2004 HSC Examination Paper

Sample Answers

Section I Part A

1. A The "oate" ending on ethyl ethanoate denotes that the chemical is an ester. Esterification is the process of forming an ester from an alkanoic acid (like ethanoic acid) and an alkanol.

2 A All biopolymers, synthetic or completely natural, are produced by living things and are therefore decomposed by bacteria. This is the property attracting most interest because it is the one property that cannot be found in synthetic polymers. The fact that they are non-biodegradable is causing land-fill problems around the world.

3 B Only transition metals have coloured flames. Copper is the only transition metal given and it produces a green flame. Zinc is not a transition metal and does not have a coloured flame.

4 B Isomers are compounds with the same molecular formula but with different structures. Both the compounds given have the same molecular formula ($C_2H_4Br_2$) but the positions of the bromine branches vary.

5 C Davy defined the hydrogen as replaceable whereas Arrhenius defined hydrogen as an ion being produced by the ionisation of an acid molecule.

6 D Ozone is composed of three oxygen atoms. Two have a double bond between them and the third is bonded by a single coordinate covalent bond.

7 D When the pH changes by one, the concentration of hydrogen ions changes by 10 times. As pH rises, the concentration of hydrogen ions is being reduced.

8 D Diagram D shows the layers in the right order.

9 A

$$n(NO) = \frac{0.66}{30}$$

$$= 0.022 \text{ mol}$$

$$n(O_3) = \frac{0.72}{48}$$

$$= 0.015 \text{ mol}$$

$\therefore O_3$ is limiting.

$n(NO_2)$ formed $= 0.015$ mol

$$V(NO_2) = 0.015 \times 22.71 \text{ L}$$

$$= 0.34 \text{ L}$$

10 C The production of phosgene is exothermic. A low temperature favours the forward reaction as this will release energy partially counteracting the change. A high pressure favours the forward reaction as two moles of gas react to form one mole of gas, partially counteracting the change by reducing the pressure.

11 A Peak X was the second peak to form and is therefore the second lightest compound.

12 C An acid will react with a base to form hydronium. Hydronium contains a coordinate covalent bond where the hydrogen ion from the hydrogen fluoride acid molecule bonds with the basic ammonia molecule.

13 C $n(CH_3CH_2CH_2OH) = \dfrac{0.6}{60}$

$= 0.01 \text{ mol}$

$\therefore \Delta H = 2021 \text{ kJ} \times 0.01 \text{ mol}$

$= 20.21 \text{ kJ}$

$\Delta H = mC\Delta T$

$20210 \text{ J} = 200 \text{ g} \times 4.18 \text{ J g}^{-1} \text{ °C}^{-1} \times \Delta T$

$\therefore \Delta T = 24.17\text{°C}$

Final temp = initial temp + 24.17°C

$= 45.17\text{°C}$

14 D The negative terminal is the anode where oxidation will occur. Metal *z* has the highest voltage, compared to Pb, when it is the anode and is therefore the metal most likely to oxidise. This is followed by *y* then Pb. Increasing ease of oxidation means that the least likely to oxidise is placed first.

15 B The carbon core of a dry cell is the cathode, which is positively charged. The outer casing is the negatively charged zinc anode.

Section I Part B

16 (a)
1. Weigh the required mass of dried $NaHCO_3$ directly into a clean dry beaker.
2. Dissolve in a small amount of distilled water.
3. Add to a clean volumetric flask washed with distilled water.
4. Wash the remnants from the beaker into the flask with a wash bottle containing distilled water.
5. Fill flask to the graduated mark with distilled water.
6. Stopper the flask and invert 10 times to mix thoroughly.

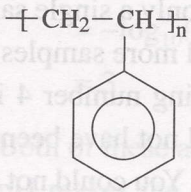
(b) $n\ (NaHCO_3) = 0.12\ mol\ L^{-1} \times 0.25\ L$
$= 0.03\ mol$

$m\ (NaHCO_3) = 0.03\ mol \times 84.008$
$= 2.5\ g$ (to 2 significant figures)

17 (a) The second monomer is called **styrene.**

(b) This statement is correct. A polymer is chosen for a particular job due to its suitable properties. Styrene is used to make the polymer polystyrene. Polystyrene foam is used as a packaging material for electrical goods and white goods because it absorbs shock, protecting the products from damage during transport. It is also light weight which is a benefit because it does not add much to the cost of transport.

Polystyrene is also used to make disposable drinking cups because it is a heat insulator. This will assist in keeping hot drinks hot and reduce the risk of the user being burned. It is also light in mass, reducing the cost in transport.

(c) 

18 Metals are located on the left hand side of the Periodic Table. Those closer to the bottom left corner are more basic, because the metals become more metallic in their properties. Non-metals are located on the right hand side of the table, except that the elements in period VIII do not form oxides. The oxides become more acidic toward the top right hand corner of the table. The oxides of some elements between these two groups are amphoteric. These tend to be the oxides of the semi-metals.

19 (a) Zinc is a more reactive metal than copper and will therefore displace the copper in solution. The more reactive metal will always oxidise and form the stable metal ion. The less reactive metal will accept electrons from the reactive metal and form the solid metal. In this example, the copper ions accept electrons from the zinc metal and form solid copper, the red-brown deposit. The copper ions are blue, and as they are converted into solid copper their concentration is reduced. This explains why the solution becomes lighter.

$$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$$

(b)
$$\text{n } (Cu^{2+}) \text{ initial} = 0.05 \times 0.250$$
$$= 0.0125 \text{ mol}$$
$$\text{n (Cu) deposited} = \frac{0.325}{63.55}$$
$$= 0.005\,11 \text{ mol}$$
$$\text{n (Cu) remaining in solution} = 0.0125 - 0.005\,11$$
$$= 0.007\,386 \text{ mol}$$
$$\text{c } (Cu^{2+}) = \frac{0.007\,386}{0.25}$$
$$= 0.029\,55 \text{ mol L}^{-1}$$
$$= 3.0 \times 10^{-2} \text{ mol L}^{-1} \text{ (to 2 significant figures)}$$

20 (a) The light source provides the characteristic emission spectrum of the element being analysed. The flame provides the heat needed to vaporise the sample being analysed.

(b) This is an approved procedure for determining small concentrations of a metal ion in a sample and is therefore considered valid. However, only a single sample of soil was taken. The procedure may have been more valid had more samples been taken. The absorbance of 0.85 is not accurate because recording number 4 is an outlier that is notably different from the other figures. It should not have been included in the average. Therefore the reliability of this result is low. You could not rely on 0.85 being the actual absorbance.

21 (a) A qualitative analysis of the water samples is an analysis of what is present in the water. A quantitative analysis is a measurement of how much is present.

(b) One factor is the proximity to farms. If there are farms upstream from the water body, fertilisers could seep into the soil and leech into the water body via the water table. This could increase the concentration of ions such as phosphate and nitrate. Another factor would be whether garbage is buried in the vicinity of the water body. Rain water may seep into the soil and dissolve various components of the garbage. These travel into ground water and are carried to the natural water body, increasing the concentration of ions.

(c)

Anion	*Reagent*	*Observations if anion is present*
Cl^-	Silver nitrate	A white precipitate forms which turns brown/purple in sunlight
PO_4^{3-}	Silver nitrate	A yellow precipitate forms
SO_4^{2-}	Barium chloride	A fine white precipitate forms

22 (a) An amphiprotic species can donate or accept a proton depending on the conditions.

(b) $H_2PO_4^-$ will act as an acid and donate a proton in basic conditions:

$$H_2PO_4^-(aq) + OH^-(aq) \rightarrow HPO_4^{2-}(aq) + H_2O(l)$$

$H_2PO_4^-$ will act as a base and accept a proton in acidic conditions:

$$H_2PO_4^-(aq) + H_3O^+(aq) \rightarrow H_3PO_4(aq) + H_2O(l)$$

23 The indicator is yellow in pure water which is neutral. However the indicator is also yellow in basic ammonia and oven cleaner. The indicator is therefore not useful in distinguishing between neutral and basic solutions.

The indicator is red in hydrochloric acid which is a strong acid and orange in the weakly acidic lemon juice. Therefore the indicator is useful in distinguishing acid from base and neutral solutions, and strong from weak acids.

24 (a) $c_1V_1 = c_2V_2$

$$c_2 = 0.01 \text{ mol L}^{-1} \times 10 \text{ mL} / 100 \text{ mL}$$
$$= 0.001 \text{ mol L}^{-1}$$

$$pH = -\log_{10}[H^+]$$
$$= -\log_{10}(0.001)$$
$$= 3$$

(b) Both of these acids can be added to foods to lower the pH of the environment. This pH makes the environment too acidic for decay-causing bacteria to survive, thus preserving the food.

(c) All three acids are the same concentration and yet the hydrochloric acid has the lowest pH. Because $pH = -\log_{10}[H^+]$, the $[H^+]$ is highest in this acid. Therefore the hydrochloric acid molecules ionise to the greatest extent. This is because HCl is the strongest of the three acids. Acetic acid is the weakest acid of the three, therefore it ionises least, producing the lowest $[H^+]$ and consequently the highest pH.

25 There are advantages and disadvantages to the use of ethanol as an alternative fuel. The advantages include the fact that it is renewable when it is produced by the fermentation of sugar from crops like corn, wheat or sugarcane.

$$C_6H_{12}O_6(aq) \rightarrow 2CH_3CH_2OH(l) + 2CO_2(g)$$

All the other fuels in the table are non-renewable as they are produced from petrochemicals to some extent. Ethanol also burns more completely than a fuel like petrol because it is a smaller molecule containing oxygen.

$$CH_3CH_2OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$$

Therefore it burns without releasing much toxic CO gas or carcinogenic soot. The disadvantages of ethanol are that it can only be used as a 10–15% ethanol/petrol blend in cars. At any higher percentage, engine modification is necessary. Any large scale use of ethanol would require much land clearing causing the loss of native forests or land currently used for crop growth. When the advantages and disadvantages are weighed up, ethanol still has potential as a fuel additive. The big advantage in lowering pollution appears to be so vital in today's society that this outweighs the loss of crop land.

26 Americium-241 is used in smoke detectors. The americium emits alpha particles and low energy gamma radiation which ionise oxygen and nitrogen molecules in the air in the detector's ionisation chamber. A low-level electric voltage applied across the chamber is used to collect these ions, causing a steady small electric current to flow between two electrodes. When smoke enters the space between the electrodes, the alpha radiation is absorbed by smoke particles causing the electric current to fall, setting off the alarm.

The benefits of using Am-241 are that it has a long half-life of 432 years meaning that the americium never needs replacing. The alpha particles do not themselves pose a health hazard as they are absorbed in a few centimetres of air or by the structure of the detector.

Am-241 however is potentially dangerous if swallowed in a soluble form. It would concentrate in the skeleton and continue to emit radiation which could cause some cellular damage.

The biggest danger and therefore problem associated with americium has to do with its production. It is made through the decay of plutonium-241 in a nuclear reactor. Plutonium is highly radioactive and emits high energy gamma radiation as it decays. Special precautions must be taken when handling this, otherwise it can cause cancer and death.

27 CFCs, chlorofluorocarbons, were developed in the 1930s as coolants in refrigerators because they boil at a little below 0°C and are non-toxic and non-flammable. Since then CFCs have been used as propellants for aerosol sprays and as solvents to clean electronic components. The problem with CFCs is that they are relatively unreactive in the troposphere where they migrate upwards to the stratosphere over many years. Here they are gradually broken apart by photodissociation.

$$CF_2Cl_2(g) \rightarrow CF_2Cl\bullet(g) + Cl\bullet(g)$$

This chlorine radical acts as a catalyst in the decomposition of ozone.

$$Cl\bullet(g) + O_3(g) \rightarrow ClO\bullet(g) + O_2(g)$$

$$ClO\bullet(g) + O\bullet(g) \rightarrow Cl\bullet(g) + O_2(g)$$

The chlorine radical is continually re-formed and so it is able to catalyse the decomposition of thousands of ozone molecules.

The use of CFCs around the world has largely been replaced by alternative, less damaging, chemicals. Initially hydrochlorofluorocarbons, HCFCs, were used. Based on the data provided in the table, the average ozone depletion potential of this group is 6.25%. This is much less than the ODP for CFCs, which average 95%. However these chemicals still caused some ozone depletion and have more recently been replaced by hydrofluorocarbons, HFCs. These cause no damage to ozone and are therefore a very suitable replacement.

Options Topics

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Sample Answers

Question 28 Industrial Chemistry

(a) (i) Add acid to water slowly, or wear safety goggles.

(ii) $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ + heat energy

The product yield can be maximised by:

using low temperatures; as the reaction is exothermic, this will favour the forward reaction producing more sulfur trioxide gas;

using high pressure; as there are fewer molecules on the product side, more sulfur trioxide will be produced.

(b) (i) Anionic detergent molecules have a negatively charged end which is hydrophilic i.e. attracted to water, and a nonpolar carbon chain which is hydrophobic and is attracted to grease and oil. The nonpolar end mixes with the oils through dispersion forces, and the hydrophilic end with water through hydrogen bonds. When the water is agitated the grease and oil are removed from the surface of the object and form droplets or micelles which are dispersed throughout the water. The polar ends immersed in the water repel each other and prevent the oil droplets from rejoining.

(ii) All linear-chained detergents are biodegradable. Anionic detergents are high foaming and this can be detrimental to the environment as foam covers the surface of water and prevents light and oxygen entering the water, thus destroying aquatic life. Cationic detergents are biocides and in small quantities can be effective in killing bacteria but in large quantities near sewage outlets they can kill the bacteria which decompose sewage. Cationic detergents are also high-foaming. Nonionic detergents produce much less foam and cause less environmental damage. Many detergents contain phosphate builders, which will increase the phosphate concentration if these are released in waterways. This will result in eutrophication, the abundant growth of cyanobacteria and other algae. This excess growth of algae depletes the oxygen supply in the water and kills aquatic life. However, many detergents produced these days do not contain phosphates.

(c) The location of chemical plants should be determined by factors which include the proximity to raw materials, a labour force, transport system, cheap energy and markets.

The production of sodium hydroxide involves the electrolysis of concentrated sodium chloride solutions (brine). This is the basis of the chlor-alkali industry which produces chlorine gas, hydrogen gas and sodium hydroxide. All these products have many industrial uses.

The overall cell reaction in the electrolytic process is:

$$2NaCl(aq) + 2H_2O(l) \rightarrow 2NaOH(aq) + Cl_2(g) + H_2(g)$$

Chlor-alkali production requires easily available brine and cheap electricity.

The Solvay process used to produce sodium carbonate requires the raw materials saturated sodium chloride solution (brine), ammonia and calcium carbonate (limestone). The overall equation is:

$$2NaCl(aq) + CaCO_3(s) \rightarrow Na_2CO_3(s) + CaCl_2(aq)$$

The process occurs in a series of steps.

There are a number of environmental issues that need to be considered in this process:

1 Large quantities of heat are produced, thus water is required as a coolant and must also be cooled before discharge into the environment to prevent damage to aquatic life.

2 Calcium chloride is produced as a byproduct. It will increase the salt levels in waterways which will affect ecosystems.

3 Excess calcium hydroxide must be neutralised with hydrochloric acid before discharge into the environment.

Plants for this process should be located close to reliable sources of salt and limestone. The brine required can be derived from seawater. The hot water and salts produced in the reactions can be safely discharged into oceans.

From our map:

Site A is close to transport for raw materials (e.g. limestone which is easier to transport as a solid than liquid brine) and for shipping to markets. As it is located close to a large city it should have efficient energy supply and there is access to a large labour force. This site is also close to the ocean, thus making it relatively easy to obtain brine in the form of seawater. This raw material is required for the production of both compounds. Proximity to the coast also would allow for the relative ease of discharge of hot water and high levels of salt which are by-products of the Solvay process.

Thus Site A seems suitable for the location of both plants to produce each of the compounds sodium carbonate and sodium hydroxide.

Site B is close to a power station, thus may be suitable for the electrolysis required in the production of sodium hydroxide. However, it is not close to a large population to provide a labour force and it is far from the coast, thus requiring the difficult transport of brine.

Site C is close to a limestone deposit but far from a labour workforce, far from a coastal area and port to transport products and release waste products of heated water and high salts concentrations from the Solvay process.

Thus, assessment of the three sites in terms of the factors which determine the location of a chemical plant for each compound indicates that Site A is the most suitable for both plants.

(d) (i) An emulsion is a mixture consisting of a dispersion of small droplets of one liquid e.g. oil throughout another liquid e.g. water.

(ii) The procedure included making an emulsion of mayonnaise (a mixture of oil, vinegar and water with egg to prevent the separation of the mixture into layers). The properties of the emulsion that were studied included appearance, colour, texture, time taken to separate into layers, scattering of light and filtration ability. These properties were compared to those of a salt water solution. Safety issues considered included working with glassware and safety goggles while working with acid (vinegar). The results are described below:

Mayonnaise: creamy, homogeneous appearance immediately after vigorous shaking; layers separated slightly after standing for 2 days; slow filtration with some oil droplets remaining in the filter paper; scatters light well thus it has a creamy colour.

Salt water: clear, homogeneous appearance immediately after vigorous shaking; clear, homogeneous appearance after standing for 2 days; no separation of components during filtration; no scattering of light.

(iii) The industrial production of soap is done on a large scale. The main differences between the industrial production of soap and production of soap in the school laboratory include the following:

In industrial production the fats and oils (e.g. tallow and palm oil) are unrefined. They are added to large kettles or reactors with concentrated sodium hydroxide solutions; heating and stirring is done using steam and pressure; solidification is controlled by adding salts; glycerol is removed and used in other processes; soap is dried to produce flakes, bars, powders and additives include perfumes and colours.

In a school laboratory, refined oil e.g. olive oil or castor oil is added to 20% sodium hydroxide solution in a beaker on a hotplate or in a water bath; soap is precipitated with concentrated sodium chloride solution; the crude soap is removed by vacuum filtration then washed to remove excess alkali, salt and glycerol. Protective clothing is worn due to the nature of the corrosive sodium hydroxide solution.