WJEC Wales Chemistry GCSE

2.6: Reversible reactions, industrial processes and important chemicals

Detailed notes

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Reversible reactions

What is a reversible reaction?

- In some chemical reactions, the products of the reaction can react to produce the original reactants
  - These are called reversible reactions
  - A + B ⇌ C + D
- The reaction to form the products is known as the forward reaction and the reaction to form the reactants from the products is the backwards reaction
- The chemical equation includes the symbol ⇌ which shows the reaction can occur in both directions
- The direction of the reaction can be changed by changing the conditions (e.g. for forwards reaction use hot conditions and for reverse use cool)
- If a reversible reaction is endothermic one way, it is exothermic in the opposite direction.
- The same amount of energy is transferred each way (just for one the energy will be lost and for the other the same amount will be gained)

The Haber process

Nitrogen + hydrogen ⇌ ammonia

$N_2 + 3H_2 \rightleftharpoons 2NH_3$

- Used to manufacture ammonia, which is used to produce nitrogen-based fertilisers
- The raw materials are nitrogen and hydrogen gas
  - Nitrogen is obtained from the air and hydrogen may be obtained from natural gas or other sources
- The purified gases are passed over a catalyst of iron at a high temperature (about 450 °C) and a high pressure (about 200 atmospheres)
- Some of the hydrogen and nitrogen reacts to form ammonia.
- The reaction is reversible, so ammonia breaks down again into nitrogen and hydrogen.
- On cooling, the ammonia liquefies and is removed.
  - The remaining nitrogen and hydrogen are recycled.

HIGHER TIER ONLY - Reaction conditions and compromise

- **The Haber Process is in dynamic equilibrium - the forward and backward reactions keep going once equilibrium is reached**
- **The chemical equation is $N_2 + 3H_2 \rightleftharpoons 2NH_3$, so there are fewer moles of gas on the product side (2 compared to 4). This means you would increase pressure to move equilibrium to the right so more ammonia is produced**
- **The forward reaction is exothermic, so a low temperature would favour the forward reaction and mean more ammonia was produced**
- **HOWEVER the actual conditions used are not low temperature and very high pressure, because a low temperature leads to a reaction rate that is too slow and a very high pressure requires too much energy.**
  - **The conditions used are a compromise between maximising reaction rate and the yield of ammonia.**

Ammonia, NH_3

Test for ammonia gas

- Ammonia gas is alkaline so will turn moist red litmus paper blue

Test for ammonium ions

- Ammonium ions react with hydroxide ions to form water and ammonia.
  - Adding a solution that contains hydroxide ions, such as sodium hydroxide solution, to your test sample will form ammonia gas IF ammonium ions are present.
  - Ammonia gas can then be detected with red litmus paper as described above.
- The ionic equation for this reaction is:
  $NH_4^+ (aq) + OH^- (aq) \rightarrow NH_3 (g) + H_2O (l)$

The production of nitrogenous fertilisers

- Nitrogenous fertilisers, such as ammonium sulfate and ammonium nitrate, are made from neutralisation reactions with ammonia.
- Sulfuric acid can be used to make ammonium sulfate, $(NH_4)_2SO_4$, in 2 different reactions:
  - Ammonia + sulfuric acid → ammonium sulfate
  - Ammonium hydroxide + sulfuric acid → ammonium sulfate + water
- Nitric acid can be used to make ammonium nitrate, NH_4NO_3, in 2 different reactions:
  - Ammonia + nitric acid → ammonium nitrate
  - Ammonium hydroxide + nitric acid → ammonium nitrate + water

Evaluation of fertilisers

Advantages	Disadvantages
• Increases crop yields and growth • Increases profits for farmers	• Can cause eutrophication - when fertilisers are washed off the land by rainwater into rivers and lakes there is an increase of nitrate and phosphate in the water, encouraging algae growth. Algae growth forms a bloom over the water surface, preventing sunlight from reaching other water plants, which then die. Bacteria break down the dead plants and use up the oxygen in the water so the body of water may be left completely lifeless. • Many stages required in their manufacture • Changes the pH of the soil • Can cause baby blue syndrome

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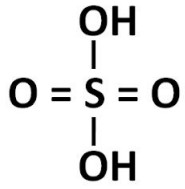
Sulfuric acid

Sulfuric acid

- A strong acid (completely dissociates to release H^+ ions)
- Molecular formula: H_2SO_4
- Structure:



- It is manufactured by the contact process

The contact process

1. $S\ (l) + O_2\ (g) \rightarrow SO_2\ (g)$
    - Sulfur is burned in air where it reacts with oxygen to form sulfur dioxide
2. $2SO_2\ (g) + O_2\ (g) \rightleftharpoons SO_3\ (g)$
    - Sulfur dioxide reacts further with oxygen to form sulfur trioxide
    - This is a reversible reaction
    - Conditions required: Vanadium(V) oxide (V_2O_5) catalyst, 450 °C and a pressure of 2 atm
3. $H_2O\ (l) + SO_3\ (g) \rightarrow H_2SO_4\ (g)$
    - Finally, sulfur trioxide is reacted with water to form sulfuric acid

The uses of sulfuric acid

- Most of the sulfuric acid made is used in the production of fertilisers
- Manufacture of chemicals e.g. HCl, HNO_3, sulfate salts, synthetic detergents, fibres, plastics, dyes and pigments, explosives and drugs
- In petroleum refining to wash impurities out of gasoline and other refinery products
- In processing metals
- Rayon is made with sulfuric acid. It serves as the electrolyte in the lead-acid storage battery

Concentrated sulfuric acid as a dehydrating agent

Dehydrating agents remove water from other compounds. Concentrated sulfuric acid is used as a dehydrating agent in 2 important reactions:

1. With sugar - concentrated sulfuric acid removes 6 water molecules per glucose ($C_6H_{12}O_6$) molecule. The reaction is highly exothermic; it releases the water molecules as steam as a black mass of carbon forms.
2. With hydrated copper(II) sulfate - hydrated copper(II) sulfate is blue but as the water is removed using sulfuric acid, anhydrous copper(II) sulfate forms, which is a white powder.