INDEPENDENT TRIAL HSC 2007

STUDENT NUMBER/NAME: .....

1. Which of the following cations exhibits an intense yellow flame when subjected to a flame test?

(A) Cr^{3+}
(B) Na^{+}
(C) Ba^{2+}
(D) Sr^{2+}

2. A compound is a colourless *liquid* that rapidly decolourises bromine water.

Which of the following is a possible formula for the compound?

(A) C_2H_4
(B) C_2H_5OH
(C) C_8H_{18}
(D) C_6H_{12}

3. A student measures the voltage between pairs of metal strips when placed in sodium sulfate solution.

Which metal gives the highest *positive* voltage in combination with copper?

(A) Silver
(B) Tin
(C) Zinc
(D) Magnesium

4. Butanoic acid and ethyl ethanoate have the same molecular formula, $C_4H_8O_2$.

Which of the following is the best chemical test to distinguish between these compounds?

(A) Dilute sodium carbonate
(B) Bromine water
(C) Solubility in water
(D) Smell

5. What is the systematic name for $CHCl = CCl_2$?

(A) 1,2 - dichloroethane
(B) 1,2,3 - trichlorethene
(C) 1,1,2 - trichloroethene
(D) 1,2 - dichloropropene

STUDENT NUMBER/NAME: .....

6. Which chemist first defined an acid as a substance which releases hydrogen ions in dilute solution?

(A) Lavoisier
(B) Davy
(C) Arrhenius
(D) Bronsted

7. When food passes from the mouth to the stomach the pH changes from 7 to 2.

What is the hydrogen ion concentration in the stomach compared with the mouth?

(A) 5 times less
(B) 5000 times less
(C) 50 times greater
(D) 100 000 times greater

8. Which reaction involves the formation of a coordinate covalent bond?

(A) $H^+ + OH^- \rightarrow H_20$
(B) $Mg(s) + 2H^+ \rightarrow Mg^2 + H_2(g)$
(C) $C_2H_4(g) + H_2(g) \rightarrow C_2H_6(g)$
(D) $CH_4(g) + Br_2(g) \rightarrow CH_3Br(g) + HBr(g)$

9. Which compound results in a lower pH when dissolved in water?

(A) Sodium hydroxide
(B) Sulfur (IV) oxide
(C) Ammonia
(D) Potassium carbonate

10. Heavy metals such as mercury and lead are toxic in waterways, even at very low concentrations.

Which of the following is the most suitable method for analysing a water sample for these metals?

(A) Displacement by a more active metal
(B) Precipitation
(C) Flame test
(D) Atomic absorption spectroscopy

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11. A paint solvent is a colourless liquid with a fruity odour and is insoluble in water.

To which group does the solvent most likely belong?

(A) Alkanoic acids
(B) Alkanols
(C) Esters
(D) Alkenes

12. One possible source of hydrogen for use as a fuel is through the 'reforming' of natural gas. The key reaction is:

$$CH_4(g) + H_2O(g) \rightarrow CO(g) + 3H_2(g) \quad \Delta H = +172 \text{ kJ}$$

A catalyst is used for this reaction.
Which of the following is the most suitable set of conditions for this reaction?

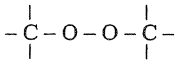
(A) Low pressure and low temperature
(B) Low pressure and high temperature
(C) High pressure and high temperature
(D) High pressure and low temperature

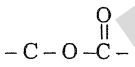
13. The first passenger-carrying balloons were made in the late 18th century using hydrogen from the reaction of iron with sulfuric acid.

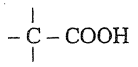
What is the mass of iron required to produce 10 kL of hydrogen at 25°C and 100kpa?

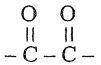
(A) 280 g
(B) 560 g
(C) 11 kg
(D) 22 kg

14. Identify the structural group that is present in all esters?

(A) 

(B) 

(C) 

(D) 

15. What is the purpose of using reflux in the production of an ester?

(A) To accelerate the reaction
(B) To increase the equilibrium yield of ester
(C) To remove the water by vaporisation
(D) All of the above

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Section I (continued)

Part B
Total marks (60)
Attempt Questions 16 – 23
Allow about 1 hour 45 minutes for this part

Answer the questions in the spaces provided.

Show all relevant working in questions involving calculations.

Question 16 (12 marks) **Marks**

Ethanol is described as a "water-like" compound but also has properties like those of hydrocarbons.

(a) Referring to ethanol's molecular structure, explain why it has similarities to both water and hydrocarbons. 3

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(b) Describe ONE "water-like" property of ethanol. 1

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Question 16 continues on the next page

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STUDENT NUMBER/NAME: .....

Question 16 (continued) **Marks**

(c) Describe ONE "hydrocarbon-like" property of ethanol. 1

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(d) Construct chemical equations to demonstrate ONE renewable and ONE non-renewable method of ethanol production. 3

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(e) The NSW Government intends to make 10% ethanol compulsory in all petrol.

Discuss the benefits and costs of using ethanol as a motor fuel. 4

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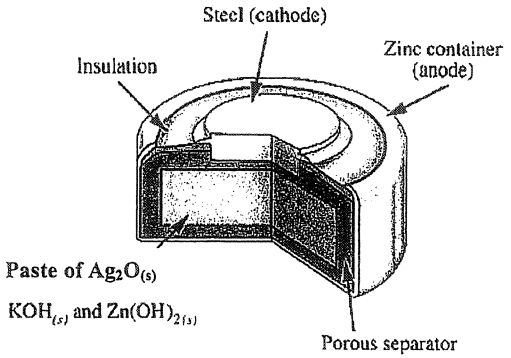
Question 17 (8 marks) **Marks**

The diagram shows a silver oxide button cell, used in calculators, watches and hearing aids.



Half-Reactions

$$Zn(OH)_{2(s)} + 2e^- \rightarrow Zn_{(s)} + 2OH^-_{(aq)} \qquad E^\circ = -1.25\ V$$

$$Ag_2O_{(s)} + H_2O_{(l)} + 2e^- \rightarrow 2Ag_{(s)} + 2OH^-_{(aq)} \qquad E^\circ = +0.34\ V$$

(a) Construct the equation for the net cell reaction. 2

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(b) Calculate the voltage of the cell, stating the polarity of the steel cathode. 2

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(c) Explain the function of the porous barrier. 2

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(d) Consider this cell when 90% of the silver oxide has reacted.

Predict the effect on the cell voltage, giving reasons for your answer. 2

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Question 18 (6 marks) **Marks**

Space probes require a power supply lasting many years. Often this is provided as heat from plutonium 238, an intensely radioactive alpha emitter.

(a) Identify the products of decay of Pu^{238}. 2

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(b) Describe TWO advantages of using an alpha-emitting source, rather than a beta or gamma emitter. 2

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(c) Assess the risks associated with this use of plutonium. 2

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Question 19 (11 marks) **Marks**

A white crystalline solid dissolves easily in water to form a solution of pH 2.8. A chemist investigating the substance makes the following observations:

- The empirical formula is CHO;
- A few crystals rapidly decolourise bromine water;
- The pH curve for its neutralisation with sodium hydroxide shows that it is a diprotic acid;
- By titration using phenolphthalein as an indicator, a solution of 0.29 g of the compound in water is neutralised by 20.9 mL of standard 0.24 mol L^{-1} sodium hydroxide solution.

(a) Identify the structural unit in the molecule which reacts with bromine water. 1

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(b) Sketch the titration curve for a weak diprotic acid reacting with sodium hydroxide solution. 2

(c) Justify the selection of phenolphthalein as an indicator in this instance. 2

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Question 19 continues on the next page

Question 19 (continued) **Marks**

(d) For the titration, explain why the volume of sodium hydroxide solution must be measured accurately, but not the volume of water used to dissolve the acid. 2

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(e) Determine the mole mass and molecular formula of the compound. 3

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(f) Propose a structural formula for the compound. 1

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End of Question 19

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STUDENT NUMBER/NAME: .....

Question 20 (7 marks) **Marks**

It has been suggested that increasing levels of atmospheric carbon dioxide will result in increased acidity in the oceans as additional carbon dioxide dissolves in the surface layers.

(a) With the aid of an equation, demonstrate the effect of more carbon dioxide on the pH of oceans. 2

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(b) Outline problems that could arise from these oceanic changes. 3

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(c) Supporting your answer with an equation, describe ONE process which might offset these effects by removing carbon dioxide from the oceans. 2

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STUDENT NUMBER/NAME: .....

Question 21 (7 marks) **Marks**

In soils, phosphate ions exist in equilibrium as follows:

$$H_2PO_4^- \rightleftharpoons HPO_4^{2-} + H^+$$

(a) Assess the importance of monitoring phosphate concentrations in soils and waterways. 3

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(b) Compare the nature of the phosphate ions in acid soil of pH 5.5 with that in alkaline soil of pH 7.5. 2

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(c) Demonstrate that EACH of these phosphate ions is amphiprotic. 2

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Question 22 (6 marks) **Marks**

The product of ozone from oxygen is strongly endothermic with $\Delta H = 142$ kJ mol^{-1}.

(a) Draw a structural formula for the ozone molecule. 1

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(b) Compare the production of ozone in the upper and lower atmospheres. 3

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(c) Explain why ozone is both a pollutant and essential to our environment. 2

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Question 23 (3 marks)

Recently, biopolymer carry bags are often used in place of bags made from addition polymers such as polyethylene.
Discuss the benefits and problems associated with the use of biopolymer carry bags. 3

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End of Section I

Question 24 – Industrial Chemistry (25 marks) **Marks**

(a) Outline the production process for the manufacture of sulfuric acid, identifying reaction conditions which must be monitored. 7

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(b) The following 'water gas' reaction is used to produce hydrogen from carbon monoxide:

$$CO(g) + H_2O(g) \rightarrow CO_2(g) + H_2(g) \quad \Delta H = -42 \text{ kJ}$$

Equal volumes of carbon monoxide and steam are mixed and brought to equilibrium at 986°C. The equilibrium mixture is found to contain 22% by volume of hydrogen.

(i) Calculate the equilibrium constant at 986°C. 2

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Question 24 continues on the next page

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STUDENT NUMBER/NAME: .....

Question 24 (continued) **Marks**

(ii) Identify methods to increase the equilibrium yield of hydrogen. 2

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(c) Compare the chemistry of saponification with esterification and justify the different conditions in which these reactions are carried out. 5

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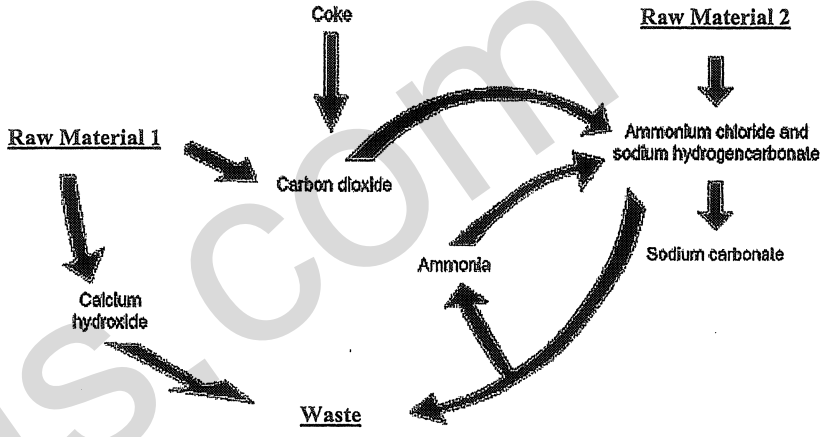
Question 24 continues on the next page

STUDENT NUMBER/NAME: .....

Question 24 (continued) **Marks**

(d) Study the flow chart of the Solvay Process shown below.



(i) Identify the raw materials 1 & 2 and the natural resources from which they are produced. 3

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(ii) Construct an equation for the equilibrium in which sodium hydrogen carbonate is formed, and outline the conditions employed to maximise the yield. 3

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STUDENT NUMBER/NAME: .....

Question 24 (continued) **Marks**

(iii) Identify the main component of the waste discharge and discuss its importance in deciding on a suitable location for this industry. 3

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End of Question 24

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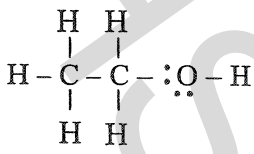
NSW INDEPENDENT TRIAL EXAMS – 2007
CHEMISTRY HSC TRIAL EXAMINATION
MARKING GUIDELINES

Section I

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
B	D	A	A	C	C	D	A	B	D	C	B	D	B	A

Section II

16(a)

Suggested Answers	Mark
 (1 mark) Ethanol has a highly polar hydroxyl group with the ability to form hydrogen bonds, similar to water. (1 mark) The non-polar CH_3CH_2 ethyl group is similar to the alkanes with weak intermolecular forces. (1 mark)	3

16(b)

Suggested Answers	Mark
Any ONE of the following – ethanol: ▪ has an unusually high boiling point, ▪ dissolves completely in water, ▪ dissolves polar solutes such as sugar.	1

16(c)

Suggested Answers	Mark
Either ONE of the following – ethanol ▪ dissolves in hydrocarbons, such as petrol. ▪ burns to form carbon dioxide and water.	1

16(d)

Suggested Answers	Mark
Renewable: from fermentation of glucose: $C_6H_{12}O_6 \xrightarrow[\text{enzymes}]{\text{yeast}} 2C_2H_5OH + 2CO_2(g)$ Non-renewable: by hydration of ethylene: $C_6H_4(g) + H_2O(g) \xrightarrow[\text{catalyst}]{\text{high pressure}} 2C_2H_5OH(g)$	3

16(e)

Suggested Answers	Mark
The main advantage is that ethanol is produced from renewable resources such as grain or sugar. This reduces our dependence on petroleum. It also burns more cleanly than hydrocarbons. (2 marks) Disadvantages include its lower energy content and the pressure on resources such as water and soil to grow the crops needed. The production of ethanol requires a higher energy input than fuels from petroleum. (2 marks)	4

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17(a)

Suggested Answers	Mark
$Ag_2O(s) + Zn(s) + H_2O \rightarrow 2\ Ag(s) + Zn(OH)_2(s)$	2

17(b)

Suggested Answers	Mark
Cell voltage = 1.59 V. (1 mark) Steel cathode is positive. (1 mark)	2

17(c)

Suggested Answers	Mark
The porous barrier prevents direct contract between anode and cathode reactants (1 mark) and provides an ion bridge for ions to migrate, completing the cell circuit (1 mark).	2

17(d)

Suggested Answers	Mark
▪ The cell voltage will remain close to 1.59 V. This is because all reactants and products are solid with fixed concentration. (1 mark) ▪ The concentrate of hydroxide ions in solution is unchanged. (1 mark)	2

18(a)

Suggested Answers	Marks
${}^{238}_{94}Pu \rightarrow {}^{234}_{92}U + {}^{4}_{2}He$ ($\propto$ particle)	2

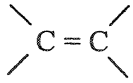
18(b)

Suggested Answers	Mark
Alpha radiation has very low penetration depositing concentrated energy and requiring no special shielding. Beta and gamma sources are more penetrating, require heavy shielding and may damage surrounding equipment.	2

18(c)

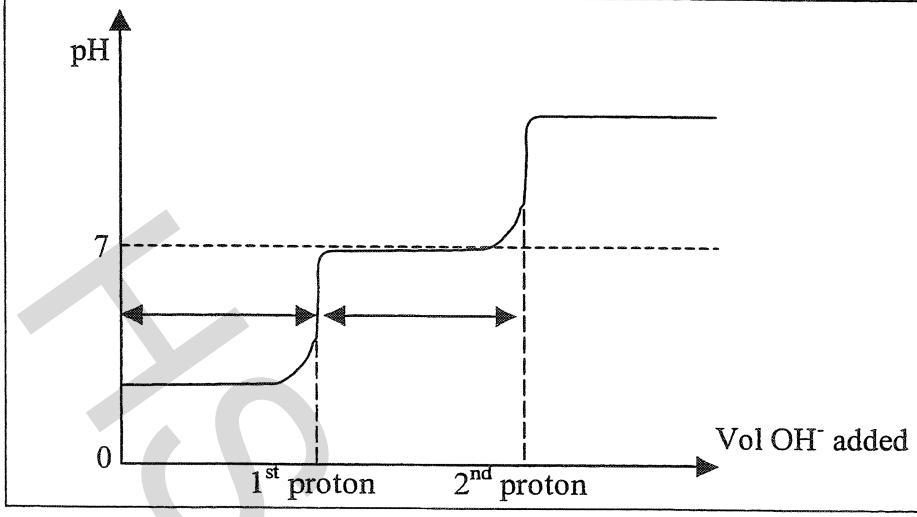
Suggested Answers	Mark
The main risk is radiation exposure to workers handling the source and to the environment if a rocket failure occurs. Contamination of other planets into which the craft might fall is also a risk.	2

19(a)

Suggested Answers	Marks
The unit is a carbon - carbon double bond: 	1

Question Consortium

19(b)

Suggested Answers	Marks
	2

19(c)

Suggested Answers	Marks
This is a weak acid and the neutralisation point is greater than 7 (see diagram above). Phenolphthalein has a range of pH 8 – 10 which detects this point.	2

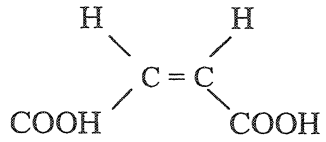
19(d)

Suggested Answers	Marks
What matters is the number of moles of acid and base. For the acid this is determined by the mass; the water volume is irrelevant. For the base the number of moles is determined by volume and concentration (CV), so volume must be measured accurately.	2

19(e)

Suggested Answers	Marks
Moles OH^- used = $20.9 \times 0.24 = 5.0 \times 10^{-3}$ mol 1 mole acid neutralises 2 moles OH^- Moles of acid = 2.5×10^{-3} Mole mass = 116 g $\therefore$ Molecular formula is $C_4H_4O_4$.	3

19(f)

Suggested Answers	Marks
Probable molecular structure is: 	1

20(a)

Suggested Answers	Marks
Carbon dioxide forms an equilibrium in water: $CO_2 + H_2O$ ($\rightleftharpoons$ H_2CO_3) $\rightleftharpoons$ $H^+ + HCO_3^-$ An increase in the CO_2 (aq) concentration drives the system to the right, increasing H^+ concentration and lowering the pH.	2

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20(b)

Suggested Answers	Marks
Lower pH may affect the growth of some marine organisms which are sensitive to changes in acidity. Shells of invertebrates and corals are built from calcium carbonate which dissolves under acidic conditions. $CaCO_3(s) + H^+ \rightarrow Ca^{2+} + HCO_3^-$ Either these organisms may lose shell material or be unable to lay down new layers under acidic conditions.	3

20(c)

Suggested Answers	Marks
Carbon dioxide is removed in photosynthesis by marine plants and this process could be accelerated by extra CO_2, thus acting to reduce CO_2. $6CO_2 + 6H_2O \xrightarrow[\text{enzymes}]{\text{plant}} C_6H_{12}O_6 + 6CO_2(g)$ The ocean floor has extensive deposits of calcium carbonate in living and non-living structures and is itself buffered with dissolved carbonate and hydrogen carbonate ions. This will neutralise added H^+ ions in turn reducing dissolved CO_2. $CO_3^{2-} + 2H^+ \rightleftharpoons HCO_3^- + H^+ \rightleftharpoons CO_2 + H_2O$	2

21(a)

Suggested Answers	Marks
Phosphate ion is an essential plant nutrient. If the level of phosphate is too low food crops will grow poorly. If it is too high, unwanted plant growth occurs, especially in waterways where algal growth can block sunlight, leading to eutrophication, with low oxygen levels and high biological oxygen demand.	3

21(b)

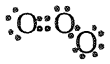
Suggested Answers	Marks
In acid soils the $H_2PO_4^-$ ion will predominate as the equilibrium responds to higher hydrogen ion concentration. Conversely, in alkaline soils the HPO_4^{2-} is the main phosphate ion present.	2

21(c)

Suggested Answers	Marks
In the equilibrium shown HPO_4^{2-} is a base and $H_2PO_4^-$ is the conjugate acid. HPO_4^{2-} also acts as an acid: $HPO_4^{2-} \rightleftharpoons H^+ + PO_4^{3-}$ $H_2PO_4^-$ can act as a base: $H_2PO_4^- + H^+ \rightleftharpoons H_3PO_4$	2

Question Solutions

22(a)

Suggested Answers	Marks
	1

22(b)

Suggested Answers	Marks
In the upper atmosphere ultraviolet light provides the energy of reaction for the production of ozone: $3O_2(g) \rightarrow 2O_3(g)$. In the lower atmosphere oxygen reacts with pollutants such as NO_x to produce ozone: $NO_x + O_2 \rightarrow O_3(g)$	3

22(c)

Suggested Answers	Marks
In the lower atmosphere ozone is a pollutant which is reactive, causes throat irritation and breathing problems and promotes photochemical smog. (1 mark) In the upper atmosphere ozone provides a vital shield by absorbing short wavelength ultraviolet light which is damaging to humans and other organisms. (1 mark)	2

23

Suggested Answers	Marks
Compared with polyethylene, biopolymers are more expensive, tear more easily and are less stable, especially when wet. The main advantage is that biopolymers are biodegradable while polyethylene, which is not, is a long-lasting pollutant.	3

Section II

Q24 Industrial Chemistry

Qu 24(a)

Suggested Answers	Marks
Sulfur dioxide gas is obtained by combustion of sulfur or the roasting of sulfide ores: $S(s) + O_2(g) \rightarrow SO_2(g)$. (1 mark) Sulfur dioxide and oxygen are passed over a platinum catalyst (or vanadium pentoxide) at moderate pressure and temperature to produce sulfur trioxide: $SO_2 + ½\ O_2 \rightleftharpoons SO_3(g)$. (2 marks) The forward reaction is exothermic and is favoured by low temperature and high pressure. However, the temperature must be high enough to reach equilibrium quickly. As well as monitoring the temperature and pressure in the reaction, the purity of the gases must also be monitored to avoid impurities which 'poison' the catalyst. (2 marks) As sulfur trioxide does not readily dissolve in water it is first dissolved in concentrated sulfuric acid to form pyrosulfuric acid: $SO_3(g) + H_2SO_4(l) \rightarrow H_2S_2O_7(l)$ $H_2S_2O_7(l) + H2O(l) \rightarrow H_2SO_4(l)$ (2 marks) The second reaction is strongly exothermic and must be performed under carefully controlled conditions.	7

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Qu 24(b)(i)

Suggested Answers	Marks
Equilibrium concentrations (% by volume): $[CO_2] = [H_2] = 22\%$ $[CO] = [H_2O] = 28\%$ (1 mark) $K = \frac{[CO_2][H_2]}{[CO][H_2O]} = \frac{28^2}{22^2} = 1.62$ (1 mark)	2

Qu 24(b)(ii)

Suggested Answers	Marks
The forward reaction is exothermic so that a lower temperature increases the yield of H_2. Increasing the concentration of water (steam) and removing carbon dioxide (by absorption or liquefaction) increases the equilibrium yield of H_2.	2

Qu 24(c)

Suggested Answers	Marks
Saponification is the reverse of esterification and involves the breaking up (hydrolysis) of an ester. (1 mark) In esterification an acid and alcohol are combined to form an ester: acid + alcohol $\rightleftharpoons$ ester + water. A strong acid (e.g. H_2SO_4) is added to provide hydrogen ions which catalyse the reaction. A dehydrating agent (e.g. conc. H_2SO_4) is used to minimise water concentration, thus driving the equilibrium to the right. (2 marks) In saponification oil or fat (glyceryl triesters) are heated with sodium hydroxide solution. Hydroxide ions both catalyse the reaction and remove fatty acids (a product) by converting them to their salts (soap). Together with excess water the reaction proceeds almost 100% to hydrolyse the ester. (2 marks)	5

Qu 24(d)(i)

Suggested Answers	Marks
Material 1 is calcium carbonate obtained from deposits of limestone. Material 2 is sodium chloride obtained by evaporation of sea water.	3

Qu 24(d)(ii)

Suggested Answers	Marks
$H_2O + NH_3 + NaCl(aq) + CO_2 \rightleftharpoons NaHCO_3(s) + NH_4Cl(aq)$, OR $NH_4HCO_3(aq) + NaCl\ (aq) \rightleftharpoons NaHCO_3(s) + NH_4Cl(aq)$ (1 mark) The yield of $NaHCO_3$ is maximised by saturating concentrated brine with ammonia and carbon dioxide (high reactant concentrations), and using low temperatures at which the $NaHCO_3$ crystallises due to its low solubility.	3

Qu 24(d)(iii)

Suggested Answers	Marks
The waste is mainly calcium chloride solution from the regeneration of ammonia. (1 mark) The only acceptable disposal is by dilution into a large body of seawater, so the plant must be in proximity to the sea with sufficient tidal flushing to rapidly dilute the calcium chloride. (2 marks)	3

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