	Y12	Wear goggles.	1 mol dm ⁻³ sodium hydroxide (CORROSIVE) is used and the solution is heated. Ammonia gas is produced. This may be done on a test-tube scale in the laboratory with good ventilation.
Hoffman bromination reaction	Y12	Wear eye protection. Use a fume cupboard. Wear chemical-resistant gloves.	Test-tube scale only. Use 3 drops of bromine to about 0.1 g of ethanamide. Add 2 cm ³ of 1 mol dm ⁻³ sodium hydroxide (CORROSIVE). On boiling, the fishy smell of the alkaline gas methylamine (HIGHLY FLAMMABLE AND IRRITANT) can be detected. Smell with care.
Detection of the amine group	Y12	Wear eye protection.	Sodium nitrite is used with 1 mol dm ⁻³ hydrochloric acid solution. The gas produced is nitrogen.
Preparation of <i>N</i> -phenylethanamide	Y12	Wear eye protection.	See <i>Hazard</i> 39.
Polymerisation of acrylamide	TT	Any procedure with this chemical requires a special risk assessment. An application should be made to CLEAPSS.	

36A Ethanedioic acid and its salts


Ethanedioic acid		Oxalic acid	HOOC-COOH
Harmful		R21/22: Harmful in contact with skin and if swallowed. All solutions equal to or stronger than 0.5 mol dm ⁻³ should be labelled HARMFUL. Dangerous with: OXIDISING AGENTS. Violent reactions may occur. WEL (mg m⁻³): 1.0 (LTEL), 2.0 (STEL).	
Store: GOrg		Disposal: W1, W4 W4: Add no more than 30 g to 1 litre of 1 mol dm ⁻³ sodium carbonate solution.	


Ammonium ethanedioate-1-water		Ammonium oxalate	(NH ₄) ₂ C ₂ O ₄ ·H ₂ O
Harmful		R21/22: Harmful in contact with skin and if swallowed. All solutions equal to or stronger than 0.3 mol dm ⁻³ should be labelled HARMFUL. Dangerous with: OXIDISING AGENTS. Violent reactions may occur. Ammonium salts must not be mixed or ground with potassium chlorate(V) or manganate(VII) because explosive mixtures can be formed.	
Potassium ethanedioate-1-water		Potassium oxalate	K ₂ C ₂ O ₄ ·H ₂ O
Potassium hydrogenethanedioate		Potassium bisethanedioate; potassium hydrogen oxalate	KHC ₂ O ₄
Potassium hydrogenethanedioate-1-ethanedioic acid-2-water		Potassium tetroxalate	KH ₃ (C ₂ O ₄) ₂ ·2H ₂ O
Harmful		R21/22: Harmful in contact with skin and if swallowed. All solutions equal to or stronger than 0.2 mol dm ⁻³ should be labelled HARMFUL. Dangerous with: OXIDISING AGENTS. Violent reactions may occur.	
Sodium ethanedioate		Sodium oxalate	Na ₂ C ₂ O ₄
Harmful		R21/22: Harmful in contact with skin and if swallowed. All solutions are LOW HAZARD because the chemical has low solubility. Dangerous with: OXIDISING AGENTS. Violent reactions may occur.	
Store: Gln		Disposal: W1, W7 W7: Add no more than 30 g to 1 litre of water or dilute to less than 0.3 mol dm ⁻³ .	


Activity	User	Control measures	Experimental points
General use of salt solutions	Y7	Wear eye protection.	Solutions should be 0.3 mol dm^{-3} or less. More concentrated solutions, if required, can be used by older age groups.
Titration	Y12	Wear eye protection.	Pipette fillers should always be used. Ethanedioic acid and its salts have to be titrated at 80°C against potassium manganate(VII) solutions. The reaction is autocatalysed by $\text{Mn}^{2+}(\text{aq})$ ions which are a product of the reaction and it will not need reheating.
Action of heat on ethanedioic acid	Y12	Wear eye protection.	With 0.5 g of acid, the reaction may be done in a well-ventilated laboratory; for larger amounts a ducted (not filter) fume cupboard is required. Carbon monoxide is produced along with carbon dioxide.
Addition of concentrated sulfuric(VI) acid	Y12	Wear eye protection. Wear disposable nitrile gloves.	Use 0.5 g of ethanedioic acid and enough concentrated sulfuric(VI) acid to cover the solid. Gentle heating will be necessary. With these amounts, the reaction may be done in a well-ventilated laboratory, otherwise a ducted (not filter) fume cupboard is required. Carbon monoxide is produced along with carbon dioxide.
As a complexing agent with iron compounds	Y12	Wear eye protection.	Follow instructions closely ¹ ; a large amount of frothing occurs because of carbon dioxide evolution.
Preparation of esters and salts	Y12	Wear eye protection.	Small-scale reactions are possible in test tubes.


¹ *Inorganic Chemistry Through Experiment*, G F Liptrot, Collins, ISBN 0 263 51591 5. This useful book can still be obtained from online second-hand booksellers.

36B Other polybasic organic acids and their salts (1)

Propanedioic acid		Malonic acid	HOOCCH ₂ COOH
Harmful		R22: Harmful if swallowed. R36: Irritating to eyes. All solutions equal to or stronger than 2 mol dm ⁻³ should be labelled HARMFUL. Dangerous with: OXIDISING AGENTS. Violent reactions may occur.	
Store: GOrg		Disposal: W1, W4	

Butanedioic acid		Succinic acid; butane-1,4-dioic acid	HOOCCH ₂ CH ₂ COOH
Irritant		R36: Irritating to eyes. All solutions are low hazard.	
Store: GOrg		Disposal: W1, W4	


trans-butenedioic acid		Fumaric acid	HOOCCHCHCOOH
Irritant		R36: Irritating to eyes. All solutions are low hazard.	
Store: GOrg		Disposal: W1, W4	


cis-butenedioic acid		Maleic acid	HOOCCHCHCOOH
Harmful		R22: Harmful if swallowed. R36/37/38: Irritating to eyes, respiratory system and skin. All solutions equal to or stronger than 2 mol dm ⁻³ should be labelled HARMFUL.	
Store: GOrg		Disposal: W1, W4	

36B Other polybasic organic acids and their salts (1)**Model risk assessments**

Activity	User	Control measures	Experimental points
Test-tube-scale procedures	Y12	Wear eye protection.	Many of these acids are used as unknowns in observational exercises. Used on a small scale, they should not provide any health and safety risks. It would be advisable, however, that teachers or experienced technicians should try out the procedures before the students attempt them. Do not inhale the vapours, if substances are heated.
<i>Cis-trans</i> isomerism of butenedioic acids	Y12	Wear eye protection.	Maleic and fumaric acids show widely-different properties, although they have the same chemical formula. Melting points are 130 °C and 287 °C respectively. Their solubilities are 7.8 g and 0.5 g per 100 cm ³ of water at room temperature. Investigation of the acidity of the two acids also shows a wide range of pK values.
Partition coefficient	Y12	Wear eye protection.	Butanedioic acid (0.5 to 2 g) is added to 50 cm ³ of a 1:1 mixture of water and 2-methylpropan-1-ol or ethoxyethane. Solutions can be titrated with 0.1 mol dm ⁻³ solutions of sodium hydroxide (IRRITANT).

36C Other polybasic organic acids and their salts (2)

2,3-dihydroxybutanedioic acid		Tartaric acid	$\text{HOOCCH(OH)CH(OH)COOH}$
2-hydroxybutanedioic acid		Malic acid; 2-hydroxysuccinic acid	$\text{HOOCCH(OH)CH}_2\text{COOH}$
Irritant		R36/37/38: Irritating to eyes, respiratory system and skin. All solutions equal to or stronger than 1.4 mol dm^{-3} should be labelled IRRITANT.	
Store: GOrg		Disposal: W1, W4	




2-hydroxypropane-1,2,3-tricarboxylic acid		Citric acid	$\text{HOOCCH}_2\text{C(OH)(COOH)CH}_2\text{COOH}$
Irritant		R36: Irritating to eyes. All solutions equal to or stronger than 1 mol dm^{-3} should be labelled IRRITANT.	
Store: GOrg		Disposal: W1, W4	

Potassium sodium 2,3-dihydroxybutanedioate-1-water; potassium sodium tartrate; Rochelle salt; $\text{KNaC}_4\text{H}_4\text{O}_6 \cdot 4\text{H}_2\text{O}$ Sodium citrate-2-water; $\text{C}_6\text{H}_5\text{O}_7\text{Na}_3 \cdot 2\text{H}_2\text{O}$	Low hazard	Store: Gln	Disposal: W7
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36C Other polybasic organic acids and their salts (2)**Model risk assessments**


Activity	User	Control measures	Experimental points
General use of these acids	Y7	Wear eye protection.	1 mol dm ⁻³ solutions are recommended.
Making crystals of Rochelle salt	Y7	-	Large crystals can be obtained from saturated solutions.
Endothermic reactions	Y7	Wear eye protection.	Mixtures of these acids in water with sodium hydrogencarbonate display a lowering of temperature.
'Exploding' plastic 35 mm film canisters	Y7	Wear eye protection. Stand 2 m back once the reaction is started.	Mix 2 g of sodium hydrogencarbonate and 1 g of citric acid in a film canister. Quickly add 1 cm ³ of hot water, fit the top on and place the canister upside down on a clear bench. Teachers will need to assess risks if several groups are doing this activity at the same time. It would be better to set them off one at a time.
Buffer solutions	Y7	Wear eye protection.	There are many buffer solution recipes, many of which involve citric acid. Guide R35 contains recipes for the preparation of buffers at precise values. <i>Recipe card</i> 14 has further details, including a universal buffer solution which can be used to make a buffer at any value between pH 3 and 10.


37 Ethane-1,2-diol and other polyols

Ethane-1,2-diol	Ethylene glycol	$\text{CH}_2\text{OHCH}_2\text{OH}$
Harmful		<p>R22: Harmful if swallowed.</p> <p>WEL (mg m^{-3}): 52 (LTEL), 104 (STEL). Flash point: 118 °C.</p> <p>Dangerous with: OXIDISING AGENTS such as potassium dichromate, perchloric acid and potassium manganate(VII). Explosive reactions can occur.</p>
<p>Store: GOrg</p> <p>Ensure the bottle top is secure. The substance absorbs water from the atmosphere.</p>		<p>Disposal: W1, W7</p> <p>W7: Add no more than 250 cm³ to 1 litre of water before pouring down a foul-water drain.</p>
Opresol		
Harmful		<p>R22: Harmful if swallowed.</p> <p>Flash point: 143 °C.</p> <p>This is a 1% (v/v) solution of 2-phenoxyethanol (IRRITANT) dissolved in diethylene glycol (HARMFUL).</p>
<p>Store: GOrg</p>		<p>Disposal: W1, W7</p> <p>W7: Add no more than 250 cm³ to 1 litre of water before pouring down a foul-water drain.</p>
Propylene phenoxetol		
Irritant		<p>R36/36: Irritating to eyes and skin.</p>
<p>Store: GOrg</p>		<p>Disposal: W1, W7</p> <p>W7: Add no more than 250 cm³ to 1 litre of water before pouring down a foul-water drain.</p>
<p>Propane-1,2,3-triol; glycerol; glycerine; triethylene glycol; $\text{CH}_2\text{OHCH}(\text{OH})\text{CH}_2\text{OH}$</p> <p>Propane-1,2-diol; propylene glycol; $\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{OH}$</p>		<p>Low hazard</p> <p>Store: GOrg</p> <p>Ensure the bottle top is secure. Water is absorbed from the atmosphere.</p> <p>Disposal: W7</p>

Activity	User	Control measures	Experimental points
Viscosity investigations	Y7	Wear eye protection.	Ethane-1,2-diol, propane-1,2,3-triol or propane-1,2-diol can be used. These are useful because containers can be washed in water afterwards. Commercial unused motor oils (LOW HAZARD) can also be used but cleaning is more difficult because they are not soluble in water. Guidance leaflet PS 67-05 describes a small-scale viscosity procedure.
Antifreeze investigations	Y7	Wear eye protection.	Water/glycol mixtures freeze below 0 °C. They will need to be cooled in ice/salt mixtures.
Melting-point determinations	Y9	Wear eye protection. Use a fresh supply.	Propane-1,2,3-triol should be used instead of dibutyl phthalate as a heating medium. However, old stocks of glycerol will contain water absorbed from the atmosphere and bubbles (water vapour) will appear on heating above 100 °C. Do not return used liquid to the stock bottle. For temperatures in excess of 150 °C, use medicinal paraffin.
Addition of potassium manganate(VII) to propane-1,2,3-triol	TT	Wear goggles or a face shield. Use safety screens.	Warm 1 cm ³ of propane-1,2,3-triol and pour it onto a spatula measure of potassium manganate(VII) on a heat-proof mat. There may be an unpredictable delay before the reaction starts. If there is no reaction, carefully place the mixture into a bowl of water (wear thermal gloves to protect from heat in case the chemicals start to react). The reaction can be used as a starter for the thermite reaction; see <i>Hazard</i> 11. It should not be used for the method described in L195, <i>Safer Chemicals, Safer Reactions</i> .
Preserving specimens	TT	Wear eye protection. Gloves may be required if treated specimens are handled.	Use <i>Opresol</i> or propylene phenoxetol as a safer alternative to formalin. For topping up preserved-specimen containers, do not mix with formalin; remove formalin first or consider topping up with formalin.

38A Ethanoic acid, methanoic acid and their salts

Ethanoic acid	Acetic acid; vinegar		CH ₃ COOH
Corrosive		<p>R10: Flammable. R35: Causes severe burns.</p> <p>Solutions equal to or stronger than 4 mol dm⁻³ should be labelled CORROSIVE. Solutions equal to or stronger than 1.7 mol dm⁻³ but weaker than 4 mol dm⁻³ should be labelled IRRITANT.</p> <p>Flash point: 43 °C.</p> <p>Dangerous with: CHROMIUM(VI) OXIDE, MANGANATES(VII), NITRIC(V) ACID, PEROXIDES. Violent or explosive reactions may occur.</p> <p>WEL (mg m⁻³): 25 (LTEL), 37 (STEL).</p>	
Store: CLa On cold days, the liquid solidifies. The melting point is 17 °C.		Disposal: W1, W4 or W7 W4 Use a fume cupboard. W7 Dilute to less than 0.1 mol dm ⁻³ and pour the solution down a foul-water drain.	


Methanoic acid	Formic acid		HCOOH
Corrosive		<p>R35: Causes severe burns.</p> <p>Solutions equal to or stronger than 2 mol dm⁻³ should be labelled CORROSIVE. Solutions equal to or stronger than 0.4 mol dm⁻³ but weaker than 2 mol dm⁻³ should be labelled IRRITANT.</p> <p>Flash point: 68 °C.</p> <p>Dangerous with: CHROMIUM(VI) OXIDE, MANGANATES(VII), NITRIC(V) ACID, PEROXIDES. Violent or explosive reactions may occur.</p> <p>PHOSPHORUS(V) OXIDE. Rapid evolution of carbon monoxide.</p> <p>WEL (mg m⁻³): 9.6 (LTEL), 28.8 (STEL).</p>	
Store: CLa		Disposal: W1, W4 or W7 W4 Use a fume cupboard. W7 Dilute to less than 0.1 mol dm ⁻³ and pour the solution down a foul-water drain.	


Sodium ethanoate-3-water; hydrated sodium acetate; NaCH ₃ COO.3H ₂ O Sodium ethanoate; anhydrous sodium acetate; NaCH ₃ COO Sodium methanoate; sodium formate; NaHCOO	Low hazard	Store: Gln	Disposal: W7
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38A Ethanoic acid, methanoic acid and their salts**Model risk assessments**

Activity	User	Control measures	Experimental points
General use of ethanoic acid	Y7	Wear eye protection. Do not inhale the vapours.	Solutions less than 4 mol dm^{-3} ethanoic acid are suitable.
'Hand warmers'	Y7	Wear eye protection.	Place 10 g of hydrated sodium ethanoate in a boiling tube and add 1 cm^3 of water. Warm the mixture in hot water until the solution becomes liquid. Place this in cold water to cool to room temperature. Now add one crystal of sodium ethanoate to initiate crystallisation. Hydrated calcium nitrate(V) can also be used.
General use of methanoic acid	Y9	Wear eye protection. Do not inhale the vapours.	Solutions less than 2 mol dm^{-3} are suitable.
Test-tube preparation of esters	Y9	Wear goggles.	Mix 10 drops of acid with 10 drops of the alcohol and add 2 drops of concentrated sulfuric(VI) acid. After warming in a bath of hot water, cool under the tap before adding the mixture to sodium carbonate solution in a beaker. Pupils should be shown how to smell the ester carefully.
Reaction with sodium	Y12	Wear goggles. Use a fume cupboard.	A dry test tube must be used. Use forceps to add a dry, 3 mm cube of sodium to about 2 cm^3 of concentrated acid. Leave until all sodium has reacted.
Reaction with phosphorus pentachloride	Y12	Wear goggles. Use a fume cupboard.	Use 1 cm^3 of concentrated ethanoic acid in a dry test tube. Add phosphorus pentachloride a little at a time. Hydrogen chloride is evolved.
Dehydration of methanoic acid	Y12	Wear goggles.	Use no more than 1 cm^3 of methanoic acid and 1 cm^3 of concentrated sulfuric(VI) acid in a test tube. Ignite the evolved carbon monoxide.
Methanoic acid/bromine reaction	Y12	Wear goggles. Use a fume cupboard initially.	Mix equal volumes of 1 mol dm^{-3} methanoic acid and 0.1 mol dm^{-3} aqueous bromine solution in a fume cupboard. Plug the test tube with mineral wool to slow down loss of bromine vapour, especially if it is removed from the fume cupboard to a colorimeter so that loss of colour can be monitored.
Preparing dilute acids	TT	Wear goggles or a face shield. Use a fume cupboard.	For ethanoic acid, see <i>Recipe Card 24</i> . To make a 1 mol dm^{-3} solution of methanoic acid, dilute 42 cm^3 of methanoic acid (90%) to 1 litre with water.

38B Ethanoic acid: related 'higher' monobasic acids

Propanoic acid		Propionic acid	$\text{CH}_3\text{CH}_2\text{COOH}$
Corrosive		R34: Causes burns. Solutions equal to or stronger than 1.3 mol dm^{-3} should be labelled CORROSIVE. Solutions equal to or stronger than 0.6 mol dm^{-3} but weaker than 1.3 mol dm^{-3} should be labelled IRRITANT Flash point: 49°C . WEL (mg m^{-3}): 31 (LTEL), 46 (STEL).	
Store: CLa		Disposal: W1, W4, W7 W4 Use a fume cupboard. W7 Dilute to less than 0.1 mol dm^{-3} .	

Butanoic acid		<i>n</i> -butyric acid	$\text{CH}_3(\text{CH}_2)_2\text{COOH}$
Pentanoic acid		<i>n</i> -valeric acid	$\text{CH}_3(\text{CH}_2)_3\text{COOH}$
Hexanoic acid		<i>n</i> -hexoic acid; caproic acid	$\text{CH}_3(\text{CH}_2)_4\text{COOH}$
Corrosive		R34: Causes burns. All have extremely obnoxious odours and bulk use is best avoided in schools.	
Store: CLa		Disposal: W1, W4	



Dodecanoic acid		Lauric acid	$\text{CH}_3(\text{CH}_2)_{10}\text{COOH}$
Hexadecanoic acid		Palmitic acid	$\text{CH}_3(\text{CH}_2)_{14}\text{COOH}$
Irritant		R36/37/38: Irritating to eyes, respiratory system and skin.	
Store: GOrg		Disposal: W2, W4	



cis-octadec-9-enoic acid ; oleic acid; $\text{CH}_3(\text{CH}_2)_7\text{CHCH}(\text{CH}_2)_7\text{COOH}$	Low hazard	Store: GOrg	Disposal: W4, W8
Octadecanoic acid ; stearic acid; $\text{CH}_3(\text{CH}_2)_{16}\text{COOH}$			


38B Ethanoic acid: related 'higher' monobasic acids**Model risk assessments**

Activity	User	Control measures	Experimental points
Cooling curves	Y7	Wear eye protection.	Octadecanoic acid is often used. (More information about cooling curves can be found in Guide L195, <i>Safer Chemicals, Safer Reactions.</i>)
General use of propanoic acid	Y9	Wear eye protection.	Solutions less than 1.3 mol dm^{-3} propanoic acid are suitable.
Test-tube preparation of esters	Y9	Wear goggles. Use a fume cupboard to dispense the acids.	Mix 10 drops of acid with 10 drops of the alcohol and add 1 or 2 drops of concentrated sulfuric(VI) acid. After warming in a bath of hot water, cool under the tap before adding the mixture to sodium carbonate solution in a beaker. Pupils should be shown how to smell the ester carefully. See <i>Making Esters</i> guidance leaflet PS67-07.
Use of butanoic, pentanoic and hexanoic acids	TT	Wear goggles or a face shield. Wear chemical-resistant gloves and a laboratory coat. Use a fume cupboard.	These acids have extremely obnoxious odours; they also occur naturally in the breakdown of body oils and give rise to the smell of 'body odour'. If they contaminate clothing, they are difficult to remove and the odour can be detected for a long time afterwards. The bottles should be handled in a fume cupboard and small drops can be dispensed into other containers.

38C Ethanoic acid: related substituted and other acids

Chloroethanoic acid		Chloroacetic acid	CH_2ClCOOH
Toxic		R25: Toxic if swallowed. R34: Causes burns. R50: Very toxic to aquatic organisms. Solutions equal to or stronger than 2.6 mol dm^{-3} should be labelled TOXIC. Solutions equal to or stronger than 1 mol dm^{-3} but weaker than 2.6 mol dm^{-3} should be labelled CORROSIVE. Solutions equal to or stronger than 0.4 mol dm^{-3} but weaker than 1 mol dm^{-3} should be labelled HARMFUL. Flash point: 126°C . WEL (mg m^{-3}): 1.2 (LTEL), 3.6 (STEL).	
Dangerous for the environment			
Store: T		Disposal: W1, W4	

Dichloroethanoic acid		Dichloroacetic acid	Cl_2CHCOOH
Trichloroethanoic acid		Trichloroacetic acid	Cl_3COOH
Corrosive		R35: Causes severe burns. R50: Very toxic to aquatic organisms. Solutions equal to or stronger than 0.7 mol dm^{-3} should be labelled CORROSIVE. Solutions equal to or stronger than 0.4 mol dm^{-3} but weaker than 0.7 mol dm^{-3} should be labelled IRRITANT.	
Dangerous for the environment			
Store: CLa		Disposal: W1, W4	

2-hydroxypropanoic acid		Lactic acid	$\text{CH}_3\text{CH}(\text{OH})\text{COOH}$
Irritant		R38: Irritating to skin, R41: Risk of serious damage to eyes.	
Store: CLa		Disposal: W1, W4	


All amino acids Ascorbic acid ; Vitamin C	Low hazard	Store: GOrg	Disposal: W7, W8
Gibberellic acid Hormone rooting powders/gels Indol-3-ylethanoic acid ; indolylacetic acid; indoleacetic acid; IAA Indol-3-ylbutanoic acid ; indolylbutyric acid; indolebutyric acid; IBA	Probably low hazard but suppliers may differ in the information they provide.		

Activity	User	Control measures	Experimental points
Chromatography of amino acids	Y7	-	Use saturated solutions for chromatography work. Only a small volume is required.
General use of vitamin C	Y7	-	For titrations against 0.1% (w/v) DCPIP solution, a 0.1% (w/v) solution of vitamin C solution is prepared.
General use of plant hormones	Y7	-	The solutions used are extremely dilute and LOW HAZARD but are best made up by the technician.
Polylactic acid	Y9	Wear goggles. Do not heat directly. Take care: the materials are very hot.	The boiling point of lactic acid is 122 °C. In a test tube, add about 5 cm ³ of lactic acid and 0.5 cm ³ of 5 mol dm ⁻³ hydrochloric acid with anti-bumping granules. Clamp the test tube upright in a beaker of glycerol. Heat the glycerol so that the lactic acid solution continually boils. After 15 minutes, remove the test tube while holding the clamp and pour some of its contents onto a white tile. The mixture should be more viscous as it cools.
Use of chloro-substituted ethanoic acids	Y12	Wear eye protection.	These are useful to demonstrate the effect of the chlorine group on the acidity of the acid. 0.1 mol dm ⁻³ solutions should be used.
Use of lactophenol for stains & mountants	Y12	Wear goggles. Wear disposable nitrile gloves. Use a fume cupboard.	Dissolve 10 g phenol in 10 cm ³ distilled water (do not heat) and add 10 cm ³ propane-1,2,3-triol and 10 cm ³ lactic acid. Used as a mountant, especially for fungi and as a solvent for stains. It should be labelled TOXIC.
Preparation of plant hormone solutions	TT	Wear eye protection. Consider wearing disposable nitrile gloves.	Hormone rooting powders include chemicals such as indol-3-ylethanoic acid, indol-3-ylbutanoic acid, gibberellic acid and naphthylacetic acid. Technicians should follow the instructions from commercial suppliers when making up solutions.

39 Ethanoic anhydride



Also known as acetic anhydride.

Corrosive		R10: Flammable. R20/22: Harmful by inhalation and if swallowed. R34: Causes burns. WEL (mg m⁻³): 2.5 (LTEL), 10 (STEL). Flash point: 54 °C.
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The substance is dangerous with:	BORIC ACID, CHROMIUM(VI) OXIDE, MANGANATES(VII), NITRIC(V) ACID, PEROXIDES. Violent or explosive reactions may occur. WATER. In the presence of ethanoic acid (which is formed in any case), the reaction can become violent. ETHANOL. If acid is present the reaction is vigorous.
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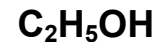
Emergencies: see standard procedures on *Hazard E*, BUT ALSO:

If spilt in the laboratory:	Wear eye protection and chemical-resistant gloves. Ventilate the area as much as possible. Cover with mineral absorbent. Clear up into a bucket and take this to a fume cupboard. Treat with a large excess of water and leave to hydrolyse (at least 12 hours). Rinse the area of the spill thoroughly. After 12 hours, pour the liquid down a foul-water drain. The mineral absorbent can be placed in the waste.
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Store: CW	Disposal: W1, W4 or Wspec Wspec: Use a fume cupboard. Add it to the water in small amounts.
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Activity	User	Control measures	Experimental points
Preparation of cellulose ethanoate	Y12	Wear goggles. Wear chemical-resistant gloves. Use a fume cupboard.	0.5 g of finely-shredded cotton wool is dissolved in a mixture of 20 cm ³ of concentrated ethanoic acid and 5 cm ³ of ethanoic anhydride. Leave for 24 hours before pouring into 500 cm ³ of water. Thin films of the ester can be made by dissolving the ester in dichloromethane in a fume cupboard and allowing the solvent to evaporate.
Preparation of <i>N</i> -phenyl-ethanamide	Y12	Wear goggles. Dispensing of ethanoic anhydride should always take place in a fume cupboard.	Refluxing may be carried out in a well-ventilated laboratory. The apparatus should be cooled before dismantling it in a fume cupboard. A convenient amount is 4 cm ³ each of concentrated ethanoic acid and ethanoic anhydride. After cooling, 4 cm ³ of phenylamine is added slowly. This mixture will need to be refluxed for 30 minutes. After adding the solution to 100 cm ³ of cold water (in a fume cupboard), the crude product forms which can be recrystallised from hot water.
Lack of acidity in 100% ethanoic acid	TT	Wear goggles or a face shield. Wear chemical-resistant gloves. Use a fume cupboard.	Add 1 cm ³ of ethanoic anhydride to 10 cm ³ concentrated ethanoic acid to remove any water present. This makes a mixture that is very dangerous to the eyes. Do not examine at eye-level.

40A Ethanol (IDA)



Schools and colleges usually buy Industrial Denatured Alcohol (IDA) but label it 'ethanol' (pure ethanol is very expensive). IDA is the accepted name for what we used to call Industrial Methylated Spirits (IMS). It consists of ethanol, a little water and 5% methanol which results in the harmful classification. Completely denatured alcohol (CDA) (formally Mineralised Methylated Spirits) contains pyridine (harmful), a chemical with an obnoxious odour, as well as a purple dye. This is not suitable for most uses in laboratories.

Highly flammable		R11: Highly flammable. R22: Harmful if swallowed. WEL (mg m⁻³): 1920 (LTEL), 5760 (STEL).
Harmful (<i>indicating the presence of methanol</i>)		Flash point: 13 °C. There is a danger of very serious irreversible effects through inhalation, in contact with skin and if swallowed. Hence, IDA is more poisonous than ethanol and CDA is even more so. Methanol should not be substituted for ethanol in spirit duplicators or chemical reactions.

The substance is dangerous with:	BROMINE. Violent reaction may occur. MERCURY(II) and SILVER NITRATE(V). Explosive fulminates may be formed. OXIDISING AGENTS. Uncontrollable reactions take place especially with NITRIC(V) ACID. PLATINUM. Finely-divided platinum (eg, platinised electrodes, catalysts) may cause ethanol to burst into flame. POTASSIUM. An explosive reaction may occur.
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Emergencies: see standard procedures on *Hazard E*, BUT ALSO:


If swallowed:	Seek medical attention if victim shows symptoms of intoxication.
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Store: FL The bulk supply should be under lock and key. You need to keep records of the volume that your school orders and uses but this will normally be covered by good stocktaking. When purchasing IDA, the school will need to provide the supplier with the reference number it has received from HM Revenue & Customs (HMRC). If, however, the school address or the volume to be ordered changes, HMRC will need to be informed. Reference numbers obtained before 2005 are still valid. If you need to reapply, download Notice 473 from the HMRC web site. This is best obtained by typing 'Notice 473' into a search engine or using the link on the CLEAPSS web site.	Disposal: W1, W7 W7: Dilute to a 5% (v/v) solution before pouring it down a foul-water drain.
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Activity	User	Control measures	Experimental points
Evaporation and cooling	Y7	-	Surgical spirits BP contains ethanol and is safe to apply to the hand so that the cooling effect can be experienced.
Any activity involving heating	Y7	Wear eye protection. Never use a naked flame to heat a highly flammable liquid.	If no electrically-heated bath is available, half-fill a beaker with boiling water from a kettle. This will provide enough heat to boil the ethanol in a test tube or smaller beaker. If ethanol vapour in a container catches fire, cover the container with a heat-proof mat or a damp cloth.
Extracting pigments from plants	Y7	Wear eye protection. Never use a naked flame to heat a highly flammable liquid.	Eg, chlorophyll. Use the method above but replace hot water in the bath after 5 minutes. Students in Y12 and above could use reflux equipment heated on a boiling-water bath.
As a fuel	Y7	Wear eye protection. Pupils should not fill or refill crucibles or spirit burners.	If small open crucibles are used, they should be placed on a heat-proof mat. Spirit burners for ethanol should not be used with any other fuel. Make sure the wick fits tightly in the holder and the holder fits tightly in the container. See L195, <i>Safer Chemicals, Safer Procedures</i> .
Preparation of ethene	Y9	Wear eye protection. Once enough gas has been collected, the apparatus should be raised out of the water to prevent suck back.	The apparatus used is the same as that for the catalytic cracking of hydrocarbons. Use mineral wool to absorb about 10 cm ³ of ethanol/IDA in a boiling tube. The catalyst can be aluminium oxide, brick or broken unglazed porcelain. Heat the catalyst strongly before warming the ethanol. The gas is collected over water. See <i>Handbook</i> 13.2.
Making esters	Y9	Wear eye protection.	See <i>Hazard</i> 38A.
Oxidation (test-tube scale)	Y9	Wear eye protection.	The reagents used are either acidified potassium dichromate(VI) or potassium manganate(VII). Add the reagents slowly, with stirring, to prevent the reaction becoming too violent. The contents sometimes 'spit out' so position the test tube safely.
Reaction with sodium	Y12	Wear eye protection.	Use an excess of ethanol and pieces of sodium about 2 mm each side. Do not add potassium to ethanol.
Ethanol gun	TT	Wear eye protection. Arrange pupils so that they are not in the firing line.	A 500 cm ³ plastic bottle is used. The cork or bung can travel the length of the laboratory. Do not exceed the stated amounts. See <i>Classic Chemical Demonstrations</i> , RSC, ISBN 1870343387.
'Burning' a £5 note	TT	Wear eye protection.	A 50% (v/v) solution of aqueous ethanol is used. Keep the solution well away from the burning note.

40B Methanol and phenylmethanol

Methanol	Methyl alcohol; wood alcohol	CH ₃ OH
Highly flammable		<p>R11: Highly flammable. R23/24/25: Toxic by inhalation, in contact with skin and if swallowed. R39/23/24/25: Toxic - danger of very serious irreversible effects through inhalation and in contact with skin and if swallowed.</p> <p>Dangerous with: BROMINE. Violent reaction may occur.</p> <p>OXIDISING AGENTS. Uncontrollable reactions take place especially with NITRIC(V) ACID. MERCURY(II) and SILVER NITRATE(V). Explosive fulminates may be formed.</p> <p>PLATINUM. Finely divided platinum (eg, platinised electrodes, catalysts) may cause methanol to burst into flame.</p>
Toxic		<p>POTASSIUM. An explosive reaction may occur.</p> <p>WEL (mg m⁻³): 266 (LTEL), 333 (STEL) (Sk). Flash point: 12 °C.</p> <p>For aqueous solutions between 1 and 10% (v/v), the risk phrase is R68/20/21/22; Harmful: possible risk of irreversible effects through inhalation, in contact with skin and if swallowed.</p>
<p>Store: FL</p> <p>Bottles used regularly in the laboratory should not be more than 500 cm³ in capacity.</p>	<p>Disposal: W1, W2 or W7</p> <p>W7: Dilute to a 1% (v/v) solution before pouring it down a foul-water drain.</p>	

Phenylmethanol	Benzyl alcohol	C ₆ H ₅ CH ₂ OH
Harmful		<p>R20/22: Harmful by inhalation and if swallowed.</p> <p>Flash point: 101 °C.</p>
<p>Store: GOrg</p>	<p>Disposal: W1, W2 or W7</p> <p>W7: Dilute to a 3% (v/v) solution before pouring it down a foul-water drain.</p>	

40B Methanol and phenylmethanol**Model risk assessments**





Activity	User	Control measures	Experimental points
Any activity involving heating	Y7	Wear eye protection. Use a fume cupboard.	Never use a naked flame to heat methanol; if no electrically-heated bath is available, half fill a large beaker with boiling water from a kettle. This will provide enough heat to boil the methanol in a test tube or smaller beaker.
As a fuel	Y7	Wear eye protection. Use a fume cupboard to store and fill the burners. Pupils should not refill burners.	If small open crucibles are used, they should be placed on a heat-proof mat. Spirit burners for methanol should not be used with any other fuel. Make sure the wick fits tightly in the holder and the holder fits tightly in the container. See L195, <i>Safer Chemicals, Safer Procedures</i> and <i>Handbook</i> 9.4.3.
Preparation of bio-diesel	Y9	Wear eye protection.	The catalyst is potassium hydroxide dissolved in methanol. This should be provided for students in stoppered test tubes, into which vegetable oil can be added. Full details can be found in the <i>Bio-diesel</i> guidance leaflet PS67-10.
Making esters	Y9	Wear eye protection.	See <i>Hazard</i> 38A.
Reaction with sodium	Y12	Wear goggles. Use a fume cupboard.	Use an excess of methanol and pieces of sodium about 2 mm each side. If the hydrogen catches fire, place a damp cloth over the container to remove oxygen. Note that potassium is not safe with any alcohol below 2-methylpropan-2-ol in molecular weight.
Oxidation of phenylmethanol	Y12	Wear eye protection.	Oxidation to benzoic acid can be carried out with alkaline potassium manganate(VII) solution. See L195, <i>Safer Chemicals, Safer Procedures</i> . This is a safer alternative to using sodium dichromate(VI) as an oxidising agent.
Catalytic oxidation of methanol (for students)	Y12	Wear goggles	In a fume cupboard, dispense small amounts, eg, 10 drops of methanol in a test tube, and then take this to the open bench near a flame (great care required) so that the hot copper spiral can be heated and inserted into the test tube.
Catalytic oxidation of methanol (demonstration)	TT	Wear goggles. The Bunsen-burner flame should be at least 75 cm away from the demonstration.	Place 25 cm ³ of methanol in a 250 cm ³ conical flask. The methanol is warmed in hot water. A platinum spiral, suspended on a glass rod, is heated in the flame and lowered into the flask. The oscillating reaction lasts for several minutes with the occasional 'pop'. The neck of the conical flask remains hot for some time afterwards.

40C Carbohydrates

D-fructose ; $C_6H_{12}O_6$ D-galactose ; $C_6H_{12}O_6$ D-glucose ; dextrose; $C_6H_{12}O_6$ D-glucose-1-phosphate (dipotassium salt) ; $C_6H_{11}O_5.PO_3K_2.2H_2O$ D-lactose ; $C_{12}H_{22}O_{11}.H_2O$ D-maltose ; $C_{12}H_{22}O_{11}.H_2O$ Sucrose ; sugar; $C_{12}H_{22}O_{11}$ Cellulose Starch (amylose) Dextrin	Low hazard	Store: GOrg	Disposal: W8
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Activity	User	Control measures	Experimental points
Fermentation	Y7	Wear eye protection.	The products should not be tasted in a laboratory or taken home.
Heating	Y7	Wear eye protection.	The products are not poisonous but the odour can be annoying and distracting. Use as small an amount as possible. Test tubes can be difficult to clean. Bottle tops (prepared by preheating them in a fume cupboard to remove the plastic insert) are more suitable.
Hydrolysis of starch	Y7	Wear eye protection.	Use 1 mol dm ⁻³ sulfuric(VI) acid (IRRITANT). The solution should be heated in test tubes in a beaker containing boiling water. Direct heating can result in ejection of liquids. Saliva can be used in place of the acid if suitable precautions are taken; see <i>Handbook</i> 14.4.3.
Reducing sugar tests	Y7	Wear eye protection.	Use Benedict's solution rather than Fehling's solution. The solution should be heated in a boiling water bath to give the red-brown precipitate of copper(I) oxide. Direct heating can result in ejection of liquids. However, Sandell's solution gives a red-brown precipitate at 50 °C.
Regenerating cellulose	Y9	Wear eye protection. Use a fume cupboard.	Dissolve 0.5 g of basic copper(II) carbonate in 25 cm ³ of 10 mol dm ⁻³ ammonia solution (CORROSIVE) to make the cellulose solvent.
Molisch's test	Y12	Wear goggles.	Molisch's reagent contains 5 g of naphthalen-1-ol in 100 cm ³ of ethanol. It should be labelled HIGHLY FLAMMABLE and HARMFUL. After the addition of 4 drops of this reagent to about 0.05 g of the carbohydrate in 1 cm ³ of water, about 1 cm ³ of concentrated sulfuric(VI) acid is added down the side of the test tube to form a lower layer. A violet colour at the interface indicates a carbohydrate.
Preparation of cellulose ethanoate	Y12	Wear goggles. Use a fume cupboard to dispense the ethanoic anhydride.	Mix 20 cm ³ of ethanoic acid, 5 cm ³ of ethanoic anhydride and 0.5 cm ³ of concentrated sulfuric(VI) acid in a beaker. Add, with stirring, 0.5 g of finely-shredded cotton wool. Leave for a day until there are no air bubbles and a clear liquid is obtained. Pour into 500 cm ³ of water to precipitate the cellulose ethanoate.
Making and burning nitrocellulose	TT	Wear goggles or a face shield. Wear chemical-resistant gloves.	The supplementary risk assessment for this demonstration (SRA 14) is available on the CLEAPSS members-only web site and on the <i>Science Publications CD-ROM</i> (2008 onwards).

41 Ethanoyl chloride and other acid chlorides



Ethanoyl chloride		Acetyl chloride	CH_3COCl
Highly flammable		R11: Highly flammable. R14: Reacts violently with water. R34: Causes burns. Flash point: 4 °C.	
Corrosive		Dangerous with: WATER. The reaction is violent, forming choking fumes of hydrogen chloride. AMMONIA and AMINES. The reaction is violent, forming dense, choking, white fumes of ammonium chloride.	
Store: FL Once opened, water vapour enters the bottle and reacts to form hydrogen chloride gas. This gas accelerates corrosion of the flammables cupboard. Store in a plastic bag or other container with anhydrous soda lime or calcium chloride.			Disposal: W1, W4 W4: Use a fume cupboard. Add the liquid in 1 cm ³ amounts. Wait until the reaction is finished before adding more.
Hexanedioyl chloride		Adipoyl chloride	$\text{ClCO}(\text{CH}_2)_4\text{COCl}$
Corrosive		R34: Causes burns. Flash point: 65 °C.	
Decanedioyl dichloride		Sebacoyl chloride	$\text{ClCO}(\text{CH}_2)_8\text{COCl}$
Corrosive		R34: Causes burns. R37: Irritating to respiratory system. Flash point: 165 °C.	
Store: CW Once opened, water vapour enters the bottle and reacts to form hydrogen chloride gas. This gas accelerates corrosion of the flammables cupboard. Store in a plastic bag or other container with anhydrous soda lime or calcium chloride. If there is a solid in the liquid, hydrolysis has occurred.			Disposal: W1, W4 W4: Use a fume cupboard. Add the liquid in 1 cm ³ amounts. Wait until the reaction is finished before adding more.


Emergencies: see standard procedures on *Hazard E*, BUT ALSO:

If spilt in the laboratory:	Wear eye protection and chemical-resistant gloves. Ventilate the area as much as possible. Consider evacuation. Cover with mineral absorbent. Clear up into a bucket and take it to a fume cupboard. Treat with a large excess of water and leave to hydrolyse. Neutralise with sodium carbonate before disposing of the liquid down a foul-water drain. Rinse the area of the spill thoroughly.
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Activity	User	Control measures	Experimental points
Nylon 'rope' preparation for pupils	Y9	Wear goggles. Wear disposable nitrile gloves to handle the nylon. Do not use tetrachloromethane or 1,1,1-trichloroethane as a solvent.	Use no more than 5 cm ³ each of the solutions (see 'demonstration' version below) in a well-ventilated laboratory. Disposal: Nylon, W8. Solutions, W2 because a class may use over 100 cm ³ of cyclohexane.
Reactions of ethanoyl chloride with ammonia and amines	Y12	Wear goggles. Use a fume cupboard.	To 1 cm ³ of concentrated ammonia, methylamine, ethylamine solution or butylamine, add ethanoyl chloride drop by drop. This is not a good preparative method for amides.
Preparation of phenyl amides	Y12	Wear goggles. Use a fume cupboard.	The Schotten-Baumann reaction prepares good yields of substituted amides. Mix reagents, eg, phenylamine, 2 mol dm ⁻³ sodium hydroxide solution and acid chloride in a fume cupboard and stopper the container before removing. The products have sharp melting points.
Nylon 'rope' demonstration	TT	Wear goggles or a face shield. Wear disposable nitrile gloves to handle the nylon. Do not use tetrachloromethane or 1,1,1-trichloroethane as a solvent.	As a demonstration: See <i>Recipe Card</i> 45. Use a solution of 2.2 g 1,6-diaminohexane in 50 cm ³ water (LOW HAZARD) for the lower aqueous layer and 1.5 g decanedioyl chloride or hexanedioyl chloride in 50 cm ³ cyclohexane (HIGHLY FLAMMABLE) for the hydrocarbon layer. The hydrocarbon solution is poured slowly onto the aqueous layer down a glass rod. The nylon forms at the interface and can be pulled out with forceps. Disposal: Nylon, W8.

42 Ethoxyethane and other ethers

Ethoxyethane	Diethyl ether; ether	$C_2H_5OC_2H_5$
Extremely flammable		<p>R12: Extremely flammable. R19: May form explosive peroxides. R22: Harmful if swallowed. R66: Repeated exposure may cause skin dryness or cracking. R67: Vapours may cause drowsiness and dizziness.</p> <p>The liquid vaporises very readily and the heavy vapour may spread over a long distance and 'flash back' from a source of ignition. Do not use in the same room as naked flames, (eg, spirit burners, Bunsen burners).</p>
Harmful		<p>Flash point: -45 °C.</p> <p>WEL (mg m⁻³): 310 (LTEL), 620 (STEL).</p> <p>Dangerous with: OXIDISING AGENTS. The reaction becomes uncontrollable. BROMINE. An explosive reaction may occur. CHLORINE. Ignition occurs on contact.</p> <p>May form explosive peroxides on standing; normally sold with inhibitors to reduce this risk.</p>
<p>Store: FL</p> <p>Do not put anything treated with ether into a refrigerator that is not specially spark-proofed; the door switch may ignite the vapour.</p>		<p>Disposal: W1, W6</p>



Methoxybenzene	Anisole; methyl phenyl ether	$CH_3OC_6H_5$
Irritant		<p>R10: Flammable. R36/37/38: Irritating to eyes, respiratory system and skin.</p> <p>Flash point: 52 °C.</p> <p>It does have a lingering odour.</p>
<p>Store: FL</p> <p>If there is not enough room in the flammables cabinet, this chemical can be stored with General Organic chemicals [GOrg].</p>		<p>Disposal: W1, W2</p>



Do not heat ethoxyethane or boil solutions to dryness because any peroxide present may explode.
Do not attempt to remove peroxides unless the ethoxyethane is to be used immediately since this procedure also removes the inhibitors.

Activity	User	Control measures	Experimental points
Oil-drop investigation	Y9	Wear eye protection. No flames or other sources of ignition should be in the same room.	A solution of 0.1 g of oleic acid in ethoxyethane or petroleum ether (40-60 °C) is used. Ethoxyethane evaporates more rapidly but teachers may prefer using the other solvent. Provide students with small volumes, eg, 5 cm ³ .
Using ethoxyethane to extract organic substances from water	Y12	Wear eye protection. No flames or other sources of ignition should be in the same room.	Release pressure frequently from the separating funnel. It would be better to consider the use of alternative solvents, such as cyclohexane, before having to use ethoxyethane.
Reactions of the aromatic ring using methoxybenzene	Y12	Wear eye protection.	Reactions take place more rapidly than with benzene because of the presence of the -OCH ₃ group. Disposal: The contents of a small-scale reaction, carried out in test tubes, can be flushed down a foul-water drain with plenty of water.
Etherising <i>Drosophila</i>	Y12	Wear eye protection. No flames or other sources of ignition should be in the same room.	It is possible to chill the flies in a fridge, keeping the bottle on its side. Tip them onto a freezer block just removed from the deep freeze. Cover the freezer block with a fine-mesh handkerchief. <i>Fly-Nap</i> is a proprietary alternative, see <i>Bulletins</i> 106 and 107 on the <i>Science Publications CD-ROM</i> .
Freezing water by rapid evaporation of ethoxyethane	TT	Wear eye protection. No flames or other sources of ignition should be in the same room.	It would be better to use a fume cupboard or at least to open all windows in the room. Dichloromethane is an alternative to ethoxyethane.
Testing for peroxide in ethers	TT	Wear eye protection. No flames or other sources of ignition should be in the same room.	Shake a crystal of potassium iodide with about 1 cm ³ of concentrated ethanoic acid in a test tube. Add an equal volume of the ethoxyethane. An immediate yellow colouration indicates the presence of peroxide and red or brown colours indicate a dangerous level. It is best to carry out a control test using ethanol for comparison.
Removal of peroxides from ethers	TT	Wear eye protection. No flames or other sources of ignition should be in the same room.	Shake in a separating funnel with roughly half the volume of 1 mol dm ⁻³ iron(II) sulfate(VI) solution. Separate and test again for peroxide. Dry with anhydrous sodium sulfate(VI). Do not store after this treatment: use or dispose of immediately.
Euthanasia of animals	TT	Wear eye protection. Use a fume cupboard.	See <i>Handbook</i> 14.1 for a full discussion of this issue.

43A Ethyl and methyl ethanoate

(see also 43B)

Ethyl ethanoate		Ethyl acetate	$\text{CH}_3\text{COOC}_2\text{H}_5$
Highly flammable		R11: Highly flammable. R36: Irritating to eyes. R66: Repeated exposure may cause skin dryness or cracking. R67: Vapours may cause drowsiness and dizziness. Flash point: $-4\text{ }^{\circ}\text{C}$. WEL (mg m^{-3}): 681 (LTEL), 1362 (STEL).	
Irritant			
Store: FL		Disposal: W1, W2 or W7 W7: Add no more than 50 cm^3 to 1 litre of water and pour down a foul-water drain.	








Methyl ethanoate		Methyl acetate	$\text{CH}_3\text{COOCH}_3$
Highly flammable		R11: Highly flammable. R36: Irritating to eyes. R66: Repeated exposure may cause skin dryness or cracking. R67: Vapours may cause drowsiness and dizziness. Flash point: $-13\text{ }^{\circ}\text{C}$. WEL (mg m^{-3}): 616 (LTEL), 770 (STEL).	
Irritant			
Store: FL		Disposal: W1, W2 or W7 W7: Add no more than 50 cm^3 to 1 litre of water and pour down a foul-water drain.	

43A Ethyl and methyl ethanoate**Model risk assessments**

Activity	User	Control measures	Experimental points
Test-tube preparation of esters	Y9	Wear goggles. Pupils could be provided with test tubes containing 1 drop of concentrated sulfuric(VI) acid.	Mix 5-10 drops of a concentrated carboxylic acid with 5-10 drops of an alcohol and add 1-2 drops of concentrated sulfuric(VI) acid. After warming in a bath of hot water, cool under the tap before adding the mixture to sodium carbonate solution in a beaker. Pupils should be shown how to smell the ester carefully.
Saponification of esters	Y9	Wear goggles.	This is best carried out with <i>Quickfit</i> apparatus because refluxing using 2 cm ³ of the ester with 20 cm ³ of 2 mol dm ⁻³ sodium hydroxide solution (CORROSIVE) is required until the immiscible layers merge into one.
Preparation of esters on a large scale	Y12	Wear goggles.	Use <i>Quickfit</i> apparatus. Concentrated sulfuric(VI) acid is used as the catalyst. Make sure the acid, alcohol and sulfuric(VI) acid are mixed well before refluxing begins.
Equilibrium mixtures	Y12	Wear goggles.	Concentrated hydrochloric acid will be added to the ethyl ethanoate/ethanoic acid/water mixtures as a catalyst. A suitably-labelled storage cupboard must be provided because mixtures take a few days to reach equilibrium. Methyl ethanoate can be used as well.
Rate of saponification	Y12	Wear eye protection.	The solutions of sodium hydroxide and ethyl ethanoate or methyl ethanoate are usually less than 0.05 mol dm ⁻³ .
Boiling points of mixtures	Y12	Wear eye protection. Use a fume cupboard.	Negative deviation from Raoult's law can be demonstrated using mixtures of ethyl ethanoate and trichloromethane.
Enthalpy of mixing	Y12	Wear eye protection. Use a fume cupboard.	Addition of trichloromethane to ethyl ethanoate in a test tube insulated with mineral wool produces a temperature rise. Hydrogen-bond strength measurements can be made.

43B Esters other than ethyl and methyl ethanoate

(See also 43A)




Propyl ethanoate		<i>n</i> -propyl acetate	$\text{CH}_3\text{COOC}_3\text{H}_7$
Highly flammable		R11: Highly flammable. R36: Irritating to eyes. R66: Repeated exposure may cause skin dryness or cracking. R67: Vapours may cause drowsiness and dizziness. WEL (mg m^{-3}): 849 (LTEL), 1060 (STEL). Flash point: 14 °C.	
Irritant			
Butyl ethanoate		<i>n</i> -butyl acetate	$\text{CH}_3\text{COOC}_4\text{H}_9$
Harmful		R10: Flammable. R66: Repeated exposure may cause skin dryness or cracking. R67: Vapours may cause drowsiness and dizziness. WEL (mg m^{-3}): 724 (LTEL), 966 (STEL). Flash point: 22 °C.	
Pentyl ethanoate		<i>n</i> -amyl acetate; pentyl acetate	$\text{CH}_3\text{COOC}_5\text{H}_{11}$
Harmful		R10: Flammable. R60: May impair fertility. WEL (mg m^{-3}): 270 (LTEL), 541 (STEL). Flash point: 25 °C.	
(3-methylbutyl) ethanoate		<i>iso</i> -amyl acetate	$\text{CH}_3\text{COOC}_5\text{H}_{11}$
Harmful		R10: Flammable. R66: Repeated exposure may cause skin dryness or cracking. Flash point: 23 °C.	
Store: FL		Disposal: W1, W2	
Methyl 2-methylpropenoate		Methyl methacrylate	$\text{CH}_2\text{C}(\text{CH}_3)\text{COOCH}_3$
Highly flammable		R11: Highly flammable. R37/38: Irritating to respiratory system and skin. R43: May cause sensitisation by skin contact. (The vapour is lachrymatory.) WEL (mg m^{-3}): 208 (LTEL), 416 (STEL). Flash point: 8 °C.	
Irritant			
Store: FL In time, it becomes viscous and solidifies into a resin.		Disposal: W1 (If it has polymerised into a resin, then W8.)	


43B Esters other than ethyl and methyl ethanoate**Model risk assessments**

Activity	User	Control measures	Experimental points
Test-tube preparation of the esters of ethanoic acid with larger alcohol groups	Y9	Wear goggles.	Mix 5-10 drops of a concentrated carboxylic acid with 5-10 drops of an alcohol and add 1-2 drops of concentrated sulfuric(VI) acid. After warming in a bath of hot water, cool under the tap before adding the mixture to sodium carbonate solution in a beaker. Pupils should be shown how to smell the ester carefully. Disposal: These esters are insoluble in water. However, very small amounts are used and they can be washed down a foul-water drain with plenty of water.
Saponification of esters from larger alcohol groups	Y9	Wear goggles.	This is best carried out with <i>Quickfit</i> apparatus because refluxing using 2 cm ³ of the ester with 20 cm ³ of 2 mol dm ⁻³ sodium hydroxide solution (CORROSIVE) is required until the immiscible layers merge into one.
Perspex preparation from methyl 2-methylpropenoate	Y12	Wear goggles. Use a fume cupboard.	The inhibitor should be removed first. Wear chemical-resistant gloves when handling methyl 2-methylpropenoate. Heat on a hot water bath. See <i>Hazard</i> 29.
Decomposing polyacrylates	Y12	Wear goggles. Use a fume cupboard. Wear disposable nitrile gloves.	The polymer is heated and degrades into the monomer. It is collected by distillation. Be careful not to ignite the vapour as it condenses.
Removing the inhibitor from methyl 2-methylpropenoate	Y12	Wear goggles. Use a fume cupboard. Wear disposable nitrile gloves.	Methyl 2-methylpropenoate should be agitated with a similar volume of 1 mol dm ⁻³ sodium hydroxide solution in a separating funnel. After removing the aqueous layer, the ester is agitated with a similar volume of water. After removing the water, the ester is placed in a conical flask to which anhydrous sodium sulfate(VI) is added to remove more water.

44A Halogenoalkanes: chloroalkanes

(See also 99, 100, 103 & 104)






1-chloropropane		<i>n</i> -propyl chloride	C ₃ H ₇ Cl
Highly flammable		R11: Highly flammable. R20/21/22: Harmful by inhalation, in contact with skin and if swallowed. Dangerous with: SODIUM. An explosive reaction may occur. Flash point: -19 °C.	
Harmful			
1-chlorobutane		<i>n</i> -butyl chloride	C ₄ H ₉ Cl
2-chlorobutane		<i>sec</i> -butyl chloride	C ₂ H ₅ CH(Cl)CH ₃
2-chloro-2-methylpropane		<i>tert</i> -butyl chloride	(CH ₃) ₃ CCl
Highly flammable		R11: Highly flammable. Dangerous with: SODIUM. An explosive reaction may occur. Flash points: 1-chlorobutane -9 °C; 2-chlorobutane 5 °C; 2-chloro-2-methylpropane -30 °C.	
Store: FL		Disposal: W1, W2	


Chloromethylbenzene		Benzyl chloride	C ₆ H ₅ CH ₂ Cl
Toxic		R45: May cause cancer. Category 2 carcinogen. R23: Toxic by inhalation. R22: Harmful if swallowed. R48/22: Harmful: danger of serious damage to health by prolonged exposure if swallowed. R37/38: Irritating to respiratory system and skin. R41: Risk of serious damage to eyes. WEL (mg m⁻³): 2.6 (LTEL), 7.9 (STEL). Flash point: 67 °C.	
Store: T		Disposal: W1, W2	



44A Halogenoalkanes: chloroalkanes**Model risk assessment**

Activity	User	Control measures	Experimental points
Hydrolysis of halogeno-alkanes (qualitative comparison of reaction rate)	Y12	Wear eye protection.	On a test-tube scale, 0.1 mol dm^{-3} silver nitrate(V) is used to monitor the production of halide ions at 50°C . Spills on the bench must be wiped up quickly to avoid silver nitrate(V) stains. Care must be taken during heating because ethanol is used. Disposal: W7 because amounts used are very small.
2-chloro-2-methylpropane preparation	Y12	Wear eye protection. Wear disposable nitrile gloves. The room should be well ventilated.	5 cm^3 of 2-methylpropan-2-ol is mixed with 15 cm^3 of concentrated hydrochloric acid in a separating funnel. This is agitated for 10 minutes and separated. The correct use of separating funnels should be demonstrated.
Rates of the hydrolysis of 2-chloro-2-methylpropane	Y12	Wear eye protection.	Any solvents used may present a greater hazard because solutions are dilute.
Chloromethylbenzene in hydrolysis reactions	TT	Wear eye protection. Use a fume cupboard.	It is often used in comparison with chlorobenzene which does not hydrolyse. Chloromethylbenzene has a pernicious odour and is best used only in a fume cupboard. Very small amounts (eg, up to 5 cm^3) should be washed away thoroughly down a foul-water drain.

44B Halogenoalkanes: bromo- and iodoalkanes (See also 99, 100, 103 & 104)

Bromoethane		Ethyl bromide	C_2H_5Br
Highly flammable Harmful	 	R11: Highly flammable. R40: Limited evidence of a carcinogenic effect. Category 3 carcinogen. R20/22: Harmful by inhalation and if swallowed. Flash point: -20 °C.	
2-bromobutane		sec-butyl bromide	$C_2H_5CH(Br)CH_3$
2-bromo-2-methyl propane		tert-butyl bromide	$(CH_3)_3CBr$
Highly flammable		R11: Highly flammable.	
1-bromobutane		n-butyl bromide	C_4H_9Br
Highly flammable Irritant	 	R11: Highly flammable. R36/37/38: Irritating to eyes, respiratory system and skin.	
Store: FL		Disposal: W1, W2	

Iodoethane		Ethyl iodide	C_2H_5I
Irritant		R10: Flammable. R36/37/38: Irritating to eyes, respiratory system and skin. Flash point: 53 °C.	
Store: GOrg		Disposal: W1, W2	











1-iodopropane		n-propyl iodide	C_3H_7I
Irritant		R10: Flammable. R36/37/38: Irritating to eyes, respiratory system and skin.	
1-iodobutane		n-butyl iodide	C_4H_9I
Harmful		R10: Flammable. R20/21: Harmful by inhalation and in contact with skin.	
Store: FL These can be stored with General Organic chemicals [GOrg]. They discolour on standing.			Disposal: W1, W2

For emergencies, see *Hazard E* as well as more detailed information which may be on this *Hazard*.

Activity	User	Control measures	Experimental points
Hydrolysis of halogenoalkanes	Y12	Wear eye protection.	On a test-tube scale, 0.1 mol dm^{-3} silver nitrate(V) is used to monitor the production of halide ions at 50°C . Spills on the bench must be wiped up quickly. Care must be taken during heating because ethanol is used. Disposal: W7 because amounts used are very small.
Preparation of bromoethane	Y12	Wear eye protection. The room should be well ventilated.	Ensure thorough mixing and cooling when sulfuric(VI) acid is added in small amounts (eg, 0.5 cm^3) to ethanol. Then add sodium bromide. The distillate should be collected under water and not purified further.
Preparation of iodoethane and 1-iodobutane	Y12	Wear eye protection.	Suggested amounts for <i>Quickfit</i> apparatus are (i) 5 cm^3 of ethanol, 0.5 g of red phosphorus and 5 g of iodine and (ii) 5 cm^3 of butan-1-ol, 0.75 g of red phosphorus and 6.5 g of iodine. These reactions start immediately, so reflux attachments must be ready.
Finkelstein reaction	Y12	Wear eye protection. Work on a test-tube scale.	A 6% (w/v) solution of sodium iodide in propanone is used. It reacts with primary bromoalkanes producing sodium bromide as a precipitate, but not with tertiary bromoalkanes.
Preparation of 1-bromobutane	Y12	Wear eye protection. Wear chemical-resistant gloves when adding concentrated sulfuric(VI) acid to the separating funnel.	The most convenient preparation involves the reaction between butan-1-ol with a mixture of potassium bromide and concentrated sulfuric(VI) acid (ie, hydrobromic acid). The room should be well ventilated because small amounts of hydrogen bromide and sulfur dioxide gas are produced. Use <i>Quickfit</i> apparatus. Ensure that if a one-necked flask is used, there is a still-head placed between the separating funnel and condenser. The apparatus should be checked by the teacher before addition of the acid. The flask should be cooled in a beaker of cold water as the acid is added and swirled well to ensure mixing after each addition. It is dangerous to start refluxing if the mixing is not thorough.

45A Hydrocarbons: aliphatic, saturated (1)

(See also 45B & 45C)




Methane ; Marsh gas; CH ₄		Ethane ; C ₂ H ₆	Propane ; C ₃ H ₈	Butane ; C ₄ H ₁₀
Extremely flammable		R12: Extremely flammable. These are asphyxiants. Propane and butane, the constituents of LPG gas, are heavier than air. Flash points: Methane -221 °C; Ethane -130 °C; Propane -104 °C; Butane -60 °C.		
Store: Situ		Disposal: W6		
Pentane		<i>n</i> -pentane	C ₅ H ₁₂	
Petroleum spirit 40-60 °C		Petroleum ether 40-60 °C		
Extremely flammable Harmful Dangerous for the environment	  	R12: Extremely flammable. R51/53: Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. R65: Harmful: may cause lung damage if swallowed. R66: Repeated exposure may cause skin dryness or cracking. R67: Vapours may cause drowsiness and dizziness. WEL (mg m⁻³): 1800 (LTEL) 5400 (STEL) - pentane only. Flash point: Pentane -43°C.		
Hexane		<i>n</i> -hexane	C ₆ H ₁₄	
Petroleum spirit 60-80 °C		Petroleum ether 60-80 °C		
Highly flammable Harmful Dangerous for the environment	  	R11: Highly flammable. R38: Irritating to skin. R48/20: Harmful: danger of serious damage to health by prolonged exposure through inhalation. R51/53: Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. R62: Possible risk of impaired fertility. R65: Harmful: may cause lung damage if swallowed. R67: Vapours may cause drowsiness/dizziness. WEL (mg m⁻³): 72 (LTEL), 216 (STEL) - hexane only. Flash point: Hexane -22 °C.		
Heptane		<i>n</i> -heptane	C ₇ H ₁₆	
Petroleum spirit 80-100 °C, 100-120 °C or 120-160 °C			Petroleum ether 80-100 °C, 100-120 °C or 120-160 °C	
Highly flammable Harmful Dangerous for the environment	  	R11: Highly flammable. R38: Irritating to skin. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. R65: Harmful: may cause lung damage if swallowed. R67: Vapours may cause drowsiness and dizziness. Flash point: Heptane -4 °C.		
Store: FL		Disposal: W1, W2 or W6		


45A Hydrocarbons: aliphatic, saturated (1)**Model risk assessments**

Activity	User	Control measures	Experimental points
The Bunsen burner	Y7	Wear eye protection.	Full instructions should be given for its use and ignition. Pupils must not lean over the flame. See <i>Handbook</i> 9.10. The type of Bunsen burner depends on whether the fuel is methane or LPG. LPG is denser than air, which leads to slower dispersion from a leak and the gas can accumulate in sinks or other low-level areas. Luminous flames of LPG are noticeably smokier than methane flames.
Fractional distillation of synthetic 'crude oil'	Y7	Wear eye protection. Genuine crude oil contains more than 0.1% benzene; it must not be used in schools. See <i>Recipe Card</i> 20.	To make the solution appear black, add 1 small measure of black oil paint (eg, Winsor and Newton's Ivory Black, available from art shops). Heating may be done with a Bunsen burner because the amount of highly flammable material is small. More information can be found in Guide L195, <i>Safer Chemicals</i> , <i>Safer Reactions</i> and <i>Handbook</i> 13.2.
General use as solvents	Y7	Wear eye protection. Switch off any naked flames close by.	Y7 should use heptane, cyclohexane or petroleum spirit 80-100 °C or 100-120 °C. Warming should be carried out using hot water from a kettle. Particular care must be taken if the solvent is distilled or refluxed. Y12 pupils can use lower boiling-point solvents when dispensed from a fume cupboard.
Combustion of fuels	Y7	Wear eye protection. Pupils should not fill or refill crucibles or spirit burners.	Small amounts, eg, 1 cm ³ of liquid absorbed on mineral wool or placed in a crucible, seated on a heat-proof mat, may be used to illustrate burning. For quantitative work, spirit burners should be used. Each should always be used with a particular hydrocarbon. Make sure the wick fits tightly in the holder and the holder fits tightly in the container. See L195, <i>Safer Chemicals</i> , <i>Safer Procedures</i> and <i>Handbook</i> 9.4.3.
Winter and summer fuel	Y12	Wear eye protection.	Use petroleum spirit 40-60 °C (winter) and petroleum spirit 80-100 °C (summer). Commercial petrol contains benzene; it must not be used.
Methane and the exploding tin	TT	Wear eye protection. Use safety screens.	The demonstrator and pupils should stand more than 2 m away, protected by safety screens and wearing eye protection. When natural gas is being fed into a tin, allow time for the air to be displaced before lighting the gas. The volume of the tin should not exceed 1 litre because the time it takes for the gas to explode can be very long.
Reducing copper(II) oxide	TT	See <i>Hazard</i> 26.	



45B Hydrocarbons: aliphatic, saturated (2)

(See also 45A & 45C)

Cyclohexane		C ₆ H ₁₂
Highly flammable Harmful Dangerous for the environment	  	R11: Highly flammable. R65: Harmful: may cause lung damage if swallowed. R38: Irritating to skin. R67: Vapours may cause drowsiness and dizziness. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. WEL (mg m⁻³): 350 (LTEL), 1050 (STEL). Flash point: -20 °C.
Store: FL		Disposal: W1, W2

Paraffin	Kerosene	
Harmful		R65: Harmful: may cause lung damage if swallowed. Flash point: 58 °C.
Store: GOrg		Disposal: W1, W2

Paraffin oil; liquid paraffin; medicinal paraffin; oil, for baths	Low hazard	Store: GOrg	Disposal: Wspec Add to an absorbent such as cat litter, sand or newspaper and place it in the normal refuse.
Paraffin wax			Disposal: W8












White spirit	Turpentine substitute		
Harmful Dangerous for the environment	 	R10: Flammable. R51/53: Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. R65: Harmful: may cause lung damage if swallowed. Flash point: 39 °C.	
Store: FL If there is not enough room in the flammables cabinet, this chemical can be stored with General Organic chemicals [GOrg].		Disposal: W1, W2	

45B Hydrocarbons: aliphatic, saturated (2)**Model risk assessments**

Activity	User	Control measures	Experimental points
Nightlights and candles	Y7	Establish a safe position on the bench.	Warn that pupils should not bend or reach over a flame in case their clothes are set alight.
Burning samples	Y7	Wear eye protection. The room should be well ventilated to remove smoke.	Small amounts, eg, 1 cm ³ , of liquid work well, absorbed onto mineral wool or placed in a crucible. Commercial fuels contain other additives and are not suitable for burning in the open laboratory.
Viscosity of engine-oil	Y7	Wear eye protection. Wear disposable nitrile gloves.	Do not use 'used' oil. Avoid skin contact. Do not heat above about 70°C. Propane-1,2,3-triol (glycerol) is a suitable alternative and disposal is easier.
Cyclohexane as a solvent	Y9	Wear eye protection. Switch off any naked flames close by.	Cyclohexane is used as an alternative to tetrachloromethane to dissolve bromine. There is a photochemical reaction but it is slow in rooms with no sunlight or artificial lighting. Solutions will keep if they are kept in a cupboard or dark bottle. The solution should be made by a teacher or technician. Cyclohexane is also used in nylon 'rope' demonstrations.
Cracking a hydrocarbon	Y9	Wear eye protection. Warn against water sucking back into a hot test tube which will break it.	Use liquid paraffin as the hydrocarbon, on mineral wool. The catalyst is aluminium oxide, broken brick or clay flower pot. The catalyst should be heated as hot as possible before the hydrocarbon is heated. The gas, which is collected over water, is HIGHLY FLAMMABLE . Once enough test tubes of gas have been prepared, disconnect the apparatus to avoid suck back of water. To test for unsaturated hydrocarbons, use 1-2 cm ³ of very dilute (eg, 0.005 mol dm ⁻³) bromine water. A trap can be inserted between the reaction and gas collection; this is not only a safety feature but also collects liquid alkenes. See <i>Handbook</i> 13.2.
Melting-point determinations	Y9	Wear eye protection. Apparatus will be very hot.	Medicinal paraffin can be used as a heating medium for substances with temperatures up to 250 °C. See <i>Handbook</i> 13.7 for details of equipment.










45C Hydrocarbons: aliphatic & unsaturated

(See also 45A & 45B)

Ethene		Ethylene	C ₂ H ₄
Extremely flammable		R12: Extremely flammable. R67: Vapours may cause drowsiness and dizziness. Flash point: -136 °C.	
Ethyne		Acetylene	C ₂ H ₂
Extremely flammable		R5: Heating may cause an explosion. R6: Explosive with or without contact with air. R12: Extremely flammable.	
Store: Situ			Disposal: W6
Cyclohexene			C ₆ H ₁₀
Highly flammable Harmful	 	R11: Highly flammable. R21/22: Harmful in contact with skin and if swallowed. WEL (mg m⁻³): 1020 (LTEL), 3060 (STEL). Flash point: -7 °C. Dangerous with: CONCENTRATED SULFURIC(VI) ACID. An exothermic reaction occurs which can spray the acid over the user.	
Hex-1-ene		Hexene; <i>n</i> -hexylene	CH ₃ (CH ₂) ₃ CHCH ₂
Highly flammable Irritant	 	R11: Highly flammable. R36/37/38: Irritating to eyes, respiratory system and skin. R18: In use, may form flammable/explosive vapour-air mixture. Flash point: -26 °C.	
Oct-1-ene		1-octene	CH ₂ CH(CH ₂) ₅ CH ₃
Highly flammable Harmful Dangerous for the environment	  	R11: Highly flammable. R36/38: Irritating to eyes and skin. R51/53: Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. R1: Explosive when dry. R65: Harmful: may cause lung damage if swallowed. Flash point: 21 °C.	
D-(+)-dipentene		Limonene	C ₁₀ H ₁₆
Irritant Dangerous for the environment	 	R10: Highly flammable. R37: Irritating to respiratory system. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. Flash point: 43 °C.	
Store: FL Peroxides form during storage. Substances have unpleasant odours.			Disposal: W1, W2




Activity	User	Control measures	Experimental points
Burning samples	Y7	Wear eye protection. The room should be well ventilated to remove smoke.	Small amounts, eg, 1 cm ³ , of liquid work well, absorbed onto mineral wool or placed in a crucible. Commercial fuels contain other additives and are not suitable for burning in the open laboratory.
Small-scale reactions of liquid alkenes	Y9	Wear eye protection. The room should be well ventilated to remove smoke. Dispense liquid from a fume cupboard or have it in stoppered test tubes.	Use about 5-10 drops of the alkene. Use cyclohexene, limonene, oct-1-ene or hex-1-ene. Reactions between conc. sulfuric(VI) acid and alkenes are very exothermic and should be limited to 3 drops of the acid added to 3 drops of alkene. Limonene has a more-pleasant odour. Disposal: Place the test tubes in a basin of water in the fume cupboard. Pour the water down a foul-water drain with more water.
Extraction of limonene	Y9	Wear eye protection.	See Guidance leaflet PS67-03 for practical details and more comment. A blender can cut orange skins more quickly and safely than a knife!
Small-scale reactions of ethyne	Y12	Wear eye protection.	Use 2 or 3 small pieces of calcium dicarbide in a test tube and add 2-3 drops of water at a time, collecting ethyne in a test tube over water. Pass the gas into bromine water, acidified potassium manganate(VII) or alkaline potassium manganate(VII) solutions.
Iodine number of vegetable oils	Y12	Wear goggles. Use a fume cupboard.	Once Wij's solution has been added to the vegetable oil and the bottle sealed, this can be removed from the fume cupboard. The titration against 0.1 mol dm ⁻³ sodium thiosulfate solution into the bottle can be carried out in the open laboratory with care. 1 cm ³ of dichloromethane can be added to follow the loss of iodine in the titration. A safer alternative, using bromine water prepared in situ, is on PS67-01.
Preparation of dicopper(I) or disilver ethynediide	TT	Wear goggles or a face shield. Do not isolate the products because they are explosive.	Ammoniacal copper(I) chloride is prepared by dissolving 1 g of copper(I) chloride in 1 cm ³ of 2 mol dm ⁻³ ammonia solution. Ammoniacal silver nitrate(V) solution is prepared by adding 2 mol dm ⁻³ ammonia solution dropwise to 1 cm ³ of 0.3 mol dm ⁻³ silver nitrate(V) until the brown precipitate dissolves. In both cases, pass the gas through the solution to precipitate red dicopper(I) ethynediide or cream disilver ethynediide. Do not isolate the solids. Disposal: Flush the solids, with lots of water, down a foul-water drain.

46 Hydrocarbons: aromatic

Benzene		<chem>C6H6</chem>
Highly flammable Toxic	 	R45: May cause cancer. Category 1 carcinogen. R46: May cause heritable genetic damage. R11: Highly flammable. R48/23/24/25: Toxic: danger of serious damage to health by prolonged exposure through inhalation, in contact with skin and if swallowed. R65: Harmful: may cause lung damage if swallowed. R36/38: Irritating to eyes and skin. Flash point: -11 °C. This substance is banned from use in schools under the COSHH Regulations.
Store: FL (pending disposal)		Disposal: W1
Methylbenzene		Toluene <chem>C6H5CH3</chem>
Highly flammable Harmful	 	R11: Highly flammable. R38: Irritating to skin. R48/20: Harmful: danger of serious damage to health by prolonged exposure through inhalation. R63: Possible risk of harm to the unborn child. Category 3 teratogen. R65: Harmful: may cause lung damage if swallowed. R67: Vapours may cause drowsiness and dizziness. It is absorbed through the skin. WEL (mg m⁻³): 191 (LTEL), 384 (STEL) (Sk). Flash point: 4 °C.
Store: FL		Disposal: W1, W2
Naphthalene		<chem>C10H8</chem>
Harmful Dangerous for the environment	 	R40: Limited evidence of a carcinogenic effect. Category 3 carcinogen. R22: Harmful if swallowed. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. WEL (mg m⁻³): 10 (LTEL), 30 (STEL). Flash point: 80 °C.
Store: GOrg		Disposal: W1, W2
Dimethylbenzene (isomers)		<i>o</i> -, <i>m</i> - and <i>p</i> -xylene <chem>(CH3)2C6H4</chem>
Harmful		R10: Flammable. R20/21: Harmful by inhalation and in contact with skin. R38: Irritating to skin. WEL (mg m⁻³): 220 (LTEL), 441 (STEL) (Sk).
Store: FL		Disposal: W1, W2
Acenaphthene		<chem>C12H10</chem>
Irritant Dangerous for the environment	 	R36/37/38: Irritating to eyes, respiratory system and skin. Harmful if swallowed. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.
Store: GOrg		Disposal: W1, W2

Activity	User	Control measures	Experimental points
Using naphthalene for melting points, cooling curves or testing conductivity	Y7	Wear eye protection.	Do not heat naphthalene in open boiling tubes on a class basis. However, the vapour level in the room can be reduced by inserting mineral wool in the neck of the boiling tube during heating. Use a fresh plug each time. Alternatives to naphthalene are hexadecan-1-ol, octadecan-1-ol, hexadecanoic acid, octadecanoic acid and phenyl salicylate. Use purer grades and smaller quantities (ie, test-tube scale) than are usual with naphthalene. The time for solidification at the melting point is longer than for similar amounts of naphthalene. Use hot water for melting all of them. See Guide L195, <i>Safer Chemicals, Safer Reactions</i> .
Purification or crystallisation of naphthalene	Y7	Wear eye protection.	Wear eye protection. Phenyl benzoate is a suitable alternative to naphthalene. Ethanol is a suitable solvent and should be warmed using a bath of hot water.
Nitration of aromatic rings	Y12	Wear goggles & chemical-resistant gloves when dispensing concentrated acids.	Use methyl benzoate in place of methylbenzene, naphthalene or benzene. See Guide L195, <i>Safer Chemicals, Safer Reactions</i> .
Dissolving sulfur	Y12	Wear eye protection. Use a fume cupboard.	Use dimethylbenzene rather than methylbenzene because it presents a reduced fire hazard at the temperatures involved in the preparation of monoclinic sulfur; see <i>Hazard</i> 96A. Use a bath of hot paraffin oil (see <i>Hazard</i> 45B) or fresh propane-1,2,3-triol for heating the solution to about 130 °C. See also <i>Hazard</i> 106.
Aromatic ring reactions	Y12	Wear eye protection. Bromination and any warming (which ought to be unnecessary) should be carried out in a fume cupboard.	Reactions on a test-tube scale can be carried out in the open laboratory with methylbenzene and/or methoxybenzene, the latter being more reactive. Use no more than 0.5 cm ³ of the reagent.

47A Hydrochloric acid and other hydrohalic acids

Hydrochloric acid		HCl (aq)
Corrosive		<p>R34: Causes burns. R37: Irritating to respiratory system.</p> <p>Solutions equal to or stronger than 6.5 mol dm^{-3} should be labelled CORROSIVE. Solutions equal to or stronger than 2 mol dm^{-3} but weaker than 6.5 mol dm^{-3} should be labelled IRRITANT.</p> <p>WEL (mg m^{-3}): 2 (LTEL), 8 (STEL).</p>
Hydrobromic acid		HBr(aq)
Corrosive		<p>R34: Causes burns. R37: Irritating to respiratory system.</p> <p>Solutions equal to or stronger than 4.5 mol dm^{-3} should be labelled CORROSIVE. Solutions equal to or stronger than 1.2 mol dm^{-3} but weaker than 4.5 mol dm^{-3} should be labelled IRRITANT.</p> <p>WEL (mg m^{-3}): 10 (STEL). Purchase the 48% (w/w) acid.</p>
Hydroiodic acid		HI(aq)
Corrosive		<p>R34: Causes burns.</p> <p>Solutions equal to or stronger than 0.7 mol dm^{-3} should be labelled CORROSIVE. Solutions equal to or stronger than 0.3 mol dm^{-3} but weaker than 0.7 mol dm^{-3} should be labelled IRRITANT. Purchase the 55% (w/w) acid.</p>
These substances are dangerous with:	<p>ALUMINIUM, MAGNESIUM, CALCIUM, SODIUM and many other reactive metals. A vigorous or violent reaction occurs.</p> <p>PHOSPHORIC(V) ACID. Hydrogen halide gas is released.</p> <p>POTASSIUM MANGANATE(VII). Explosions can occur.</p> <p>SULFURIC ACID. Hydrogen halide gas is released.</p>	
<p>Store: CLa</p> <p>Store large containers at a low level, preferably in a tray to contain spills. Once bottles are opened, gases can leak into the store; this accelerates the corrosion of metals. The gases can also diffuse through plastic so that labels on the containers fade and disintegrate. The gases react with ammonia and amines to deposit a white powder over bottles.</p>		<p>Disposal: W1, W4</p> <p>W4: Use a fume cupboard.</p>


For emergencies, see *Hazard* E as well as more detailed information which may be on this *Hazard*.

47A Hydrochloric acid and other hydrohalic acids


Model risk assessments

Activity	User	Control measures	Experimental points
Use of dilute acids	Y7	Wear eye protection.	This refers to solutions equal to or less than 2 mol dm^{-3} . Use the most-dilute solution which produces the desired result. Guidance can be found in L195, <i>Safer Chemicals</i> , <i>Safer Reactions</i> .
Use of concentrated acids	Y9	Wear goggles. Use a fume cupboard. Wear disposable nitrile gloves.	Acids, more concentrated than 2 mol dm^{-3} , may be used with careful supervision. Security is important; bottles of concentrated acids have been stolen.
Preparation of chlorine	Y12	Wear goggles. Use a fume cupboard.	See <i>Hazard</i> 89 for a safe, controllable method using 5 mol dm^{-3} hydrochloric acid. See <i>Handbook</i> 13.3.
Preparation of solutions	Y12	Wear goggles. Use a fume cupboard. Wear chemical-resistant gloves.	See <i>Recipe Card</i> 31 for hydrochloric acid. A 1 mol dm^{-3} solution is prepared by diluting 113 cm^3 of 48% hydrobromic acid to 1 litre with water. A 1 mol dm^{-3} solution is prepared by diluting 137 cm^3 of 55% hydroiodic acid to 1 litre with water.
Large-scale-preparation of chlorine	TT	Wear goggles or a face shield. Use a fume cupboard. Wear chemical-resistant gloves.	The reaction between concentrated hydrochloric acid and potassium manganate(VII) has caused several accidents by the inadvertent use of the wrong acid. If this method is used, double check that the correct acid is available and cover the potassium manganate(VII) with water first. An explosion has occurred when potassium manganate(VII) and concentrated hydrochloric acid were mixed but it seems neither sulfuric(VI) acid nor a tube blockage could have been responsible. It could possibly have been caused by the production of chlorine oxides; see J C Curry, <i>SSR</i> , 1965, 46 (160), 770. See <i>Handbook</i> 13.3 for details of equipment.
Aqua Regia for use in analysis of alloys	TT	Wear goggles or a face shield. Use a fume cupboard. Wear chemical-resistant gloves.	This very corrosive mixture is made by adding 5 cm^3 fresh concentrated nitric(V) acid to 15 cm^3 concentrated hydrochloric acid in a clean container. If the acids are warm, cool them before mixing. Do not attempt to stopper and store; any darkening beyond a yellow colour indicates appreciable decomposition. Disposal: W4: Immediately after use, in a fume cupboard and proceed very slowly.

47B Halide salts: ie, Group 1 chlorides, bromides and iodides

Lithium chloride		LiCl	
Harmful		R22: Harmful if swallowed. R36/38: Irritating to eyes and skin. Solutions equal to or stronger than 5 mol dm ⁻³ should be labelled HARMFUL. Solutions equal to or stronger than 4 mol dm ⁻³ but less than 5 mol dm ⁻³ should be labelled IRRITANT.	
Store: Gln		Disposal: W1, W7 W7: Dilute to less than 2 mol dm ⁻³ before pouring the solution down a foul-water drain.	
Sodium chloride ; halite; rock salt; NaCl Potassium chloride ; muriate of potash; KCl Caesium chloride ; CsCl		Low hazard	Store: Gln Disposal: W7
Sodium bromide ; NaBr Potassium bromide ; KBr		Low hazard	Store: Gln Disposal: W7
Sodium iodide ; NaI Potassium iodide ; KI Sometimes these substances turn yellow in storage. Make up solutions and add a crystal or two of sodium thiosulfate.		Low hazard	Store: Gln Disposal: W7
Rubidium chloride ; RbCl The naturally-occurring isotope ⁸⁷ Rb [abundance 27.8%] is radioactive. However, the energy released is low and, with the amounts used in schools, the <i>Ionising Regulations</i> 1999 do not apply. If kept as a radioactive substance, store in the radioactives cupboard but, if kept for flame tests, keep with General Inorganic chemicals [Gln].		Low hazard	Store: Spec Disposal: W2, W7

Activity	User	Control measures	Experimental points
General use of salt solutions and heat of solution	Y7	Normal laboratory rules.	When these salts dissolve in water, there is a temperature change. Potassium chloride cools the solution down as it dissolves, making it a safer alternative to demonstrate endothermic processes than ammonium nitrate(V).
Displacement reactions	Y7	Wear eye protection.	Use 0.02 mol dm^{-3} halogen solutions: a 0.5% (w/v) solution of iodine, 0.3% (w/v) solution of bromine (HARMFUL and IRRITANT) and 0.1% (w/v) solution of chlorine. Aqueous solutions of chlorine and bromine have a limited shelf life. Cyclohexane can be used to remove the halogen from the aqueous layer to demonstrate its presence more clearly.
Electrolysis of salt solutions	Y7	Wear eye protection. The room should be well ventilated. Asthmatics must be careful not to inhale the small amount of gas produced.	The amount of chlorine produced should not cause a hazard with good ventilation if the current flowing is less than 0.5 A and the activity is stopped as soon as chlorine is detected using moist blue litmus paper. Pupils should not be encouraged to smell the gases directly. Bromide solutions release bromine at the anode and iodides release iodine. Hydrogen is released at the cathode.
Flame tests using nichrome wire	Y7	Wear eye protection - goggles if concentrated acid is used. Use very small amounts of solid on a watch glass in order not to contaminate a stock bottle.	Use chlorides of lithium, sodium, potassium, rubidium, caesium, calcium, strontium, copper(II) and lead(II). Looped nichrome wire sealed into borosilicate glass tubing (see <i>Handbook</i> 11.13 and <i>Bulletin</i> 126) can be used as the holder. The wire is best cleaned by repeatedly dipping it into concentrated hydrochloric acid (CORROSIVE), dipping into the solid and heating it. However, with Y7 and 8 and some older groups, 2 mol dm^{-3} hydrochloric acid (IRRITANT) can be substituted. Do the sodium test last because the wire is more difficult to clean afterwards. Potassium salts are contaminated with sodium and the intense yellow masks the pale lilac-coloured flame of potassium. By looking at the potassium flame through cobalt blue glass, the yellow colour due to sodium is masked.
Flame tests using wooden splints	Y7	Wear eye protection.	Splints are soaked overnight in water. Remove the excess water and dip the end into the solid. Place the splint in the flame. Use a fresh splint with each test.

Extremely flammable		<p>R12: Extremely flammable.</p> <p>Flash point: -240 °C.</p> <p>Readily forms an explosive mixture with air. Mixtures between 4 and 74% by volume are explosive. The ignition temperature for these mixtures is 500 °C, which is lower than the temperature of a Bunsen-burner flame.</p> <p>Ignition can occur well below this temperature in the presence of transition metals and their oxides¹.</p>
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Do *not* attempt to breathe hydrogen to change the pitch of the voice.

The substance is dangerous with:	<p>OXYGEN, CHLORINE: Explosive reactions occur.</p> <p>TRANSITION METAL OXIDES: These oxides, under certain conditions, lower the activation energy and ignition temperature of the reaction between hydrogen and oxygen.</p>
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Store: Cyl

Cylinders: Keep ready for use one cylinder in an upright position, **not** in the same vicinity as a flammables cupboard. Cylinders must always be fixed securely to a bench or in a trolley. Any additional cylinders of hydrogen must be removed to an outside store. Their location should be known to the site manager in case of fire. Hydrogen cylinders should be fitted with a needle valve to provide fine control of gas flow, as well as with a pressure regulator. See *Handbook* 9.9 for more details.

Canisters²: These should be stored on their side in a container (so they do not roll), on the shelves of a secure chemical store. They must **not** be placed in the flammables cupboard.

Disposal: W6



¹ For further details and alternative ideas, consult the article by H G Andrew, SSR, 61, (215), p 292.


² Manufactured by Cryoservice, these are available from Scientific & Chemical Supplies Ltd.


For emergencies, see *Hazard* E as well as more detailed information which may be on this *Hazard*.

Activity	User	Control measures	Experimental points
Test-tube preparation of hydrogen	Y7	Wear eye protection. Do not use dilute nitric(V) acid.	Use 2 mol dm ⁻³ hydrochloric acid or 1 mol dm ⁻³ sulfuric(VI) acid with zinc turnings or magnesium ribbon. Samples of hydrogen can be collected in test tubes or boiling tubes. The 'pop' test can be carried out by pupils.
Collecting the gas in a syringe, etc	Y10	Wear eye protection. No naked flames in the room.	Accidents have occurred when heating has been carried out with a Bunsen burner. Use warm or hot water to vary the temperature of the reagents.
Small-scale reduction of copper(II) oxide	Y10	Wear eye protection.	For a microscale version (which does not require a safety screen and can be carried out by pupils), obtain commercial microscale apparatus (see <i>Handbook</i> 13.3) or use a version made up from materials found in science departments (see Guide L195).
Generating hydrogen	TT	Use a cylinder or canister in preference to the generation of hydrogen if possible. Wear goggles.	When using a cylinder, see <i>Handbook</i> 9.9. If a cylinder is not available, use granulated zinc or magnesium turnings, never the powdered metals. If zinc is used, add a small amount of copper(II) sulfate(VI) to the acid (2 or 3 mol dm ⁻³ sulfuric or 3 to 5 mol dm ⁻³ hydrochloric acids are suitable). Use apparatus with a minimum of 'dead' volume. It is a good idea to use a plastic container instead of a glass flask. If the gas is required dry, use anhydrous calcium chloride, never concentrated sulfuric(VI) acid.
Lighting hydrogen at a jet	TT	Wear goggles or a face shield. Use safety screens if the gas is generated chemically.	Collect samples of the gas in a test tube and ignite it at least a metre away. When it burns quietly, ie, without a loud 'pop', the gas is pure. It may even be possible to use the burning hydrogen sample to ignite the jet.
Large-scale reduction of copper(II) oxide	TT	Wear a face shield. Pupils should wear eye protection and be kept at least 2 m from the apparatus. Use safety screens. Do not use concentrated sulfuric(VI) acid as a drying agent.	This demonstration has caused accidents, caused by hydrogen/air explosions, one of which resulted in the prosecution of a teacher. Use anhydrous calcium chloride, loosely packed in a U-tube for the drying agent. Ensure the apparatus is flushed free of air with hydrogen before lighting the Bunsen burner. Practice the procedure before demonstrating it in front of a class. See <i>Handbook</i> 13.3.
Hydrogen/air explosions	TT	Wear goggles or a face shield. Use safety screens. Do not ignite balloons near loose ceiling tiles.	See Guide L195, <i>Safer Chemicals, Safer Reactions</i> for a safe procedure in which hydrogen burns and then explodes with air. It can also be carried out in balloons, soap bubbles, plastic bags and plastic bottles (designed for fizzy drinks).
Hydrogen/oxygen explosions	TT	Wear goggles or a face shield. Wear ear defenders. Pupils should be more than 5 m from exploding bottles, with fingers in ears.	See Guide L195 for details of how to prepare, electrolytically, soap bubbles of the hydrogen/oxygen mixture which are exploded on small Petri dishes or crucibles. Mixtures in plastic bottles (designed for fizzy drinks) and balloons should not exceed about 300 cm ³ . Larger volumes must be exploded outdoors. The noise is very loud!

49 Hydrogen halides

Hydrogen chloride		HCl
Toxic		R23: Toxic by inhalation. R35: Causes severe burns. Dangerous with: AMMONIA. Irritating, dense fumes are produced. WEL (mg m⁻³): 2 (LTEL), 8 (STEL).
Corrosive		

Hydrogen bromide		HBr
Corrosive		R35: Causes severe burns. R37: Irritating to respiratory system. Dangerous with: AMMONIA. Irritating, dense fumes are produced. WEL (mg m⁻³): 10 (STEL).

Hydrogen iodide		HI
Corrosive		R35: Causes severe burns. Dangerous with: AMMONIA. Irritating, dense fumes are produced.

Emergencies: see standard procedures on *Hazard E*, BUT ALSO:

If released in the laboratory:	Evacuate the laboratory if over 1 litre of gas is released. Open a few outside windows, shut off all services and leave with all doors and internal windows closed.
If chemical is inhaled:	Medical attention may be needed, even if there are no initial symptoms.

Store: Situ These gases should be made in situ.	Disposal: W6
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Activity	User	Control measures	Experimental points
Test for hydrogen halides	Y9	Wear eye protection.	Use moist blue litmus, which will turn red. Alternatively, dip a glass rod in concentrated ammonia solution sited in a fume cupboard and bring the rod close to the gas, watching for white fumes.
Large-scale preparation of hydrogen chloride gas	Y12	Wear goggles. Use a fume cupboard.	See <i>Hazardcard 72</i> for the test-tube preparation. Drip concentrated sulfuric(VI) acid onto crushed rock salt. There is no need to dry the gas prepared in this way. Do not collect the gas over water. Hydrogen chloride gas can also be produced steadily by dripping 10 cm^3 of concentrated sulfuric(VI) acid onto 5 mol dm^{-3} hydrochloric acid and drying the gas with anhydrous calcium chloride.
Action of heat on hydrogen iodide	Y12	Wear eye protection.	See <i>Hazardcard 72</i> for the preparation of the gas. If a length of nichrome wire, heated in a Bunsen-burner flame, is inserted into hydrogen iodide gas, iodine is produced. This may be done in a well-ventilated laboratory on a test-tube scale.
As by-product of organic reactions	Y12	Wear eye protection.	Preparative organic chemistry often involves reactions giving off hydrogen chloride gas. Use a fume cupboard or pass the gas into water via an inverted funnel. See <i>Handbook 13.3</i> .
Preparation of anhydrous iron(II) chloride	Y12	Wear goggles. Use a fume cupboard.	Pass the hydrogen chloride (see large-scale preparation) over very hot iron wool in a combustion tube. Clear crystals of the anhydrous product will appear in the tube.
Fountain experiment	TT	Wear eye protection. Use safety screens. Use a fume cupboard to prepare the gas.	Use a thick-walled, borosilicate, round-bottomed flask or a Büchner flask made to BS 1739. (The pressure reduction could implode a weak flask.) Apparatus may then be moved to the laboratory bench once the flask is full of hydrogen chloride. See <i>Handbook 13.3</i> .
Dissolving hydrogen chloride in solvents	TT	Wear eye protection. Use a fume cupboard.	Prepare hydrogen chloride by dripping concentrated sulfuric acid onto 5 mol dm^{-3} hydrochloric acid. Direct the gas via an inverted funnel. This prevents sucking back and allows a large surface area for the dissolving process. Water or dry methylbenzene (dry with calcium chloride overnight) can be used.

For solutions equal to or greater than 28 'vol' (ie, 7.7% w/v, 2.24 mol dm⁻³) but less than 170 'vol'

Harmful

(NB. CHIP classes hydrogen peroxide as CORROSIVE and OXIDISING above 50% w/v, ie, 170 vol or 13.6 mol dm⁻³.)



R22: Harmful if swallowed. R41: Risk of serious damage to eyes.

Dangerous with: ORGANIC COMPOUNDS such as propanone, ethanol, glycerol and many others. Dangerous or explosive reactions can occur.
METALS AND METAL OXIDES (especially if finely divided) and TIN(II) CHLORIDE.
Violent decomposition of hydrogen peroxide takes place.

WEL (mg m⁻³): 1.4 (LTEL), 2.8 (STEL).

This downgrades the level of hazard from previous information.

Emergencies: see standard procedures on *Hazcard E*, BUT ALSO:

Dangerous if swallowed: Causes serious internal damage due to release of oxygen.
Call for an ambulance immediately.

Store: CLb

It should be stored in an opaque container. Take care when removing the cap because gas pressure may have built up.

It should be diluted immediately before use (because the inhibitor which slows down decomposition is diluted as well) and placed into a *clean* bottle.

Disposal: W1, W7

W7: Dilute to less than 30 'vol' before pouring it down a foul-water drain.

For solutions equal to or greater than 18 'vol' (ie, 5% w/v, 1.5 mol dm⁻³) but less than 28 'vol' hydrogen peroxide

Irritant



R36: Irritating to eyes.

Store: Gln

It is an expensive way of buying water! However, it is suitable for schools teaching to KS3. Other secondary schools should buy 100 'vol' and dilute according to use.

Disposal: W7

For solutions less than 18 'vol' hydrogen peroxide








Low hazard

Store:
Gln

Disposal:
W7


Activity	User	Control measures	Experimental points
General use of 20 'vol' solutions	Y7	Wear eye protection.	If more-dilute solutions will achieve the desired results, these should be used.
Preparation of oxygen	Y7	Wear eye protection.	See <i>Hazcard</i> 69. Catalysts that can be used include: manganese dioxide, a few crystals of potassium manganate(VII) covered with water or potassium iodide. Drip hydrogen peroxide solution onto the catalyst. See also <i>Handbook</i> 13.3.
Rate of decomposition	Y9	Wear eye protection.	Use concentrations of 20 'vol' and below. Pupils' investigative work should be checked to ensure that the amount of catalyst used will not give rise to over-frothing. See also <i>Hazcard</i> 33.
Rate of reaction with iodide ions	Y9	Wear eye protection.	Iodine is produced. Details of the 'blue flash' or Harcourt Esson reaction can be found on <i>Recipe Card</i> 18. Disposal: Add solutions to 0.1 mol dm ⁻³ sodium thiosulfate, 0.2 mol dm ⁻³ sodium carbonate or 0.2 mol dm ⁻³ sodium hydroxide solutions to remove iodine before pouring down a foul-water drain.
General use of solutions above 28 'vol'	Y12	Wear goggles. Wear disposable nitrile gloves.	If more-dilute solutions will achieve the desired results, these should be used. 20 vol hydrogen peroxide is 1.7 mol dm ⁻³ or a 5.7% solution.
Reaction with chromium(VI) compounds	Y12	Wear eye protection.	Use 2 cm ³ of acidified 0.1 mol dm ⁻³ potassium dichromate(VI) solution, 2 cm ³ of pentyl (amyl) ethanoate and 2 cm ³ of 20 'vol' hydrogen peroxide solution. After the blue complex has formed in the ester layer, pour the solution into a bowl of water in the fume cupboard.


51 Hydrogen sulfide and its soluble salts





Hydrogen sulfide			H ₂ S
Extremely flammable		<p>R12: Extremely flammable. R26: Very toxic by inhalation. R50: Very toxic to aquatic organisms. Solutions equal to or stronger than 0.3 mol dm⁻³ should be labelled TOXIC. Solutions equal to or stronger than 0.03 mol dm⁻³ but weaker than 0.3 mol dm⁻³ should be labelled HARMFUL.</p> <p>The gas is slightly soluble in water; a saturated solution is about 0.8 mol dm⁻³.</p> <p>Dangerous with: PEROXIDES, many OXIDISING AGENTS and SOME METAL OXIDES. These can cause the gas to ignite.</p> <p>SODA LIME. The gas is absorbed exothermically and, if air is present, soda lime may become red hot.</p> <p>WEL (mg m⁻³): 7 (LTEL), 14 (STEL).</p>	
Very toxic			
Dangerous for the environment			
Store: Situ This should be made in situ. Cylinders are unsuitable.		Disposal: W6	
Ammonium sulfide [available as a 20% (w/v) solution]			(NH ₄) ₂ S
Corrosive		<p>R31: Contact with acids liberates toxic gas. R34: Causes burns. R50: Very toxic to aquatic organisms.</p> <p>Solutions equal to or stronger than 0.7 mol dm⁻³ should be labelled CORROSIVE. Solutions equal to or stronger than 0.2 mol dm⁻³ but weaker than 0.7 mol dm⁻³ should be labelled IRRITANT.</p> <p>20% (w/v) ammonium sulfide solution is 3 mol dm⁻³.</p>	
Dangerous for the environment			
Potassium sulfide			K ₂ S
Sodium sulfide-9-water			Na ₂ S.9H ₂ O
Corrosive		<p>R31: Contact with acids liberates toxic gas. R34: Causes burns. R50: Very toxic to aquatic organisms. The solutions are strongly alkaline.</p> <p>Solutions equal to or stronger than 0.4 mol dm⁻³ should be labelled CORROSIVE. Solutions equal to or stronger than 0.2 mol dm⁻³ but weaker than 0.4 mol dm⁻³ should be labelled IRRITANT.</p>	
Dangerous for the environment			
Store: CS (CLb for ammonium sulfide) The solids absorb water from the atmosphere and will produce hydrogen sulfide gas. Store in a container with anhydrous calcium chloride.		Disposal: W1 or W7 W7: Dilute the solution until it is less than 0.1 mol dm ⁻³ before pouring it down a foul-water drain.	

Activity	User	Control measures	Experimental points
Precipitation of metal sulfides	Y9	Wear eye protection. Use a fume cupboard to dispense the solution into test tubes which should be stoppered. The room should be well ventilated.	It is better not to use hydrogen sulfide gas with pupils of this age; use instead 0.1 mol dm^{-3} hydrogen sulfide solution or ammonium, potassium or sodium sulfide solutions. The solutions must not be inhaled directly.
Preparation of hydrogen sulfide	Y12	Use a fume cupboard.	The usual method involves the action of 3 mol dm^{-3} hydrochloric acid on iron(II) sulfide. Use a small gas-generating system, eg, one based on a 250 or 500 cm^3 flask, not Kipp's apparatus which stores a large volume of the gas.
Preparation of hydrogen sulfide solution	TT	Wear eye protection. Use a fume cupboard.	Bubble hydrogen sulfide through water via an inverted funnel for several minutes. Solutions do not keep; sulfur is gradually precipitated and stains the vessel. The concentration of a saturated solution is 0.8 mol dm^{-3} . Disposal: W7 - Add to more water and pour it down a foul-water drain.
Preparation of 0.1 mol dm^{-3} ammonium sulfide solution	TT	Wear eye protection. Use a fume cupboard.	Recently-bought 20% (w/v) ammonium sulfide solution is about 3 mol dm^{-3} . Dilute 3.3 cm^3 of the 20% (w/v) ammonium sulfide to 100 cm^3 with water to obtain the required solution. Disposal: Pour the solution down a foul-water drain.

52 2-hydroxybenzenecarboxylic acid, aspirin & similar esters (See also 13 & 64)



2-hydroxybenzenecarboxylic acid		2-hydroxybenzoic acid; salicylic acid	$\text{HOC}_6\text{H}_4\text{COOH}$
Harmful		R22: Harmful if swallowed. R41: Risk of serious damage to eyes.	
Store: GOrg		Disposal: W1, W4	


2-ethanoyloxybenzenecarboxylic acid		o-acetylsalicylic acid; aspirin	$\text{CH}_3\text{COOC}_6\text{H}_4\text{COOH}$
Harmful		R22: Harmful if swallowed.	
Store: GOrg		Disposal: W1, W4	



Methyl 2-hydroxybenzenecarboxylate		Methyl 2-hydroxybenzoate; methyl salicylate; oil of wintergreen	$\text{C}_6\text{H}_4(\text{OH})\text{COOCH}_3$
Harmful		R22: Harmful if swallowed. R36: Irritating to eyes.	
Methyl 4-hydroxybenzenecarboxylate		Methyl 4-hydroxybenzoate; Nipagin	$\text{HOC}_6\text{H}_4\text{COOCH}_3$
Irritant		R36/37/38: Irritating to eyes, respiratory system and skin.	
Phenyl-2-hydroxybenzenecarboxylate		Phenyl-2-hydroxybenzoate; phenyl salicylate; salol	$\text{C}_6\text{H}_4(\text{OH})\text{COOC}_6\text{H}_5$
Irritant		R36/37/38: Irritating to eyes, respiratory system and skin. R51/53: Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.	
Dangerous for the environment			
Store: GOrg		Disposal: W1, W2	

Activity	User	Control measures	Experimental points
Testing acidity	Y7	Wear eye protection.	Work on a test-tube scale is suitable. 2-hydroxybenzoic acid is only slightly soluble in water.
Melting salol	Y7	Wear eye protection.	The test tube holding the solid should be heated in hot water. The melting point is 42 °C so that, if placed in boiling water, a significant amount of vapour is released which could cause problems. This can be solved by placing a mineral wool plug in the neck of the test tube. See L195, <i>Safer Chemicals, Safer Reactions</i> . On cooling, salol exhibits super-cooling (even down to 25 °C) before solidification takes place with a considerable amount of heat evolved. It could be considered too complicated to use as an example of cooling curves.
Analysis of aspirin	Y9	Wear eye protection.	Excess 1.0 mol dm ⁻³ sodium hydroxide solution (CORROSIVE) is added to react with the aspirin before titrating the unreacted alkali with 0.1 mol dm ⁻³ hydrochloric acid.
Test-tube scale reactions of 2-hydroxybenzoic acid	Y12	Wear eye protection.	The majority of reactions may be carried out in a well-ventilated laboratory. However, reacting this substance with soda lime may produce vapours of phenol or benzene; such reactions must be carried out in a fume cupboard. Methyl 4-hydroxybenzoate may be used as well to illustrate the reaction between carboxylic and phenol groups. See L195, <i>Safer Chemicals, Safer Reactions</i> . Disposal: W7.
Preparation of aspirin	Y12	Wear eye protection. Dispense ethanoic anhydride from a fume cupboard.	2 g of 2-hydroxybenzoic acid, 4 cm ³ of ethanoic anhydride and 5 drops of 85% (w/w) phosphoric(V) acid are refluxed on a boiling water bath for 5 minutes in a well-ventilated laboratory. Carefully add 2 cm ³ of water down the condenser to destroy excess anhydride. The contents in the flask will boil!
Using an anti-fungal agent	TT	Wear eye protection.	Methyl 4-hydroxybenzoate (Nipagin) is used in preparing <i>Drosophila</i> medium; see <i>Recipe Card 22</i> .

53 Hydroxyammonium and hydrazine salts

Hydroxyammonium chloride		Hydroxylamine hydrochloride; hydroxylammonium chloride	NH_3OHCl
Hydroxyammonium sulfate(VI)		Hydroxylammonium sulfate	$(\text{NH}_3\text{OH})_2\text{SO}_4$
Harmful		R22: Harmful if swallowed. R36/38: Irritating to eyes and skin. R43: May cause sensitisation by skin contact. R48/22: Harmful: danger of serious damage to health by prolonged exposure if swallowed. R50: Very toxic to aquatic organisms. Solutions equal to or stronger than 0.1 mol dm^{-3} should be labelled HARMFUL. Dangerous with: HEAT. The salts are explosive if heated to high temperature.	
Dangerous for the environment			
Store: Gln		Disposal: W1, W7 W7 Dilute to less than 0.1 mol dm^{-3} before pouring down a foul-water drain.	



Butanedione dioxime		Diacetyl-dioxime; dimethylglyoxime	$\text{CH}_3\text{C}(\text{NOH})\text{C}(\text{NOH})\text{CH}_3$
Harmful		R22: Harmful if swallowed.	
Store: GOrg		Disposal: W7	

Hydrazine hydrate & its salts			$\text{NH}_2\text{NH}_2 \cdot x\text{H}_2\text{O}$
Toxic		Not recommended for general use in schools. R10: Flammable. R45: May cause cancer. Category 2 carcinogen. R23/24/25: Toxic by inhalation, in contact with skin and if swallowed. R34: Causes burns. R43: May cause sensitisation by skin contact. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.	
Dangerous for the environment			
Store: T (Pending disposal)		Disposal: W1	

Activity	User	Control measures	Experimental points
Testing for nickel salts	Y9	Wear eye protection.	Use a 1% (v/v) solution of butanedione dioxime in ethanol (IDA).
Reaction with iron(III) salts	Y12	Wear eye protection. The room should be well ventilated.	Iron(III) ions in acidic solutions oxidise hydroxyammonium ions to nitrogen oxides and are, in turn, reduced to iron(II) ions. The reaction can be investigated stoichiometrically by using 0.02 mol dm ⁻³ potassium manganate(VII) solution to find the amount of iron(II) ions formed in the reaction. Because dilute solutions are used, the small amounts of gaseous nitrogen oxides produced present a very low risk.
Preparation of oximes	Y12	Wear eye protection.	Dissolve 1 g of hydroxyammonium chloride and 2 g of sodium ethanoate in 4 cm ³ of water. Add 1 g of a ketone or aldehyde. If insoluble, add enough ethanol for it to dissolve. Reflux for 10 minutes and cool the solution. Alternatively, leave overnight to form oxime which may be recrystallised from petroleum ether (60-80 °C). Oximes have useful diagnostic melting points.

54A Iodine (See also 54B)

I₂

Harmful		R20/21: Harmful by inhalation and in contact with skin. R50: Very toxic to aquatic organisms.
Dangerous for the environment		Solutions stronger than or equal to 1 mol dm ⁻³ should be labelled HARMFUL. WEL (mg m⁻³): 1.1 (STEL). Avoid contact with the eyes. The solid has a corrosive action on the skin, causing burns if left for some time.

The substance is dangerous with:	POTASSIUM, SODIUM, ALUMINIUM, MAGNESIUM, ZINC. Violent reactions occur. AMMONIA solution. An explosive solid is formed.
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Emergencies: see standard procedures on *Hazard E*, BUT ALSO:

If spilt in the laboratory:	Wear eye protection and chemical-resistant gloves. Ventilate the room. Scoop all the solid into sodium thiosulfate solution. Spread 0.5 mol dm ⁻³ sodium thiosulfate solution over the area of the spill. Leave for an hour. Mop up and rinse the area of the spill.
If vapour affects the eyes:	If the eyes are affected by the vapour, discomfort may be delayed for some hours.
If spilt on the skin or clothes:	Brush off the solid immediately. Skin or clothing may be treated with 0.1 mol dm ⁻³ sodium thiosulfate solution until the brown stain is removed. Then wash with water. If a large area is affected, or blistering occurs, seek immediate medical attention.


Store: CS The vapour can escape out of poorly-sealed bottles and accelerates corrosion of metals in the room. Make sure the top is firmly secured. The bottle of iodine could be placed inside another container.	Disposal: W1, W4 or Wspec Wspec: Add no more than 10 g of iodine to 1 litre of 1 mol dm ⁻³ sodium thiosulfate solution. The pale-coloured solution can then be poured down a foul-water drain.
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54A Iodine**Model risk assessments**

Activity	User	Control measures	Experimental points
Effect of heating to show sublimation	Y7	Wear eye protection. If procedures involve amounts larger than those in methods 1-3, use a fume cupboard.	Do not encourage complete sublimation of any sample. Method 1: Use no more than 0.05 g in an open test tube. Method 2: Use up to 0.25 g in a test tube which has a mineral-wool plug. Method 3: For a demonstration in the open laboratory, heat no more than 0.25 g in a long test tube.
Titration with sodium thiosulfate	Y9	Wear eye protection.	Add starch indicator towards the end of the titration with sodium thiosulfate solution to avoid precipitation of the blue complex.
Iodoform test	Y12	Wear eye protection.	The product is strongly irritant to the eyes. Disposal: See <i>Hazcard</i> 104.
Weighing the solid	Y12	Wear eye protection. Consider the use of disposable nitrile gloves.	Always weigh in a small beaker or weighing boat, not on paper. Iodine corrodes balance pans rapidly.
Reaction with alkalis	Y12	Wear eye protection. Wear disposable nitrile gloves.	If potassium iodate(V) is to be prepared, see note on weighing iodine. Do not heat potassium iodate(V) to dryness.
Preparation of Wij's solution	TT	Wear goggles. Use a fume cupboard.	Dissolve 13 g of iodine in 1 litre of concentrated ethanoic acid. Remove 25 cm ³ of the solution and pass dry chlorine through the remainder until the colour is orange. Add 25 cm ³ of original solution to remove excess chlorine.
Reaction with metals	TT	Wear eye protection. Use a fume cupboard.	Some reactions, eg, see <i>Hazcard</i> 1, are violent and iodine fumes are produced via an exothermic reaction. See <i>Handbook</i> 13.4.
Reaction with chlorine	TT	Wear goggles. Use a fume cupboard.	Place a few crystals of iodine in a test tube and direct chlorine gas over them. Liquid iodine monochloride is formed which turns into solid yellow iodine trichloride.

54B Iodine solution (See also 54A)

I₂

Harmful		<p>R20/21: Harmful by inhalation and in contact with skin.</p> <p>Solutions stronger than or equal to 1 mol dm⁻³ should be labelled HARMFUL. Solutions weaker than 1 mol dm⁻³ are LOW HAZARD. (Iodine solution for normal use has a concentration of 0.1 mol dm⁻³ or below.)</p> <p>WEL (mg m⁻³): 1.1 (STEL).</p> <p>Avoid contact with the eyes. The solution has a corrosive action on the skin, causing burns if left for some time.</p>
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The substance is dangerous with:	AMMONIA solution. An explosive solid is formed.
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Emergencies: see standard procedures on *Hazard E*, BUT ALSO:

If spilt in the laboratory:	Wear eye protection and chemical-resistant gloves. Ventilate the room. Add mineral absorbent. You may need to wash the area of the spill with 0.5 mol dm ⁻³ sodium thiosulfate solution.
If vapour affects the eyes:	If the eyes are affected by the vapour, discomfort may be delayed for some hours.
If spilt on the skin or clothes:	Skin or clothing may be treated with 0.1 mol dm ⁻³ sodium thiosulfate solution until the brown stain is removed. Then wash with water. If a large area is affected, or blistering occurs, seek immediate medical attention.


<p>Store: Gln</p> <p>The vapour can escape out of poorly-sealed bottles and accelerates corrosion of metals in the room. Make sure the top is firmly secured.</p>	<p>Disposal: W1, W4 or Wspec</p> <p>Wspec: Add the solution to 1 litre of 1 mol dm⁻³ sodium thiosulfate solution. The pale-coloured solution can then be poured down a foul-water drain.</p>
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54B Iodine solution**Model risk assessments**

Activity	User	Control measures	Experimental points
Use of solutions	Y7	Wear eye protection, even with solutions less than 1 mol dm^{-3} .	Avoid spills as much as possible; solutions stain the skin, books, paper and bench surfaces. Extra care is required with solutions greater than 1 mol dm^{-3} .
Demonstrating solution colour	Y7	Wear eye protection.	Possible solvents include cyclohexane, ethyl ethanoate, <i>Volasil</i> 244, tetrachloroethene, propanone, methylbenzene and potassium iodide solution.
Titration with sodium thiosulfate	Y9	Wear eye protection.	Add starch indicator towards the end of the titration with sodium thiosulfate solution to avoid precipitation of the blue complex.
Iodoform test	Y12	Wear eye protection.	The product is strongly irritant to the eyes. Disposal: See <i>Hazard</i> 104.
Rate of reaction with propanone	Y12	Wear eye protection.	In the presence of an acid catalyst, iodopropanone (IRRITANT) is formed which is strongly lachrymatory. The solution should be poured down the sink with plenty of running water as soon as measurements are completed.
Preparation of iodine solution	Y12	Wear eye protection. Wear disposable nitrile gloves.	Iodine is not very soluble in water. It is soluble in potassium iodide solution when the $\text{I}_3^-(\text{aq})$ is formed. The procedure is slow and it is better to use a mechanical stirrer. To make 250 cm^3 of a 0.1 mol dm^{-3} solution, 10 g of potassium iodide is dissolved in 200 cm^3 of water and 6.35 g of iodine is added. To see that the iodine has dissolved, pour the solution from one beaker to another. Once all the iodine has dissolved, make up the solution to 250 cm^3 with water.

55A Iron and its carbonates, oxides & sulfides

(See also 55B & 55C)

Iron powder		Fe
Highly flammable		R11: Highly flammable. Avoid contact with the eyes. If present in the eye, iron dust and filings can cause severe irritation because iron oxidises rapidly in the saline environment.
Store: Gln	Disposal: W1, W5 W5: Use a fume cupboard.	

Iron filing; Fe Iron(II) carbonate (saccharated) - [reducing sugar present to slow down oxidation] FeCO_3 Iron(II) oxide; ferrous oxide; FeO Iron(III) oxide; ferric oxide; haematite; Fe_2O_3 Iron(II) iron(III) oxide; magnetite; ferrosferric oxide; Fe_3O_4 Iron(II) sulfide; ferrous sulfide; FeS Iron(II) disulfide; pyrites; FeS_2	Low hazard (For iron filings, see warning above about contact with eyes.)	Store: Gln	Disposal: W8
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55A Iron and its carbonates, oxides & sulfides

Model risk assessments

Activity	User	Control measures	Experimental points
Iron and magnetism	Y7	Wear eye protection. Do not rub eyes with contaminated fingers.	If a magnet is covered with <i>Clingfilm</i> , removal of the iron powder or filings from the magnet is easier.
Action of acids on iron	Y7		To show a reaction, 0.4 mol dm^{-3} hydrochloric acid is suitable.
Rusting investigations	Y7		To clean 'rusty' test tubes, add a spatula of sodium metabisulfite with 1 mol dm^{-3} hydrochloric acid. Leave in a fume cupboard until the rust is removed. Rinse the solution down a foul-water drain.
Iron and sulfur	Y7	Wear eye protection. Do not use open tin lids. The room should be well ventilated. Do not substitute iron with more reactive metals such as aluminium or magnesium.	The prepared mixture ratio is 7 parts of iron powder or filings to 4 parts of powdered roll sulfur. Fill an ignition tube with about 0.2 g of the mixture and insert a mineral-wool plug into the mouth of the tube. For a demonstration, use no more than 2 g of the prepared mixture in a borosilicate test tube and insert a mineral-wool plug into the mouth of the tube. Once the reaction starts, no further heating should take place. See Guide L195.
Heating iron(II) carbonate	Y7	Wear eye protection. The room should be well ventilated.	To slow down oxidation, it is sold mixed with a reducing sugar (ie, saccharated). Heating iron(II) carbonate as an example of the effect of heat on carbonates is therefore not a good choice.
Iron(II) oxide preparation	Y12	Wear eye protection.	Prepare iron(II) ethanedioate via a precipitation reaction, filter and let the precipitate dry. Heat small amounts of iron(II) ethanedioate in an ignition tube (carbon monoxide is produced). If iron (II) oxide is poured out of the ignition tube, it oxidises in the air, with sparks.
Large-scale reduction of iron(III) oxide by hydrogen	TT	Wear a face shield. Pupils should also wear eye protection. Use safety screens. Do not use concentrated sulfuric(VI) acid to dry hydrogen.	See <i>Hazard 48, Large-scale reduction of copper(II) oxide</i> . There is no obvious colour change but the product is magnetic. Small-scale procedures would be preferable and they are similar to the procedures with copper oxide.

55B Iron(II) salts

(See also 55A & 55C)


Iron(II) sulfate(VI)-7-water		Hydrated ferrous sulfate; ferrous sulfate heptahydrate	$\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$
Diammonium iron(II) sulfate(VI)-6-water		Ferrous ammonium sulfate	$(\text{NH}_4)_2\text{Fe}(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$
Harmful		<p>R22: Harmful if swallowed. Solutions equal to or stronger than 1 mol dm^{-3} should be labelled HARMFUL.</p> <p>WEL (mg m^{-3}): 1 (LTEL), 2 (STEL) as iron.</p>	
<p>Store: Gln</p> <p>These compounds are oxidised in moist air and turn brown.</p>		<p>Disposal: W1, W7</p> <p>W7: Dilute to less than 0.2 mol dm^{-3} before pouring down a foul-water drain.</p>	
Anhydrous iron(II) chloride		Ferrous chloride	FeCl_2
Harmful		<p>R22: Harmful if swallowed. R38: Irritating to skin. R41: Risk of serious damage to eyes.</p> <p>WEL (mg m^{-3}): 1 (LTEL), 2 (STEL) as iron.</p>	
<p>Store: Situ</p> <p>The solid absorbs water and is oxidised in air.</p>		<p>Disposal: W1, W7</p> <p>W7: The small amounts prepared in the laboratory can be added to water and the solution poured down a foul-water drain.</p>	
Iron(II) chloride-4-water		Hydrated ferrous chloride	$\text{FeCl}_2 \cdot 4\text{H}_2\text{O}$
Harmful		<p>R22: Harmful if swallowed. R38: Irritating to skin. R41: Risk of serious damage to eyes.</p> <p>Although the solid is HARMFUL, solutions equal to or stronger than 0.2 mol dm^{-3} should be labelled IRRITANT.</p> <p>WEL (mg m^{-3}): 1 (LTEL), 2 (STEL) as iron.</p>	
<p>Store: Situ</p> <p>The solid is oxidised in air (the colour changes from green to brown).</p>		<p>Disposal: W1, W4</p> <p>W4: Add no more than 100 g of the solid to 1 litre of 1 mol dm^{-3} sodium carbonate solution. Remove the precipitate of hydrated iron(II) hydroxide which will turn brown after air oxidation to iron(III) oxide. Place this solid in the normal refuse. The solution can then be poured down a foul-water drain.</p>	


55B Iron(II) salts**Model risk assessments**



Activity	User	Control measures	Experimental points
General use of salt solutions	Y7	Wear eye protection.	Rinse used glassware thoroughly before placing it in the dishwasher; iron(II) solutions accelerate pitting in stainless steel. Iron(II) chloride solution, often specified in many texts for investigations on the chemistry of the iron(II) ion, is rapidly oxidised during storage. For these procedures, iron(II) sulfate(VI) solutions are preferable.
Preparation of iron(II) sulfate(VI) crystals	Y7	Wear eye protection. The room should be well ventilated.	Oils, carbides and sulfides in the iron filings can produce nauseating smells when added to 1 mol dm ⁻³ sulfuric(VI) acid. If test tubes are used, plug their mouths with mineral wool. Reduced iron powder reacts more quickly than filings and produces less smell. See <i>Handbook</i> 13.4 for details of the procedure. Disposal: Do not place excess iron metal down sinks because it can stain porcelain badly and pit stainless steel.
Complex equilibrium reactions	Y12	Wear eye protection.	0.1 mol dm ⁻³ iron(II) solutions form complexes with thiocyanates, ethanedioates and fluorides. See <i>Hazard</i> 95C for risk warnings about thiocyanates. Do not isolate thiocyanate complexes.
Preparation of iron(II) chloride	Y12	Wear goggles. Use a fume cupboard.	Dry hydrogen chloride is passed over heated iron. The product appears as 'glassy' crystals in the combustion tube.
Preparation of iron(II) sulfate(VI) solutions	TT	Wear eye protection.	See <i>Recipe Cards</i> 5 & 40. Diammonium iron(II) sulfate(VI) solution is more stable than iron(II) sulfate(VI) solution during storage. Do not warm the solutions to dissolve the salts because this accelerates the oxidation of iron(II) ions to iron(III).

55C Iron(III) salts

(See also 55A & 55B)

Iron(III) sulfate(VI)-9-water		Hydrated ferric sulfate	$\text{Fe}_2(\text{SO}_4)_3 \cdot 9\text{H}_2\text{O}$
Ammonium iron(III) sulfate(VI)-12-water		Ferric alum; iron alum	$\text{NH}_4\text{Fe}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$
Irritant		R36/38: Irritating to eyes and skin. Solutions equal to or stronger than 0.3 mol dm^{-3} should be labelled IRRITANT. WEL (mg m^{-3}): 1 (LTEL), 2 (STEL) as iron.	
Store: Gln They absorb water. Keep inside other containers with soda lime.		Disposal: W1, W7 W7: Dilute to less than 0.2 mol dm^{-3} before pouring down a foul-water drain.	



Anhydrous iron(III) chloride		Ferric chloride	FeCl_3
Iron(III) chloride-6-water		Hydrated ferric chloride	$\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$
Harmful (Some suppliers claim they are CORROSIVE.)		R22: Harmful if swallowed. R38: Irritating to skin. R41: Risk of serious damage to eyes. Although the solids are HARMFUL, solutions equal to or stronger than 0.2 mol dm^{-3} should be labelled IRRITANT. WEL (mg m^{-3}): 1 (LTEL), 2 (STEL) as iron.	
Store: CW They absorb water. Keep inside other containers with soda lime.		Disposal: W1, W4 W4: Add no more than 100 g of the solid to 1 litre of 1 mol dm^{-3} sodium carbonate solution. Remove the precipitate of hydrated iron(III) oxide and place this in the normal refuse. The solution can then be poured down a foul-water drain.	

Iron(III) nitrate(V)-9-water		Hydrated ferric nitrate	$\text{Fe}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$
Oxidising		R8: Contact with combustible material may cause fire. R36/38: Irritating to eyes and skin. Solutions equal to or stronger than 0.5 mol dm^{-3} should be labelled IRRITANT. WEL (mg m^{-3}): 1 (LTEL), 2 (STEL) as iron.	
Irritant			
Store: Ox It absorbs water. Keep inside another container with soda lime.		Disposal: W1, W7 W7: Dilute to less than 0.2 mol dm^{-3} before pouring down a foul-water drain.	

55C Iron(III) salts

Model risk assessments

Activity	User	Control measures	Experimental points
General use of salt solutions	Y7	Wear eye protection.	Rinse used glassware thoroughly before placing it in the dishwasher: iron(III) solutions accelerate pitting in stainless steel.
Redox equilibrium reactions	Y9	Wear eye protection.	Use 0.1 mol dm^{-3} solutions of iron(III) chloride and potassium iodide. Iodine solution is produced.
Etching solutions	Y9	Wear eye protection.	See <i>Recipe Cards</i> 41 & 50 for iron(III) chloride used to etch copper. Disposal: W4, using sodium carbonate solution.
Complex equilibrium reactions	Y12	Wear eye protection.	0.1 mol dm^{-3} iron(III) solutions form complexes with thiocyanates, ethanedioates and fluorides. See <i>Hazcard</i> 95C for risk warnings about thiocyanates. Do not isolate thiocyanate complexes.
Preparation of barium ferrate(VI)	Y12	Wear goggles and chemical-resistant gloves	Add 2 g of sodium hydroxide to 50 cm^3 of 2 mol dm^{-3} sodium chlorate(I) solution and warm to boiling. Dropwise, add 0.5 mol dm^{-3} iron(III) nitrate(V) solution. Boil for a further 2 minutes and add 0.5 mol dm^{-3} barium nitrate(V) solution and filter off the red solid. The addition of 2 mol dm^{-3} hydrochloric acid to barium ferrate(VI) oxidises water to oxygen.
Preparation of anhydrous iron(III) chloride	Y12	Wear goggles. Use a fume cupboard.	Iron(III) chloride requires chlorine to be passed over heated iron. Use apparatus similar to that for making anhydrous aluminium chloride, described in <i>Handbook</i> 13.4.
Preparation of iron(III) solutions	TT	Wear eye protection.	See <i>Recipe Card</i> 41. Diammonium iron(III) sulfate(VI) solution is more stable during storage. Do not warm the solution when stirring or a colloidal suspension will form.

Lead metal		Pb
Lead(II) carbonate	Cerrusite	PbCO ₃
Lead(II) oxide	Lead monoxide; yellow lead; litharge; massicot	PbO
Lead(IV) oxide	Lead dioxide	PbO ₂
Dilead(II) lead(IV) oxide	Red lead	Pb ₃ O ₄
Lead(II) sulfide	Galena	PbS
Toxic		<p>R61: May cause harm to the unborn child. Category 1 teratogens. R62: Possible risk of impaired fertility. R20/22: Harmful by inhalation and if swallowed. R33: Danger of cumulative effects. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.</p> <p>Dangerous with (oxides): ALUMINIUM, MAGNESIUM powders and ORGANIC MATERIAL. Vigorous or explosive reactions may occur.</p> <p>WEL (mg m⁻³): 0.15 (LTEL), 0.45 (STEL) as lead.</p>
Dangerous for the environment		
Store: T		Disposal: W1, W2



Emergencies: see standard procedures on *Hazard E*, BUT ALSO:

If spilt in the laboratory	Wear eye protection and chemical-resistant gloves. Scoop up as much solid as possible into a bucket. Rinse the area with water and clear up, washing water down a foul-water drain and diluting further. Keep the solid for disposal using a licensed waste contractor.
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Lead and its carbonate, oxides and sulfide may be of concern to those who are pregnant. In schools, however, they are used in tiny quantities compared with their use in industry. There is little risk from simply using the chemicals. Inhalation is a remote possibility if significant amounts of dust become airborne, hence care should be taken to avoid this. Swallowing is unlikely if eating and drinking are totally banned in the laboratories/prep room and hands are washed after handling these substances.

Activity	User	Control measures	Experimental points
Use of lead metal	Y7	Wash hands afterwards.	The metal will rub off on skin. Lumps of lead can be wrapped in <i>Clingfilm</i> .
Heating lead(II) sulfide	Y7	Wear eye protection. Use a fume cupboard.	Sulfur dioxide is also produced. Particles can shoot off during heating.
Reduction of lead oxides and ores with carbon	Y7	Wear eye protection. Ventilate the room. With bottle tops, technicians should remove the plastic inserts by strongly heating them. Wear eye protection. Ventilate the room. Tie long hair back. Used blowpipes and rubber tubing should be disinfected with <i>Milton</i> solution before rinsing. Do not cool charcoal blocks in water as they will split.	A mixture of 1 g of lead(II) oxide or lead(II) carbonate and 0.1 g of powdered wood charcoal is heated strongly in a crucible. After 5 minutes, add another 0.1 g of charcoal. A prepared beer-bottle top also works well. Hot metal containers can be dropped into a glass beaker of cold water to prevent further oxidation. Blowpipe method: To reduce the amount blown into the air, mix the oxide or ore with a little water to dampen them before placing the paste on the carbon block. Rubber tubing can be connected to the blowpipe. After use, cool the blocks in air. Used hot carbon blocks can cause fires when stacked. Store in an air-tight metal container, eg, a biscuit tin. Alternatively, make a depression in a piece of soft wood with a screwdriver and, using the blowpipe, char it before adding damp lead oxide. Wood blocks can be doused in water.
Melting lead metal	Y7	Wear eye protection. Wear thermal gloves.	Open windows to provide ventilation. Melting can be done in a beer-bottle top (burn away the plastic insert) supported on a pipe-clay triangle.
Making 'glass'	Y7	Wear eye protection. Take care to avoid raising dust of lead(II) oxide.	This uses zinc oxide, lead(II) oxide and boric acid. Allow plenty of time for the crucible to cool before immersing it in 2 mol dm ⁻³ nitric(V) acid for cleaning. For details, see <i>Hazard 14</i> .
Preparation of lead(IV) oxide	Y12	Wear goggles.	Add 4 cm ³ of 5 mol dm ⁻³ nitric(V) acid to dissolve 1 g of lead in a boiling tube, warming it in a boiling-water bath. Neutralise with 2 mol dm ⁻³ sodium hydroxide solution drop by drop until there is a faint white precipitate. Add 10 cm ³ of 2 mol dm ⁻³ sodium hydroxide and 6 cm ³ of 10-14% sodium chlorate(I) solution (CORROSIVE) and place in a boiling-water bath. Filter off the dark-brown precipitate and wash with water.
Showing lead crystals	TT	Wear thermal gloves and eye protection. Ensure good ventilation.	Pour a small pool of molten lead onto a ceramic tile to cool. The tile should be in a wooden tray.

57A Lead salts: halides, nitrate(V) and sulfate(VI)**(See also 56 & 57B)**

Lead(II) bromide		PbBr ₂
Lead(II) chloride		PbCl ₂
Lead(II) iodide		PbI ₂
Lead(II) nitrate(V)		Pb(NO ₃) ₂
Lead(II) sulfate(VI)		PbSO ₄
Toxic		R61: May cause harm to the unborn child. Category 1 teratogens. R62: Possible risk of impaired fertility. R20/22: Harmful by inhalation and if swallowed. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. Solutions equal to or stronger than 0.01 mol dm ⁻³ should be labelled TOXIC. Solutions less than 0.01 mol dm ⁻³ are LOW HAZARD. WEL (mg m⁻³): 0.15 (LTEL), 0.45 (STEL) as lead.
Dangerous for the environment		
Store: T		Disposal: W1, W2

Emergencies: see standard procedures on *Hazard E*, BUT ALSO:

If a solid is spilt in the laboratory:	Wear eye protection and chemical-resistant gloves. Scoop up as much solid as possible into a bucket. Rinse the area with water and clear up, washing water down a foul-water drain and diluting further. Keep the solid for disposal using a licensed waste contractor.
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Lead salts may be of concern to those who are pregnant. In schools, however, they are used in tiny quantities compared with their use in industry. There is little risk from simply using the chemicals. Inhalation is a remote possibility if significant amounts of dust become airborne, hence care should be taken to avoid this. Swallowing is unlikely if eating and drinking are totally banned in the laboratories/prep room and hands are washed after handling these substances.



57A Lead salts: halides, nitrate(V) and sulfate(VI)**Model risk assessments**

Activity	User	Control measures	Experimental points
Use of lead(II) nitrate(V) solutions	Y7	Wear eye protection. Wash hands thoroughly after use.	Solutions of concentrations less than 0.01 mol dm^{-3} are suitable for simple precipitation reactions with carbonates, iodides and sulfates(VI). More-concentrated solutions may have to be used to precipitate the bromide and chloride.
Formula of lead(II) bromide	Y9	Wear eye protection. Wash hands thoroughly after use.	Use about 2-3 g of lead(II) bromide suspended in hot water in a beaker to which about 0.3 g of aluminium powder (an excess) is added. A spongy ball of lead forms on stirring, which can be filtered, dried and weighed.
Heating lead(II) nitrate(V)	Y9	Wear eye protection. Wash hands thoroughly after use. If pupils heat more than 1 g at a time, a fume cupboard must be used. Otherwise, the room should be well ventilated.	Lead(II) nitrate(V) decomposes on heating to form nitrogen dioxide and oxygen. The reaction is liable to eject hot particles as the crystals decompose; a loose plug of mineral wool will stop these particles but allow the gases through. After the investigation, test tubes will have been weakened by lead(II) oxide; they should be allowed to cool, wrapped in paper and placed in the normal refuse.
Preparation of lead(IV) chloride	Y12	Wear eye protection. Wear disposable nitrile gloves.	Add 0.5 g of lead(IV) oxide to 10 cm^3 of cold concentrated hydrochloric acid. Decant off the acidic solution of lead(IV) chloride.
Electrolysis of molten salts: lead bromide, chloride or iodide	TT	Wear eye protection. Use a fume cupboard.	These salts are appreciably volatile at melting temperatures. Impure lead(II) bromide may give off some bromine on melting as well as during electrolysis and the pure iodide starts to decompose just above the melting point. Consider using anhydrous zinc chloride as a safer alternative; consult L195, <i>Safer Chemicals, Safer Procedures and Handbook</i> 11.4.

57B Lead salts: chromate(VI) and ethanoate

(See also 56 & 57A)

Lead(II) chromate(VI)		PbCrO ₄
Toxic		<p>R40: Limited evidence of a carcinogenic effect. Category 3 carcinogen. R61: May cause harm to the unborn child. Category 1 teratogen. R62: Possible risk of impaired fertility. R33: Danger of cumulative effects. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.</p> <p>WEL (mg m⁻³): 0.05 (LTEL), 0.15 (STEL) as chromium.</p> <p>If the solid is spilt in the laboratory: see 57A.</p>
Dangerous for the environment		
Store: T Do not dry and store.		Disposal: W1, W2

Lead(II) ethanoate-3-water		Hydrated lead acetate	Pb(CH ₃ COO) ₂ ·3H ₂ O
Toxic		<p>R40: Limited evidence of a carcinogenic effect. Category 3 carcinogen. R61: May cause harm to the unborn child. R62: Possible risk of impaired fertility. Category 1 teratogen. R48/22: Harmful: danger of serious damage to health by prolonged exposure if swallowed. R33: Danger of cumulative effects. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.</p> <p>Solutions equal to or stronger than 0.01 mol dm⁻³ should be labelled TOXIC. Solutions less than 0.01 mol dm⁻³ are LOW HAZARD.</p> <p>WEL (mg m⁻³): 0.15 (LTEL), 0.45 (STEL) as lead.</p> <p>If the solid is spilt in the laboratory: see 57A.</p>	
Dangerous for the environment			
Store: T		Disposal: W1, W2	





Lead salts may be of concern to those who are pregnant. In schools, however, they are used in tiny quantities compared with their use in industry. There is little risk from simply using the chemicals. Inhalation is a remote possibility if significant amounts of dust become airborne, hence care should be taken to avoid this. Swallowing is unlikely if eating and drinking are totally banned in the laboratories/prep room and hands are washed after handling these substances.

57B Lead salts: chromate(VI) and ethanoate**Model risk assessments**

Activity	User	Control measures	Experimental points
Use of lead(II) ethanoate solutions	Y7	Wear eye protection. Wash hands thoroughly after use.	If solutions of a lead salt are required, lead nitrate(V) should be used and not lead ethanoate because the nitrate(V) presents a lower risk to health.
Preparation of lead(II) chromate(VI)	Y9	Wear eye protection. Wear disposable nitrile gloves. Wash hands thoroughly after use.	Use only small amounts: eg, 5 cm ³ of 0.5 mol dm ⁻³ lead(II) nitrate(V) solution and 25 cm ³ of 0.25 mol dm ⁻³ potassium chromate(VI) solution give a satisfactory result. There is a particular problem of handling the filter paper, so gloves should be worn. Benches often become coated with the yellow solid and should be washed down after the investigation. Disposal: Collect all samples of lead(II) chromate(VI) and keep for disposal by a licensed waste contractor.
Painting with lead pigments	Y9	Wear eye protection. Wear disposable nitrile gloves. Wash hands thoroughly after use.	Because a mortar and pestle are required to grind the precipitates into a fine powder to make pigments, care should be taken not to raise dusts and contaminate hands, clothes and the bench. Lead pigments might be better prepared by teachers or technicians. Once added to the binding agent, eg, egg yolk, the lead pigments can be used by pupils at Y9. More details can be found in <i>The Chemistry Of Art</i> , RSC, ISBN 1857092821.

58 Lithium and its compounds


(See also 47B and 91)

Lithium		Li
Highly flammable		<p>R14/15: Reacts violently with water liberating highly flammable gases. R34: Causes burns.</p> <p>DANGEROUS WITH: NITRIC(V) ACID. The metal ignites on contact. 1,1,1-TRICHLOROETHANE and similar compounds. The metal reacts explosively. MERCURY. A violent reaction can occur.</p> <p>Emergencies: see standard procedures on <i>Hazard E</i>, BUT ALSO:</p>
Corrosive		<p>If particles enter the eyes: Flood the eye with gently-running water tap water until a first aider arrives. Send the affected person to hospital and ensure that irrigation is continued during the journey.</p> <p>Lithium fires: Although difficult to ignite, lithium burns vigorously. Sand and other fire extinguishers are useless. Smother burning metal with sodium chloride.</p> <p>If metal is spilt in the laboratory: Scoop up as much as possible into a dry container. Drench the area of the spill with water, leave for 15 minutes and clear up.</p>
<p>Store: FW</p> <p>Store under oil. It is less dense than oil and floats, so some bottles have a device fitted to the lid which pushes the lithium further into the oil.</p>		<p>Disposal: W1, W5</p> <p>W5: The reaction is not violent.</p>
Lithium carbonate		Li ₂ CO ₃
Harmful		R22: Harmful if swallowed. R36: Irritating to eyes.
Store: Gln		Disposal: W1, W5
Lithium nitrate(V)		LiNO ₃
Oxidising		R8: Contact with combustible material may cause fire.
Store: Ox		Disposal: W1, W7

Activity	User	Control measures	Experimental points
Heating lithium nitrate(V)	Y9	Wear goggles.	If more than 1 g is heated, use a fume cupboard, because nitrogen dioxide is produced. The crystals may shoot out on heating or emit hot particles, so place a loose plug of mineral wool in the mouth of the test tube.
Reaction of lithium with water	Y9	Wear goggles. Ensure that the bottle of metal is returned to the prep room; students have stolen samples.	Use a piece with sides no longer than 5 mm and carry out the reaction in a beaker of water. (The activity has been described advising the use of a test tube; this is not recommended.) To collect hydrogen for testing, invert a test tube over the reacting lithium.
Reaction of lithium with hydrochloric acid	Y9	Wear goggles. Ensure that the bottle of metal is returned to the prep room; students have stolen samples.	Use less than 0.2 g of lithium per investigation in about 50 cm ³ of 1 mol dm ⁻³ hydrochloric acid. It is possible to measure the enthalpy of this reaction as well. (If the enthalpy of solution of lithium chloride is found, a thermochemical cycle can be constructed to find the enthalpy of formation of lithium chloride.)
Heat of reaction	Y12	Wear goggles.	Use a disposable, expanded-polystyrene cup when investigating enthalpy change for the reaction of lithium metal with water.
Heating the metal	TT	Wear goggles or a face shield. Use safety screens.	Use a cube of lithium with sides about 3 mm long. Lithium has been known to explode when heated on porcelain, so heat the sample on the ceramic centre of a gauze, or on a combustion spoon.

59A Magnesium

(See also 59B)

Magnesium turnings or powder		Mg
Highly flammable	 <p>R11: Highly flammable. R15: Contact with water liberates highly flammable gases. Dangerous with: 1,1,1-TRICHLOROETHANE and similar compounds. The metal reacts violently. ALCOHOLS. The metal reacts violently after a lengthy induction period. BROMINE and CHLORINE. The metal reacts violently. SILVER NITRATE(V). When added to the metal, an explosion may occur in the presence of water. OXIDISING AGENTS. Explosive mixtures are formed with the metal. SULFATES(VI) and METAL OXIDES. Mixtures of solids with the metal (especially the powder) may be explosive. SULFUR. The metal reacts violently and explosively.</p>	
Store: FW An oxide layer forms on the turnings and the powder is particularly prone to oxidation.		Disposal: W1, W5 W5: The reaction with acid produces a lot of heat. Add a bit at time.


Magnesium ribbon; Mg	Low hazard (Some suppliers give ribbon the same hazard label and risk phrases as the powder.)	Store: FW	Disposal: W5
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The metal is difficult to ignite but burns vigorously and is difficult to extinguish. Powdered magnesium is particularly dangerous, if blown into a Bunsen-burner flame. Extinguish fires by smothering with sand. Some pencil sharpeners made of magnesium alloy have been found to ignite when heated in a Bunsen-burner flame. Magnesium ribbon has been stolen, so reels of the ribbon should **not** be left out in the laboratory. It is good practice to have a limited number of pre-cut lengths to hand out when needed.

Activity	User	Control measures	Experimental points
Burning magnesium ribbon	Y7	Wear eye protection. Limit the length to 2 cm.	For larger lengths burnt by the teacher or burning in oxygen, do not look directly at the flame. Blue glass, Polaroid, coloured filters and even partially-opened fingers in front of the eyes offer protection.
Reaction of ribbon with acid	Y7	Wear eye protection.	The reaction is well-controlled with ribbon. To illustrate the reaction, 0.4 mol dm^{-3} hydrochloric acid is suitable. If the hydrogen is to be collected, use 1 mol dm^{-3} acid.
Reaction of powder or turnings with acid	Y9	Wear eye protection.	If used for comparison of reaction rates, use only a very small quantity, eg, a pinch, because the solution can rise out of the test tube which can become very hot.
Rate of the acid/metal reaction	Y9	Wear eye protection.	If comparing the rate of reaction with the initial temperature of the acid, warm the acid in a water bath rather than using a Bunsen burner.
Burning the metal in steam	TT	Wear goggles or a face shield. Do not use magnesium <i>powder</i> .	Some magnesium silicide is formed with the glass of the apparatus. This weakens the glass so it easily breaks. See <i>Handbook</i> 13.4. Disposal: Add the used glassware to about 500 cm^3 of water to destroy the silicide (ignition may occur because silane burns in air).
Reaction of the metal with silica	TT	Wear goggles or a face shield. Use safety screens. Protect the bench with hard-board or heat-proof mats.	Carry out in a borosilicate boiling tube. Mix 2 g of magnesium powder with 1 g of dry, powdered silica. The reaction is violent. After cooling, add 2 mol dm^{-3} hydrochloric acid dropwise to produce silanes which catch fire spontaneously.
Reaction of the metal powder with copper oxide	TT	Wear goggles or a face shield. Use safety screens. The room should be well ventilated to remove the smoke. Protect the bench with hard-board or heat-proof mats. Pupils should stand towards the back of the room. This is best performed at the end of a lesson after which the class leaves.	Weigh 0.5 g of each reagent on paper. Mix by passing them from one piece of paper to the other and place the mixture in a bottle top (the plastic insert should be burnt out first). Place the bottle top on a pipe-clay triangle supported by a tripod. Keep heating strongly with a Bunsen burner, retire to where the pupils are standing and watch carefully; the induction period may be a few seconds or as long as a minute. If the reaction fails to work (probably the magnesium powder has oxidised), DO NOT RETURN TO THE APPARATUS AND POKE THE MIXTURE. It is best to turn the gas off at the main control for the laboratory and allow the mixture to cool before adding to water. Place used bottle tops in the waste. See <i>Handbook</i> 13.4.

59B Magnesium compounds

(See also 59A)

Magnesium nitrate(V)-6-water		Hydrated magnesium nitrate	$\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$
Oxidising		R8: Contact with combustible material may cause fire.	
Store: Ox It absorbs water from the atmosphere.		Disposal: W1, W7 W7: Dilute to less than 0.2 mol dm^{-3} before pouring down a foul-water drain.	

Magnesium chlorate(VII)		Magnesium perchlorate	$\text{Mg}(\text{ClO}_4)_2$
Oxidising		R8: Contact with combustible material may cause fire. R36/37/38 irritating to eyes, respiratory system and skin.	
irritant			
Store: Ox (pending disposal)		Disposal: W1	

Magnesium carbonate hydroxide ; basic magnesium carbonate; magnesium carbonate; $3\text{MgCO}_3 \cdot \text{Mg}(\text{OH})_2 \cdot 3\text{H}_2\text{O}$ (Pure magnesium carbonate cannot be obtained.)	Low hazard	Store: Gln	Disposal: W8
Magnesium chloride-6-water ; hydrated magnesium chloride; $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$		Store: Gln It absorbs water from the atmosphere.	Disposal: W7
Magnesium oxide ; Magnesia; MgO		Store: Gln	Disposal: W8
Magnesium sulfate(VI) ; MgSO_4		Store: Gln	Disposal: W7
Magnesium sulfate(VI)-7-water ; Epsom salts; hydrated magnesium sulfate; $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$		Store: Gln	Disposal: W7


59B Magnesium compounds**Model risk assessments**


Activity	User	Control measures	Experimental points
General use of solutions	Y7	Wear eye protection.	The solutions may be cloudy if made with tap water.
Heating the carbonate	Y7	Wear eye protection.	The residue of magnesium oxide, when added to water, is slightly alkaline but not hazardous.
Heating the nitrate(V)	Y7	Wear eye protection. The room should be well ventilated.	If heated in the open laboratory, keep amounts to below 0.5 g per group. Otherwise, use a fume cupboard. Nitrogen dioxide is evolved.
Heating the sulfate(VI)	Y7	Wear goggles if using an evaporating basin.	If heated in an evaporating basin, there can be considerable 'spitting'. The Bunsen-burner flame should be turned down as low as possible. Anhydrous magnesium sulfate(VI) makes an excellent drying agent for organic liquids.
Electrolysis of magnesium sulfate(VI)	Y7	Wear eye protection.	If electrolysis of 2 mol dm ⁻³ magnesium sulfate(VI), with bromocresol green added as an indicator, is carried out in a Hoffman voltameter, the acid, neutral and alkaline colours of the indicator develop in 3 columns. See <i>Handbook</i> 11.4.
Magnesium chlorate(VII) for drying gases	It is recommended not to use this chemical in schools. Use silica gel instead.		



60 Manganese and its compounds

(See also 81)

Manganese metal; Mn (The powder would be HIGHLY FLAMMABLE.)	Low hazard	Store: Gln	Disposal: W1, W3, W8
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Manganese(IV) oxide		Manganese dioxide; pyrolusite	MnO ₂
Harmful		<p>R20/22: Harmful by inhalation and if swallowed.</p> <p>Dangerous with: ALUMINIUM and OTHER METAL POWDERS. Explosive reactions can occur.</p> <p>POWERFUL OXIDISING AGENTS such as POTASSIUM CHLORATE(V). These form unstable mixtures.</p> <p>WEL (mg m⁻³): 0.5 (LTEL), 1.5 (STEL) as manganese.</p>	
Store: Gln		Disposal: W2	

Manganese(II) chloride-4-water			MnCl ₂ ·4H ₂ O
Harmful		<p>R22: Harmful if swallowed.</p> <p>Solutions equal to or stronger than 1.2 mol dm⁻³ should be labelled HARMFUL.</p> <p>WEL (mg m⁻³): 0.5 (LTEL), 1.5 (STEL) as manganese.</p>	
Store: Gln		<p>Disposal: W1, W7</p> <p>W7: Dilute to less than 0.5 mol dm⁻³ before pouring down a foul-water drain.</p>	

Manganese(II) sulfate(VI)-7-water			MnSO ₄ ·7H ₂ O
Harmful		<p>R48/20/22: Harmful: danger of serious damage to health by prolonged exposure through inhalation and if swallowed. R51/53: Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.</p> <p>Solutions equal to or stronger than 0.9 mol dm⁻³ should be labelled HARMFUL.</p> <p>WEL (mg m⁻³): 0.5 (LTEL), 1.5 (STEL) as manganese.</p>	
Dangerous for the environment			
Store: Gln		<p>Disposal: W1, W7</p> <p>W7: Dilute to less than 0.3 mol dm⁻³ before pouring down a foul-water drain.</p>	

Activity	User	Control measures	Experimental points
Using manganese metal	Y7	Wear eye protection.	It reacts slowly with 0.4 mol dm^{-3} hydrochloric and sulfuric(VI) acids.
Use of manganese solutions	Y7	Wear eye protection.	These can be used to precipitate the hydroxide or carbonate. Oxidation in air darkens the precipitate to manganese(IV) oxide.
Preparation of oxygen	Y7	Wear eye protection. Do not use 'oxygen mixture'.	Drip '20 vol' hydrogen peroxide onto manganese(IV) oxide granules. For demonstration purposes, Andrews' method of gas generation is preferred (see <i>Handbook</i> 13.3) because this prevents the hydrogen peroxide shooting out of the thistle funnel in conventional apparatus. The problem with this catalyst is that the oxygen is produced at a fast rate to begin with and much of the gas is lost while the pupils assemble the rest of the apparatus.
Test-tube preparation of chlorine (1)	Y12	Wear goggles. Use a fume cupboard.	Add 1 cm^3 of concentrated hydrochloric acid to about 0.1 g of manganese(IV) oxide. Warm carefully and test for chlorine.
Test-tube preparation of chlorine (2)	Y12	Wear goggles. Use a fume cupboard.	Mix 0.3 g of sodium chloride, 0.3 g of manganese(IV) oxide and add 1 cm^3 of concentrated sulfuric(VI) acid. The mixture should be warmed very gently. This method is not recommended for large-scale preparation of the gas (see <i>Hazard</i> 89).
Preparation of potassium manganate(VII)	Y12	Wear goggles. Wear disposable nitrile gloves. Use safety screens.	The mixture used, of molten potassium hydroxide (5.6 g) and potassium chlorate(V) (2.5 g), is very dangerous. Use a crucible in a pipe-clay triangle on a tripod standing over a sand tray and work behind safety screens. Add 0.8 g of manganese(IV) oxide to the melt and heat for 10 minutes. After cooling, remove the safety screens. Grind the mixture, add 50 cm^3 of distilled water and bubble carbon dioxide through it until the green colour disappears. (Place a spot of solution on filter paper to look for any remaining green colour.) Filter and crystallise the solution.

61 Mercury and cadmium

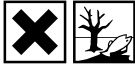




Mercury			Hg
Toxic		<p>R23: Toxic by inhalation. R33: Danger of cumulative effects. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.</p> <p>WEL (mg m⁻³): 0.025 (LTEL), 0.075 (STEL).</p> <p>Serious poisoning is rare in schools. The metal should not be left exposed to the open air for long and should never be heated except in an efficient fume cupboard. The risk is to teachers or technicians exposed over a long period to small vapour concentrations, from spilt mercury that was not cleared up, when symptoms may be mild and unnoticed.</p> <p>Dangerous with: ALKALI METALS. A violent reaction can occur.</p>	
Dangerous for the environment		<p>ALUMINIUM. Ignition may occur.</p> <p>AMMONIA. Explosive solids are formed after a period of contact.</p> <p>BROMINE and CHLORINE. A violent reaction can occur.</p> <p>Emergencies: see standard procedures on <i>Hazard E</i>, BUT ALSO:</p> <p>If spilt in the laboratory: Use a good syringe or a 'pooter' connected to a vacuum pump via a trap to suck up the bulk of large spills (<i>Handbook 7.7</i>). Mop up the remainder with a hot paste of a 1:1 mixture of lime (calcium hydroxide) and flowers of sulfur in water. Spread the same mix, dry, in inaccessible areas where mercury may be lurking.</p> <p>If swallowed: Oddly enough there is little danger but seek medical attention.</p> <p>If spilt on the skin or clothes: Remove contaminated clothing. Carefully wash the affected area. Check jewellery for silver colour staining (amalgam). A gold ring may be heated gently in a fume cupboard to drive off mercury.</p>	
Store: T Use plastic bottles which are only filled to one third of their volume. Do not attempt to clean mercury yourself, except to remove surface dirt by shaking with sticky tape in a strong bottle or to remove surface water using filter paper.		Disposal: W1, W2 or Wspec Wspec: Small amounts in the threads of broken thermometers etc may be sealed in polythene bags or placed in plastic bottles with a secure top to avoid evaporation until a collection takes place.	
Cadmium			Cd
Toxic Dangerous for the environment	 	<p>R45: May cause cancer. R26/27/28: Very toxic by inhalation, in contact with skin and if swallowed. R62: Possible risk of impaired fertility. R63: Possible risk of harm to the unborn child.</p> <p>WEL (mg m⁻³): 0.025 (LTEL) 0.075 (STEL).</p>	
Store: T (An exhibition sample can be kept.)		Disposal: W1	

For emergencies, see *Hazard E* as well as more detailed information which may be on this *Hazard*.

Remove gold, silver and platinum jewellery and wear gloves before handling mercury.

Activity	User	Control measures	Experimental points
Using thermometers	Y7	Breakages must be reported and treated.	When accuracy is required, mercury thermometers should be used. Otherwise use spirit thermometers. See <i>Handbook</i> 10.7.
Using NiCad batteries	Y7	-	See <i>Handbook</i> 9.5.
Use in manometers	Y12	Wear disposable nitrile gloves. Remove rings and jewellery if possible.	Use a large, deep, non-metallic, smooth-surface, spillage tray. Do not leave the mercury uncovered for long periods. On a regular basis, examine rubber connections in apparatus for perishing.
Thermometer holders and stirrer seals	Y12	Do not use.	Replace holders for thermometers (known as pockets) with screw-cap thermometer sleeves. A PTFE gland is now used for stirrer seals.
Reaction with iodine	TT	Wear eye protection. Use a fume cupboard.	Warm slightly. Use only 1-2 g iodine and a drop of mercury.
Heating to form the oxide(II)	TT	Use a fume cupboard for several days.	Heat the mercury in a borosilicate flask fitted with a 20 cm long, 1 cm wide tube as an air-cooled reflux.
Density demonstration	TT	Wear disposable nitrile gloves. Remove rings and jewellery if possible.	Wrap the metals in cling film before placing them on the surface. It is better to keep samples solely for this activity in case the cling film breaks and mercury forms an amalgam on the surface of the metal.
Electrical contact and Barlow's wheel	TT	Use a fume cupboard.	Use a large, deep, non-metallic, smooth-surface, spillage tray. As an alternative to mercury for Barlow's wheel, use acidified saturated copper(II) sulfate(VI) solution as the conducting liquid.
Disposal of sodium amalgam	TT	Use a fume cupboard.	Waste from a Castner-Kellner cell must be treated with 1 mol dm ⁻³ hydrochloric acid or left in water with an iron nail for several days before being added to the stock of dirty mercury. Label the flask appropriately.
Measuring the temperature of ovens	TT	-	Do not use mercury thermometers in aluminium-lined ovens or incubators. If the thermometer breaks in the oven, the released mercury can amalgamate with the aluminium or vaporise when heated.

62 Mercury and cadmium compounds


Mercury(I) chloride		Calomel; mercurous chloride	Hg ₂ Cl ₂	
Harmful Dangerous for the environment		R22: Harmful if swallowed. R36/37/38: Irritating to eyes, respiratory system and skin. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. WEL (mg m⁻³): 0.025 (LTEL), 0.075 (STEL) as mercury.		
Store: Gln		Disposal: W1, W2		
Mercury(II) chloride		Mercuric chloride	HgCl ₂	
Mercury(II) nitrate(V)		Mercuric nitrate	Hg(NO ₃) ₂	
Very toxic		R28: Very toxic if swallowed. R48/24/25: Toxic: danger of serious damage to health by prolonged exposure in contact with skin and if swallowed. R34: Causes burns. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. Solutions equal to or stronger than 0.04 mol dm ⁻³ should be labelled TOXIC. Solutions equal to or stronger than 0.004 mol dm ⁻³ but weaker than 0.04 mol dm ⁻³ should be labelled HARMFUL. WEL (mg m⁻³): 0.025 (LTEL), 0.075 (STEL) as mercury. Mercury(II) nitrate(V) is dangerous with ETHANOL: explosive mercury fulminate forms.		
Dangerous for the environment				
Store: T		Disposal: W1, W2		
Mercury(I) and mercury(II) oxide		Mercurous oxide and mercuric oxide	Hg ₂ O and HgO	
Mercury(II) sulfate(VI)		Mercuric sulfate	HgSO ₄	
Very toxic Dangerous for the environment		R26/27/28: Very toxic by inhalation, in contact with skin and if swallowed. R33: Danger of cumulative effects. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in aquatic environment. WEL (mg m⁻³): 0.025 (LTEL), 0.075 (STEL) as Hg.		
Store: T		Disposal: W1, W2		
Mercury(II) sulfide; mercuric sulfide; cinnabar; HgS			Low hazard	Store: Gln Disposal: W1
Cadmium salts	Very toxic Dangerous for the environment		Not suitable for school use	Store: T (pending disposal) Disposal: W1
If all chemicals are spilt in laboratory:		Keep residues and cleaning cloths for disposal by an authorised contractor.		

Activity	User	Control measures	Experimental points
General use of solutions	Y9	Wear disposable nitrile gloves. Wear goggles.	Use solutions less than 0.04 mol dm^{-3} .
Effect of mercury(II) salts on aluminium	Y12	Wear disposable nitrile gloves. Wear goggles.	Wipe aluminium foil with cotton wool soaked in 1 mol dm^{-3} mercury(II) chloride and scratch the foil with a spatula under the solution. Disposal: for contaminated cotton wool - W1, W2
Cole's modification of Millon's reagent for testing tryptophan and proteins	TT	Do not use standard Millon's reagent Wear chemical-resistant gloves. Wear goggles or face shield. Y9 students can use the solution, once prepared.	Solution A: Dilute 100 cm^3 of concentrated sulfuric(VI) acid in 800 cm^3 of water. Dissolve 100 g mercury(II) sulfate(VI) in it and make up to 1 litre. Label the solution TOXIC and CORROSIVE. Solution B: Dissolve 5 g sodium nitrate(III) (nitrite) in 500 cm^3 water. Before use, mix two volumes of solution A with one volume of solution B. Label the solution TOXIC and CORROSIVE. The Sakaguchi test is specific for arginine; see <i>Hazardcard</i> 89.
Heating mercury(II) oxide	TT	Wear goggles. Use a fume cupboard.	Use 0.1 g of mercury(II) oxide in an ignition tube.
Action of heat on mercury(II) nitrate(V)	TT	Wear goggles. Use a fume cupboard.	Because nitrogen oxides and mercury vapour are emitted, use no more than 0.1 g of mercury(II) nitrate(V) in an ignition tube.
Nessler's reagent	TT	Do not use. Commercial water-testing strips for ammonia in water are now available.	
Millon's reagent	TT	The original reagent involves dissolving mercury in concentrated nitric(V) acid. Cole's modification is safer and should be used instead.	

63 Methanal

HCHO

Also known as formaldehyde and, in solution, formalin.

Toxic	 <p>R40: Limited evidence of a carcinogenic effect. Category 3 carcinogen. R23/24/25: Toxic by inhalation, in contact with skin and if swallowed. R34: Causes burns. R43: May cause sensitisation by skin contact. Solutions equal to or stronger than 25% are TOXIC, solutions equal to or stronger than 1% but weaker than 25% are HARMFUL and solutions equal to or stronger than 0.2% but weaker than 1% are IRRITANT. WEL (mg m⁻³): 2.5 (LTEL), 2.5 (STEL). Flash point: 56 °C.</p>
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Emergencies: see standard procedures on *Hazard E*, BUT ALSO:


If spilt in the laboratory:	<p>If more than 200 cm³ of 40% solution is spilt, evacuate the laboratory, opening windows in the process. After two hours, it may be safe to re-enter and deal with the spilt liquid but take care and wear eye protection.</p> <p>With smaller spills, wear eye protection and chemical-resistant gloves. Ventilate the area of the spill. Absorb the spilt liquid with mineral absorbent. Treat as a Toxic spill as described in <i>Handbook 7.7</i>. Mop the area of the spill thoroughly.</p>
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<p>Store: T</p> <p>In a locked cupboard in a large laboratory. In small rooms, escaping vapour is lachrymatory.</p> <p>In the past, there have been warnings against storing methanal solution with concentrated hydrochloric acid because, under special conditions, their vapours may form a very carcinogenic product. However, in school laboratories and prep rooms this reaction has never been shown to occur.</p>	<p>Disposal: W1, W2 or W7</p> <p>W7: Dilute the solution 100 times before disposal down a foul-water drain.</p>
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Activity	User	Control measures	Experimental points
General use of solution	Y9	Wear eye protection.	Use solutions weaker than 25%.
Extracting earthworms from soil	Y9	Wear eye protection. Wash hands after handling soil and earthworms.	A 0.2-1% solution, prepared in a fume cupboard by a teacher or technician, may be used. Methanal, as supplied, is diluted 200 times, eg, 10 cm ³ of methanal diluted to 400 cm ³ with water. However, this extraction method is harmful to the earthworms and a safer method is to use a 1.5% aqueous solution of a <i>ready-mixed, English</i> mustard!
Preparation of resins with urea	Y9	Wear goggles. Wear disposable nitrile gloves. Use a fume cupboard.	Do not use methods involving hydrochloric acid. Dissolve 5 g of urea in 10 cm ³ of 40% methanal solution in a disposable, expanded-polystyrene cup. Add 5 cm ³ of 1 mol dm ⁻³ sulfuric(VI) acid and stir. Leave in the fume cupboard until a solid forms. The reaction gives out heat and methanal vapour. Wear gloves when extracting the white resin from the cup.
Preparation of phenol/ formaldehyde resin	Y12	Wear goggles. Wear disposable nitrile gloves. Use a fume cupboard.	Do not use methods involving hydrochloric acid. Dissolve 0.2 g of sodium hydroxide in 10 cm ³ of 40% methanal solution and add 3 g of phenol. Heat the mixture until viscous. On cooling, it sets to a brittle solid, <i>Bakelite</i> , wear gloves when handling it.
Investigations involving preserved specimens	Y12	Wear eye protection. Wear disposable nitrile gloves.	Wherever possible, preserve specimens in an alternative fluid, eg, <i>Opresol</i> or propylene phenoxetol (see <i>Hazard</i> 37) or 70% ethanol. If a specimen preserved in methanal is to be examined, soak it in pure water or 30% ethanol for at least an hour before using it and rinse cavities as they are opened. See <i>Handbook</i> 15.8.
Use as a fixative/ preservative	TT	Wear goggles. Wear disposable nitrile gloves. Use a fume cupboard.	See <i>Recipe cards</i> 10 & 43 and <i>Handbook</i> 15.8. For fixing microbiological cultures, see <i>Handbook</i> 15.2.11. Stopper or seal jars carefully.

64 Methyl benzenecarboxylate and other esters

(See also 52)

Methyl benzenecarboxylate		Methyl benzoate	$\text{C}_6\text{H}_5\text{COOCH}_3$
Harmful		R20/21/22: Harmful by inhalation, in contact with skin and if swallowed. Flash point: 83 °C.	
Store: GOrg		Disposal: W1	


Ethyl benzenecarboxylate		Ethyl benzoate	$\text{C}_6\text{H}_5\text{COOC}_2\text{H}_5$
Irritant		R36/38. Irritating to eyes and skin. Flash point: 85 °C.	
Store: GOrg		Disposal: W1	


Dibutyl benzene-1,2-dicarboxylate		Dibutyl phthalate	$\text{C}_6\text{H}_4(\text{COOC}_4\text{H}_9)_2$
Toxic		R61: May cause harm to the unborn child. Category 2 teratogen. R62: Possible risk of impaired fertility. R50: Very toxic to aquatic organisms. WEL (mg m⁻³): 5 (LTEL), 10 (STEL).	
Dangerous for the environment			
Store: T		Disposal: W1, W2	


Ethyl 3-phenylpropenoate; ethyl cinnamate; $\text{C}_6\text{H}_5\text{CHCHCOOC}_2\text{H}_5$ Phenyl benzenecarboxylate; phenyl benzoate; $\text{C}_6\text{H}_5\text{COOC}_6\text{H}_5$ Methyl 3-nitrobenzenecarboxylate; methyl 3-nitrobenzoate; $\text{NO}_2\text{C}_6\text{H}_4\text{COOCH}_3$	Low hazard	Store: GOrg	Disposal: W1, W2 (Although low hazard, they are insoluble in water and keeping them for removal by an authorised waste contractor would be sensible.)
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Activity	User	Control measures	Experimental points
Crystallisation of phenyl benzoate	Y7	Wear eye protection.	Phenyl benzoate may be recrystallised from ethanol.
Hollow-prism activities	Y7	Wear eye protection. Wear chemical-resistant gloves when preparing and cleaning. Wear a lab coat; the odour from spills on clothes can last for ages.	Ethyl cinnamate, which has a strong, penetrating odour, should be used in place of carbon disulfide. The prism needs thorough cleaning with propanone after use to prevent attack on the cement. The resultant wide spectrum is especially suitable for explaining the action of chlorophyll in photosynthesis.
Heating bath for melting-point determinations	Y9	Wear eye protection. Apparatus will be very hot. Avoid dibutyl phthalate if possible.	Liquids are required which do not decompose when heated. See <i>Hazcards</i> 37 and 45B for preferred heating media. Dibutyl phthalate should only be used for heating to temperatures greater than 250 °C but less than 300 °C. Disposal: W3 (unless contaminated).
Saponification (hydrolysis) of benzoate esters	Y12	Wear goggles.	Reflux attachments must be connected to the reaction flask. 2 mol dm ⁻³ sodium hydroxide (CORROSIVE) is used for the hydrolysis. At refluxing temperatures, these esters are FLAMMABLE. Saponification procedures are an excellent way of recycling esters made in other A-level activities.
Nitration of methyl benzoate	Y12	Wear eye protection. Wear chemical-resistant gloves when making nitrating mixture.	See <i>Hazcards</i> 67 & 98A. See also Guide L195, <i>Safer Chemicals</i> , <i>Safer Reactions</i> . Phenyl benzoate can also be used. Disposal: W3 (Further reactions of methyl 3-nitrobenzoate may be carried out; see L195.)

65A Nickel, nickel(II) carbonate and nickel(II) oxide

Nickel		Ni
Harmful		R40: Limited evidence of a carcinogenic effect. Category 3 carcinogen. R43: May cause sensitisation by skin contact. WEL (mg m⁻³): 0.1 (LTEL), 0.3 (STEL).
Store: Gln		Disposal: W1, W3

Nickel(II) carbonate (basic)		<chem>NiCO3.2Ni(OH)2.4H2O</chem>
Harmful Dangerous for the environment		R40: Limited evidence of a carcinogenic effect. Category 3 carcinogen. R22: Harmful if swallowed. R43: May cause sensitisation by skin contact. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. WEL (mg m⁻³): 0.1 (LTEL), 0.3 (STEL) as nickel.
Store: Gln		Disposal: W1, W5 W5: Add no more than 50 g to 1 litre of 1 mol dm ⁻³ ethanoic acid and pour down a foul-water drain.



Nickel(II) oxide		NiO
Toxic		R49: May cause cancer by inhalation. Category 1 carcinogen but applies only to inhalation. R43: May cause sensitisation by skin contact. R53: May cause long-term adverse effects in the aquatic environment. WEL (mg m⁻³): 0.1 (LTEL), 0.3 (STEL) as nickel.
Store: T		Disposal: W1




65A Nickel, nickel(II) carbonate and nickel(II) oxide**Model risk assessments**

Those with sensitive skin should wear disposable gloves during use. Others should wash their hands after use.

Activity	User	Control measures	Experimental points
Nickel-based batteries	Y7	-	See <i>Handbook</i> 9.5 for more details.
Heating nickel(II) carbonate	Y9	Wear eye protection. Use a fume cupboard or insert a plug of mineral wool to stop any nickel(II) oxide dust being ejected.	Use no more than 1 g of nickel(II) carbonate. Disposal: In a fume cupboard, place the test tube and its contents into 1 mol dm ⁻³ sulfuric(VI) acid. Pour the green solution down a foul-water drain with more water.
Pigments or glazes	-	It is not advisable to use nickel(II) oxide in pigments and glazes.	

65B Nickel(II) salts


Nickel(II) sulfate(VI)-7-water		$\text{NiSO}_4 \cdot 7\text{H}_2\text{O}$
Ammonium nickel(II) sulfate(VI)-6-water		$(\text{NH}_4)_2\text{SO}_4 \cdot \text{NiSO}_4 \cdot 6\text{H}_2\text{O}$
Nickel(II) chloride-6-water		$\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$
Harmful Dangerous for the environment	 	<p>R40: Limited evidence of a carcinogenic effect. Category 3 carcinogen. R22: Harmful if swallowed. R42/43: May cause sensitisation by inhalation and skin contact. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.</p> <p>Solutions equal to or stronger than 0.03 mol dm^{-3} should be labelled HARMFUL.</p> <p>WEL (mg m^{-3}): 0.1 (LTEL), 0.3 (STEL) as nickel.</p>
Store: Gln		<p>Disposal: W1, W7</p> <p>W7: Dilute to less than 0.5 mol dm^{-3} before pouring down a foul-water drain.</p>


Nickel(II) nitrate(V)-6-water		$\text{NiNO}_3 \cdot 6\text{H}_2\text{O}$
Oxidising Harmful Dangerous for the environment	  	<p>R8: Contact with combustible material may cause fire. R40: Limited evidence of a carcinogenic effect. Category 3 carcinogen. R22: Harmful if swallowed. R42/43: May cause sensitisation by inhalation and skin contact. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.</p> <p>Solutions equal to or stronger than 0.03 mol dm^{-3} should be labelled HARMFUL.</p> <p>WEL (mg m^{-3}): 0.1 (LTEL), 0.3 (STEL) as nickel.</p>
Store: Gln		<p>Disposal: W1, W7</p> <p>W7: Dilute to less than 0.5 mol dm^{-3} before pouring down a foul-water drain.</p>

Those with sensitive skin should wear disposable gloves during use. Others should wash their hands after use.

Activity	User	Control measures	Experimental points
Use of nickel(II) solutions	Y9	Wear eye protection.	Use 0.1 mol dm^{-3} solutions of nickel nitrate(V), sulfate(VI) or chloride for precipitation reactions or in chromatography.
Preparation of nickel(II) sulfate(VI)	Y9	Wear eye protection.	Do not start from nickel(II) oxide; use nickel(II) carbonate instead. Add 15 cm^3 of 1.0 mol dm^{-3} sulfuric(VI) acid to 1.2 g of nickel(II) carbonate (a small excess). The mixture requires filtering before evaporation.
Plating	Y9	Wear eye protection.	Mix equal volumes of 0.2 mol dm^{-3} nickel(II) sulfate(VI) and 0.42 mol dm^{-3} ammonium sulfate(VI) solutions. [Alternatively, use 0.1 mol dm^{-3} ammonium nickel(II) sulfate(VI) solution.]
Preparation of complexes	Y12	Wear eye protection.	The particular hazards of individual complexes are not well known. If sensible precautions are followed with toxic or corrosive ligands (eg, concentrated ammonia solution), such as wearing gloves and using fume cupboards, there is no reason why these investigations should not be carried out on a small scale by responsible students. Nickel tetracarbonyl is VERY TOXIC and HIGHLY FLAMMABLE and should not be made in school labs.
Heating nickel(II) nitrate(V)	TT	Wear eye protection. Use a fume cupboard.	Nitrogen dioxide is produced. The solid product is nickel(II) oxide. Disposal: The small amount of residue should be dissolved in 1 mol dm^{-3} hydrochloric acid before pouring the solution down a foul-water drain.

66 Ninhydrin



Ninhydrin		1,2,3-indanetrione hydrate; 2,2-dihydroxy-1,3-indanedione	$C_9H_6O_4$
Harmful		R22: Harmful if swallowed. R36/37/38: Irritating to eyes, respiratory system and skin. The myth that this substance is a carcinogen is not supported by information from suppliers. It is often dissolved in butan-1-ol. Contact with skin produces a violet stain which can persist for several days.	
Store: GOrg		Disposal: W1, W7 W7: Dissolve no more than 100 g in 1 litre of water before pouring down a foul-water drain.	

Ninhydrin spray			
Harmful		R10: Flammable. R22: Harmful if swallowed. R37/38: Irritating to respiratory system and skin. R41: Risk of serious damage to eyes. R67: Vapours may cause drowsiness and dizziness. WEL (mg m⁻³): 154 (STEL) (Sk) (for butan-1-ol). Flash point: 29 °C (for butan-1-ol).	
Store: FL		Disposal: W1 Empty spray canister: W8 (Note: some containers are refillable.)	

Activity	User	Control measures	Experimental points
Locating amino acids on chromatograms (spray)	Y9	Wear eye protection. Use a fume cupboard. Wear disposable nitrile gloves. When the spray is used, there must be no sources of ignition nearby. Windows must be open near the oven during the heating process.	Set the oven at 110 °C. The solvent mixture used to develop chromatograms is butan-1-ol, concentrated ethanoic acid and water (in the ratio 4:1:2 by volume). For two-way chromatography, the second solvent mixture is ethanol, concentrated ammonia and water (in the ratio 8:1:1 by volume).
Locating amino acids on chromatograms (solution)	Y9	Wear eye protection. Wear disposable nitrile gloves. Windows must be open near the oven during the heating process.	Set the oven at 110 °C. Provide the ninhydrin solution in a shallow trough/tray into which the chromatograms are to be dipped.
Making up a solution	TT	Wear eye protection. Wear disposable nitrile gloves.	See <i>Recipe Card 46</i> .

67 Nitric(V) acid



Oxidising		<p>R8: Contact with combustible material may cause fire. R35: Causes severe burns. Solutions equal to or stronger than 0.5 mol dm^{-3} should be labelled CORROSIVE. Solutions equal to or stronger than 0.1 mol dm^{-3} but weaker than 0.5 mol dm^{-3} should be labelled IRRITANT. Solutions weaker than 11 mol dm^{-3}, ie, 70% (w/w), are deemed not to be OXIDISING.</p> <p>WEL (mg m^{-3}): 2.6 (STEL).</p>
Corrosive		

The substance is dangerous with:	<p>COMBUSTIBLE MATERIAL including many ORGANIC SUBSTANCES such as ETHANOIC ACID, ETHANOL, PROPANONE. Violent reactions may occur.</p> <p>LITHIUM, MAGNESIUM, SODIUM, POTASSIUM. The metals can ignite on contact.</p> <p>THIOCYANATES, THIOSULFATES. Violent reactions may occur.</p>
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Emergencies: see standard procedures on *Hazard E*, BUT ALSO:

If chemical splashes on the skin:	Skin turns yellow on contact and will peel off in due course. If the splashed area is treated correctly with water, peeling will happen gradually over several days. If the contamination is not treated quickly, peeling may be severe and painful. It will require medical attention.
If spilt in the laboratory:	Keep others away. Wear eye protection and chemical-resistant gloves (and rubber boots if spill is large). Ventilate the area of the spill as much as possible. Cover with mineral absorbent and clear up into a bucket. Wash the area of the spill thoroughly. See <i>Handbook 7.7</i> .

<p>Store: CLa</p> <p>Bottles should not be stored in direct sunlight; dark glass bottles or opaque containers are best. Light decomposes the colourless acid. If there is a brown colouration, decomposition has occurred and the liquid should be disposed of. Fuming nitric(V) acid (100%) should only be made in situ and not stored in schools.</p>	<p>Disposal: W1, W4</p> <p>W4: Add no more than 50 cm^3 of concentrated nitric(V) acid slowly to 1 litre of 1 mol dm^{-3} sodium carbonate. Do not attempt to dispose of large volumes of fuming nitric(V) acid by this method.</p>
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Activity	User	Control measures	Experimental points
Reaction of dilute acid with metals	Y7	Wear eye protection. The room should be well ventilated.	Use solutions no stronger than 0.4 mol dm^{-3} . Use less than 1 g of metal. Hydrogen is often not evolved when metals react with dilute nitric(V) acid; nitrogen monoxide is produced which reacts with oxygen to form nitrogen dioxide.
Reaction with copper or brass	Y9	Wear goggles. Wear chemical-resistant gloves. Use a fume cupboard.	The action of 70% acid produces mainly nitrogen dioxide. The action of 35% (half-concentrated) acid produces mainly nitrogen monoxide.
Etching metals	Y9	Wear goggles. Wear chemical-resistant gloves.	Mixtures of ethanol and nitric(V) acid (<i>nital</i>) are not safe. A 2% solution (v/v) of nitric(V) acid in ethanol can be made but not stored.
Nitrating mixture	Y12	Wear goggles. Wear chemical-resistant gloves. Glass apparatus must be dry before use.	Cool concentrated nitric(V) acid in an ice bath and add the required volume of concentrated sulfuric(VI) acid. Swirl the mixture to ensure the mixing is thorough before proceeding. See L195, <i>Safer Chemicals</i> , <i>Safer Procedures</i> for details of the nitration of methyl benzoate.
'Aqua Regia' for use in analysis of alloys	TT	Wear goggles or a face shield. Wear chemical-resistant gloves. Use a fume cupboard.	This very corrosive mixture is made by adding 5 cm^3 fresh concentrated nitric(V) acid to 15 cm^3 concentrated hydrochloric acid in a clean container. If the acids are warm, cool them before mixing. Do not attempt to stopper and store; any darkening beyond a yellow colour indicates appreciable decomposition and the mixture should be disposed of at once by pouring into a large excess of water and flushing down a foul-water drain.
Preparation of fuming nitric(V) acid and reaction with sawdust	TT	Wear goggles or a face shield. Wear chemical-resistant gloves. Use a fume cupboard. Use all-glass apparatus (no rubber bungs or corks).	Concentrated sulfuric(VI) acid is added to potassium nitrate(V). Fuming nitric(V) acid (CORROSIVE and OXIDISING) is approximately 98% pure and more hazardous than the acid normally purchased as 'concentrated' (<i>Handbook</i> 13.4). Use no more than 2 cm^3 of the 98% acid on dry sawdust.
Decomposition of concentrated nitric(V) acid	TT	Wear goggles or a face shield. Wear chemical-resistant gloves. Use a fume cupboard.	Use all-glass apparatus (no rubber bungs or corks).
Cleaning glassware	TT	Wear goggles or a face shield. Wear chemical-resistant gloves. Use a fume cupboard.	Nitric(V) acid cleaning baths should be suitably labelled and left in a working fume cupboard. 1 mol dm^{-3} nitric(V) acid is useful for removing scale deposits.

68 Nitrogen and its oxides

Nitrogen; N ₂		Low hazard (but it can be an asphyxiant)	Store: Cyl	Disposal: W6
Dinitrogen monoxide		Nitrous oxide; laughing gas		N ₂ O
Oxidising		R8: Contact with combustible material may cause fire. WEL (mg m⁻³): 183 (LTEL), 849 (STEL).		
Store: Situ There would be no harm in keeping a cylinder of dinitrogen monoxide and this would certainly overcome the problems of its preparation.				Disposal: W6
Nitrogen dioxide		Nitrogen peroxide		NO ₂
Dinitrogen tetroxide				N ₂ O ₄
Very toxic		R26: Very toxic by inhalation. R34: Causes burns. (The HSE, in Chemical Hazard Alert Notice 29 Nitrogen Dioxide, advises that the levels of this gas in air are reduced to 1 ppm (ie, 1.9 mg m ⁻³) to prevent development of emphysema.) Pupils with known breathing difficulties must not inhale the gas; it may trigger an asthmatic attack. Dangerous with: FINELY-DIVIDED METALS, eg, IRON and MAGNESIUM. These may ignite. HYDROGEN. This gas will ignite spontaneously when air is also present.		
Nitrogen monoxide		Nitric oxide		NO
Very toxic		R26/27: Very toxic by inhalation and in contact with skin. (The HSE, in Chemical Hazard Alert Notice 28 Nitrogen monoxide, advises that the levels of the gas in air are reduced to 1 ppm (ie, 1.4 mg m ⁻³) to prevent development of emphysema.) Pupils with known breathing difficulties must not inhale the gas; it may trigger an asthmatic attack. Dangerous with: CARBON DISULFIDE. An explosive reaction can occur.		


Emergencies: see standard procedures on *Hazard E*, BUT ALSO:

If released in the laboratory:	If over 1 litre of gas is evolved, evacuate the laboratory. Open a few outside windows, shut off all services and leave with all doors and internal windows closed.
Store: Situ (It is unwise to keep cylinders of these gases in schools.)	
Disposal: W6	

Activity	User	Control measures	Experimental points
Preparation of nitrogen dioxide	Y12	Wear eye protection. Use a fume cupboard.	The action of concentrated (70%) nitric(V) acid on copper turnings gives other nitrogen oxides as well. For a product free of other oxides, but containing oxygen, heat lead(II) nitrate(V). Collect the gas by upward displacement of air or collect liquid dinitrogen tetroxide by cooling the gas with an ice/salt mixture (see <i>Handbook</i> 13.3).
Preparation of nitrogen monoxide	Y12	Wear eye protection. Use a fume cupboard.	Cover iron(II) sulfate(VI) crystals with 5 mol dm ⁻³ hydrochloric acid. Drop a solution of 50 g sodium nitrate(III) (nitrite) in 100 cm ³ water onto the iron(II) sulfate(VI) solution. A less-pure product is made by the addition of 5 mol dm ⁻³ nitric(V) acid to copper turnings. Collect the gas over water (see <i>Handbook</i> 13.3).
Preparation of dinitrogen monoxide	Y12	Wear eye protection. Do not heat ammonium nitrate(V).	Dissolve 10 g of hydroxyammonium chloride in 50 cm ³ water. Drip this solution into a warmed solution containing 100 g of iron(III) ammonium sulfate(VI) in 200 cm ³ water. Collect over water (see <i>Handbook</i> 13.3).
Demonstrating gaseous equilibrium	Y12	Wear eye protection.	Using dry nitrogen dioxide, half fill a plastic 50 or 60 cm ³ syringe with a Luer lock and seal with a cap. The plunger can be moved in and out to alter the pressure of the gas and produce changes in colour.
Preparation of nitrogen	Y12	Wear eye protection.	Mix 6 g of sodium nitrate(III) (nitrite) with 10 g of ammonium chloride or sulfate(VI). Add water and warm gently. Collect the gas over water (see <i>Handbook</i> 13.3).
Use of liquid nitrogen	TT	Wear goggles or a face shield. Wear thermal gloves.	See <i>Handbook</i> 11.2 which gives details of the requirements for transporting and using liquid nitrogen.
Preparation of dinitrogen monoxide	TT	Use safety screens. Wear goggles or a face shield.	The more traditional preparation requires heating a mixture of 13 g powdered ammonium sulfate(VI) and 20 g potassium nitrate(V) dissolved in water. Stop heating if brown fumes are seen.
Nitrogen dioxide and diffusion of gases	TT	Wear eye protection. Use a fume cupboard for gas preparation and disposal.	See L195, <i>Safer Chemicals, Safer Reactions</i> for diffusion demonstrations as an alternative to bromine. The demonstration can be performed in a well-ventilated laboratory.
The 'barking dog' demonstration	TT	This is a very hazardous demonstration to carry out. The reaction of nitrogen monoxide with carbon disulfide would require a special risk assessment. An application should be made to CLEAPSS.	

69 Oxygen

O₂

Oxidising		<p>R8: Contact with combustible material may cause fire.</p> <p>Combustible substances burn much more fiercely in even slightly oxygen-enriched air. This is unlikely to be a risk in schools, even if a cylinder leak occurs (the small cylinders often used in schools contain about 1.5 m³ of the gas), but science staff should be aware of the situation.</p> <p>Liquid oxygen is particularly dangerous to handle and is not recommended for use in schools.</p>
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The substance is dangerous with:	<p>COMBUSTIBLE MATERIALS. These will burn more fiercely in an atmosphere of oxygen.</p> <p>CONCENTRATED AMMONIA SOLUTION. Explosions can occur.</p>
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Emergencies: see standard procedures on *Hazard E*, BUT ALSO:

If gas is directed over a person:	<p>All sources of ignition should be extinguished. The person should go outside for several minutes so that oxygen can diffuse from his/her clothing.</p>
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<p>Store: Cyl</p> <p>Keep ready for use in an upright position, not in the same vicinity as a flammables cupboard. See <i>Handbook 9.9</i> for more details.</p>	<p>Disposal: W6</p>
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Activity	User	Control measures	Experimental points
Small-scale preparation	Y7	Do not use 'oxygen mixture'. Wear eye protection.	<p>The scale of the activity should determine the concentration of hydrogen peroxide and state of the catalyst, usually manganese(IV) oxide, required. If the catalyst is too-finely divided, oxygen is produced so quickly that it is not easy to collect it. In this case, it is better to use 5 to 10 'vol' hydrogen peroxide solution with younger pupils.</p> <p>Solid potassium iodide is a slower catalyst and can be used with 20 'vol' hydrogen peroxide solution. As oxygen is produced, it first has to saturate the solution before the gas is evolved; this gives pupils time to arrange test tubes for gas collection. The solution turns a pale yellow because a little iodine is produced as a side reaction.</p> <p>Always have ready plenty of hydrogen peroxide solution because pupils easily make mistakes and the preparation may need to be started again. See <i>Handbook</i> 13.3 for details.</p>
Burning substances in oxygen	Y7	Wear eye protection. Protect the bench with hard-board or heat-proof mats.	Some pupils will have problems as they try to hold burning substances in tongs and add them to a boiling tube of oxygen. They may require several attempts to achieve success or the teacher might carry out a demonstration.
Large-scale preparation	Y12	Do not use 'oxygen mixture'. Wear eye protection. Wear disposable nitrile gloves.	Initially, 20 'vol' solution should be used. As more peroxide solution is added to used reagent, it becomes diluted and the rate of reaction decreases; in this case it is better to add 100 'vol' hydrogen peroxide. See <i>Handbook</i> 13.3 for details of the apparatus to be used.
Using a cylinder	TT	See <i>Handbook</i> 9.9 for details.	

70 Phenols

Phenol		Carbolic acid	$\text{C}_6\text{H}_5\text{OH}$
Toxic		<p>R68: Possible risk of irreversible effects. Category 3 mutagen. R23/24/25: Toxic by inhalation, in contact with skin and if swallowed. R48/20/21/22: Harmful: danger of serious damage to health by prolonged exposure through inhalation, in contact with skin and if swallowed. R34: Causes burns.</p> <p>Dangerous with: SODIUM NITRITE. An explosive mixture is formed.</p> <p>WEL (mg m^{-3}): 7.7 (LTEL), 23.1 (STEL) (Sk). Odour threshold is 0.997 mg m^{-3} (0.05 ppm).</p>	
Corrosive		<p>Emergencies: see standard procedures on <i>Hazard E</i>, BUT ALSO:</p> <p>If spilt on skin or clothes: Remove all contaminated clothing as quickly as possible. Small amounts of water may increase absorption. Flood the area with water for at least 15 minutes (preferably in a shower). If immediately available, swab repeatedly with glycerol, then with soap and water. Seek medical attention as soon as possible. Phenol burns are very serious.</p>	
2-, 3- or 4-methylphenol		<i>o</i> -, <i>m</i> - or <i>p</i> -cresol	$\text{CH}_3\text{C}_6\text{H}_4\text{OH}$
Toxic		<p>R24/25: Toxic in contact with skin and if swallowed. R34: Causes burns.</p> <p>WEL (mg m^{-3}): 22 (LTEL), 66 (STEL).</p>	
Store: T		<p>Disposal: W1 or W4</p> <p>W4: Add no more than 1 g to 100 cm^3 of 1 mol dm^{-3} sodium carbonate solution before pouring it down a foul-water drain.</p>	
4-aminophenol			$\text{H}_2\text{NC}_6\text{H}_4\text{OH}$
Harmful Dangerous for the environment		<p>R20/22: Harmful by inhalation and if swallowed. R68: Possible risk of irreversible effects. Category 3 mutagen. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects.</p>	
Store: GOrg			Disposal: W1, W4, W5
Naphthalen-1-ol or naphthalen-2-ol		1-naphthol or 2-naphthol; α -naphthol or β -naphthol	$\text{C}_{10}\text{H}_7\text{OH}$
Harmful		<p>R21/22: Harmful in contact with skin and if swallowed. R37/38: Irritating to respiratory system and skin. R41: Risk of serious damage to eyes.</p>	
Store: GOrg (Samples obtained before 1990 should be disposed of; they may contain toxic impurities.)			Disposal: W1, W2
2,4,6-trinitrophenol; picric acid; $(\text{NO}_2)_3\text{C}_6\text{H}_2\text{OH}$ Please contact CLEAPSS if you have, or need to use, this explosive chemical.			



Activity	User	Control measures	Experimental points
Handling phenol	Y12	Wear goggles. Wear disposable nitrile gloves. Wear a laboratory coat.	The crystals clump together and need poking with a spatula to remove them from the bottle. Contact with the solid is likely, so gloves are essential. Crystals often end up on the bench and floor, so thorough cleaning is required.
Reactions of phenol and cresol	Y12	Wear goggles. Wear disposable nitrile gloves when dispensing.	Methyl 4-hydroxybenzoate can be used as an alternative. It is much easier to handle and gives similar results (see Guide L195, <i>Safer Chemicals, Safer Reactions</i>). Also see <i>Hazard</i> 88.
Resins formed with methanal	Y12	Wear eye protection. Wear nitrile gloves during resin preparation and handling. Use a fume cupboard. Do not use methods involving hydrochloric acid.	Dissolve 0.2 g of sodium hydroxide in 1 cm ³ of a 40% methanal solution and add 3 g of phenol. Heat the mixture until viscous. On cooling, it sets to a brittle solid, <i>Bakelite</i> . Disposal of the resin: Wash with water and place it in the normal refuse.
Nitration of phenol	Y12	Wear eye protection. Wear disposable nitrile gloves. Do not use the usual nitrating mixture which can yield nitrosophenols.	Use a solution of 1 g of sodium nitrate(V) dissolved in 1 mol dm ⁻³ sulfuric(VI) acid in an ice bath. Any products must only be handled wearing gloves and the test tube should be wrapped in paper and discarded after use, not washed.
Reaction with diazonium salts	Y12	Wear eye protection. Wear disposable nitrile gloves.	Check that diazotisation is complete by testing for excess nitric(III) acid (use starch/iodide paper) before proceeding to the next reaction step. Phenols, cresols and naphthols can be used. See <i>Hazcards</i> 4A & 93.
Formation of trihalophenols	Y12	Wear goggles. Wear disposable nitrile gloves when dispensing.	This illustration of the enhanced activity of the aromatic nucleus by the presence of the OH group requires a dilute solution of phenol and can be done on a test-tube scale. Shake up one crystal of phenol with 1 cm ³ of water and add 0.1% (v/v) bromine water drop by drop.
Preparation of phenolphthalein	Y12	Wear eye protection. Use a fume cupboard.	Use amounts no larger than 0.5 g of phthalic anhydride, 0.5 g phenol and 1 drop of concentrated sulfuric(VI) acid. Heat for 3 minutes in the fume cupboard. Cool the mixture and add 0.4 mol dm ⁻³ sodium hydroxide solution to obtain the mauve colour.
Mutual solubility	Y12	Wear eye protection. Wear disposable nitrile gloves.	Phenol/water systems may be investigated with care.
Preparation of paracetamol	Y12	Wear eye protection. Wear disposable nitrile gloves.	Full details of the preparation of paracetamol from phenol or 4-aminophenol are found in <i>Paracetamol - a curriculum resource</i> , RSC, ISBN 0854043756.

71 Phenylethene, phenylethyne and their polymers

Phenylethene	Styrene		C_6H_8
Harmful		R10: Flammable. R20: Harmful by inhalation. R36/38: Irritating to eyes and skin. Flash point: 32 °C. Dangerous with: AIR. Vapour/air mixtures are explosive. WEL (mg m⁻³): 430 (LTEL), 1080 (STEL).	
Store: FL Although this substance is supplied with a stabiliser, it polymerises during storage over the years. The liquid becomes viscous and then solidifies into a resin. Check regularly.		Disposal: W1, W2 If solid, the resin can be disposed of as W8.	
Phenylethyne	Phenylacetylene		C_6H_5CCH
Harmful		R10: Flammable. R36/37: Irritating to eyes and respiratory system. Flash point: 31 °C.	
Store: FL		Disposal: W1, W2	
Polyphenylethene; polystyrene All other plastics		Low hazard	Store: GOrg Disposal: W8





Activity	User	Control measures	Experimental points
Hot-wire cutting of polystyrene	Y7	Wear eye protection. The room should be well ventilated.	Make sure expanded polystyrene is used and not polyurethane which produces toxic gases.
Plastics identification	Y7	Wear eye protection. The room should be well ventilated.	Burning tests for the identification of plastics should be carried out on samples no larger than 5 mm square. Do not include samples of PVC or PTFE in the plastics to be identified. See <i>Handbook</i> 13.6.
Plastics pyrolysis	Y9	Wear eye protection. The room should be well ventilated.	Polythene [poly(ethene)] and polypropylene [poly(propene)] can be heated in a test tube to destruction in the absence of air, collecting the gases over water. Acrylics and polystyrene must be heated in a fume cupboard to distill the liquid monomer. There is no value in heating nylon, polycarbonates, PVC, PTFE and thermosetting plastics in this way; they decompose and also produce very toxic products.
Bromination	Y12	Wear goggles. Wear disposable nitrile gloves. Use a fume cupboard.	Add a 5% solution of bromine in ethane-1,2-diol to 4 cm ³ of phenylethene until the red colour just remains. The product, 1-phenyl-1,2-dibromoethane, is a skin irritant and care should be taken during its extraction. However, it can be prepared in an ethane-1,2-diol solution so that phenylethyne can be synthesised directly from it (see below).
Preparation of phenylethyne	Y12	Wear goggles. Wear disposable nitrile gloves. Use a fume cupboard.	Use <i>Quickfit</i> apparatus. Add 2 g of potassium hydroxide pellets to 5 g of ethane-1,2-diol; this is an exothermic reaction, so cool the flask under a tap if necessary. Add the 1-phenyl-1,2-dibromoethane solution in ethane-1,2-diol. Distil the mixture to produce phenylethyne.
Reactions of phenylethyne	Y12	Wear eye protection.	This substance can be used to illustrate the chemistry of the carbon-carbon triple bond. The products formed after reacting phenylethyne with ammoniacal silver nitrate(V) and ammoniacal copper(I) chloride solutions should not be isolated because they could be explosive.
Removal of inhibitor from phenylethene	Y12	Wear goggles. Wear chemical-resistant gloves.	The inhibitor is 4- <i>tert</i> -butyl catechol (HARMFUL). Phenylethene should be washed with 1 mol dm ⁻³ sodium hydroxide solution and then water in a separating funnel before drying with anhydrous sodium sulfate(VI) for ten minutes.
Polymerisation of phenylethene	Y12	Wear goggles. Wear disposable nitrile gloves.	See <i>Hazard</i> 29.

72 Phosphoric(V) acid and its salts

Phosphoric(V) acid		Orthophosphoric acid	H ₃ PO ₄	
Corrosive		R34: Causes burns. Solutions equal to or stronger than 2.5 mol dm ⁻³ should be labelled CORROSIVE. Solutions equal to or stronger than 0.5 mol dm ⁻³ but weaker than 2.5 mol dm ⁻³ should be labelled IRRITANT. WEL (mg m⁻³): 1.0 (LTEL), 2.0 (STEL). Dangerous with: WATER. Heat is evolved. Always add acid to water cautiously. CHLORATES, POTASSIUM MANGANATE(VII). Explosive products are formed. SODIUM, POTASSIUM and other metals. Dangerous reactions can occur. HYDROCHLORIC ACID, CHLORIDES. Hydrogen chloride is given off.		
Store: CLa Usually sold as an 85% (w/w) solution although other concentrations are available.			Disposal: W4	
Potassium phosphate(V)-2-water		Potassium orthophosphate dihydrate	K ₃ PO ₄ ·2H ₂ O	
Sodium phosphate(V)-12-water		Sodium orthophosphate dodecahydrate	Na ₃ PO ₄ ·12H ₂ O	
Adenosine triphosphate		ATP	-	
Irritant		R36/38: Irritating to eyes and skin.		
Store: Gln		Disposal: W7		
Ammonium dihydrogenphosphate(V); NH ₄ H ₂ PO ₄ Ammonium phosphate(V)-3-water; (NH ₄) ₃ PO ₄ ·3H ₂ O Ammonium sodium hydrogenphosphate(V); microcosmic salt; NH ₄ NaHPO ₄ Calcium dihydrogenphosphate(V)-2-water; Ca(H ₂ PO ₄) ₂ ·2H ₂ O Diammonium hydrogenphosphate(V); (NH ₄) ₂ HPO ₄ Dipotassium hydrogenphosphate(V); K ₂ HPO ₄ Disodium hydrogenphosphate(V); disodium hydrogen orthophosphate; Na ₂ HPO ₄ Disodium hydrogenphosphate(V)-12-water; Na ₂ HPO ₄ ·12H ₂ O Potassium dihydrogenphosphate(V); KH ₂ PO ₄ Sodium dihydrogenphosphate(V)-2-water; NaH ₂ PO ₄ ·2H ₂ O		Low hazard	Store: Gln	Disposal: W7
Calcium phosphate(V); calcium orthophosphate, Ca ₃ (PO ₄) ₂				W8

Activity	User	Control measures	Experimental points
General use of phosphoric(V) acid	Y7	Wear eye protection.	Use solutions no stronger than 2.5 mol dm^{-3} with Y7.
Microcosmic salt bead test	Y7	Wear eye protection.	This is very similar to the borax bead test. Make a clear bead by fusing a small quantity of microcosmic salt onto a loop of nichrome wire in a Bunsen-burner flame. After the bead has been formed, coat it with a dry sample of the metal salt to be tested and reintroduce the bead into the burner flame. The inner cone of the flame is the reducing flame; the outer portion is the oxidising flame. Observe the colours in each part of the flame. The various colours identify the metallic element. The relevant colours are published in many older text books and on the internet.
Use of buffer solutions	Y7	-	Buffer solutions between pH 2 and 10 make use of various phosphate salts. See <i>Recipe card 14</i> and <i>Guide R35 pH measurement</i> .
Phosphate test	Y9	Wear eye protection.	See <i>Hazard card 9A</i> .
Preparation of hydrogen halides	Y12	Wear goggles. Wear disposable nitrile gloves.	Phosphoric(V) acid is used to prepare hydrogen halides from the relevant sodium or potassium salts in place of sulfuric(VI) acid which gives a number of toxic side products. Use a fume cupboard for larger-scale preparations but the following small-scale method, with less than 10 sets of students, can be done in a well-ventilated, large laboratory. Use 2 g of the sodium or potassium halide in a boiling tube, 2 cm^3 of phosphoric(V) acid and 1 g of phosphorus(V) oxide to absorb water. Warm the mixture gently. Collect the gas in test tubes using downward delivery. Stopper the test tubes.
Dehydration of cyclohexanol	Y12	Wear goggles. Wear gloves during the addition of phosphoric(V) acid to cyclohexanol.	Make sure the reagents are thoroughly mixed before they are heated on a water bath at 70°C for 15 minutes and distilled. The product is cyclohexene.

73A Phosphorus


White phosphorus		Yellow phosphorus	P
Highly flammable		<p>R17: Spontaneously flammable in air. R26/28: Very toxic by inhalation and if swallowed. R34: Causes burns.</p> <p>WEL (mg m^{-3}): 0.1 (LTEL), 0.3 (STEL).</p> <p>Dangerous with: OXIDISING AGENTS, particularly CHLORATES and METAL OXIDES, because both produce explosive mixtures. It is illegal to make the mixture of potassium chlorate(V) and sulfur.</p> <p>Emergencies: see standard procedures on Hazcard E, BUT ALSO:</p> <p>If spilt on the bench, skin or clothes: Immerse the area of the spill in 0.2 mol dm⁻³ copper(II) sulfate(VI) solution (which turns black where there is phosphorus contamination) for 15 minutes. Seek medical attention.</p>	
Very toxic			
<p>Store: Spec</p> <p>Best stored with the TOXIC chemicals. The solid must be kept under water. Change the water frequently by flushing through with fresh water from the tap. Keep away from sodium, potassium and oxidising agents. The addition of sodium chloride to the water will reduce the risk of the bottle breaking caused by the water freezing. Never store white phosphorus in an outside store because of the freezing risk. White phosphorus is not currently available from suppliers because of importing problems.</p>			<p>Disposal: W1, Wspec</p> <p>Wspec: Do not dispose of large amounts of white phosphorus before contacting CLEAPSS first.</p>
Red phosphorus			P
Highly flammable		<p>R11: Highly flammable. R16: Explosive when mixed with oxidising substances. R52/53: Harmful to aquatic organisms, may cause long-term adverse effects in the aquatic environment. WEL (mg m^{-3}): 0.1 (LTEL), 0.3 (STEL).</p> <p>Dangerous with: OXIDISING AGENTS, particularly CHLORATES and METAL OXIDES, because both produce explosive mixtures.</p>	
Dangerous for the environment			
<p>Store: FS</p> <p>Keep it away from oxidising agents. There may be liquid above the solid in old bottles; this is phosphoric acid. Water vapour has entered the bottle and reacted with the phosphorus. It is probably best to dispose of the chemical in this state via a hazardous waste contractor.</p>			<p>Disposal: W1, W6</p>


73A Phosphorus


Model risk assessments


Activity	User	Control measures	Experimental points
Changing red phosphorus to white	Y12	Wear goggles. Wear disposable nitrile gloves. Use a fume cupboard.	Place a small piece of red phosphorus in a boiling tube fitted with a bung with two delivery tubes. Flush air out with carbon dioxide and place in water at 45-50 °C. White phosphorus condenses on the cooler surface of the boiling tube.
Cutting white phosphorus	TT	Wear goggles or a face shield. Wear chemical-resistant gloves. Wear a laboratory coat. Do not do this on your own.	Handle with tongs. Cut the phosphorus under water in a plastic washing-up bowl, three-quarters filled with water. Do not use a glass vessel. Use a sharp knife because white phosphorus is quite hard.
Changing white phosphorus to red	TT	Wear goggles or a face shield. Wear chemical-resistant gloves. Use a fume cupboard.	Place a small piece of white phosphorus in a boiling tube, half filled with water. Add 1 crystal of iodine as a catalyst. Maintain at 90 °C for 30 minutes but do not boil.
Igniting white phosphorus in air or oxygen	TT	Wear goggles or a face shield. Use a fume cupboard.	Ignite phosphorus with the tip of a hot glass rod rather than a flame. The reaction with oxygen is very bright and students should protect their eyes from the glare of the light.
The bell jar demonstration	TT	Wear goggles or a face shield. Wear chemical-resistant gloves. The room should be well ventilated.	Place white phosphorus [1.5 g of phosphorus for every 5 litres of air in a bell jar gives a small excess of phosphorus (to ensure complete combustion)] in an evaporating basin and float this on water in a trough before placing a bell jar over it. Use a long, hot, glass rod to ignite the phosphorus before replacing the stopper in the bell jar. Hold the bell jar down because the exothermic reaction increases gas pressure inside the jar before the expected contraction of volume begins. Leave the apparatus until the white fumes have dissolved in the water. Unreacted phosphorus may still remain in the basin and could catch fire, so submerge the basin with a long glass rod before removing the bell jar. Remove the basin full of water in a fume cupboard. Pour the water carefully away, fill the basin with 1 mol dm ⁻³ copper(II) sulfate(VI) solution and leave it for 24 hours before clearing up the basin with care.
Burning in chlorine	TT	Wear goggles or a face shield. Wear chemical-resistant gloves. Use a fume cupboard.	Place a piece of white phosphorus (while still wet) with sides no larger than 5 mm in the chlorine. It will ignite spontaneously in a short while. Soak the deflagrating spoon and gas jar in 1 mol dm ⁻³ copper(II) sulfate(VI) solution for 24 hours after use.

73B Group V elements and compounds: other than phosphorus

Antimony		Sb
Harmful		R20/22: Harmful by inhalation and if swallowed. R36/37/38: Irritating to eyes, respiratory system and skin. WEL (mg m⁻³): 0.5 (LTEL), 1.5 (STEL).
Store: Gln		Disposal: W1

Antimony(III) chloride		Antimony trichloride	Sb(Cl) ₃
Bismuth(III) chloride		Bismuth trichloride	Bi(Cl) ₃
Corrosive Dangerous for the environment		R34: Causes burns. R51/53: Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. WEL (mg m⁻³): 0.5 (LTEL), 1.5 (STEL) as Sb for antimony(III) chloride.	
Store: CW It absorbs water from the atmosphere.			Disposal: W1, W7

Arsenic		As
Toxic Dangerous for the environment		R23/25: Toxic by inhalation and if swallowed. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. WEL (mg m⁻³): 0.1 (LTEL), 0.3 (STEL).
Store: T An exhibition sample may be kept. Arsenic compounds are NOT suitable for school use.		Disposal: W1



Bismuth(III) oxychloride		BiOCl
Bismuth(III) nitrate(V)		Bi(NO ₃) ₃
Oxidising Irritant		R8: Contact with combustible material may cause fire. R36/37/38: Irritating to eyes, respiratory system and skin.
Store: Gln		Disposal: W1


Bismuth; Bi	Low hazard	Storage: Gln	Disposal: W2
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73B Group V elements and compounds: other than phosphorus Model risk assessments

Activity	User	Control measures	Experimental points
Adding bismuth(III) chloride to water	Y9	Wear eye protection.	Place about 0.1 g of bismuth(III) chloride in a test tube and add 2 cm ³ of water. Add concentrated hydrochloric acid, drop by drop, until the solution clears. Add water until the precipitate appears and add concentrated hydrochloric acid again to show that the reaction is reversible. The precipitate is bismuth(III) oxychloride and the clear solution is bismuth(III) chloride.
Investigating the chemistry of bismuth(III) ions	Y9	Wear eye protection.	To dissolve bismuth(III) nitrate(V), a little 1 mol dm ⁻³ nitric(V) acid needs to be added. If a 0.1 mol dm ⁻³ solution is prepared, the hydroxide, iodide and sulfide can be precipitated. If water is added to bismuth nitrate(V) solution, the basic salt precipitates.
Adding antimony to chlorine	TT	Wear goggles or a face shield. Use a fume cupboard.	Sprinkle antimony dust into a gas jar of chlorine. The dust catches fire and burns brilliantly.
Investigating the properties of Wood's metal	TT	Wear eye protection.	Wood's metal is an alloy with a low melting point (65.5 °C) consisting of approximately 50% bismuth, 25% lead, 12.5% tin and 12.5% cadmium. It is molten in hot water. The hazard of the metal sold by one supplier is HARMFUL: (R21/22 Harmful in contact with skin and if swallowed). The metal is used in 'joke' spoons which melt in a cup of hot tea! (Do not drink it!) Its peculiar properties may be shown to all pupils.

74 Phosphorus chlorides

Phosphorus(III) chloride		Phosphorus trichloride	PCl ₃
Very toxic		R14: Reacts violently with water. R29: Contact with water liberates toxic gas. R26/28: Very toxic by inhalation and if swallowed. R48/20: Harmful: danger of serious damage to health by prolonged exposure through inhalation. R35: Causes severe burns. Dangerous with: WATER. A violent reaction occurs, emitting hydrogen chloride. SODIUM, POTASSIUM. A violent reaction occurs. WEL (mg m⁻³): 1.1 (LTEL), 2.9 (STEL).	
Corrosive			
Store: CW Hydrogen chloride leakage from opened bottles corrodes labels and any iron and steel in the vicinity. Place the bottle in an outer container with some soda lime. Keep only small quantities (250 g or less), so that stock is always fresh.		Disposal: W1, W4 W4: Use a fume cupboard. Add no more than 10 cm ³ of the liquid, in 1 cm ³ volumes, to 1 litre of 1 mol dm ⁻³ sodium carbonate solution. Carry this out slowly because the reaction produces gases and heat. Pour the solution down a foul-water drain.	


Phosphorus(V) chloride		Phosphorus pentachloride	PCl ₅
Very toxic		R14: Reacts violently with water. R29: Contact with water liberates toxic gas. R26: Very toxic by inhalation. R22: Harmful if swallowed. R48/20: Harmful: danger of serious damage to health by prolonged exposure through inhalation. R34: Causes burns. Dangerous with: WATER. A violent reaction occurs, emitting hydrogen chloride. SODIUM, POTASSIUM. A violent reaction occurs. WEL (mg m⁻³): 0.87 (LTEL), 2.0 (STEL).	
Store: CW Hydrogen chloride leakage from opened bottles corrodes labels and any iron and steel in the vicinity. Place the bottle in an outer container with some soda lime. Keep only small quantities (250 g or less), so that stock is always fresh.			
		Disposal: W1, W4 W4: Use a fume cupboard. Add 10 g of solid in about 1 g portions to 1 litre of 1 mol dm ⁻³ sodium carbonate solution. Carry this out slowly because the reaction produces gases and heat. Pour the solution down a foul-water drain.	

Activity	User	Control measures	Experimental points
Action of water on phosphorus(III) chloride	Y12	Wear goggles. The room should be well ventilated.	Place 5 drops of phosphorus(III) chloride in a dry test tube and add slowly 2 cm ³ of water. You may need to warm the mixture gently to complete the reaction. Hydrogen chloride is produced. If this is done on a larger scale, a fume cupboard must be used.
Action of water on phosphorus(V) chloride	Y12	Wear goggles. The room should be well ventilated.	Place 0.1 g of phosphorus(V) chloride in a test tube and cautiously add 2 cm ³ of water. Hydrogen chloride is produced. If this is done on a larger scale, a fume cupboard must be used.
Test for the -OH group in organic molecules	Y12	Wear goggles. Use a fume cupboard.	Use no more than 2 cm ³ of the suspected alcohol or carboxylic acid in a test tube and add phosphorus(V) chloride with a small spatula. Hydrogen chloride is produced.
Preparation of acid chlorides	Y12	Wear eye protection. Use a fume cupboard. Wear chemical-resistant gloves.	Use <i>Quickfit</i> apparatus. 2 cm ³ of phosphorus(III) chloride is added to 4 cm ³ of ethanoic acid very slowly via a dropping funnel. The temperature of a water bath is raised to 45 °C. Once the hydrogen chloride gas has evolved, the temperature is increased to 90 °C to distil off the acid chloride. An absorption tube containing anhydrous calcium chloride is used to prevent moisture entering the equipment.

75 Phosphorus(V) oxide





Also known as phosphorus pentoxide and diphosphorus pentoxide.

Corrosive		R35: Causes severe burns. WEL (mg m⁻³): 1.0 (LTEL), 2.0 (STEL).
The substance is dangerous with:	WATER. A violent reaction occurs. Any combustible material in the vicinity may even ignite. METHANOIC ACID. Carbon monoxide is given off. SODIUM, POTASSIUM. These metals may ignite on contact. IODIDES. A violent reaction occurs.	
Store: CS Place this in a desiccator or other outer container with anhydrous calcium chloride. Keep small quantities (250 g or less), so that stock is always fresh.		Disposal: W1, W4 W4: Use a fume cupboard. Add 10 g of solid in about 1 g portions to 1 litre of 1 mol dm ⁻³ sodium carbonate solution. Carry this out slowly because the reaction produces gases and heat. Pour down a foul-water drain.

75 Phosphorus(V) oxide**Model risk assessments**

Activity	User	Control measures	Experimental points
Addition to water	Y9	Wear goggles.	Add 0.1 g of phosphorus(V) oxide to 2 cm ³ of water. The reaction is very vigorous.
Preparation of acid anhydrides	Y12	Wear goggles. Wear chemical-resistant gloves. Use a fume cupboard.	-
Use as a drying agent	TT	Wear goggles or a face shield. Wear chemical-resistant gloves.	Take care disposing of the used solid. A glassy crust often forms, concealing dry oxide which will react violently with water. It must not be reused. Safer alternatives include silica gel (easily re-used) and saturated calcium chloride solution.

Highly flammable		R14/15: Reacts violently with water liberating extremely flammable gases. R34: Causes burns.
Corrosive		
The substance is dangerous with:		WATER. Hydrogen is given off which ignites. Corrosive liquid spits out. 1,1,1-TRICHLOROETHANE and other chlorinated hydrocarbons such as tetrachloromethane. Explosive mixtures are formed. MANY OTHER SUBSTANCES. Check the appropriate <i>Hazard</i> for any substances used.

Emergencies: see standard procedures on *Hazard E*, BUT ALSO:

If particles enter the eyes:	Flood the eye with gently-running tap water until a first aider arrives. Send the affected person to hospital and ensure that irrigation is continued during the journey.
If spilt on the floor:	Wear eye protection and chemical-resistant gloves. Cover with mineral absorbent or anhydrous sodium carbonate (soda ash) and scoop up into a dry bucket. Rinse the area with water and mop up. Add the mixture in small amounts to an excess of propan-2-ol (isopropyl alcohol).
If it catches fire:	The metal burns vigorously and is very difficult to extinguish. For small fires, smother with mineral absorbent or anhydrous sodium carbonate (soda ash) or by using a dry-powder extinguisher. Do not use carbon dioxide or water-based fire extinguishers or even clean, dry sand.

Store: FW

Store under medicinal paraffin. Do not place the bottle in the flammables cupboard because this will contain chemicals that react with potassium. If old stock has a strong custard-yellow crust, do not cut it; it has been known to catch fire and/or explode. This is caused by the interaction of residual traces of mineral oil with the surface layer of yellow superoxide, initiated by blade pressure or impact. Use the W1 disposal method if there are several lumps of potassium affected in this way. If only slightly yellow, cut off the surface carefully and dispose of the material as in Wspec.



Disposal: W1, Wspec

Wspec: Working with another person, using a fume cupboard in a secure room, add no more than 2 g in small pieces, one at a time, to 100 cm³ of 2-methylpropan-2-ol in a 400 cm³ beaker. There may be some sparks. Place a heat-proof mat over the beaker to prevent alcohol vapour catching fire. Leave the reaction (suitably labelled) to finish before adding more pieces of potassium. If the pieces are more than slightly yellow, do not cut into the potassium but place the metal in a 1:1 mixture of 2-methylpropan-2-ol and medicinal paraffin. It may take several hours to react.

After any use of potassium in the laboratory, the demonstrator must ensure that the bottle is securely locked away. There have been several instances of pupils stealing the chemical. In addition, any white tiles, bricks or equipment used to cut potassium during the demonstration must be placed in a trough of water. This ensures that the technician will not encounter any sudden fires when clearing up after the demonstrations.

Activity	User	Control measures	Experimental points
Preparing potassium for use	TT	Wear goggles or a face shield. Do not use organic solvents to remove the oil.	Place the metal onto a tile and cut off the required potassium with a sharp knife. Dab the metal with a paper tissue to remove the oil. There have been reports of petroleum spirit or hexane being used to remove the oil. During washing up, unused pieces of potassium were unknowingly added to water and the igniting hydrogen caused the residual hydrocarbon to burn the face of a technician.
Burning potassium in air and oxygen	TT	Wear goggles or a face shield. The gas jar must be dry. The room should be well ventilated. Use safety screens.	Burn a small piece, with sides no larger than 3 mm, on a deflagrating spoon. The oxygen should come from a gas cylinder or canister or, if prepared chemically, dried and collected by downward delivery in a dry gas jar.
Reaction of potassium with water	TT	Wear goggles or a face shield. The room should be well ventilated. Use safety screens to surround the trough.	Use a small piece with sides no larger than 3 mm. Never attempt to constrain the potassium; always allow it to roam freely on a large surface of water. Place the safety screens as close to the trough as possible to avoid pieces flying out over the class. Burning particles and/or corrosive liquids will almost certainly be ejected. Alternatively, an acrylic sheet can be placed over the top of the trough.
Reaction with alcohols	TT	Wear goggles or a face shield. Use dry apparatus.	Use small pieces, with sides no larger than 3 mm. Use 2-methylpropan-2-ol or higher alcohols. Do not use methanol, ethanol, propanol, propan-2-ol, butanol and butan-2-ol because these alcohols catch fire.
Reaction with chlorine	TT	Wear goggles or a face shield. Use a fume cupboard.	This must be carried out by igniting potassium on a brick and placing a gas jar of chlorine over the burning potassium. This is similar to the method for sodium; see L195, <i>Safer Chemicals, Safer Reactions</i> .

77 Potassium chlorate(V) & chlorate(VII) and sodium chlorate(V)








Potassium chlorate(V)		KClO ₃
Potassium chlorate(VII)	Potassium perchlorate	KClO ₄
Sodium chlorate(V)		NaClO ₃
Oxidising		<p>R9: Explosive when mixed with combustible material. R20/22: Harmful by inhalation and if swallowed. R51/53: Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.</p> <p>It is <i>illegal</i> to make mixtures of chlorates with SULFUR and PHOSPHORUS.</p> <p>Dangerous with: AMMONIA and AMMONIUM SALTS. Unstable, explosive salts form even when mixed dry.</p> <p>METAL POWDERS, MANGANESE(VI) OXIDE, SULFIDES, THIOSULFATES, CARBON, SUGARS, HYDROCARBONS. Unstable & dangerous mixtures are formed.</p> <p>CONCENTRATED SULFURIC(VI) ACID and PHOSPHORIC(V) ACID. Explosive chlorine oxides or chloric acids are produced.</p> <p>COMBUSTIBLE MATERIALS: SUGAR, WOOD, CLOTHES etc, impregnated with solutions, ignite easily and burn very vigorously when dry. These reactions may be carried using special risk assessments (eg, the howling jelly-baby demonstration).</p> <p>Emergencies: see standard procedures on <i>Hazard E</i>, BUT ALSO:</p> <p>If spilt in the laboratory: It is essential to ensure that no significant impregnation of wood, cloth or other combustible matter occurs. Never use fabric gloves to handle these substances.</p>
Harmful		
Store: Ox		<p>Disposal: W1, Wspec</p> <p>Wspec: Dilute to, or prepare, a 0.1 mol dm⁻³ solution. Add about 10 g of sodium or potassium metabisulfite to 100 cm³ of this solution. Leave for 1 hour in a fume cupboard. Pour the solution down a foul-water drain.</p>

Potassium chlorate(V) and sodium chlorate(V) should *not* be available in the laboratory at the same time as concentrated sulfuric(VI) acid. Do not confuse sodium chlorate(V) (NaClO₃), a commercial weed killer, usually found as a solid, with sodium chlorate(I) (NaClO), a disinfectant, which is only found as a solution. Where chlorates are required by a scheme of work, potassium chlorate(V) usually satisfies the requirements and there is little need to keep sodium chlorate(V).

77 Potassium chlorate(V) & chlorate(VII) and sodium chlorate(V) Model risk assessments

Activity	User	Control measures	Experimental points
Solubility investigations using potassium chlorate(V)	Y9	Wear eye protection. Take care not to allow the solution to impregnate wood or clothing.	The solubility changes from 7.1 g to 57 g per 100 cm ³ of water in the temperature range 20 to 100 °C, making this an ideal chemical to investigate solubility changes with temperature. Collect all solutions at the end for disposal. Some courses suggest this activity for younger pupils and, with well-motivated pupils, this may be possible. Aluminium potassium sulfate(VI) and sodium tetraborate (anhydrous) are safer alternatives.
Redox reactions	Y12	Wear eye protection.	Work on a test-tube scale. Use 0.1 mol dm ⁻³ solutions to oxidise iron(II) or iodide ions.
Action of heat	Y12	Wear goggles. Do not add manganese(IV) oxide to catalyse the reaction.	Use 1-2 g in a dry, borosilicate test tube. Place a mineral-wool plug in the neck of the test tube; this stops the student allowing the glowing splint to touch the molten salt. Under careful conditions, potassium chlorate(VII) can be made and isolated. These crystals should not be stored but immediately disposed of after isolation and weighing.
Catalysis of the decomposition of potassium chlorate(V)	TT	Wear goggles or a face shield.	'Oxygen mixture', ie, potassium chlorate(V) and manganese(IV) oxide, should not be stored nor used for the preparation of oxygen (see below). A mixture can be made to demonstrate the catalytic activity of oxides using about 0.3 g of potassium chlorate(V) and a pinch of manganese(IV) oxide or copper(II) oxide in an ignition tube. Zinc oxide or magnesium oxide could be used to show that they have no effect.
Preparation of oxygen using chlorates	TT	There are better ways of producing oxygen. Do not use this method.	Numerous accidents have been reported with the traditional method of heating potassium chlorate(V) with manganese(IV) oxide. See <i>Hazard</i> 69 for the preparation of oxygen.
Howling jelly-baby demonstration	TT	Wear goggles or a face shield. Use safety screens.	The supplementary risk assessment for this demonstration is available on the CLEAPSS members-only web site and <i>Science Publications CD-ROM</i> .

78 Potassium & sodium chromate(VI) and dichromate(VI)

Potassium chromate(VI)			K ₂ CrO ₄
Toxic		R49: May cause cancer by inhalation. Category 2 carcinogen. R46: May cause heritable genetic damage. Category 2 mutagen. R36/37/38: Irritating to eyes, respiratory system and skin. R43: May cause sensitisation by skin contact. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.	
Dangerous for the environment			
Sodium chromate(VI)			Na ₂ CrO ₄
Very toxic		R45: May cause cancer. Category 2 carcinogen. R46: May cause heritable genetic damage. Category 2 mutagen. R60: May impair fertility. R61: May cause harm to the unborn child. Category 2 teratogen. R26: Very toxic by inhalation. R25: Toxic if swallowed. R48/23: Toxic: danger of serious damage to health by prolonged exposure through inhalation. R21: Harmful in contact with skin. R34: Causes burns. R42/43: May cause sensitisation by inhalation and skin contact. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.	
Dangerous for the environment			
Potassium dichromate(VI)			K ₂ Cr ₂ O ₇
Sodium dichromate(VI)-2-water			Na ₂ Cr ₂ O ₇ ·2H ₂ O
Oxidising Very toxic Dangerous for the environment		R45: May cause cancer. R46: May cause heritable genetic damage. Category 2 carcinogen and mutagen. R60: May impair fertility. R61: May cause harm to the unborn child. Category 2 teratogen. R8: Contact with combustible material may cause fire. R21: Harmful in contact with skin. R25: Toxic if swallowed. R26: Very toxic by inhalation. R34: Causes burns. R42/43: May cause sensitisation by inhalation and skin contact. R48/23: R48/23. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.	
	 		

For all these chemicals:

Solutions equal to or stronger than 0.2 mol dm^{-3} should be labelled VERY TOXIC [except potassium chromate(VI) - TOXIC]. Solutions equal to or stronger than $0.003 \text{ mol dm}^{-3}$ but weaker than 0.2 mol dm^{-3} are TOXIC. Solutions weaker than $0.003 \text{ mol dm}^{-3}$ are LOW HAZARD.

Dangerous with: ALUMINIUM, MAGNESIUM, CARBON, SULFUR, PHOSPHORUS, COMBUSTIBLE MATERIALS, including ORGANIC SUBSTANCES. Form explosive or vigorously-burning mixtures. **WEL (mg m^{-3}):** 0.05 (LTE), 0.15 (STEL) as chromium.

Store: T	Disposal: W1, Wspec Wspec: In a fume cupboard, add no more than 1 litre of 0.02 M solution or 5 g of the solid to 1 litre of 0.1 mol dm^{-3} sodium metabisulfite solution made up in 1 M sulfuric(VI) acid and then pour the solution down the foul-water drain.
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Activity	User	Control measures	Experimental points
Precipitation reactions	Y9	Wear goggles. Consider wearing disposable nitrile gloves.	Do not isolate the chromates of barium, copper, lead and zinc, which are carcinogens. Disposal: flush down a foul-water drain with water.
Preparation of potassium chromium(III) sulfate(VI)	Y9	Wear goggles. Consider wearing disposable nitrile gloves. The room should be well ventilated.	Dissolve 3 g of potassium dichromate(VI) in 25 cm ³ of 1 mol dm ⁻³ sulfuric(VI) acid. Add 2 cm ³ of ethanol, dropwise with stirring, keeping the temperature below 50 °C. Ethanal is produced as well. Leave overnight for crystals (also known as chrome alum) to form.
Small-scale oxidation of ethanol to ethanal or ethanoic acid	Y9	Wear goggles. Consider wearing disposable nitrile gloves.	The reaction of acidified dichromate(VI) solution with ethanol can be violent. Ensure that all the solid is dissolved by stirring well before adding ethanol. Sodium dichromate(VI) is often used because it is more soluble. In a boiling tube, use no more than 2 cm ³ of the alcohol and add an equal volume of the acidified 0.1 mol dm ⁻³ dichromate solution. Mix well. Do not distil to dryness.
Large-scale oxidation of ethanol to ethanal or ethanoic acid	Y12	Wear goggles. Wear chemical-resistant gloves.	It is important to mix the contents of the flask very thoroughly after each small addition of alcohol and, at the reflux stage, to raise the temperature very slowly. Have a beaker of cold water available to cool down any vigorous reactions. The reagents have been known to shoot out of the flask and 'paint' the ceiling.
Titrations	Y12	Wear eye protection.	See <i>Hazard</i> 10B.
Chromyl(VI) chloride preparation	Y12	Wear goggles. Wear chemical-resistant gloves. Use a fume cupboard. Follow the preparation instructions, precisely.	Use no more than 0.1 g of solid potassium dichromate(VI), 0.1 g of sodium chloride and 2 cm ³ of concentrated sulfuric(VI) acid. Warm gently to produce red fumes of chromyl(VI) chloride (CORROSIVE, TOXIC, OXIDISING & DANGEROUS FOR THE ENVIRONMENT; it is a category 2 carcinogen and mutagen). Disposal: Add contents to water and flush down a foul-water drain with more water.
Cleaning glassware	TT	Do not use 'chromic acid'.	It is better to use a proprietary scientific glassware detergent such as <i>Decon 90</i> or <i>Extran 300</i> . 'Chromic acid' is not always effective in any case and can be dangerous with organic deposits.
Using potassium dichromate(VI) test papers	TT	Wear goggles or a face shield. Wear chemical-resistant gloves.	Test papers should be prepared before the lesson. Soak strips of filter paper in 0.1 mol dm ⁻³ potassium dichromate(VI) solution, acidified with an equal volume of 0.1 mol dm ⁻³ sulfuric(VI) acid. For pupils, use a drop of this solution on filter paper.



79 Potassium hexacyanoferrate(II) and hexacyanoferrate(III)


Potassium hexacyanoferrate(II)-3-water		Potassium ferrocyanide	$K_4Fe(CN)_6 \cdot 3H_2O$
Low hazard	-	<p>R32: Contact with acids liberates very toxic gas. Some data sheets warn that it is harmful to aquatic organisms, may cause long-term adverse effects in the aquatic environment.</p> <p>Dangerous with: ACIDS. Do not heat with dilute or concentrated acids because toxic gases will be evolved. NITRITES. These may explode on heating. HEAT. A toxic gas is evolved.</p>	
Store: Gln		Disposal: W7	

Potassium hexacyanoferrate(III)		Potassium ferricyanide	$K_3Fe(CN)_6$
Low hazard	-	<p>R32: Contact with acids liberates very toxic gas. Some data sheets warn that it is harmful to aquatic organisms, may cause long-term adverse effects in the aquatic environment.</p> <p>Dangerous with: ACIDS. Do not heat with dilute or concentrated acids because toxic gases will be evolved. AMMONIA. An explosive mixture is formed. NITRITES, COPPER SULFATE(VI) and CHROMIUM(VI) OXIDE. These may explode on heating. HEAT. A toxic gas is evolved.</p>	
Store: Gln		Disposal: W7	

Activity	User	Control measures	Experimental points
General use of potassium hexacyanoferrate(II) solution	Y7	Wear eye protection. Do not have Bunsen burners on. Do not add concentrated acids to these solutions because toxic gases are produced.	With iron(III) ions, Prussian blue forms. With iron(II) ions, a white precipitate forms which turns blue with oxidation. Copper(II) ions give a brown precipitate and silver nitrate(V) a white precipitate. Use 0.1 mol dm ⁻³ solutions of these reagents in test tubes. Disposal: Wash all the precipitates down a foul-water drain with plenty of water.
General use of potassium hexacyanoferrate(III) solution	Y7	Wear eye protection. Do not have Bunsen burners on. Do not add concentrated acids to these solutions because toxic gases are produced.	With iron(III) ions, there is a brown colouration. With iron(II) ions, a blue precipitate forms. Copper(II) ions give a green precipitate and silver nitrate(V) produces an orange-red precipitate. Use 0.1 mol dm ⁻³ solutions of these reagents in test tubes. Disposal: Wash all the precipitates down a foul-water drain with plenty of water.
Detection of rust with ferroxyl indicator	Y7	Wear eye protection. Do not have Bunsen burners on. Do not add concentrated acids to these solutions because toxic gases are produced.	Potassium hexacyanoferrate(III) (0.05 mol dm ⁻³ solution) is used to detect iron(II) ions on iron and steel products (dark-blue patches appear). These represent the anode areas where rusting will start. Cathode areas become alkaline and can be detected by the addition of phenolphthalein. Also see <i>Recipe Card 37</i> .
Photochemical reaction	Y7	Wear eye protection.	Use very dilute solutions, eg, 0.5 cm ³ of 1% iron(III) chloride solution, 0.5 cm ³ of 1% potassium hexacyanoferrate(III) solution and 0.5 cm ³ of 1% sodium citrate solution plus 50 cm ³ of water. Expose the beaker to light from an overhead projector or equivalent very bright light source.
Blueprints	Y7	Wear eye protection. Do not have Bunsen burners on. Do not add concentrated acids to these solutions because toxic gases are produced.	The solution, consisting of 5 g of potassium hexacyanoferrate(III) and 9 g of ammonium iron(III) citrate (LOW HAZARD but it does stain clothes) dissolved in 100 cm ³ of water, should be prepared immediately before use. It is painted onto paper in dull indoor light and hung to dry over blotting paper. The dried paper is greenish blue; if an object is put on it and the paper is left in sunlight, the exposed parts will turn blue. Any unchanged green parts can be washed away with water. Hands should be washed thoroughly after use.

80 Potassium iodate(V) and bromate(V)

Potassium bromate(V)			KBrO ₃
Toxic		R9: Explosive when mixed with combustible material. R45: May cause cancer. Category 2 carcinogen. R25: Toxic if swallowed. It is not a volatile material. Solutions equal to or stronger than 0.005 mol dm ⁻³ should be labelled TOXIC. Solutions weaker than 0.005 mol dm ⁻³ are LOW HAZARD. Dangerous with: ALUMINIUM, MAGNESIUM, CARBON, SULFUR, PHOSPHORUS, COMBUSTIBLE MATERIALS, including ORGANIC SUBSTANCES. Mixtures may be explosive or burn vigorously.	
Oxidising			
Store: Ox		Disposal: W1, W7 W7: 1 g should be dissolved in 1 litre of water before pouring down a foul-water drain.	




Potassium iodate(V)			KIO ₃
Oxidising		<p>R8: Contact with combustible material may cause fire.</p> <p>All solutions are low hazard.</p> <p>Dangerous with: ALUMINIUM, MAGNESIUM, CARBON, SULFUR, PHOSPHORUS, COMBUSTIBLE MATERIALS, including ORGANIC SUBSTANCES. Mixtures may be explosive or burn vigorously.</p>	
Store: Ox		<p>Disposal: W1, W7</p> <p>W7: 50 g should be dissolved in 1 litre of water before pouring down a foul-water drain.</p>	

Activity	User	Control measures	Experimental points
Redox reactions	Y9	Wear eye protection.	Use only on a test-tube scale.
Titration using iodate solutions	Y9	Wear eye protection.	A 0.0167 mol dm ⁻³ solution of potassium iodate(V) is used as a primary standard for thiosulfate solutions (see <i>Handbook</i> 13.8). When potassium iodide is added in the presence of acid, an iodine solution is produced.
Bromate/bromide clock reaction	Y9	Wear eye protection.	The bromate/bromide clock reaction uses 0.005 mol dm ⁻³ potassium bromate (solution A) and 0.01 mol dm ⁻³ potassium bromide (solution B). Solution C is 40 cm ³ of 1 mol dm ⁻³ sulfuric(VI) acid and 2 cm ³ of methyl orange solution made up to 100 cm ³ with water. Solutions B and C are mixed first. The clock is started when solution A is added and stopped when the solution becomes colourless.
Using bromate/bromide mixtures in titrations	Y9	Wear eye protection.	A mixture of 1.12 g of potassium bromate(V) and 12 g of potassium bromide in 1 litre of water can be handled by pupils using a burette to add it to acidified aqueous suspensions of vegetable oils. Bromine water is generated but is removed by the unsaturated carbon-carbon bonds. See PS 67-01 on the <i>Science Publications CD-ROM</i> .
The Landolt clock reaction	Y12	Wear eye protection.	This uses potassium iodate(V) solution. See <i>Recipe Card</i> 18.
Winkler's oxygen analysis	Y12	Wear goggles. Wear chemical-resistant gloves.	This is used to measure dissolved oxygen in water. See <i>Recipe Card</i> 74. The procedure uses 8 mol dm ⁻³ sodium hydroxide solution and potassium iodate solution.
Oscillating reactions	Y12	Wear eye protection.	The Belousov-Zhabotinski (B-Z) reaction uses potassium bromate solution. See <i>Recipe Card</i> 48.
Making bromine water	TT	Wear goggles or a face shield. Wear chemical-resistant gloves Use a fume cupboard.	Add 1.12 g of potassium bromate(V), 12 g of potassium bromide and 14 cm ³ of 2 mol dm ⁻³ hydrochloric acid into a 1 litre jug or measuring cylinder. Add water to 1 litre and pour the solution into a labelled bottle.
Action of heat on iodates and bromates	TT	Wear goggles or a face shield. Use a fume cupboard.	Iodine and bromine are produced.

81 Potassium manganate(VII)



Also known as potassium permanganate.

Oxidising		R8: Contact with combustible material may cause fire. R22: Harmful if swallowed. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.
Harmful		All solutions are LOW HAZARD.
Dangerous for the environment		Solid potassium manganate(VII) should not be made available in the laboratory at the same time as concentrated sulfuric(VI) acid.

The substance is dangerous with:	METAL POWDERS (eg, magnesium), ORGANIC and COMBUSTIBLE MATERIALS. Explosive or vigorously-burning mixtures are formed; the mixture with PROPANE-1,2,3-TRIOL (glycerol) ignites after a delay (but, under controlled conditions, it is an acceptable demonstration). AMMONIA and AMMONIUM COMPOUNDS. These may form unstable explosive salts even when mixed dry. CONCENTRATED SULFURIC(VI) ACID & CONCENTRATED PHOSPHORIC(V) ACID. Manganese(VII) oxide (manganese heptoxide), which is explosive, is formed.
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Emergencies: see standard procedures on *Hazard E*, BUT ALSO:



If spilt on the skin or clothes:	Brush off as much solid as possible. Wash off the skin with plenty of water. Remove and soak clothing and rinse thoroughly. 20 'vol' hydrogen peroxide solution (IRRITANT) in 2 mol dm ⁻³ hydrochloric acid (1:1) may remove the stain from clothes. Rinse well.
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Store: Ox Solutions should be stored in dark bottles.	Disposal: W1, W7 or Wspec. W7: Solutions less than 0.3 mol dm ⁻³ or 5% (w/v) may be poured down a foul-water drain. Wspec: Dissolve 10 g of solid in 1 litre of water and add 1 litre of 1 mol dm ⁻³ sulfuric(VI) acid. Add sodium metabisulfite, with stirring, until the solution is colourless. Then pour the solution down a foul-water drain.
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Activity	User	Control measures	Experimental points
General use of solution	Y7	Wear eye protection.	To test for alcohols or unsaturation, use a 0.02 mol dm^{-3} solution. Disposal: Solutions can be poured down a foul-water drain.
Removing earthworms from soil	Y7	Wear eye protection. Wash hands after handling soil and earthworms.	Use a 0.01 mol dm^{-3} solution. This may be used as a safer alternative to methanal. However, the solution will damage plants. It is preferable to use a solution of mustard; see <i>Hazardcard</i> 63.
Studying diffusion	Y7	Wear eye protection.	Melt about 1 g of magnesium nitrate(V)-6-water in a test tube and add 1 small crystal of potassium manganate(VII). Pour the purple melt onto aluminium sheet so that it cools down and re-solidifies. For diffusion in liquids, this lump can be placed into a beaker of cold water at the edge. When warmed, the solid will start to dissolve and the potassium manganate(VII) will be released to illustrate diffusion.
Heating	Y7	Wear goggles. Do not inhale the dust produced in this activity, it can irritate the nasal passages.	Particles are ejected as the crystals explode but this can be controlled by placing a mineral-wool plug at the mouth of the test tube. This allows oxygen to pass through to be collected over water or relight a glowing splint but stops the dust contaminating the delivery tube.
Titration	Y9	Wear eye protection.	A 0.02 mol dm^{-3} solution of potassium manganate(VII) is suitable. For permanganate value (PV) testing of water, in pollution studies, a $0.002 \text{ mol dm}^{-3}$ solution is used. Disposal: Solutions can be poured down a foul-water drain.
Preparation of potassium manganate(VI)	Y12	Wear goggles.	Place 0.3 g of potassium manganate(VII) and 0.3 g of manganese(IV) oxide into a borosilicate test tube. Add 3 pellets of solid potassium hydroxide and warm cautiously. On cooling, add 5 cm^3 of water to release the green manganate(VI) ion.
Reaction with hydrohalic acids	Y12	Wear goggles. Use a fume cupboard.	The appropriate halogen is produced. Use on a test-tube scale only. Add 1 cm^3 of the concentrated acid to about 0.1 g of potassium manganate(VII). For the large-scale preparation of chlorine; see <i>Hazardcard</i> 47A.
Cleaning test tubes after heating	TT	Wear goggles or a face shield. Wear chemical-resistant gloves. Use a fume cupboard if many test tubes are to be cleaned.	Pour the contents down a foul-water drain with lots of running water. Rinse the glassware. The manganese(IV) oxide stains can be removed by adding concentrated hydrochloric acid and again rinsing with water. A small amount of chlorine will be evolved.

82 Potassium and sodium nitrate(V)

Potassium nitrate(V)		KNO ₃
Oxidising		R8: Contact with combustible material may cause fire. Dangerous with: ALUMINIUM, MAGNESIUM, SODIUM, POTASSIUM and other metals. Explosive mixtures are formed. COMBUSTIBLE MATERIALS including ORGANIC SUBSTANCES, AMMONIUM SALTS, CYANIDES, SULFIDES, THIOSULFATES, ETHANOATES. Unstable, explosive mixtures are formed.
Store: Ox	Disposal: W1, W7 W7: Dilute to less than 5% (w/v) before pouring the solution down a foul-water drain.	

Sodium nitrate(V)		NaNO ₃
Oxidising		R8: Contact with combustible material may cause fire. R22: Harmful if swallowed. R36: Irritating to eyes. Dangerous with: ALUMINIUM, MAGNESIUM, SODIUM, POTASSIUM and other metals. Explosive mixtures are formed. COMBUSTIBLE MATERIALS including ORGANIC SUBSTANCES, AMMONIUM SALTS, CYANIDES, SULFIDES, THIOSULFATES, ETHANOATES. Unstable, explosive mixtures are formed.
Harmful		
Store: Ox	Disposal: W1, W7 W7: Dilute to less than 5% (w/v) before pouring the solution down a foul-water drain.	



Emergencies: see standard procedures on *Hazard E*, BUT ALSO:


If spilt in the laboratory:	Scoop up as much solid as possible. Absorb solutions with mineral absorbent. Rinse the area of the spill and the cloth thoroughly. It is essential to ensure that no significant impregnation of wood, cloth or other combustible matter occurs.
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Black powder: Up to 100 g of black powder (gun powder) can be prepared, if an adequate risk assessment is carried out. An accident resulted in one of the few prosecutions of a science teacher. Competent chemists should contact CLEAPSS to discuss the matter further.

Activity	User	Control measures	Experimental points
Potassium nitrate(V) solubility	Y7	Wear eye protection.	Potassium nitrate(V) is used because there is a large variation of solubility with temperature, ie, from 40 g in 100 cm ³ of water at 26 °C to 175 g at 80 °C.
Fire writing	Y7	Wear eye protection.	Use sodium nitrate(V) which is much more soluble (88 g per 100 cm ³ of water) than potassium nitrate(V) in water at room temperature.
Action of heat on Group I nitrates(V)	Y7	Wear goggles. Place a mineral-wool plug at the mouth of the test tube.	This is best done in a small test tube (ignition tube). Oxygen is evolved. The solid product (a nitrite) is TOXIC ; see <i>Hazardcard</i> 93. A glowing splint should be held at the mouth of the ignition tube. The mineral-wool plug stops pupils inserting the burning splint into the decomposing nitrate(V). If this were to be done, there would be a violent reaction. This reaction can be demonstrated by the teacher. See also <i>Hazardcard</i> 58.
Brown ring test	Y12	Wear eye protection. Wear disposable nitrile gloves.	Dissolve about 0.3 g of potassium nitrate(V) in about 3 cm ³ of distilled water and add the same volume of a freshly-prepared 0.5 mol dm ⁻³ iron(II) sulfate(VI) solution. Cool the mixture under running water and cautiously add concentrated sulfuric(VI) acid to form a lower layer. A brown ring forms at the junction of the two liquids. Alternative version: Place a few crystals of the suspected nitrate(V) on a spotting plate or tile and add one or two drops of concentrated sulfuric(VI) acid. Then drop into the centre of the mixture a tiny crystal of iron(II) sulfate(VI). A brown ring starts to form around the crystal after about twenty seconds if nitrate(V) is present. Concentrated phosphoric(V) acid can be used; the reaction is slower and the ring takes one or two minutes to form. With nitrites, the ring forms immediately, giving a ready differentiation between the two anions. See <i>Hazardcard</i> 1 for the test with Devarda's alloy.
Reaction of sugar with a nitrate(V)	TT	Wear goggles. Use safety screens.	Use only 1 g of the nitrate(V), mixed with enough sugar to cover a 3 cm disc. Heat in a crucible, not a test tube. Do not use any other oxidising agents.
Burning wood with a nitrate(V)	TT	Wear goggles. Use safety screens.	Clamp the test tube above a Bunsen burner. Carry out the action of heat on potassium or sodium nitrate(V), testing for oxygen with a glowing wooden splint but letting the splint drop into the molten nitrate(V).

83 Propanal and other aldehydes

Propanal		Propionaldehyde	$\text{CH}_3\text{CH}_2\text{CHO}$
Highly flammable		R11: Highly flammable. R36/37/38: Irritating to eyes, respiratory system and skin. Flash point: -40 °C. Dangerous with: AMMONIACAL SILVER NITRATE(V) SOLUTION. Explosive products are formed.	
Irritant			
Store: FL		Disposal: W1, W7 W7: Prepare a 5% solution before pouring it down a foul-water drain.	

Butanal		Butyraldehyde	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CHO}$
Highly flammable		R11: Highly flammable. Flash point: -7 °C.	
Store: FL		Disposal: W1, W7 W7: In a fume cupboard, prepare a 5% solution before pouring it down a foul-water drain.	



Benzenecarbaldehyde		Benzaldehyde	$\text{C}_6\text{H}_5\text{CHO}$
Harmful		R22: Harmful if swallowed. Flash point: 64 °C.	
Store: GOrg		Disposal: W1, W2	



Emergencies: see standard procedures on *Hazard E*, BUT ALSO:

If spilt in the laboratory:	Shut off all possible sources of ignition. Ventilate the area of the spill. For large spills, evacuate the area and leave the liquid to evaporate.
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Activity	User	Control measures	Experimental points
As a reducing agent	Y7	Wear eye protection.	Reducing sugars (eg, glucose) are much safer to use in preparing silver mirrors than aldehydes. The corrosive products should not be inhaled. See also <i>Hazcard</i> 40C & 91 for information on Benedict's and Fehling's solutions.
Test-tube reactions of aldehydes	Y12	Wear eye protection.	Propanal and butanal are suitable for small-scale procedures, eg, a few drops. The corrosive products should not be inhaled. These reactions are more reliable, compared to the use of ethanal.
Large-scale oxidation reactions	Y12	Wear goggles. Use a fume cupboard.	These reactions are best done with benzaldehyde which produces benzoic acid. The aliphatic aldehydes produce organic acids with obnoxious smells.
Addition of sulfur dioxide	Y12	Wear goggles. Use a fume cupboard to prepare saturated sodium hydrogensulfite.	Prepare saturated sodium hydrogensulfite solution by passing sulfur dioxide through saturated sodium metabisulfite solution. Add 3-5 drops of aldehyde to 2 cm ³ of saturated sodium hydrogensulfite solution. Add a stopper and agitate the test tube carefully.
Cannizzaro's reaction	Y12	Wear goggles. Use a fume cupboard. Wear disposable nitrile gloves.	Mix 5 cm ³ of benzaldehyde with a very concentrated solution of sodium hydroxide (4 g dissolved in 5 cm ³ of water and cooled to room temperature). The flask should be stoppered before leaving overnight. Add water to the solid, warming to dissolve it and, on cooling, remove the alcohol with three washings of ethoxyethane. Acidification of the solution produces benzoic acid.
Condensation reactions	Y12	Wear eye protection. Wear disposable nitrile gloves.	See <i>Hazcard</i> 30. Propanal, butanal and benzaldehyde are more reliable than ethanal in producing precipitates with Brady's reagent.

84A Propan-1-ol and propan-2-ol

Propan-1-ol	<i>n</i> -propanol, propyl alcohol		CH ₃ CH ₂ CH ₂ OH
Highly flammable		<p>R11: Highly flammable. R41: Risk of serious damage to eyes. R67: Vapours may cause drowsiness and dizziness.</p> <p>It is absorbed through the skin.</p> <p>Flash point: 15 °C.</p> <p>WEL (mg m⁻³): 500 (LTEL), 625 (STEL) (Sk).</p> <p>Dangerous with: OXIDISING AGENTS. Alcohols will react vigorously. KETONES (other than propanone). Peroxides form in days, giving an explosion risk. POTASSIUM. The alcohol will catch fire.</p>	
Irritant			
Store: FL		<p>Disposal: W1, W7</p> <p>W7: Prepare a 5% solution before pouring it down a foul-water drain.</p>	






Propan-2-ol	iso-propanol; isopropyl alcohol		CH ₃ CHOHCH ₃
Highly flammable		R11: Highly flammable. R36: Irritating to eyes. R67: Vapours may cause drowsiness and dizziness. Flash point: 12 °C. WEL (mg m⁻³): 999 (LTEL), 1250 (STEL).	
Irritant		Dangerous with: OXIDISING AGENTS. Alcohols will react vigorously. KETONES (other than propanone). Peroxides form in days, giving an explosion risk. POTASSIUM The alcohol will catch fire.	
Store: FL Propan-2-ol should be in a dark bottle which limits the formation of peroxides. It can normally be kept for several years if it is to be used as a solvent or a fuel. If it is ever to be boiled to almost dryness, the sample should not be more than 2 years old.		Disposal: W1, W7 W7: Prepare a 5% solution before pouring it down a foul-water drain.	

84A Propan-1-ol and propan-2-ol

Model risk assessments

Activity	User	Control measures	Experimental points
Any activity involving heating propanols	Y7	Wear eye protection. Never use a naked flame to heat a highly-flammable liquid. Never distil to dryness.	If no electrically-heated bath is available, half fill a large beaker with boiling water from a kettle. If propanol vapour catches fire, cover the container with a heat-proof mat to starve the fire of oxygen.
Degreasing and cleaning agent	Y7	Wear eye protection.	Use propan-2-ol.
As a fuel in spirit burners	Y7	Wear eye protection. Pupils should not refill spirit burners.	The room should be well ventilated but draughts may affect experimental work. The use of a spirit burner should be dedicated to a specific alcohol. Make sure the wick fits tightly in the holder and the holder fits tightly in the container. See L195, <i>Safer Chemicals, Safer Procedures and Handbook</i> 9.4.3.
Test-tube preparation of esters	Y9	Wear goggles.	Use 5-10 drops of organic acid with 5-10 drops of the alcohol and 1-2 drops of concentrated sulfuric(VI) acid. After warming, cool under running tap water before adding to 0.5 mol dm ⁻³ sodium carbonate solution in a beaker. Smell the ester with care. See also PS67-07.
Preserving specimens	Y12	Wear eye protection. Avoid naked flames.	See <i>Handbook</i> 14.7 and 15.8 for the use of propan-1-ol.
Boiling points of an ideal mixture	Y12	Wear eye protection.	Use propan-1-ol and propan-2-ol in various ratios by volume. Using a boiling water bath is not efficient in this procedure. Keep overall volumes of samples to be heated with a flame to less than 20 cm ³ to limit the extent of a fire, should the equipment break.
Reaction with sodium	Y12	Wear eye protection. Do not substitute potassium for sodium.	Use an excess of the alcohol and pieces of sodium about 2 mm each side in dry apparatus.
Oxidation by acidic dichromate(VI)	Y12	Wear eye protection.	Acidify the dichromate(VI) with 1 mol dm ⁻³ sulfuric(VI) acid; this is suitable for a procedure in a test tube. The reaction may be violent if reagents have not been mixed properly before heating.
Extracting caffeine from tea	Y12	Wear eye protection.	Propan-1-ol, saturated with sodium chloride, can be used as an alternative to dichloromethane. See L195, <i>Safer Chemicals, Safer Reactions</i> .

84B Butanols

Butan-1-ol		<i>n</i> -butyl alcohol; butanol	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$
Harmful		<p>R10: Flammable. R22: Harmful if swallowed. R37/38: Irritating to respiratory system and skin. R41: Risk of serious damage to eyes. R67: Vapours may cause drowsiness and dizziness.</p> <p>It is absorbed through the skin.</p> <p>WEL (mg m^{-3}): 154 (STEL) (Sk). Flash point: 29 °C.</p>	
Butan-2-ol		<i>sec</i> -butyl alcohol	$\text{CH}_3\text{CH}_2\text{CH}(\text{OH})\text{CH}_3$
Irritant		<p>R10: Flammable. R36/37: Irritating to eyes and respiratory system. R67: Vapours may cause drowsiness and dizziness.</p> <p>WEL (mg m^{-3}): 308 (LTEL), 462 (STEL). Flash point: 24 °C.</p>	
2-methylpropan-1-ol		<i>iso</i> -butanol; isobutyl alcohol	$(\text{CH}_3)_2\text{CHCH}_2\text{OH}$
Irritant		<p>R10: Flammable. R37/38: Irritating to respiratory system and skin. R41: Risk of serious damage to eyes. R67: Vapours may cause drowsiness and dizziness.</p> <p>WEL (mg m^{-3}): 154 (LTEL), 231 (STEL). Flash point: 28 °C.</p>	
2-methylpropan-2-ol		<i>tert</i> -butyl alcohol	$(\text{CH}_3)_3\text{COH}$
Highly flammable		<p>R11: Highly flammable. R20: Harmful by inhalation.</p> <p>WEL (mg m^{-3}): 308 (LTEL), 462 (STEL). Flash point: 11 °C.</p>	
Harmful		<p>This substance is solid on a cool day.</p>	




For all these substances:

Dangerous with: OXIDISING AGENTS. Alcohols will react vigorously.
KETONES (other than propanone). Peroxides form in days, giving an explosion risk.

Store: FL	<p>Disposal: W1, W7</p> <p>W7: Dilute these alcohols to less than 10% (w/v), before pouring down a foul-water drain.</p>
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Activity	User	Control measures	Experimental points
Butanol in solvents for chromatography	Y7	Wear eye protection. Mixtures should be prepared beforehand in a fume cupboard by a technician or teacher wearing eye protection.	For plant pigments, amino acids, food dyes: see <i>Handbook</i> 11.1. Pupils can use the solvents in the laboratory because the chromatograms can be run in stoppered or covered containers. Vapours should not be smelled directly. Disposal: Used solvent mixtures should be added to a bucket of water in a fume cupboard before washing to waste.
As a fuel in spirit burners	Y7	Wear eye protection. Pupils should not refill spirit burners.	The room should be well ventilated but draughts may affect experimental work. The use of a spirit burner should be dedicated to a specific alcohol. Make sure the wick fits tightly in the holder and the holder fits tightly in the container. See L195, <i>Safer Chemicals, Safer Procedures</i> and <i>Handbook</i> 9.4.3.
Test-tube preparation of esters	Y9	Wear goggles.	Use 5-10 drops of organic acid with 5-10 drops of the alcohol and 1-2 drops of concentrated sulfuric(VI) acid. After warming, cool under running tap water before adding to 0.5 mol dm ⁻³ sodium carbonate solution in a beaker. Smell the ester with care. See also PS67-07.
Oxidation by acidic dichromate(VI)	Y12	Wear eye protection. Use a fume cupboard.	Carry out using only drops of the chemicals. Butan-1-ol oxidises to butanoic acid (IRRITANT) which has a vile odour that takes some time to dissipate.
Reaction with alkali metals	Y12	Wear goggles.	Use dry equipment. Place 10 cm ³ of a butanol in a boiling tube and use pieces about 2 mm each side. There may be 'sparks' when potassium is used.
Disposal of potassium	TT	Wear goggles. Use a fume cupboard. The room must be secure.	Working with another person, using a fume cupboard in a secure room, add no more than 2 g in small pieces, one at a time, to 100 cm ³ of 2-methylpropan-2-ol in a 400 cm ³ beaker. There may be some sparks. Place a heat-proof mat over the beaker to prevent alcohol vapour catching fire. Leave the reaction (suitably labelled) to finish before adding more pieces of potassium. If the pieces are more than slightly yellow, do not cut into the potassium but place the metal in a 1:1 mixture of 2-methylpropan-2-ol and medicinal paraffin. It may take several hours to react.

84C Other alcohols




Pentan-1-ol		<i>n</i> -amyl alcohol; 'pentanol'	$\text{CH}_3(\text{CH}_2)_3\text{CH}_2\text{OH}$
3-methylbutan-1-ol		<i>iso</i> -amyl alcohol	$(\text{CH}_3)_2\text{CH}(\text{CH}_2)_2\text{OH}$
Harmful		R10: Flammable. R20: Harmful by inhalation. WEL (mg m⁻³): 366 (LTEL), 458 (STEL) - for 3-methylbutan-1-ol. Flash points: Pentan-1-ol 33 °C; 3-methylbutan-1-ol 43 °C.	
Store: FL		Disposal: W1, W2 or Wspec Wspec: Burn small volumes of the alcohols using a spirit burner in a fume cupboard. Alternatively, dissolve no more than 30 cm ³ in 1 litre of water before pouring down a foul-water drain.	
Hexan-1-ol		<i>n</i> -hexyl alcohol; 'hexanol'	$\text{CH}_3(\text{CH}_2)_4\text{CH}_2\text{OH}$
Heptan-1-ol		<i>n</i> -heptyl alcohol; 'heptanol'	$\text{CH}_3(\text{CH}_2)_5\text{CH}_2\text{OH}$
Octan-1-ol		<i>n</i> -octyl alcohol; 'octanol'	$\text{CH}_3(\text{CH}_2)_6\text{CH}_2\text{OH}$
Octan-2-ol		<i>iso</i> -octyl alcohol	$\text{CH}_3(\text{CH}_2)_5\text{CH}(\text{OH})\text{CH}_3$
Harmful		R21/22: Harmful in contact with skin and if swallowed. R36: Irritating to eyes. Flash points: Hexan-1-ol 59°C; Heptan-1-ol 73°C; Octan-1-ol 81°C; Octan-2-ol 71°C.	
Store: GOrg		Disposal: W1, W2 or Wspec Wspec: Burn small volumes of the alcohol using a spirit burner in a fume cupboard.	
Cyclohexanol			$\text{C}_6\text{H}_{11}\text{OH}$
Harmful		R20/22: Harmful by inhalation and if swallowed. R37/38: Irritating to respiratory system and skin. WEL (mg m⁻³): 208 (LTEL), 624 (STEL). Flash point: 59 °C.	
Store: GOrg		Disposal: W1, W2 or Wspec Wspec: Burn small volumes of the alcohol using a spirit burner in a fume cupboard. Alternatively, dissolve no more than 30 cm ³ in 1 litre of water before pouring down a foul-water drain.	
Hexadecan-1-ol; cetyl alcohol; palmityl alcohol; $\text{CH}_3(\text{CH}_2)_{14}\text{CH}_2\text{OH}$			Low hazard Store: GOrg Disposal: W2, W8

Activity	User	Control measures	Experimental points
Cooling curves	Y7	Wear eye protection.	Hexadecan-1-ol is often suggested as a replacement for naphthalene although it needs to be very pure to give a satisfactory cooling curve; cooling also takes longer because of stronger inter-molecular attractions. For further details, see L195, <i>Safer Chemicals, Safer Procedures</i> .
As a fuel in spirit burners	Y9	Wear eye protection. Pupils should not refill spirit burners.	The room should be well ventilated but draughts may affect experimental work. The use of a spirit burner should be dedicated to a specific alcohol. Make sure the wick fits tightly in the holder and the holder fits tightly in the container. See L195, <i>Safer Chemicals, Safer Procedures and Handbook 9.4.3</i> .
Preparation of cyclohexene	Y12	Wear eye protection. The room should be well ventilated.	Use a mixture of 4 cm ³ of phosphoric(V) acid and 10 cm ³ of cyclohexanol. Make sure the chemicals are thoroughly mixed and that anti-bumping granules are added before heating on a boiling water bath. The product, cyclohexene, has an offensive odour and disposal of small amounts should be carried out in a working fume cupboard (allow to evaporate). Some texts use concentrated sulfuric(VI) acid but phosphoric(V) acid is a safer dehydrating agent.
Preparation of octenes	Y12	Wear eye protection. The room should be well ventilated.	A mixture of 4 cm ³ of phosphoric(V) acid and 10 cm ³ of octan-2-ol is used. A naked Bunsen-burner flame is required because the boiling point of the product is about 120 °C. The product (a mixture of octene isomers) has a less-offensive smell than cyclohexene and can be used in test-tube reactions of alkenes.

85 Propanone and other ketones



Propanone		Acetone	CH ₃ COCH ₃
Highly flammable		R11: Highly flammable. R36: Irritating to eyes. R66: Repeated exposure may cause skin dryness or cracking. R67: Vapours may cause drowsiness and dizziness. WEL (mg m⁻³): 1210 (LTEL), 3630 (STEL). Flash point: -18 °C.	
Irritant		Dangerous with: 1,1,1-TRICHLOROETHANE AND OTHER ORGANOHALOGENS. May react violently after a long induction period. NITRIC(V) ACID AND OTHER OXIDISING AGENTS. A violent reaction occurs.	
Butan-2-one		Butanone; methyl ethyl ketone; MEK	C ₂ H ₅ COCH ₃
Highly flammable		R11: Highly flammable. R36: Irritating to eyes. R66: Repeated exposure may cause skin dryness or cracking. R67: Vapours may cause drowsiness and dizziness. It is absorbed through the skin.	
Irritant		WEL (mg m⁻³): 600 (LTEL), 899 (STEL) (Sk). Flash point: -1 °C. Dangerous with: (As for propanone)	
Store: FL	Disposal:	W1, W2 or W7 W7: Dilute to less than 10% (v/v) or 2 mol dm ⁻³ before pouring down a foul-water drain.	
Cyclohexanone			C ₆ H ₁₀ O
Harmful		R10: Flammable. R20: Harmful by inhalation. WEL (mg m⁻³): 41 (LTEL), 82 (STEL) (Sk). Flash point: 43 °C.	
Phenylethanone		Acetophenone	C ₆ H ₅ COCH ₃
Harmful		R22: Harmful if swallowed. R36: Irritating to eyes.	
Diphenylmethanone		Benzophenone	C ₆ H ₅ COC ₆ H ₅
Irritant		R36/38: Irritating to eyes and skin	
Store: GOrg	Disposal:	W1, W2	

Activity	User	Control measures	Experimental points
Use in chromatography solvents	Y7	Wear eye protection.	Propanone will create a significant fire hazard when large areas of paper are being dried. Keep away from sources of ignition.
Warming propanone and butanone	Y7	Wear eye protection. Never use a naked flame to heat ketones.	If no electrically-heated bath is available, fill a large beaker with boiling water from a kettle to use as a hot-water bath. Use a well-ventilated room for test-tube amounts, otherwise use a fume cupboard.
Preparing a chlorophyll solution for chromatography	Y7	Wear eye protection.	Grind a few leaves in a mortar with about 10 cm ³ of propanone to extract pigments. Decant into a boiling tube and add 10 cm ³ of petroleum spirit (100-120°C). Swirl the mixture and remove the upper petroleum spirit layer with a pipette into another boiling tube. Dry with a little anhydrous sodium sulfate(VI) and keep it in the dark before use. Pigments may be more visible if the chromatogram is run in the dark or tubes are covered with foil.
Finkelstein reaction	Y12	Wear eye protection.	A 6% (w/v) solution of sodium iodide in propanone is used. It reacts with some bromoalkanes (eg, primary) to produce a precipitate of sodium bromide. Use on a test-tube scale.
Reactions of a carbonyl group	Y12	Wear eye protection.	All these ketones can be used for reactions in a test tube. Disposal: With such small amounts, the contents can be flushed down the foul-water drain with plenty of water.
Reaction of propanone with iodine	Y12	Wear eye protection.	The product (iodopropane) is strongly irritant to the eyes. Dispose of it immediately by pouring it down a foul-water drain. 2 mol dm ⁻³ propanone, used in this procedure, is 147 cm ³ of propanone made up to 1 litre with water.
Hydrogen bond-strength measurement	Y12	Wear eye protection.	(Negative deviation from Raoult's law.) It is recommended that neither propanone nor butanone is mixed with trichloromethane. Ethyl ethanoate should be used as an alternative.
Drying glassware	TT	Wear eye protection. Use a fume cupboard.	Using propanone for drying should not be a routine procedure but reserved for cases in which speed is necessary. Rinse in propanone in a fume cupboard and leave there to dry.



Silicon tetrachloride		SiCl ₄	
Irritant		R14: Reacts violently with water. R36/37/38: Irritating to eyes, respiratory system and skin. Dangerous with: WATER. There is a vigorous exothermic reaction releasing hydrochloric acid fumes. SODIUM and other reactive metals. Vigorous reactions can occur. See the reverse of this card before opening a bottle or ampoule.	
Store: Spec This liquid reacts with water to form hydrogen chloride and silicon dioxide. Once opened, this silicon dioxide can seal the bottle, which then may explode in hot weather. Store inside another container which contains silica gel desiccant. Monitor the bottle regularly to check that the top can be opened. Keep small quantities only (100 cm ³ or less). Dispose of any remaining after 2 years.		Disposal: W1, W4 W4: Add the solid to 1 mol dm ⁻³ sodium carbonate solution in small amounts in a fume cupboard. Wait until the reaction is finished before more is added.	
Mineral wool		Triton Kaowool, Rocksil, ceramic wool	
Harmful		R40: Limited evidence of a carcinogenic effect.	
Store: Gln		Disposal: W1	
Silicon; Si Silicon(IV) oxide; SiO ₂ ; sand, silica Silica gel Silica gel (with LOW HAZARD indicators) Mineral wool (<i>Superwool 607</i>)	Low hazard	Store: Gln	Disposal: W8
Silica gel [with blue moisture indicator ie, < 0.5% cobalt(II) chloride]		Store: Gln	Disposal: W3, Wspec Wspec Add the solid to water. Leave for 24 hours. Pour the liquid down a foul-water drain and place the solid in normal refuse.

Activity	User	Control measures	Experimental points
Use of silica gel as a desiccant	Y7	Wear gloves if using large amounts. Beware of dust from blue silica gel.	The advantage of the blue moisture-indicating gel, containing cobalt(II) chloride, is that it can be reheated and used again. The risk to health from cobalt chloride is very low. The other types of indicating silica gel, which are impregnated with various indicators, can only be used once.
Use of mineral wool	Y7	-	See <i>Handbook</i> 9.11.3 or L195, <i>Safer Chemicals, Safer Reactions</i> for a detailed account. The size of the fibres may cause a risk to health but exposure is low in school laboratories. <i>Super-wool 607</i> is a low-hazard form and should be used in preference to other types.
Reaction of silicon tetrachloride with water	Y12	Wear goggles. Do not pour from the bottle.	Place 1-2 cm ³ of water in a test tube and add about 5 drops of silicon tetrachloride. To prevent contaminating the neck of the bottle with silicon tetrachloride, always use a pipette for transferring the chemical.
Preparation of silicon tetrachloride	Y12	Wear goggles. Use a fume cupboard.	Chlorine is passed over heated silicon powder. See <i>Hazard</i> 22A for the method of chlorine preparation. A calcium chloride trap should be placed at the end of the apparatus to keep out moisture. Do not attempt to keep the product.
Opening an ampoule or bottle of silicon tetrachloride	TT	Wear a face shield. Wear chemical-resistant gloves. Use a fume cupboard. Cool the bottle or ampoule in a refrigerator for several hours before opening.	Several accidents have been reported in which a reaction with moisture in the air has caused a build up of pressure and the bottle stopper has jammed. In some cases, the bottle has exploded during storage. Never return liquid to the bottle and avoid opening the bottle on very wet days. If it is possible to purchase this reagent in ampoules, then do so.

87 Silver and its compounds

Silver metal; Ag		Low hazard	Store: Gln	Disposal: W2, W3
Silver nitrate(V)				AgNO ₃
Corrosive		<p>R34: Causes burns. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.</p> <p>Solutions equal to or stronger than 0.5 mol dm⁻³ are CORROSIVE. Solutions equal to or stronger than 0.2 mol dm⁻³ but weaker than 0.5 mol dm⁻³ are IRRITANT.</p> <p>Dangerous with: AMMONIA. Explosive compounds are formed under certain conditions.</p>		
Dangerous for the environment		<p>ETHANOL. Explosive silver fulminates may be formed.</p> <p>MAGNESIUM. Mixture of solids explodes in the presence of a drop of water.</p> <p>WEL (mg m⁻³): 0.01 (LTEL), 0.03 (STEL) as silver.</p> <p>Emergencies: see standard procedures on Hazcard E, BUT ALSO:</p> <p>Solutions are very dangerous to the eyes and blacken the skin. If ingested, they can cause internal damage because of absorption into the blood, followed by deposition of silver in various tissues. The solution stains clothing and some bench materials.</p>		
Store: CS It is usual to keep a silver-residues bottle but do not dispose of Tollen's reagent in this way.			Disposal: W3, W7 W7: Dilute to less than 0.05 mol dm ⁻³ before pouring down a foul-water drain.	
Silver bromide; AgBr Silver chloride; AgCl Silver iodide; AgI	Low hazard	Store: Gln in dark bottles (light-sensitive)	Disposal: W2, W3 or Wspec Wspec: Add 1 mol dm ⁻³ sodium thiosulfate solution to dissolve the solid. Dilute so that the concentration of silver is less than 0.05 mol dm ⁻³ and pour down a foul-water drain.	

Activity	User	Control measures	Experimental points
Silver nitrate(V) test for halides (ie, chlorides, bromides and iodides)	Y7	Wear eye protection. Use a fume cupboard if concentrated ammonia is used.	Work on a test-tube scale. A 0.05 mol dm^{-3} solution should suffice unless the concentration of halide ion is extremely dilute. 2 mol dm^{-3} ammonia solution dissolves the precipitated silver chloride, concentrated ammonia dissolves precipitated silver bromide but silver iodide is unaffected by any concentration of ammonia solution. Disposal: Keep any precipitates for recycling. If ammonia has been added, pour the solutions and suspensions down a foul-water drain with more water.
Sensitised paper	Y7	Wear goggles. Wear disposable nitrile gloves when handling the solution and paper.	A 6% (w/v) silver nitrate(V) solution should be prepared by the teacher or technician. In a dim light, the solution is painted onto paper. After drying, the paper should be put into light-proof envelopes.
Titration using silver nitrate(V)	Y9	Wear eye protection.	More details can be found in <i>Handbook</i> 13.8. 0.05 mol dm^{-3} solutions are suitable although older text books may suggest 0.1 mol dm^{-3} .
Titration of chloride in urine samples	Y9	Wear eye protection. Pupils must use and dispose of their own urine samples.	See <i>Handbook</i> 14.4 for safe use of urine. The titration uses Volhard's method, which involves potassium thiocyanate solution (see <i>Hazard</i> 95C).
Testing for aldehydes with Tollen's reagent [ammoniacal silver nitrate(V)] Silver mirror test	Y12	Wear eye protection. Tollen's reagent must be prepared in situ by the students and not by the technician the day before.	Add one drop of 0.4 mol dm^{-3} sodium hydroxide solution to 1 cm^3 of 0.1 mol dm^{-3} silver nitrate(V). Add 1 mol dm^{-3} ammonia solution until the precipitate just redissolves. See <i>Recipe Card</i> 47. Use a new, clean test tube and discard the solution within half an hour of preparation by washing it down a sink followed by a large amount of water. Make on a test-tube scale only and do not heat the solution directly; use a bath of hot water. (The explosive silver fulminate forms on standing.) Do not dispose of the solution in a 'silver-residues' bottle.
Making up solutions of silver nitrate(V)	Y12	Wear goggles. Wear disposable nitrile gloves when dispensing the solid.	Distilled or deionised water must be used to make up solutions.
Recycling of silver from solutions	TT	Wear eye protection.	The method involves electrolysis of the solution using carbon electrodes with a very low current generated by applying a potential difference of 1 V over a period of one week. See Wilson, SSR, 66, No 234, page 120. This can also be applied to photographic solutions.

Highly flammable Corrosive	 	R14/15: Reacts violently with water liberating highly flammable gases. R34: Causes burns.
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The substance is dangerous with:	<p>WATER. Hydrogen is given off and it may ignite.</p> <p>ACIDS. Explosive reactions occur.</p> <p>1,1,1-TRICHLOROETHANE and other chlorinated hydrocarbons such as tetrachloromethane. Explosive mixtures may be formed.</p> <p>MERCURY, SULFUR, BROMINE, IODINE & OXIDISING AGENTS. Violent reactions may occur.</p>
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Emergencies: see standard procedures on *Hazard E*, BUT ALSO:

If particles enter the eyes:	Flood the eye with gently-running water until a first aider arrives. Send the affected person to hospital and ensure that irrigation continues during the journey.
If spilt on the skin or clothes:	Remove any solid with forceps. Flood the affected area with large quantities of water. If a large area is affected or blistering occurs, seek medical attention.
If spilt in the laboratory:	Wear goggles and chemical-resistant gloves. Cover with dry sand or anhydrous sodium carbonate (soda ash) and scoop up into a dry bucket. Rinse area with water and mop up. Add the mixture in small amounts to an excess of Industrial Denatured Alcohol.
If it catches fire:	Sodium burns vigorously and is very difficult to extinguish. Small-scale fires are best treated by smothering with dry sand. If a fire extinguisher is used at all, it must be a dry-powder type.

<p>Store: FW</p> <p>Keep it under lock and key in a secure box (see <i>Handbook 7.3</i>). Keep small quantities only (25 g is adequate) so that stock is fresh. It is worth keeping cut samples of sodium in liquid (medicinal) paraffin in another bottle ready for use. The level of oil should always be higher than the sodium metal. Corrosion occurs on the surface of the metal and needs to be cut off.</p>	<p>Disposal: W1, Wspec</p> <p>Wspec: Add the solid (no more than 5 g) in small pieces (sides no bigger than 0.4 mm) to 100 cm³ propan-2-ol. Place a heat-proof mat over the beaker to extinguish any flames caused by propan-2-ol burning. Once the reactions have stopped, carefully add the solution to a bucket of water before disposal down a foul-water drain.</p>
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After any use of sodium in the laboratory, the demonstrator must ensure that the bottle is securely locked away. There have been several instances of pupils stealing the chemical. In addition, any white tiles, bricks or equipment used to cut sodium during the demonstration must be placed in a trough of water. This ensures that the technician will not encounter any sudden fires when clearing up after the demonstrations.

Activity	User	Control measures	Experimental points
Reaction with ethanol and phenol	Y12	Wear goggles. Glass apparatus must be free of water.	Use prepared pieces of sodium with sides no bigger than 2 mm. Add to 10 cm ³ of ethanol in a boiling tube. With phenol, warm a mixture of phenol and sodium (similar-size pieces) until the phenol just melts. Do not continue heating. After cooling, add ethanol to destroy any unreacted sodium.
Fusion test	Y12	Wear goggles.	Do not attempt with chlorinated organic compounds; explosions can occur. Use approximately 0.2 g sodium and 0.1 g of sample and heat to redness for 2 minutes. Plunge into water behind safety screens. A safer technique is Middleton's test (see <i>Hazard</i> 107). Do not use powdered magnesium in these tests.
Burning in oxygen and air	TT	Wear goggles or a face shield. Pupils should also wear eye protection. Use safety screens.	Do not use too large a piece of sodium on the deflagrating spoon (1 g reacts with 500 cm ³ of gas). A black crust of carbon from the covering oil will burn off to reveal molten sodium which catches fire. Put this into the gas jar of oxygen. After cooling, add plenty of water to remove the oxide which coats unreacted sodium which may then spark as it reacts with the water. Leave a warning notice if the gas jar is left for cleaning.
Reaction with chlorine	TT	Wear goggles or a face shield. Pupils should also wear eye protection. Use a fume cupboard.	Follow the same procedure as for burning sodium in oxygen. Unfortunately, the steel spoon reacts as well, giving brown fumes of iron(III) chloride. However, see L195, <i>Safer Chemicals, Safer Reactions</i> for a version which produces a colourless product.
Reaction with water	TT	Wear goggles or a face shield. Pupils should also wear eye protection. Pupils should be 2-3 m away. Ensure there is good ventilation. Use safety screens.	Use prepared pieces with sides no larger than 4 mm. Never attempt to constrain the sodium; allow it to roam freely on a large surface of water. Place the safety screen as close to the trough as possible to avoid pieces flying out over the class. The behaviour of the sodium is very unpredictable and it may explode and eject particles. In place of safety screens, an acrylic sheet can be placed on top of the trough.
Preparation of pieces	TT	Wear goggles or a face shield. All equipment must be dry.	Place a piece of sodium on a white tile and cut the required volume of sodium. Remove the oil with tissues. After use, place all equipment in a bowl of water to destroy any remaining sodium.


Sodium chlorate(I)		Bleach; sodium hypochlorite	NaClO
Corrosive		<p>R34: Causes burns. R31: Contact with acids liberates toxic gas. Solutions equal to or stronger than 10% (w/v) available chlorine (ie, 1.4 mol dm^{-3}) should be labelled CORROSIVE. Solutions equal to or stronger than 5% (ie, 0.7 mol dm^{-3}) but weaker than 10% should be labelled IRRITANT.</p> <p>Dangerous with: CONCENTRATED SULFURIC(VI) ACID. A dangerous reaction occurs. AMMONIUM SALTS, METHANOL, AMINES. Explosive products are formed. ACIDS. Chlorine is liberated.</p> <p>Emergencies: see standard procedures on <i>Hazard E</i>, BUT ALSO:</p> <p>If splashed into the eyes: Flood the eye with gently-running tap water until a first aider arrives. Unless the solution is very dilute, send the affected person to hospital and ensure that irrigation is continued during the journey.</p>	
Store: CLb During storage, the solution loses chlorine to the atmosphere. Pressure may build up; open bottles carefully. Available only as a 10-14% (w/v) available chlorine solution. Do not store longer than 2 years. The storage room should be well ventilated. Chlorine also accelerates rusting in the storage area.		Disposal: W7 W7: Dilute the solution 20 times with water before pouring down a foul-water drain.	
Sodium dichloroisocyanurate		Dry-Chlor; Presept; water-purification tablets	$\text{NaC}_3\text{N}_3\text{O}_3\text{Cl}_2$
Oxidising Harmful Dangerous for the environment	  	<p>R8: Contact with combustible material may cause fire. R22: Harmful if swallowed. R31: Contact with acids liberates toxic gas. R36/37: Irritating to eyes and respiratory system. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.</p> <p>10% (w/v) available-chlorine solution is formed when 31 g of the solid is added to 100 cm^3 of water. (Label this solution CORROSIVE, as above.)</p>	
Store: Gln Although the chemical produces a slight odour, it can be stored for several years.		Disposal: W1, W7 W7: Use a fume cupboard. Add no more than 10 g to 1 litre of water before pouring down a foul-water drain.	

Activity	User	Control measures	Experimental points
Use of sodium chlorate(I) solution	Y7	Wear eye protection.	Diluted solutions below 5% available chlorine may be used. Many shop-bought, chlorine-based bleaches are sold at this strength but often also contain detergent.
	Y9	Wear eye protection.	Solutions over 5% (w/v) available chlorine may be used.
	Y12	Wear goggles. Wear disposable nitrile gloves.	Solutions over 10% (w/v) available chlorine may be used.
Sakaguchi test for arginine	Y9	Wear goggles.	Solution A: 5% (w/v) sodium hydroxide solution. Solution B: 1% (w/v) naphthalen-1-ol in ethanol. Solution C: Sodium chlorate(I) solution, 10-14% available chlorine. To 3 cm ³ of test solution, add 1 cm ³ of A and two drops of B. Mix well and add one drop of C. A red colour indicates arginine.
Analysis of bleaches	Y9	Wear eye protection.	A ten-fold dilution of a commercial bleach solution or 0.1 mol dm ⁻³ sodium dichloroisocyanurate should be prepared. On addition of 1 mol dm ⁻³ hydrochloric acid and solid potassium iodide, iodine solution is formed which can be titrated against 0.1 mol dm ⁻³ sodium thiosulfate solution.
Preparation of chlorine	TT	Use a fume cupboard. Wear goggles or a face shield. Wear chemical-resistant gloves. Check that you are not using solid sodium chlorate(V).	A safe, controllable method is to drop 5 mol dm ⁻³ hydrochloric acid onto recently-bought, full-strength, sodium chlorate(I) solution. In addition, place anti-bumping granules in the flask and immerse it in warm water. Do not use sulfuric(VI) acid or silica gel to dry chlorine; use anhydrous or saturated calcium chloride solution. To generate enough gas to prepare aluminium chloride, add bleaching powder, calcium chlorate(I), as well. Commercial bleach, possibly containing detergent and more dilute, should not be used. See <i>Handbook</i> 13.3.
Disinfectants in biology	TT	Wear goggles. Make sure the room is well ventilated.	See <i>Handbook</i> 15.12.3. Sodium dichloroisocyanurate is a solid which reacts in water to release chlorine (it is used in swimming pools and water-purifying tablets). Its storage life is longer than liquid bleaches.
Preparation of chlorine water	TT	Wear eye protection. Use a fume cupboard. Asthmatics should take care.	See <i>Recipe card</i> 28 and <i>Hazard card</i> 22B.

90 Sodium dithionite




Also known as sodium hydrosulfite.


Harmful		R7: May cause fire. R31: Contact with acids liberates toxic gas. R22: Harmful if swallowed. WEL (mg m⁻³): 1 (LTEL), 3 (STEL).
The substance is dangerous with:	WATER. Addition of small amounts of water to the solid can cause spontaneous ignition. OXIDISING AGENTS. Explosive mixtures may form. ACIDS. Sulfur dioxide is liberated.	
If spilt in the laboratory:	If the solid or concentrated solution is producing appreciable amounts of sulfur dioxide, the fire brigade should be called. Scoop up as much solid as possible. Rinse the area with a large excess of water, add mineral absorbent and clear up.	
Store: FS With moisture, sulfur dioxide will be produced. FIRE RISK: This substance, if slightly damp, can ignite spontaneously in air.		Disposal: W1, Wspec Wspec: Add 20 g of the solid to 1 litre of water in 5 g amounts in a fume cupboard. Wait until the reaction is finished before more is added. Pour the liquid down a foul-water drain.

Activity	User	Control measures	Experimental points
Indigo reduction prior to dyeing	Y9	Wear eye protection. Open all windows. Wear disposable nitrile gloves and an apron to avoid stains on the skin and clothes.	Heat 100 cm ³ of 0.1 mol dm ⁻³ sodium hydroxide solution in a 400 cm ³ beaker to boiling. Place the hot solution on a heat-proof mat. Add 0.4 g of indigo and 0.3 g of sodium dithionite with stirring. The solution should be the slightly-yellow colour of the soluble leuco-indigo. Samples of cotton cloth should be stirred into the hot solution for 3 minutes, rinsed in water and placed on a tray to dry. As the cloth dries, oxygen in the air oxidises slightly-yellow leuco-indigo to the deep-blue/purple of indigo.
Oxygen production in photosynthesis	Y9	Wear eye protection.	A 0.1% (w/v) aqueous solution of indigo carmine is used. Just before the procedure, a 0.3 mol dm ⁻³ solution of sodium dithionite is prepared. This is added to the dye until the colour is yellowish green. <i>Elodea</i> , <i>Cabomba</i> or other pond weed is placed in two test tubes of this reduced solution. One is placed in the light and the other in the dark. Oxygen, produced in photosynthesis, will restore the solution to the original blue colour.
As a reducing agent	Y9	Wear eye protection.	It is a very strong reducing agent. When the solid is added in 1 g amounts to 0.1 mol dm ⁻³ solutions of copper(II) sulfate(VI) or silver nitrate(V), the metal precipitates out.
Making solutions	Y12	Wear eye protection. Open all windows.	Weigh out sodium dithionite in a small, dry beaker. Add the solid to at least 80% of the final volume of water, with stirring. These solutions do not keep and must be made just before being used.

91 Sodium hydroxide and other hydroxides


Sodium hydroxide		Caustic soda	NaOH
Lithium hydroxide			LiOH
Potassium hydroxide		Caustic potash	KOH
Corrosive		<p>R35: Causes severe burns.</p> <p>Solutions equal to or stronger than 0.5 mol dm^{-3} are CORROSIVE. Solutions equal to or stronger than 0.05 mol dm^{-3} but less than 0.5 mol dm^{-3} are IRRITANT.</p> <p>Dangerous with: WATER. An exothermic reaction may eject hot solution if only a small amount of water is present.</p> <p>ZINC, ALUMINIUM. Hydrogen is evolved.</p> <p>TRICHOETHANE. A dangerous reaction may occur.</p> <p>WEL (mg m^{-3}): 1.0 (STEL) - Lithium hydroxide; 2.0 (STEL) - Sodium/potassium hydroxide.</p> <p>Emergencies: see standard procedures on <i>Hazard E</i>, BUT ALSO:</p> <p>If solution is splashed into the eyes: Flood the eye with gently-running tap water until a first-aid arrives. Unless the solution is very dilute, send the affected person to hospital and ensure that irrigation is continued during the journey.</p>	
Store: CS It absorbs both water and carbon dioxide from the atmosphere. If the solid forms a cake, it may be necessary to dispose of it.		Disposal: W1, W5 W5: Dissolve the solid first to make a 1 mol dm^{-3} solution and then pour it down the foul-water drain.	

Soda lime and Carbosorb

Corrosive		<p>R34: Causes burns.</p> <p>If particles are blown into the eyes: Flood the eye with gently-running tap water until a first-aid arrives. Send the affected person to hospital and ensure that irrigation is continued during the journey.</p>	
Store: CS Composition by mass: 5% NaOH, 1% KOH, 0.2% silica, 14-19% water and Ca(OH)_2 to make a total of 100%. It is used to absorb carbon dioxide. <i>Carbosorb</i> is a self-indicating version supplied by VWR containing over 80% sodium hydroxide on a silicate base: it is more efficient than soda lime but more expensive.		Disposal: W1, Wspec Wspec: Add to 1 mol dm^{-3} nitric(V) acid with stirring. When the solid has dissolved, pour the solution down a foul-water drain with more water.	

The use of eye protection must be strictly enforced even when using dilute solutions.

Activity	User	Control measures	Experimental points
Use of alkali solutions	Y7	Wear eye protection.	Solutions should be less than 0.5 mol dm^{-3} . Determine the smallest concentration that enables a procedure to work satisfactorily.
	Y9	Wear goggles.	Solutions should be less than 2 mol dm^{-3} . Determine the smallest concentration that enables a procedure to work satisfactorily.
Use of solid hydroxides	Y9	Wear goggles.	Access should be limited to the quantity that is required. The solid absorbs water. Spatulas or forceps must be used to transfer the solid.
Fehling's solution B and the test for reducing sugars	Y9	Wear goggles.	Avoid the use of Fehling's solution if possible. Use Benedict's solution for food testing with Y7 upwards. Fehling's solution is required for testing with aldehydes. Fehling's solution B is CORROSIVE and, after mixing with copper sulfate(VI) solution, it must be heated in a boiling water bath. Direct heating causes bumping. See <i>Recipe Card 25</i> for its preparation.
Enthalpy changes	Y9	Wear goggles.	2 mol dm^{-3} solutions of alkalis are mixed with 2 mol dm^{-3} acid solutions or 2 mol dm^{-3} salt solutions. These reactions are performed in disposable, expanded-polystyrene cups which should be supported in glass beakers.
Saponification of oils (hydrolysis of lipids and the making of soap)	Y9	Wear goggles. Wear disposable nitrile gloves. Y9 will require very close supervision.	Hot concentrated sodium hydroxide solution is VERY CORROSIVE. Use no more than 15 cm^3 of 5 mol dm^{-3} sodium hydroxide solution per activity. With some pupils it may be better to have beakers with the required amount of solution already measured out and, for others, this is better as a demonstration. Use borosilicate glass beakers for the reaction. Spills are most likely to occur during stirring of hot liquids. Students above Y12 should use <i>Quickfit</i> or similar apparatus. Pupils must not put the soap they make on their skin.
Making solutions	Y12	Wear goggles.	Add solid pellets a few at a time to water with stirring. (See <i>Recipe Card 65</i> .) A great deal of heat is generated.
Using soda lime in spirometers	TT	Wear goggles or a face shield. Ensure air is breathed out through the soda lime.	Full details are provided in <i>Handbook 14.5</i> . Take care not to raise dust when handling the solid. There is no need for pupils to wear eye protection when using the spirometer.




Disodium disulfate(IV)		Sodium disulfite; sodium metabisulfite	$\text{Na}_2\text{S}_2\text{O}_5$
Sodium sulfate(IV)		Sodium sulfite	Na_2SO_3
Sodium hydrogensulfate(IV)		Sodium bisulfite; sodium hydrogensulfite	NaHSO_3
Dipotassium disulfate(IV)		Potassium disulfite; potassium metabisulfite	$\text{K}_2\text{S}_2\text{O}_5$
Potassium sulfate(IV)		Potassium sulfite	K_2SO_3
Potassium hydrogensulfate(IV)		Potassium bisulfite; potassium hydrogensulfite	KHSO_3
Harmful		<p>R22: Harmful if swallowed. R41: Risk of serious damage to eyes. R31: Contact with acids liberates toxic gas.</p> <p>Solutions equal to or stronger than 0.25 mol dm^{-3} are HARMFUL. Solutions less than 0.25 mol dm^{-3} are LOW HAZARD. However, sulfur dioxide gas is given off and this is TOXIC.</p> <p>Dangerous with: ACIDS. Sulfur dioxide is produced.</p> <p>SODIUM NITRITE: A vigorous, exothermic reaction occurs.</p> <p>WEL (mg m^{-3}): 1 (LTEL), 3 (STEL).</p> <p>Inhalation of sulfur dioxide by pupils or staff with known breathing difficulties such as asthma may exacerbate these pre-existing conditions. Teachers should be aware of pupils who suffer from breathing problems because the smell of sulfur dioxide can be detected from sulfite solutions.</p>	
<p>Store: Gln</p> <p>All these substances react with moisture in the air to release sulfur dioxide. They are also subject to oxidation when exposed to oxygen in the air. The metabisulfites last longer during storage.</p>		<p>Disposal: W1, Wspec</p> <p>Wspec: Add the solid to water in small amounts in a fume cupboard. Add litmus indicator followed by 1 mol dm^{-3} sodium carbonate solution until the solution is alkaline. Then pour the liquid down a foul-water drain.</p>	

¹ Metabisulfites are sold as a source of hydrogensulfites. For every mole of the metabisulfite dissolved in water, 2 moles of the hydrogensulfate(IV) are formed.



Inhalation of sulfur dioxide by pupils or staff with known breathing difficulties such as asthma may exacerbate these pre-existing conditions. Teachers should be aware of pupils who suffer from breathing problems because the smell of sulfur dioxide can be detected from sulfite solutions.

Activity	User	Control measures	Experimental points
Use of solid and solutions	Y7	Wear eye protection. The room should be well ventilated. Do not inhale over the solution.	The solution can be used as a substitute for SO ₂ solution and to provide an atmosphere of sulfur dioxide; see <i>Recipe card</i> 28. It avoids pupils preparing SO ₂ gas in the open laboratory. Solution quantities must be restricted to 1 cm ³ in test tubes unless a fume cupboard is used.
Simulating acid rain and air pollution	Y7	Wear eye protection. The room should be well ventilated. Do not inhale over the solution.	For acid rain, use 10 ⁻⁴ mol dm ⁻³ sulfuric(VI) acid instead of sodium metabisulfite solution. 0.1 mol dm ⁻³ (19 g dm ⁻³) sodium metabisulfite solution (<i>without</i> acidification) will generate an atmosphere of SO ₂ gas sufficient for studies of the effects on plant growth. Prepare and dispose of the 0.1 mol dm ⁻³ solution in a fume cupboard.
Test for a sulfite	Y9	Wear eye protection.	The test-tube reaction (action of dilute acid on a suspected sulfite) is safe to carry out in a well-ventilated laboratory. Pupils must not directly smell the sulfur dioxide gas produced. It may be detected using damp starch/iodide or potassium dichromate paper held by tongs at the mouth of the test tube. Dichromate(VI) test papers should be prepared before the lesson by the technician or teacher by soaking strips of filter paper in a 0.1 mol dm ⁻³ solution of potassium dichromate(VI).
Harlow's solutions for macerating woody tissue	Y12	Wear eye protection.	These are a safer alternative than several other reagents for macerating woody tissue. Solution A is saturated chlorine water. Solution B is made with 30 g sodium sulfate(IV) in 1 litre of water. Wood shavings are placed in solution A for 2 to 3 hours, then transferred to solution B at 90°C for 15 minutes. Repeat the cycle until the tissues fall apart.
Disposal of oxidising agents	TT	Wear eye protection. Use a fume cupboard.	Acidified solutions of chlorates, bromates, iodates, persulfates, chromates and manganates(VII) can be reduced by sodium metabisulfite. Make a 10 % (w/v) solution of the oxidising agent in dilute sulfuric(VI) acid and add solid sodium metabisulfite in small amounts until the reduction is complete. The resulting solution should be washed down a foul-water drain.

Do not confuse these compounds with sodium nitrate(V) and potassium nitrate(V).

Sodium nitrate(III)		Sodium nitrite	NaNO_2
Potassium nitrate(III)		Potassium nitrite	KNO_2
Oxidising		<p>R8: Contact with combustible material may cause fire. R25: Toxic if swallowed. R50: Very toxic to aquatic organisms.</p> <p>Solutions equal to or stronger than 3.5 mol dm^{-3} should be labelled TOXIC. Solutions equal or greater than 0.4 mol dm^{-3} but less than 3.5 mol dm^{-3} should be labelled HARMFUL.</p> <p>Dangerous with: ACIDS. Nitrogen oxides are given off.</p> <p>COMBUSTIBLE MATERIALS. Wood, clothes etc impregnated with the solution ignite easily and burn vigorously when dried.</p> <p>AMMONIUM SALTS, CYANIDES, THIOSULFATES. Explosive, unstable mixtures are formed. They may explode even on contact.</p> <p>PHENOL. An explosive, unstable mixture is formed.</p> <p>The reactions between nitrites and secondary & tertiary amines should <i>not</i> be carried out, even as a test, because the products are carcinogenic.</p> <p>Emergencies: see standard procedures on <i>Hazard E</i>, BUT ALSO:</p> <p>If spilt on skin or clothes: Remove contaminated clothing. Wash off the skin with plenty of water. Soak contaminated clothing and rinse repeatedly.</p> <p>If spilt in the laboratory: Wear goggles. Scoop up as much solid as possible. If in solution, add mineral absorbent and treat as a toxic spill. Rinse the area with water and clear up. It is essential to ensure that no significant impregnation of wood, cloth or other combustible matter occurs.</p>	
Toxic			
Dangerous for the environment			
Store: T		<p>Disposal: W1, Wspec</p> <p>Wspec: For 25 g amounts, dissolve in 500 cm^3 of water in a 1 litre beaker, add 25 g of ammonium chloride and heat to boiling. Wear goggles. The gas evolved is nitrogen and the nitrite is completely destroyed.</p>	

Activity	User	Control measures	Experimental points
Use of solutions	Y9	Wear eye protection.	Use a 0.1 mol dm^{-3} solution prepared by a teacher or technician. It decolourises acidified potassium manganate(VII) solution. It produces iodine from potassium iodide solution with the release of nitrogen monoxide gas. With iron(II) sulfate(VI) solution, it produces a brown colouration.
Preparation of nitrogen	Y9	Wear eye protection.	Mix 2 cm^3 of 1 mol dm^{-3} ammonium chloride and 2 cm^3 of 1 mol dm^{-3} sodium nitrite solutions. Do not warm. Older students can use larger quantities.
Diazotisation of aromatic amines	Y12	Wear eye protection. Do not prepare any that involve the use of old samples of naphthalenols.	Some azo dyes are suspect carcinogens. Check that diazotisation is complete by testing for excess nitric(III) acid before proceeding to the next reaction step. Where possible, prepare water-soluble dyes such as methyl orange. See also <i>Hazard</i> 4A.
Preparation of nitric(III) acid (nitrous acid)	Y12	Wear eye protection. This must be made just before it is required. A fume cupboard may be required for larger volumes of material.	Add 1 g of sodium nitrite to 10 cm^3 of ice-cold 1 mol dm^{-3} sulfuric(VI) acid. On warming, nitrogen oxides (TOXIC) are produced.
Preparation of ammonium nitrite	-	Do not attempt to prepare the solid salt.	Solutions can explode if sufficiently concentrated.


Sodium peroxide		Na ₂ O ₂
Potassium superoxide		KO ₂
Oxidising		<p>R8: Contact with combustible material may cause fire. R35: Causes severe burns. R14: Reacts violently with water.</p> <p>Dangerous with: COMBUSTIBLE MATERIAL including ORGANIC SUBSTANCES. Violent or explosive reactions can occur. May ignite spontaneously, particularly if damp.</p> <p>ETHANOIC ACID, ETHANOIC ANHYDRIDE. An explosion may occur. HYDROGEN SULFIDE. The gas may ignite. TIN(II) CHLORIDE. This may form an explosive mixture. WATER. A vigorous reaction occurs, producing a corrosive solution.</p> <p>Emergencies: see standard procedures on <i>Hazard E</i>, BUT ALSO:</p> <p>If dust is blown into the eyes: Flood the eye with gently-running tap water until a first aider arrives. Send the affected person to hospital and ensure that irrigation is continued during the journey.</p> <p>If spilt on skin or clothes: Brush off as much solid as possible. Flood the area with large quantities of water. Remove contaminated clothing and soak it. If a large area is affected or if blistering occurs, seek medical attention.</p>
Corrosive		
<p>Store: Ox These yellow powders turn white on storage because carbon dioxide and water are absorbed. These substances may be found in tins that corrode and burst. Check them regularly.</p>		<p>Disposal: W1, W5 W5: Add 10 g of solid in small amounts to 1 litre of water in a fume cupboard. Wait until the reaction is finished before adding more solid. Add litmus and 1 mol dm⁻³ ethanoic acid until acidic. Pour down a foul-water drain.</p>


Do not weigh out these substances on filter paper.


Activity	User	Control measures	Experimental points
Reaction of sodium peroxide with water	Y12	Wear goggles. Wear chemical-resistant gloves when dispensing the solid.	Use a metal spatula and add about 0.1 g to 2 cm ³ of water in a test tube. The resulting solution is CORROSIVE.
Reaction of potassium superoxide with water	Y12	Wear goggles. Wear chemical-resistant gloves when dispensing the solid.	Use a metal spatula and add about 0.5 g to 50 cm ³ of water in a beaker. The resulting solution is CORROSIVE.
Reaction of both substances with sulfuric(VI) acid	Y12	Wear goggles. Wear chemical-resistant gloves when dispensing the solid. Reactions with dilute hydrochloric acid could form chlorine and chlorine oxides	Use a metal spatula and add about 1 g to 50 cm ³ of 1 mol dm ⁻³ sulfuric(VI) acid in a beaker. The resulting solution is CORROSIVE. When a small amount of manganese(IV) oxide is added, there is further effervescence of oxygen indicating that hydrogen peroxide had been formed.
Preparation of oxygen	TT	The addition of water to these substances is not a recommended method. See <i>Hazcard</i> 69.	



95A Sodium and potassium salts (1)

(See also 95B & 95C)

Sodium bismuthate(V)		NaBiO ₃
Harmful		R22: Harmful if swallowed.
Store: Gln		Disposal: W1, W2

Anhydrous sodium carbonate		Na ₂ CO ₃
Sodium carbonate-10-water	Washing soda	Na ₂ CO ₃ ·10H ₂ O
Potassium carbonate		K ₂ CO ₃
Irritant		R36: Irritating to eyes. Solutions equal to or stronger than 1.8 mol dm ⁻³ are IRRITANT.
Store: Gln The anhydrous salts absorb water; hydrated salts lose water and become powdery.		Disposal: W1, W5

Sodium fluoride		NaF
Potassium fluoride		KF
Toxic		R25: Toxic if swallowed. R36/38: Irritating to eyes and skin. R32: Contact with acids liberates very toxic gas. Solutions equal to or stronger than 4 mol dm ⁻³ should be labelled TOXIC. Solutions equal to or stronger than 0.5 mol dm ⁻³ but weaker than 4 mol dm ⁻³ should be labelled HARMFUL. WEL (mg m⁻³): 2.5 (LTEL), 7.5 (STEL) as fluoride.
Store: T		Disposal: W1

Sodium hexanitrocobaltate(III)		Sodium cobaltinitrite	Na ₃ Co(NO ₂) ₆
Oxidising Toxic	 	R8: Contact with combustible material may cause fire. R40: Limited evidence of a carcinogenic effect.	
Store: Ox			Disposal: W1

95A Sodium and potassium salts (1)



Model risk assessments


Details of the use of the chloride, bromide and iodide salts of sodium and potassium can be found on *Hazardcard 47B*.

Activity	User	Control measures	Experimental points
Flame tests	Y7	See <i>Hazardcard 47B</i> .	
General use of carbonates	Y7	Wear eye protection.	-
Titration with sodium carbonate	Y7	Wear eye protection.	For making standard solutions of sodium carbonate for titrations, see <i>Recipe Card 61</i> .
General use of fluoride salts	Y9	Wear eye protection. No concentrated sulfuric(VI) acid should be in the vicinity.	A 0.1 mol dm ⁻³ solution is used to show that there is no reaction with silver nitrate(V) solution.
	Y12		Sodium fluoride solution is also used in transition metal chemistry; the addition of a 0.1 mol dm ⁻³ fluoride solution decolourises iron(III) thiocyanate complexes.
Detection of potassium and ammonium ions using sodium hexanitrocobaltate(III)	Y9	Wear eye protection.	A 0.1 mol dm ⁻³ solution of sodium hexanitrocobaltate(III) is added to a solution containing potassium or ammonium ions. The appearance of a yellow precipitate confirms the presence of potassium or ammonium ions.
Detection of manganese ions using sodium bismuthate	Y12	Wear goggles.	The suspected manganese salt is dissolved in 6 mol dm ⁻³ nitric(V) acid. When a small amount of sodium bismuthate is added, the purple colour of the manganate(VII) ion forms.
Preparation of sodium fluoride solutions	TT	Wear goggles. Wear disposable nitrile gloves.	-

95B Sodium and potassium salts (2)



(See also 95A & 95C)

Disodium peroxodisulfate(VI)		Sodium persulfate	$\text{Na}_2\text{S}_2\text{O}_8$
Dipotassium peroxodisulfate(VI)		Potassium persulfate	$\text{K}_2\text{S}_2\text{O}_8$
Oxidising Harmful	 	R8: Contact with combustible material may cause fire. R22: Harmful if swallowed. R36/37/38: Irritating to eyes, respiratory system and skin. R42/43: May cause sensitisation by inhalation and skin contact. Solutions equal to or stronger 0.04M should be labelled harmful.	
Store: Ox The oxidising power may deteriorate on storage. In water, oxygen is very slowly evolved. Above 60 °C, the deterioration is rapid in solution.		Disposal: W1, W7, Wspec W7: Solutions should be diluted to less than 0.2 mol dm ⁻³ . Wspec: Dissolve 5 g of the solid in 100 cm ³ of water and add 5 g of sodium metabisulfite. Pour the solution down a foul-water drain.	

Sodium silicate solution		Water glass	
Corrosive		R34: Causes burns. Suppliers publish various risk phrases for this chemical and much depends on the formulation of the solution.	

Emergencies: see standard procedures on *Hazard E*, BUT ALSO:

If splashed into the eyes:	Flood the eye with gently-running tap water until a first aider arrives. Unless the solution is very dilute, send the affected person to hospital and ensure that irrigation is continued during the journey.		
Store: Gln Do not buy the solid. It is very slow to dissolve in water.	Disposal: W1, W7 (solution) Disposal: W1, W2 (solid) W7: Dilute the original solution 5 times before pouring down a foul-water drain.		


Sodium azide		NaN_3	
Sodium cyanide		NaCN	
Potassium cyanide		KCN	
Very toxic Dangerous for the environment	 	R26/27/28: Very toxic by inhalation, in contact with skin and if swallowed. R32: Contact with acids liberates very toxic gas. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.	
Store: T		Disposal: W1	

95B Sodium and potassium salts (2)**Model risk assessments**

Activity	User	Control measures	Experimental points
Chemical garden using sodium silicate	Y7	Wear goggles. A technician or teacher should carry out dilution of the supplied solution.	Do not buy solid sodium silicate; the dissolving process is very slow. See <i>Recipe Card</i> 66. The crystals should be added in the place where the container is to be displayed. Movement of the apparatus causes the strands to break. Some of the metal salts used to make the chemical garden are hazardous, such as manganese(II) sulfate(VI), copper sulfate(VI), cobalt(II) chloride, iron(II) sulfate(VI), iron(III) sulfate(VI), chromium(III) chloride and nickel(II) sulfate(VI). Check the relevant <i>Hazardcard</i> .
Clock reaction using sodium persulfate solutions	Y9	Wear eye protection.	The persulfate/iodide clock reaction is less complicated than the hydrogen peroxide/iodide reaction because acid ions do not have to be present. The reaction is very susceptible to catalysis by transition metal ions [especially copper(II) ions], so equipment must be clean. See <i>Recipe Card</i> 18.
Preparing persulfate solutions	TT	Wear eye protection.	Do not heat the solutions because persulfates begin to decompose above 50 °C.
Use of sodium azide	TT	Wear goggles. Wear disposable nitrile gloves when weighing out sodium azide.	Some procedures for Winkler's method (see <i>Recipe Card</i> 74) of measuring dissolved oxygen in water contain a 1% (w/v) solution of sodium azide in the alkaline/iodide solution. This removes any nitrite ions which would interfere with the reaction. An experienced teacher or technician should make up the azide-containing solution and the resulting solution can be used by responsible students. Sodium azide is not as toxic as sodium cyanide. Any other uses of sodium azide would require a special risk assessment. Winkler's procedure can, however, be carried out without sodium azide present.
Use of cyanides	-	It is not advisable to use these solids in school science. Any proposed use would require a special risk assessment.	

95C Sodium and potassium salts (3)

(See also 96A & 95B)

Sodium thiocyanate-2-water		NaCNS.2H ₂ O
Potassium thiocyanate		KCNS
Harmful		R20/21/22: Harmful by inhalation, in contact with skin and if swallowed. R32: Contact with acids liberates very toxic gas. R52/53: Harmful to aquatic organisms, may cause long-term adverse effects in the aquatic environment. Solutions equal to or stronger than 3 mol dm ⁻³ should be labelled HARMFUL.
Store: Gln		Disposal: W1, W7 W7: Solutions should be diluted to less than 2 mol dm ⁻³ before pouring them down a foul-water drain.

Sodium alginate Sodium carbonate-hydrogencarbonate-2-water; sodium sesquicarbonate; Na ₂ CO ₃ .NaHCO ₃ .2H ₂ O Sodium dodecyl sulfate(VI); sodium lauryl sulfate; C ₁₂ H ₂₅ OSO ₃ Na Potassium hydrogencarbonate; potassium bicarbonate; KHCO ₃ Sodium hydrogencarbonate; sodium bicarbonate; NaHCO ₃ Sodium octadec-9-enoate; sodium oleate; C ₁₇ H ₃₃ COONa Sodium octadecanoate; sodium stearate; soap; C ₁₇ H ₃₅ COONa Sodium tauroglycocholate; bile salts Sodium thiosulfate-5-water; hypo; NaS ₂ O ₃ .5H ₂ O	Low hazard	Store: Gln	Disposal: W8
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95C Sodium and potassium salts (3)

Model risk assessments

Activity	User	Control measures	Experimental points
Using soap	Y7	-	Use pure water to prepare soap solutions. See <i>Recipe Card 60</i> .
Use of bile salts	Y7	-	A 3% solution is normally used in lipase activities.
Use of alginates	Y7	-	Alginate gels have been known to block sinks. Any gels should be separated from water (adding calcium chloride or nitrate(V) solution would complete the process) and placed in the normal refuse.
Thiosulfate/iodine reaction	Y7	Wear eye protection.	The reaction with iodine does not produce hazardous products.
Thiocyanates complexes	Y9	Wear eye protection. Do not heat the complexes or solutions.	The reaction with a 0.1 mol dm^{-3} solution of iron(III) ions (usually dissolved in 0.1 mol dm^{-3} hydrochloric acid) and thiocyanate ions produces a very deep red solution. At dilute concentrations, no toxic gases are released.
Thiocyanates in silver nitrate(V) titrations	Y9	Wear eye protection. Do not heat the solution.	Volhard's method for measuring chlorides uses thiocyanates as an indicator. The use of 4 mol dm^{-3} nitric(V) acid in this procedure does not form dangerous gases at room temperature.
Sodium thiosulfate/bromine reaction	Y9	Wear eye protection.	Reactions with bromine and chlorine produce solutions of hydrobromic and hydrochloric acid respectively. Sulfur will be deposited and sulfur dioxide will be given off.
The sodium thiosulfate/acid reaction	Y9	Wear eye protection. Use a stop bath of 0.5 mol dm^{-3} sodium carbonate with indicator added. Known sufferers of asthma should be closely monitored.	For a procedure which uses reduced volumes, see Guide L195, <i>Safer Chemicals, Safer Reactions</i> . Sulfur dioxide is produced in this reaction. This is more of a problem if the reaction is carried out at higher temperatures. The temperature should not exceed 55°C in any case; because the reaction rate is so fast above this temperature, it becomes difficult to establish the rate with accuracy. Place sodium thiosulfate solution in the refrigerator, so that temperatures lower than room temperature can be studied. Disposal: Solutions should be poured into 0.5 mol dm^{-3} sodium carbonate solution before pouring down a foul-water drain.
Using anhydrous sodium thiosulfate	TT	Wear eye protection. Use a fume cupboard.	Heat the sodium thiosulfate gently in an evaporating basin until it melts. On further heating, the thiosulfate solidifies, with spitting. It is used in enthalpy measurements.

96A Sulfur

S₈

Low hazard	-	Although sulfur has no hazard classification, fine sulfur dust may be irritating to the eyes.
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The substance is dangerous with:	<p>HEAT. It burns to form sulfur dioxide, a toxic gas.</p> <p>MAGNESIUM, ALUMINIUM, ALKALI METALS. Very reactive mixtures are formed which can be very dangerous. These should not be performed in schools.</p> <p>ZINC. The reaction is very exothermic.</p> <p>OXIDISING AGENTS, METAL OXIDES. Explosive mixtures are formed. (Amongst others, mixtures with potassium and sodium chlorates and silver nitrate(V) are particularly unstable.)</p> <p>It is illegal to make a mixture of potassium chlorate(V) and sulfur.</p>
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Store: FS Powdered roll sulfur is rhombic sulfur, mined from the earth and pulverised into a powder. It consists of S ₈ molecules. Monoclinic sulfur (see the reverse of this card) has the S ₈ molecules arranged differently and is an allotrope of sulfur. Flowers of sulfur are amorphous, ie, there is no specific formula or crystal structure, and they are not considered to be allotropes.	Disposal: W8
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Inhalation of sulfur dioxide (formed when sulfur burns) by pupils or staff with known breathing difficulties such as asthma may exacerbate these pre-existing conditions. Effects of exposure can be delayed for some hours.


Activity	User	Control measures	Experimental points
Melting sulfur	Y7	Wear eye protection. Use a mineral-wool plug in the mouth of the test tube. This will minimise sulfur vapour escaping into the atmosphere and catching fire.	Use no more than 2 g of powdered roll sulfur in a test tube. Heating should be carried out over a small flame from a Bunsen burner with the collar half open; heating must be gradual because sulfur is a poor conductor of heat. Amber, molten sulfur darkens and thickens at 160 °C. Inversion of test tubes should be done with care.
Reaction of sulfur with copper	Y7	Wear eye protection. Do not substitute copper and use more-reactive metals such as aluminium or magnesium.	Mix 0.2 g of copper powder and 0.1 g of sulfur (flowers or rhombic) in a small, borosilicate test tube. Place a mineral-wool plug in the mouth of the test tube and heat strongly. Remove the flame once the reaction starts. Alternatively, in a fume cupboard, heat sulfur in a boiling tube until it is boiling and hold some weighed, bright copper foil in the sulfur vapour. The foil can be reweighed.
Preparation of rhombic crystals	Y12	Wear eye protection. Do not use carbon disulfide. Use a fume cupboard.	May be obtained by saturating dimethylbenzene (xylene) with powdered roll sulfur at 40 °C on a water bath. The solution is decanted into a shallow dish and small rhombic crystals form as it cools.
Making plastic sulfur	TT	Wear eye protection. Use a fume cupboard.	Once heated sulfur has become molten and viscous, on further heating the liquid sulfur becomes more mobile. It can then be poured into a beaker of cold water to make plastic sulfur. If the sulfur catches fire, have a heatproof mat or damp cloth available to cover the beaker.
Burning sulfur	TT	Wear eye protection. The room should be well ventilated.	No more than 0.3 g can be burnt in the open laboratory; sulfur dioxide is formed. Use a fume cupboard for larger amounts or if it is required for pupils to carry out the reaction.
Preparation of monoclinic crystals	TT	Wear eye protection. Use a fume cupboard. Use <i>Quickfit</i> equipment with a reflux condenser attached.	<ol style="list-style-type: none"> Heat sulfur until it is just molten, pour it onto filter paper and leave it to solidify. Break the crust (take care, the sulfur is very hot). Using an oil bath or electric heating, heat a saturated solution of powdered roll sulfur in dimethylbenzene to about 130 °C. Allow to cool. See also <i>Hazard</i> 106. They may also be prepared from a solution of sulfur in hot olive oil.
Reactions with iron and zinc	Y7/ TT	See <i>Hazard</i> 55A and L195, <i>Safer Chemicals</i> , <i>Safer Reactions</i> for reactions with iron and <i>Hazard</i> 107 for zinc.	

96B Sulfur chlorides

Disulfur dichloride		Sulfur monochloride	S ₂ Cl ₂
Toxic		<p>R14: Reacts violently with water. R25: Toxic if swallowed. R20: Harmful by inhalation. R29: Contact with water liberates toxic gas. R35: Causes severe burns. R50: Very toxic to aquatic organisms.</p> <p>Dangerous with: WATER. A violent reaction occurs, emitting hydrogen chloride and sulfur dioxide.</p> <p>SODIUM, POTASSIUM, ALUMINIUM POWDER. A violent reaction occurs.</p> <p>UNSATURATED HYDROCARBONS. Ignition may occur.</p> <p>WEL (mg m⁻³): 5.6 (STEL).</p> <p>Emergencies: see standard procedures on <i>Hazard E</i>, BUT ALSO:</p> <p>If spilt in the laboratory: If the spill is large, evacuation should be considered. It may be necessary to call the fire brigade. Wear goggles and chemical-resistant gloves. Ventilate the area of the spill. Spread dry mineral absorbent over the spill and scoop up as much as possible.</p>	
Corrosive			
Dangerous for the environment			
Store: Situ The substance should not be stored but made and disposed of in the same lesson. It has a pungent odour.		Disposal: W1 for any bottles bought in the past, W4 W4: Add the product of the reaction, in small amounts, to 1 mol dm ⁻³ sodium carbonate solution in a fume cupboard. Wait until the reaction is finished before adding more. Pour the solution down a foul-water drain.	
Sulfur dichloride oxide		Thionyl chloride	SOCl ₂
Corrosive		<p>R14: Reacts violently with water. R20/22: Harmful by inhalation and if swallowed. R29: Contact with water liberates toxic gas. R35: Causes severe burns.</p> <p>WEL (mg m⁻³): 4.9 (STEL).</p> <p>For 'Dangerous with:' and 'Emergencies:', see above.</p>	
Store: CW This liquid has a pungent and long-lasting smell. Keep small quantities (100 cm ³ or less) in a labelled desiccator with soda lime so that the stock is always fresh.		Disposal: W1, W4 W4: Add the liquid in small amounts to 1 mol dm ⁻³ sodium carbonate solution in a fume cupboard. Wait until the reaction is finished before adding more. Pour the solution down a foul-water drain.	

Activity	User	Control measures	Experimental points
Large-scale preparation of disulfur dichloride	Y12	Wear goggles. Use a fume cupboard. Wear chemical-resistant gloves. Wear a laboratory coat, because the product is particularly foul smelling.	The method involves the preparation and drying of chlorine. This is passed over heated sulfur in a combustion tube. Do not attempt to store the product but dispose of it as soon as possible by adding it to water.
Preparation of acid chlorides	Y12	Wear goggles. Use a fume cupboard. Wear chemical-resistant gloves. Wear a laboratory coat because thionyl chloride is particularly foul smelling.	When the procedure is finished, all used equipment should be placed in a bucket of water to remove all traces of thionyl chloride.
Reaction of sulfur chlorides with water	Y12	Wear goggles. Use a fume cupboard. Wear chemical-resistant gloves.	Amounts should be limited to 5 drops added to 5 cm ³ of water in a test tube in a rack.
Burning sulfur in chlorine	TT	Wear goggles or a face shield. Use a fume cupboard.	Burn sulfur on a deflagrating spoon and insert into a gas jar of chlorine. Add water to dispose of the disulfur dichloride.
Endothermic reaction	TT	Wear goggles or a face shield. Use a fume cupboard.	A boiling tube with 4 g of cobalt(II) chloride-6-water is equipped with a temperature probe. Add 10 cm ³ of thionyl chloride. Hydrogen chloride and sulfur dioxide are produced. The temperature of the reaction drops. Other hydrated metal chlorides can be used as well.

Inhalation of sulfur dioxide by pupils or staff with known breathing difficulties such as asthma may exacerbate these pre-existing conditions. Effects of exposure can be delayed for some hours.

Toxic	 <p>R23: Toxic by inhalation. R34: Causes burns. WEL (mg m⁻³): 2.7 (LTEL), 2.7 (STEL). The HSE, in <i>Chemical Hazard Alert Notice 34, Sulfur Dioxide</i>, advises that the level should be reduced to 1 ppm (ie, 2.7 mg m⁻³). This is a choking gas with serious effects on lungs and eyes resulting in possible bronchitis and conjunctivitis.</p>
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Emergencies: see standard procedures on *Hazard E*, BUT ALSO:

If a canister is leaking:	<p>Open the valve slightly in an efficient fume cupboard and leave it on until all the gas has been released.</p> <p>If done in the open air, find a secure area that people will not normally visit, eg, a flat roof, place yourself upwind of the canister and open the valve slightly. Leave for 24 hours.</p>
If a canister valve has stuck:	Contact CLEAPSS for instructions about disposal.


<p>Store: Situ</p> <p>Aluminium canisters containing the gas are no longer obtainable. If you have one, tighten the valve with light finger pressure only. Do not store in a fume cupboard or with other corrosive substances. Store in a plastic container or polythene bag containing some self-indicating silica gel. Close the bag with a wire fastener and keep it in the ventilated store.</p>	<p>Disposal: W6</p> <p>W6: When a canister is known to be empty, it should be cut in half and placed in the normal refuse.</p>
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Inhalation of sulfur dioxide by pupils or staff with known breathing difficulties such as asthma may exacerbate these pre-existing conditions. Effects of exposure can be delayed for some hours.

Activity	User	Control measures	Experimental points
Use of sulfur dioxide solution	Y7	Wear eye protection. Use a fume cupboard.	For its preparation, using sulfur dioxide or sodium/potassium metabisulfite, see <i>Recipe card</i> 28. Pupils should take what they require from a bottle of the solution in a fume cupboard. They must be warned not to inhale the sulfur dioxide that is given off.
Test for sulfur dioxide	Y9	Wear eye protection.	Use filter paper with 1 or 2 drops of the acidified potassium dichromate(VI) test solution on it. This is easier for pupils to handle. For demonstration purposes, a larger area of filter paper should be covered with the solution. The gas may also be bubbled through orange acidified 0.1 mol dm^{-3} potassium dichromate(VI) solution which turns green.
Reaction with magnesium	Y9	Wear eye protection. Use safety screens.	Do not look directly at burning magnesium as it is plunged into a boiling tube of sulfur dioxide gas. Specks of yellow sulfur can be seen.
Small-scale preparation	Y9	Wear eye protection. Use a fume cupboard.	Warm any sulfite with 1 mol dm^{-3} hydrochloric acid. Pupils must not directly inhale the sulfur dioxide gas produced. Once the test is positive, the warming should be stopped.
Large-scale preparation	Y12	Wear eye protection. Use a fume cupboard to prepare the gas.	The traditional method using concentrated sulfuric(VI) acid and copper turnings must be performed with care. It is better to add 2 mol dm^{-3} sulfuric(VI) acid from a separating funnel onto sodium metabisulfite. Warming will be necessary. See <i>Handbook</i> 13.3.
Fountain experiment	TT	Wear eye protection. Use safety screens. Use a fume cupboard.	Use a thick-walled, borosilicate, round-bottomed flask or a Büchner flask made to BS 1739. (The reduction in pressure could implode a weak flask.) See <i>Handbook</i> 13.3.
Contact process	TT	Use a fume cupboard. Wear goggles or a face shield.	Details for this process are complex and advice from CLEAPSS should be obtained.
Making a solution of sulfur dioxide	TT	Use a fume cupboard. Wear eye protection.	Pass the gas through a large inverted funnel with its rim below the surface of the water. This provides a large surface area for dissolving and prevents sucking back; see <i>Handbook</i> 13.3.

98A Sulfuric(VI) acid



Corrosive		<p>R35: Causes severe burns.</p> <p>Solutions equal to or stronger than 1.5 mol dm^{-3} should be labelled CORROSIVE. Solutions equal to or stronger than 0.5 mol dm^{-3} but weaker than 1.5 mol dm^{-3} should be labelled IRRITANT.</p> <p>WEL (mg m^{-3}): 1 (LTEL), 3 (STEL).</p> <p>Always add the concentrated acid slowly to cold water, or preferably ice, when diluting, never the reverse. Stir frequently to ensure thorough mixing.</p>
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The substance is dangerous with:	<p>WATER. A vigorous reaction occurs when the concentrated acid is diluted.</p> <p>HYDROCHLORIC ACID, CHLORIDES. Hydrogen chloride is given off.</p> <p>CHLORATES, MANGANATES(VII) (permanganates). Spontaneously-explosive products are formed.</p> <p>PHOSPHORUS (WHITE). Ignition can occur.</p> <p>SODIUM, POTASSIUM and many other metals. Dangerous reactions can take place.</p>
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Emergencies: see standard procedures on *Hazard E*, BUT ALSO:

If spilt on skin or clothes:	<p>Remove contaminated clothing and quickly wipe as much liquid as possible off the skin with a dry cloth before drenching the area with a large excess of water. If a large area is affected or blistering occurs, seek medical attention.</p>
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<p>Store: CLa</p> <p>Once open, the acid will absorb water from the atmosphere. Full bottles of liquid are very heavy. Fuming sulfuric(VI) acid (oleum) is even more dangerous to use and is not recommended for use in schools.</p>	<p>Disposal: W1, WSpec</p> <p>Wspec: Wear goggles or a face shield and chemical-resistant gloves. Add slowly no more than 10 cm^3 of concentrated sulfuric(VI) acid to 1 litre of 1 mol dm^{-3} sodium carbonate solution (containing indicator) which should be constantly stirred. Let the mixture cool (or add ice), before adding more acid. Pour the solution down a foul-water drain.</p>
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98A Sulfuric(VI) acid

Model risk assessments

Activity	User	Control measures	Experimental points
General use	Y7	Wear eye protection.	For many purposes, 0.4 mol dm^{-3} is adequate. Use solutions no stronger than 1.5 mol dm^{-3} . See Guide L195.
General use of more concentrated acid	Y9	Wear goggles. Consider the need for disposable nitrile gloves.	Concentrations greater than 1.5 mol dm^{-3} can be used. With concentrated acid, quantities should be as small as possible. No large containers should be left on a bench or in unused fume cupboards. Bottles have been stolen. Bottles should not be carried by pupils.
Addition to copper(II) sulfate(VI)	Y9	Wear goggles. Wear disposable nitrile gloves.	Use 0.5 g of hydrated copper(II) sulfate(VI) in a dry test tube and cover it with concentrated sulfuric(VI) acid. The colour change is gradual. Disposal: Pour the contents of the test tubes into a bowl of cold water.
Electrolysis of sulfuric(VI) acid	Y9	Wear eye protection.	Usually, a Hoffman voltameter is used with 1 mol dm^{-3} sulfuric(VI) acid to obtain hydrogen and oxygen in a 2:1 ratio. Platinum electrodes must be used; (if carbon electrodes are used, carbon dioxide is produced at the anode). 2 mol dm^{-3} magnesium sulfate(VI) solution is a safer, alternative electrolyte. See <i>Handbook</i> 11.4.
Reaction with chlorides, bromides & iodides	Y12	Wear goggles. Use a fume cupboard. Wear chemical-resistant gloves.	Use about 0.3 g of potassium or sodium halide with about 5 drops of the concentrated acid. With chlorides, hydrogen chloride is formed. With bromides and iodides, the acid forms the halogen and is itself reduced to sulfur dioxide and, with the iodide, hydrogen sulfide as well.
Reaction with copper	Y12	Wear goggles. Use a fume cupboard. Wear chemical-resistant gloves.	Warm about 1 g of copper turnings with 1 cm^3 of concentrated acid. Sulfur dioxide is evolved. Disposal: After cooling, place the test tubes with their contents in a bowl of cold water.
Reaction with sucrose	TT	Wear goggles or a face shield. Use a fume cupboard. Wear chemical-resistant gloves.	Half-fill a 100 cm^3 beaker with sucrose and add concentrated sulfuric(VI) acid to just saturate the sugar. After a delay of a minute or two, the mixture goes black and begins to rise, producing sulfur dioxide and carbon monoxide. Do not touch the carbon mass formed unless gloves are worn. Disposal: Plunge the beaker and carbon into an excess of water when cool. The carbon is placed in the normal refuse.
Diluting concentrated acid	TT	Wear goggles or a face shield. Wear chemical-resistant gloves.	The concentrated acid must be added in small amounts to a beaker (twice the capacity of the final volume) of water or, better still, ice with lots of stirring. See <i>Recipe Card</i> 69 and Guide L195.
For drying gases	TT	Avoid this use, especially for hydrogen. See <i>Handbook</i> 13.2 for suitable alternative drying agents.	

98B Sulfates(VI) and sulfamic acid

Amidosulfonic acid		Sulfamic acid	$\text{H}_2\text{NSO}_3\text{H}$
Irritant		R36/38: Irritating to eyes and skin. R52/53: Harmful to aquatic organisms, may cause long-term adverse effects in the aquatic environment. It is used as a descaler. Solutions have a very low pH.	
Store: Gln		Disposal: W1, W4	



Sodium hydrogensulfate(VI)		Sodium bisulfate	$\text{NaHSO}_4 \cdot \text{H}_2\text{O}$
Corrosive		R34: Causes burns. R37: Irritating to respiratory system. It was used as 'solid' sulfuric(VI) acid. It is still used as a toilet cleaner, eg, <i>Harpic</i> and <i>Sanilav</i> . Solutions equal to or stronger than 0.8 mol dm^{-3} should be labelled CORROSIVE. Solutions equal to or stronger than 0.3 mol dm^{-3} but weaker than 0.8 mol dm^{-3} should be labelled IRRITANT.	
Store: CW		Disposal: W4	


Potassium sulfate(VI); potassium sulfate; K_2SO_4 Sodium sulfate(VI); anhydrous sodium sulfate; Na_2SO_4 Sodium sulfate(VI)-10-water; hydrated sodium sulfate; Glauber's salt; $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$	Low hazard	Store: Gln	Disposal: W7
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98B Sulfates(VI) and sulfamic acid**Model risk assessments**

Activity	User	Control measures	Experimental points
General use of salt solutions	Y7	Wear eye protection.	Heat is evolved if anhydrous salts are added to water.
Descaling procedures using sulfamic acid	Y9	Wear goggles.	Sulfamic acid can be used by technicians to descale pure-water stills and by pupils as an example of descaling.
Use of 'solid sulfuric(VI) acid'	Y9	Wear goggles	Sodium hydrogensulfate(VI) can be used to make solutions which will behave in a similar manner to dilute sulfuric(VI) acid. However, explaining the chemistry may be considered confusing. Solutions have a very low pH value, similar to dilute sulfuric(VI) acid.
Drying agents	Y9	Wear eye protection.	The anhydrous sulfates(VI) of sodium and magnesium can be used as drying agents for organic solvents.
Electrolysis of sodium sulfate(VI) solution	Y9	Wear eye protection.	<p>Sodium sulfate(VI) can be used as a safer substitute for dilute sulfuric(VI) acid when electrolysis is being carried out. Soap bubbles which explode can be made by electrolysis of 0.2 mol dm⁻³ sodium sulfate(VI) solution with nickel electrodes for a short period. Details are in L195, <i>Safer Chemicals, Safer Procedures</i>.</p> <p>During the electrolysis of sodium sulfate(VI) solution, use pH indicator solution or a pH probe adjacent to the electrodes to monitor the alterations in pH in the vicinity; see <i>Handbook</i> 11.4.</p>

99 Tetrachloroethene and trichloroethene

Tetrachloroethene		Perchloroethylene; tetrachloroethylene	C ₂ Cl ₄
Harmful		<p>R40: Limited evidence of a carcinogenic effect. Category 3 carcinogen. R51/53: Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.</p> <p>Dangerous with: ALUMINIUM, MAGNESIUM. Violent reactions may occur. SODIUM, POTASSIUM, LITHIUM. Explosive reactions can occur. ALKALIS. Dangerous reactions can occur. CIGARETTES. Smoking in the presence of the vapour may generate lethal phosgene.</p> <p>WEL (mg m⁻³): 345 (LTEL), 689 (STEL).</p>	
Dangerous for the environment			
Store: GOrg		Disposal: W1, W2	

Trichloroethene ¹		Trichloroethylene	CHClCCl ₂
Toxic		<p>R45: May cause cancer. Category 2 carcinogen. R68: Possible risk of irreversible effects. Category 2 mutagen. R67: Vapours may cause drowsiness and dizziness. R36/38: Irritating to eyes and skin. R52/53: Harmful to aquatic organisms, may cause long-term adverse effects in the aquatic environment.</p> <p>Dangerous with: ALUMINIUM, MAGNESIUM. Violent reactions may occur. SODIUM, POTASSIUM, LITHIUM. Explosive reactions can occur. ALKALIS. Dangerous reactions can occur. CIGARETTES. Smoking in the presence of the vapour may generate lethal phosgene.</p> <p>WEL (mg m⁻³): 550 (LTEL), 820 (STEL).</p>	
Store: T		Disposal: W1, W2	

Emergencies: see standard procedures on *Hazard E*, BUT ALSO:

If spilt in the laboratory:	Ventilate the area of the spill as much as possible. Cover with mineral absorbent and scoop it into a bucket. Add dispersing agent, if available, or washing-up liquid over the mixture and stir to form an emulsion. Pour the liquid down a foul-water drain with excess water.
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¹ This is **NOT** the same as 1,1,1-trichloroethane (see *Hazard 103*).



These substances should be used as a last resort. A risk assessment should be carried out to find alternatives wherever possible; a full discussion is found in L195, *Safer Chemicals, Safer Reactions* but if in doubt, contact CLEAPSS.

Activity	User	Control measures	Experimental points
Acrylic (eg, Perspex) cement	Y9	Do not use tetrachloroethene or trichloroethene if possible. Instead, use dichloromethane; see <i>Hazardcard 28</i> . Put 7 g of acrylic scrap in a wide-mouthed jar and add 100 cm ³ dichloromethane. For use of cement, see <i>Hazardcard 28</i> .	
Solvent extraction and refluxing	Y12	Do not use tetrachloroethene or trichloroethene as a solvent for this purpose. Cyclohexane or dichloromethane may be suitable alternatives.	
Preparation of tin(IV) iodide	Y12	Wear eye protection. Use a fume cupboard.	Better to use dichloromethane. Originally 1,1,1-trichloroethane was the solvent for this reaction but tetrachloroethene could also be used.
Solvent for bromine	Y12	Wear eye protection. Use a fume cupboard.	Cyclohexane can be used, provided that it is stored out of the light (eg, in a dark bottle or labelled cardboard box). However, plastic screw tops or bungs will be affected if stored for over a month. In a clear bottle, exposed to light, noticeable deterioration will occur within 2 days. A 1% bromine solution in tetrachloroethene will lose its colour after a few days. Trichloroethene is unsuitable because decolourisation is rapid.
Attraction to electrostatic fields	Y12	Wear eye protection. Use a fume cupboard.	Tetrachloroethene is a safer alternative to tetrachloromethane.
Hydrolysis of Group (IV) halides	Y12	Wear eye protection. Use a fume cupboard.	Tetrachloroethene, ethanol and water (1:1:1 by volume) display no changes in conductivity when an electric current is passed through. This could be used as a substitute for tetrachloromethane.
Testing the efficiency of filter fume cupboards	TT	Wear eye protection.	Trichloroethene is used. If, when using a detection tube to find the concentration of vapour emitted through the exhaust, the level is above the permitted amount, open all windows. See <i>Handbook 20.10.6</i> . This test is required only if it is necessary to determine whether a faulty seal causes leaks from a filter fume cupboard. It should not be used to test the quality of the filter that removes corrosive chemicals.

100 Tetrachloromethane

CCl₄

Also known as carbon tetrachloride.

Toxic		R40: Limited evidence of a carcinogenic effect. Category 3 carcinogen. R23/24/25: Toxic by inhalation, in contact with skin and if swallowed. R48/23: Toxic: danger of serious damage to health by prolonged exposure through inhalation. R52/53: Harmful to aquatic organisms, may cause long-term adverse effects in the aquatic environment. R59: Dangerous to the ozone layer.
Dangerous for the environment		WEL (mg m⁻³): 13 (LTEL), 39 (STEL). The odour threshold level is higher than the Workplace Exposure Limit. This substance is no longer available for schools to purchase. However, some may still have stocks. The <i>COSHH Regulations</i> ban its use in all “diffusive applications” which would certainly include use in open test tubes. It is doubtful whether tetrachloromethane should now be used at all. It should certainly never be used simply as a solvent where safer substitutes are suitable.
The substance is dangerous with:	ALUMINIUM, MAGNESIUM. Violent reactions may occur. SODIUM, POTASSIUM, LITHIUM. Explosive reactions can occur. CIGARETTES. Smoking in the presence of tetrachloromethane vapour may generate lethal phosgene gas.	
Store: T (pending disposal)		Disposal: W1, W2



An assessment of risks should be made to find alternatives wherever possible; a full discussion is found in L195, *Safer Chemicals, Safer Reactions* but if in doubt, contact CLEAPSS.

Activity	User	Control measures	Experimental points
Nylon 'rope' preparation	-	Use cyclohexane in place of tetrachloromethane. See <i>Hazcard</i> 3B.	
Periodicity of chlorides	-	See <i>Hazcard</i> 99, 'Hydrolysis of Group (IV) halides'.	
Solvent for bromine	-	See <i>Hazcards</i> 45B and 99.	
Distribution of iodine between water and tetrachloromethane	-	See <i>Hazcard</i> 106.	
Effect of electrostatic charge	-	See <i>Hazcard</i> 99.	

101 Thorium compounds

Some employers do not allow thorium compounds in schools except artefacts such as gas mantles impregnated with thorium compounds. Where other compounds are permitted, 'Local Rules' for the use of radioactive sources must be followed and use is usually restricted to radon-220 (thoron) generators.

Additional stocks may be kept only where there is adequate expertise and the employer's RPA agrees.




Thorium(IV) nitrate(V)		Th(NO ₃) ₄
Thorium(IV) oxide, carbonate and hydroxide		ThO ₂ ; Th(CO ₃) ₂ ; Th(OH) ₄
Very Toxic		<p>R26/28: Very toxic by inhalation and if swallowed. R33: Danger of cumulative effects. R51/53: Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. Thorium compounds are alpha emitters and the generation of airborne dust must be avoided. They have been known to cause dermatitis.</p> <p>Emergencies: see standard procedures on <i>Hazard E</i>, BUT ALSO:</p> <p>Spills and decontamination: Wear a laboratory coat, disposable gloves, toxic dust mask (EN149, category FFP2S). Items contaminated with radioactive material, such as paper wipes and disposable gloves should be sealed in a strong plastic bag and placed in the normal refuse. Refer to notes below and CLEAPSS Guide L93 for more information.</p>
[Ionising radiation (Radioactive)]		<p>If spilt on the skin or clothes: Remove as much solid as possible with damp tissues/absorbent paper towels. Wipe towards the centre of the spill. Remove contaminated clothing. Wash the skin thoroughly with plenty of soap and water. Check the skin for contamination. Clothing contaminated with radioactive material should be sealed in a plastic bag for disposal in normal refuse. If clothing contamination is minimal, rinse repeatedly and then wash thoroughly.</p> <p>If spilt in the laboratory: Recover as much solid as possible by scooping gently into a dry container. Wipe towards the centre of the spill with damp tissues/absorbent paper towels. Check the area for contamination.</p>
<p>Store: Rad</p> <p>As a Toxic & Radio-active chemical, locked in the radio-actives store (see Guide L93).</p>	<p>Disposal:</p> <p>Wspec:</p>	<p>Wspec</p> <p>Up to 100g/day of thorium compounds may be placed in the normal refuse, subject to restrictions, depending on who collects the refuse; contact CLEAPSS if necessary. If in labelled containers, remove markings. Grout into a larger container; see Guide L93. Alternatively, but less satisfactory because it involves more risk of contact with the radioactive material, small quantities may be dissolved in water [the oxide, hydroxide and carbonate should dissolve in 2 mol dm⁻³ nitric(V) acid]. Dilute this solution greatly and pour down a foul-water drain.</p>

Activity	User	Control measures	Experimental points
Use of thorium compounds in gas mantles	Y12	Keep in a strong, self-sealing, plastic bag.	May be used to show radioactivity in the environment. A recently-developed piece of equipment allows several gas mantles to act as the source in a radon-220 generator.
Radon-220 (thoron) generator for half-life investigations.	Y12	The generator should be inspected and leak tested every year.	Approved patterns of Radon-220 (thoron) generator, with filter, contain about 20g of thorium compound (usually thorium hydroxide powder). Refer to the risk assessment in Guide L93, <i>Managing Ionising Radiations and Radioactive Substances</i> .
Checking spill areas for activity.	TT	-	Hold the Geiger-Müller window as close as possible to the area of the spill without touching it. Pass the tube slowly over the whole area, recording the total number of counts over a period of 5 minutes. Check the background reading over the same period in another room. If the spill area gives more than 1.5 times the background count, repeat the decontamination and check again.

Work with open thorium compounds, as shown below, may only take place where employees have adequate expertise and the employer's Radiation Protection Adviser agrees. Wear eye protection, laboratory coat, gloves, toxic dust mask (EN149, category FFP2S). Work in a draught-free area (eg, fume cupboard with extraction turned off). Contaminated items, eg, paper wipes, should be sealed in a plastic bag and placed in the normal refuse. Waste solutions should be dealt with by staff by diluting greatly and washed down a foul-water drain.

Separation of daughter products	TT	Must have RPA agreement.	Do not attempt to concentrate extracts.
Dissolving the oxide, carbonate or hydroxide	TT	Must have RPA agreement.	Use 2 mol dm ⁻³ nitric(V) acid. Add the thorium compound to the acid, testing a very small quantity for solubility first. Dissolving may take some time and, occasionally, mechanical stirring may be necessary.



102 Tin and its compounds



Tin metal ; Sn Tin(II) oxide ; stannous oxide; SnO Tin(IV) oxide ; stannic oxide; cassiterite; SnO ₂ Tin(II) sulfate(VI) ; stannous sulfate; SnSO ₄		Low hazard (Inhalation of dusts should be avoided.)	Store: Gln	Disposal: W2, W8
Tin(II) chloride-2-water		Hydrated stannous chloride		SnCl ₂ .2H ₂ O
Harmful		R21/22: Harmful in contact with skin and if swallowed. R36/37/38: Irritating to eyes, respiratory system and skin. NB: Some suppliers suggest that it is corrosive, R34: Causes burns. WEL (mg m⁻³): 2 (LTEL), 4 (STEL) as tin. Dangerous with: OXIDISING AGENTS, eg, nitrates(V) or peroxides. Explosive mixtures can be formed.		
Store: Gln		Disposal: W1, W2, W4 W4: Once the solution is alkaline, the slurry can be poured down a foul-water drain. This is only suitable for very small amounts.		
Tin(IV) chloride		Stannic chloride		SnCl ₄
Corrosive		R34: Causes burns. R52/53: Harmful to aquatic organisms, may cause long-term adverse effects in the aquatic environment. WEL (mg m⁻³): 2 (LTEL), 4 (STEL) as tin. Dangerous with: TURPENTINE. An explosive reaction may occur.		
Store: CW		Disposal: W1, W2, W4 W4: Once the solution is alkaline, the slurry can be poured down a foul-water drain. This is only suitable for very small amounts.		
Tin(IV) iodide		Stannic iodide		SnI ₄
Harmful		R22: Harmful if swallowed. R36/38: Irritating to eyes and skin. WEL (mg m⁻³): 2 (LTEL), 4 (STEL) as tin.		
Store: Gln		Disposal: W1, W2		



Do not prepare or isolate tin(II) nitrate(V); several explosions have been reported.

Activity	User	Control measures	Experimental points
General use of tin(II) chloride solution	Y9	Wear eye protection.	The solution will be acidic. It is a useful mordant in dyeing. The solution will react with zinc to produce tin and with 1 mol dm^{-3} sodium hydroxide solution to form the hydroxide which dissolves in excess alkali (amphoteric).
Preparation of tin(II) chloride solution	Y12	Wear goggles.	The solid has to be dissolved in concentrated hydrochloric acid first and then diluted with water. It may still be cloudy, so leave the solid to settle and decant the clear solution later. Solutions more concentrated than 0.2 mol dm^{-3} are difficult to prepare. Add a piece of tin to stabilise the solution. See <i>Recipe card 70</i> .
Preparation of tin(IV) chloride	Y12	Use a fume cupboard. Wear goggles.	See <i>Hazcard 22A</i> for chlorine gas preparation. Place sand in a pear-shaped flask with 3 g of tin on the top. Heat until the tin melts before introducing the chlorine. Protect the distillate from water in the atmosphere with a trap containing anhydrous calcium chloride.
Hydrolysis of tin(IV) chloride	Y12	Wear goggles. Use a fume cupboard.	Add 2-3 drops of water to 0.2 cm^3 of tin(IV) chloride. The solid can be dissolved in 1 mol dm^{-3} hydrochloric acid to which an excess of 1 mol dm^{-3} sodium hydroxide solution is added to demonstrate its amphoteric nature.
Preparation of tin(IV) iodide	Y12	Wear goggles. Use a fume cupboard. Do not use tetrachloromethane.	Dissolve the iodine in dichloromethane or tetrachloroethene. Use an excess of tin and stop refluxing when the violet colour becomes faint enough to reveal the yellow precipitate of tin(IV) iodide. Disposal: For solvent and tin(IV) iodide, W1, W2.
Preparation of tin(IV) oxide	Y12	Wear goggles. Use a fume cupboard.	Add 2 cm^3 of concentrated nitric(V) acid to 0.5 g of tin in an evaporating basin or crucible. Warm until the reaction starts and then remove the heat source. Add water and filter off the solid.

103 1,1,1-trichloroethane and other halogenated ethanes

1,1,1-trichloroethane		Methyl chloroform	<chem>CH3CCl3</chem>
Harmful		R20: Harmful by inhalation. R59: Dangerous to the ozone layer. This substance is no longer available for schools to purchase. However, some may still have stocks. The <i>COSHH Regulations</i> ban its use in all “diffusive applications” which would certainly include use in open test tubes.	
Dangerous for the environment		WEL (mg m⁻³): 555 (LTEL), 1110 (STEL). Dangerous with: ALUMINIUM, MAGNESIUM. Violent reactions may occur. SODIUM, POTASSIUM, LITHIUM. Explosive reactions can occur. ALKALIS. Dangerous reactions can occur. CIGARETTES. Smoking in the presence of the vapour may generate lethal phosgene.	
Store: GOrg		Disposal: W1, W2	



1,2-dichloroethane		Ethylene dichloride	<chem>CH2ClCH2Cl</chem>
Highly flammable		R45: May cause cancer. Category 2 carcinogen. R11: Highly flammable. R22: Harmful if swallowed. R36/37/38: Irritating to eyes, respiratory system and skin.	
Toxic		It can be absorbed through the skin. It is volatile. Flash point: 13 °C. WEL (mg m⁻³): 21 (LTEL), 63 (STEL).	
Store: FL		Disposal: W1	

1,2-dibromoethane		Ethylene dibromide	<chem>CH2BrCH2Br</chem>
Toxic		R45: May cause cancer. Category 2 carcinogen. R23/24/25: Toxic by inhalation, in contact with skin and if swallowed. R36/37/38: Irritating to eyes, respiratory system and skin. R51/53: Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.	
Dangerous for the environment		It can be absorbed through the skin. WEL (mg m⁻³): 3.9 (LTEL), 11.7 (STEL) (Sk).	
Store: FL		Disposal: W1	

An assessment of risks should be made to find alternatives wherever possible; a full discussion is found in L195, *Safer Chemicals, Safer Reactions* but, if in doubt, contact CLEAPSS.

Activity	User	Control measures	Experimental points
Use in chromatographic solvents	Y7	If 1,1,1-trichloroethane is cited in any text, dichloromethane usually works as an alternative, although the R _f values will be different.	
Addition of bromine water to ethene	Y9	Wear eye protection.	See <i>Hazard</i> 45C. 1,2-dibromoethane and other compounds are formed whenever ethene is reacted with bromine water. However, the amount is so small that both exposure and risk to health are extremely low.
Nylon 'rope' preparation	Y9	Use cyclohexane in place of 1,1,1-trichloroethane; see <i>Hazard</i> 3B. This applies to both the students' version and the demonstration.	
Partition coefficient	Y12	Wear eye protection.	The partition coefficient of ammonia between water and 1,1,1-trichloroethane used to be investigated. It is possible to use ethyl ethanoate as a substitute but the strength of the ammonia should not be more than 1 mol dm ⁻³ .
As a solvent for bromine	TT	Wear eye protection. Do not use 1,1,1-trichloroethane.	Instead, use cyclohexane as the solvent and store the solution, for short periods, in a dark-glass bottle in a cupboard, away from any light. Make just enough for the required practical. Disposal: W6 for the small amount of remaining solution. <i>Volasil 244</i> can also be used as a solvent, although there are problems with this solvent as well. See <i>Hazard</i> 106.
Making thiokol rubber	-	Schools are advised not to carry out this preparation unless a special risk assessment is obtained. The procedure uses 1,2-dibromoethane or 1,2-dichloroethane.	

104 Trichloromethane and triiodomethane




Trichloromethane		Chloroform	CHCl ₃
Harmful		<p>R40: Limited evidence of a carcinogenic effect. Category 3 carcinogen. R22: Harmful if swallowed. R48/20/22: Harmful: danger of serious damage to health by prolonged exposure through inhalation and if swallowed. R38: Irritating to skin.</p> <p>Dangerous with: ALUMINIUM, MAGNESIUM. Violent reactions may occur. SODIUM, POTASSIUM, LITHIUM. Explosive reactions can occur. PROPANONE. An explosive reaction can occur under certain conditions. CIGARETTES. Smoking in the presence of trichloromethane vapour may generate lethal phosgene gas.</p> <p>WEL (mg m⁻³): 9.9 (LTEL), 29.7 (STEL) (Sk).</p> <p>It is absorbed through the skin. The odour threshold is 100 mg m⁻³ (20 ppm) which is above the STEL value.</p> <p>Emergencies: see standard procedures on <i>Hazard E</i>, BUT ALSO:</p> <p>If spilt in the laboratory: If more than 10 cm³, evacuate the room. Ventilate the area of the spill by opening all windows (the vapour is much denser than air and will not affect teachers or technicians while they quickly open the windows). Only return when the spill has evaporated.</p>	
Store: GOrg		Disposal: W1, W2	
Triiodomethane		Iodoform	CHI ₃
Harmful		<p>R22: Harmful if swallowed.</p> <p>WEL (mg m⁻³): 9.8 (LTEL), 16 (STEL).</p>	
Store: GOrg		Disposal: W1, W2	

It is doubtful whether trichloromethane should be used at all except in an efficient fume cupboard. It should certainly never be used simply as a solvent where safer substitutes are suitable. An assessment of risks should be made to find alternatives wherever possible; a full discussion is found in L195, *Safer Chemicals, Safer Reactions* but, if in doubt, contact CLEAPSS.

Activity	User	Control measures	Experimental points
Extraction of caffeine from tea	Y9	Wear eye protection.	See <i>Hazardcard</i> 28. See also Guide L195, for the use of propan-1-ol, saturated with sodium chloride, in place of any organohalogens used to extract caffeine.
Adhesives/ acrylic cements	Y9	Use dichloromethane	See <i>Hazardcards</i> 28 and 99.
Mixture with propanone - Raoult's Law	Y12	Wear eye protection. Use a fume cupboard.	Do not use a mixture with propanone, which may prove to be explosive. The boiling points of a range of mixtures of trichloromethane and ethyl ethanoate work well. A mixture of methanoic acid and butanone will also give a positive-deviation mixture.
Hydrogen bond-strength measurement	Y12	Wear eye protection. Use a fume cupboard. Do not mix with propanone and butanone.	Adding 1 cm ³ of trichloromethane to 9 cm ³ of ethyl ethanoate in a lagged boiling tube produces a small rise in temperature.
Deflection by an electrostatic field	Y12	Wear eye protection. Use a fume cupboard.	Trichloroethene is a safer alternative. Both reagents should be returned to their respective bottles after the procedure.
Preparation of triiodomethane (iodoform test)	Y12	Wear goggles.	1 g of iodine is dissolved in 10 cm ³ of 1 mol dm ⁻³ potassium iodide solution. 1 cm ³ of ethanol is added. 5 mol dm ⁻³ sodium hydroxide solution is added drop by drop until the iodine colour is removed and the yellow precipitate of triiodomethane is visible. The solid can be recrystallised from ethanol. Other reagents that can form iodoform are propan-2-ol, propanone and other chemicals with a CH ₃ CO group.
As a solvent	-	Use a safer alternative. See L195, <i>Safer Chemicals, Safer Reactions</i> .	

105 Uranium compounds

'Local Rules' for the use of radioactive sources must be followed. Normally, schools should not have more than 100g in total of all uranium compounds. See Guide L93, *Managing Ionising Radiations and Radioactive Substances*.

Uranyl(VI) nitrate(V)-6-water		$\text{UO}_2(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$
Also applies to uranium(IV) oxide, uranyl(VI) ethanoate, uranyl(VI) magnesium ethanoate and uranyl(VI) zinc ethanoate.		
Very Toxic		<p>R26/28: Very toxic by inhalation and if swallowed. R33: Danger of cumulative effects. R51/53: Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. The risk of poisoning is more serious than any risk from radioactivity for the soluble salts. The generation of airborne dust must be avoided.</p> <p>WEL (mg m^{-3}): 0.2 (LTEL), 0.6 (STEL) as uranium.</p> <p>Emergencies: see standard procedures on <i>Hazard E</i>, BUT ALSO:</p>
Dangerous for the environment		<p>Spills and decontamination: Wear a laboratory coat, gloves, toxic dust mask (EN149, category FFP2S). Items contaminated with radioactive material, such as paper wipes, should be sealed in a strong plastic bag and placed in the normal refuse. Refer to notes below and CLEAPSS Guide L93 for more information.</p> <p>If spilt on the skin or clothes: Remove as much solid as possible with damp tissues/absorbent paper towels. Wipe towards the centre of the spill. Remove contaminated clothing. Wash the skin thoroughly with plenty of soap and water. Check the skin for contamination. Clothing contaminated with radioactive material should be sealed in a plastic bag for disposal in normal refuse. If clothing contamination is minimal, rinse repeatedly and then wash thoroughly.</p> <p>If spilt in the laboratory: Recover as much solid as possible by scooping gently into a dry container. Wipe towards the centre of the spill with damp tissues/absorbent paper towels. Check the area for contamination.</p>
[Ionising radiation (Radioactive)]		
<p>Store: Rad</p> <p>As a Toxic & Radioactive chemical, locked in the radioactives store (see CLEAPSS Guide L93).</p>	<p>Disposal:</p> <p>Wspec:</p>	<p>Wspec</p> <p>Up to 100g/day of uranium compounds may be placed in the normal refuse, subject to some restrictions depending on who collects the refuse; contact CLEAPSS if necessary. If in labelled containers, remove markings. Grout into a larger container (see CLEAPSS Guide L93). Alternatively, but less satisfactory because it involves more risk of contact with the radioactive material, small quantities of uranyl compounds may be dissolved in water; other uranium compounds in 2 mol dm^{-3} nitric(V) acid. Dilute this solution greatly and pour down a foul-water drain.</p>


Activity	User	Control measures	Experimental points
General use of solutions	Y12	Wear eye protection. Wear disposable gloves. Wear a laboratory coat.	When testing for sodium ions with uranyl(VI) zinc ethanoate, redissolve the precipitate in excess water and wash down a foul-water drain, diluting greatly.
Protactinium generator for half-life investigations	Y12	The generator should be inspected and leak tested every year.	Refer to the risk assessment in CLEAPSS Guide L93.
Preparation of a protactinium generator	TT	Wear eye protection. Wear disposable gloves. Wear a laboratory coat. Do not attempt to concentrate extracts.	30 cm ³ of solution for a protactinium generator may be prepared according to <i>Recipe card</i> 57. The solvent used is pentyl ethanoate (HARMFUL), also known as <i>n</i> -amyl acetate. Alternatively, commercial generators may be obtainable.
Disposal of the contents of a protactinium generator	TT	Wear eye protection. Wear disposable gloves. Wear a laboratory coat.	Tip the contents into excess water and detergent to dilute the acid and disperse the organic solvent. Wash down a foul-water drain. Refer to the risk assessment in CLEAPSS Guide L93.
Checking spill areas for activity.	TT	-	Hold the Geiger-Müller window as close as possible to the area of the spill without touching it. Pass the tube slowly over the whole area, recording the total number of counts over a period of 5 minutes. Check the background reading over the same period in another room. If the spill area gives more than 1.5 times the background count, repeat the decontamination and check again.

106 *Volasil 244*





The chemical name is octamethylcyclotetrasiloxane.

Volasil 244 is the most popular product of this range used in schools; other products include *Volasil 245* and *345*.

Harmful		<p>R62: Possible risk of impaired fertility. R53: May cause long-term adverse effects in the aquatic environment.</p> <p>WEL (mg m⁻³): 123 (LTEL), 369 (STEL).</p> <p>Flash point: 57 °C.</p> <p>This substance is used in many commercial cosmetic preparations. The manufacturers of this substance are concerned about its misuse and have imposed hazard warnings and exposure limits, not presently warranted by EU legislation.</p>
If it catches fire:		<p>The boiling points of volasils are much higher than that of water and adding water to hot volasils could result in a spray of hot liquid, not unlike a fat-pan fire. Use a damp cloth, heatproof mat or fire blanket to starve the fire of oxygen.</p>
Store: GOrg <i>Volasil</i> is a trade name; VWR International Ltd and its distributors market the product.		<p>Disposal: W1, W2 or Wspec</p> <p>Wspec: Small volumes of the liquid may be burnt. The products are carbon dioxide, water and silicon dioxide (sand).</p>

Activity	User	Control measures	Experimental points
Melting-point determinations	Y7	Wear eye protection.	<i>Volasil 244</i> has a melting point of 17.5 °C. A test tube of material can be cooled in an ice bath. Supercooling occurs unless it is stirred. It is suitable as a cryoscopic solvent because it will dissolve small amounts of naphthalene and ethanoic acid.
As a solvent for bromine and iodine	Y9	Wear eye protection.	If prepared just before a lesson, a 0.05% (v/v) solution of bromine in <i>Volasil 244</i> is reasonably stable. At higher concentrations, and/or if left for some time, the solution becomes a gel because the molecular ring structure breaks and a polymer is formed. See Guide L195 for further details.
Halogen identification	Y9	Wear eye protection.	When chlorine or bromine water are added to solutions of halides, <i>Volasil 244</i> can be added to ensure better identification of the halogen formed in the reaction. However, cyclohexane works just as well and is less expensive.
Combustion	Y9	Wear eye protection.	1 cm ³ samples of <i>Volasil 244</i> can be burnt in a crucible in the laboratory. The products are carbon dioxide, water and silicon dioxide (sand).
Crystallisation of sulfur	Y12	Wear goggles.	Warm a mixture of powdered roll sulfur and <i>Volasil 244</i> to above the melting point of sulfur and allow it to cool. Needle-shaped crystals of monoclinic sulfur appear.
Distribution of iodine between water and <i>Volasil 244</i>	Y12	Wear goggles.	<i>Volasil 244</i> is a suitable alternative to the use of tetrachloromethane or benzene in partition constant investigations. Details can be obtained from CLEAPSS if required.
Addition of concentrated sulfuric(VI) acid	Y12	Wear goggles.	If 5 drops of concentrated sulfuric(VI) acid are added to 3 cm ³ of <i>Volasil 244</i> , the solution becomes viscous as polymerisation takes place. Disposal: Wash the 'jelly' product in water and place it in the normal refuse.
Nylon 'rope' preparation	Y9 & TT	Wear eye protection.	<i>Volasil 244</i> can be used in place of 1,1,1-trichloroethane. See <i>Hazcard 3B</i> .







107 Zinc

Zinc powder and dust			Zn
Highly flammable		<p>R15: Contact with water liberates extremely flammable gases. R17: Spontaneously flammable in air. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.</p> <p>Dangerous with: WATER, ALKALINE SOLUTIONS. Moist zinc dust can ignite spontaneously.</p> <p>ACIDS and ALKALIS. Hydrogen is evolved.</p> <p>IODINE, MANGANESE(IV) OXIDE, POTASSIUM CHLORATE(V). Violent reactions can occur.</p> <p>SULFUR. A violent or explosive reaction occurs.</p> <p>AMMONIUM SULFIDE SOLUTION. Hydrogen sulfide is evolved.</p>	
Dangerous for the environment			
<p>Store: FW</p> <p>Zinc 'dust' is fine zinc powder which is almost inevitably oxidised, ie, is only about 90 % Zn. On this card, 'powder' refers to zinc which is obviously 'gritty'.</p>			<p>Disposal: W1, W5</p>
Zinc granules; Zn			<p>Low hazard</p> <p>Store: Gln</p> <p>Disposal: W8</p>

Activity	User	Control measures	Experimental points
General use	Y7	Wear eye protection.	Reactions with acids, alkalis and salts may be carried out on a test-tube scale using zinc granules or powder.
Reaction with copper(II) oxide	Y7	Wear eye protection. Do not stir the mixture with a metal spatula.	Place 0.5 g of the mixture on ceramic paper (see L195, <i>Safer Chemicals, Safer Procedures</i>) and heat from above. To see the copper, use tongs to place the hot ceramic paper into a beaker of 1 mol dm ⁻³ hydrochloric acid.
Middleton's test	Y12	Wear goggles.	Mix about 0.1 g of the sample with about 1 g of a mixture of zinc powder (2 parts) and anhydrous sodium carbonate (1 part) in an ignition tube and heat strongly for about two minutes in a hot Bunsen-burner flame. Then plunge the red-hot tube into 20 cm ³ water in a beaker. Test for zinc sulfide in the solid residue and sodium cyanide or halides in the filtrate as in the sodium fusion test.
Reaction with iodine	TT	Wear goggles or a face shield. Use a fume cupboard. Use (gritty) powder, not zinc dust.	Use 0.5 g of zinc powder and 1 g of iodine. Add about 1-2 cm ³ of ethanol to initiate the reaction. The heat of reaction will produce iodine fumes.
Reaction with sulfur	TT	Wear goggles or a face shield. Use safety screens. Do not use zinc dust. Students should move to the back of the room. The room should be well ventilated.	Protect the bench with a large piece of hardboard. The demonstration is best done at the end of a lesson. The reaction of zinc with sulfur may be carried out as a demonstration by heating a small heap of a freshly-prepared mixture (5 g of zinc powder, 2.5 g of powdered roll sulfur) on a tin lid. Once the heating starts, move away from the area. Never carry out this reaction with the mixture confined in any way.
Hydrogen preparation (large-scale)	TT	Wear goggles or a face shield. Keep naked flames well away.	Modern samples of zinc are purer so the preparation does not work as well unless a little copper(II) sulfate(VI) solution is added to produce copper which acts as a catalyst. Use 5 mol dm ⁻³ hydrochloric acid or 3 mol dm ⁻³ sulfuric(VI) acid with zinc plus 1-5 cm ³ of 1 mol dm ⁻³ copper(II) sulfate(VI) solution. See <i>Handbook</i> 13.3.
Burning zinc	TT	Wear eye protection. The room should be well ventilated.	The zinc oxide fumes (also known as 'philosopher's wool'), formed when zinc powder reacts with oxygen, are regarded as a hazardous dust.

108A Zinc compounds (1)

See also 108B



Zinc chloride		ZnCl ₂
Zinc bromide		ZnBr ₂
Corrosive		R34: Causes burns. R22: Harmful if swallowed. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. Solutions equal to or stronger than 0.7 mol dm ⁻³ should be labelled CORROSIVE. Solutions equal to or stronger than 0.3 mol dm ⁻³ but weaker than 0.7 mol dm ⁻³ should be labelled IRRITANT. WEL (mg m⁻³): 1 (LTEL), 2 (STEL) as a fume which has very tiny particles.
Dangerous for the environment		
Store: CW These chemicals absorb water.		Disposal: W1, W4 W4: Add to 1 mol dm ⁻³ sodium carbonate solution to absorb hydrogen chloride gas. Pour the suspension down a foul-water drain.
Zinc chromate(VI)		ZnCrO ₄
Toxic		R45: May cause cancer. Category 1 carcinogen. R22: Harmful if swallowed. R43: May cause sensitisation by skin contact. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. WEL (mg m⁻³): 0.05 (LTEL) 0.15 (STEL) as chromium.
Dangerous for the environment		
Store: T Do not dry and store.		Disposal: W1
Zinc nitrate(V)-6-water		Hydrated zinc nitrate
		Zn(NO ₃) ₂ .6H ₂ O
Oxidising		R8: Contact with combustible material may cause fire. R22: Harmful if swallowed. R36/37/38: Irritating to eyes, respiratory system and skin. Solutions equal to or stronger than 0.8 mol dm ⁻³ should be labelled HARMFUL.
Harmful		
Store: Ox	Disposal: W1, W7 W7: Dilute to less than a 0.2 mol dm ⁻³ solution before pouring it down a foul-water drain.	


108A Zinc compounds (1)**Model risk assessments**

Activity	User	Control measures	Experimental points
Use of zinc nitrate(V) solution	Y7	Wear eye protection.	0.4 mol dm ⁻³ solutions are suitable for most purposes.
Heating zinc nitrate(V)	Y9	Wear eye protection. The room should be well ventilated.	Use no more than 1 g in a test tube unless a fume cupboard is used. Nitrogen dioxide and oxygen are produced.
Electrolysis of zinc bromide solution	Y9	Wear eye protection. Do not inhale the contents of the reaction.	Bromine is produced at the anode which turns the solution orange. Zinc forms at the cathode. Use a solution no stronger than 0.3 mol dm ⁻³ . Do not allow electrolysis to proceed for too long to avoid bromine evaporating from the solution. If zinc bromide is not available, use a mixture of 0.5 mol dm ⁻³ zinc sulfate(VI) and 0.5 mol dm ⁻³ potassium bromide.
Using anhydrous zinc chloride	Y12	Wear goggles.	Hydrogen chloride is produced on the addition of water.
Precipitating zinc chromate(VI)	Y12	Wear goggles. Wear disposable nitrile gloves.	This is better avoided because there are safer chromates to precipitate, eg, barium chromate(VI) (see <i>Hazard</i> 10B) and lead chromate(VI) (see <i>Hazard</i> 57B).
Electrolysis of molten zinc chloride	TT	Wear goggles or a face shield. Use a fume cupboard.	Zinc chloride can be used as an alternative to lead bromide. Crystals of zinc appear on the surface of the melt during electrolysis. It can be carried out on a small scale. See Guide L195, <i>Safer Chemicals</i> , <i>Safer Procedures</i> and <i>Handbook</i> 11.4.

108B Zinc compounds (2)

See also 108A

Zinc sulfate(VI)-7-water		Hydrated zinc sulfate	$\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$
Harmful		R22: Harmful if swallowed. R41: Risk of serious damage to eyes. R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. Solutions equal to or stronger than 0.4 mol dm^{-3} should be labelled IRRITANT.	
Dangerous for the environment			
Store: Gln		Disposal: W1, W7 W7 Dilute to less than 0.3 mol dm^{-3} before pouring down a foul-water drain.	

Zinc oxide		ZnO	
Dangerous for the environment		R50/53: Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.	
Store: Gln		Disposal: W8	

Zinc carbonate; $\text{ZnCO}_3 \cdot \text{Zn(OH)}_2$ Zinc sulfide; zinc blende; ZnS	Low hazard	Store: Gln	Disposal: W8
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108B Zinc compounds (2)

Model risk assessments

Activity	User	Control measures	Experimental points
Heating zinc carbonate	Y7	Wear eye protection.	Zinc carbonate is a basic carbonate. On heating, water will be given off, as well as carbon dioxide.
Heating zinc oxide	Y7	Wear eye protection.	This is an example of a reversible physical change. The solid turns yellow on heating and then reverts to white on cooling.
General use of zinc sulfate(VI) solution	Y7	Wear eye protection.	0.4 mol dm ⁻³ solutions are suitable for most purposes, such as displacement reactions, precipitation and electrolysis.
Preparing zinc sulfate(VI) crystals	Y7	Wear eye protection. The room should be well ventilated.	<p>The main problems encountered are the white fume of sulfur trioxide (CORROSIVE) and sulfur dioxide gas (TOXIC) produced, either by heating unreacted sulfuric(VI) acid too strongly or heating anhydrous zinc sulfate(VI).</p> <p>Excess zinc is added to 1.4 mol dm⁻³ sulfuric(VI) acid (IRRITANT) which must be heated. To avoid spitting, this can be done in a boiling tube placed in a boiling-water bath. Keep the volume of acid to no more than 15 cm³. The reaction is not quick, even in hot water. The use of zinc powder and/or 1 cm³ of 1 mol dm⁻³ copper(II) sulfate(VI) solution increases the rate of reaction.</p> <p>If the pH of the solution is checked before filtering, it must be greater than 4.</p> <p>After filtering, zinc sulfate(VI) solutions must never be heated to dryness. See <i>Handbook</i> 13.4.</p>
Making 'glass'	Y7	Wear eye protection. Take care to avoid raising dust of lead(II) oxide.	<p>A recipe for glass is 6.5 g lead(II) oxide, 3.5 g boric acid and 0.5 g zinc oxide. Tiny grains of transition element oxides [except nickel(II) oxide] can be added to provide colour. Allow time for the crucible to cool. The apparatus used to make this glass should be immersed in 1 mol dm⁻³ nitric(V) acid for cleaning.</p> <p>Disposal: W2 or Wspec. Dissolve the glass in 1 mol dm⁻³ nitric(V) acid and dilute to 1 litre before pouring down a foul-water drain.</p>