Equilibrium and reversible reactions

Equilibrium is an important process in industry. Manufacturers want to make as much product as possible, minimising the quantity of starting materials left over. They also want to minimise energy use when conducting reactions at high temperatures and pressures.

To make reversible chemical reactions as efficient and sustainable as possible, manufacturers need to understand equilibrium. Because the **equilibrium position** – the concentrations of substances present at equilibrium – affects the **yield** of the product.

Did you know …?

In 2020, the Haber process – a reversible reaction – produced over 176 million tonnes of ammonia for fertiliser and other uses.

Reversible reactions

Most chemical reactions you have studied so far are **irreversible**, eg combustion, where the reaction only takes place in one direction.

However, many chemical reactions are **reversible**: the products can react together to reform the original reactants. A reversible reaction is represented by a double arrow symbol: ⇌.

An example of a reversible reaction is, **A + B ⇌ C + D**, where A, B, C and D are used to represent substances.

The **forwards reaction**: A + B → C + D, and the **reverse reaction**: C + D → A + B, are occurring at the same time.

Dynamic equilibrium

In **dynamic equilibrium,** the forwards and reverse reactions occur at **the same rate** in a **closed system.** The **concentrations** of substances at equilibrium are **constant,** ie they are not changing.

This means that a reaction is not immediately at equilibrium.

At the start of the reaction, the concentrations of the initial reactants, A and B, are at their highest, so the rate of the forwards reaction is highest.

Did you know …?

Dynamic equilibrium can only happen in a **closed system**. This is a system or reaction vessel where nothing can enter or leave.

When A and B react, their concentrations decrease, decreasing the rate of the forwards reaction. C and D are produced, increasing their concentrations and, therefore, the rate of the reverse reaction.

Eventually, the rates of the forwards and reverse reactions become equal and equilibrium is reached. Particles are still reacting, but as A and B react to produce C and D, C and D react to produce A and B, maintaining a constant concentration.

An analogy to represent equilibrium …

What would someone see if they watched you move up an escalator at the same speed the escalator was moving down? It would look like you were standing still. But both you and the escalator are still moving, just like the particles at equilibrium are still reacting while their concentrations stay constant.

Energy changes in reversible reactions

If the forwards reaction is **exothermic**, the reverse reaction will be **endothermic** and vice versa. This is because the same amount of energy is transferred in both reactions.

An example of this is the reaction:

water + anhydrous copper sulfate (white) ⇌ hydrated copper sulfate (blue)

Where the forwards reaction is exothermic and the reverse reaction is endothermic.

Blue hydrated copper sulfate turns white when heated (endothermic) due to the removal of water, then becomes blue again when the water condenses and reacts with the anhydrous copper sulfate (exothermic).