OCR B GCSE Chemistry

Topic 6: Making useful chemicals

How are chemicals made on an industrial scale?
(separate science only)

Notes

1. Recall the importance of nitrogen, phosphorous and potassium compounds in agricultural production (separate science only)

- Compounds of nitrogen, phosphorus and potassium are used as fertilisers to improve agricultural productivity
- plants can't absorb these elements in their pure form, so they are contained in soluble salts which the plants can take in through their roots

2. Explain the importance of the Haber process in agricultural production and the benefits and costs of making and using fertilisers, including: the balance between demand and supply of food worldwide, the sustainability and practical issues of producing and using synthetic and natural ferilisers on a large scale, the environmental impact of over-use of synthetic fertilisers (eutrophication) (separate science only)

- Benefits
    - Ammonia is used to make fertiliser salts containing nitrogen
    - Help plants grow, meaning that crop yields are increased
- Costs
    - Balance between demand and supply of food worldwide – if there is a large demand and a small supply then the fertilisers will sell for a lot, but if there is a small demand and a large supply then they will not sell for much
- Eutrophication
    - Fertilisers are washed off the land by rainwater into rivers and lakes
    - Increases nitrate/phosphate in the water
    - Encourages algae growth
    - This forms a bloom over the water surface
    - Prevents sunlight reaching water plants, meaning they die
    - Bacteria break down these dead plants
    - They use up oxygen in the water to do so, leaving the body of water lifeless
- Sustainability
    - Rate of reaction must be high enough to make enough product each day
    - Percentage yield must be high enough to make product each day
        - A low percentage yield would mean that unreacted starting materials would be recycled

3. (HT only) explain how the commercially used conditions for the Haber process are related to the availability and cost of raw materials and energy supplies, control of equilibrium position and rate including: the sourcing of raw materials and production of the feedstocks; nitrogen (from air), and hydrogen (from natural gas and steam) ; the effect of a catalyst, temperature and pressure on the yield and rate of reaction ; the separation of the ammonia and recycling of unreacted nitrogen and hydrogen (separate science only)

- The haber process:
  - The Haber Process is used to manufacture ammonia, which is used to produce nitrogen-based fertilisers
  - 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/hydrocarbons or steam
  - 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.

    nitrogen + hydrogen ⇌ ammonia
  - On cooling, the ammonia liquefies and is removed.
  - The remaining nitrogen and hydrogen are recycled.
- Relation to availability and cost of raw materials and energy supplies
  - Catalysts (iron is used) decrease costs since they increase the rate of reaction so lower temperatures can be used, although there is the initial cost of the catalyst
  - Recycling unreacted starting materials
  - Automating equipment means less workers to pay
- Control of equilibrium position
  - A compromise temperature is used
    - Forward reaction is exothermic, therefore a low temperature would give optimal position of equilibrium
    - Still need a relatively high temperature to ensure that the rate of reaction is not too low, as this would make the process uneconomical
  - compromise in pressure
    - fewer moles of gas on product side, so a high pressure gives optimal position of equilibrium and reaction rate
    - however high pressures require a lot of energy and very expensive equipment

4. (HT only) explain the trade-off between rate of production of a desired product and position of equilibrium in some industrially important processes (separate science only)

- 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

5. define the atom economy of a reaction (separate science only)

- A measure of the amount of reactants that become useful products (or of the efficiency of a reaction)

6. calculate the atom economy of a reaction to form a desired product from the balanced equation using the formula: atom economy = mass of atoms in desired product ÷ total mass of atoms in reactants (separate science only)

atom economy = (Mr of desired product from reaction / sum of Mr of all reactants) x 100

- Important for sustainable development and for economic reasons to use reactions with high atom economy

7. Use arithmetic computation when calculating atom economy (separate science only)

- see above

8. (HT only) explain why a particular reaction pathway is chosen to produce a specified product given appropriate data such as atom economy (if not calculated), yield, rate, equilibrium position, usefulness of by-products and evaluate the sustainability of the process (separate science only)

- Be prepared to give reasons why a particular reaction pathway is chosen, in reference to information given in the question regarding atom economy, yield, rate, equilibrium position and usefulness of by-products

9. Describe the industrial production of fertilisers as several integrated processes using a variety of raw materials and compare with laboratory syntheses. Including: demand for fertilisers (including ammonium sulfate) is often met from more than one process ; some fertilisers are made as a bi-product or waste product of another process ; process flow charts are used to summarise industrial processes and give information about raw materials, stages in the process, products, by-products and waste ; lab processes prepare chemicals in batches, industrial processes are usually continuous (separate science only)

- NPK fertilisers are formulations of various salts containing appropriate percentages of the elements
- Ammonia can be used to manufacture ammonium salts (such as ammonium nitrate and ammonium sulfate) and nitric acid
- Potassium chloride, potassium sulfate and phosphate rock are obtained by mining, but phosphate rock cannot be used directly as a fertiliser
    - Phosphate rock is treated with nitric acid or sulfuric acid to produce soluble salts that can be used as fertilisers
- Demand for fertilisers
    - Many different reactions can make different fertilisers
    - E.g. ammonia + nitric acid → ammonium nitrate
    - Ammonia + phosphoric acid → ammonium phosphate
    - Ammonia + sulfuric acid → ammonium sulfate
    - Potassium hydroxide + nitric acid → potassium nitrate
- some fertilisers are made as a bi-product or waste product of another process

10. Compare the industrial production of fertilisers with laboratory syntheses of the same products (separate science only)

- 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)