# DOT POINT

## NSW CHEMISTRY MODULES 5 TO 8

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# Contents

## Words to Watch

**account, account for** State reasons for, report on, give an account of, narrate a series of events or transactions.

**analyse** Interpret data to reach conclusions.

**annotate** Add brief notes to a diagram or graph.

**apply** Put to use in a particular situation.

**assess** Make a judgement about the value of something.

**calculate** Find a numerical answer.

**clarify** Make clear or plain.

**classify** Arrange into classes, groups or categories.

**comment** Give a judgement based on a given statement or result of a calculation.

**compare** Estimate, measure or note how things are similar or different.

**construct** Represent or develop in graphical form.

**contrast** Show how things are different or opposite.

**create** Originate or bring into existence.

**deduce** Reach a conclusion from given information.

**define** Give the precise meaning of a word, phrase or physical quantity.

**demonstrate** Show by example.

**derive** Manipulate a mathematical relationship(s) to give a new equation or relationship.

**describe** Give a detailed account.

**design** Produce a plan, simulation or model.

**determine** Find the only possible answer.

**discuss** Talk or write about a topic, taking into account different issues or ideas.

**distinguish** Give differences between two or more different items.

**draw** Represent by means of pencil lines.

**estimate** Find an approximate value for an unknown quantity.

**evaluate** Assess the implications and limitations.

**examine** Inquire into.

**explain** Make something clear or easy to understand.

**extract** Choose relevant and/or appropriate details.

**extrapolate** Infer from what is known.

**hypothesise** Suggest an explanation for a group of facts or phenomena.

**identify** Recognise and name.

**interpret** Draw meaning from.

**investigate** Plan, inquire into and draw conclusions about.

**justify** Support an argument or conclusion.

**label** Add labels to a diagram.

**list** Give a sequence of names or other brief answers.

**measure** Find a value for a quantity.

**outline** Give a brief account or summary.

**plan** Use strategies to develop a series of steps or processes.

**predict** Give an expected result.

**propose** Put forward a plan or suggestion for consideration or action.

**recall** Present remembered ideas, facts or experiences.

**relate** Tell or report about happenings, events or circumstances.

**represent** Use words, images or symbols to convey meaning.

**select** Choose in preference to another or others.

**sequence** Arrange in order.

**show** Give the steps in a calculation or derivation.

**sketch** Make a quick, rough drawing of something.

**solve** Work out the answer to a problem.

**state** Give a specific name, value or other brief answer.

**suggest** Put forward an idea for consideration.

**summarise** Give a brief statement of the main points.

**synthesise** Combine various elements to make a whole.

## What the book includes

This book provides questions and answers for each dot point in the NSW Chemistry Stage 6 Syllabus for each module in the Year 12 Chemistry course:

- Module 5 Equilibrium and Acid Reactions
- Module 6 Acid/Base Reactions
- Module 7 Organic Chemistry
- Module 8 Applying Chemical Ideas

## Format of the book

The book has been formatted in the following way:

**1.1 Subtopic from syllabus.**

**1.1.1 Assessment statement from syllabus.**

**1.1.1.1** First question for this assessment statement.

**1.1.1.2** Second question for this assessment statement.

The number of lines provided for each answer gives an indication of how many marks the question might be worth in an examination. As a rough rule, every two lines of answer might be worth 1 mark.

## How to use the book

Completing all questions will provide you with a summary of all the work you need to know from the syllabus. You may have done work in addition to this with your teacher as extension work. Obviously this is not covered, but you may need to know this additional work for your school exams.

When working through the questions, write the answers you have to look up in a different colour to those you know without having to research the work. This will provide you with a quick reference for work needing further revision.

Module 5 Equilibrium and Acid Reactions

Module 6 Acid/Base Reactions

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## Module 7 Organic Chemistry

**INQUIRY QUESTION**

How do we systematically name organic chemical compounds?



**INQUIRY QUESTION**

How can hydrocarbons be classified based on their structure and reactivity?



**INQUIRY QUESTION**

What are the products of reactions of hydrocarbons and how do they react?



**Dot Point** **Page**

**INQUIRY QUESTION**

How can alcohols be produced and what are their properties?



**INQUIRY QUESTION**

What are the properties of organic acids and bases?



**INQUIRY QUESTION**

What are the properties and uses of polymers?

**Dot Point** **Page**

## Module 8 Applying Chemical Ideas

**INQUIRY QUESTION**

How are the ions present in the environment identified and measured?



**INQUIRY QUESTION**

How is information about the reactivity and structure of organic compounds obtained?



**INQUIRY QUESTION**

What are the implications for society of chemical synthesis and design?

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# MODULE 5

## Equilibrium and Acid Reactions


In this module you will:

- Understand that chemical systems can be open or closed and can include physical changes and chemical reactions.
- Describe the characteristics of a closed system at equilibrium.
- Investigate the effects of changes in temperature, concentration of chemicals and pressure on equilibrium systems.
- Learn how to predict these changes using Le Châtelier's principle.
- Analyse quantitative relationships between reactants and products in equilibrium reactions to determine the value of the equilibrium constant.
- Use equilibrium constant values to predict the equilibrium position and determine whether or not a precipitate will form, calculate the concentrations of ions in a saturated solution at equilibrium and calculate the solubility of an ionic compound.
- Focus on processing data to determine patterns and trends and thus solve problems.
- Be able to communicate scientific understanding of ideas about equilibrium.

## 5.1 Static and dynamic equilibrium.

**INQUIRY QUESTION**

What happens when chemical reactions do not go to completion?

**5.1.1 Conduct practical investigations to analyse the reversibility of chemical reactions, for example:**

- **Cobalt(II) chloride hydrated and dehydrated.**
- **Iron(III) nitrate and potassium thiocyanate.**
- **Burning magnesium.**
- **Burning steel wool.**

**5.1.1.1** Distinguish between reversible and irreversible reactions, including examples of each.

**5.1.1.2** Explain the meaning of the terms:

(a) Reversible reaction.

(b) Equilibrium.

(c) Relate these terms (reversible reaction and equilibrium) to the synthesis of ammonia from hydrogen and nitrogen.

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**5.1.1.3** You investigated the hydration and dehydration of cobalt chloride.

$CoCl_2 + 6H_2O(l) \rightleftharpoons CoCl_2.6H_2O$

Strips of paper can be impregnated with cobalt chloride and stored in a desiccator.

A strip of blue cobalt chloride paper is taken out of a desiccator and placed on a clean, dry Petri dish.

Another strip of pink cobalt chloride paper is taken off a damp paper towel and placed on another clean, dry Petri dish.

The two strips are left on the bench in the room and observed.

(a) What effect does a desiccator have on cobalt chloride paper? ..........

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(b) Predict what will happen to the two strips of cobalt chloride paper. ..........

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(c) Research uses of cobalt chloride paper. ..........

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**5.1.1.4**

(a) Name the process that occurs when you burn a substance such as magnesium or steel wool.

..........

(b) Did you find that combustion reactions could be reversed? ..........

..........

**5.1.1.5** Some chemical reactions are reversible.

Write symbolic equations for the following reversible reactions.

(a) Sulfur dioxide + oxygen $\rightleftharpoons$ sulfur trioxide

..........

(b) Nitrogen + hydrogen $\rightleftharpoons$ ammonia

..........

(c) Nitrogen dioxide $\rightleftharpoons$ dinitrogen tetroxide

..........

(d) Phosphorus pentachloride $\rightleftharpoons$ phosphorus trichloride + chlorine

..........

(e) Hydrogen + iodine $\rightleftharpoons$ hydrogen iodide

..........

## 5.1.2 Model static and dynamic equilibrium and analyse the differences between open and closed systems.

### 5.1.2.1

(a) Why are equilibrium situations described as dynamic rather than static?

(b) Each of the following situations would have constant macroscopic properties. Classify each as being in either steady state, static equilibrium or dynamic equilibrium.

(i) A Bunsen burner turned to the hot flame and burning steadily.

(ii) A tank with water entering at the same rate as it is running out through the tap.

(iii) A chemical reaction shown by the equation $A \rightleftharpoons B$, where [A] and [B] are constant but not equal.

### 5.1.2.2

These diagrams show an attempt to model a chemical reaction, in aqueous solution, at equilibrium. Explain how these activities provide a model of equilibrium.



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**5.1.2.3**

(a) Explain what is meant by a model in chemistry. ..........

(b) Describe how you modelled equilibrium. ..........

**5.1.2.4**

(a) Outline some advantages of using models in chemistry. ..........

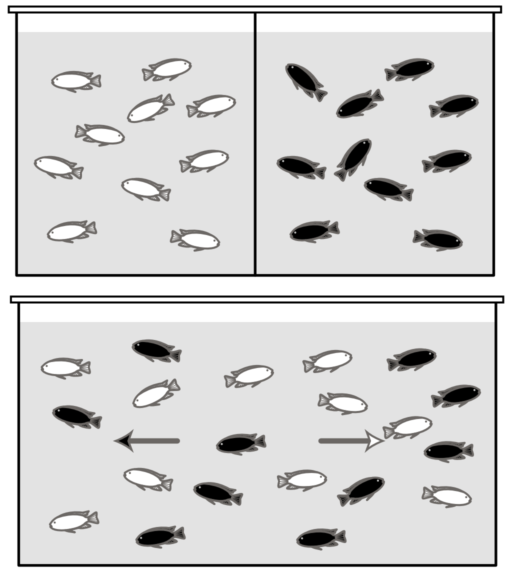
(b) Outline some limitations of using models in chemistry. ..........

**5.1.2.5** Describe a model of equilibrium that you have used. Was your model useful? Did it help explain the concept of equilibrium? Did it generate research?

**5.1.2.6** What is meant by static equilibrium? Give two examples of static equilibrium.

**5.1.2.7** Distinguish between an open and a closed system. Illustrate your answer.

**5.1.2.8** In the classroom, a large oblong fish tank was divided by a partition into two equal halves. Students placed 10 small, white fish in the water on one side of the tank and 10 small, black fish in the other side. The partition was removed and the fish began to swim from one side to the other.



(a) Explain why the second diagram can be considered as showing a reversible reaction which has reached equilibrium.

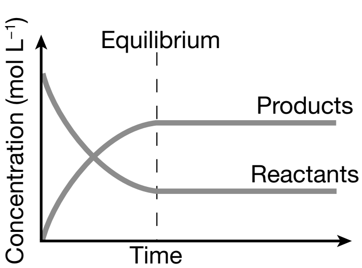
**(b)** If one black and one white fish jump out of the tank, can this still be an equilibrium situation? Explain.

**5.1.2.9**

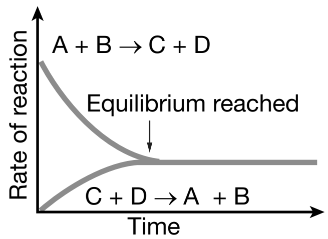
(a) Outline the properties/characteristics of a system in chemical equilibrium.

(b) The following graphs illustrate two of the characteristics of a system at equilibrium. Outline the characteristic each graph illustrates.

(i)




(ii)

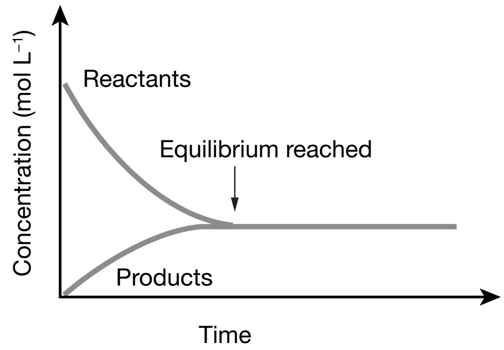



Graph (i)

Graph (ii)

(c) Look at the graph shown and compare it with the two graphs in (b) above.

Does this graph represent a characteristic of all systems at equilibrium. Justify your answer.

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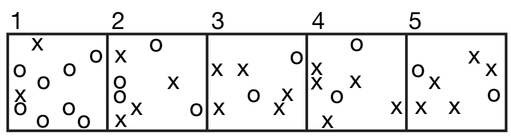
**5.1.2.10** In the following series of diagrams, molecules of $NO_2(g)$ (shown as o) are reacting to produce $N_2O_4(g)$ (shown as x) and eventually the two gases reach equilibrium: $2NO_2(g) \rightleftharpoons N_2O_4(g)$.




(a) Identify the stage at which this system reaches equilibrium. Justify your choice**.**

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(b) Is this a physical or chemical equilibrium? Explain. ..........................................................................................

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**5.1.2.11** When a reaction goes to completion, all of the reactants are used up. Explain why this never happens in a system at equilibrium.

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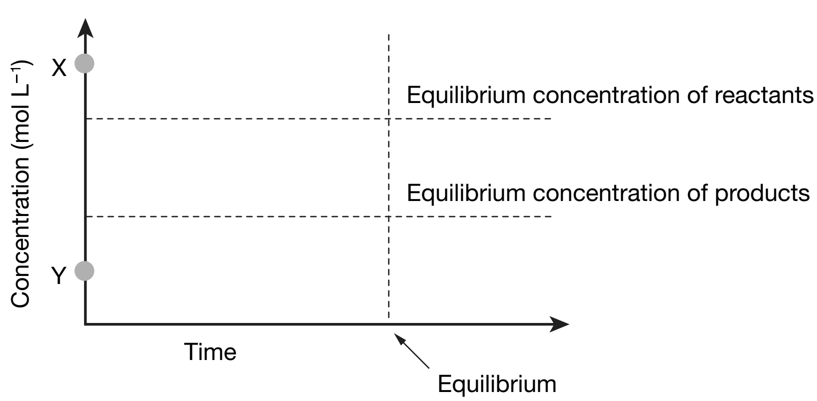
**5.1.2.12** Sketch curves on the following axes to show how the concentration of reactants and products is likely to change as a system approaches equilibrium. Point X shows the original concentration of reactants and point Y shows the original concentration of products.

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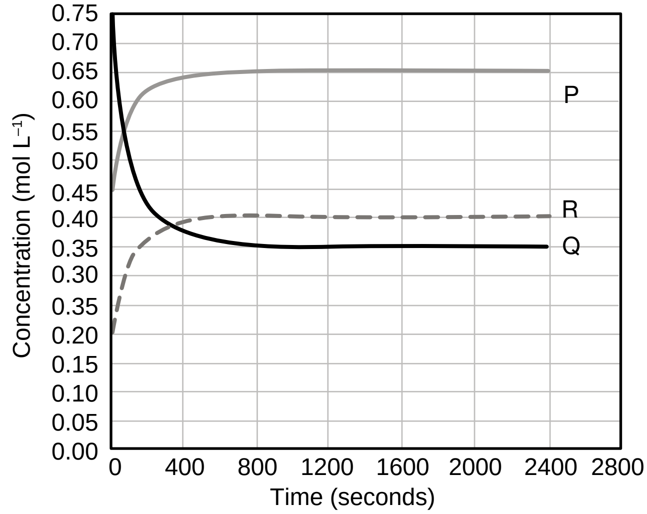
**5.1.2.13** The graphs show changes in concentration of three species involved in a chemical reaction.




(a) Calculate the change in concentration of each of the species involved.

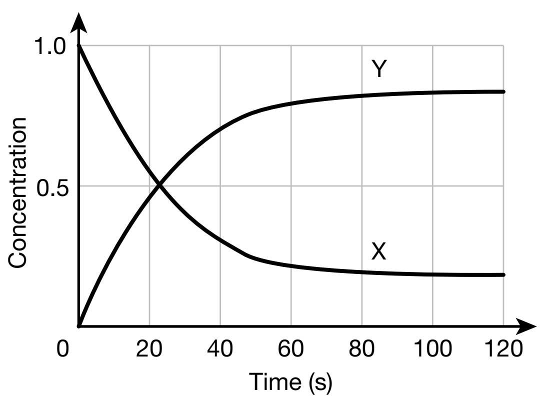
(b) Deduce an equation for the reaction shown by these graphs.

(c) At what time is equilibrium reached? Explain how you know.

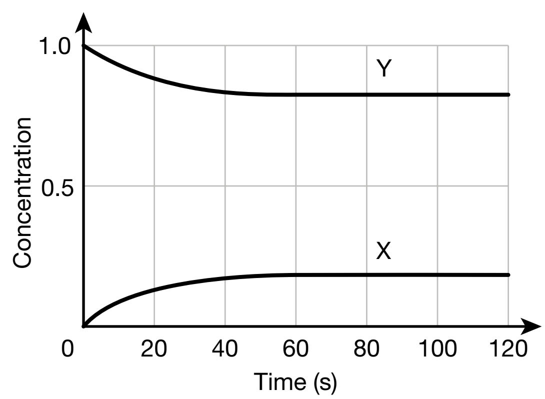
(d) At equilibrium, are the concentrations of the reactants and products the same?

**5.1.2.14** The two graphs below illustrate a simple reversible reaction, X $\rightleftharpoons$ Y. In one graph the chemist starts with only chemical X present in the sealed reaction vessel. In the other graph the reaction commences with only chemical Y present. In each case the reaction is carried out under the same conditions. Account for similarities and differences in the shapes of the two graphs.

(a)




(b)

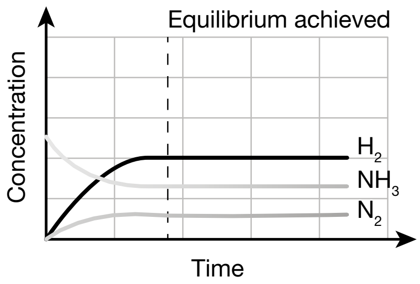


**5.1.2.15** Nitrogen and hydrogen react to form ammonia which decomposes to form hydrogen and nitrogen gas. In a closed container, under constant conditions, this mixture will reach equilibrium.

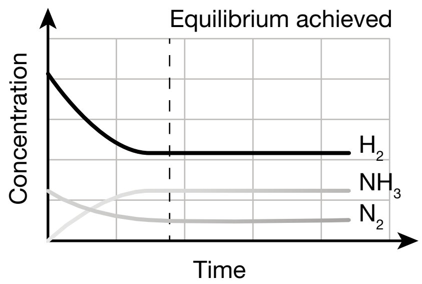
$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

The graphs show equilibrium being achieved from different initial concentrations of gases.

(i)




(ii)




(a) Compare the initial concentrations of hydrogen, nitrogen and ammonia illustrated in graphs (i) and (ii).

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(b) Write the forward reaction for each graph. ..........................................................................

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(c) Compare the final concentrations of gases in graphs (i) and (ii). ...............................................

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**5.1.2.16** The diagram shown is not an example of equilibrium. It is described as being in a steady state.

Distinguish between dynamic equilibrium and a steady state system. Tabulate your answer.

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**5.1.2.17** Water can be described as having ions in equilibrium as shown by:

$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$

At any instant in time, only about 1 molecule of water in every 10 000 000 water molecules will be ionised. Identify the correct alternative.

(A) The forward rate is greater than the reverse rate.
(B) Both forward and reverse rates are the same.
(C) Most water molecules are ions.
(D) The reverse rate is greater than the forward rate.

**5.1.2.18** Which of the following is generally considered as going to completion?

(A) Combustion.
(B) Neutralisation.
(C) Burning magnesium.
(D) All of the above.

**5.1.2.19** Chemical reactions are carried out in three beakers. Which of the following cannot form an equilibrium?

(A) A reaction between solutions of sodium hydroxide and hydrochloric acid.
(B) A reaction between calcium carbonate and dilute hydrochloric acid.
(C) A reaction between sodium chloride and silver nitrate.
(D) All of the above, as beakers are open to the environment.

**5.1.2.20** Which of the following is not necessarily a characteristic of a reversible system at equilibrium?

(A) It is a closed system, no matter enters or leaves the system.
(B) The macroscopic properties stay constant.
(C) The concentration of reactants is equal to the concentration of products.
(D) The rates of the forward and reverse reactions are equal.

**5.1.3 Analyse examples of non-equilibrium systems in terms of the effect of entropy and enthalpy, for example:**

- **Combustion reactions.**
- **Photosynthesis.**

**5.1.3.1**

(a) Recall the meaning of enthalpy. ..........

(b) Recall the meaning of entropy. ..........

(c) Which direction of change in enthalpy and entropy favours a non-equilibrium chemical reaction?

**5.1.3.2** Would it be possible for the combustion of carbon in an open system to reach an equilibrium?

**5.1.3.3** Some people claim that respiration is the reverse reaction of photosynthesis.

Photosynthesis: $6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(aq) + 6O_2(g)$

Respiration: $C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$

Does this mean that photosynthesis is a reversible reaction?

**5.1.3.4** Entropy and enthalpy are both drivers of reactions such as photosynthesis and combustion, and you will recall that Gibbs free energy ($\Delta G°$) reflects the balance between entropy and enthalpy as drivers of any chemical reaction. ($\Delta G° = \Delta H - T\Delta S$)

Entropy and enthalpy are not drivers of reaction for equilibrium reactions. Explain.

**5.1.4 Investigate the relationship between collision theory and reaction rate in order to analyse chemical equilibrium reactions.**

**5.1.4.1** Recall what is meant by collision theory and show how it is related to activation energy.

**5.1.4.2** Distinguish between reaction rate and equilibrium position in an equilibrium reaction.

**5.1.4.3** Can the rate of a reaction and the position of an equilibrium reaction be changed by the same factors?

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# Answers

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# Module 5 Equilibrium and acid reactions

**5.1.1.1** Many chemical reactions proceed until all the reactants are used up. They go to completion. The amount of product formed depends on the amount of the starting materials, e.g. combustion reactions, neutralisation, action of acids on metals. However, other reactions may proceed in both directions at the same time, that is, products can re-form reactants. Examples of reversible reactions are the decomposition of dinitrogen tetroxide to form nitrogen dioxide, the dissociation of weak acids, the ionisation of water and the Haber process for the formation of ammonia from nitrogen and hydrogen.

**5.1.1.2** (a) Reversible reaction – a reaction which can proceed in both directions.

(b) Equilibrium – a reversible reaction proceeding in a closed system and with the rate of the forward reaction equal to the rate of the reverse reaction.

(c) Hydrogen and nitrogen react very slowly to form ammonia and, at the same time, the ammonia decomposes into nitrogen and hydrogen. This means the reaction is *reversible* and can be written as:
$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

In a closed system, *equilibrium* will be reached when the rate of the forward reaction is the same as the rate of the reverse reaction. However, for this reaction the equilibrium is slow to be reached and lies to the left.

**5.1.1.3** (a) The desiccator contains, in its base, a deliquescent substance such as calcium chloride which absorbs moisture from the air and dissolves it. This dries out the air inside the desiccator, providing a dry environment. Being in the desiccator dries out the strip of cobalt chloride.

(b) The two strips will slowly change colour and both end up the same colour. They will reach an equilibrium position and then not change any more unless conditions around them change. The equilibrium position (and thus their colour) will depend on conditions such as the atmospheric moisture in the room.

(c) Various, for example: Cobalt chloride paper can be used to detect for the presence of water, e.g. as indicators of weather conditions such as humidity, to determine whether or not an unknown liquid is water, to detect any water leaking from a pipe or container, in biology experiments to see whether water is released from the top and bottom surfaces of a leaf.

**5.1.1.4** (a) Combustion.

(b) No. Combustion reactions go to completion; they cannot be reversed.
$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$

**5.1.1.5** (a) $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

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

(c) $2NO_2(g) \rightleftharpoons N_2O_4(g)$

(d) $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$

(e) $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

**5.1.2.1** (a) Although the macroscopic properties stay constant at equilibrium, there is still continual change happening at a microscopic level as both the forward and reverse reactions continue to occur. The forward and reverse reactions are in dynamic balance as they both continue at the same rate. A static equilibrium would be found in physical systems, e.g. riding a bike, where being in equilibrium means you don't fall off because opposing forces are balanced.

(b) (i) Steady state (chemical) system – matter and energy are entering and leaving the system at a constant rate.

(ii) Steady state (physical) system.

(iii) Dynamic equilibrium.

**5.1.2.2** Individual students represent ions in a solution. Each pair of dancers represents a unit of product. At equilibrium the concentration of reactants stays constant. In the diagram there are always six students sitting (reactants). At equilibrium the concentration of products also stays constant and there are always two pairs dancing. Whenever one pair sits down another pair stands up to dance, so the rate of the forward reaction (standing up) equals the rate of the reverse reaction (sitting down).

**5.1.2.3** (a) A model is a representation of reality. It is an hypothesis or theory based on observations about the behaviour of substances. Models can take many forms, e.g. diagrams, actual structures, maps, flow charts.

(b) Various, e.g.
We collected some beads with four different colours. We used black and white beads. We called these the reactants. We also used spotted and striped beads, these were our products.
For a reversible reaction, the reaction would be:
black bead + white bead $\rightleftharpoons$ spotted bead + striped bead
To model this we showed two different reactions taking place at the same time.

Forward reaction: black bead + white bead $\rightarrow$ spotted bead + striped bead

Reverse reaction: spotted bead + striped bead $\rightarrow$ black bead + white bead