2002 HSC Examination Paper

Sample Answers

Section I Part A

1 A The presence of oxygen will allow decomposing bacteria to colonise the mixture.

2 B Concentrated H_2SO_4 is the catalyst used to dehydrate ethanol, and dilute H_2SO_4 is used to hydrate ethylene.

3 C This answer relates to the impact electrolysis has had. The other answers merely relate to the functions of electrolysis.

4 A The anode is defined as the electrode where oxidation occurs no matter what the type of cell.

5 D In electroplating something with copper, the copper ions are reduced at the cathode and so the object to be plated needs to be the cathode. The anode should supply the ions that will be reduced, in this case, copper ions. The electrolyte should contain the ions to be reduced, in this case copper ions.

6 C $HCO_3^- + H^+ \rightarrow H_2CO_3$

$HCO_3^- + OH^- \rightarrow CO_3^{2-} + H_2O$

7 B Containing hydrogen relates to Davy, containing oxygen relates to Lavoisier and being an electron pair acceptor relates to Lewis.

8 A Rinsing the burette and pipette with water would dilute the solutions so they need to be rinsed with the solutions going into them. The critical thing about the conical flask is the number of moles of solution in it, so it needs to be rinsed with water.

9 D The reactants are an alkanol and an alkanoic acid (steps 5 and 3), acid is added as a catalyst (step 2) and the mixture is heated under reflux (step 1).

10 D Esterification is a dehydration reaction that requires an acid catalyst.

11 B The products of incomplete combustion of a hydrocarbon are carbon monoxide and carbon. Water and carbon dioxide are products of complete combustion.

12 D

13 C Haber developed a process that fixed nitrogen in a form that could be used as a fertiliser for plants and a reactant and catalyst in industry.

14 C The production of ammonia is an exothermic reaction. When the reaction is run at higher temperatures, the equilibrium will shift in reverse reducing the yield of ammonia. However, at the higher temperature the reaction will be faster and will reach equilibrium earlier.

15 A When HCl was added and no precipitate formed, Pb^{2+} could not have been present. When the addition of KSCN did not result in a precipitate, Fe^{3+} could not have been present. Only one alternative answer contains neither of these ions.

Section I Part B

16 (a) Cyclohexene

(b) Add 10 drops of cyclohexane to 4 mL bromine water in a test tube and shake. Repeat with cyclohexene holding all volumes and conditions constant. The one that decolourises the bromine is the cyclohexene.

(c) The cyclohexene decolourised the bromine and the cyclohexane had no effect.

$C_6H_{10}(l) + Br_2(aq) \rightarrow C_6H_{10}Br_2(l)$

17 Alkanes and their corresponding alkenes are non-polar carbon chain molecules with weak dispersion forces between the molecules. Physical properties such as melting point and solubility are due to intermolecular forces. These properties are therefore similar.

Chemical properties are due to bonding within the molecules. Alkenes have at least one reactive double bond. Alkanes have only unreactive single bonds within the molecule.

18 (a) Condensation polymerisation

(b) Biopolymers are polymers made by living organisms. These long chain molecules can be modified to meet specific applications or they could be broken down into smaller molecules and used to build new synthetic polymers. A number of types of bacteria have been identified that produce biopolymers. *Alcaligenes eutrophus* can be made to secrete a plastic-like polymer, poly(hydroxybutanoate), when its diet is

restricted. The polymer is very like poly(propylene) and has been used to make shampoo bottles and disposable razor handles. The advantage of the plastic is that it is biodegradable, so reducing landfill, and renewable, unlike plastics made from petroleum products. The gene that codes for this biopolymer has been genetically engineered and cut from this bacterium and spliced into a more common bacteria, *E. coli* which can be handled more easily. The company that now owns the patent for this biopolymer, Cargill Dow, has managed to splice the gene into crops like corn and grow a field of crop that can be harvested to obtain the biopolymer. The disadvantages are that this plastic costs four times as much as poly(propylene) to produce and has taken over 20 years to develop.

Another biopolymer called *Elastin* is being developed at Sydney University as an artificial human skin useful in replacing skin for burns patients.

The biopolymer *Medicoat* is a slippery product used to coat catheters so that bacteria cannot get a hold and reproduce causing infection.

The advantages of these and other biopolymers is that they can improve our way of life by supplying products that society needs but does not currently have. They can also replace non-biodegradable plastics made from the non-renewable petroleum. The disadvantages are the huge cost of production, the time in research (only one in a hundred researched biopolymers make it to the shelves as products) and the fact that they are more readily available to industrial countries than to the third world.

19 (a) Large atoms are unstable when their atomic number is greater than 83.

Smaller atoms are unstable when their neutron:proton ratio is too high. For example carbon-14 is unstable because its neutron:proton ratio is greater than 1:1.

(b) A radioactive isotope can undergo decay by alpha or beta decay.

Alpha decay involves emitting a helium nucleus from the isotope nucleus.

Beta decay involves a neutron in the nucleus becoming a proton by emitting an electron.

$$^{238}_{92}\mathrm{U} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{234}_{90}\mathrm{Th}$$

$$^{235}_{91}\mathrm{Pa} \rightarrow {}^{0}_{-1}e + {}^{235}_{92}\mathrm{U}$$

20 (a) Ammonia

(b) The student's assessment of solutions A and B are correct because both turned thymol blue to a blue colour. This indicates a pH greater than 8.0, which is basic.

The student's assessment of solution C may be incorrect. The solution turned thymol blue yellow indicating a pH of less than 8.0. This could be basic if the pH is between 7 and 8, acidic if the pH is less than 7, or neutral if the pH is 7.

21 The industrial sources of sulfur dioxide include the burning of coal in power stations and the smelting of sulfide ores. The sources of nitrogen oxides include car engines and other high temperature combustion environments.

Both of these gases contribute to acid rain. A pH as low as 2 can occur in rainwater when these gases dissolve in atmospheric moisture.

Sulfur dioxide produced is readily oxidised in the air to form sulfur trioxide.

$$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$$

Nitrogen reacts with oxygen in high-energy combustion conditions to form nitric oxide.

$$N_2(g) + O_2(g) \rightarrow 2NO(g)$$

The nitric oxide is readily oxidised to form nitrogen dioxide.

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

When dissolved in rain these gases produce acids and subsequently acid rain.

$$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$$

$$4NO_2(g) + 2H_2O(l) + O_2(g) \rightarrow 4HNO_3(aq)$$

Acid rain can affect aquatic organisms as lakes and rivers become acidic. Acid rain can damage plants in forests because the soil water can become acidic. Metal and stone buildings can be damaged because of the effect of acid on limestone, marble and metal.

$$CaCO_3(s) + 2H^+(aq) \rightarrow Ca^{2+}(aq) + CO_2(g) + H_2O(l)$$

Nitrogen oxides also contribute to photochemical smog. The brown $NO_2(g)$ gives smog its characteristic colour. Nitrogen dioxide absorbs UV radiation to form nitric oxide and oxygen atoms. The oxygen atoms combine with molecular oxygen to form ozone.

$$NO_2(g) \xrightarrow{UV} NO(g) + O(g)$$

$$O_2(g) + O(g) \rightarrow O_3(g)$$

Ozone is poisonous to humans.

The increasing smog production in big cities is reducing our quality of life, and increasing levels of acid rains are destroying forests in Europe and North America.

22 (a) $pH = -\log(0.01)$
$= 2$

(b) pH of the sulfuric acid is lower than that of the hydrochloric acid because H_2SO_4 is diprotic and will ionise to produce twice the concentration of hydrogen ions compared to the HCl.

(c) Acetic acid is a weak acid and therefore only a small proportion of the molecules will ionise. This will produce a lower concentration of hydrogen ions compared to hydrochloric acid which will ionise fully because it is a strong acid. The higher concentration of hydrogen ions will give a lower pH because $pH = -\log[H^+]$.

23 (a) Carbon dioxide

(b) $m(CO_2) = 630 - 620 = 10$ g

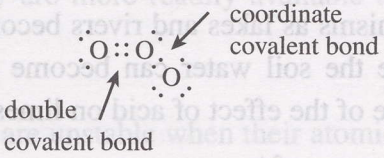
$$n(CO_2) = \frac{10}{44.0} = 0.227 \text{ mol}$$

$V(CO_2) = 0.227 \times 24.47 = 5.56$ L

24 AAS spectroscopy is used to measure the concentration of metal ions to ppm or ppb. Trace elements are elements needed in very small amounts by living things. Zinc, copper and iron are all trace elements found in soil that when limited can affect agricultural productivity. Therefore the use of AAS has allowed the monitoring of levels of trace elements in soil to levels not possible before. When levels are found to be low, additional chemicals can be added to the soil to increase the amounts of the trace element.

25 (a) 1,2-dichloro-1,1,2,2-tetrafluoroethane

(b)



(c) When CFCs reach the stratosphere, UV radiation splits a chlorine radical from the CFC molecule.

$$CF_3Cl \xrightarrow{UV} CF_3 + Cl$$

This Cl radical is very reactive and reacts with an ozone molecule to form an oxygen molecule and an oxygen chloride molecule.

$$O_3 + Cl \rightarrow O_2 + OCl$$

The OCl molecule then reacts with an oxygen radical to form an oxygen molecule releasing the chlorine radical to react with many more ozone molecules.

$$OCl + O \rightarrow O_2 + Cl$$

Thousands of ozone molecules can be decomposed in this manner by one CFC molecule reducing the thickness of the ozone layer.

26 (a) Take 10 mL of the water sample in a test tube. Add a few drops of a soap solution and shake. If a good lather forms the water is soft. If little lather or a scum forms it is hard.

(b) $n(MgCO_3) = 6 \times 10^{-4} \times 0.150 = 9 \times 10^{-5}$ mol

$m(MgCO_3) = 9 \times 10^{-5} \times 84.32 = 7.59 \times 10^{-3}$ g

7.59×10^{-3} g $\times 1000 = 7.59$ mg

27 A flocculating agent such as aluminium sulfate or iron chloride is stirred slowly into the water to cause the suspended material to form larger clumps. These are left to settle in a process called sedimentation. The water is then passed through a sand/anthracite filter where any remaining suspended material is removed. The anthracite removes colour and some microbial matter. A chlorine–ammonia gas mixture is added to kill microbes. The ammonia extends the life of the chlorine. The chlorine forms hypochlorite ions which are the active disinfecting agent.

$$Cl_2 + H_2O \rightarrow HClO + H^+ + Cl^-$$

$$HClO \rightarrow H^+ + ClO^-$$

Options Topics
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Sample Answers

Question 28 Industrial Chemistry

(a) (i) Saponification is the hydrolysis of a fat or oil, under alkaline conditions, to produce a soap and glycerol.

(ii) The way in which soaps clean surfaces can be explained in terms of the solubility of polar and non-polar substances. When soaps dissolve in water, they dissociate into a negatively charged ion, derived from the fatty acid or oil, and a sodium or potassium ion, derived from the alkali used to make it. The negatively charged ion contains a long non-polar hydrocarbon chain, called a hydrophobic end, and a polar carboxylic (COO–)group, which is hydrophilic, and can form hydrogen bonds with water. This negatively charged fatty acid ion is called a surfactant. The hydrocarbon chain strongly attracts non-polar grease molecules, due to dispersion forces, while the hydrophilic end readily dissolves in water. When water is agitated, the oil and grease are removed from the surface being cleaned because they are attached by dispersion forces to the hydrocarbon chain of the surfactant ion. The grease is surrounded by spherical aggregates of surfactant ions whose polar 'heads' are directed towards the water, while the non-polar 'tails' are attached to the grease.

(b)

$$2SO_2 + O_2 \rightleftharpoons 2SO_3$$

initial:	0.06	0.05	0.04 mol L^{-1}
change:	0.04	0.02	–
final:	0.02	0.03	0.04

$$K = \frac{[SO_3]^2}{[SO_2]^2[O_2]}$$

$$= \frac{(0.04)^2}{(0.02)^2(0.03)}$$

$$= 133$$

(c) (i) When sulfuric acid reacts with water, the reaction is extremely exothermic. This is because even though the acid ionises strongly, it ionises incompletely, and this produces a high concentration of hydronium ions.

$$H_2SO_4 + H_2O \rightarrow H_3O^+ + HSO_4^-$$

(ii) Hot, concentrated sulfuric acid can act as an oxidising acid with many metals to produce sulfur dioxide.

$$Cu(s) + 2H_2SO_4(aq) \rightarrow Cu^{2+}(aq) + SO_4^{2-}(aq) + SO_2(g) + 2H_2O(l)$$

Sulfuric acid is a strong dehydrating agent, removing water from sucrose to leave carbon.

$$C_{12}H_{22}O_{11}(s) \rightarrow 12C(s) + 11H_2O(l)$$

Sulfuric acid can also be used to precipitate heavy metal cations, such as barium, as their sulfates.

$$Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4(s)$$

(d) (i) A solution of cobalt chloride is divided up equally into two test tubes. To one test tube, dilute hydrochloric acid is added until a colour change occurs. The second test tube is alternately heated in a Bunsen flame and cooled under running water, until a colour change is seen in each procedure.

(ii) The procedure shown in part (i) can be represented by the following equation:

$$Co(H_2O)_6^{2+} + 4Cl^- \rightleftharpoons CoCl_4^{2-} + 6H_2O$$

Pink Blue

It can be seen that the addition of Cl^- ions, from the HCl, forces the reaction to the right, according to Le Chatelier's Principle, which states that when a system is at equilibrium, the system reacts to any change imposed by partially counteracting the change. Thus, the liquid in the test tube appears bluer. Similarly, when heated, the liquid in the test tube appears more blue, because the forward reaction is endothermic, and the system has reacted to the change imposed by shifting to the right. When cooled, the reverse reaction occurs, producing more of the pink $Co(H_2O)_6^{2+}$.

(e) Three main methods have been used to produce sodium hydroxide by electrolysis. These are the diaphragm process, the mercury process and the membrane process. NaOH was originally produced by the diaphragm process, but this method employed a diaphragm made of asbestos which was later found to be highly dangerous. This process also produced NaOH which was contaminated with chloride ions and the strong oxidising agent, sodium hypochlorite.

The next process employed was the mercury cell, which involved the use of a flowing liquid mercury cathode. The advantage of this method was that sodium ions were reduced to sodium metal which dissolved in the mercury to produce an amalgam. The mercury could be recycled and reused, and the chlorine gas produced at the anode could be collected. This process had the advantage that the sodium hydroxide produced was of high quality, but in the process some poisonous mercury invariably escaped into nearby waterways, and for environmental reasons, this process was phased out and replaced by the membrane process.

The membrane process employs a synthetic polymer, such as Teflon, to separate the anode and cathode compartments. This type of cell produces very pure NaOH, without the health risks associated with both asbestos and mercury, and with no release of dangerous chemicals to the environment. For this reason, the membrane cell is currently the preferred option for the industrial production of sodium hydroxide.