WJEC England GCSE Chemistry

Topic 11: Production, use and disposal of important chemicals and materials

Notes

(Content in bold is for Higher Tier only)

The Haber process

- Used to manufacture ammonia, which is used to produce nitrogen-based fertilisers, making the process important for agricultural production
- The raw materials for the Haber process are nitrogen and hydrogen.
- 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.

$$\text{nitrogen} + \text{hydrogen} \rightleftharpoons \text{ammonia}$$

- On cooling, the ammonia liquefies and is removed.
- The remaining nitrogen and hydrogen are recycled.

NB: (HT only) be prepared to interpret graphs of reaction conditions versus rate (rate of reaction = gradient of line with rate – concentration graphs)

Production and uses of NPK fertilisers

- Compounds of nitrogen, phosphorus and potassium are used as fertilisers to improve agricultural productivity
- NPK fertilisers contain compounds of all three elements
- production of fertilisers:
    - In the lab:
        - reactants: ammonia solution and dilute sulfuric acid (bought from chemical manufacturers)
        - SMALL scale (very little is produced)
        - only involves a few stages (titration then crystallisation)

    - In industry:
        - reactants: natural gas, air, water (to make ammonia) and sulfur, air, water (to make sulfuric acid)
        - LARGE scale (produces a lot)
        - Many stages required (need to make ammonia and sulfuric acid, react accurate volumes then evaporate)
- Potential drawback of overuse:
    - When they're 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

Test for ammonia

- Ammonia gas makes damp red litmus paper turn blue
- to test for ammonium ions, add sodium hydroxide and then test the gas given off with red litmus paper
- Ammonia forms a white smoke of ammonium chloride when hydrogen chloride gas, from concentrated hydrochloric acid, is held near it

Compromises needed

- **for reversible reactions, optimal conditions in terms of position of equilibrium depend on the reaction itself, but for some a low pressure or temperature is optimal**
- **optimal conditions in terms of reaction rate are a high temperature and high pressure for any reaction**
- **in cases where the optimal conditions for equilibrium position and reaction rate are different, a compromise is reached- otherwise yield would be too low**
- **there is still a limit to using high pressures/temperatures even if they give higher yields- to save money and also, if they are too high – this could be dangerous**

social and environmental impact of decisions made in siting chemical plants:

- when deciding where to create chemical plants, several factors must be considered, including environmental and economic factors. Some examples of these include:
  - chemical plants create jobs, supporting the local economy
  - they create noise and dust pollution, especially whilst being created, so they shouldn't be close to too many houses
  - a natural habitat for wildlife will be destroyed

calculations:

- percentage yield= actual yield ÷ theoretical yield x100
- to find theoretical yield of a product, given the mass of a reactant:
  - Find moles of that one substance: moles = mass / molar mass
  - Use balancing numbers to find the moles of desired reactant or product (e.g. if you had the equation: $2NaOH + Mg \rightarrow Mg(OH)_2 + 2Na$, if you had 2 moles of Mg, you would form 2x2=4 moles of Na)
  - Mass = moles x molar mass(of the reactant/product) to find mass
- atom economy: a measure of the amount of reactant that is converted into useful product
- atom economy= relative molecular mass of useful product ÷ molecular mass of all reactants
- **certain reaction pathways are chosen based on multiple factors including: atom economy, yield, rate, equilibrium position and usefulness of byproducts**

Corrosion and its prevention

- Corrosion = destruction of materials by chemical reactions with substances in the environment. Both air and water need to be present.
- Can be prevented by applying a coating that acts as a barrier, such as greasing, painting or electroplating
  - Aluminium has an oxide coating that protects the metal from further corrosion
  - Some coatings are reactive and contain a more reactive metal to provide sacrificial protection
    - E.g. zinc is used to galvanise iron

Alloys as useful materials

- Most metals in everyday uses are alloys.
- Pure copper, gold, iron and aluminium are all too soft for everyday uses and so are mixed with small amounts of similar metals to make them harder for everyday use.
- this works because in a pure metal, all the + metal ions are the same size and in a regular arrangement, allowing the layers to slide over each other relatively easily, making the metal soft and malleable. In an alloy, you have + ions of different metals, which have different sized ions. This disrupts the regular structure and prevents the ions being able to slide as easily, leaving a much harder, stronger metal.

- Steels are alloys since they used mixtures of carbon and iron
  - Some steels contain other metals. Alloys can be designed to specific uses.
  - Low-carbon steels are easily shaped - used for sheeting (malleable)
  - High carbon steels are hard - used for cutting tools
  - Stainless steels (containing chromium and nickel) are resistant to corrosion - used for cutlery

Ceramics, polymers and composites

- glass ceramics: transparent, hard, brittle, poor heat and electrical conductors
  - uses: windows, bottles
- clay ceramics: opaque, hard, brittle, poor heat and electrical conductors
  - uses: bricks and porcelain
- polymers: can be made transparent/translucent/opaque, poor heat and electrical conductors, can be tough or ductile
  - uses: plastic bags, bottles
- metals: shiny, good heat and electrical conductors, hard, tough
  - uses: cars, bridges, electrical cables

Life cycle assessment

- These are carried out to assess the environmental impact of products in each of these stages:
  - Extracting and processing raw materials
  - Manufacturing and packaging
  - Use and operation during its lifetime
  - Disposal at the end of its useful life, including transport and distribution at each stage
- Use of water, resources, energy sources and production of some wastes can be fairly easily quantified
- Allocating numerical values to pollutant effects is less straightforward and requires value judgements, so LCA (life cycle assessment) is not a purely objective process

Ways of reducing the use of resources

- Reduction in use, reuse and recycling of materials by end users reduces the use of limited resources, use of energy sources, waste and environmental impacts
- Metals, glass, building materials, clay ceramics and most plastics are produced from limited raw materials.
  - Much of the energy for the processes comes from limited resources
  - Obtaining raw materials from the Earth by quarrying and mining causes environmental impacts
  - Some products, such as glass bottles, can be reused
    - Glass bottles can be crushed and melted to make different glass products
  - Other products cannot be reused and so are recycled for a different use
  - Metals can be recycled by melting and recasting or reforming into different products

Practical Assessments

- SP11 Determination of the percentage of water in a hydrated salt, e.g. copper(II) sulfate