HSC COLLEGE
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YEAR 12 CHEMISTRY
MODULE 5

THEORY BOOKLET 1

IQ 1 : STATIC & DYNAMIC EQUILIBRIUM
IQ 2: FACTORS THAT AFFECT EQUILIBRIUM

Level 5, Suite 7 / 11 The Boulevarde, Strathfield 2135
(02) 8012 8488
enquiry@skyedu-hsc.com

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Reversible Reaction & Equilibrium

Syllabus Covered

Inquiry Question: What happens when chemical reactions do not go through to completion?

In this section, students will learn to:

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

- **(a) Cobalt (II) chloride hydrated and dehydrated**
- **(b) Iron (III) nitrate and potassium thiocyanate**
- **(c) Burning magnesium**
- **(d) Burning steel wool (ACSCH090)**

★ **Model static and dynamic equilibrium and analyse the differences between open and closed systems (ACSCH079, ACSCH091)**

1.1 Reversible Reaction

- Typically, when we think of what happens during a chemical reaction, we think of the reactants getting totally used up so that none of the reactants are left leaving only the products. In other words, we have been generally considering chemical reactions as one-way events. Such reactions are called **irreversible reactions**.
- In this section we will see that this isn't always the case. We will see that many chemical reactions are, in fact, **reversible** under the right conditions. And because many reactions can be reversed, our idea of a reaction ending with no reactants left, only products, will need to be modified.
- The concept of **chemical equilibrium**, which involves such two-way reactions called reversible reactions, will be introduced in this section too.

Definition & Notation

- **Reversible reactions are reactions that can proceed in both forward and reverse directions.**
- Most reactions encountered so far in chemistry are irreversible reactions which is indicated by a unidirectional arrow (→), indicating the reaction can only proceed in the forward direction (i.e. from reactants to the products).
- In contrast, reversible reactions are represented using a double arrow (⇌), which is called a **'reversible sign'**.
- Therefore, a general reversible reaction can be written as follow:

$$\boxed{\text{Reactants} \rightleftharpoons \text{Products}} \quad \text{or} \quad \boxed{A + B \rightleftharpoons C + D}$$

- This notation indicates that the reaction may proceed in either way (i.e. from reactants to the products and from products to the reactants).
- Note that the double arrow, (⇌), represents a reversible reaction, **NOT** an equilibrium! The concept of equilibrium will be introduced later.
- **All physical changes are reversible reactions** (e.g. water can readily freeze to ice which can melt to form water again). **However, only some chemical changes are reversible**.

1.2 Examples of Reversible Reactions

Cobalt (II) Chloride Hydrated and Dehydrated

- The first example investigates a reversible reaction between cobalt chloride and water. The equation for this reaction can be written as follow:

$$\boxed{CoCl_{2(s)} + 6H_2O_{(l)} \rightleftharpoons CoCl_2 \cdot 6H_2O_{(s)}}$$

Anhydrous Blue

Hydrated Pink/Purple

- Dry cobalt chloride paper is blue, but when it comes in contact with water at room temperature it turns pink (i.e. forward reaction occurs).

$$CoCl_{2(s)} + 6H_2O_{(l)} \rightarrow CoCl_2 \cdot 6H_2O_{(s)}$$

- Increasing the temperature can cause this reaction to go in reverse and the blue colour is restored.

$$CoCl_2 \cdot 6H_2O_{(s)} \rightarrow CoCl_{2(s)} + 6H_2O_{(l)}$$

- In the above reaction, the forward reaction can be described as a reaction between cobalt (II) chloride and water. However, since the reaction is reversible it can also be described as heating the hydrated cobalt (II) chloride to remove the water when considering the reverse reaction.
  - Note that the process of removing water is called **dehydration** in chemistry. So the above reaction in the reverse direction can be described as the dehydration of hydrated cobalt (II) chloride.

Hydrated vs Anhydrous Salts

- The adjective 'hydrated' in front of the name of any salt means that there are water molecules physically attached to that salt.
- In order to indicate the exact number of water molecules attached, we use prefixes such as mono-, di-, tri, tetra- and so on in front of the term 'hydrate'.
- So, the cobalt chloride with 6 water molecules attached can be called **"cobalt chloride hexahydrate"**, if not just hydrated cobalt chloride.
- In contrast, if the salt is completely free of water (i.e. fully dehydrated), then it is called an **anhydrous** salt.

Practical Work

1. Collect a piece of cobalt chloride paper and a paper towel.
2. Dampen the paper towel and press the piece of dry cobalt chloride paper against it. Observe the colour change.
3. Gently warm the pale pink cobalt chloride paper held in tongs well above a Bunsen flame. Observe the colour change that occurs.

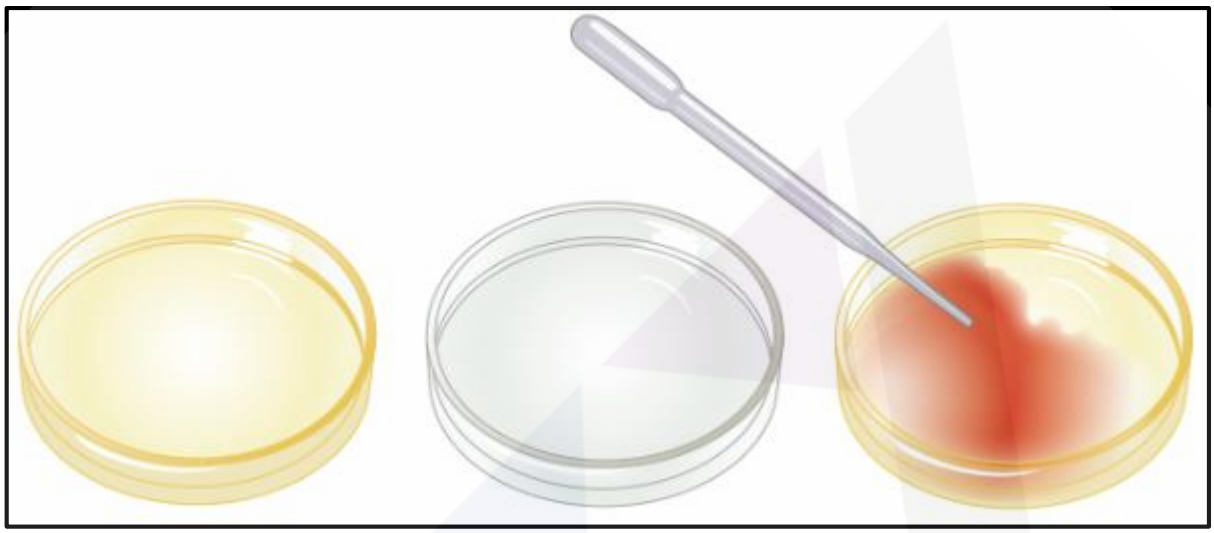
✶ A simple experiment such as the one above can prove that chemical reactions can be made to proceed in both the forward and reverse directions depending on the reaction condition provided.

Iron (III) Nitrate and Potassium Thiocyanate

- Solutions of iron (III) nitrate are pale yellow and solutions of potassium thiocyanate are colourless.
- When these two solutions are mixed, they form the red-coloured complex ion, iron (III) thiocyanate.
- The reaction can be represented by the equation:

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

Pale Yellow Colourless Red



- The diagram above shows the pale yellow $Fe(NO_3)_3$ solution to the left, the colourless $KSCN$ solution in the centre and the red $FeSCN^{2+}$ solution produced when these two are mixed on the right.
- The above reaction is also a reversible reaction meaning that certain conditions may be altered to favour the reverse reaction.
- In this example, the temperature of the red solution may be increased to observe the fading of the red colour. This indicates that the reverse reaction is taking place.

1.3 Open System vs Closed System

- A chemical reaction can be regarded as a system, with everything else around it (the rest of the universe) being the surroundings.
- Figures below illustrates how you can distinguish between two different types of systems: open systems and closed systems.
- The most common situation in everyday life is an open system.
- **In an open system, matter and energy can be exchanged with the surroundings. In contrast, a closed system only exchanges energy with the surroundings.**