Chapter 4: Chemical reactions

Pages 89–110

Teacher notes

Introducing the chapter

In Year 9, students studied chemical reactions in terms of the rearrangement of atoms to form new products. Combustion reactions and acid reactions were studied in relation to the Law of Conservation of Mass. This chapter extends this understanding to examine the changes that occur to chemicals as they interact with each other and how this can be used in a range of situations, such as the production of metals, polymers and pharmaceuticals. Future applications, such as aspects of nanotechnology, are also examined. By understanding the types of reactions occurring, the products and the rate at which they are formed can be controlled. The potential hazards of using chemicals are examined in relation to their effects on surrounding systems.

Teacher notes

4.1 Synthesis and decomposition reactions can be represented by equations

Pages 90–91

Teaching tip: simplified chemical equations

Many of the reactions covered in this chapter can be written in a general form. This may help students to better visualise these reactions in a simplified way.

Synthesis

A + B → AB

Decomposition

AB → A + B

Teaching tip: terminology

Although it is not explicitly stated in the student book, it is beneficial to students that they are taught (with examples) that synthesis and decomposition reaction can be labelled as single displacement and double displacement reactions.

Teaching tip: differentiation for advanced students

Whilst many students will accept that decomposition reactions are a type of reaction, more advanced students will ask why the reactions do not occur all the time. Decomposition reactions can be broken into three main types.

• In catalytic decomposition reactions, the reactant will readily break apart and the rate can be increased with the use of a catalyst.

• An electrolytic decomposition requires the use of an electrical current to provide the energy to initiate the reaction.

• In thermal decomposition, direct heat or radiation is used to initiate the reaction.

Irrespective of the initiating factor for the decomposition reaction, energy is always exchanged as a result.

Teaching tip: practice

Students often have difficult with generating balanced chemical equations and so it is best to give them as much opportunity as possible to practise, as it is an essential VCE Chemistry concept.

Follow the ‘Gradual Release of Responsibility Model’. Sometimes referred to as ‘I do it, we do it, you do it,’ this model proposes a plan of instruction that includes demonstration, prompt, and practice.

Additional activity: flowchart

The production of aluminium can be broken into a series of steps that students can cut and paste in to a flow chart. Students should show chemical reactions wherever possible.

1 The bauxite must be crushed into a fine powder and mixed with sodium hydroxide to form a slurry.

2 High pressure and temperatures are used to encourage the aluminium to react with the sodium hydroxide to form sodium aluminate solution. Many other impurities will not dissolve in the caustic soda.

3 The impurities are allowed to settle and are then filtered out.

4 The still-warm sodium aluminate solution is pumped into large tanks and seed crystals of alumina are added. Alumina crystals form around the seed crystals as the solution cools. The increased weight causes the crystals to sink to the bottom, where they can be filtered off.

5 The resulting precipitate is rinsed and dried, eventually producing a fine white powder.

6 The alumina powder is dissolved in cryolite and an electric current is passed through the mixture. The resulting electrolysis produces metallic aluminium.

Going further:

A useful weblink is available on your obook/assess. To access it, click the weblink tile on the Dashboard for this unit.

Teacher notes

4.2 Acid reactions depend on strength and concentration

Pages 92–93

Introducing the topic

Acids react with many different compound and form similar products, always following the same patterns. They can be strong, weak, concentrated or dilute solution.

Teaching tip: prior learning

Students investigated acid reactions in year 9. This content should be revised/pretested before starting.

Teaching tip: strength vs concentration complexity and visualisation

Many students, even at a VCE level, struggle with the concept, as their real world understanding of something concentrated is that it is strong. This misconception must be overcome first.

Get students to draw a strong vs weak solution and a concentrated vs dilute solution. They get students drawing a strong concentrated solution, a weak concentrated solution, a strong dilute solution and a weak dilute solution to visualise these concepts.

Teaching tip: simplified chemical equations

Many of the reactions covered in this chapter can be written in a general form. This may help students to better visualise these reactions in a simplified way.

Acids and metals

acid + metal → salt + H2

acid + metal oxide → metal salt + H2O

acid + metal hydroxide → salt + H2O

acid + metal carbonate → salt + H2O + CO2

Additional activity: chemical equation bingo

Students can make up bingo cards with four to six products from the various chemical equations listed above (e.g. CO2, H2O, HCl, Mg, O2, H2, MgO, CuSO4, NaCl). The reactants of an equation can then be read out. If the student has a product of the equation on their bingo card it can be crossed off (‘the product of a combustion reaction’). When students have crossed off all the chemicals on their list, they should shout ‘BINGO!’.

Additional activity: acid and metal reactions

Many of these reactions have already been experienced by students. A class can be broken into groups to demonstrate an example of each reaction to the rest of the class.

Students should write up a method for each experiment, including the list of equipment they need, the concentrations of the chemicals and the safety hazards to be aware of (they may use previous experiments as a guide). Each group should present their experiment, together with a balanced equation and a generalised equation for the reaction.

Possible reactions students could use are detailed below.

Acids and metals

• Adding magnesium ribbon to 1 M HCl will produce hydrogen and magnesium chloride.

• The ‘pop test’ from earlier in this chapter will demonstrate the production of hydrogen.

Acids and metal oxides

• A rusty nail and a drop of 1 M HCl (in the presence of universal indicator)

Acids and metal hydroxides

• 1 M HCl and 1 M NaOH (in the presence of universal indicator)

Acids and metal carbonates

• making sherbet (teaspoon citric acid,  teaspoon bicarbonate soda, icing sugar and jelly crystals)

OR

• vinegar and bicarbonate soda

• students can test for the presence of carbon dioxide using a lit splint.

Additional activity: research acids

Get students to research where common acids are found naturally and share them with the class – for example, stomach acid in HCL.

One example may include:

The most common acid found in the environment is carbonic acid. A very weak acid it is formed when carbon dioxide is dissolved in the water according to the reaction:

CO2 + H2O → H2CO3

Although this acid plays an important role in controlling breathing in humans, it can cause a pH of 5.5 by the time rain falls to the ground. This may seem strong enough to do some damage; however, it is the acids formed by sulfur and nitrogen gases in pollution that cause much greater damage to exposed metal surfaces, limestone and plant life.

Going further:

A useful weblink is available on your obook/assess. To access it, click the weblink tile on the Dashboard for this unit.

Teacher notes

4.3 The solubility rules predict the formation of precipitates

Pages 94–95

Introducing the topic

Solubility rules will predict if a product in an ionic reaction (double displacement reaction) will form a solid (s) or remain dissolved in solution (aq – aqueous).

Additional activity: predicting the products of precipitation reactions

Before completing the precipitation experiment, ask students to predict whether products will be soluble or insoluble according to the solubility rules, see below.

Lower level students can simply say ‘solid’ or ‘aqueous’, while higher level students can write out the balanced chemical equation, balance it and assign states before conducting the experiment.

This will form their hypothesis for the experiment.

Teaching tip: simplified chemical equations

Many of the reactions covered in this chapter can be written in a general form. This may help students to better visualise these reactions in a simplified way.

Precipitation

soluble + soluble → insoluble + soluble

Additional activity: research

Ask students to research where precipitation reactions are used in society. They must then report back to the class. Some examples include:

• making pigments — some paints such as Prussian blue are created through a chemical reaction between ferric chloride and potassium ferrocyanide that causes an insoluble pigment to be formed; this pigment is then dried and can be used

• testing for the presence of contaminants in water — many commercially produced tests use the principle of adding a compound to water that will react with possible contaminants, causing them to precipitate (giving a positive result for contamination)

• identifying blood types — if the wrong blood type is transfused into a person, their blood will clot. Precipitation reactions are used to identify the blood type of a person before transfusion

• softening hard water — water containing calcium ions and magnesium ions is said to be ‘hard’. This interferes with the use of soap when cleaning. Sodium carbonate can be used to cause the metal ions to precipitate. The solids can then be filtered out, making the water more appropriate for use

• metal purification — many commercial companies use precipitation to separate metals from their naturally occurring ores.

Solubility rules

Many students have difficulty understanding the rules of solubility. Many students need to be encouraged to approach this in a systematic manner.

**Nitrates (NO3-)** all soluble

**Chlorides (Cl-)** all soluble **EXCEPT** Ag+, Hg2+, (Pb2+ slightly soluble)

**Bromides (Br-)** all soluble **EXCEPT** Ag+, Hg2+, Pb2+

**Iodides (I-)** all soluble **EXCEPT** Ag+, Hg2+, Pb2+

**Sulfates (SO4 2-)** all soluble **EXCEPT** Ba2+, Pb2+ (Ca2+ slightly soluble)

**Carbonates (CO3 2-)** all **In**soluble **EXCEPT** Na+, K+, NH4+ (Li+ slightly soluble)

**Phosphates (PO4 3-)** all **In**soluble **EXCEPT** Na+, K+, NH4+ (Li+ slightly soluble)

**Hydroxides (OH-)** all **In**soluble **EXCEPT** Na+, K+, NH4+, Li+ (Ba2+, Ca2+ slightly soluble)

**Sulfides (S2-)** all **In**soluble **EXCEPT** Li+, Na+, K+ and the Group 2 Sulfides

Going further:

A useful weblink is available on your obook/assess for Balancing Chemical Equations. To access it, click the weblink tile on the Dashboard for this unit.

Teacher notes

4.4 Combustion reactions between hydrocarbons and oxygen produce carbon dioxide, water and energy

Pages 96–97

Introducing the topic

Combustion reactions form some of the most important reactions for our society. Not only do they produce large amounts of energy but they also produce carbon dioxide which may be harmful to the environment.

Teaching tip: simplified chemical equations

Many of the reactions covered in this chapter can be written in a general form. This may help students to better visualise these reactions in a simplified way.

Combustion

fuel + O2 → H2O + CO2 + energy

metal + O2 → metal oxide + energy

Additional activity: combustion discussion

A discussion of burning fuel provides an excellent opportunity to brainstorm the use of combustion reactions in society. Ask students where chemical reactions are used to generate energy and create a conversation around other products that are produced.

This may lead into a conversation on renewable and no-renewable sources of energy. Biofuels, when combusted, do not contribute to greenhouse gases and the CO2 released from the process is just the CO2 which has already come from the atmosphere. Fossil fuels, however, have been storing CO2 for millions of years and so when they are burnt will increase the concentration of CO2 in the atmosphere.

Additional activity: balanced chemical equations practice

Allow students to practise writing the products of balanced chemical equations and assigning states. If hydrocarbons (specifically alkanes) are used, there is a pattern in the complexity of balancing where the hydrocarbons which have an even number of carbons are trickier to balance.

Get the more advanced students to come up with a hypothesis which explain why.

Going further:

A useful weblink is available on your obook/assess. To access it, click the weblink tile on the Dashboard for this unit.

**BBC Bitesize: Products and Effects of Combustion**

<http://www.bbc.co.uk/education/guides/z6xbkqt/activity>

Teacher notes

4.5 Polymers are long chains of monomers

Pages 98–99

Introducing the topic

The concept of polymers consisting of a chain of smaller units (called monomers) is an important part of senior chemistry and biology. It explores the structure, bonding and properties of various plastics.

Teaching tip: prior learning

Link this topic to electron configuration and covalent bonding when discussing the structures of polymers and that no metals are found in these structures.

Teaching tip: real world applications/ brainstorming

Start a discussion with students by getting them to look around and identify the polymers that they can see, this can be turned into a list. Students can they start to investigate which are recyclable and non-recyclable, which are cross-linked and linear, which are thermosetting and thermos plastic.

If possible, get them to identify the plastic and look for trends between the type of plastic and the properties identified above.

This can be transformed into a mind map.

Teaching tip: bubble wrap buildings

Introduce students to a building made of bubble wrap and ask them to identify the advantages and disadvantages. Students share these responses with the class.

Advantages/ Disadvantages:

Ethylene tetrafluoroethylene is a 250 micrometre-thick lightweight polymer. Stretching it thin and then folding it creates small air bubbles within the material that lets light pass through whilst trapping and storing heat. This provides insulation much like that of a ‘doona’ that is also fire resistant, shatter-proof and can be easily cleaned. The light weight of the panels means the support framework is also lighter and hence easier to construct than traditional glass panels. The overall effect is much like that of a greenhouse with 90% of the heat being trapped and recycled into heating the pools inside. One of the disadvantages of this material is that it transmits sound at a greater level than glass. This can make it very noisy when it rains as the air pockets in the ethylene tetrafluoroethylene can act as mini drums, magnifying the sound.

Additional activity: modelling polymers

Paper chains can be used to represent linear polymers that form a long chain. Every tenth link in the chain can be a different colour, representing the nitrogen atom in nylon. Branches can hang off this link.

The cross-linked polymer can be made using a series of rubber bands. The bands can be folded over a paperclip with the two end loops hanging off together. A second rubber band can be passed through the loops of the first band and folded over. The third band passes through the loops of the second and so on. This will create a chain of loops that will be elastic. The ends of the chain can be tied off with a small strip of elastic. This elastic can also be used to link several such chains together, representing the elastic lattice nature of these polymers.

The paper chain can also be called a ‘thermosetting polymer’, which does not change shape when heated but can char.

The elastic bands can also represent thermoplastic polymers (or elastomers) because they spring back into shape when stretched.

It is often important for students to link the theory to everyday items. Ask students to bring in an item they think is made of nylon and ask them to explain the properties of their item in terms of the properties of nylon. This creates relevance in the study of chemistry and provides an opportunity to discuss possible careers in chemistry.

Going further:

A useful weblink is available on your obook/assess. To access it, click the weblink tile on the Dashboard for this unit.

Teacher notes

4.6 Temperature, concentration, surface area and stirring affect reaction rate

Pages 100–103

Introducing the topic

This section explores how energy is used and produced in chemical reactions. It investigates the effect that various effect have on the rate of a chemical reaction. It is important to revise the particle model for students to understand the collision theory.

Teaching tip: real world rates of reaction

A discussion of burning fuel provides an excellent opportunity to introduce rates of reaction. A campfire can be used as an example. The rate at which a fire burns (indicated by how hot it is) can be increased by:

• adding more wood or blowing on the fire (increasing the concentration of reactants)

• chopping the wood into smaller pieces (increasing the surface area of the reactants)

• starting the fire on a hot day (increasing the temperature).

These general principles can be revisited in the next section of this chapter.

Teaching tip: rates of reaction jigsaw activity

This is an ideal topic for a jigsaw activity. A class can be broken into groups, with each group to research one of these methods.

Each student should write down what their group discovers. When finished, one student from each group reports back to a second group to describe their research.

Together, the second group should discuss how the movement of particles can explain the first group’s findings.

The rusting of an iron bridge can be prevented by a coat of paint, which provides a barrier against the oxygen needed for the oxidation process. Alternatively, key parts of a bridge (such as bolts) can be galvanised before they are used. This provides a protective coating of zinc over the bolt, preventing damage.

Bread is made with yeast. Yeast undergoes respiration, producing carbon dioxide. If the yeast in ‘rising bread’ is kept warm, it will respire faster, producing more carbon dioxide for the bread to rise faster.

To speed up the oxidation of alcohol to make vinegar, the mixture can be heated and extra oxygen mixed through.

To increase the combustion of fuel in a rocket engine, extra oxygen can be added.

The activity of a pain-killing drug can be increased by having a stronger concentration of the drug.

Reactions can be increased by

• increasing the concentration of the reactants (more particles to collide and react)

• increasing the temperature of the reactants (particles move faster and collide more often)

• adding a catalyst (helps the particles to meet)

• decreasing the size of the reactant particles (greater surface area for a reaction to occur)

• stirring the mixture (helps the particles meet).

Teaching tip: real world rates of reaction analogies

In getting students to understand the reasons why industry needs to speed up or slow down a chemical reaction, they can brainstorm and share an everyday examples where they needed to speed up. Some examples include:

• In a hurry to get to school? Crush the multivitamin so that it dissolves faster.

• Really bad headache? Crush the aspirin or Panadol tablet so that it dissolves or is absorbed faster.

• Bath salts will dissolve faster in a hot bath than in a warm bath.

• A fire will light quicker and be hotter if it has easy access to oxygen.

• Closing a door behind you when escaping from a fire will make the fire burn slower.

• Painting over a scratch on a bike will prevent the bike from rusting.

• Chewing food will speed up the rate at which it is digested.

• High-octane fuel has a higher concentration of burnable fuel. Thus, the combustion reactions in an engine will be more effective.

Additional activity: designing your own experiment

Students design an experiment to discover how to make an alka-seltzer tablet dissolve faster. Students are given a demonstration of an alka-selzer tablet dissolving in 100mL of water. The teacher must record the temperature of the water and time how long it takes the tablet to dissolve. Students record this information in the demonstration section below:

Demonstration

Materials:

• 1 alka-seltzer tablet

• 250mL beaker

• 100mL measuring cylinder

• 100mL water

• Thermometer

• Stop watch

Method:

1 Place 100mL of water in the beaker.

2 Measure the temperature of the water and record this on your handout, below.

3 (Have the stop watch ready) Place the alka-seltzer tablet in the water and time how long it takes to dissolve.

4 Record your results on your handout, below.

Temperature of the water:

Time taken to dissolve:

What did you observe happening?

Student Investigation

What If?

• What if warm water was used?

• What if cold water was used?

• What if the tablet was broken up?

• What if 200mL of water was used?

• What if 50mL of water was used?

You may choose from the following materials:

• Kettle

• Ice

• Mortar and pestle

• Butter knife

• 200mL measuring cylinder

• 1 alka-seltzer tablet

• 250mL beaker

• 100mL measuring cylinder

• 100mL water

• Thermometer

• Stop watch

They must then design, carry out and write up their experimental report using their knowledge of the rates of chemical reaction in a poster format, as per new VCAA Chemistry assessment guidelines.

Additional activity: kinaesthetic modelling activities

How can you speed up the rate of a chemical reaction?

**Temperature**

Everything around us is made up of moving particles. In solids, the particles are vibrating; in liquids, they are rolling over each other; and in gases, there is little attraction between them so they bounce around in the available space. This then extends to temperature. Hot particles move faster than slow particles. Get students to walk and then speed walk in straight lines around the room to see how often they meet another student.

**Increase the surface area**

The concept of surface area can be easily demonstrated using small building blocks (like Lego). The blocks should be a mix of single cubes, double cubes or larger ones. Draw a template of a single square. This can then be duplicated until a grid is formed (like graph paper).

The students can then compare how many squares it takes to cover four single blocks compared with the four blocks jointed together. Students should realise the volume (and hence the mass) is constant; however, the number of squares reflects the surface available for the reaction to occur.

**Increasing the concentration and/or temperature**

This can be demonstrated by students moving around a set area. Measure and mark a square 3 m × 3 m on the ground. This is the set volume. Place two students (molecules) in the square and ask them to move around randomly. (Every time they bump into each other, a reaction will occur.) Then increase the concentration by placing four students (molecules) in the square. The number of collisions will increase, representing the increase in the rate of the reaction.

An increase in temperature can be represented by the students moving at a faster pace as they move around the square.

**Stir and mix – use a catalyst**

This activity is dependent on the atmosphere of the class. Teachers should use their judgement to determine whether this activity is appropriate.

Stirring and mixing can be demonstrated using the activity above. The 3 m × 3 m square is measured out on the ground and two or four students are placed in the square and told to move around to represent molecules moving in a set volume. To demonstrate mixing, when the students move to the outer reaches of the square, other students placed around the square can gently push them towards the centre of the square. This should increase the number of collisions between the two (or four) students (molecules), demonstrating an increase in the rate of the reaction.

The effectiveness of a catalyst can be demonstrated by placing a responsible student (or teacher) in the square to pull the moving molecules towards each other. The catalyst should not chase the students; however, when a student is within range they should hold on to them until a second student is in range and then cause them to bump gently into each other. The catalyst should then release all molecules and start again. This is to demonstrate that a catalyst must be in contact with the molecules before being activated.

Developing an understanding of the movement of molecules is difficult for many students because they must imagine the movements and reactions of things too small to see. Kinaesthetic activities, such as those described above, can assist in developing the students’ understanding of such concepts.

Going further:

Many useful weblinks are available on your obook/assess. To access it, click the weblink tile on the Dashboard for this unit.

Teacher notes

4.7 Catalysts increase the rate of a reaction

Pages 104–105

Introducing the topic

Catalysts increase the rate of a chemical reaction without being used up. They can therefore be re-used and are essential in chemical industry, as it allows reactions to occur at an optimal speed to produce chemical products such as medicines at a rate which satisfies consumer need.

Teaching tip: terminology

It is important to use the correct terminology when discussing these concepts. It is incorrect to say ‘catalysts do not take part in the reaction’. Catalysts, such as enzymes, must be in contact with the reactants in order to speed up the rate of the reaction. Therefore, they do take part in the reaction. They do not, however, get used up in the reaction.

Differentiation

Higher level students would benefit from looking at chemical rate diagrams for endothermic and exothermic reactions. On these rate diagrams they must draw the effect of a catalyst as lowering the activation energy of a chemical reaction (i.e. the energy required to break reactant bonds) and explain why this happens.

The idea of reversible reactions is an important concept to introduce to students at this level because it leads into equilibrium, which is often a part of senior chemistry studies. Reversible reactions occur in closed systems where the amount of reactants is limited and the products are not removed.

Many reactions start with a large number of reactants and little product. As the reactions progress, the amount of reactants decreases and the number of products increases. Some products undergo spontaneous breakdown so that the reactants reform. This is reversal. As the reaction continues, the amount of product being formed will eventually be equal to the amount being reversed. This is the concept of chemical equilibrium. A simple analogy is walking the wrong way on an escalator. You walk forwards at the same speed as the escalator is moving backwards. Both you and the escalator are moving, but you are not going anywhere.

Additional activity: experiment 4.7 extension

As a fun additional aspect of Experiment 4.7, if you add a small squirt of dishwashing detergent and two drops of food dye before adding the manganese dioxide powder, the bubbles that are generated during the experiment will be captured in a colourful stream of bubbles.

This experiment is referred to as the ‘Foam Column’ or ‘Elephant’s Toothpaste’.

There are many youtube videos which demonstrate this concept.

There is a disadvantage in a school, in that the hydrogen peroxide used is of a lower concentration. The higher the concentration, the more bubbles produced and the better the effect. The videos use high concentration chemical.

Additional activity: iodine clock experiment

This is another great experiment to show to students, perhaps in a youtube video, as it can be lengthy to set-up.

It demonstrates higher concentrations reacting faster and lower concentrations taking longer to react.

Going further:

A useful weblink is available on your obook/assess. To access it, click the weblink tile on the Dashboard for this unit.

Iodine Clock: <https://www.youtube.com/watch?v=_qhYDuJt8fI>

Elephant’s Toothpaste: <https://www.youtube.com/watch?v=p1eG2y2mn54>

Teacher notes

4.8 Green chemistry reduces the impact of chemicals on the environment

Pages 106–107

Introducing the topic

Chemists use green chemical principals to reduce the amount of pollutants and waste generated in chemical reactions. They also do this to reduce the amount of hazardous waste and create a safer and cleaner world.

Additional activity: brainstorm

Get students to brainstorm the everyday items that they use which are produced in chemical reactions or harm the environment.

For every item that they brainstorm, another student must propose a method of reducing this waste or improving this process.

Additional activity: research

The use of chemicals previously thought to be safe is constantly being revised by government scientists. Students can research some of these chemicals, including those listed below, to discover their original uses and the reasons behind the review of their use.

• thalidomide

• asbestos

• benzene

• chlorobenzidine

• DDT

Additional activity: informational poster

Students must generate a poster of one ‘non-green’ chemical product and create an informational poster outlining the hazards involved, where the products end up (i.e. waste) and how everyone can adjust/improve their daily practices in order to use more ‘green’ chemicals or reduce the waste.

Going further:

A useful weblink is available on your obook/assess. To access it, click the weblink tile on the Dashboard for this unit.