

2005 HSC Examination Paper

Sample Answers

Section I Part A

1 B All isotopes with a nuclear mass greater than that of lead are unstable. The number of electrons possessed by an atom has no effect on its stability.

2 C Cellulose is a potential raw material for the production of monomers that could be used to make plastics. It is a condensation polymer that can be hydrated to form glucose which can be fermented to ethanol. Ethanol can be dehydrated to ethylene which is used by the petrochemical industry.

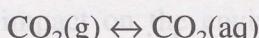
3 B ΔH_c (butan-1-ol) = $-2676 \text{ kJ mol}^{-1}$
 $= -2676 \text{ kJ per } 74.0 \text{ g (molar mass = } 74.0 \text{ g)}$
 $= 36.16 \text{ kJ per } 1.0 \text{ g}$

4 D The monomers must be such that water can be removed to allow the monomers to link up. When a hydroxyl is removed from the end of one of the monomers in answer D and a hydrogen from the end of the other the polymer formed is the example given. Water is the other product.

5 B In this electrochemical cell aluminium is the anode and is oxidised to aluminium ions. The blue copper(II) ions are reduced to a reddish coloured copper metal precipitate. The loss of Cu^{2+} ions will cause the blue colour to fade.

6 A Ethyl pentanoate is an ester. Esters are commonly used for flavouring.

7 C A carbon dioxide equilibrium existed in the unopened soft drink bottle.



The forward reaction is exothermic so that as the soft drink warmed up on the bench the equilibrium shifted in reverse to absorb the heat-producing bubbles of carbon dioxide. The pressure would have been reduced when the bottle was opened. The equilibrium would shift in reverse to counteract this change also, producing more gas bubbles.

8 A Sulfuric acid is a strong diprotic acid. It will ionise completely to hydrogen sulfate.



Therefore 0.1 mol L^{-1} H_2SO_4 will produce 0.1 mol L^{-1} H^+ .

Hydrogen sulfate will not ionise completely as it is not a strong acid.

Therefore 0.1 mol L^{-1} HSO_4^- will form less than 0.1 mol L^{-1} H^+ .

The final concentration of H^+ will be greater than 0.1 mol L^{-1} and less than 0.2 mol L^{-1} . The pH of 0.1 mol L^{-1} H^+ is 1.0 and the pH of 0.2 mol L^{-1} H^+ is 0.7. The pH will be between 0.7 and 1.0.

- 9 D** A buffer is an equilibrium between a weak acid and its conjugate base in approximately equal concentrations. CH_3COOH is a weak acid and CH_3COO^- is its conjugate base.
- 10 C** The equivalence point in the second titration is in the basic region. A suitable indicator would need to completely change colour within this basic area. Cresolphthalein is the only indicator shown that will start and finish changing colour on the vertical part of the graph, the equivalence point.
- 11 A** Atomic Absorption Spectroscopy is used to determine the concentration of metal ions in solution when in very low concentrations. Calcium is the only metal option.
- 12 B**
- 13 C**
- 14 D** You would expect the river source to have the highest concentration of dissolved oxygen as the quarry and town would deplete the oxygen. You would expect the quarry to have a basic pH as limestone is basic. You would expect the town to have the highest biochemical oxygen demand as this is an indirect measure of bacteria in a water sample and the town would have more organic waste than a river source or a quarry.
- 15 A** 0.60 moles of thiosulfate reacts with 0.30 moles of iodine from the 2:1 ratio in the equation. 0.30 moles of iodine would be produced from 0.30 moles of MnO(OH)_2 from the ratio in the second equation. 0.30 moles of MnO(OH)_2 would be formed from 0.15 moles of oxygen from the ratio in the first equation.

Section I Part B

- 16 (a)** Cyclohexene.
- (b)** Bromine water was used as a diagnostic test for alkenes. It is toxic by all routes of exposure including the inhalation of bromine fumes. This hazard was addressed by only using bromine water in a fume cabinet where the fumes are sucked away and cannot be inhaled.
- (c)** 2 mL bromine water was placed into two test tubes. 2 mL cyclohexane was added to one and 2 mL cyclohexene to the other. Both were shaken in the absence of UV light. Only the alkene would cause the bromine water to decolourise.



Therefore 1.0 mol I^- reacts with 1.0 mol H^+ .

Hydrogen sulphide will not ionise completely as it is not a strong acid.

Therefore 1.0 mol I^- HSO_4^- will form less than 1.0 mol H^+ .

The final concentration of H^+ will be greater than 1.0 mol L^{-1} and less than 1.0 mol L^{-1} .

I^- reacts with H^+ to form H_2I , a very weak acid.

H_2I will be present at 0.1 mol L^{-1} .

- 17** (a) There is significant heat loss from the flame into the surroundings rather than into the water above the flame where the temperature is being recorded.

$$(b) \Delta H_c = -m C \Delta T$$

$$= -200 \times 4.18 \times 24^\circ$$

$$= \frac{-20.064 \text{ kJ}}{x \text{ grams ethanol}}$$

$$\Delta H_c = -367 \text{ kJ mol}^{-1}$$

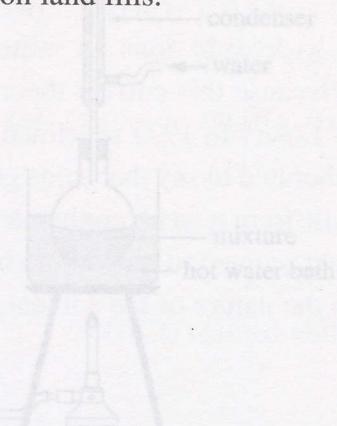
$$n (\text{ethanol}) = \frac{-20.064}{-1367}$$

$$m (\text{ethanol}) = 0.0147 \text{ mol} \times 46.0 \\ = 0.675 \text{ g} \\ = 0.68 \text{ g (2 sig fig)}$$

- 18** The biopolymer, polyhydroxybutanoate (biopol), was developed in the 1920s but it is the recent developments that have had impacts on society and the environment. The bacterium *Alcaligenes eutrophus* contains a gene for the production of this plastic-like substance. In recent times, thanks to genetic engineering techniques, the gene has been located and transferred to the more familiar bacterium *E. coli*. This bacterium is easier to work with and reproduces at a faster rate, making the production of biopol more economically viable.

The development of biopol has had only a limited impact on society to date. It has been used to make shampoo bottles and disposable razor handles but is no longer used for these owing to the high cost of production. It is currently used only in the medical industry to make non-toxic dissolvable sutures. These have had a large impact on internal surgery as they dissolve over time and the patient does not need to have them removed.

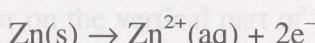
The impact on the environment of biopol is limited by its low usage but it has the potential to have a large impact in the future if it gains wider usage. This is because biopol is biodegradable and if used to replace plastic products it will reduce the pressure on land fills.



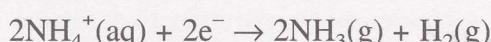
19 (a) The DRY CELL (Cell X) can have an impact on the environment if disposed of in land fill. The outer zinc case corrodes and zinc ions escape into the surrounding soil. A high concentration of zinc ions is toxic to vegetation.

(b) This type of cell contains a graphite cathode inserted into an electrolyte that is a moist paste of NH_4Cl , ZnCl_2 and MnO_2 in a zinc can anode.

The zinc anode oxidises:



The electrons produced are used to reduce the ammonium ion to ammonia and hydrogen at the graphite cathode.



Manganese(IV) oxide is an oxidising agent which converts the hydrogen gas to water.



The ammonia gas reacts with the Zn^{2+} ion.



These reactions have a net potential of 1.5 volts.

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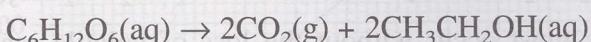
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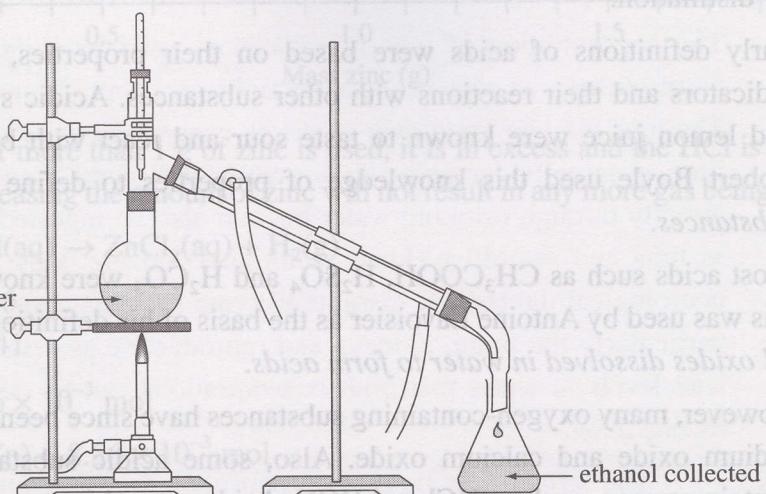
- (c) 2 mL bromine water was placed into two test tubes. 2 mL cyclohexene was added to one and 2 mL cyclohexane to the other. Both were shaken in the absence of UV light. Only the alkene would cause the bromine water to decolourise.

20 Glucose is fermented to produce an ethanol mixture. Fermentation is carried out in large vats. Yeast is added to the glucose solution under anaerobic conditions as it provides the enzyme zymase which catalyses the process. Maximum yield is achieved at optimal conditions of temperature (around 35 °C) and pH and with inorganic nutrients such as ammonium phosphate to provide nitrogen and phosphorus. This produces a 10% ethanol mixture.

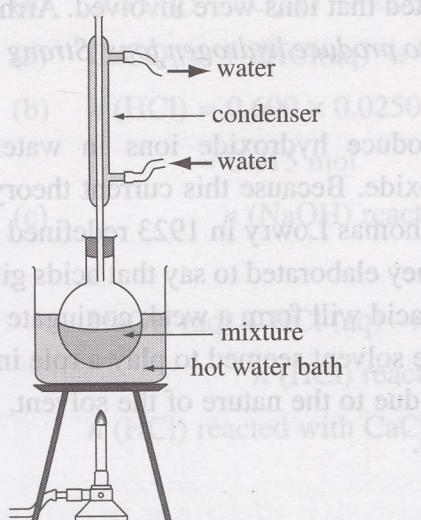


The ethanol is purified by distillation to a 92% concentration. The process of distillation involves heating the mixture until the ethanol boils at 78°C. The ethanol vapour is cooled and condenses and is separated.

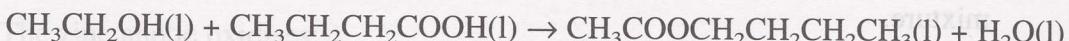
Equipment setup



To produce the purity of ethanol needed in esterification, (98%), the alcohol is mixed with a dehydrating agent, which is later recovered and reused. Pure ethanol is mixed with pure butanoic acid and heated under reflux to produce the ester, ethyl butanoate.



The mixture is heated in a heating mantle or water bath for a lengthy time so that the reactants reach their activation energy. To speed up the process, concentrated sulfuric acid is added which acts as a catalyst and assists in the dehydration process. Hydrogen is removed from the alkanol and hydroxyl from the acid so that they can link together forming the ester. Water is the other product.



The mixture is heated but this must occur without the loss of volatile reactants. The reaction is therefore carried out by refluxing where the volatile substances are condensed in an upright condenser and are returned to the reaction flask for further heating.

The excess acid can be neutralised using sodium carbonate and the ester can be purified by distillation.

- 21** Early definitions of acids were based on their properties, including their effect on indicators and their reactions with other substances. Acidic substances such as vinegar and lemon juice were known to taste sour and react with bases. In the 17th century, Robert Boyle used this knowledge of properties to define acids as *all sour-tasting substances*.

Most acids such as CH_3COOH , H_2SO_4 and H_2CO_3 were known to contain oxygen and this was used by Antoine Lavoisier as the basis of his definition in 1779. He thought that *all oxides dissolved in water to form acids*.

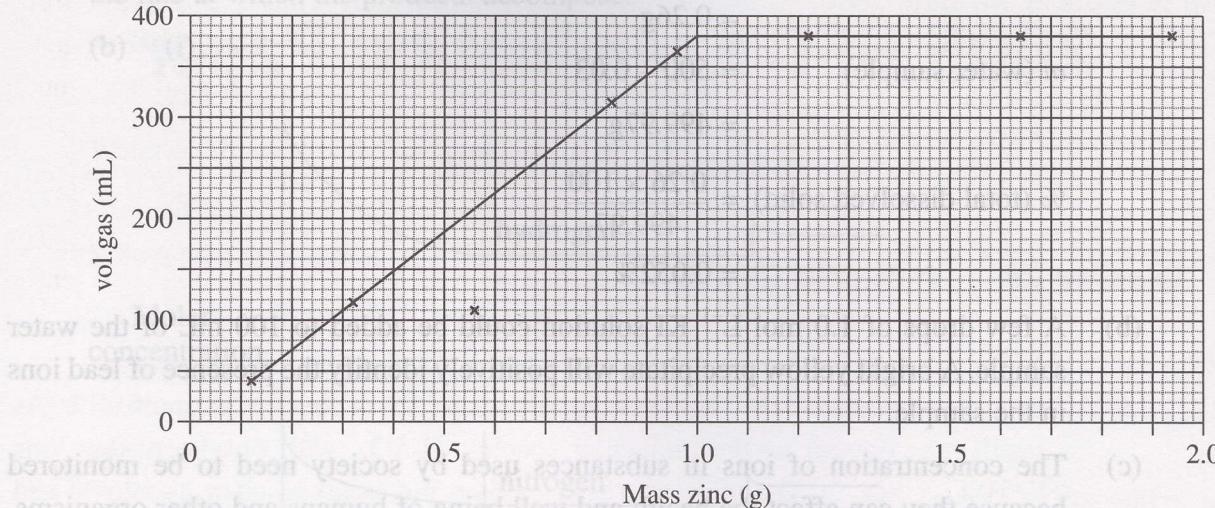
However, many oxygen-containing substances have since been found to be basic, such as sodium oxide and calcium oxide. Also, some acidic substances were known not to contain oxygen, such as HCl and HCN . Acids were shown to react with metals forming salts, e.g. ZnCl_2 . Humphry Davy, in the early 1800s, used these observations to define acids as *substances that contain replaceable hydrogen*.

In 1884, Svante Arrhenius proposed a theory to explain the properties of acids that were known by that time. Acids were known to conduct electricity and react with metals to produce hydrogen gas. These observations suggested that ions were involved. Arrhenius defined acids as *substances that ionise in solution to produce hydrogen ions. Strong acids ionise fully and weak acids slightly*.

Arrhenius defined bases as substances that produce hydroxide ions in water but carbonates were shown to be basic without hydroxide. Because this current theory had inconsistencies like this, Johannes Brønsted and Thomas Lowry in 1923 redefined acids as *proton donors* and bases as *proton acceptors*. They elaborated to say that acids give up protons to form conjugate bases and that a strong acid will form a weak conjugate base. They came to this conclusion by observing that the solvent seemed to play a role in acid behaviour. The strength of an acid appeared to be due to the nature of the solvent. They also observed that different salts had different pHs.

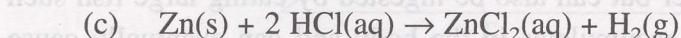
22 (a)

The system has reached equilibrium at the rate at which products form is equal to the rate at which the products decompose.



(b) 380 mL gas. If more than 1 g of zinc is used, it is in excess and the HCl is limiting.

Therefore increasing the amount of zinc will not result in any more gas being formed.



$$n(\text{Zn}) = \frac{0.56}{65.41}$$

$$= 8.56 \times 10^{-3} \text{ mol}$$

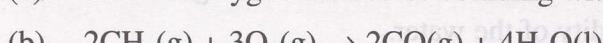
$$n(\text{H}_2) = n(\text{Zn}) = 8.56 \times 10^{-3} \text{ mol}$$

$$V(\text{H}_2) = 8.56 \times 10^{-3} \times 24.79$$

$$= 0.212 \text{ L}$$

$$= 210 \text{ mL (2 sig. fig.)}$$

23 (a) Too few oxygen molecules colliding with the fuel molecules.

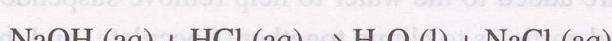


(b) $n(\text{HCl}) = 0.600 \times 0.0250$

$$= 0.015 \text{ mol}$$

(c) $n(\text{NaOH}) \text{ reacted} = 0.100 \times 0.0142$

$$= 1.42 \times 10^{-3} \text{ mol}$$



$$n(\text{HCl}) \text{ reacted} = n(\text{NaOH}) = 1.42 \times 10^{-3}$$

$$n(\text{HCl}) \text{ reacted with CaCO}_3 = 0.015 - 1.42 \times 10^{-3}$$

$$= 0.01358 \text{ mol}$$

$$n(\text{CaCO}_3) = \frac{0.01358}{2}$$

$$= 6.79 \times 10^{-3} \text{ mol}$$

$$m(\text{CaCO}_3) = 6.79 \times 10^{-3} \times 100.09$$

$$= 0.68 \text{ g}$$

25 (a) m (total dissolved solid) = $45.59 - 45.33$
 $= 0.26\text{g}$

m (water sample) = $500 - 0.03$
 $= 499.97\text{g}$

$$\% \text{ (total dissolved solid)} = \frac{0.26 \times 100}{499.97}$$
 $= 0.052\%$

- (b) A few drops of 1.0 mol L^{-1} KI solution could be added to 100 mL of the water sample. A bright yellow precipitate will positively identify the presence of lead ions in the sample.
- (c) The concentration of ions in substances used by society need to be monitored because they can affect the health and well being of humans and other organisms. The ions may be toxic over a certain concentration or they may accumulate over time, eventually damaging body organs or systems. Lead ions are easily absorbed directly through drinking water but can also be ingested by eating large fish such as tuna and swordfish. Lead accumulates in the body and can eventually cause neurological damage. It disrupts enzyme systems, damaging all body organs but particularly the brain, kidneys and reproductive system. It is only by monitoring lead levels in water that high concentrations can be detected and steps taken to reduce them.
- 26 *Source 1* The farmer may be using a phosphate fertiliser on the vegetable patch. The phosphate may leach into the lake and cause eutrophication. This causes high levels of toxins in the catchment water which can cause ill health in humans drinking the water.

Source 2 The logged native forest is more prone to erosion of soil than unlogged forest, because it doesn't have the vegetation roots to bind the soil. It gets washed into the catchment dam, increasing the turbidity of the water.

Before it reaches the town the water could undergo sieving, flocculation, sedimentation and filtering to purify it.

Method 1. SIEVING. The water passes through a metal grate which catches and removes larger objects such as twigs, fish and leaves.

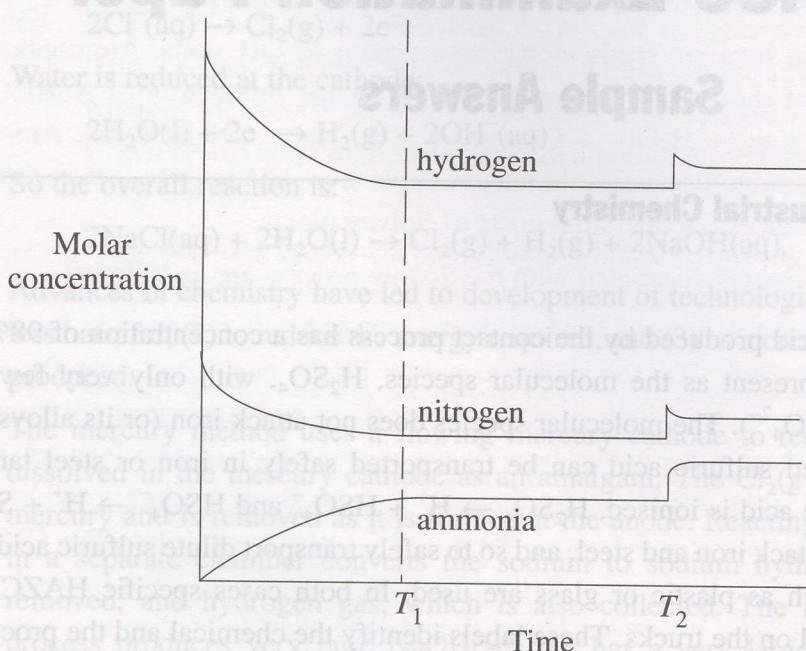
Method 2. FLOCCULATION and SEDIMENTATION. Chemicals such as aluminium hydroxide and iron chloride are added to the water to help remove suspended particles. These ions cause the suspended particles to clump together (flocculate) and then they are more likely to settle out or be caught by a filter. Sedimentation is the settling out process.

Method 3. FILTERING. Material that remains suspended may be removed when the water passes through a sand and anthracite filter.

These methods together purify water. None of the methods is effective on its own as they remove different particles from the water. A membrane filter is more effective at removing fine suspended particles than a sand filter but it is more costly and impractical for purifying a town's water supply as it slows down the rate of water flow and purification.

- 27 (a) The system has reached equilibrium. The rate at which products form is equal to the rate at which the products decompose.

- (b) (i)



When the volume is reduced the concentrations of reactants and products immediately increase, which increases the total pressure. The equilibrium shifts forward to partially counteract this change because there are four moles of reactants and only two moles of products. A forward shift reduces the number of molecules as four react to form two. This reduces the pressure.

Developments in polymer chemistry, leading to the development of chemically active, semi-permeable membranes have led to the membrane method for producing $NaOH(aq)$.

In this case a synthetic membrane with negatively charged pores is used, which allows

Na^+ ions to migrate from the anode compartment to the cathode compartment (where

OH^- ions are being formed from H_2O (lithium H_2O later), but do not allow H^+ or Cl^- ions

to migrate. This produces a very pure $NaOH(aq)$, and eliminates the dangers of using

chlorine gas. The energy requirement of this process is also lower than that of the other two methods.

(c) Sodium hydroxide was originally made by the reaction of sodium carbonate with lime:



The dissociation of electrolytes (such as

sodium carbonate) causes this and by the early 1800s dissociative ionisation of

$NaOH$ (in electrolytic cells – as advances in technology was the dominant factor, and

is still used today). These three ways of producing $NaOH$ electrolytically, the

Options Topics**2005 HSC Examination Paper****Sample Answers****Question 28 Industrial Chemistry**

- (a) (i) Oleum.
- (ii) The sulfuric acid produced by the contact process has a concentration of 98%. As a result it is present as the molecular species, H_2SO_4 , with only very few ions (H^+ , HSO_4^- , SO_4^{2-}). The molecular species does not attack iron (or its alloys) and so concentrated sulfuric acid can be transported safely in iron or steel tankers. Dilute sulfuric acid is ionised, $\text{H}_2\text{SO}_4 \rightarrow \text{H}^+ + \text{HSO}_4^-$ and $\text{HSO}_4^- \rightarrow \text{H}^+ + \text{SO}_4^{2-}$. The H^+ ions attack iron and steel, and so to safely transport dilute sulfuric acid inert containers such as plastic or glass are used. In both cases specific HAZCHEM labels are used on the trucks. These labels identify the chemical and the procedure to be followed in case of a spill.
- (b) (i) The addition of a catalyst would have no effect on the yield of N_2O_4 because a catalyst increases the rate of the forward and reverse reactions equally. It does this by providing an alternative mechanism with a lower activation energy. Increasing the pressure of the reaction system will increase the yield of N_2O_4 . Le Chatelier's principle tells us that when disturbed, an equilibrium system will shift in order to minimise the disturbance. The system will shift to offset the increase in pressure by producing more N_2O_4 , because this results in fewer moles of gas in the system, and pressure is the result of collisions between gas particles and the vessel walls. Thus producing more N_2O_4 reduces the pressure on the system.
- (ii) the vessel is 1 L so the initial concentrations are as follows:

$$[\text{NO}_2] = 0.132 \text{ M} \text{ and } [\text{N}_2\text{O}_4] = 0 \text{ M.}$$

$$\text{At equilibrium } [\text{N}_2\text{O}_4] = 0.0400 \text{ M.}$$

This means that 0.0800 M of NO_2 reacted (using the mole ratio in the equation).

As a result, at equilibrium $[\text{NO}_2] = 0.0520 \text{ M.}$ ($0.132 - 0.0800 = 0.0520$)

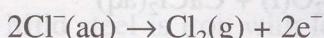
$$\text{Therefore } K \text{ (at } 25^\circ\text{C}) = \frac{[\text{N}_2\text{O}_4]}{[\text{NO}_2]^2} = \frac{0.04}{(0.052)^2} = 14.7929 = 14.8$$

(Note: 3 significant figures are required in the answer. Units are not required).

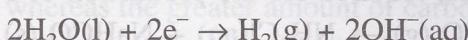
- (c) Sodium hydroxide was originally made by the reaction of sodium carbonate with lime: $\text{Na}_2\text{CO}_3(\text{aq}) + \text{Ca}(\text{OH})_2(\text{aq}) \rightarrow 2\text{NaOH}(\text{aq}) + \text{CaCO}_3(\text{s})$. The discovery of electrolysis (an advance in chemistry) changed this and by the early 1900s electrolytic production of NaOH (in electrolytic cells – an advance in technology) was the dominant method, and is still used today. There are three main methods of producing NaOH electrolytically: the

purification.

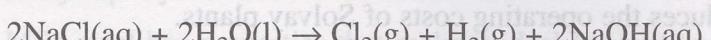
mercury cell, the membrane cell and the diaphragm cell. In each case a purified brine solution is electrolysed. In each case chloride ions from the brine are oxidised at the anode:



Water is reduced at the cathode:



So the overall reaction is:



Advances in chemistry have led to development of technologies to (1) make the process less harmful, (2) to reduce the energy required, and (3) to increase the purity of the NaOH produced.

The mercury method uses a flowing mercury cathode to reduce Na^+ to Na which is dissolved in the mercury cathode as an amalgam. The $\text{Cl}_2(\text{g})$ does not dissolve in the mercury and is removed as it is formed at the anode. Reacting the amalgam with water in a separate chamber converts the sodium to sodium hydroxide solution, which is removed, and hydrogen gas, which is also collected. The mercury is recycled. The process produces very pure NaOH(aq) but has a very large energy requirement and releases mercury (very poisonous) to the environment (about 3 g per tonne of NaOH produced).

The environmental issues associated with mercury poisoning and the energy costs of the mercury method were able to be overcome when advances in the chemistry of asbestos fibres led to the development of asbestos diaphragm technology. In this case inert electrodes are used and an asbestos diaphragm separates the anode and cathode compartments. This allows the electrodes to be closer together, lowering the resistance of the cell, reducing the energy required. The diaphragm keeps the Cl_2 and H_2 separate, but allows Na^+ ions to migrate to the cathode compartment to form NaOH(aq). A disadvantage of this method is that the diaphragm becomes clogged, requiring costly maintenance, and the NaOH(aq) is contaminated with NaCl which must be removed.

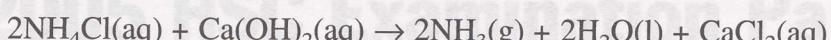
More serious though is that asbestos is a carcinogen, causing lung cancer.

Developments in polymer chemistry, leading to the development of chemically active, semi-permeable membranes have led to the membrane method for producing NaOH(aq). In this case a synthetic membrane with negatively charged pores is used, which allows Na^+ ions to migrate from the anode compartment to the cathode compartment (where OH^- ions are being formed from the reduction of water), but do not allow OH^- or Cl^- ions to migrate. This produces a very pure NaOH solution, and eliminates the dangers of using mercury or asbestos. The energy requirement of this process is also lower than that of the other two methods.

For more information on the history of the development of NaOH production, see the section on the history of the development of the chemical industry.

(d) (i) $\text{Na}_2\text{CO}_3(\text{s})$ or sodium carbonate.

(ii) Ammonia is recovered by the following acid/base reaction:



The ammonium ions are acids, donating a proton to OH^- ions. Ammonia is an essential part of the Solvay process, required for the production of $\text{NaHCO}_3(\text{s})$: $\text{NH}_3(\text{g}) + \text{NaCl}(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g}) \rightarrow \text{NH}_4\text{Cl}(\text{aq}) + \text{NaHCO}_3(\text{s})$. Ammonia recovery is desirable because ammonia is expensive, and recycling the ammonia significantly reduces the operating costs of Solvay plants.

(iii) Environmental issues associated with the Solvay process are as follows:

CaCl_2 is produced as a waste product. Some is sold for de-icing roads, but supply far exceeds demand. The remainder is waste. Plants positioned near the ocean release it into the ocean. Plants positioned near rivers and lakes must not discharge the CaCl_2 into these water bodies because the concentration of dissolved solids and particularly Cl^- ions would disrupt the aquatic ecosystems leading to widespread death of aquatic flora and fauna. These Solvay plants evaporate the CaCl_2 to dryness and bury it. Evaluation: Selling the CaCl_2 for the de-icing of roads is an excellent use because it recovers some costs for the plant and converts a waste into a commodity. Discharge into the oceans is safe and effective because the pre-existing ion concentrations in sea water make the contribution to total ion concentration from CaCl_2 insignificant. Drying and burial is the least acceptable method of disposal because there is inevitably some leaching of the salt into waterways because of its high solubility, leading to increases in the concentration of dissolved solids in these waterways.

Some of the processes in a Solvay plant generate large amounts of heat, and these processes are water cooled. The resulting heated water is disposed of by discharge into oceans for plants near oceans, and for those near other waterways the heated water is cooled in cooling ponds before discharge into waterways. Evaluation: Both of these methods are effective and safe, because of (1) the diluting effect of the ocean for those plants, and (2) the use of cooling ponds eliminates the danger of thermal pollution of waterways because the water is cooled before discharge.

Excess $\text{Ca}(\text{OH})_2$ is produced and this must be disposed of. It can be neutralised using HCl prior to release into rivers, whereas plants located near oceans can release it directly into the ocean. Evaluation: Neutralisation is effective for plants located near rivers because it prevents pH changes in aquatic ecosystems. The buffering and dilution effect of the oceans means that direct discharge of $\text{Ca}(\text{OH})_2$ into the ocean is also an effective and safe method of disposal for plants located near the ocean.

There are small losses of ammonia despite recycling. Evaluation: Careful monitoring and management is required to eliminate these since ammonia is a toxic air pollutant. Plants should be designed with the elimination of ammonia losses in mind.