CHEMISTRY GLOSSARY

1. Acid: A substance that produces hydrogen ions (H+) as the only positive ions when dissolved in water.

2. Activation energy: The minimum energy that molecules must possess during their collisions in order for a chemical reaction to occur.

3. Addition reaction: A reaction in which a molecule (element or compound) adds to an unsaturated compound to form a single new compound.

4. Alcohol: An organic compound containing the hydroxyl group, -OH.

5. Alkali: A base that is soluble in water.

6. Alkali metals: The elements in Group 1 of the Periodic Table.

7. Alkane: Hydrocarbon having the general formula CnH2n+2

8. Alkene: Hydrocarbon that contains one or more carbon-carbon double bonds. Alkenes with only one carbon-carbon double bond have the general formula CnH2n.

9. Alloy: A mixture of a metal with non-metals or other metals.

10. Anhydrous: Anhydrous salts are salts without water of crystallization.

11. Anion: A negatively charged ion which moves towards the anode during electrolysis.

12. Anode: A positively charged electrode in an electrolytic cell.

13. Aqueous: Describing the solution of a substance in water, i.e. the aqueous solution. In chemical equations, aqueous solutions are represented by the symbol (aq).

14. Atom: The smallest particle of an element.

15. Avogadro's constant: The number of particles in one mole of a substance. Its value is 6 x 1023.

16. Avogadro's law: At constant temperature, the volume of a gas is directly proportional to the number of moles of the gas present.

17. Base: A substance that reacts with an acid to form a salt and water only.

18. Boiling point: The temperature at which a liquid turns rapidly to its vapour.

19. Carboxylic acid: An organic acid containing the carboxyl group, -COOH.

20. Cathode: A negatively charged electrode in an electrolytic cell.

21. Cation: A positively charged ion which moves towards the cathode during electrolysis.

22. Chromatography: A method of separating the components in a mixture.

23. Collision theory: A chemical reaction can occur only if the reacting particles collide with one another.

24. Combustion: The chemical name for burning. Burning occurs when a substance reacts very rapidly with oxygen.

25. Compound: A substance formed in a chemical change when two or more elements are joined together.

26. Condensation: The process by which a vapour or a gas turns to liquid on cooling.

27. Corrosion: The wearing away of the surface of a metal by chemical reaction.

28. Covalent bond: The type of bond formed when electrons are shared between two non-metal atoms.

29. Cracking: The breaking down of long chain hydrocarbon molecules with heat and/or catalyst to produce smaller hydrocarbon molecules and/or hydrogen.

30. Decomposition: A chemical reaction that results in the breaking down of a compound into two or more components.

31. Diatomic molecule: A molecule that consists of two atoms.

32. Displacement reaction: A reaction in which an atom or molecule takes the place of another atom or molecule in a compound.

33. Distillation: A process of obtaining the pure solvent from a solution. When the solution is boiled, the solvent is vaporized and the vapour condenses to reform the pure liquid.

34. Electrode: A rod or a plate which carries electricity in or out of an electrolyte during electrolysis.

35. Electrolysis: A process in which electrical energy is used to cause a chemical reaction to occur, typically to separate the electrolyte into its elements.

36. Electron: A negatively charged sub-atomic particle that surrounds the nucleus of an atom.

37. Electronic configuration: The arrangement of electrons in the various shells of an atom or a molecule.

38. Element: A substance made from only one type of atom. It cannot be separated into simpler substances by chemical processes or by electricity.

39. Endothermic reaction: A reaction which absorbs heat from the surroundings.

40. Evaporation: The process by which a liquid changed to its vapour on the surface of the liquid.

41. Exothermic reaction: A process that gives off heat to the surroundings.

42. Fermentation: The conversion of glucose by microorganisms such as yeast into ethanol and carbon dioxide.

43. Filtrate: The clear liquid which passes through the filter during filtration.

44. Filtration: The process of separating a solid from a liquid or a solution.

45. Fossil fuels: Fuels produced many millions of years ago from the decaying remains of animals or plants, includes oil, natural gas and coal.

46. Fractional distillation: A process that separates the components in a mixture on the bases of their different boiling points. The component with the lowest boiling point boils off first and is distilled over.

47. Freezing point: The temperature at which a liquid changes to a solid.

48. Fuel: A substance that burns easily to produce energy.

49. Functional group: An atom or group of atoms that gives characteristic properties to an organic compound.

50. Giant structure: A three-dimensional network of atoms or ions packed together in a regular pattern.

51. Group: A vertical column of elements in the Periodic Table.

52. Halogen: The non-metallic elements in Group VII (7) of the Periodic Table.

53. Homologous series: A family of organic compounds with members of the family having the same functional group and similar chemical properties.

54. Hydrated salts: Salts that contain water of crystallization.

55. Hydrocarbons: Organic compounds made up from the elements hydrogen and carbon only.

56. Hydrogenation: The addition of a hydrogen molecule across a double bond.

57. Immiscible: Two liquids that do not mix.

58. Indicators: Compounds that have distinctly different colours in acidic and alkaline solutions. 59. Ion: A positively or negatively charged particle. It is formed when an atom or group of atoms loses or gains electrons.

60. Ionic bond: The electrostatic force that holds positive and negative ions together in an ionic compound.

61. Isotopes: Atoms of the same element that have the same atomic number but different mass/nucleon number.

62. Melting point: The temperature at which a solid changes to a liquid.

63. Metal: An element that is shiny and conducts electricity in the solid state. Metals burn in oxygen to form basic oxides or amphoteric oxides.

64. Mixture: A substance made by mixing other substances together. The components in a mixture can be easily separated by physical methods because they are not chemically joined together like in compounds.

65. Mole: The amount of a substance which contains 6 x 1023 particles.

66. Molecule: A group of atoms held together by covalent bonds. Molecules may be elements or compounds.

67. Nucleon number: Also known as the mass number. It is the sum of the number of protons and neutrons in the nucleus of an atom.

68. Neutralization: The reaction between an acid and a base to produce a salt and water only.

69. Neutron: A sub-atomic particle in the nucleus of an atom. It has a mass but no electrical charge.

70. Organic chemistry: The branch of chemistry that deals with carbon compounds.

71. Oxidation: A reaction where a substance gains oxygen or loses hydrogen. Oxidation is also defined as the loss of electron(s) or the increase in the oxidation state of the element.

72. Oxides: Compounds of an element with oxygen.

73. Oxidizing agent: A substance that brings about oxidation. It is itself reduced. An oxidizing agent is an acceptor of electrons.

74. Period: A horizontal row of elements in the Periodic Table.

75. Periodic table: A table that contains horizontal rows and vertical columns of elements. The elements are arranged in order of their atomic numbers and in accordance with their chemical properties.

76. pH scale: A scale that measures the acidity or alkalinity of a solution.

77. Pollution: The presence in the environment of toxic substances which are harmful to living things.

78. Polymer: A very large molecule built up of a number of repeating units called monomers.

79. Polymerization: A chemical reaction in which simple molecules, called monomers, react with each other to form larger molecules called polymers.

80. Polyunsaturated: Vegetable oils that contain many carbon-carbon double bonds in their molecules.

81. Precipitate: An insoluble solid that is produced in a solution as a result of a chemical reaction.

82. Protein: A polymer of amino acids.

83. Protons: Positively charged sub-atomic particles found in the nucleus of an atom.

84. Proton number: The number of protons in the nucleus of an atom.

85. Pure substance: A single substance which is not mixed with other substances. It has definite melting and boiling points. (e.g. pure water boils at exactly 100°C and freezes at 0°C)

86. Reactivity series: A list of elements in order of their reactivity. The more reactive the element, the higher its position in the series. An element higher up the series will displace a less reactive one from a solution of its salt.

87. Redox reaction: A reaction where both oxidation and reduction take place simultaneously.

88. Reducing agent: A substance that brings about reduction. It is itself oxidized. A reducing agent is a donor of electrons.

89. Reduction: The removal of oxygen, the addition of hydrogen, the gain of electrons, or the decrease in the oxidation state of the substance.

90. Relative atomic mass: The number of times the mass of one atom of an element is heavier than 1/12 of the mass of a carbon-12 atom.

91. Relative molecular mass: The sum of the relative atomic masses of each of the atoms in one molecule of a substance.

92. Residue: The solid which remains on the filter paper after filtration.

93. Respiration: The slow combustion of food in the cells of living organisms to release energy.

94. Rusting: The slow oxidation of iron in the presence of air and water to form hydrated iron (III) oxide (rust).

95. Salt: The ionic compound formed by the replacement of one or more hydrogen ions of an acid by a metallic ion or an ammonium ion.

96. Saturated hydrocarbons: Hydrocarbons that contain only single bonds between carbon atoms.

97. Solute: The substance that dissolves in a solvent to form a solution.

98. Solvent: The liquid in which a solute dissolves.

99. Steel: An alloy of iron and carbon.

100. Structural formula: A formula which shows how the atoms are arranged in a molecule.

101. Sublimation: The process of changing from the solid state directly to the gaseous state without passing through the liquid state.

102. Suspension: A mixture of a liquid and an insoluble solid where the insoluble solid remains suspended throughout the solution.

103. Titration: The gradual addition of a solution from a burette to another solution in a conical flask until the chemical reaction between the two solutions is complete; the 2 solutions tend to be an acid and an alkali.

104. Unsaturated molecule: Any hydrocarbon that contains one or more carbon-carbon double bonds.

105. Valence electrons: Electrons in the outer shell that are used by the atom for forming chemical bonds.

106. Water of crystallization: Water molecules that are chemically bonded in the crystals of some salts.

AN UNDERSTANDING OF KEY CONCEPTS

MYP Chemistry requires you to understand 3 key concepts

System

Relationship

Change

Systems

Systems are sets of interacting or interdependent components. Systems provide structure and order in human, natural and built environments. Systems can be static or dynamic, simple or complex.

Systems in sciences describe sets of components that function due to their interdependence or complementary nature. Common systems in science are closed systems, where resources are not removed or replaced, and open systems, where necessary resources are renewed regularly. Modelling often uses closed systems to simplify or limit variables.

Other key concepts can also be important in sciences. For example, development is an important aspect in the continual growth through change that epitomizes scientific knowledge. Science offers important perspectives on the definition, measurement and meaning of time, place and space. Creativity is always important for scientists working together to extend the limits of human understanding.

Relationships

Relationships are the connections and associations between properties, objects, people and ideas—including the human community's connections with the world in which we live. Any change in relationship brings consequences—some of which may occur on a small scale, while others may be far reaching, affecting large networks and systems such as human societies and the planetary ecosystem.

Relationships in sciences indicate the connections found among variables through observation or experimentation. These relationships also can be tested through experimentation. Scientists often search for the connections between form and function. Modelling is also used to represent relationships where factors such as scale, volume of data, or time make other methods impractical.

Change

Change is a conversion, transformation or movement from one form, state or value to another. Inquiry into the concept of change involves understanding and evaluating causes, processes and consequences.

In sciences, change is viewed as the difference in a system's state when observed at different times. This change could be qualitative (such as differences in structure, behaviour, or level) or quantitative (such as a numerical variable or a rate). Change can be irreversible, reversible or self-perpetuating.

List of Content under each concept

- Periodic table (metals and non-metals; transition metals, noble gases, trends, periods, groups)
- International Union of Pure and Applied Chemistry (IUPAC naming and classification of: alkanes, alkenes, alcohols, carboxylic acids and esters; structural formulas)
- The atmosphere (characteristics of gases; atmospheric composition, testing and treatment; extraction, emission and environmental implications)
- Matter (states and properties of matter; particle/kinetic theory, diffusion; atomic structure [including isotopes]; electron configuration and valency)
- Pure and impure substances (types of mixtures [solutions, oils, alloys, emulsions]; separation techniques, including: filtration, distillation [including crude oil], chromatography)
- Bonding (structure and bonding, properties, chemical formulas, chemical reactions and the conservation of mass; balancing equations, the mole concept and chemical calculations; reaction kinetics [rates, and factors affecting rates/collision theory]; equilibria/reversible reactions; energy changes in reactions, endo- and exothermicity; combustion of fuels)
- Types of chemical reaction (acids and bases, neutral solutions, acid/base reactions, pH and indicators, formation of salts, uses of salts; redox reactions, reactivity series; extraction of metals, and corrosion, electrochemical cells)

Topic 1: Periodic Table

Concept: Relationship

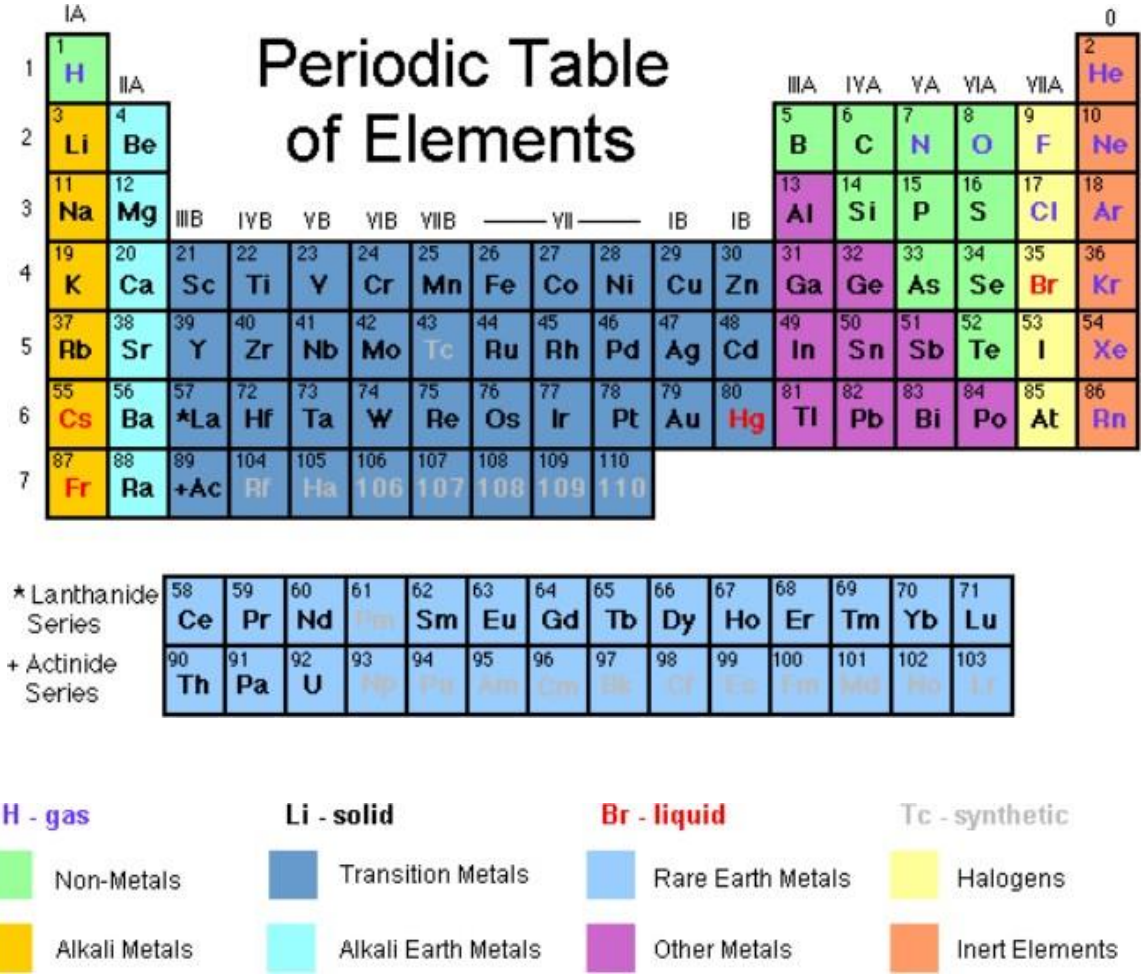
Related Concept: Patterns, Evidence

The scientific method is a collection of approaches to experimentation, designed to increase our knowledge and understanding of scientific concepts, and enable us to test the validity of our conclusions. Observations, both qualitative and quantitative, can prompt a question or identify a problem.

Evidence is of fundamental importance to scientists. Experiments performed in a controlled environment within laboratories enables the scientific community to collect evidence and determine if patterns exist. A **pattern** is a distribution of variables in time and space. This distribution of variables is sometimes identifiable as a unique pattern. Scientists look for patterns to help them make predictions.

An important feature in chemistry is the search for trends, anomalies and discrepancies in the behavior of elements which can be used to classify them into groups in similar characteristics. We classify elements as metals and non-metals based on what we observe from the way in which they react with other elements and compounds. Identifying these patterns in the properties of elements enables us to make predictions about their behavior when they are present in the new reactions and compounds.

Whether you are considering qualitative or quantitative evidence, you are trying to identify **relationships** between variables. Understanding the relationship between these variables, for example, between the properties of elements and the arrangement of electrons in the atom is crucial in making sense of theses anomalies. For these reasons, this topic will explore the concept of relationship.



Practice Questions

Criterion A

1. An element, M, has the electron distribution 2+8+18+3.
   - I. Which group in the Periodic Table is element M likely to be in?
   - II. Predict whether element M is a poor or a good conductor of electricity. Justify your choice.
2. The halogens are a collection of diatomic non-metals in Group VII.
   - I. State the meaning of the term diatomic.
   - II. What do the electron distributions of the halogens have in common?
   - III. How do their electron distributions differ?
   - IV. Complete the table.

halogen	solid, liquid or gas at room temperature	colour
chlorine	.....	.....
bromine	.....	.....
iodine	.....	.....

3. Three of the halogens in Group VII are listed below.
   Chlorine
   Bromine
   Iodine
   I. How does their color change down the group?
   II. How do their melting and boiling points change down the Group?
   III. Predict the color and physical state of astatine, At.
4. The reactivity of group I elements increases down the group. Explain why?
5. Which holds its outer electron more strongly: a lithium atom, or a sodium atom? Explain why do you think so.
6. Describe the trend in reactivity in Group VII elements. Is this trend the same as for Group I?
7. Describe how the number of valence electrons changes with group number, across the periodic table.
8. Describe the change in character from metal to non-metal, across Period 3.
9. Electron affinity is the energy released when an electron is added to a neutral atom. Explain the variation of electron affinity across the period and down the group. Give reasons for the same.
10. Imagine that a new element called MYPium had been isolated. It has low density, and is a solid which is soft and easily cut with a knife. It is extremely reactive with both air and water. It is a good conductor of heat and electricity, and has a low melting point. Interpret this information to judge:
    I. In which group in the periodic table you would place MYPium
    II. How would you store it
    III. The method that was probably used to purify MYPium to its metal state.
11. Outline the trends in the chemistry of the patterns in the medium long periodic table.
    I. Across each period
    II. Down the groups of metals
    III. Down the groups of non-metals
12. Explain how the delocalized electrons in metals contribute to the following physical properties:
a. Lustre
b. Conductivity of heat
c. Conductivity of electricity
d. Maleability

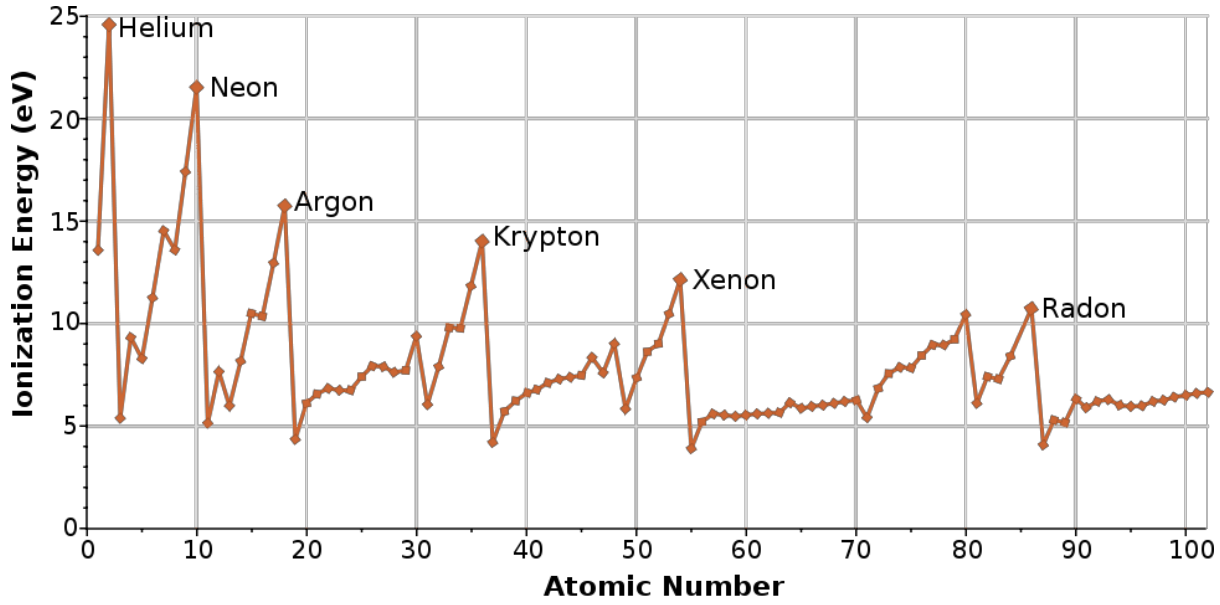
Criterion B

Thermal conductivity is the rate of movement of heat through a material. By observing patterns in the way materials conduct heat, chemists have been able to classify specific groups of elements and compounds as high, medium and low thermal conductivity materials. Design an investigation to test the thermal conductivity of a series of metals. Please include the following in your investigation:

i. explain a problem or question to be tested by a scientific investigation
ii. Formulate and explain a testable hypothesis using correct scientific reasoning
iii. Explain how to manipulate the variables, and explain how sufficient, relevant data will be collected
iv. Design a logical, complete and safe method selecting appropriate materials and equipment.

Criterion C

1. The following graph represents the relationship between the ionization energy and atomic number for nobel gases. Accurately interpret the data and explain results using scientific reasoning.



Criterion D

Imagine your school is hosting an exhibition, 'The past and future of the periodic table'.

Your task is to create an exhibit of an alternative representation of the periodic table. It can be linear, two-dimentional or three dimentional. To be more than a periodic table, you should include a written description with your model that explains the following:

- How the scientific discovery of elements was the impetus for their purification and refinement. You should highlight one particular group or chemical element as an example.

- How understanding of the periodicity and grouping is useful , and explain the interaction of the group or chemical element you have highlighted with a moral,ethical, social,economic,political, cultural or environmental factor as a result of its use.

Topic 2: International union of pure and applied Chemistry

Key concept: System

Related concept: Function

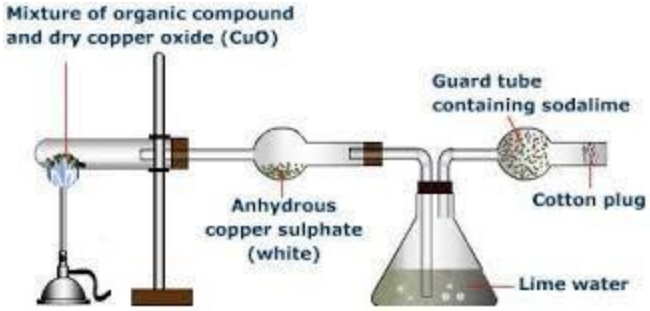
When they are performing research, scientists speak of chemical **systems**. What is a chemical system? When we want to define a chemical system, we need to examine the conditions of the physical and chemical environment inside and outside of the system. When we understand the characteristics of each type of system it enables us to use the system in more efficient ways. Industrial processes may take place in open, closed and isolated systems. Chemists and chemical engineers working within industry are constantly refining industrial processes to use finite sources like fossil fuels more efficiently. Industrial processes that produce fewer by-products and have reduced consequences for the environment are increasingly recognized as the way of future.

Fossil fuels are hydrocarbons (compounds made of carbon and hydrogen), primarily coal, and fuel oil or natural gas, formed from the remains of dead plants and animals. The utilization of fossil fuels has enabled large-scale industrial development and largely supplanted water-driven mills, as well as the combustion of wood or peat for heat. The burning of fossil fuels by humans is the largest source of emissions of carbon dioxide, which is one of the greenhouse gases that allows radiative forcing and contributes to global warming. A small portion of hydrocarbon-based fuels are biofuels derived from atmospheric carbon dioxide, and thus do not increase the net amount of carbon dioxide in the atmosphere.
Fossil fuels have revolutionized the field of organic chemistry and synthetic chemistry. Now we use fossil fuels and compounds derived from it in different forms and having different **functions.**

Practice Questions

Criterion A

1. The presence of carbon and hydrogen in many organic compounds can be demonstrated using the apparatus below.



I. Define: limestone and marble using the modern definition of 'organic' or 'inorganic'.
II. Evaluate whether the description 'organically grown', applied to some foods and materials like cotton, is a scientific claim or is based on other criteria.

2. Explain why the boiling point of the alkane increases with the length of the carbon chain.
3. Deduce the formula of decane, an alkane containing ten carbon atoms, and predict the physical state of a sample of decane at standard temperature and pressure.
4. Alkenes and organic compounds with carbon-carbon triple bonds, called alkynes, are considered unsaturated.
   I. Outline the meaning of 'unsaturated' in this context.
   II. Predict the names of the first six compounds in the alkyne homologous series.
   III. Explain the reactivity of alkynes compared with alkanes, given the following information: alkynes are not necessarily more reactive than alkenes with the same number of carbon atoms, but alkenes are more reactive than unsaturated hydrocarbons with the same number of carbon atoms.
5. Suggest why, when making ethanol using an addition reaction, a high temperature (300^0C) and a high pressure (70atm) are used during hydration.
6. Antifreeze, used in the radiators of cars in cold climates, contains ethylene glycol, a kind of alcohol. Explain why this compound is preferred to methanol.
7. Explain why esters are immiscible in water, although alcohols and carboxylic acids (with short length of alkyl chains) tend to be water soluble.
8. Synthetic polymers are disposed of in landfill sites and by burning.
   I. Describe two problems caused by the disposal of synthetic polymers in landfill sites.
   II. Describe one problem caused by burning synthetic polymers.
   III. State two uses of synthetic polymers.
9. The alcohols form a homologous series.
   I. State three characteristics of a homologous series.
   II. The following two alcohols are members of homologous series and they are isomers.

$$CH_3 — CH_2 — CH_2 — CH_2 — OH \quad \text{and} \quad (CH_3)_2CH — CH_2 — OH$$

   i. Explain why they are isomers.
   ii. Deduce the structural formula of another alcohol which is also an isomer of these alcohols.

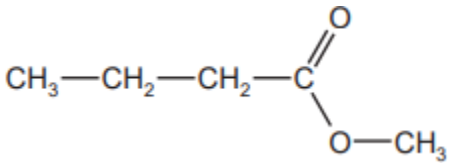
10. Alcohols can be made from petroleum by the following sequence of reactions.
    Alkanes from petroleum → alkene → alcohol

Describe the manufacture of ethanol from hexane. Include in your description an equation and type of reaction for each step.

11. Esters, polyesters and fats all contain ester linkage. Esters can be made from alcohols and carboxylic acids. For example, the ester ethyl ethanoate can be made by the following reaction.

$$CH_3COOH + CH_3CH_2OH \rightarrow CH_3COOCH_2CH_3 + H_2O$$

I. Name the carboxylic acid and the alcohol from which the following ester could be made.



II. The following two monomers can form a polyester.

Draw the structural formula of this polyester. Include two ester linkages.

III. Fats and vegetal oils are esters. The formula of two examples of natural esters are given below.

ester 1 ester 2

One ester is saturated, the other is unsaturated. Describe a test to distinguish between them.

State which one of the above esters is unsaturated. Give a reason for your choice.

Both esters are hydrolysed by boiling with aqueous sodium hydroxide. What types of compounds are formed?

12. A South Korean chemist has discovered a cure for smelly socks. Small particles of silver are attached to a polymer, polypropene, and this is woven into the socks.

I. Give the structural formula of the monomer.

II. Draw the structural formula of the polymer.

III. Suggest which one, monomer or polymer, will react with aqueous bromine and why?

13. Propanoic acid is a weak acid.

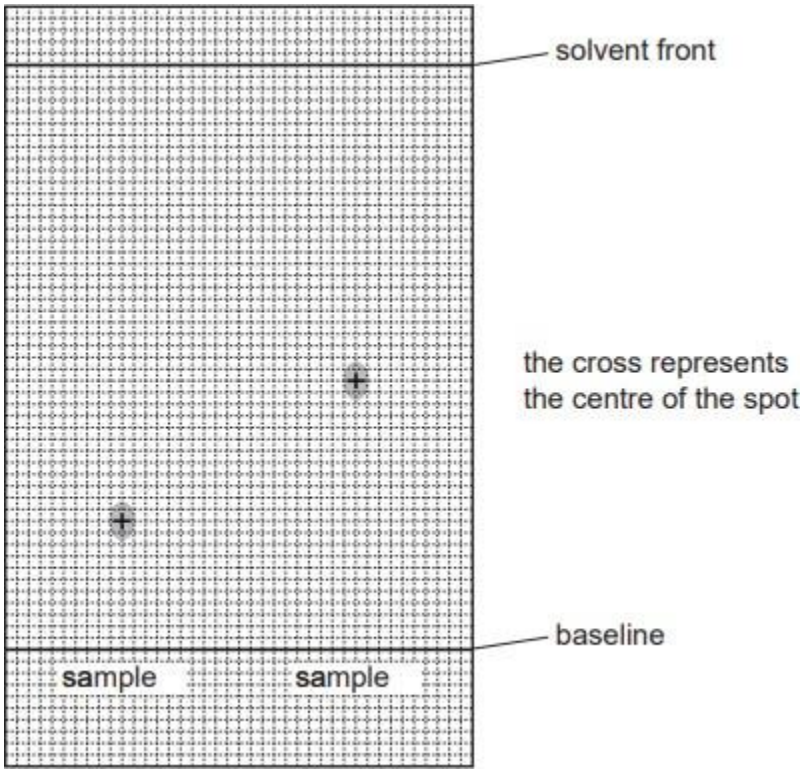
I. The following equation represents its reaction with ammonia.

$$CH_3-CH_2-COOH + NH_3 \longrightarrow CH_3-CH_2-COO^- + NH_4^+$$

Explain why propanoic acid behaves as an acid and ammonia as a base.

II. Explain the expression weak acid.

14. Esters can be used as solvents in chromatography. The following shows a chromatogram of plant acids.



An ester was used as the solvent and the chromatogram was sprayed with bromothymol blue.

I. Suggest why it was necessary to spray the chromatogram.

II. Explain what is meant by the Rf value of a sample.

III. Calculate the Rf values of the two samples and use the data in the table to identify the plant acids.

plant acid	R_f value
tartaric acid	0.22
citric acid	0.30
oxalic acid	0.36
malic acid	0.46
succinic acid	0.60

sample 1 R_f = ... It is ..... acid.

sample 2 R_f = ... It is ..... acid.

15. Write down the names of the following hydrocarbons:

(i) CH_4

(ii) $CH_3CH_2CH_3$

(iii) $CH_3CH_2CH_2CH_2CH_3$

(iv) $CH_3CH=CH_2$

(v) $CH_2=CH_2$

(vi) $CH_2=CHCH_2CH_3$

16. Draw fully displayed formulae (showing all the bonds) for:

(i) butane

(ii) ethane

(iii) but-2-ene

(iv) propane

(v) methanol

(vi) 2-methylpropane

(vii) 2-methylpropene

(viii) pent-1-ene

17. During the first few years of the 21st century, there was serious worry about the effect of increasing carbon dioxide levels on global temperatures. One of the results of this was a drive to increase the amount of biofuels in order to replace fuels based on oil or gas. By 2007 – 2008, it became obvious that increased use of biofuels was having undesirable effects, such as increasing the world prices of some foods, and, in some cases, even

producing more carbon dioxide than they saved. Explain why the production of biofuels led to this undesirable effects.

18. Cracking is a process that splits larger hydrocarbons into smaller ones.
    I. Give two reasons why an oil company might want to crack a hydrocarbon.
    II. State the conditions under which cracking is carried out.
    III. A molecule of the hydrocarbon $C_{11}H_{24}$ was cracked to give two molecules of ethene, and one other molecule. Write an equation for the reaction which took place.

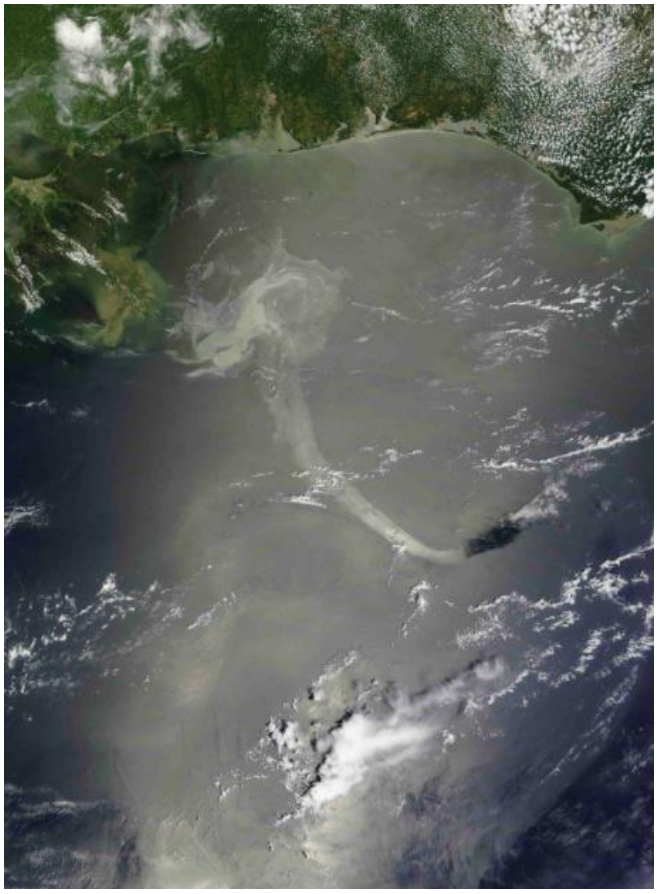
Criterion B

The solubility of alcohols changes with change in the carbon chain length. Design an investigation to check how the chain length and molecular weight impacts the solubility of alcohol in a polar solvent like water. Please include the following in your investigation:
i. explain a problem or question to be tested by a scientific investigation
ii. Formulate and explain a testable hypothesis using correct scientific reasoning
iii. Explain how to manipulate the variables, and explain how sufficient, relevant data will be collected
iv. Design a logical, complete and safe method selecting appropriate materials and equipment.

1. Organic chemistry is the study of the structure, properties, composition, reactions, and preparation of carbon-containing compounds. Most organic compounds contain carbon and hydrogen, but they may also include any number of other elements (e.g., nitrogen, oxygen, halogens, phosphorus, silicon, sulfur).

   Jane and Sally are two entrepreneurs in the field of chemistry. They along with their team hunts problems around the globe arising due to organic compounds and arrive at a comprehensive solution to this problem in association local authorities.

   - One of their recent project is mentioned below.



Crude oil coats the water's surface in the Gulf of Mexico after the Deepwater Horizon oil rig sank following an explosion. The leak was a mile below the surface, making it difficult to estimate the size of the spill. One liter of oil can create a slick 2.5 hectares (6.3 acres) in size. This and similar spills provide a reminder that hydrocarbons and water don't mix.

- Initial investigation has revealed that this consignment contained only hydrocarbons. As a part of a of Jane and Sally's team you task is to determine the composition of this oil spill. By designing a suitable investigation try and identify the probable hydrocarbons in the mixture, You are having access to all common lab apparatus (Except for industrial fractionating column)

Your investigation need to address the following points

- Explain the relevance of the problem to be tested by a scientific investigation(AL: 3-4)
- Formulate and explain a testable hypothesis using correct scientific reasoning (AL: 7-8)
- Explain how to manipulate the variables, and explain how sufficient, relevant data will be collected(AL: 5-6)
- Design a logical, complete and safe method in which he or she selects appropriate materials and equipment.(AL: 5-6)

Criterion C

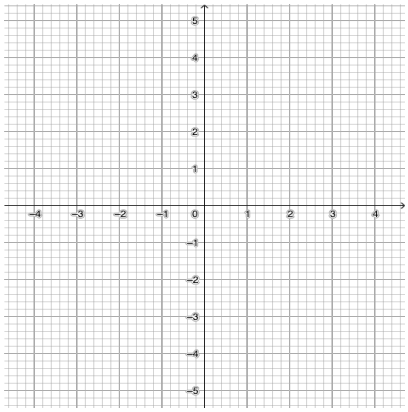
Crude oil is a complicated mixture of hydrocarbons, many of which are alkanes. This

mixture by itself is of no importance, but after a series of purification techniques and chemical processes it becomes very useful. Cracking is a reaction in which larger saturated hydrocarbon molecules are broken down into smaller, more useful hydrocarbon molecules, some of which are unsaturated (C=C).

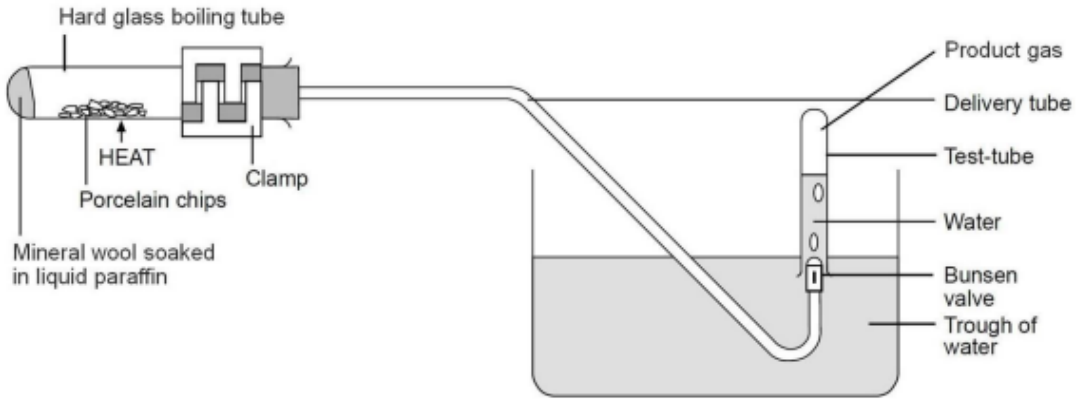
The boiling points of the some molecules obtained after cracking a large hydrocarbon are shown in the table below.

Number of carbon atoms in hydrocarbon	Boiling point in °C
1	–162
2	–89
3	–42
4	–0.5
5	36
6	69
x	–6.3

- Present the above data using a suitable graph and explain the trend in boiling points of the following molecules and using the graph identify the number of carbon atoms in the molecule x and name the molecule.(AL: 7-8)



- Catalytic cracking can be demonstrated using the following experimental setup.
  Using the diagram, discuss and explain certain evidences that prove that smaller molecules are made in the experiment?



1. While investigation the solubility of alcohol in polar solvent like water, the following data was collected.

Name	Formula	Solubility
Methanol	CH_3OH	miscible
Ethanol	C_2H_5OH	miscible
Propanol	C_3H_7OH	miscible
Butanol	C_4H_9OH	0.11
Pentanol	$C_5H_{11}OH$	0.030
Hexanol	$C_6H_{13}OH$	0.0058
Heptanol	$C_7H_{15}OH$	0.0008

i. correctly organize and present data in a graphical form.
ii. Accurately interpret data and explain results using scientific reasoning
iii. Discuss the validity of a hypothesis (created in Criterion B task) based on the outcome of a scientific investigation

iv. Discuss the validity of the method (created in Criterion B task) based on the outcome of a scientific investigation
v. describe improvements or extensions to the method that would benefit the scientific investigation.

Criterion D

All the elements in IUPAC group 14 share to some extent carbon's chemical bonding properties based on four valence electrons. Imagine a world not based on carbon. This idea has often been used in science fiction. Could you match the creativity of some of these efforts?
Your 700 – 1200 word story should include:

- A scientific explanation of the consequences of using a different element to form a system of molecules.
- A moral, ethical, social, economic, political, cultural or environmental factor, as found in all fine literature – including yours! For example, would recycling be possible with your alternative group 14 element or would, as a result of their chemistry, a logical response by your fictional characters provide moral or social insight into our own world?

There are several possible presentations for this assignment, including as a cartoon strip.
All sources should be fully documented.

Topic 3: The Atmosphere

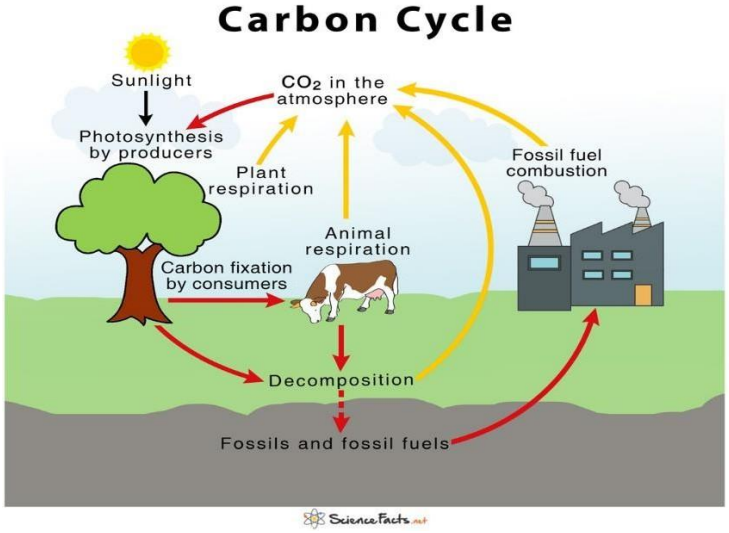
Key concept: System

Related concept: Interaction, Consequences

Science has long understood the concept of cause and effect, also known as causality. However, a **consequence** could be the result of several different factors acting together. Within the scientific community there is little debate about the occurrence of global warming or climate change, as there is a wealth of scientific evidence proving that these phenomena are occurring. Our **interactions** with the global environment are being questioned, especially given the mounting evidence of uncontrolled pollution, climate change and global warming. Moreover, the increasing interconnectedness of **systems** and communities is resulting in an increasingly integrated global economy with goods, money and people moving more freely around the world. Understanding what causes them and how to mitigate their effects on the future of our planet is a significant concern for the current and future generations. The impact of localized system is not simply the sum of its individual parts. Pollution that is created by the decisions of individual and local human-made systems has global consequences on an expanded scale.

Criterion A

1. The very first atmosphere of the Earth would have contained helium and hydrogen. Suggest why these gases are now only present in trace amounts in the air.
2. Estimate the likely time in which the following events occurred:
    i. The 'oxygen catastrophe' (also called the Great Oxygenation Event), during which the rising concentration of atmospheric oxygen poisoned early life forms, which were anaerobic
    ii. 'Snowball Earths', periods lasting many millions of years during which the Earth became covered in ice, including to the equator, which reflected solar radiation.
    iii. Explain how changes in percentage of carbon dioxide over millions of years may have triggered these events.
3. Describe how living organisms contributed to the changing composition of the atmosphere.
4. Suggest how carbon dioxide may be removed from the air before it is liquefied.
5. Interpret the below diagram to state:
    i. The effect of deforestation on the carbon cycle
    ii. How the carbon cycle could be balanced



6. The environment is sometimes divided into abiotic (non-living) and biotic (living) components.
    i. Identify inorganic substances other than nitrogen and phosphorous that are likely to have roles in both components of the environment.
    ii. Describe how plant growth connects nutrients such as phosphorous to the atmosphere.
7. Air is a raw material from which several useful substances can be separated. They are separated in the following process. Dry and 'carbon dioxide free' air is cooled under pressure. Most of the gases liquefy as the temperature falls below - 200^0C. The liquid mixture is separated by fractional distillation. The boiling points of the gases left in the air after removal of water vapor and carbon dioxide are given in the table below.

Gas	Boiling Point (^{0}C)
Argon	-186

Helium	-269
Krypton	-157
Neon	-246
Nitrogen	-196
Oxygen	-183
Xenon	-108

i. Interpret and state which three substances in the liquid mixture will be the first to change from liquid to gas as the temperature is slowly increased.
ii. Suggest why the air needs to be dried, and why carbon dioxide is removed before it is liquefied.
iii. Make a scientifically supported judgement about which of the gases will not have become liquid at - 200^0C.

8. Explain the difference between a 'pollutant' and a 'contaminant,
9. Chemists have confirmed that the depletion of the ozone layer is caused by a class of compounds called chlorofluorocarbons, CFCs. An example is dichlorodifluorometha ne, CF_2Cl_2. In the stratosphere, the dichlorodifluoromethane molecules absorb ultraviolet radiation and undergo dissociation and release reactive atoms. The bond energies between atoms in the molecule are given below.

Bond	Energy needed (kJ mol^{-1})
C - F	492
C - Cl	324
C - H	414

i. Describe the outer electron structure of a molecule of CF_2Cl_2 using a Lewis structure diagram.
ii. Suggest which bond between atoms in CF_2Cl_2 is most likely to be broken during the dissociation process and why.
iii. Predict and explain the relative environmental effects on a per molecule basis of the following three CFCs:
- Monochlorotrifluoromethane
- Dichlorordifluorormethane
- Trichloromonofluoromethane

iv. Bromomethane, CH_3Br, is used as a pesticide in agriculture to fumigate soils. However, hydrobromofluorocarbons, HBFCs, and bromocarbons are also implicated in ozone depletion. The energy required to break C – Br bond is 285 kJ mol^{-1}. Evaluate whether HBFCs are likely to be more or less reactive than CFCs.

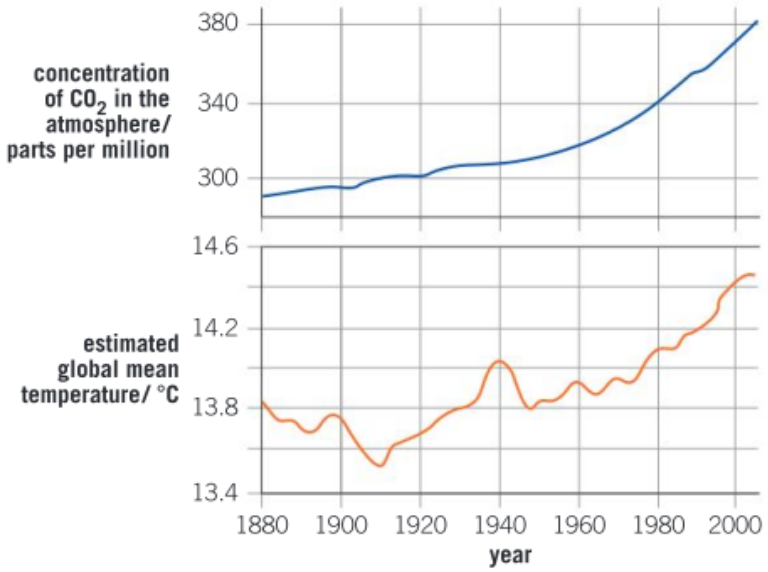
10. Mount Everest is over 8.8 km high. Climbers carry oxygen when attempting to reach its summit. Explain why.
11. A mixture of oxygen and acetylene burns with a much hotter flame than a mixture of air and acetylene. Why?
12. Nitrogen is used to keep food frozen during transportation. Which properties make it suitable for this?
13. You have some seawater, and cobalt (II) chloride paper.

i. How will you prove that the liquid contains water?
ii. How will you prove that it is not pure water?
iii. How might you obtain pure water from it?

14. It is not a good idea to rely on smell, to identify a gas. Suggest at least two reasons why.
15. Hydrogen cannot be collected by upward displacement of air. Why not?

- Average temperatures around the world are increasing—this is called global warming. Most scientists agree that the main cause of this is the increase in the levels of greenhouse gases, in particular, carbon dioxide and, to a lesser extent, methane.
Carbon dioxide and global mean temperatures

Image 1



- What evidence do we have that the combustion of fossil fuels is having a negative impact, causing global warming and climate change?

L 5-6

- In 2015, the global benchmark value of 400 parts per million for the concentration of carbon dioxide in the atmosphere was exceeded for the first time in recorded history. Can our efforts as individuals to minimize our contributions of carbon dioxide emissions make a difference on a global scale?

L 7-8

Criterion B

What are the consequences of water's ability to accrete soluble pollutants as a result of the water cycle? How could these dilute solutions affect living or built environments over time?

Design an investigation on how pollutants in water may interact with living plants or minerals. A risk analysis and environmental impact must be included in your plan.

Criterion C

1. In 1953, the American chemist Stanley Lloyd Miler conducted a famous experiment of the early atmosphere. Refer to the following video to understand the experiment.

https://www.youtube.com/watch?v=NNijmxsKGbc

i. Evaluate whether the Miller-Urey experiment proves life originated on Earth.
ii. Interpret the outline of the method and judge whether you expect Miller-Urey's results to be replicable

2. The table below shows the approximate composition of the Earth's atmosphere every 500 million years from when the Earth was formed $4.5 * 10^9$ years ago.

Millions of years ago	**Approximate percentage of CO_2**	**Approximate percentage of O_2**	**Approximate percentage ofgas X**
4500	92	0	10
4000	42	0	30
3500	22	1	40
3000	18	1.5	56
2500	12	5	62
2000	9	12	72
1500	7	15	75
1000	3	18	78
500	1	30	69
0	0.05	21	78

i. Present the information given in the table in a graphical format to show how the approximate percentages of the three gases have changed over time.
ii. Identify gas X, explaining your reasoning.
iii. Identify the phenomenon that led to the introduction of oxygen gas in the Earth's atmosphere.

Criterion D

Humans have conquered most of Earth except the deepest oceans. We are good at changing our environment to suit our needs. The population of earth is rapidly increasing and consuming more resources than the Earth can provide. Already, potable water supplies have been reduced in some parts of the world because of climate change.

Although Mars is a much smaller planet, its land area is similar to that found on Earth, because our nearest planet does not have oceans. The recent discovery of seasonal flows of liquid water hints at the exciting suggestion that the planet could be made suitable for human habitation.

Evaluate the feasibility of moving to Mars and setting up life there. Your 800-1200 word report should:

- Explain the problem or issue your project solves.
- Evaluate how such a project would interact with a moral, ethical, social, environmental, economic, political or cultural factor.
- Demonstrate appropriate communication skills for a scientific audience, for example, terminology and details of chemical reactions involved, and documentation of primary and secondary sources of information.

Topic 4: Matter

Key concept: Change

Related concept: Form

The theories and laws of chemistry are fundamentally important in supporting the development and progress of fields as varied as physics, biology, astronomy, medicine, engineering, geology, microbiology, pharmacology, oceanography and climatology. All these areas of knowledge have important and inseparable relationships with the laws of chemistry. For this reason, chemistry is often referred to as the central science.

The concept of **form** includes the features of an object that can be observed, identified, described, classified and categorized. The nature of science informs us that experimental evidence can be collected using our senses. We make observations of the form, or features, of matter and the interactions matter undergoes during chemical reactions. The **interaction** between matters during a chemical reaction can help us understand the changes in the form of matter or vice versa. Evidence collected by observation is used to develop theories about the nature of matter. Our ability to define and understand the form of matter helps us advance our understanding of the universe.

Practice Questions

Criterion A

1. Compare these values of enthalpies of fusion and vaporization. Explain why the enthalpy of vaporization for a substance is greater than its enthalpy of fusion.

	Enthalpy of fusion (J g^{-1})	Enthalpy of vaporization (J g^{-1})
Water	+334	+2260
Carbon dioxide	+184	+574
Lead	+23	+871

2. Steam burns are regarded as being far more harmful than a burn from boiling water. What change of state is occurring when steam reaches your skin? Why are the burns severe?
3. At -78.5°C solid carbon dioxide (dry ice) sublimates. However, the white vapour you see is not carbon dioxide – it is a mist of water droplets condensed from the air. Explain the changes in the state that occurs.
4. State the names, symbols and charges of three cations and three anions that are isoelectronic with the noble gas neon.
5. Explain why a globally consistent approach to describing matter is important.
6. There is a fourth state of matter called plasma, found in extremely hot environments like the Sun. Suggest why Dalton did not include this form in the atomic theory.
7. Apply your knowledge about the attraction and kinetic energy of particles in a solid, liquid or gas to suggest the form of matter these groups of people could be modelling:
    - Students sitting at desks in the hall taking an external exam
    - A crowd leaving a movie theatre through a single door
    - All the students pushing up against the window of the canteen
    - Recess, small children rushing around the play area
    - Drama class, everyone walking randomly around, keeping a similar distance apart
8. Example, using examples about the nature of matte, the limitations of developing scientific knowledge by argument and discussion alone.
9. The change of state from liquid to a gas can be either evaporation or boiling. Explain the difference between evaporation and boiling.
10. Some liquids are stored in sealed bottles for a very long time-decades or more. Explain why they don't evaporate.

11. Use the data given for the substances listed below to decide which of them will be solids, liquids or gases at a room temperature of 25°C and atmospheric pressure.

Substance	Melting point/°C	Boiling point/°C
sodium	98	883
radon	−71	−62
ethanol	−117	78
cobalt	1492	2900
nitrogen	−210	−196
propane	−188	−42
ethanoic acid	16	118

i. Which substance is a liquid over the smallest range of temperature?
ii. Which two substances are gaseous at -50°C?
iii. Which substances has the lowest freezing point?
iv. Which substance is liquid at 2500 °C?
v. A sample of ethanoic acid was found to boil at 121 °C at atmospheric pressure. Use the information in the table to comment on this result.

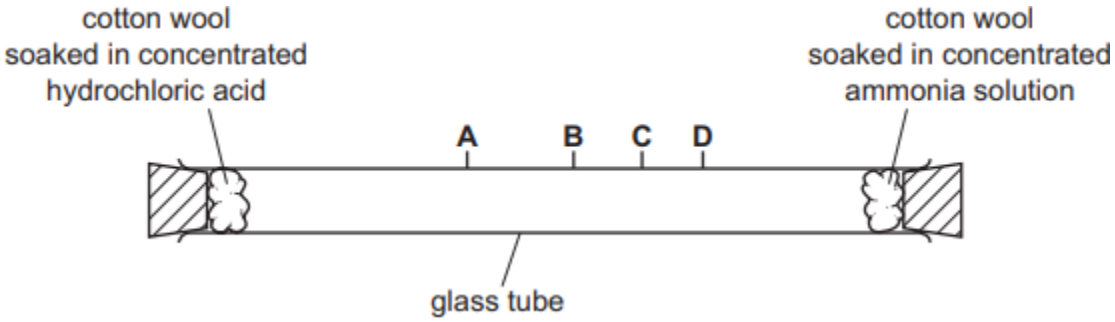
12. In 1986, an explosion at Chernobyl in the Ukraine released a radioactive cloud containing various radioactive isotopes. Three such isotopes are shown in the table. Use your periodic table to answer the following questions.

Element	Nucleon (mass) number
strontium	90
iodine	131
caesium	137

i. How many electrons are there in one atom of strontium-90?
ii. How many protons are there in one atom of iodine-131?
iii. How many neutrons are there in an atom of caesium-137?
iv. The prevailing winds carried fall-out from Chernobyl towards Scandinavia. In Sweden, caesium-137 built up in lichen which is the food eaten by reindeer. This gave rise to radioactive meat. If radioactive caesium was reacted with chlorine, would you expect the caesium chloride produced to be radioactive? Explain your answer.
v. State a beneficial use in industry of a radioactive isotope.

vi. State a medical use of a radioactive isotope.

13. Suggest how the number of neutrons in a nucleus makes a difference to the 'kinetic properties' of molecules with these atoms. Suggest how molecules with different isotopes of elements may 'fractionate' or separate into different mixtures.
14. Kinetic theory explains the properties of matter in terms of the arrangement and movement of particles. Nitrogen is a gas at room temperature. Nitrogen molecules are spread far apart and move in a random manner at high speed.
    i. Draw the electronic structure of a nitrogen molecule.
    ii. Compare the movement and arrangement of the molecules in solid nitrogen to those in nitrogen gas.
    iii. A sealed container contains nitrogen gas. The pressure of the gas is due to the molecules of the gas hitting the walls of the container. Use the kinetic theory to explain why the pressure inside the container increases when the temperature is increased.
15. Concentrated ammonia solution gives off ammonia gas. Concentrated hydrochloric acid gives off hydrogen chloride gas. NH_3 and HCl are both colourless gases. Ammonia reacts with HCl to make white solid ammonium chloride.
    Apparatus is set up as shown.



After ten minutes a white solid forms in the tube where the gases meet.

    i. Outline the chemical equation for the reaction of ammonia with hydrogen chloride.
    ii. State the process by which the ammonia and hydrogen chloride gases move in the tube.
    iii. At which point, A, B, C or D, does the white solid form? Explain why the white solid forms at the point.
    iv. The experiment was repeated at a higher temperature. Predict how the results of the experiment would be different. Explain your answer.

Criterion B

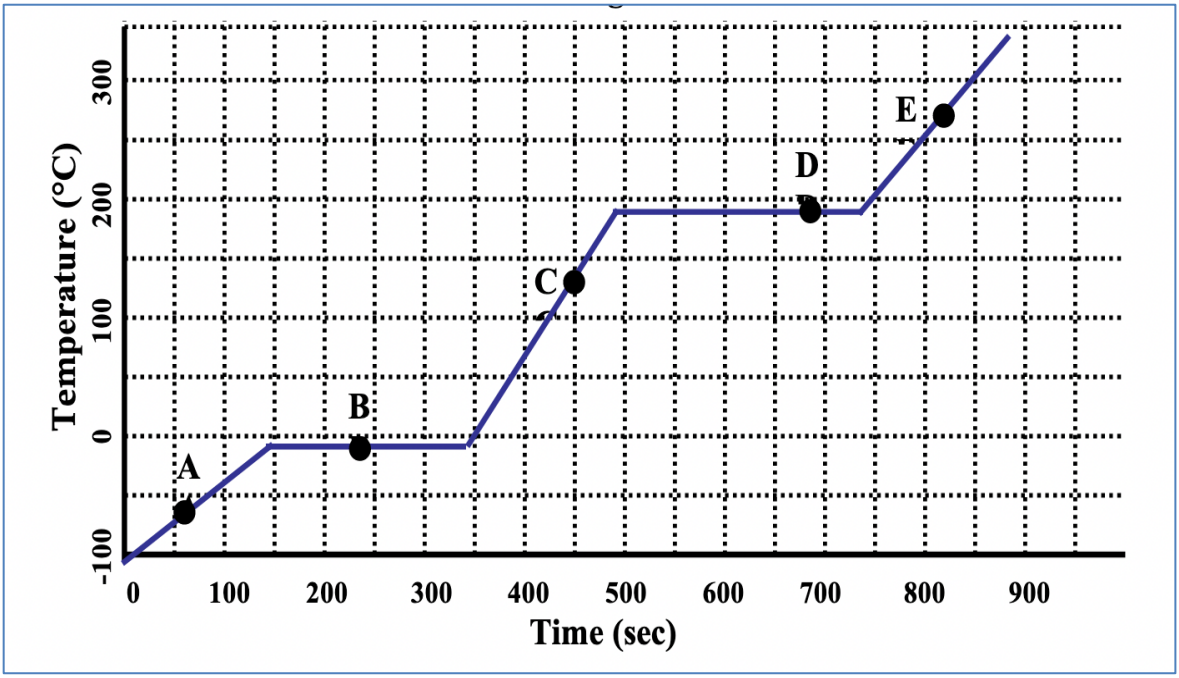
The effect of adding a Mentos (a brand of peppermint sweet) or an alternative such as powdered sugar to a carbonated drink is a physical change. The rough surface of the added substance provides 'nucleation' sites where the dissolved carbon dioxide gas begins to accumulate and quickly forms bubbles of gas. Both soft drinks and sweets come in many forms, for example, 'diet' versions of soft drinks usually contain phenylalanine or potassium benzoate, as well as other additives such as caffeine and flavourings. Sweets come in a range of textures. Finally, the effects of adding other substances or environmental conditions might be considered. The range of possible variables provides ample scope for you to design an open- ended experimental investigation and evaluate your result.

Design an investigation to see how gas formed in a reaction can be used to make an exciting display for younger chemists.

Criterion C:

1. An unknown substance X was heated slowly from -100˚C to 300˚C, and its temperature was recorded every minute. The data obtained is represented by the heating curve given below.

Interpret the graph given below and determine whether or not substance X is pure. Justify your answer using data from the graph. Also identify the melting and boiling points of substance X.
[C:C, ii, L:7-8]



Heating Curve of substance X

Criterion C

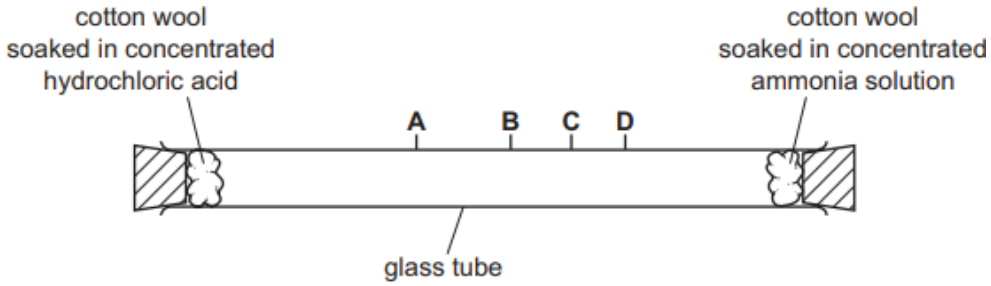
A student investigated used the following method to investigate what happens when two gas molecules collide.

Materials and equipment:

- Eye protection
- Concentrated ammonia solution
- Concentrated hydrochloric acid solution
- Cotton wool
- Large bore (2-3 cm diameter) glass tube
- Corks or bungs to fit the glass tube
- Retrot stand and clamps
- Timer

Method:

- Put on eye protection
- Add a few drops of each solution to plugs of cotton wool
- Secure the plugs inside each end of the glass tubing with corks or bungs. Immediately, start timing until evidence of a chemical reaction is observed.
- Clamp the tubing in a horizontal position
- Measure the distance between the reaction product, and the cotton wool at the ends of the tube



Use the above set up and answer the following questions:

i. List evidence that the two gases reacted.
ii. Suggest why the tube was placed horizontally and not vertically.
iii. Formulate a balanced equation for the reaction between ammonia and hydrochloric acid.
iv. Analyse how the location of the product can be used to calculate the rate of diffusion of each gas, using the formula, distance/time (ms^{-1}).
v. The formula for calculating the kinetic energy (KE) is ½ mv^2, where m is mass and v is velocity. Suggest one reason the molecules in different vapours might diffuse at different velocities at the same temperature.
vi. Suggest why this experiment should be carried out in a fume hood. Where do the extracted gases go?

Criterion D

Explaining science to the public is always more effective when you 'start with a story'. There are stories about the application of stable isotopes in anthropological, forensic and environmental contexts, or use of unstable isotopes in geological dating and medicine. Science journalism often uses a short case study to make the science relevant.

Reflect on the uses of isotopes, stable or unstable in any field. You can choose any isotope of your choice and in any field.

- Explain the problem or issue the product solves using a case study. It is recommended, but not essential, that you use a fairly recent example. Your story should have generality. Therefore, you need to explain the science involving the isotopes.

- Science does not work in isolation. To discuss moral, ethical, social, economic, political, cultural or environmental considerations in your case study, consider creating empathy. Mystery or true crime stories are popular approaches.

- Naturally, your use of scientific terminology should be appropriate and correct.

- Consider including quotations. Direct speech captures the protagonists' emotions and adds immediacy. However, recognize that inventing dialogue will shift your case study from a documentary focus into the creative territory of the playwright. How should you navigate this territory with integrity?

Criterion D:

We express ourselves through various methods, including the cosmetics we use. Johnson & Johnson is a popular company which manufactures iconic baby talcum powder. In October 2019, US health regulators announced that Johnson & Johnson baby powder has possible asbestos contamination. Asbestos is a known carcinogen. Studies by the FDA have shown that the usage of such cosmetics linked to deadly mesothelioma.

Reflect on the consequences of contamination of cosmetics on our health. Also discuss the ethical implications of buying or selling contaminated materials.

[C:D, ii, L:7-8]

Write your answers below.

Topic 4: Pure and impure substances

Key concept:

Relationship

Related

concept:

Form

The concept of **form** includes the features of an object that can be observed, identified, described, classified and categorized. The nature of science informs us that experimental evidence can be collected using our senses. We make observations of the form, or features, of matter and the interactions matter undergoes during chemical reactions. The interaction between matters during a chemical reaction can help us understand the changes in the form of matter or vice versa. Evidence collected by observation is used to develop theories about the nature of matter. Our ability to define and understand the form of matter helps us advance our understanding of the universe.

Copper appears in many forms. Chemists need to have techniques they can use to identify them. Our relationship with the universe shapes our development as individuals, impacting on our place in the world and what it is to be human. Technological developments over the last hundred years have affected our **relationships** both on a personal and a wider level.

Practice Questions

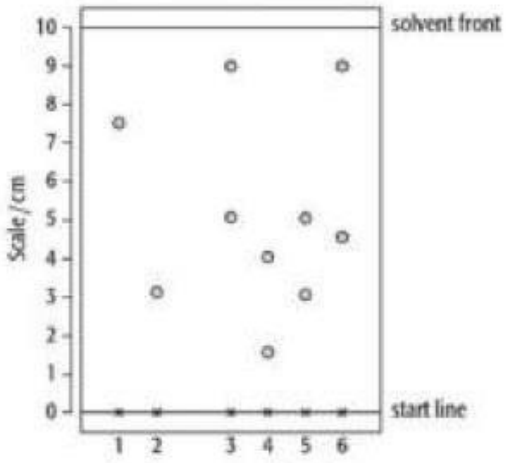
Criterion A

1. Glass is an example of a material for which appearances can be deceptive. For centuries, people have added chemical substances to the silicates that are the basis of glass in order to produce different and attractive varieties.
   i. Describe the physical properties of glass.
   ii. Outline why pure glass can be considered a 'super-viscous liquid'.

iii. Describe the model for the arrangement of particles in glass that best explains the behaviour of glass.

iv. Explain why a slowly cooled material might be stronger than one cooled quickly?

2. State the difference between an emulsion and a suspension.
3. When clothes are washed,
   i. Suggest why it is difficult to remove grease spots from clothing using pure water
   ii. If the clothing soiled with grease spots is treated with a spray-on stain remover, washing becomes more effective. Suggest the chemical a stain remover might be, and describe how it works.
4. Describe how to separate the following. In each example, give a description of the procedure used and explain why this method works.
   i. Copper powder from a mixture containing copper and zinc powders.
   ii. Nitrogen from a mixture of nitrogen and oxygen
   iii. Glycine from a mixture of the two amino acids glycine and alanine. Glycine has a lower Rf value
   iv. Magnesium hydroxide from a mixture of magnesium hydroxide and zinc hydroxide
5. An important aspect of chemistry is purity and methods of purification. State an example of a substance used in everyday life which must be pure.
6. Suppose you had a valuable collection of small diamonds, which you kept safe from thieves by mixing them with white sugar crystals and storing the mixture in a jar labelled 'sugar'. The time has now come when you want to sell the diamonds. Describe how you would recover all the diamonds from the sugar.
7. Suppose you had some potassium nitrate contaminated with small amounts of potassium carbonate. Potassium carbonate is more soluble in water than potassium nitrate. Describe how you would make a pure sample of potassium nitrate from the impure mixture.
8. Chromatography is used by the 'Horse Racing Forensic Laboratory' to test for the presence of illegal drugs in racehorses. A concentrated sample of urine is spotted onto chromatography paper on the start line. Alongside this, known drugs are spotted. The chromatogram is run using methanol as the solvent. When finished, the paper is read by placing it under ultraviolet light. A chromatogram of urine from four racehorses is shown below.



Spot	Description
1	caffeine
2	paracetamol
3	urine sample horse **A**
4	urine sample horse **B**
5	urine sample horse **C**
6	urine sample horse **D**

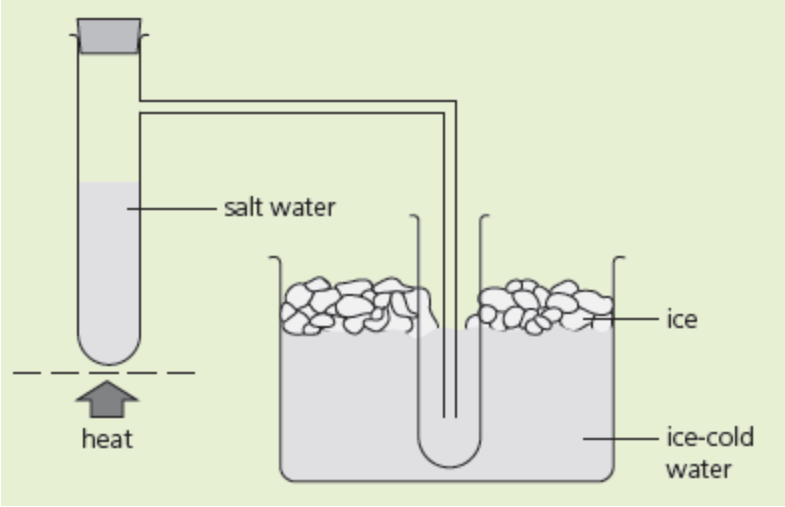
i. State two factors which determine the distance a substance travels up the paper.

ii. From the results, the sample from one horse contains an illegal substance. State which horse, and the drug present.

iii. Give a reason for the use of this drug.

iv. The results for known drugs are given as 'R_f values'. Calculate the R_f value for caffeine.

9. At a party, in a bucket of iced water (i.e. containing both liquid and solid phases of water), you can notice that cans of a regular soda sink, but cans of 'diet' sodas float. In the morning, when all the ice cubes have melted, the regular 'Coca-Cola' and regular 'Dr Pepper' drinks both float along with the diet sodas! Interpret this information and make scientifically supported judgements.
10. Creamy mayonnaise is an emulsion of oil and water. Identify the role of adding small amount of egg yolk or mustard powder in the recipe.
11. In the French perfumery industry, pomade is made by placing fresh lavender on highly purified blocks of animal fat in cool, dark rooms. After a few days, the fat is dissolved using cool alcohol, leaving the essential oils from the flowers behind. Explain how this separation process demonstrates an awareness of the physical properties of essential oils.
12. You mix instant coffee with water to make a cup of coffee. Is the coffee an impurity? Explain.
13. The below apparatus can be used to obtain pure water from salt water.



i. State the purpose of the ice-cold water?

ii. The glass arm must reach far down into the second test tube. Why?

iii. Where in the apparatus does this take place?

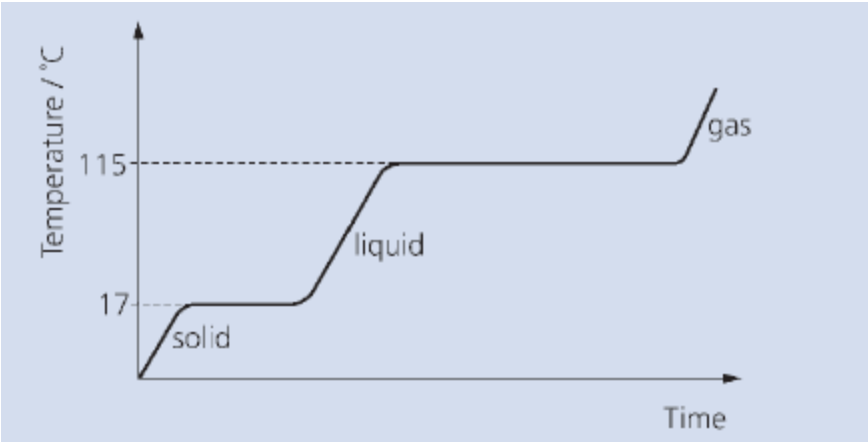
- Evaporation
- Condensation

iv. State the name of this separation method.

v. Outline what will remain in the first test-tube, at the end of the experiment?

14. It is good laboratory practice to label all glassware being used to prevent accidents. However, during an experiment you forget to label your beakers, each containing distilled water and salt solution respectively. Describe a method to distinguish between distilled water and salt solution in the laboratory.

15. Below is a heating curve for a pure substance. It shows how the temperature rises over time, when the substance is heated until it melts, then boils.



i. State the melting point of the substance.

ii. Outline what happens to the temperature while the substance changes state?

iii. The graph shows that the substance takes longer to boil than to melt. Suggest a reason for this.
iv. How can you tell that the substance is not water?
v. Sketch a rough heating curve for pure water.

Criterion B

Design an investigation to identify the differences in properties between pure and impure substances.
You are required to identify a property of a pure substance and compare how this property changes as a result of adding an impurity. Please include the following in your investigation:
i. explain a problem or question to be tested by a scientific investigation
ii. Formulate and explain a testable hypothesis using correct scientific reasoning
iii. Explain how to manipulate the variables, and explain how sufficient, relevant data will be collected
iv. Design a logical, complete and safe method selecting appropriate materials and equipment.

Criterion C

1. Based on the investigation designed in Criterion B task, answer the following questions:
   i. State whether your results support or refute your hypothesis.
   ii. Comment on the reliability of your results: reflect on how closely results are clustered around the mean-very scattered results, or 'outliers', need to be explained
   iii. Comment on the validity of your results-reflect on whether your results could have any alternatives explanation apart from the problem you planned.
   iv. Evaluate the validity of the method. This means, that the measurements you made were relevant to the properties you investigated. The range of your data for repeated trials may give you an indication.
2. Inverting an emulsion

   Materials and equipment:
   - 150 ml of thick cream
   - Beater

   Method:
   - Set a little cream aside
   - Beat the cream, until it looks fluffy and white, just right for spreading on a cake.

- Set a little of this cream aside
- Beat the remainder of the cream until it 'separates'

i. State the effect extra 'beating' had on the color of the cream
ii. Apply your understanding of emulsions to explain what happened.
iii. Suggest how butter is made from cream.

Criterion D

Molecular gastronomy – scientifically purposeful or showy pretence?

Imagine yourself in the role of a feature journalist for a magazine, writing an article in which you are required to describe and report the claims about molecular gastronomy. What do you think?

Your feature article should be no more than 1200 words and should include the following features:

- A human interest story about a meal created using molecular gastronomy, explaining how science was used for effect.
- A discussion and evaluation about how the development of the molecular gastronomy movement might interact with moral, ethical, social, economic, political, cultural or environmental considerations.
- Language appropriate for your audience: high quality science journalism describes complex ideas concisely and accurately

Topic 5: Bonding

Key concept: System

Related concept: Balance, Energy, Conditions

When they are performing research, scientists speak of chemical **systems**. What is a chemical system? When we want to define a chemical system, we need to examine the **conditions** of the physical and chemical environment inside and outside of the system. In reality, a chemical system is simply a chemical reaction being studied. Changes in conditions in and around the system changes the outcome of the process.

Systems within our universe are dynamic. They constantly undergo both internal and external changes, which require these systems to react and respond. Abiotic and biotic components of the system contribute towards maintaining the **balance** in conditions and relationship. Uncontrolled development applies external pressure on ecosystems, resulting in an imbalance. Chemical and physical systems display characteristics that involve a balance in matter and energy, referred to as equilibrium. The control over the balance between reactants and products is essential in many industrial processes and synthetic reactions.

Energy is integral to all aspects of our lives. Work is performed as energy and transformed from one type to another. Thermodynamics investigates the transfer of energy to and from system, and from one form to another.

Practice Questions

Criterion A

1. Harmful algal blooms in marine ecosystems have a major impact in the aquatic environment causing an imbalance in the ecosystem. How is aquafarming affected by these occurrences? How might this be a threat to human health?
2. Fertilizers are produced by a reaction between an acid and ammonia. The following word equations summarize the formation of a variety of fertilizers. Write balanced chemical equations for these, including the states of matter for all the reactants and products.
    i. Ammonia + nitric acid → ammonium nitrate
    ii. Ammonia + sulphuric acid → ammonium sulfate
    iii. Ammonia + phosphoric acid → ammonium phosphate
    iv. Potassium hydroxide + nitric acid → potassium nitrate + water
3. State the source of reactants, nitrogen and hydrogen, used in the Haber process?
4. The hot and cold compresses contain a chemical and an inner bag containing water. By squeezing the outer bag, the inner bag is ruptured and the water mixes with the chemical. The chemical in the hot compress is magnesium sulfate; the cold compress contain ammonium nitrate. Outline which reaction is endothermic and which is exothermic?
5. Describe the energy changes that occur after a sparkle is lit.
6. Calculate the energy released by the combustion of methanol when the temperature of 30 g of water is raised by 30^{o}C. The specific heat capacity of water is 4,200 J kg^{-1} K^{-1}.
7. Chemical reactions are all around us. They are fundamental part of all that we do. Within the human body, chemical reactions are constantly occurring.
    i. State what you understand by a chemical reaction.
    ii. Where do chemical reactions take place? Give some examples of different types of chemical reactions
    iii. State what is required for a chemical reaction to occur. Your explanation of this question may be helped by the use of diagrams or illustrations.
8. In terms of energy, explain why only a certain proportion of reacting particles in a chemical system will be transformed from reactants into products, at a given temperature.

9. Applying your understanding of chemical kinetics, suggest reasons why science needs to find ways to increase the rate of a chemical reaction.
10. Calculate the molar mass of the following compounds using the values of A_r found in the periodic table.

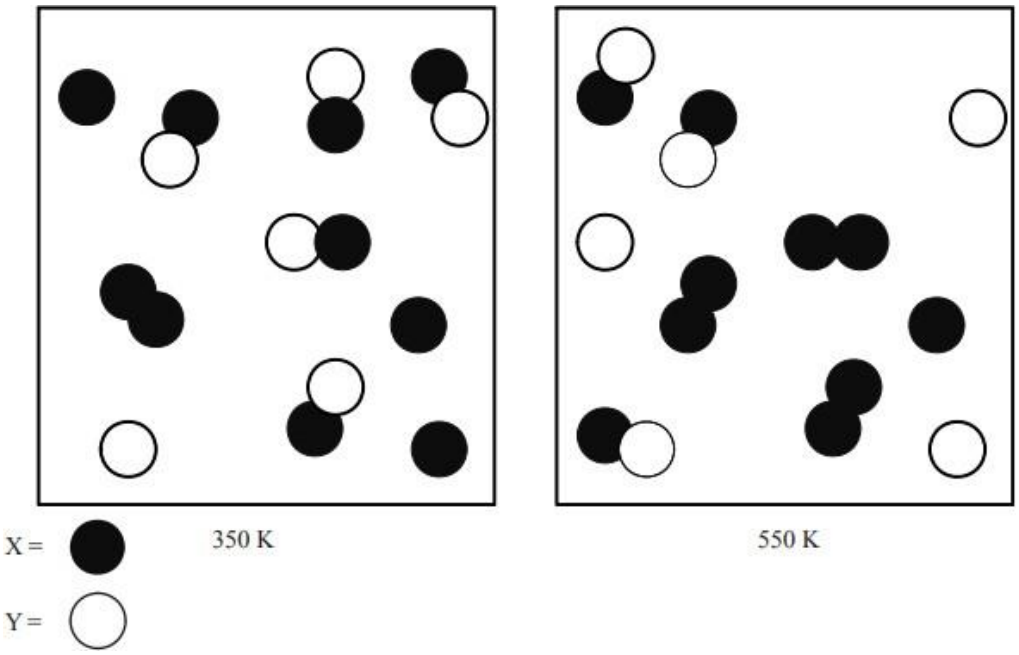
    CO_2, SO_3, HNO_3, Na_2CO_3, $KMnO_4$, $CaCl_2$, $Al(NO_3)_3$, $Fe_2(SO_4)_3$, $(NH_4)_2SO_4$, $Na_2S_2O_3.7H_2O$
11. Copper sulfate reacts with sodium hydroxide to produce a precipitate of copper hydroxide. Calculate the mass of sodium hydroxide needed to convert 15.95 g of copper sulfate into copper hydroxide. Calculate the mass of copper hydroxide produced.
12. Magnesium oxide is made up of Mg^{2+} and O^{2-} ions. How does the amount of charge present on the ions in an ionic compound affect the melting and boiling points? Explain your reasoning.
13. The strength of an ionic bond is also dependent on the distance between the two ionic centers. How are the melting and boiling points affected by the ionic radius of the interacting ions?
14. Sodium chloride has a melting point of 801^{o}C and a boiling point of 1413^{o}C. Cesium has a larger ionic radius than sodium, and iodine has a larger ionic radius than chlorine. How do the melting and boiling points of sodium chloride and cesium chloride compare? Explain your reasoning.
15. Do you expect magnesium oxide, MgO, to be more soluble or less soluble than sodium chloride? Explain
16. For each of the following pairs of elements, deduce the formula and the name.
    - Vanadium (III) and sulfate ion
    - Titanium (II) and hydrogen carbonate ion
    - Manganese (VI) and oxide ion
    - Aluminium and bromine
    - Calcium and chlorine
    - Strontium and phosphorous
17. For each of the following elements/molecules determine the number of valence electrons and derive its Lewis symbol(structure)
    - Phosphorous
    - Silicon
    - Oxygen
    - Sodium
    - Hydrogen
    - Fluorine
18. Metals are known to be excellent conductors of electricity. Explain the features of metallic bonding that enable metals to conduct an electric current.
19. Copper is often used as a conductive material in electronics, power generation and distribution, and circuitry. How does the presence of impurities in copper affect its ability to conduct electricity?

20. Over the last 40 years there have been significant increases in the number of people flying. To meet this demand, aircraft manufacturers are building greater numbers of aircraft using more resources such as aluminum alloys. Is this a fair and equitable use of the planet's resources if not all people can afford to fly?
21. The difference between precision and accuracy is important in the chemical laboratory. When you collect data, which of the following situations is easier to explain and why: results with poor precision or results with poor accuracy?
22. Explain how delocalized electrons in metals contribute to the following physical properties.
    - Lustre
    - Conductivity of heat
    - Conductivity of electricity
    - Malleability and Ductility
23. Imagine you are an archaeologist exploring an ancient monument. Inside the monument is a scattering of round objects, made of a dark, dense, hard material.
    i. List tests you could conduct to determine what type of bonds might be found in the substance
    ii. Evaluate your confidence that you could categorize almost any solid material with these tests.
24. State the meaning of 'allotrope'. Identify the location of carbon in the periodic table and suggest how this may help explain its ability to form more than one kind of bond.
25. Sketch a sequence of diagrams to illustrate how single, double and triple bonds between the two carbon atoms affect the relative positions of their nuclei.
26. The strength of a bond is related to the size of the atoms and electronegativity. Interpret the general patterns of the elements in the periodic table to make scientifically supported judgement about which in each pair of covalent bonds below is likely to have the larger dipole:
    i. An H-F bond or an H-S bond
    ii. An H-O bond or an H-F bond
    iii. An H-Cl bond or a Cl-Cl bond
27. Hydrated cobalt (II) chloride is pink but anhydrous cobalt (II) chloride is blue. Suggest how this compound might be used to determine the probability of rain.
28. Use a labelled diagram to describe how different types of bonds result in the different physical properties of two allotropes of carbon, graphite and diamond.
29. An 'ideal' gas is a theoretical concept consisting of point particles (which have mass but no volume) which interact perfectly elastically. Suggest how intermolecular forces between gas molecules may cause an actual gas to depart from this model.
30. Interpret each of the examples below and use collision theory to make a judgement about the causes.
    i. It is difficult to light coal, but coal dust in mines can cause explosions. Similar ly, although all foods burn, in sweet factories that use corn flour, special precautions have to be taken to filter the fine powder from the air as it is a fire hazard.

ii. A biology student prepared a 'wet mount' with a suspension of fine grey dust collected from a vacuum cleaner. At very high magnification, she saw small specks jerking about.

31. Suggest why is it more dangerous to be trapped in a bushfire (wild fire) in a car with a nearly empty petrol tank than one that is nearly full of fuel.
32. If in a chemical reaction, ΔH is positive:
    i. State the type of reaction involved
    ii. Outline the sources of this thermal energy, in terms of bonds of the chemical reactants and products.
33. Explain why food cooks more quickly in a pressure cooker.
34. The effect of concentration and temperature on the rate of a reaction can be explored using the reaction between magnesium ribbon and dilute sulfuric acid. A student dropped a 2cm length of magnesium ribbon inti 25 cm^3 of dilute sulfuric acid in a boiling tube (a large excess of acid). She stirred the contents of the tube continuously and timed how long it took for the magnesium to disappear.
    i. What would you expect to happen to the time taken for the reaction if she repeated the experiment using the same length of magnesium with a mixture of 20 cm^3 of acid and 5 cm^3 of water? Explain.
    ii. What would you expect to happen to the time taken for the reaction if she repeated the experiment using the original quantities of magnesium and acid, but first heated the acid to 50^{o}C? Explain
    iii. Why is it important to keep the reaction mixture stirred continuously?
35. Catalysts speed up reactions, but can be recovered chemically unchanged at the end of the reaction.
    i. Explain how catalyst has this effect on a reaction.
    ii. Describe how you would find out whether copper (II) oxide was a catalyst for the decomposition of hydrogen peroxide solution.
36. The diagrams below represent equilibrium mixtures for the following reaction at 350 K and 550 K respectively. Deduce and explain whether the reaction is exothermic or endothermic.

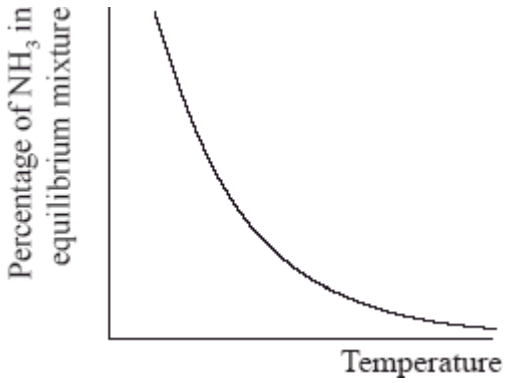
$$Y + X_2 \rightleftharpoons XY + X$$



37. Ammonia contains the elements nitrogen and hydrogen, It is manufactured using Haber's process.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

i. The percentage of ammonia in the equilibrium mixture varies with temperature. Use the following graph to deduce whether the forward reaction is exothermic or endothermic and explain your choice.



ii. The table shows how the percentage of ammonia in the equilibrium mixture with pressure at 600^0 Celsius.

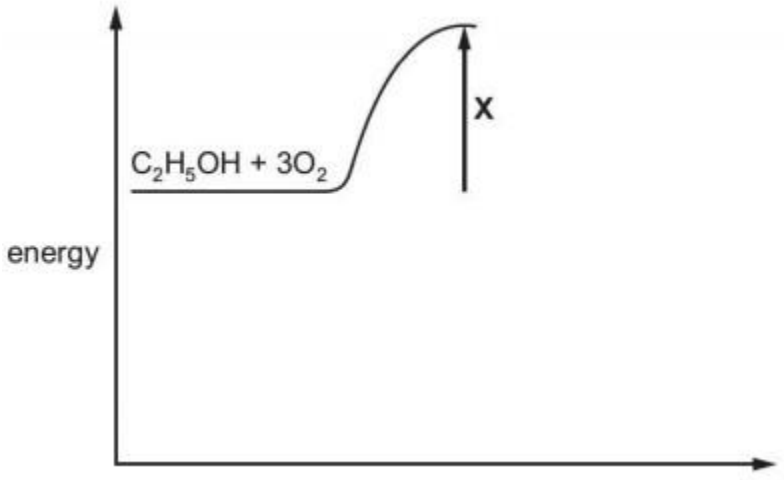
percentage ammonia	8	12	15	20
pressure/atm	200	300	400	500

- Explain why the percentage of ammonia increases as the pressure increases?
- How would the percentage of ammonia change if the measurements had been made at a lower temperature? Explain your answer.

38. The chemical equation for the complete combustion of ethanol is shown below.

$$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$$

The energy released when one molecule of ethanol undergoes complete combustion is 1280 KJ. Part of the energy level diagram for the reaction is shown.



Complete the energy level diagram to show

- The products of thereaction
- The overall energy change of the reaction

i. What does X represent?

ii. The chemical equation for the complete combustion of methanol, CH_3OH, is shown below.

$$2CH_3OH + 3O_2 \rightarrow 2CO_2 + 4H_2O$$

Use the bond energies in the table to determine the energy change, ΔH, for the complete combustion of one molecule of methanol.

bond	bond energy in kJ/mol
C–H	410
C–O	360
O–H	460
O=O	500
C=O	805

39. Iodine reacts with chlorine to form dark brown iodine monochloride.
$I_2 + Cl_2 \rightarrow 2ICl$

This reacts with more chlorine to form yellow Iodine trichloride.
There is an equilibrium between these two iodine chlorides.

$$\underset{\text{dark brown}}{ICl(l)} + Cl_2(g) \rightleftharpoons \underset{\text{yellow}}{ICl_3(s)}$$

i. Explain what is meant by equilibrium?

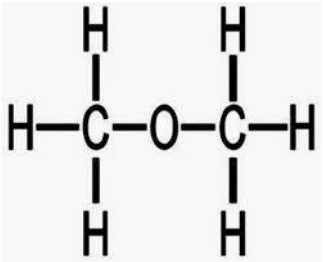
ii. When the equilibrium mixture is heated it becomes a darker brown color. Is the reverse reaction endothermic or exothermic? Give a reason for your choice.

iii. The pressure on the equilibrium mixture is decreased. How would this affect the position of equilibrium and why? Describe what would you observe.

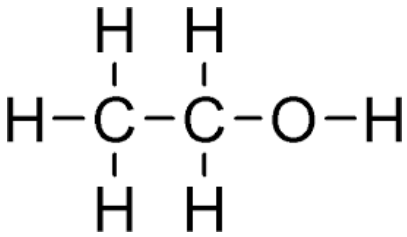
40. Magnesium chloride is an ionic compound. Draw a diagram to show the formula of the compound, the charges on the ions and gives the arrangement of the valency electrons around the negative ion.

Use x to represent an electron from Magnesium atom
Use o to represent an electron from chlorine atom

41. The structure of two compounds are given below.



Methoxymethane



Ethanol

Methoxymethane, CH_3OCH_3, and ethanol, C_2H_5OH, have the same relative molecular mass. Explain why methoxymethane has a much lower boiling point than ethanol.

42. Sea water has a very high concentration of dissolved sodium chloride. Suggest why it is unsafe to swim in the ocean during an electrical storm?
43. Calculate the maximum mass of carbon dioxide given off when 20.0 g of small lumps of calcium carbonate react with 40 cm^3 of hydrochloric acid, concentration 2.0 mol/dm^3.
44. In an experiment, 50.0 cm^3 of hydrochloric acid of concentration 2.0 mol/dm^3 was used. 6.4 g of $SrCl_2.6H_2O$ was made. Calculate the percentage yield.
45. A compound X contains carbon, hydrogen and oxygen only. X contains 54.54% of carbon by mass, 9.09% of hydrogen and remaining oxygen by mass. Calculate the empirical formula of compound X. Compound X has a relative molecular mass of 88. Deduce the molecular formula of compound X.

Criteria B

1. An aqueous solution of hydrogen peroxide decomposes very slowly to form oxygen and hydrogen. The speed of decomposition can be increased by using a catalyst. Two possible catalysts that can be used are the solids copper (II) oxide and Chromium (III) Oxide. Plan an investigation to find out which of these two oxides is the better catalyst for the decomposition. (Your investigation should include a description of the problem or question the investigation is testing, hypothesis with scientific reasoning, appropriate materials and equipment's and describe a safe method for your investigation and include how you will collect the relevant data. List the dependent and the independent variables in your experiment.
2. Investigate a factor that affects the rate of a reaction, for example temperature, concentration, surface area, pressure. Safety precautions, risk and environmental impact analysis must be included in your plan. Use a method that will provide quantitative data, enabling you to represent and analyze the results graphically.
3. Some camping shops sell 'hand warmers' inside the airtight, plastic bag each hand-warmer consists of a small packet made from a porous fabric, filled with a dark grey powder. Design an investigation into factors that may affect the energy they generate.

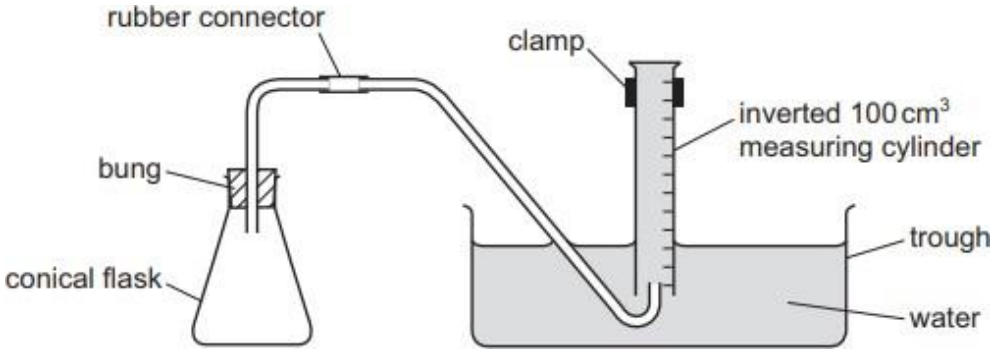
4. Plan an experimental investigation into the effects of different atmospheres on combustion of candles, held in sealed containers.
5. When solid C and solid D separately react with dilute hydrochloric acid, one reaction is exothermic and one reaction is endothermic. Design and describe a safe method to determine:

   ● Which reaction is exothermic and which reaction is endothermic
   ● Which energy change is greater.

   You are provided with solid C and solid D, dilute hydrochloric acid and common laboratory apparatus.
6. A student was provided with list of compounds labelled A, B, C, D and E. The substances provided to him are an ionic compound, non – polar molecular solid, a metal, a polar molecular solid and a giant molecular substance. Plan an investigation to help the student classify the each five solids correctly as ionic compound, non – polar molecular solid, a metal, a polar molecular solid and a giant molecular substance (Your investigation should include a hypothesis with scientific reasoning, appropriate materials and equipment's , method for the experiment and an observation table to show how the data will be collected.

Criteria C

1. A student investigated the rate of the reaction between magnesium ribbon and two different solutions of dilute sulphuric acid, solution G (pH 4) and solution H (pH 5.5). The acid was in excess in both the experiments.
   Two experiments were carried out.
   Experiment 1
   - The apparatus was set up as shown in the diagram

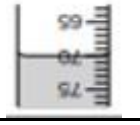


   - Using a measuring cylinder, 50 cm^3 of solution G was poured into the conical flask. A piece of magnesium ribbon was to the conical flask and the bung was replaced.
   - The timer was started immediately and the total volume of gas collected in the measuring cylinder was measured every 20 secs for 180 secs (3 mins)

Experiment 2

- Experiment 1 was repeated using 50 cm^3 of solution H instead of solution G.

i. Use the measuring cylinder diagrams to record the volumes of gas collected in Experiment 1.

	Experiment 1		Experiment 2
Time/sec	Measuring cylinder Diagram	Volume of gas/cm^3	Volume of gas/cm^3
0			0
20			8
40			14
60			21
80			27
100			33
120			39
140			45
160			50

180			55

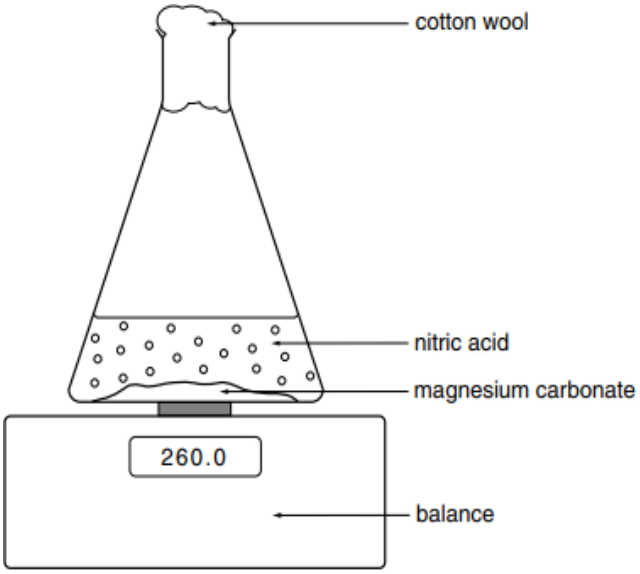
ii. Plot the results for experiments 1 and 2 on the graph paper.

iii. Which experiment had the faster rate of reaction?

iv. Discuss the validity of your hypothesis and the method based on the results obtained above.

v. Describe methods to improve the results in Experiment 1.

2. Dilute nitric acid was added to a large amount of magnesium carbonate in a conical flask as shown below.



The flask was placed on a balance and the mass of the flask and contents recorded every minute. The results are shown in the table.

time / min	0	1	2	3	4	5	6
mass of flask and contents / g	260.0	257.9	256.8	256.6	255.8	255.6	255.6

i. Plot the results of the experiment in the form of a graph joined by smooth line.

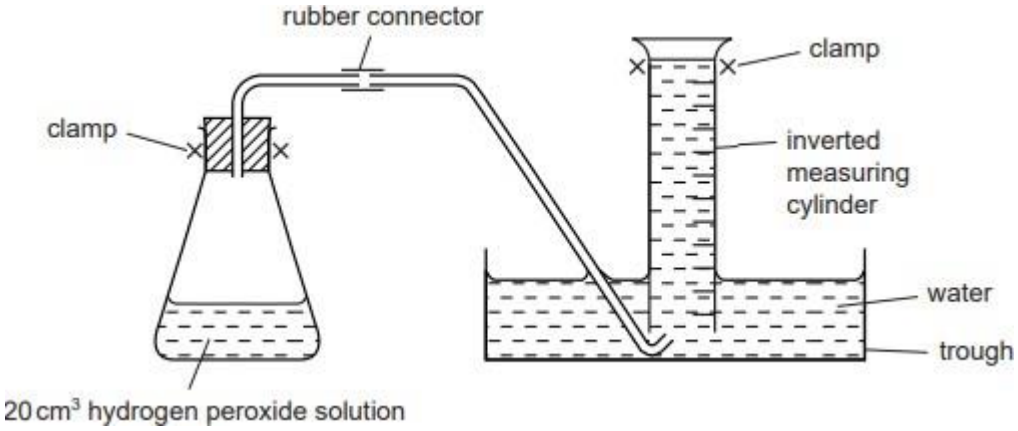
ii. Which result appears to be inaccurate? Justify your choice.

iii. Why does the mass of the flask and the contents decrease?

iv. Suggest the purpose of the cotton wool.

v. At what time did the reaction finish?

3. The student investigates the rate of the reaction when aqueous hydrogen peroxide is broken down using manganese (IV) oxide. The apparatus was set up as shown below.



Experiment 1

By using a measuring cylinder, 20 cm^3 of hydrogen peroxide solution was poured into a conical flask. One spatula of manganese (IV) oxide was added to the flask, the bung was quickly placed and the timer started immediately. The volume of gas collected in the measuring cylinder was measured every 10 seconds.

Experiment 2

The experiment 1 was repeated using 15 cm^3 of hydrogen peroxide and 5 cm^3 of distilled water.

Experiment 3

The experiment 1 was again repeated using 10 cm^3 of hydrogen peroxide and 10 cm^3 of distilled water.

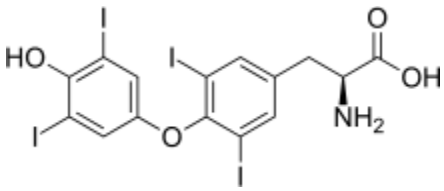
i. The student presented the following hypothesis for the investigation.
"The rate of reaction in experiment 1 will be faster and more volume of gas will be collected as the solution is more concentrated leading to more particles undergoing effective collisions." Discuss on whether or not this is a valid hypothesis.

ii. Evaluate the validity of the method and suggest and describe modifications to the method that would reduce any errors that may be present in the method used.

Criteria D

1. *Read the following passage and answer the question*

Supramolecular chemistry is an emerging interdisciplinary science that attempts to design complex molecules for applications in very fields like medicine, technology and so on. These molecules assemble themselves guided by intermolecular forces. Using the idea, materials with more than one type of chemical bond showing more than one type physical properties can be made. One example of synthetic compound is levothyroxine, a synthetic thyroid replacement hormone. Thyroxine is synthesized via the iodination of tyrosines (monoiodotyrosine) and the coupling of iodotyrosines (diiodotyrosine) in the thyroglobulin. The molecular formula of levothyroxine is $C_{15}H_{11}I_4NO_4$ and the structure is shown below.



Thyroid replacement hormones are medications used to treat hypothyroidism, a condition in which the production of thyroid hormone in the body is abnormally low. Thyroid hormones increase cellular metabolism (activity of cells) that is responsible for growth, development of tissues, maintenance of brain function, body temperature regulation and several other cellular processes. Low levels of thyroid hormones in the body can result in many problems given the numerous activities that they mediate. The thyroid gland, a gland found in the lower neck is responsible for the production of thyroid hormones. It produces two main hormones, thyroxine (T4) and triiodothyronine (T3). The hormone responsible for most of the biological effects in the body is T3. When T4 is released into the blood by the thyroid gland, most of it is converted to T3 which

is responsible for the cellular metabolic processes. Commercially available thyroid hormones are either natural or synthetic (man-made). Desiccated thyroid or thyroid extract (Armor Thyroid, Nature-Throid), a natural thyroid hormone is derived from beef or pork. Levothyroxine sodium (for example, Synthroid, Levoxyl andLevothroid), is the synthetic version of thyroxine (T4), liothyronine sodium (Cytomel, Triostat), is the synthetic version of tT3 and liotrix (Thyrolar) is a synthetic thyroid hormone containing a mixture of T4and T3.

Desiccated thyroid extract is prepared from pig thyroid glands. The glands are dried (desiccated), ground to powder, combined with binder chemicals, and pressed into pills. This was a new use for parts that were previously unwanted slaughterhouse offal (***Offal*** refers to the internal organs and entrails of a butchered animal), and Armour and Company, the dominant American meatpacker in the 20th century, supplied the best-known brand of thyroid extract.

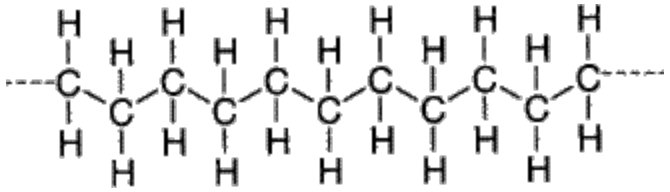
As use of animal thyroid gland became more widespread, chemists set about extracting the vital ingredient responsible for overcoming symptoms of hypothyroidism. The first success went to US chemist Edward Kendall, who succeeded in isolating 7g of thyroxine from some 3,000kg of pig thyroid gland in 1914.During the middle of the last century, synthetic thyroid medication came on the market. This synthetic version of the T4 hormone is known generically as levothyroxine, and sometimes referred to by the most common brand name, Synthroid. Levothyroxine became increasingly popular, and during the second half of the 20th century, it became the treatment of choice for the mainstream medical community. Physicians claimed it was more stable and consistent than natural desiccated thyroid, and that the body was able to convert T4 into the active T3 the body needed to resolve hypothyroidism. For several decades, the vast majority of thyroid patients was prescribed levothyroxine drugs to treat hypothyroidism. As of 2011, levothyroxine was the second most commonly prescribed medication in the United States, with 23.8 million prescriptions filled each year.

a. State the problem or issue the synthetic levothyroxine is trying to address.
b. Discuss the type of bonding present in the molecule of Levothyroxine.
c. Discuss and evaluate how the use of the synthetic hormone interacts with the ethical, social and economic factor.

2. *Read the following passage and answer the question*

Man-made Polymers: Invention of Celluloid

Supramolecular chemistry is an emerging interdisciplinary science that attempts to design complex molecules for applications in very fields like medicine, technology and so on. These molecules assemble themselves guided by intermolecular forces. Using the idea, materials with more than one type of chemical bond showing more than one type physical properties can be made. One example of synthetic compound is celluloid a type of plastic.



During the Victorian era, it was fashionable for wealthy gentlemen to own a billiard table and a set of billiard balls crafted of the finest and most perfect ivory. The best billiard balls once came exclusively from the tusks of Asian elephants. No natural material other than elephant ivory had the physical size, strength, and beauty to perform in the billiard room and the concert hall. But mass markets in the western world for ivory billiard balls, combs, piano keys, and commercial trinkets, placed the wild elephant in serious jeopardy in the late 19th and early 20th centuries. While one African elephant tusk could yield hundreds of slips of piano key ivory, only four or five quality billiard balls could be made from the average tusk of an Indian, Ceylonese, or Indo-Chinese elephant. Raw tusks arrived at shops in New York and Chicago where master ivory turners would reduce blocks of ivory to gleaming spheres. Today, synthetic materials attempt to reproduce the performance of ivory balls on the billiard table, while in dark corners of old pool halls and in the collections of the Smithsonian, balls such as this one from 1925 recall a time when, at the expense of elephants, the only real billiard balls were cut from fresh Asian ivory. But 19th century hunters had virtually decimated the elephant herds of Africa and India, the source of ivory. By 1863, the ivory shortage had become so critical that a New York billiard-ball manufacturer offered a $10,000 prize to the person who could create a useful substitute.

The winners were John Wesley Hyatt, a young printer in Albany, New York, and his brother, Isaiah. They never received the money. But they did change history — by inventing celluloid, one of the world's first plastics. Plastics are typically organic polymers of high molecular mass and often contain other substances. Polymers are giant organic compounds made up of many smaller subunits called monomers. One of the first synthetic compound developed using the idea of bonding and the properties related to bonding was Celluloid. Celluloid not only resembled ivory, it had astonishing properties: at normal temperatures, it was a permanent, hard solid; when heated, it became soft and could be moulded or rolled into sheets. It soon became the material of choice for billiard balls and dozens of other products. The Hyatt's made celluloid by applying heat and pressure to a mix of cellulose nitrate and camphor; it was thus a plastic made by modifying natural materials.

Discuss and evaluate the problem or issue the synthetic material in the above paragraph is trying to address taking into account the factors listed below:

Environmental, moral, social, cultural, economic and ethical factor.

3. Bioremediation is the science of using 'extremophiles', naturally adapted organisms to clean contaminated environments. Examples include microbes (Archaea) and certain plants. Special enzymes in these organisms enable them to thrive in surroundings that are toxic for most organisms.
   Design an information leaflet of no more than 1200 words to campaign for investment in the use of bioremediation to repair environmental damage at low cost.
   In your leaflet:
   Describe and explain how the extremophile you selected is able to use and improve the damaged environment, with reference to its special enzymes or transport proteins, and equations for the biochemical reactions.
   Discuss and evaluate the implications of the commercial use of the extremophile on our planet.

Criteria D

4. Palm oil is one of the most widely consumed oils in the world. An ancient native tree of Africa, which is over 5,000 years old, it is now mostly grown commercially in south-east Asia. Palm oil is used for a range of purposes including frying and baking food stuffs and as a biofuel, when blended with other fuels. The organic waste from processing the oil is also used as a biofuel, meaning that there is very little waste from the entire process. As the use of trans-fats in food manufacturing has become increasingly unpopular in the past few decades, due to the proven deleterious effects on people's health from increased cholesterol, the use of palm oil has sky-rocketed. However, palm oil itself may present health challenges due to the very high amount of saturated fat, specifically the 16-carbon saturated fatty acid, palmitic acid.
   The vast palm oil plantations which now cover huge areas of Malaysia, Indonesia, and Thailand, to name a few countries, have led to the environmental problems of deforestation, smoke haze, and reduction in animal and plant species, as once varied landscapes have become farmed monocultures. Yet, the fact remains that palm oil can be produced economically and is therefore used globally in food manufacturing and as an alternative fuel source. It has also lifted hundreds of thousands of previously subsistence farmers out of poverty and contributes significantly to many countries' GDP (gross domestic product).
   The article above provides an overview of the benefits and problems of palm oil production. The iodine number of a fat is indicative of the level of saturation. The lower the iodine number, the greater the level the saturation and the more harmful the oil is for humans. Other sources of fats for food manufacturing include olive oil (iodine number 79-95), lard (iodine number 43), and soya bean oil (iodine number 125-145). Palm oil has an average iodine number of 48-58. Saturated fatty acids lead to an increase in the level

of cholesterol in the blood stream, and an increased risk of coronary heart disease.

- Summarize how our increased scientific understanding of the impact of human development on the environment enables us to identify the issues that exist with palm oil production.

- Examine the iodine number of different oils used in food manufacturing and household cooking and determine which is considered the most healthy to consume. Explain the reasons for your answer.

5. Why is fossil fuel so important in the context of geopolitics and global economy?

Topic 6: Types of Chemical Reactions

Key concept: Change

Related concept: Consequences, Interaction, Movement

Science has long understood the concept of cause and effect, also known as causality. However, a **consequence** could be the result of several different factors acting together. The **interaction** between matters during a chemical reaction can help us understand the changes in the form of matter or vice versa. **Movement** is the act, process or result of moving from one location or position to another. Matter is in constant movement relative to its surroundings. Often we are aware of this movement through the observations we make using our senses. From kinetic theory of matter we know that atoms, molecules and ions are in constant motion. Studying their movement requires work on a completely different scale – a scale so small that it is difficult to imagine. Often it is the changes observed that help us to understand the movement. For this reason, the key concept is **change.**

Practice Questions

Criterion A

1. Broad –spectrum antibiotic medications have transformed modern medicine and saved millions of lives, but have also been shown to increase gastric fluid pH level, influencing gut microbe diversity and composition.
    i. Thinking about the environment of our gut microbiome, to what extent should we consider the potential effects of over-prescribing antibiotics in relation to our health?
    ii. To what extent are these health consequences heightened in immunocompromised individuals? Would individuals with weaker immune systems be affected more or less? Why?
    iii. How might the over-prescription of antibiotics have effects that extend beyond our gut environment?
    iv. Evaluate and justify to what extent the benefits of antibiotic medication overshadow the consequences of their over-use.
2. Identify examples of corrosion in your school, home or community. Describe the impact of corrosion. How can it be prevented or reduced?
3. Explain any differences in the reactions between the iron in the boiled water compared to that in the normal distilled water. What does this tell you about the required conditions for corrosion of a metal?
4. Why does magnesium replace hydrogen when it reacts with hydrochloric acid?
5. Would pure silver jewelry react with an acid? Justify
6. Predict how the reaction between lead and hydrochloric acid would compare to the reaction between magnesium and hydrochloric acid. Describe how your observations of the two reactions would differ.
7. Zinc is a transition metal.
    i. Describe the appearance of a fresh piece of zinc metal.
    ii. Describe what happens when you dip the zinc metal into copper (II) sulfate solution. Explain the type of reaction you think has occurred.
    iii. How does the zinc's appearance change after it has been in the solution for 15 minutes?
    iv. Write a balanced chemical equation to describe the reaction.
    v. What are the half equations for the reaction between zinc and copper (II) sulfate?
8. For each of the following ionic equations:
    i. Balance the equation so the net charge is the same on each side of the equation
    ii. Construct the two half-reactions from the ionic equation
    iii. Balance the charges for each half-equation by adding electrons
    iv. Identify the species that is being oxidized and the species being reduced.

    - $Cu^{2+} + Mg \rightarrow Cu + Mg^{2+}$
    - $Al + Fe^{3+} \rightarrow Al^{3+} + Fe$
    - $Ag^{+} + Cd \rightarrow Cd^{2+} + Ag$
    - $Sn + Pb^{2+} \rightarrow Sn^{4+} + Pb$
9. Why do negatively charged anions from the salt bridge move into the anode cell and positively charged cations move into the cathode cell when the half-cells are connected?

10. Compile a list of voltaic cell applications that impact your daily lives and discuss how your life would be different if these applications did not exist.
11. Why do we need to protect the surface of metals from air?
12. How can we convert electrical energy into chemical energy?
13. A current of 10A is applied for 360 s to a solution of copper (II) sulfate. The same reaction conditions were then applied to a solution of aluminum nitrate. Predict which conditions will result in a greater mass of metal being deposited at the cathode. Explain your choice.
14. Predict what you might observe if you could measure the electrical conductivity of ions in a solution during a precipitation reaction.
15. Evaluate the claim that precipitation reactions are not chemical 'reactions' at all, because they only involve a change of phase of a pair of ions.
16. Calcium nitrate is a fertilizer. Suggest an example of an ionic compound (aq) that will react with calcium nitrate to produce a precipitate.
17. Imagine the labels had peeled off from three old jars of stock chemicals. Your teacher knows the jars contain solid sodium carbonate, sodium chloride and sodium sulfate, but hopes you are able to suggest a strategy for determining the compound in each jar. Outline how you could solve this problem in a safe manner.
18. Explain, using a diagram, why a proton (H+) is another name for a hydrogen ion.
19. Discuss whether strong acids and bases are simply special examples of ionic solutions.
20. Identify whether a solution is acidic, alkaline or neutral, if its pH is 9, 4, 7, 1, 10, 2.
21. Compare the expressions:
    i. A concentrated solution of an acid
    ii. A solution of a strong acid
22. Explain why the strong acid or base require more dilutions to reach the same pH as the weak acid or base.
23. Explain why the pH is a measure of concentration, rather than of acid 'strength'.
24. Outline why:
    i. Calamine solution (which contains zinc carbonate) is effective for relieving pain from bee stings (which contain methanoic acid)
    ii. Milk of magnesia(which contains magnesium hydroxide) is given to people suffering from 'heart burn' , a pain caused by their acidic stomach contents (which contain hydrochloric acid) backing up into their oesophagus
25. Describe what you expect to observe, and the movement of electrons between the reactants, when
    i. A piece of magnesium is added to dilute sulfuric acid
    ii. An iron nail is added to dilute nitric acid
    iii. Aluminium is added to dilute hydrochloric acid
    iv. Describe the redox features of each of these reactions.
26. Aluminium, chromium and manganese are all moderately reactive metals. Analyze the following information to arrange them in the correct reactivity series order, starting with the most reactive one.
    - Chromium is manufactured by heating chromium (III) oxide with aluminium.
    - If manganese is heated with aluminium oxide there is no reaction.

- If manganese is heated with chromium (III) oxide, chromium is produced.

27. If you add some powdered aluminium to a small amount of cold dilute hydrochloric acid in a boiling tube, very little happens. If you warm this gently, it starts to fizz very rapidly.
    i. Name the gas given off to produce the fizzing.
    ii. If you used an excess of hydrochloric acid, you would end up with a colourless solution. Name the solution
    iii. Write the full balanced equation for the reaction
    iv. Explain wht the aluminium hardly reacts at all with the dilute acid in the cold, but reacts vigorously after even gentle heating.
28. Given some small bits of the metal titanium, and any simple apparatus that you might need, describe how you would find out the approximate position of titanium in the reactivity series using only water and dilute hydrochloric acid.
29. When acid rain containing dilute sulphuric acid falls on limestone buildings, which contain calcium carbonate, the buildings gradually erode. Explain this observation using your knowledge of chemical reaction. Use a balanced chemical equation to support your answer
30. When magnesium and copper (II) sulphate are heated together, the following reaction occurs.

$$Mg(s) + CuSO_{4\,(aq)} \rightarrow MgSO_{4\,(aq)} + Cu(s)$$

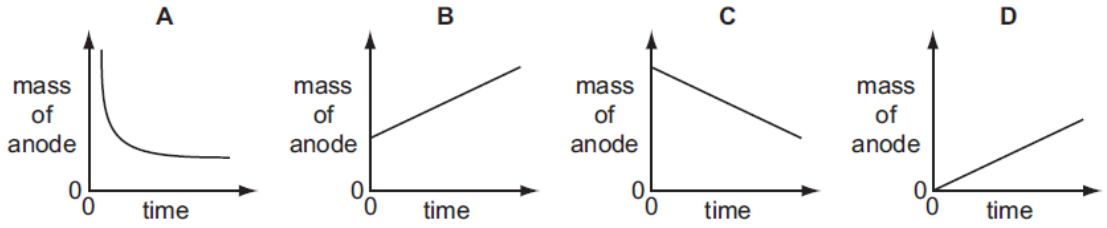
    Explain why the reverse reaction does not occur

31. In etching, a waxy layer is placed on the surface of a metal plate. The artist cuts through the waxy layer, making the pattern or picture. This is then painted with, or dipped in acid that 'eats out' the metal wherever the wax has been cut. The wax is then removed and the picture is displayed where the acid has reacted with the metal. Use your knowledge about the reactions of metals to explain how this process works. Justify using valid scientific reasoning with an example why this process does not work with some metals.
32. Barium carbonate, $BaCO_3$, is an insoluble solid. When barium carbonate is heated strongly, it undergoes thermal decomposition. One of the products is barium oxide.
    i. Write a chemical equation for the thermal decomposition of barium carbonate.
    ii. Suggest the pH of the solution formed when barium oxide is added to water.
    iii. Barium nitrate decomposes on heating the same way as magnesium nitrate decomposes. Name the two gaseous products formed when barium nitrate is heated.

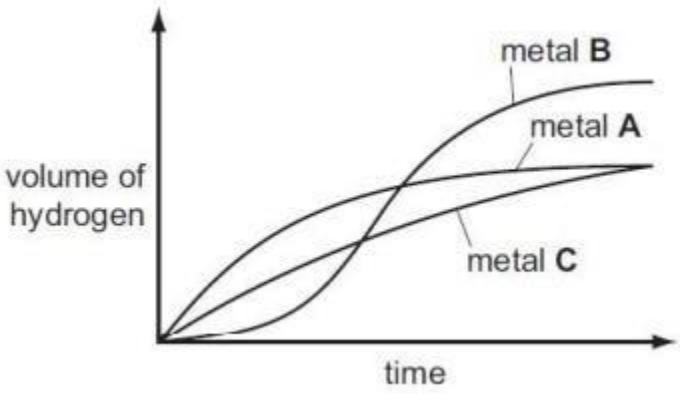
33. Analyze the given statement and explain your understanding using valid scientific reasoning.
    i. The insides of food cans are coated with tin but not with zinc
    ii. Iron in shipwrecks in deep, cold water rusts slowly

34. Electrolysis has made it possible to obtain reactive metals such as aluminum from their ores, which has resulted in significant developments in engineering and technology. State and explain one reason why Aluminium is preferred to iron in many uses.

35. Aqueous copper (II) sulphate is electrolyzed using copper electrodes. The current produced is constant and the anode is weighed at regular intervals. Which graph will be obtained when the mass of anode is plotted against time? Justify your choice using valid reasoning along with equations.



36. Zinc is a very important metal. Zinc is extracted from its ore zinc blende which contains ZnS. Describe using balanced chemical equation how zinc sulphide can be converted into zinc metal.
37. Excess hydrochloric acid was added to powdered zinc. The hydrogen evolved was collected and its volume measured every 20 seconds. The experiments were repeated at the same temperature using the same amount of powdered magnesium and Aluminium.



Identify metals **A, B** and **C** by choosing from zinc, magnesium and aluminum and justify your choice using valid scientific reasoning and appropriate chemical equations.

38. In an experiment to investigate the rate of rusting of steel, three pieces of steel were used. One piece of steel was completely coated with copper, one piece completely coated with zinc and one piece was left uncoated. All three pieces were left exposed to the atmosphere. Which of the three pieces of steel will start to rust faster. Explain your choice.

39. In each reaction, identify the acid, base, conjugate acid, and conjugate base. Then, write which acid/base theory or theories describe the reaction.

    a. $NH_3 + H_2O \rightarrow NH_4^+ + OH^-$
    b. $2NaOH + H_2SO_4 \rightarrow 2H_2O + Na_2SO_4$
    c. $HSO_3^- + CN^- \rightarrow HCN + SO_3^{2-}$
    d. $NH_2^- + H_2O \rightarrow NH_3 + OH^-$

40. Define an acid in terms of the Lewis theory. Deduce, giving a reason, whether NF_3 is able to function as a Lewis acid or as a Lewis base.
41. Silicon (IV) oxide, SiO_2, and Zirconium (IV) oxide, ZrO_2, are both macromolecules. They have similar physical properties but SiO_2 is acidic and ZrO_2 is amphoteric.
    a. State a reagent that reacts with the oxides of both elements.
    b. State a reagent that reacts with only one of the oxides.

42. Soil forms when rock is broken up over many years by the action of rain and the weather. It may be acidic because of the type of rock it came from. But rotting vegetation, and heavy use of fertilizers, can also make it acidic.

    a. Farmers use lime (CaO) to help control acidity in soil. Explain why?
    b. Name one product that will form when it is used.

43. HF and HCl are both acids. They react with water to produce respective ions.

$$HCl + H_2O \rightleftharpoons H_3O^+ + Cl^-$$

$$HF + H_2O \rightleftharpoons H_3O^+ + F^-$$

    a. At equilibrium only 1% of the hydrogen chloride exists as molecules, the rest has formed ions. In the other equilibrium, 97% of hydrogen fluoride exists as molecules, only 3% has formed ions. What does this tell you about the strength of each acid?
    b. How would the pH of the two solutions differ? Explain your answer.
    c. Describe two different methods, one chemical and one physical method, other than measuring the pH that could be used to distinguish the strength of the two acid solutions of the same concentration.

44. Allison has always wanted to start her own carbonated drink company. Recently, she opened a factory to produce her drinks. She wants her drink to "out-fizz" all the competitors. That is, she wants to maximize the solubility of the gas in her drink. What conditions (high/low temperature, high/low pressure) would best allow her to achieve this goal? Justify your choice with valid scientific reasoning.

45. Nitrogen dioxide, oxygen and water react to form dilute nitric acid. Describe how lead (II) nitrate crystals could be prepared from dilute nitric acid and lead (II) oxide.

46. The hydrogen ion has never been found in a sample of water. So how do we explain the properties of acids and bases if this is true?
47. The compound NaOH is a base by all three of the acid-base theories. However, each of the three theories describes what a base is in different terms. Use your knowledge of these theories to describe NaOH as an Arrhenius base, a Brønsted-Lowry base, and a Lewis base.
48. A beaker contains sodium hydroxide solution and 5 drops of universal indicator. To this beaker sulphuric acid was added until no more changes were observed.
    i. Describe how the indicator color changes as the reaction proceeds with respect to the change in pH of the solution?
    ii. Explain the relationship between the changing pH of the solution and the ions in the solution as the sulphuric acid is added to the beaker?

49. The table below lists the pH of one of a pair of solutions, in standard conditions.

    i) Suggest the missing pH of the solutions listed in the table.

Clue	Solution A	Solution B
Solution B has a hydrogen ion concentration about 100 times less concentrated than solution A	pH 5	
Solution B has a hydrogen ion concentration about 1000 times more concentrated than solution A	pH 11	
Solution B has a hydrogen ion concentration about 10 times more concentrated than solution A		pH 10
Solution B has a hydrogen ion concentration about 10000 times less concentrated than solution A		pH 12
Solution A has a hydrogen ion concentration about 10 times less concentrated than solution B	pH 3	

    ii) Identify which of the solutions in (a) is likely to have the most dissociated ions.

    iii) Identify which of the solutions in (a) is likely to have the greatest electrical conductivity and why?

50. A pH indicator or acid-base is a compound that changes color in solution over a range of pH values. Only a small amount of indicator compound is needed to produce a visible color change. State one advantage of using a universal indicator over phenolphthalein indicator in determining the pH of a solution.

Criteria B

1. Indigestion tablets contain calcium carbonate. The tablets work by neutralizing the excess of acid in the stomach. You are provided with 2 different brands of indigestion tablet (F and G), dilute hydrochloric acid and common laboratory apparatus. Plan an investigation to find which brand of indigestion tablet is best at neutralizing acid.
2. Some students investigated whether the pH of an acid changes when it is diluted by mixing the acid with different volumes of water. They drew up a variable table to help them set a fair test. The table below shows how the students diluted their acid.

Volume of the acid (cm^3)	Volume of water (cm^3)	Total Volume (cm^3)
50	0	50
40	10	50
30	20	50
20	30	50

   (a) Why did the students need to have a total volume of $50cm^3$ each time?
   (b) How will the students measure the pH of the diluted acid? Draw up a variable table for the same.
3. Beach sand is a mixture of sand and broken shells (calcium carbonate). Calcium carbonate reacts with dilute hydrochloric acid to form a solution of calcium chloride. Plan an investigation to extract calcium carbonate from beach sand in the form of calcium chloride crystals.
4. Dissolving substances reduces their concentration and hence reduces their environmental impact. Plan an investigation to check how temperature affects the solubility of an ionic compound. For the investigation include an inquiry question, hypothesis for the investigation and the various variables along with how the variables will be manipulated in the given experiment.
5. Design a safe, logical and complete method to investigate how concentration of acids affects its pH
6. The reactivity series of metals provide very important information that can be used to understand the uses of metals in various context. Design a safe, logical and complete method to investigate how the voltage produced in an electrochemical cell can be used to predict and arrange the metals according to their reactivity.
7. Understanding how to control conditions to reduce corrosion helps us to increase the working lifetime of metal objects. Plan an investigation to understand how to limit the corrosion of iron.

Criteria C

1. Read this account of a student's method for extracting the juice from orange peel. She wanted to test the juice to see if it would make a useful indicator.

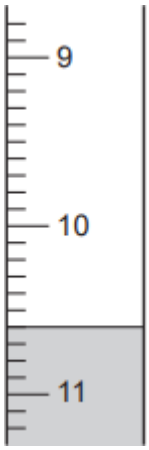
She took four pieces of orange peel and put them into 200 ml of cold water. She stirred the mixture for 10 minutes and then poured the juice into a beaker ready to test on our acids and bases.

Results
She found that our juice seemed very weak. We found it hard to see any color changes.

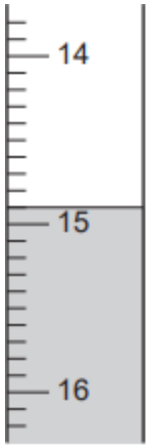
Discuss how you could improve the method so that she gets a more concentrated juice. (Note: You need to include the input and output variables, the aim of the experiment and the step wise procedure you would use).

1. A student investigated an aqueous solution of calcium hydroxide and water. Two experiments were carried out.

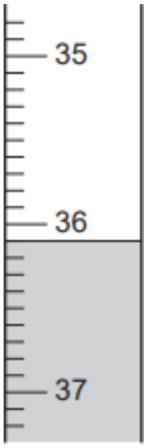
   Experiment 1: By using a measuring cylinder 25 cm^3 of the aqueous solution of calcium hydroxide was placed in a flask. Phenolpkthalein indicator was added to the flask. A burette was filled to the 0.0 cm^3 mark with solution M of hydrochloric acid. Solution M was added slowly to the flask until the colour just disappeared. Use the burette diagram to record the volume in the table and complete the column.



   Experiment 2: Experiment 1 was repeated using a different solution, N, of hydrochloric acid. Use the burette diagram to record the volume in the table and complete the column.



initial



final

Table of results:

burette readings/cm^3	Experiment 1	Experiment 2
final reading		
initial reading	0.0	
difference		

i. State the type of chemical reaction that occurs when hydrochloric acid reacts with calcium hydroxide?
ii. In which experiment was the greater volume of hydrochloric acid used?
iii. Compare the volumes of acid used in Experiments 1 and 2.
iv. Suggest an explanation for the difference in volumes.
v. Predict the volume of hydrochloric acid M that would be needed to react completely if Experiment 1 was repeated with 50 cm^3 of calcium hydroxide solution.
vi. Suggest one change you could make in the experiment to obtain more accurate results.

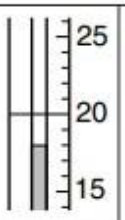
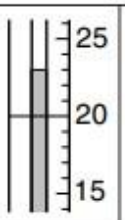
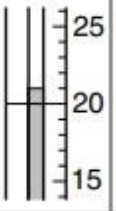
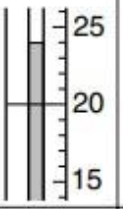
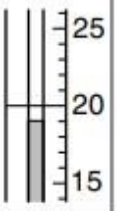
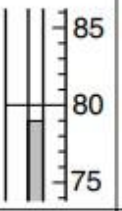
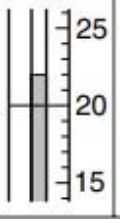
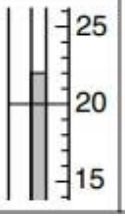
2. An investigation was carried out on the reactions of four different metals. Equal masses of copper, magnesium, iron and zinc were used.

Experiment 1: A 15 cm3 sample of dilute hydrochloric acid was added to each of four boiling tubes. The initial temperature of the acid was measured. Zinc was added to the first tube, iron to the second tube, magnesium to the third tube and copper to the fourth tube.

The maximum temperature reached in each tube was measured and any observations were recorded in the table.

i. Use the thermometer diagrams to complete the results table.

Table of results

metal added	temperature of acid/°C		temperature difference/°C	observations
	initial	maximum		
zinc				gas given off slowly
iron				gas given off very slowly
magnesium				gas given off rapidly: lighted splint pops
copper				no visible reaction

ii. Which metal is most reactive with sulphuric acid?

iii. Give two reasons why you chose this metal.

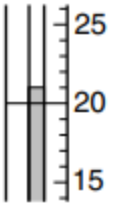
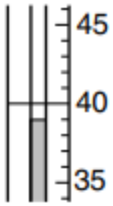
iv. Name the gas given off.

The reaction between magnesium and aqueous copper (II) sulphate was then investigated.

Experiment 2: A 5 cm3 sample of aqueous copper (II) sulphate was measured into a test-tube. The initial temperature of the solution was measured. Magnesium powder was added to the test-tube and the maximum temperature reached was measured.

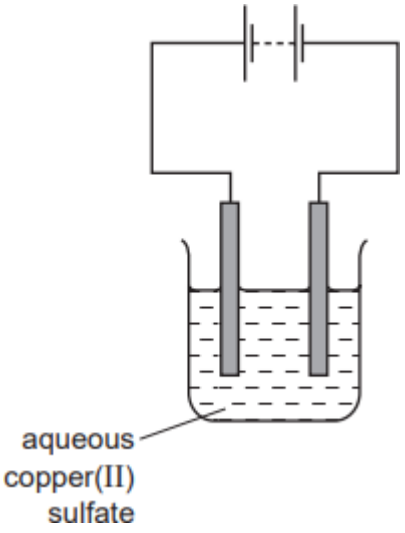
i. Use the thermometer diagrams to complete the results table.

Table of results

initial temperature of aqueous copper(II) sulphate		
maximum temperature reached after magnesium added		

ii. Interpret the results of experiement 1 and 2 to put the four metals in order of reactivity (least to most reactive). Justify your answer with valid scientific reasoning.

3. Electricity was passes through aqueous copper (II) sulfate using inert electrodes as show in the diagram below. Copper was deposited at one of the electrodes.



i. State a suitable material for the electrodes.
ii. At which electrode was copper deposited?
iii. Give one other observation seen during the electrolysis.

The electrode at which copper was deposited was removed at intervals, washed, dried and weighed. The results are shown in the table below:

iv. Suggest how the electrodes was washed?
v. How could the electrode be dried quickly?
vi. Complete the table by calculating the total increase in mass for the remaining time intervals.

Table of results

time / min	mass of electrode / g	total increase in mass / g
0	3.75	0.00
10	4.00	0.25
20	4.25	0.50
30	4.50	
40	4.75	
50	4.90	
60	4.90	
70	4.90	

vii. Plot the points on the graph. Draw a graph with two intersecting straight lines.
viii. Suggest why the last three readings were the same.

Criterion D:

1. *Read the following passage and comment on the given statement:*

Ocean acidification, one of the greatest curses resulting from the considerable development of anthropogenic (environmental pollution originating from human activity) greenhouse gas emissions have environmental and economic impact on a Global scale."

"*Every one of us has a personal relationship with the marine environment*". The oceans provide extraordinary ecosystem services to societies, food, regulation services including moderation of climate (carbon absorption), recreation, provision of vital food, medicines etc. Our coasts provide space to live and directly and indirectly create wealth, including millions of jobs in industries such as fishing, aquaculture and tourism.

Living marine flora and fauna can play a valuable role in the defense of coastal regions i.e. **disturbance prevention**. Marine ecosystems and the presence of organisms in the front line of sea defense can dampen and prevent the impact of tidal surges, storms and floods providing a 'buffering' effect that protects humans from the effects of these destructive perturbations.

Greenhouse gas regulation is vital in regulating the climate of our planet. The seabed has a significant role in this process through its ability to absorb CO_2.

One of the most tangible services provided by the marine environment is the provision of food for human consumption. Plants and animals derived directly from marine biodiversity provide a significant part of the human diet. Fisheries in particular, and the accompanying employment, provide a significant example of the importance of this function.

The oceans are a source of natural raw materials such as medicines, feed for livestock, polysaccharides. The oceans host a range of marine plants and animals creating huge potential to extract chemicals for pharmaceuticals from these organisms. An example includes the extract (arabinosides), collected from the sponge Tethya crypta and used in the treatment of herpes.

Red, brown and green algae provide a source of polysaccharides for a variety of human uses. Seaweeds are important in agriculture as feed for livestock and as compost for farmland. Chiton from shrimp and crab shells is used in agriculture as well as in human food supplements.

Marine biodiversity provides the basis for a wide range of leisure and recreational activities including: (sea) bird watching,rock pooling, beachcombing, sport fishing, recreational diving, and whale-watching. The provision of leisure and recreation results in significant employment opportunities.

Life is becoming harder and harder for the planet's shellfish, a new study has found, thanks to acidifying seawater that gives them softer and softer shells. And since a wide range of ocean predators rely on shellfish for food — from seals and seabirds to whales and humans — this could be the start of an ecological sea change. Untreated chemical waste from industries like oils and greases, acids, release of harmful gases are leading to unbalance in the marine ecosystem. But of all ocean acidification has posed a greater threat. Ocean acidification refers to the increase in acidity of the ocean water. It is caused when the excess CO_2 released due to human use enters the water bodies and combines with water to form carbonic acid. When carbon dioxide (CO_2) mixes with water molecule (H_2O) it forms carbonic acid (H_2CO_3) that then breaks down easily into hydrogen ions (H^+) and bicarbonate (HCO_3^-), those available hydrogen ions bond with other carbonate ions to form more bicarbonate. The problem here is that marine organisms possessing shells (many molluscs, crustaceans, corals, coralline algae, foraminifera's) need available carbonate ions to form the calcium carbonate ($CaCO_3$) that comprises their shells. In essence, ocean acidification is robbing these organisms of their necessary building blocks. Not only does the ocean acidification affect the calcification process but also disrupts the entire ecosystem by killing important marine plants and animals, killing the aesthetic beauty of the ecosystem, making renewable energy production difficult and so on.

2. A sustainable energy future that is fair should recognize the right of every person to benefit equality from the world's energy resources. Each country has access to a range of natural resources to meet some of its energy needs, and a proportion must be met through chemical solutions. Develop a 1200 – word proposal to recommend strategies based on scientific knowledge that could help to end 'energy poverty' in a developing country of choice. Assume a five-year time frame and a hypothetical budget of 10 billion US dollars.
3. **PROJECT GOALS** Honda is working towards making the hydrogen-powered society of the future a reality by studying the entire process of hydrogen production, storage and

supply, including investigation of technologies that will reduce the level of carbon dioxide that is emitted in the hydrogen production process. Like other automotive companies, Honda Motor Company is conducting a significant hydrogen fuel cell research and development program. In fact, Honda delivered the first commercial fuel cell vehicle (FCV) to the City of Los Angeles, California on 2 December 2002, and four additional vehicles were delivered in early 2003. Honda also launched the FCV fleet program in Japan on the same day. Honda's FCX vehicle is the first FCV in the world to be certified by the California Air Resources Board (CARB) and by the Environmental Protection Agency (EPA). A significant milestone in this program was achieved in July 2001, when Honda became the first automobile manufacturer to open a solar-powered hydrogen production and fueling station. The station is located at Honda's research and development center in Torrance, CA. It is being used to:

• Conduct studies on hydrogen production, storage and fueling using renewable energy sources

• Support the company's ongoing fuel cell-powered vehicle development program

Also, Honda is operating the station to help verify more efficient methods for producing hydrogen using renewable energy while, at the same time, gaining insight into the challenges involved in developing hydrogen production and fueling stations for the future.

Figure 1: Honda's hydrogen production, storage and fueling station in Torrance, CA

PROJECT DESCRIPTION In July 2001, Honda R&D Company, Ltd. and U.S. - Based Honda R&D Americas, Inc. opened its first solar powered hydrogen production and fueling station. The station uses an array of photovoltaic (PV) cells to extract hydrogen from water via electrolysis. When power from the PV array is unavailable or insufficient (e.g., due to

cloud cover, etc.), electricity from the grid is used for the electrolysis process. The station is shown in Figure 1. The only other similar facility in the United States that uses solar energy to produce hydrogen for FCVs is the facility at SunLine Transit Agency in Thousand Palms, CA, where hydrogen is generated for fuel cell-powered city buses and small urban vehicles such as golf carts. Honda's 2003 model year FCV builds on the company's FCX-V3 and V4 experimental cars, which were extensively demonstrated, showcased and evaluated in the United States and Japan. Using its FCX-V3 and V4 vehicles, Honda has been participating in the California Fuel Cell Partnership based in Sacramento, CA.

ENVIRONMENTAL ASPECTS AND SAFETY ISSUES Safety was a top priority in the development of the station. Honda engineers worked closely with City of Torrance officials during planning, design and construction. The station was built to standards for hydrogen systems developed by the National Fire Protection Association. In addition, an infrared camera is used to monitor operations at all times. The system is designed to immediately shut down in the event of an earthquake. The Honda fueling station achieves vehicle refueling without special clothing requirements, in contrast to Ford and the Chicago Transit Authority, which require their fueling operators to wear special fire resistant clothing (i.e., Nomex suits) leather gloves and eye protection. Honda designed the station, including hardware and refueling procedures, with maximum safety requirements so that hydrogen fuel may be accepted by society. The refueling operation is easy enough for everyone to use because the station requires the user to go through specific refueling steps, communicated through the touch screen interface panel. Once hydrogen begins flowing into the vehicle, Honda has no special safety rule regarding where the operator should position himself. For example, Chicago requires the operator to leave the area until fueling was completed. At Honda, the operator usually stands by and watches the fueling process. The only weather/environmental condition that Honda has identified during which fueling is not to be done is an actual or expected thunder and/or lightning storm. Since the facility is outdoors, in general, fueling is not done when it is raining.

Discuss and evaluate in detail why Honda has come with so many innovative solutions to build hydrogen powered societies. In your answer briefly **describe** at least two innovative technologies that are been introduced in this case study and what are the environmental impacts of the same**.**

MYP Science Command Terms

Command term	Definition
Analyse	Break down in order to bring out the essential elements or structure. (To identify parts and relationships, and to interpret information to reach conclusions.)
Annotate	Add brief notes to a diagram or graph.
Apply	Use knowledge and understanding in response to a given situation or real circumstances. Use an idea, equation, principle, theory or law in relation to a given problem or issue.
Calculate	Obtain a numerical answer showing the relevant stages in the working.
Classify	Arrange or order by class or category.
Comment	Give a judgment based on a given statement or result of a calculation.
Construct	Display information in a diagrammatic or logical form.
Define	Give the precise meaning of a word, phrase, concept or physical quantity.
Demonstrate	Make clear by reasoning or evidence, illustrating with examples or practical application.
Describe	Give a detailed account or picture of a situation, event, pattern or process.
Design	Produce a plan, simulation or model.
Determine	Obtain the only possible answer.
Discuss	Offer a considered and balanced review that includes a range of arguments, factors or hypotheses. Opinions or conclusions should be presented clearly and supported by appropriate evidence.
Document	Credit sources of information used by referencing (or citing), following one recognized referencing system. References should be included in the text and also at the end of the piece of work in a reference list or bibliography.
Draw	Represent by means of a labelled, accurate diagram or graph, using a pencil. A ruler (straight edge) should be used for straight lines. Diagrams should be drawn to scale. Graphs should have points correctly plotted (if appropriate) and joined in a straight line or smooth curve.
Estimate	Obtain an approximate value for an unknown quantity.
Evaluate	Make an appraisal by weighing up the strengths and limitations.
Explain	Give a detailed account including reasons and causes. (See also "Justify".)
Find	Obtain an answer showing relevant stages in the working.

Formulate	Express precisely and systematically the relevant concept(s) or argument(s).
Identify	Provide an answer from a number of possibilities. Recognize and state briefly a distinguishing fact or feature.
Interpret	Use knowledge and understanding to recognize trends and draw conclusions from given information.
Justify	Give valid reasons or evidence to support an answer or conclusion. (See also "Explain").
Label	Add title, labels or brief explanation(s) to a diagram or graph.
List	Give a sequence of brief answers with no explanation.
Measure	Obtain a value for a quantity.
Organize	Put ideas and information into a proper or systematic order.
Outline	Give a brief account or summary.
Plot	Mark the position of points on a diagram.
Present	Offer for display, observation, examination or consideration.
Recall	Remember or recognize from prior learning experiences.
Select	Choose from a list or group.
Show	Give the steps in a calculation or derivation.
Sketch	Represent by means of a diagram or graph (labelled as appropriate). The sketch should give a general idea of the required shape or relationship, and should include relevant features.

Solve	Obtain the answer(s) using appropriate methods.
State	Give a specific name, value or other brief answer without explanation or calculation.
Suggest	Propose a solution, hypothesis or other possible answer.
Summarize	Abstract a general theme or major point(s).
Verify	Provide evidence that validates the result.
Write down	Obtain the answer(s), usually by extracting information. Little or no calculation is required. Working does not need to be shown.

DATA SHEET
The Periodic Table of the Elements

Group																
I	II										III	IV	V	VI	VII	0
							1 H Hydrogen 1									4 He Helium 2
7 Li Lithium 3	9 Be Beryllium 4										11 B Boron 5	12 C Carbon 6	14 N Nitrogen 7	16 O Oxygen 8	19 F Fluorine 9	20 Ne Neon 10
23 Na Sodium 11	24 Mg Magnesium 12										27 Al Aluminium 13	28 Si Silicon 14	31 P Phosphorus 15	32 S Sulphur 16	35.5 Cl Chlorine 17	40 Ar Argon 18
39 K Potassium 19	40 Ca Calcium 20	45 Sc Scandium 21	48 Ti Titanium 22	51 V Vanadium 23	52 Cr Chromium 24	55 Mn Manganese 25	56 Fe Iron 26	59 Co Cobalt 27	59 Ni Nickel 28	64 Cu Copper 29	65 Zn Zinc 30	70 Ga Gallium 31	73 Ge Germanium 32	75 As Arsenic 33	79 Se Selenium 34	80 Br Bromine 35	84 Kr Krypton 36
85 Rb Rubidium 37	88 Sr Strontium 38	89 Y Yttrium 39	91 Zr Zirconium 40	93 Nb Niobium 41	96 Mo Molybdenum 42	Tc Technetium 43	101 Ru Ruthenium 44	103 Rh Rhodium 45	106 Pd Palladium 46	108 Ag Silver 47	112 Cd Cadmium 48	115 In Indium 49	119 Sn Tin 50	122 Sb Antimony 51	128 Te Tellurium 52	127 I Iodine 53	131 Xe Xenon 54
133 Cs Caesium 55	137 Ba Barium 56	139 La Lanthanum 57 *	178 Hf Hafnium 72	181 Ta Tantalum 73	184 W Tungsten 74	186 Re Rhenium 75	190 Os Osmium 76	192 Ir Iridium 77	195 Pt Platinum 78	197 Au Gold 79	201 Hg Mercury 80	204 Tl Thallium 81	207 Pb Lead 82	209 Bi Bismuth 83	Po Polonium 84	At Astatine 85	Rn Radon 86
Fr Francium 87	226 Ra Radium 88	227 Ac Actinium 89															

140 Ce Cerium 58	141 Pr Praseodymium 59	144 Nd Neodymium 60	Pm Promethium 61	150 Sm Samarium 62	152 Eu Europium 63	157 Gd Gadolinium 64	159 Tb Terbium 65	162 Dy Dysprosium 66	165 Ho Holmium 67	167 Er Erbium 68	169 Tm Thulium 69	173 Yb Ytterbium 70	175 Lu Lutetium 71
232 Th Thorium 90	Pa Protactinium 91	238 U Uranium 92	Np Neptunium 93	Pu Plutonium 94	Am Americium 95	Cm Curium 96	Bk Berkelium 97	Cf Californium 98	Es Einsteinium 99	Fm Fermium 100	Md Mendelevium 101	No Nobelium 102	Lr Lawrencium 103

*58-71 Lanthanoid series
90-103 Actinoid series

Key: a = relative atomic mass; X = atomic symbol; b = proton (atomic) number

The volume of one mole of any gas is 24 dm^3 at room temperature and pressure (r.t.p.).