Cambridge GCSE Notes
5070 Chemistry

Abrar Faiyaz Rahim, degrees pending

Contents

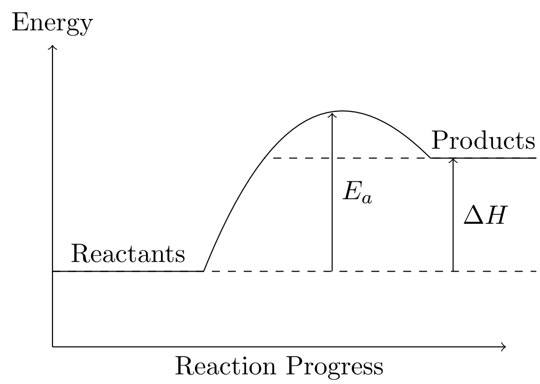
1 Chemical energetics

1.1 Exothermic and endothermic reactions

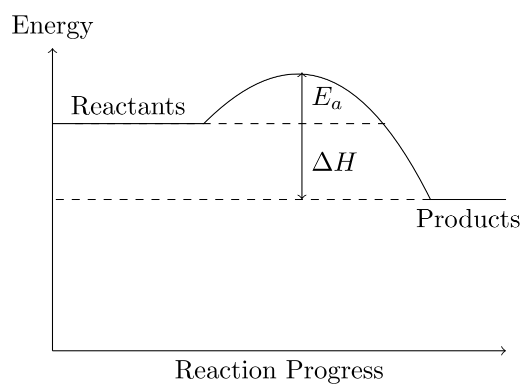
An exothermic reactions transfers thermal energy to the surroundings leading to an increase in the temperature of the surroundings. An endothermic reaction takes in thermal energy from the surroundings leadin gto a decrease in the temperature of the surroundings.

The transfer of energy during a reaction is caleed the enthalpy change, ΔH of the reaction. The value is negative for exothermic reactions and positive for endothermic reactions.

Activation energy, E_a is the minimum energy that colliding particles must have to react.



Endothermic Reaction



Exothermic Reaction

Above are reaction pathway diagrams, showing the energy of a reaction as it progresses. The energy of products is greater than that of the reactants in endothermic reactions and the opposite is true for exothermic reactions. The differences in energy and their correspondences are labelled.

Remember that M-EXO (making is exo) and B-ENDO (breaking is endo).

Bond breaking is an endothermic process and bond making is an exothermic process. When a reaction, overall, has bonds broken with more energy than bonds made, it is endothermic. The opposite is also applies.

Enthalpy change can be calculated as:

enthalpy = (energy needed to break bonds) - (energy needed to make bonds)

$$\Delta H = E_b - E_f$$

where E_b is the energy needed to break bonds and E_f is that needed to form bonds.

2 Chemical reactions

2.1 Physical and chemical changes

In a physical change, the substances present remain chemically the same and no new substances are formed. Such changes are often easy to reverse.

Changes such as melting and boiling are endothermic as heat is taken in, changes such as condensing and freezing are exothermic as heat is given out.

Chemical changes are those where a new substances is formed. Most chemical changes happen through chemical reactions, almost all of which are exothermic, very few are endothermic.

2.2 Rate of reaction

A reaction progresses when effective collisions occur between reactants to form a molecule of a product. The rate of effective collisions is hence the rate of the reaction. This rate of effective collisions can be influenced. These effective collisions can only occur if the colliding particles have a minimum energy (E_a).

Increasing the number of particles per unit volume means there are more particles per unit volume, when that is the case the particles are more likely to react.

Increasing the kinetic energy (KE) of particles by applying heat makes them move faster, meaning more particles are likely to collide more frequently and with energy greater that E_a.

A catalyst is that which increases the rate of a reaction, decreases the E_a and is unchanged at the end of the reaction.

Changing solution concentration changes particles per unit volume, refer above.

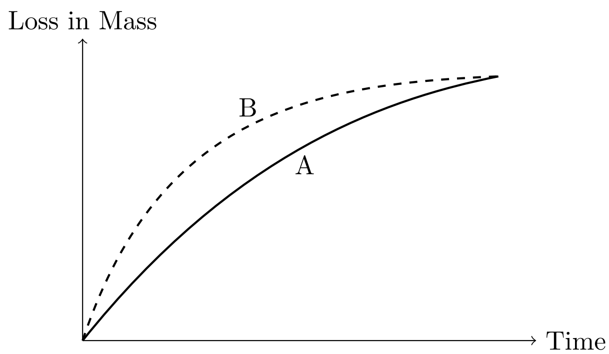
Changing gas pressure does the same, refer above.

Increasing surface area of solids means there are more exposed surfaces with which reactants can effectively collide, meaning effective collisions are more likely. The opposite is also true.

Increasing temperature increases KE of particles, refer above.

Addition of a catalyst, including enzymes, increases reaction rate and decreases E_a.

Investigating the rate of a reactioon comes down to measuring the rate at which reactants are used up or the rate at which products are formed. The information can be represented in a graph:



In reaction B, the reactants were powdered, with increased surface area and hence the reaction had a faster rate than A with just solid reactants. Notice that they loss in mass is equal but the rate of loss of mass is the difference.

2.3 Reversible reactions and equilibrium

Most reactions are one-way, i.e., reactants react to form products and that's it. Some reactions, are reversible, in such reactions, reactants react to form products and those products also react to form reactants. Such reactions are shown with a "$\rightleftharpoons$":

$$N_2\,(g) + 3\,H_2\,(g) \underset{\text{backward reaction}}{\overset{\text{forward reaction}}{\rightleftharpoons}} 2\,NH_3\,(g)$$

Changing the direction of a reversible reaction can depend on the conditions applied to it. Such is the case for hydrating and making anhydrous salts.

$$CoCl_2 \cdot 6\,H_2O \underset{\text{water}}{\overset{\text{heat}}{\rightleftharpoons}} CoCl_2 + 6\,H_2O$$
$$CuSO_4 \cdot 6\,H_2O \underset{\text{water}}{\overset{\text{heat}}{\rightleftharpoons}} CuSO_4 + 6\,H_2O$$

Note that, $CuSO_4$ is white while the hydrated form $CuSO_4 \cdot H_2O$ is blue. Hydrated cobalt (II) chloride is pink whereas the anhydrous form is blue.

A closed system is that where no reactants or products can escape from the reacting system. In such a system, a reversible reaction is in equilibrium when the rate of forward reaction equals the rate of backward reaction and the concentrations of reactants and products are not changing. The reagents are reacting but the concentrations do not change.

The position of equilibrium tells us the rate of forward reaction compared to backward reactions. That means, if the position of equilibrium is to the right, the rate of forward reaction is greater than that of the backward reaction and vice versa.

Note that, when a change is made to the conditions of a system in dynamic equilibrium, the system moves so as to oppose that change.

Changing temperature affects the reaction depending on the enthalpy of the reaction. Changing the temperature will cause the equilibrium to shift in the direction that will reverse that change. Increasing the temperature in a reaction where the forward reaction is exothermic will shift equilibrium to left, as the system will oppose the change by increasing rate of endothermic reaction to lower temperature. The opposite is also true.

Changing pressure only affects reactions whose reagents are all gaseous. Increasing pressure moves equilibrium toward the side which has less gaseous moles. The opposite is also true.

Increasing concentration of reactants moves equilibrium to right and more products are formed and vice versa.

Using a catalyst does not affect equilibrium position, but the speed at which the system reaches equilibrium is affected by catalyst.

Below is the symbol equation for the Haber process.

$$\mathrm{N_2(g)} + 3\,\mathrm{H_2(g)} \xrightleftharpoons[200\,\mathrm{atm}]{450\,^\circ\mathrm{C}} 2\,\mathrm{NH_3(g)}\ \Delta H < 0$$

The nitrogen is gotten from fractional distillation of liquid air and hydrogen is gotten from cracking of crude oil. The above reaction requires an iron catalyst.

In the Contact process, sulfur dioxide is converted into sulfur trioxide.

$$2\,\mathrm{SO_2(g)} + \mathrm{O_2(g)} \xrightleftharpoons[2\,\mathrm{atm}]{450\,^\circ\mathrm{C}} 2\,\mathrm{SO_3(g)}\ \Delta H < 0$$

The Contact process requires a vanadium (V) oxide, V_2O_5 catalyst. Sulfur dioxide is gotten from burning or roasting sulfide ores:

$$\mathrm{S(s)} + \mathrm{O_2(g)} \longrightarrow \mathrm{SO_2(g)}$$

and oxygen is gotten from air.

The conditions in the above industrial processes are such that to optimise economical costs and safety.

2.4 Redox

Roman numbers are used to indicate the oxidation number of an element in a compound (iron (II), vanadium (V), etc.).

A redox reaction is where reduction and oxidation occurs simultaneously.

The oxidation of a compound is its gain of oxygen, loss of electrons or increase in oxidation number.

The reduction of a compound is its loss of oxygen, gain of electrons or decrease in oxidation number.

Rules for identifying oxidation number:

- It is zero in uncombined states (B, Mg).
- It is the same as the charge on an ion (B^{+2}).
- Sum of oxidation numbers in a compound is zero.

- Sum of oxidation numbers in an ion is equal to the charge in the ion.

Acidified potassium manganate(VII), $KMnO_4$, is an oxidising agent with a purple colour, which it loses when it is added to a reducing agent. Aqueous potassium iodide, KI, is a reducing agent which turns brown in presence of an oxidising agent.

An oxidising agent is that which oxidises another substance and is itself reduced. A reducing agent as a substance that reduces another substance and is itself oxidsed.

Using changes in oxidation numbers, oxidising and reducing agents can be identified.