SURFING

NSW CHEMISTRY 5&6

Module 5 Equilibrium and Acid Reactions
Module 6 Acid/Base Reactions

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Introduction

This book covers the Chemistry content specified in the NSW Chemistry Stage 6 Syllabus. Sample data has been included for suggested experiments to give you practice to reinforce practical work in class.

Each book in the *Surfing* series contains a summary, with occasional more detailed sections, of all the mandatory parts of the syllabus, along with questions and answers.

All types of questions – multiple choice, short response, structured response and free response – are provided. Questions are written in exam style so that you will become familiar with the concepts of the topic and answering questions in the required way.

Answers to all questions are included.

A topic test at the end of the book contains an extensive set of summary questions. These cover every aspect of the topic, and are useful for revision and exam practice.

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.

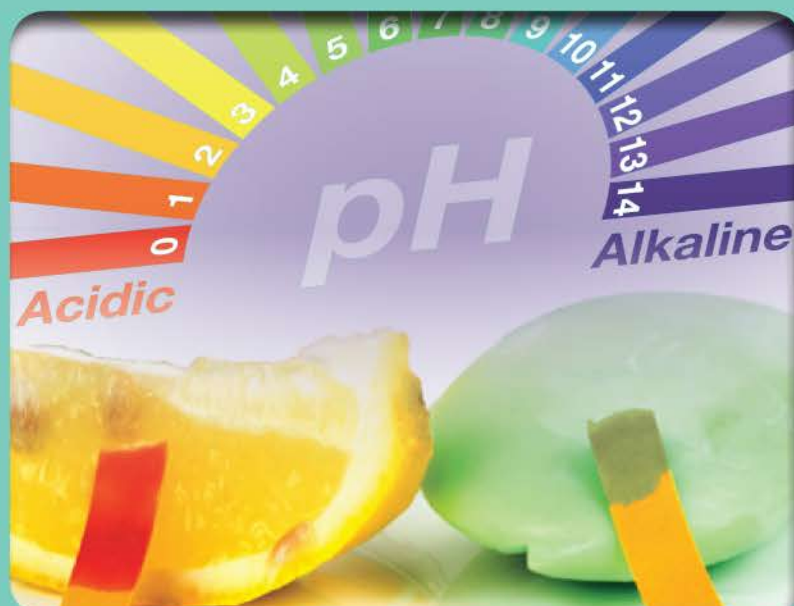
Surfing

NSW CHEMISTRY 5&6

Module 5

Equilibrium and Acid Reactions

Content Focus



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.

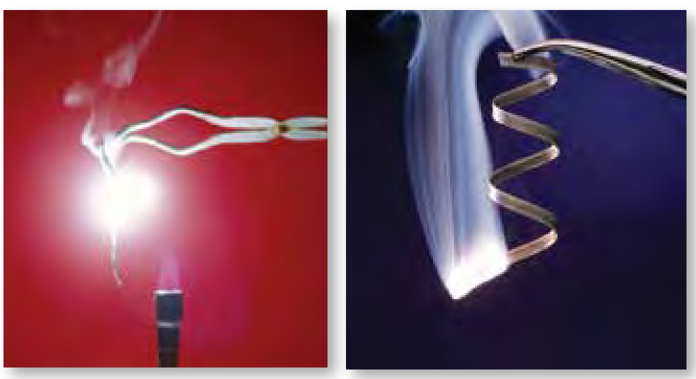
1 Investigating Reversibility Of Chemical Reactions

In the laboratory you have already seen many chemical reactions that go to completion, some very rapidly and others more slowly.

In this topic you will have a chance to carry out reactions that are reversible – reactions that can proceed in either direction depending on prevailing conditions. You will learn to predict the direction in which a reaction will proceed by evaluating the conditions such as temperature, concentration and pressure to see if they favour the formation of reactants or products.

Irreversible reactions

One of the irreversible reactions you have already seen is the combustion of **magnesium** ribbon. You know that energy is needed to start this reaction, and once started it continues with no more energy input as this is a highly exothermic reaction.



Bunsen starts magnesium burning

Magnesium continues to burn, giving out heat and a brilliant white light

Figure 1.1 Burning magnesium.

$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$

This reaction cannot be reversed. You cannot convert the magnesium oxide produced back to the original elements magnesium and oxygen by changing conditions such as temperature – it is an irreversible reaction.

Steel wool is another substance that can be burnt in the laboratory in a non-reversible reaction. In the presence of oxygen, the thin pieces of steel burn to produce iron oxide. In pure oxygen, the reaction is much faster and more vigorous.

$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$

Figure 1.2 Burning steel wool in oxygen.

Reversible reactions

Many transition metals form coloured salts, and their colour can vary as their oxidation state or degree of dehydration changes.

Copper chloride and iron chloride are examples as you can see in Figure 1.2.

(a) (b)

Figure 1.2 (a) Copper(I) chloride (CuCl) is green and copper(II) chloride is blue. (b) Crystals of iron(II) chloride tetrahydrate ($FeCl_2.4H_2O$) are green and crystals of iron(III) chloride hexahydrate ($FeCl_3.6H_2O$) are mustard yellow.

Cobalt chloride is another transition metal salt that changes colour. When hydrated its crystals are pink/purple ($CoCl_2.6H_2O$), when dehydrated it becomes anhydrous (without water) and is blue in colour. Cobalt chloride can be dried by heating the crystals to evaporate the water or by placing it in a desiccator. (If you are unfamiliar with a desiccator, see Question 3.)

(a) (b)

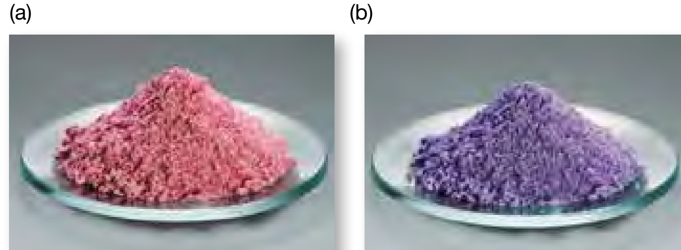


Figure 1.3 (a) Hydrated cobalt(II) chloride is pink/purple. (b) Anhydrous cobalt(II) chloride ($CoCl_2$) is blue.

Cobalt chloride paper

Strips of paper can be soaked in cobalt chloride solution to form cobalt chloride paper. This is blue when dried and it can be stored in a dry place such as a desiccator. It can be used to test for water leaks from tiny cracks – if the paper is applied and goes pink, then water is present.

Figure 1.4 Cobalt chloride paper goes pink in the presence of water.

Simple weather indicators can be made by soaking blotting paper in cobalt chloride and cutting it into interesting shapes such as the petals of a flower. It changes colour as the atmospheric humidity changes.

Another reversible reaction you will carry out involves **iron(III) nitrate and potassium thiocyanate**. When solutions of these ionic compounds are mixed, they react to form a blood-red complex called iron(III) thiocyanate. This is sometimes used as fake blood.

The nitrate ions and potassium ions are spectator ions and do not take part in the reaction, so the reaction is:

$$Fe^{3+}(aq) + SCN^{-}(aq) \rightleftharpoons [FeSCN]^{2+}$$

Pale yellow colourless brown/red

This is a reversible reaction as both the forward and reverse reactions are occurring at the same time. The reactants do not all get used up. At any instant all species (reactants and products) are present in the reaction vessel.

Adding extra iron ions or thiocyanate ions separately, makes the colour a deeper red, as they react with ions that have not been used up.

$$Fe^{3+}(aq) + SCN^{-}(aq) \rightarrow [FeSCN]^{2+}$$

Pale yellow colourless brown/red

Adding extra iron thiocyanate to the mixture produces a lighter colour as the reaction is pushed in the reverse direction.

$$[FeSCN]^{2+} \rightarrow Fe^{3+}(aq) + SCN^{-}(aq)$$

Brown/red pale yellow colourless

These changes could only happen if the reaction had not gone to conclusion – the reaction vessel must contain some reactants and also some product as both the forward and reverse reactions are happening simultaneously.

QUESTIONS

1. Describe the safety precautions you used when carrying out experiments involving:
   (a) The combustion of substances such as magnesium and steel wool.
   (b) The use of chemicals such as salts of transition elements.
2. (a) Describe how you made cobalt chloride change colour in the laboratory.
   (b) What happens to blue copper sulfate crystals when they are heated in a crucible above a Bunsen burner. Can this change be reversed?
   (c) Research uses of cobalt chloride paper.
3. The diagram illustrates a desiccator found in most school laboratories. What is a desiccator and what is it used for?

4. (a) In the reaction between iron nitrate and potassium thiocyanate, how could you determine which ions are spectator ions?
   (b) Research why iron thiocyanate can have a colour similar to blood.
5. Some students made up aqueous solutions of Fe^{3+} and SCN^{-} ions. They added these solutions and formed deep red iron(III) thiocyanate.
   Explain the following observations as they continued their investigation.
   (a) They added more of the solution containing Fe^{3+}, and the colour went a deeper red.
   (b) They also added more SCN^{-} and again the colour went a deeper red.
   (c) Extra $[FeSCN]^{2+}$ was added, and the mixture became lighter in colour.

2 Open and Closed Systems

In this course you will be looking at chemical equilibrium systems. So we will look first at what is meant by a system, and then what is meant by equilibrium.

You can think of a **system** as any part of the Universe that is being studied. Sometimes a system can be very large, such as a whole ocean. A system can also be relatively small, such as the contents of a test tube.

In chemistry, the systems we study can be either open or closed; they can involve either physical changes or chemical reactions; and the changes taking place can either go to completion or be reversible.

Open and closed systems

An **open system** is one which interacts with its environment – this means that both energy and matter can move in and out of the system. Energy and matter are constantly moving between the system and the environment.

In a **closed system**, energy may still be able to flow in and out, between the system and the environment, but matter cannot enter or leave the system. When a reaction reaches equilibrium, no energy enters or leaves the system either. (If you are also studying physics, note that this definition is different in physics.)

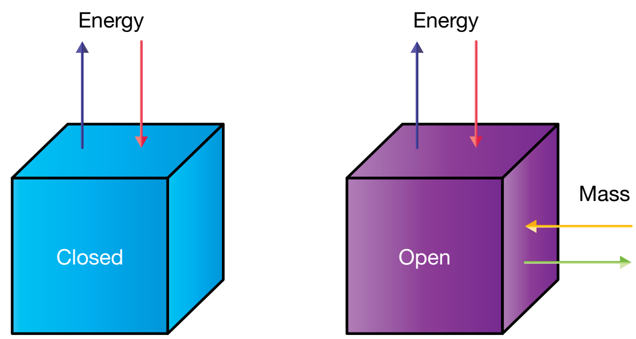


Figure 2.1 Open and closed systems.

A physical change

You will recall that a physical change is one in which no new substances are made, for example a change of state. The particles stay the same, but they may move differently, speeding up or slowing down. This may occur in an open or a closed system.

If we heat water in a container without a lid, then we have a **physical change** (evaporation) taking place in an **open system**.

If we put the lid on, then we have the same **physical change** taking place, but in a **closed system**. Heat can go in, but no matter can enter or leave the container.

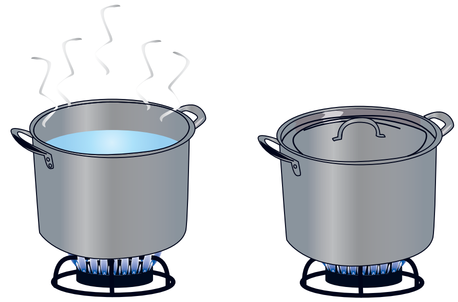


Figure 2.2 A physical change in an open and a closed system.

A chemical change

You will recall that a chemical change is one in which one or more new substances are formed, for example combustion, the action of acids on active metals, synthesis and decomposition.

Chemical changes can also occur in both open and closed systems.

Reversible and Irreversible reactions

Sometimes, when a physical or a chemical change occurs in a closed system, the products will recombine and re-form the reactants. The forward and reverse reactions will continue to occur at the same time. This reaction would be called a reversible reaction.

All physical changes and some chemical reactions are reversible, they can go in both directions under suitable conditions.

Reversible physical changes

Physical changes are easily reversed, for example evaporation and condensation are reversible.

In a sealed container, water will evaporate:

$$H_2O(l) \rightarrow H_2O(g)$$

At the same time water vapour will condense:

$$H_2O(g) \rightarrow H_2O(l)$$

This is a reversible physical change, so we can show it by using arrows going in both directions.

$$H_2O(l) \rightleftharpoons H_2O(g)$$

Reversible and irreversible chemical reactions

Many chemical reactions that you have seen in the laboratory **go to completion and cannot be reversed – we describe these reactions as irreversible**. For example, neutralisation reactions, reactions involving combustion, and reactions between metals and acids all go to completion. And of course you cannot turn a cake back into the ingredients – such as flour, eggs, sugar and milk – used to make it.

However, there are also many chemical reactions that are **reversible in a closed system**; both the forward and the reverse reactions can occur at the same time.

Under suitable conditions, in a closed system, as the products build up, they may start to re-form the reactants. Both the forward and reverse reaction will then take place at the same time. This can only happen if nothing escapes from the container. If for example a gas escapes, both reactions cannot occur. Remember, the reaction system must be closed to be reversible.

As in physical changes, we show a reversible chemical reaction by using arrows going in both directions. Here are some examples of reversible chemical reactions.

- **Dinitrogen tetroxide** is a colourless gas that decomposes at room temperature to form brown nitrogen dioxide gas. In a sealed container, the reverse reaction also occurs, with some nitrogen dioxide combining to re-form dinitrogen tetroxide.

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

- An important reversible reaction that you learned about in year 11 when you studied acids, is the **ionisation of water** to form hydrogen ions and hydroxide ions.

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

- Many reversible reactions occur in **living organisms**, for example, reactions involved in the transport of oxygen and carbon dioxide around the body in blood.

  Haemoglobin + $O_2(g) \rightleftharpoons$ oxyhaemoglobin

  $CO_2(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + H^+(aq)$

- We also make use of some reversible reactions. For example, some eyeglasses have **photochromatic (transition) lenses** that darken in ultraviolet light. These work by means of a reversible reaction. They contain substances such as a silver halide which darkens in UV light, making the lens darker. Indoors the reaction reverses and the lenses become clear again.

Some reactions that go to completion can, under the right conditions, become reversible. For example, at some stage you will have heated calcium carbonate and watched it decompose into calcium oxide and carbon dioxide.

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

You probably bubbled the gas produced through limewater, which turned milky, showing that the gas was carbon dioxide.

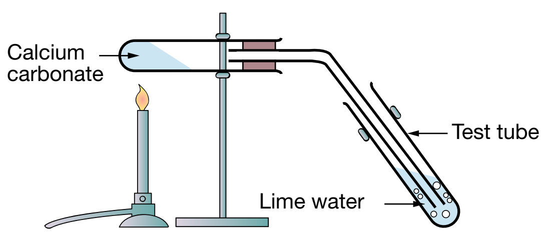


Figure 2.3 Decomposing calcium carbonate.

Note that this is an open system. There is a stopper in the test tube, but the carbon dioxide gas produced is escaping from the system through the tubing.

Heat energy is going into the system and matter (CO_2 gas) can escape. This is a **chemical change** in an **open system**.

However, if you were able to heat calcium carbonate gently in a closed container, heat energy would be going in, but no reactants or products could enter or leave. This would be a **chemical change** in a **closed system**.

This is not something you would do in a school laboratory. You would never enclose a reaction that produces a gas as this would not be safe. However, in an industrial situation, with containers that can withstand pressure, this reaction could be enclosed. In that case, some of the products – calcium oxide and carbon dioxide – would recombine to form calcium carbonate. The reverse reaction would occur.

$$CaO(s) + CO_2(g) \rightarrow CaCO_3(s)$$

Both forward and reverse reactions would be taking place at the same time, and we would have a reversible reaction in a closed system.

$$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$$

QUESTIONS

1. Recall the differences between a physical and a chemical change.
2. Describe the meaning of the following terms.
   (a) A system.
   (b) Open system.
   (c) Closed system.
   (d) Reversible reaction.
3. Some chemical reactions are reversible.
   (a) Write word equations for the following reversible reactions.
      (i) $FeCl_3(s) + 3H_2O(l) \rightleftharpoons Fe(OH)_3(s) + 3HCl(aq)$
      (ii) $CuSO_4.5H_2O(s) \rightleftharpoons CuSO_4(s) + 5H_2O(l)$
      (iii) $NH_4Cl(s) \rightleftharpoons NH_3(g) + HCl(g)$
      (iv) $CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$
      (v) $3O_2(g) \rightleftharpoons 2O_3(g)$
   (b) Write symbolic equations for the following reversible reactions.
      (i) Sulfur dioxide + oxygen $\rightleftharpoons$ sulfur trioxide
      (ii) Nitrogen + hydrogen $\rightleftharpoons$ ammonia
      (iii) Nitrogen dioxide $\rightleftharpoons$ dinitrogen tetroxide
      (iv) Phosphorus pentachloride $\rightleftharpoons$ phosphorus trichloride + chlorine
      (v) Hydrogen + iodine $\rightleftharpoons$ hydrogen iodide

3 Static Versus Dynamic Equilibrium

Equilibrium in chemistry refers to a situation where no changes can be seen happening in a chemical system. Usually a mention of equilibrium in chemistry refers to dynamic equilibrium, but you need to make sure that you can distinguish dynamic from static equilibrium.

Static equilibrium

Static equilibrium occurs when nothing is happening in a reaction. The forward and reverse reaction rates are both zero. This is the equilibrium of a system at rest.

An example is the conversion between the two allotropes of carbon – diamond and graphite. Theoretically the reaction is: C(diamond) $\rightleftharpoons$ C(graphite)

But at room temperature, you are not going to see either reaction taking place, so this could be considered a static equilibrium situation.

Another example is a reaction in which there is a limiting reagent. Once the limiting reagent has been used up, neither forward nor reverse reaction will occur, so a static equilibrium exists.

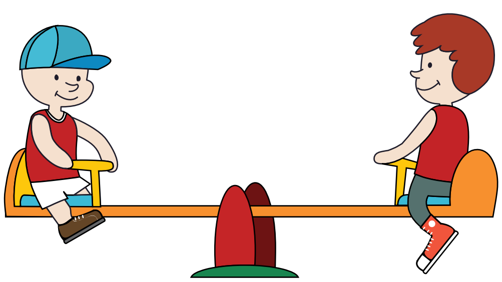


Figure 3.1 Static equilibrium. The seesaw is balanced and not moving.

Dynamic equilibrium

Dynamic equilibrium refers to a system in which the forward and reverse reactions are occurring at the same time and at the same rate, so that there is no *net* change.

You might like to try **modelling a reversible reaction coming to a state of dynamic equilibrium** with your friends by dancing.

In reversible reactions the forward and reverse reactions both occur at the same time and we can model this using a dance.

People getting up to dance, represent the reactants coming together. Couples breaking up and sitting down, represent the product breaking up and reactants re-forming again. There are always some couples forming and others breaking up, just as in a reversible reaction there are always particles combining and others breaking up.

If the dance goes on for a long time, you could eventually reach a state of dynamic equilibrium – the number of couples getting up at any instant could be the same as the number of couples sitting down.

If you just glanced at the dancing couples, you might think there was no change happening – there might always seem to be the same number of couples on the floor dancing. But looking more closely, you would see that although the number of people dancing stays the same, it is not always the same people dancing.

The dance is then in dynamic equilibrium. It is in equilibrium because it seems to be staying the same. It is dynamic because there is constant change happening.

The same thing happens when a chemical reaction is at dynamic equilibrium. There may seem to be no observable change taking place, but the forward and reverse reactions are occurring at the same rate and there is constant change at an atomic level.

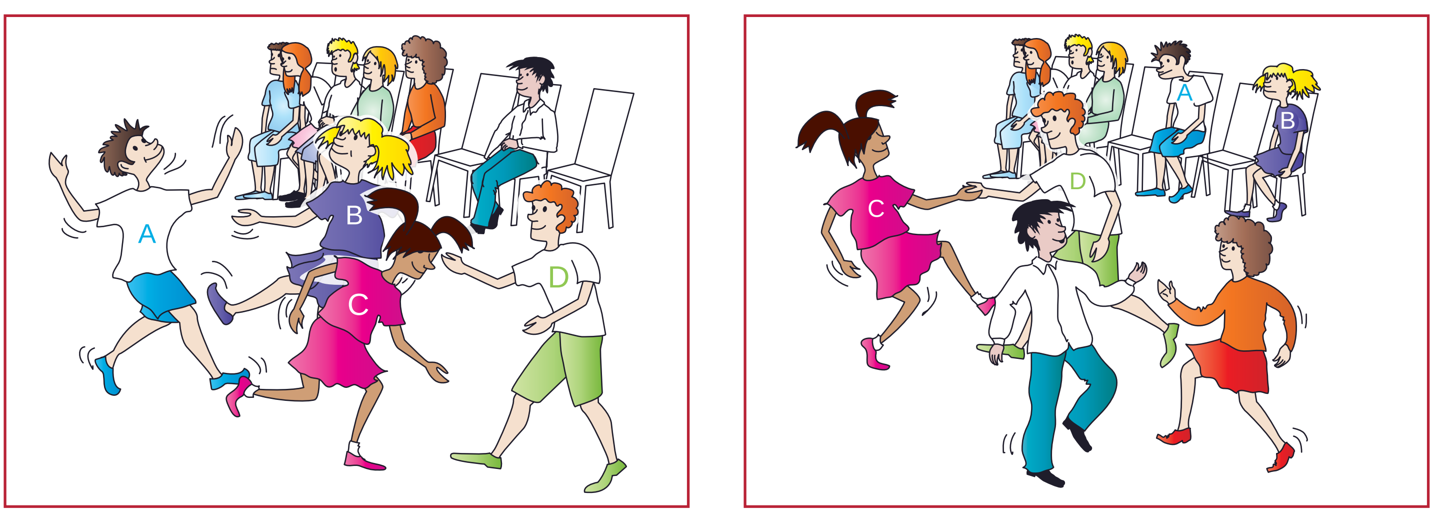


Figure 3.2 Modelling a reversible reaction and dynamic equilibrium.

Steady state

A steady state condition such as that illustrated in Figure 3.2 is *not* an example of equilibrium. It is mentioned here because conditions are stable within the system – there is no net change over time (just like in equilibrium), so students sometimes mistake it for a type of equilibrium or a model of equilibrium.

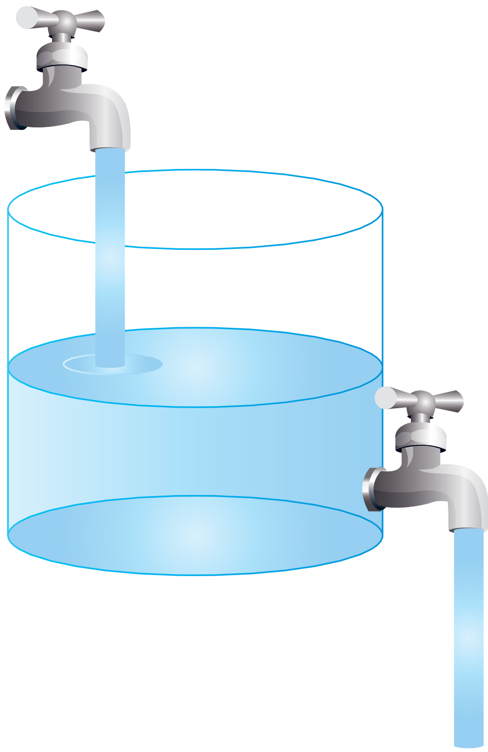


Figure 3.3 Steady state.

This is a physical system, in which matter and energy are entering and leaving the system at a constant rate so that conditions have become stable within the system. Water is flowing in and out of the container at the same rate, so the water level (and the volume) stays the same – it becomes stable, and the system is said to be in steady state. However, this is not a case of forward and reverse reactions occurring at the same rate.

We can summarise the main differences as follows.

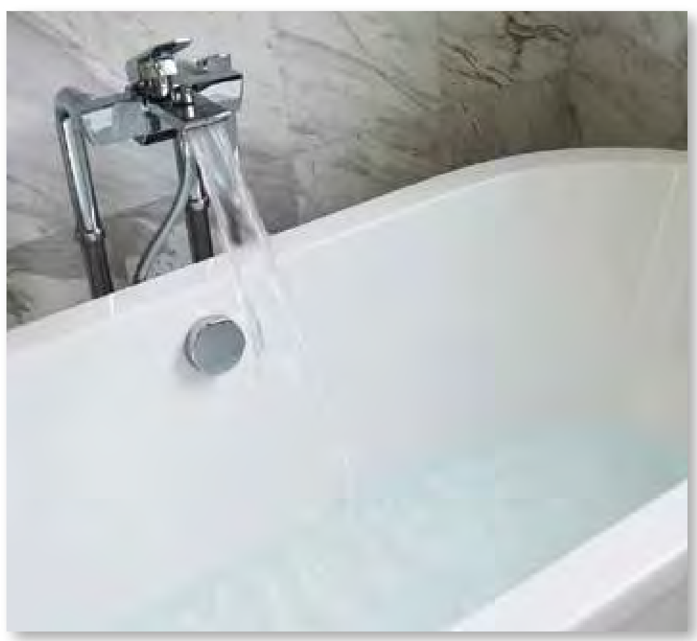
Table 3.1 Dynamic equilibrium versus steady state.

Dynamic equilibrium	Steady state
Net free energy does not enter or leave the system.	Free energy is continuously put into the system.
Any difference in entropy between the system and the external environment tends to disappear.	The system is being maintained in a higher state of order and entropy than its surroundings.
System is closed.	System is open.

Steady state is not an example of equilibrium and cannot be used as a model of equilibrium.

QUESTIONS

1. Distinguish between static and dynamic equilibrium.
2. The first person to realise that chemical reactions could be reversible was the French chemist Claude Louis Berthollet. He observed salt lakes where he saw solid calcium carbonate being formed by a reaction between sodium carbonate and calcium chloride which are both dissolved in the lake water.
   (a) Write an equation for this reaction.
   (b) Berthollet also noticed that sodium carbonate was being deposited as a solid around the edges of the lake, and he realised that the reverse reaction must also have been occurring at the same time. Write an equation for this reverse reaction.
   (c) Write these reactions as an equilibrium reaction.
3. What is meant by steady state, and why is this not an example of equilibrium?
4. Each of the following situations would have constant macroscopic properties. Classify each as being in either a dynamic equilibrium, a static equilibrium or a steady state,
   (a) A chemical reaction in which a limiting reagent has been used up.
   (b) A Bunsen burner which is burning steadily at the same rate.
   (c) A chemical reaction represented by $A \rightleftharpoons B$ in which the forward reaction rate is equal to the reverse reaction rate and there is no observable change taking place.
   (d) A bath with a constant water level. There is no plug and the tap is turned on so that water is continually entering and leaving the bath at the same rate.



Answers

Module 5 Equilibrium and Acid Reactions

1 Investigating Reversibility Of Chemical Reactions

1. (a) Safety precautions for combustion of magnesium and other substances include, wearing goggles to protect the eyes from sparks and burning materials, do not look at the burning material as the light may be very bright and damage the eyes, ensure the burning material is being securely held or supported so it cannot fall and start a fire, ensure that there is no combustible material nearby or underneath the burning substance to avoid starting a fire. A fire blanket and extinguisher should always be on hand in science laboratories in case of accidents.
   (b) Various, e.g. wear goggles to prevent chemicals being splashed into the eyes and always wash hands thoroughly to remove any chemicals as they may be toxic, e.g. ingestion of copper chloride is toxic.
2. (a) To dehydrate pink cobalt chloride crystals the water of crystallisation must be removed. This can occur if the crystals are placed in a desiccator, or if they are heated gently to evaporate the water.
   $CoCl_2.6H_2O(s) \rightleftharpoons CoCl_2(s) + 6H_2O(g)$

   (b) When blue copper sulfate crystals are heated the water of crystallisation present in their crystals evaporates and a white solid (anhydrous copper sulfate) is produced.
   This reaction can be reversed. If a few drops of water is added to the anhydrous copper sulfate it re-forms the blue crystals of hydrated copper sulfate.
   $CuSO_4.5H_2O(s) \rightleftharpoons CuSO_4(s) + 5H_2O(g)$
   (c) Various, for example: Cobalt chloride paper can be used to detect for the presence of water, e.g. 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 both top and bottom surfaces of a leaf.
3. A desiccator is a sealable container used to absorb moisture or provide a dry environment. It usually contains a drying agent (desiccant) below the plate with holes. The drying agent is a hygroscopic substance (it absorbs water) such as anhydrous calcium chloride or silica gel. The lid is greased to make an airtight seal. Some desiccators can have a vacuum applied.
4. (a) Repeat the experiment, replacing each ion in turn with a different ion and see if the reaction still happens, e.g. instead of using iron nitrate, you could use calcium nitrate; instead of using potassium thiocyanate, you could use sodium thiocyanate.
   (b) The red colour of blood is due to the haemoglobin molecule which contains iron in a similar structure to the iron complex produced in this reaction. (*Note:* All animals do not have red blood – you might want to find out more about this.)
5. (a) All of the reactants must not have been used up – the reaction had not gone to completion.
   (b) This also shows that the reaction had not gone to completion – adding excess of either reactant can produce more product. Both reactants were still present, along with the product.
   (c) For the colour to become lighter, some of the product must have broken up and re-formed the reactants which were both much lighter in colour. The reaction must have gone in the reverse direction.

2 Open and Closed Systems

1. A physical change – No new substance is produced, particles stay the same and it is usually easy to reverse. Examples include change of state – melting, evaporation, condensation.
   A chemical change – A new substance forms, particles are changed as atoms are rearranged and it is usually difficult to reverse.
2. (a) A system refers to any part of the Universe that is being studied.
   (b) An open system is one that interacts with its environment – energy and matter can move between the system and its environment.
   (c) A closed system does not interact with its environment – energy can move in and out of the system but matter cannot.
   (d) A reversible reaction is one that goes in both directions – forward and in reverse.
3. (a) (i) Iron(III) chloride + water $\rightleftharpoons$ iron(III) hydroxide + hydrochloric acid
   (ii) Copper(II) sulfate (hydrated) $\rightleftharpoons$ anhydrous copper(II) sulfate + water
   (iii) Ammonium chloride $\rightleftharpoons$ ammonia + hydrogen chloride
   (iv) Carbon dioxide + water $\rightleftharpoons$ carbonic acid
   (v) Oxygen $\rightleftharpoons$ ozone
   (b) (i) $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$
   (ii) $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$
   (iii) $2NO_2(g) \rightleftharpoons N_2O_4(g)$
   (iv) $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$
   (v) $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

3 Static Versus Dynamic Equilibrium

1. In both static and dynamic equilibrium, the rates of the forward and reverse reaction are the same.
   Static equilibrium refers to a situation in which there is no net change because the forward and reverse reactions are both zero.
   Dynamic equilibrium refers to a reaction in which there is no net change because the forward and reverse reactions are occurring at the same rate.
2. (a) $Na_2CO_3(aq) + CaCl_2(aq) \rightarrow CaCO_3(s) + 2NaCl(aq)$
   (b) $CaCO_3(s) + 2NaCl(aq) \rightarrow Na_2CO_3(s) + CaCl_2(aq)$
   (c) $Na_2CO_3(aq) + CaCl_2(aq) \rightleftharpoons CaCO_3(s) + 2NaCl(aq)$
3. A steady state condition, such as that illustrated is not an example of equilibrium. It is mentioned here because students sometimes mistake it for a type of equilibrium as there is no net change over time. There are no forward and reverse reactions. There is no net change in the water content because the water flows in and out at the same rate.
4. (a) Static equilibrium.
   (b) Steady state.
   (c) Dynamic equilibrium.
   (d) Steady state.

4 Characteristics Of Equilibrium

1. (a) A reversible reaction is a reaction which proceeds in both directions at the same time.
   (b) Various. Macroscopic properties include state (solid/liquid/gas), colour, temperature and pressure. For example, you could observe the colour – when the colour stays constant (there are no longer any visible changes taking place) then the system is at equilibrium.
2. Although the macroscopic properties stay constant at equilibrium, there is continual change happening at a submicroscopic level as both the forward and reverse reactions continue to occur. A static equilibrium can be found in physical systems, e.g. riding a bike – where being in equilibrium means that you do not fall off because opposing forces are balanced.