CHAPTER 10

Excel

Sample
HSC Examination Paper 2

Chemistry

General Instructions

- Reading time — 5 minutes
- Working time — 3 hours
- Write using black pen
- Draw diagrams using pencil
- NESA approved calculators may be used
- A formulae sheet, data sheet and Periodic Table are provided at the back of this book (pp. 321–324)
- For questions in Section II, show all relevant working in questions involving calculations

Total marks: 100

Section I – 20 marks

- Attempt Questions 1–20
- Allow about 35 minutes for this section

Section II – 80 marks

- Attempt Questions 21–37
- Allow about 2 hours and 25 minutes for this section

Section I

20 marks
Attempt Questions 1–20
Allow about 35 minutes for this section

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1 Consider the following equilibrium reaction involving the pink ion ($Co(H_2O)_6^{2+}$) and the blue ion ($CoCl_4^{2-}$) in water solution:

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

Identify an observation made about the equilibrium if potassium nitrate crystals are dissolved in the solution.

(A) The solution becomes more pink.

(B) The solution becomes more blue.

(C) The solution becomes colourless.

(D) No change in colour occurs.

2 Select the set of conditions that will promote the bulk fermentation of sugars derived from molasses to produce ethanol.

	Temperature (°C)	*Presence or absence of air*	*Organism causing fermentation*
(A)	20	Absence	Wild yeast
(B)	37	Absence	Alcohol-tolerant yeast
(C)	37	Presence	Alcohol-tolerant yeast
(D)	37	Absence	Genetically modified bacteria

3 A 0.050 mol/L solution of a weak monoprotic acid, HA, was prepared in distilled water. The concentration of A^- ions at equilibrium was found to be 0.0010 mol/L. Calculate the pH and the degree of dissociation of this weak acid.

	pH	*Degree of dissociation (%)*
(A)	1.3	0.1
(B)	1.0	2.0
(C)	3.0	2.0
(D)	3.0	5.0

4 Select the response that correctly identifies the hydrolysis equilibrium present in an aqueous solution of a nominated salt and the colour that the methyl orange indicator would turn in that solution.

	Salt	*Hydrolysis equilibrium*	*Methyl orange colour*
(A)	Potassium hydrogen sulfate	$HSO_4^-(aq) + H_2O(l) \rightleftarrows SO_4^{2-}(aq) + H_3O^+(aq)$	Red
(B)	Sodium acetate	$Na^+(aq) + H_2O(l) \rightleftarrows NaOH(aq) + H^+(aq)$	Blue
(C)	Potassium sulfite	$SO_3^{2-}(aq) + H_2O(l) \rightleftarrows HSO_3^-(aq) + OH^-(aq)$	Orange
(D)	Sodium hydrogen carbonate	$HCO_3^-(aq) + H_2O(l) \rightleftarrows H_2CO_3(aq) + OH^-(aq)$	Crimson

5 A sample of an aqueous solution is believed to contain iron (III) ions. The solution is divided into two test tubes. The chemist adds sodium hydroxide solution to tube 1 and a brown precipitate forms. This observation indicates that iron (III) ions are present. Identify a useful reagent that could be added to the second test tube that would confirm the presence of iron (III) in this solution.

(A) Potassium bromide solution

(B) Nitric acid

(C) Potassium thiocyanate solution

(D) Silver nitrate solution

6 Identify the molecule that will have the greatest solubility in water.

(A) C_4H_{10}

(B) $C_9H_{19}OH$

(C) CH_3OH

(D) $C_{10}H_{22}$

7 A green salt was dissolved in water and the solution was acidified with dilute nitric acid. No change was observed. A sample of the acidified solution was tested with dilute barium nitrate solution and no precipitate formed. A second sample of the acidified solution was tested with silver nitrate solution and a white precipitate formed. Identify the anion present in the green salt.

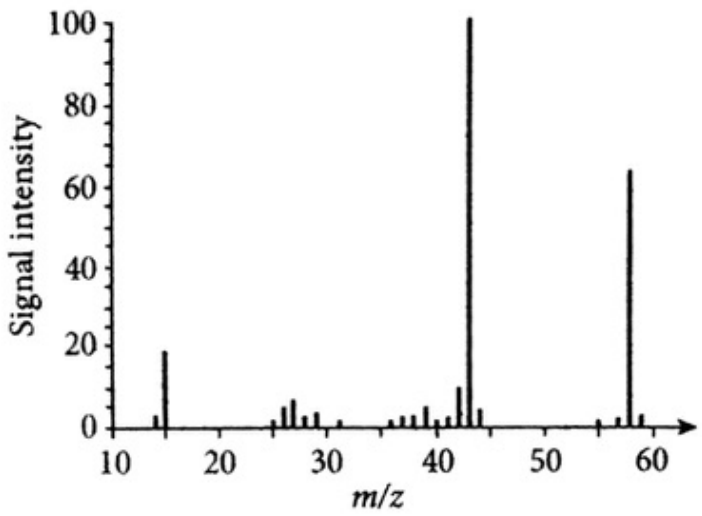
(A) Chloride

(B) Sulfate

(C) Carbonate

(D) Nitrate

8 The mass spectrum of an organic molecule is shown in the diagram.



Identify which compound has produced this mass spectrum.

(A) Propanoic acid

(B) Propanone

(C) Acetic acid

(D) Butanone

9 Select the correct statement about ethanol as a fuel for motor vehicles.

(A) Ethanol releases more energy on combustion than does the same mass of petrol.

(B) Ethanol produces less carbon monoxide and soot on combustion compared with petrol.

(C) Ethanol combustion does not lead to an enhanced greenhouse effect and global warming.

(D) Ethanol fuel is produced in Australia by the cracking of petroleum fractions.

10 Select the correct statement about the shapes of hydrocarbon molecules and the hybridisation of atomic orbitals.

(A) Double C=C bonds form due to interactions between sp^2 orbitals from each carbon atom as well as p orbitals from each.

(B) In alkanes the carbon orbitals hybridise to form four sp^2 molecular orbitals arranged tetrahedrally around the nucleus of the carbon atom.

(C) The C≡C triple bond forms when two sp orbitals and the remaining one p orbital from each carbon atoms interact.

(D) The sp^2 orbitals are tetrahedral in orientation.

11 The following table lists the K_w values at three temperatures.

Temperature	10	25	40
K_w	3.0×10^{-15}	1.0×10^{-14}	2.9×10^{-14}

Select the correct statement about the autoionisation of water.

(A) The water ionisation equilibrium is exothermic.

(B) The water becomes slightly alkaline when cooled from 25 °C to 10 °C.

(C) The water becomes slightly acidic when warmed from 25 °C to 40 °C.

(D) The water remains neutral when cooled from 25 °C to 10 °C.

12 Acid *W* is 2.0 mol/L formic acid. Acid *X* is 0.20 mol/L nitric acid. Identify the correct statement about acid *W* and acid *X*.

(A) Acid *W* and acid *X* are both strong acids but acid *W* is more concentrated than acid *X*.

(B) Acid *W* and acid *X* are both incompletely dissociated in water.

(C) Acid *W* is a weak acid and acid *X* is a strong acid but acid *W* is more concentrated than acid *X*.

(D) Acid *W* and acid *X* are both weak acids but acid *W* is more concentrated than acid *X*.

13 An esterification reaction is performed in the school laboratory. Identify the true statement about this experiment.

(A) A catalyst such as dilute sulfuric acid increases the yield of ester.

(B) Small pieces of crushed ceramic boiling chips are added to the reaction flask. They are used to prevent dangerous vibrations during reflux.

(C) The equilibrium yield of ester is maximised by using the correct stoichiometric ratio of reactants.

(D) The reaction vessel is closed so that volatile compounds do not escape and equilibrium can be achieved.

14 Soap is a surfactant. Identify the true statement about soap.

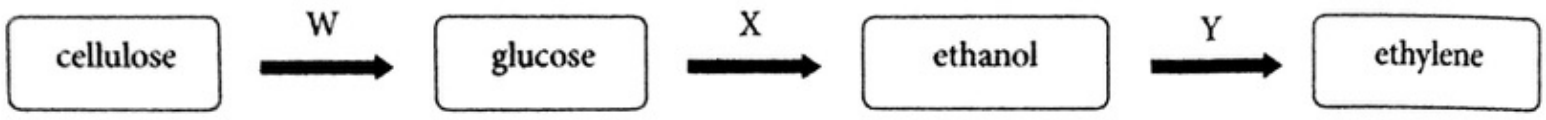
(A) The long hydrocarbon chain of the soap is called the tail and it has little affinity for water. These tails are said to be hydrophilic.

(B) The positively charged head group of the soap is hydrophobic, which means it has a high affinity for water.

(C) The soap ions at the water surface alter the physical properties of the surface molecules. The soap ions interfere with the normal hydrogen-bonding forces between water molecules and so the soap lowers the surface tension of the water.

(D) At very low soap concentrations the soap ions form micelles that contain clusters of 20 to 30 soap anions at the water surface.

15 The flowchart shows how cellulose in biomass can be converted into useful industrial chemicals.



Identify the chemical processes in stages W, X and Y.

	W	*X*	*Y*
(Â)	Acid hydrolysis	Fermentation	Dehydration
(B)	Enzymic reaction	Oxidation	Dehydration
(C)	Acid hydrolysis	Substitution	Oxidation
(D)	Esterification	Fermentation	Addition

16 Low density polyethylene is produced from ethylene monomers using a free radical reaction. The reaction has three stages called initiation, propagation and termination. Identify which of the following reactions represents the termination step in the free radical polymerisation of ethylene. (RO· = free radical)

(A) $ROCH_2CH_2\cdot + CH_2CH_2 \rightarrow ROCH_2CH_2CH_2CH_2\cdot$

(B) $RO\cdot + CH_2CH_2 \rightarrow ROCH_2CH_2\cdot$

(C) $RO(CH_2CH_2)_x\cdot + RO(CH_2\,CH_2)_y\cdot \rightarrow RO(CH_2CH_2)_x(CH_2CH_2)_yOR$

(D) $RO(CH_2CH_2)_x(CH_2CH_2)_yOR \rightarrow RO(CH_2CH_2)_x\cdot + RO(CH_2\,CH_2)_y\cdot$

17 Hept-3-ene reacted with hydrogen bromide in the presence of a phosphoric acid catalyst. Identify the type of reaction that occurs and the name(s) of the product(s) that form.

	Reaction type	*Product(s)*
(A)	Substitution	3-bromoheptane
(B)	Addition	2-bromoheptane; 3-bromoheptane
(C)	Addition	3-bromoheptane
(D)	Oxidation	2-bromoheptane; 3-bromoheptane

18 Proton NMR (or H-1 NMR) is also used to analyse organic compounds. Identify the number of chemical shift peaks in the proton NMR spectrum of methyl propanoate.

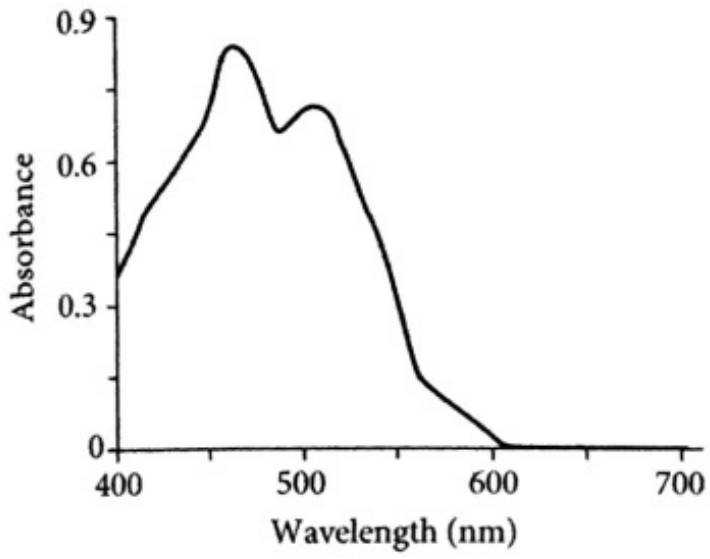
(A) 2

(B) 3

(C) 4

(D) 5

19 The visible spectrum of beta carotene is shown in the diagram. Beta carotene is a plant pigment.



Identify the colour of this pigment.

(A) Green

(B) Blue

(C) Blue-violet

(D) Red-orange

20 A 500 mL standard solution of oxalic acid dihydrate ($(COOH)_2 \cdot 2H_2O$) is to be prepared. Calculate the mass of oxalic acid dihydrate required to prepare a 0.250 mol/L solution.

(A) 15.8 g

(B) 31.6 g

(C) 7.90 g

(D) 6.30 g

Chemistry

Section II
Answer Booklet

80 marks
Attempt Questions 21–37
Allow about 2 hours and 25 minutes for this section

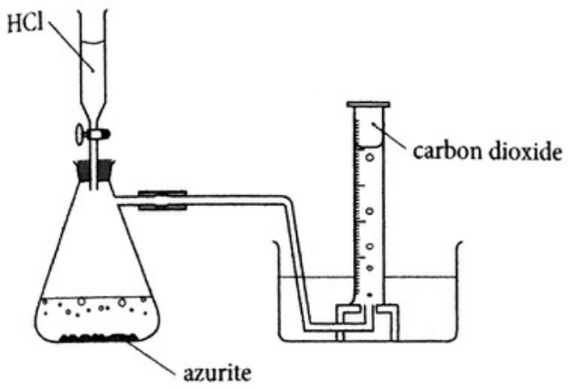
Instructions

- Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.
- Show all relevant working in questions involving calculations.

Please turn over

Question 21 (6 marks) **Marks**

Azurite ($Cu_3(CO_3)_2(OH)_2$) is a deep-blue copper mineral. A weighed sample of impure azurite was reacted with hydrochloric acid and the volume of carbon dioxide evolved was measured by the downward displacement of water in a 500 mL measuring cylinder.



(a) Azurite is a basic mineral that is neutralised by hydrochloric acid. Write a balanced equation for the reaction. **1**

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(b) 3.50 g of impure azurite was placed in the conical flask. Excess hydrochloric acid was added from the dropping funnel and the carbon dioxide was collected in the measuring cylinder.

At 25 °C, the volume of gas collected was 440 mL.

(i) Calculate the number of moles of carbon dioxide collected. **1**

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(ii) Calculate the number of moles of azurite that reacted. **1**

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(iii) Calculate the percentage by weight of pure azurite in the mineral sample. **3**

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Question 22 (7 marks) **Marks**

Haematite is a red-brown iron (III) oxide mineral. An impure sample of haematite was analysed using a back titration. 0.0750 g of impure haematite was weighed and placed in a conical flask. 40.00 mL of standard 0.100 mol/L hydrochloric acid was added from a burette and the mineral allowed to completely dissolve. The remaining acidic solution was then titrated using 0.100 mol/L potassium hydroxide.

Calculate the percentage by weight of pure Fe_2O_3 in the impure haematite. 7

Question 23 (3 marks)

Draw structural formulae of three branched-chain isomers of the alkyne with the molecular formula C_6H_{10}. Name these isomers using the IUPAC nomenclature. 3

Question 24 (4 marks) **Marks**

(a) Alkanoic acids react with amines to form amides. Write a condensed structural formula equation for the reaction of butanoic acid with ethanamine. Name the organic product. **2**

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(b) Amides are very weak bases in water solution. Write a condensed structural formula equation for the reaction of hexanamide with hydrochloric acid solution. Name the organic product. **2**

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Question 25 (6 marks)

Brass is an alloy of copper and zinc. A 300 mg brass sample was dissolved in nitric acid and the solution diluted to 100 mL in a volumetric flask. A series of five dilution standards of copper ions were prepared. AAS was used to measure the absorbance of the five standards and the brass solution.

(a) Explain why the zinc ions in the brass solution do not interfere with the absorbance measurement of the copper ions. **1**

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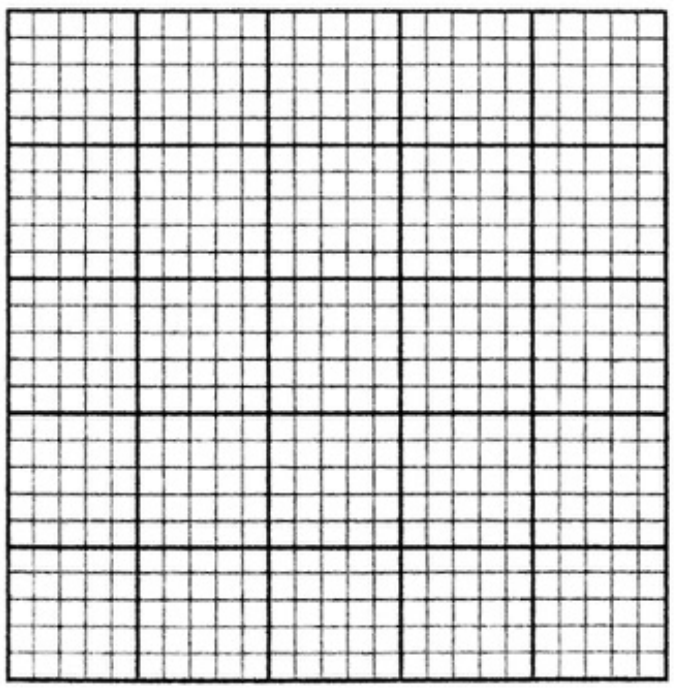
(b) The table shows the absorbance results for the copper standards and the brass solution.

$[Cu^{2+}]$ *(mg/L)*	0	1000	2000	3000	4000	5000	*Brass*
Absorbance (A)	0	0.110	0.220	0.330	0.440	0.550	0.183

(i) Draw a calibration graph. **3**



Question 25 continues

Question 25 (continued) **Marks**

(ii) Determine the concentration of copper in the brass solution. **1**

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(iii) Determine the percentage by weight of copper in the brass. **1**

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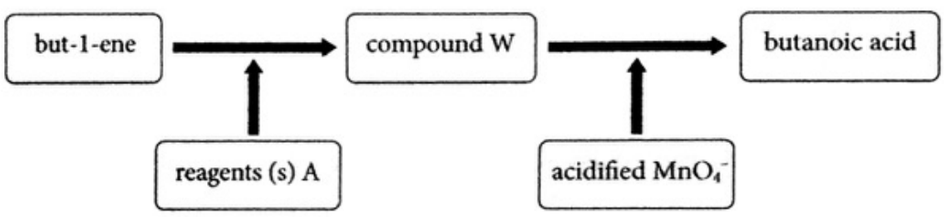
Question 26 (5 marks)

The flowchart shows two reactions to convert but-1-ene to butanoic acid.



(a) Identify the reagent(s) *A* used to convert but-1-ene to compound *W*. Name compound *W*. **2**

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(b) An acidified solution of potassium permanganate oxidises *W* to butanoic acid. Write the reduction half-equation. **1**

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(c) Write a balanced equation for the reaction of butanoic acid with potassium hydroxide solution. Name the product. **2**

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Question 27 (5 marks)

A calorimetry experiment was performed using an aluminium calorimeter containing 100 g of water. Ethanol was used to fill a spirit burner. The burner was weighed. The burner was placed under the calorimeter and the wick was lit. Over a period of 10 minutes the temperature of the water increased by 16.0 °C. The burner was then reweighed. 1.85 g of ethanol had undergone combustion.

(a) Calculate the heat absorbed by the water. Refer to the Data Sheet for the specific heat capacity of water. **1**

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Question 27 continues

Question 27 (continued) **Marks**

(b) The enthalpy of combustion of ethanol is –1367 kJ/mol. Calculate the heat released on the complete combustion of 1.86 g of ethanol. **2**

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(c) Explain why the heat absorbed by the water is less than the heat released, calculated in part (b). **2**

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Question 28 (4 marks)

Glycolic acid ($CH_2(OH)COOH$) is a weak monoprotic acid.

(a) What is the IUPAC name for glycolic acid? **1**

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(b) 100 mL of a 0.200 mol/L glycolic acid solution is prepared. An accident occurred and 40 mL of the solution was spilled on the bench. Sodium carbonate solid was added to neutralise the spilled acid.

(i) Write a balanced equation for the neutralisation reaction. **1**

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(ii) Calculate the mass of sodium carbonate that will neutralise the glycolic acid solution. **2**

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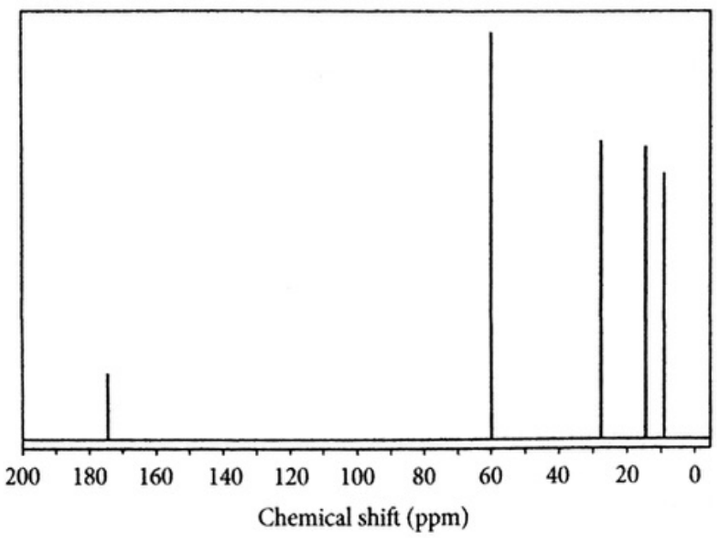
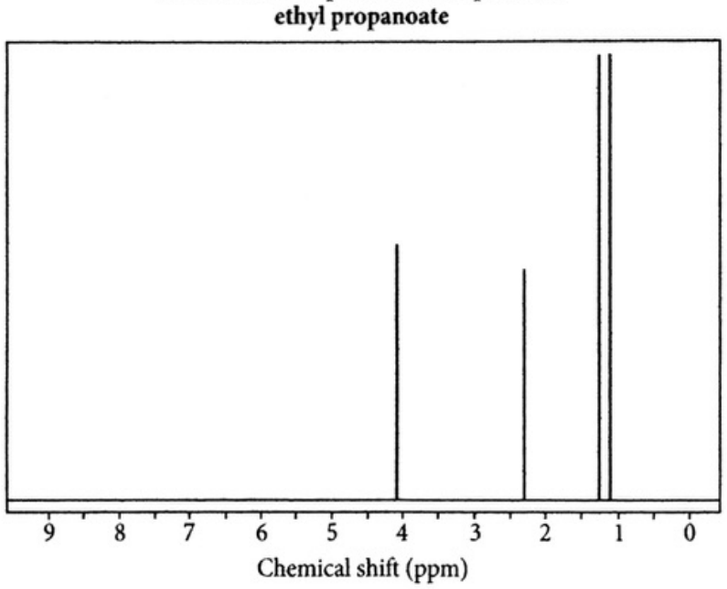
Question 29 (8 marks)

Ethyl propanoate was analysed using C-13 NMR spectroscopy, proton NMR (low-resolution) spectroscopy, infrared spectroscopy and mass spectroscopy. The following diagrams show these spectra.

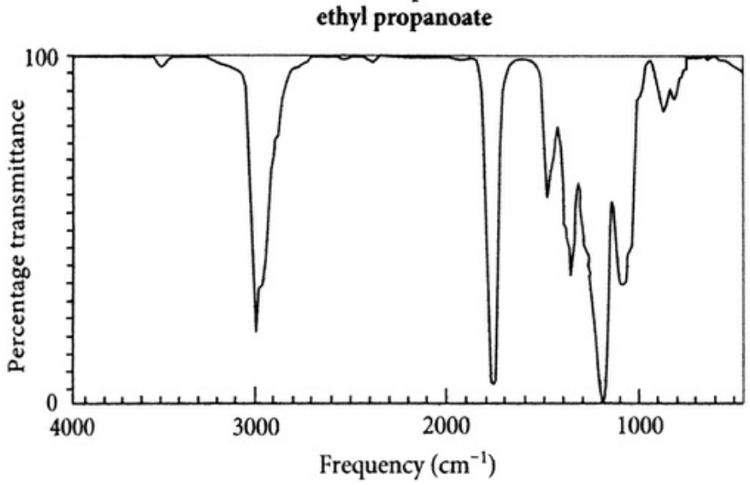
C-13 NMR spectrum
ethyl propanoate



Low-resolution proton NMR spectrum
ethyl propanoate

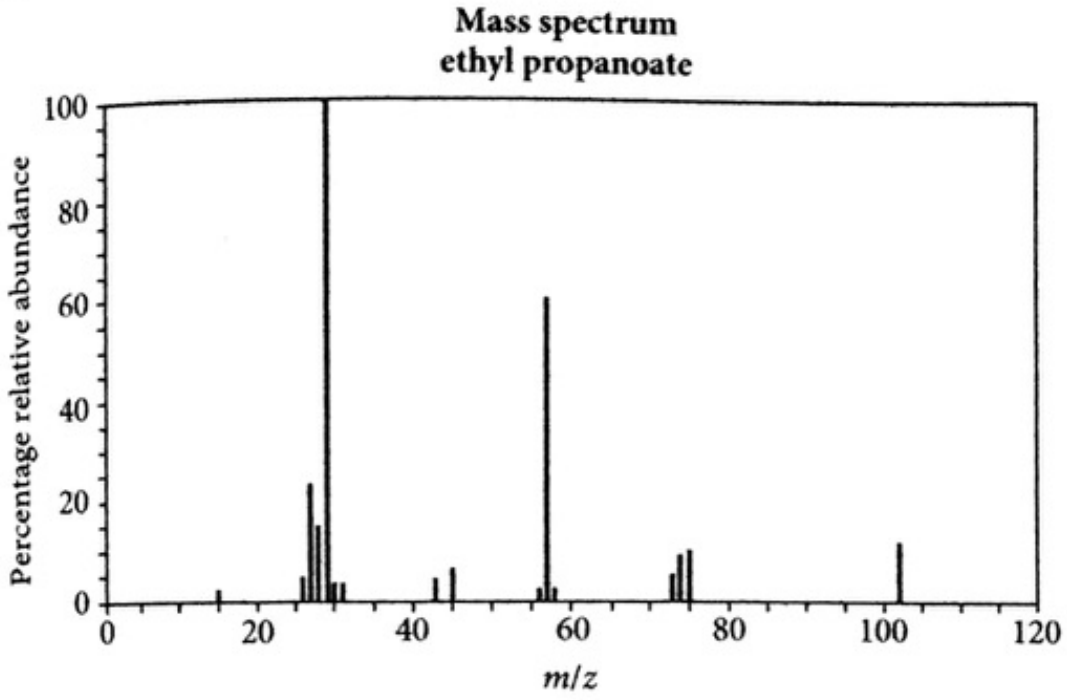


Infrared spectrum
ethyl propanoate



Question 29 continues

Question 29 (continued) **Marks**



With reference to the structure of ethyl propanoate, identify the features of each spectrum that are consistent with the structure of ethyl propanoate. Refer to the IR and NMR tables in the data sheet. **8**

Question 30 (5 marks) **Marks**

An analytical chemist investigated lead pollution in soils near a lead ore smelter. Galena or lead (II) sulfide is roasted in air to form lead (II) oxide and sulfur dioxide. The lead (II) oxide is then smelted with coke (carbon) to form lead and carbon dioxide.

(a) Write balanced equations for the roasting and smelting reactions. **2**

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(b) AAS was used to measure the lead levels in the soil. The procedure can be summarised in a number of steps. Use the code letters to arrange the steps of the AAS analysis in the correct order.

A. Filter the acid-soil mixture.

B. Dry a sample of the soil.

C. Determine the lead concentration in the soil extract from the calibration graph.

D. Extract lead from the dried soil using concentrated nitric acid.

E. Collect the filtrate and dilute systematically in a volumetric flask.

F. Construct a calibration graph.

G. Weigh a sample of the dried soil.

H. Aspirate each lead standard (in turn) in the AAS flame and record the absorbance.

I. Prepare a series of lead dilution standards.

J. Aspirate the lead extract in the AAS flame. **3**

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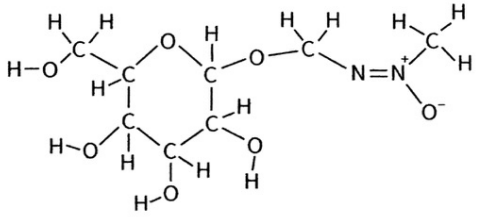
Question 31 (2 marks)

Indigenous Australians have used cycad nuts as a major food source for thousands of years. The nuts contained a toxic compound called cycasin. The toxicity of these cycad nuts in humans is due to microbes in the intestine breaking the cycasin into methylazomethanol that is then converted in the liver to a carcinogenic compound.

The structure of cycasin is shown in the diagram.



Question 31 continues

Question 31 (continued) **Marks**

Indigenous Australians made the nuts edible by repeatedly leaching the toxin out of the flesh of the nut using running water.

Explain why the cycasin is able to be leached out of the nut into water. **2**

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Question 32 (8 marks)

Nitrogen gas reacts with oxygen gas in a car engine to form nitric oxide (NO) gas.

(a) Write a balanced equation for the reaction. **1**

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(b) Use the data to calculate the minimum temperature at which the reaction is spontaneous. **3**

Data: ΔH = 180 kJ/mol; ΔS = 25 J/K/mol

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(c) The exhaust gases from the car engine pass through a catalytic converter. In catalytic converters, NO and CO gases in the exhaust react to form nitrogen gas and carbon dioxide. Write a balanced equation for this reaction. **1**

(d) Prior to the use of catalytic converters in cars, nitric oxide was emitted into air, where it reacted with oxygen to form nitrogen dioxide gas.

(i) Write a balanced equation for this reaction. **1**

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(ii) Nitrogen dioxide is an acidic oxide. Explain the environmental damage caused by these emissions. **2**

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Question 33 (4 marks) **Marks**

(a) Gaseous hydrogen iodide (HI) dissolves in water. The solution that forms turns green universal indicator red. Use an ionic equation to explain why hydrogen iodide solution (i.e. hydriodic acid) is an Arrhenius acid. **2**

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(b) Hydriodic acid solution neutralises calcium hydroxide solution. Write a whole formula equation and an ionic equation for this neutralisation. **2**

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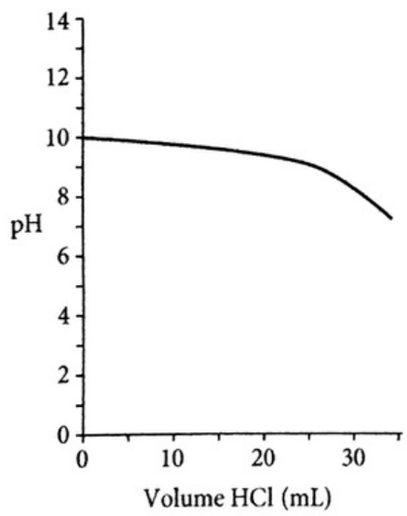
Question 34 (3 marks)

A solution is prepared containing sodium carbonate and sodium hydrogen carbonate. The concentrations of the two salts are:

- 0.025 mol/L Na_2CO_3
- 0.025 mol/L $NaHCO_3$

Hydrochloric acid was slowly added to the solution and the pH monitored. The graph shows the pH change as the acid is added.



(a) Write an equation to show that an equilibrium exists between the carbonate and hydrogen carbonate ions. **1**

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Question 34 continues

Question 34 (continued) **Marks**

(b) The graph shows that the pH drops very slowly on the addition of the first 10 mL of acid. Use an equation to explain this observation. **2**

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Question 35 (4 marks)

The pH ranges of four indicators are tabulated below.

Indicator	*pH range*	*Low pH colour*	*Intermediate pH colour*	*High pH colour*
Thymol blue	1.2 – 2.8	Red	Orange	Yellow
Thymolphthalein	9.3 – 10.5	Colourless	Pale blue	Blue
Phenol red	6.8 – 8.4	Yellow	Orange	Red
Bromocresol green	3.8 – 5.4	Yellow	Green	Blue-green

Identify the most suitable indicator for each of the following titrations and state the colour change observed at the end point.

(a) 25 mL of ammonia solution is titrated with 0.100 mol/L HCl. **2**

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(b) 25 mL of acetic acid solution is titrated with 0.100 mol/L KOH. **2**

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Question 36 (4 marks) **Marks**

Ozone occurs naturally in very low concentrations (0.02 ppm) in the troposphere. At higher concentrations it is a lower-atmosphere pollutant. Ozone can form in the troposphere in two main ways:

- Ozone is produced when oxygen is decomposed to reactive oxygen radicals ($O\cdot$) by electrical discharges from various high-voltage devices. The oxygen atoms, which have unpaired electrons, rapidly combine with oxygen molecules to form ozone.
- Nitrogen oxides, such as NO_2, are formed in the high-temperature environment of the internal combustion engine in cars. Once NO_2 is exposed to the UV radiation in sunlight, it decomposes to form reactive oxygen radicals. These oxygen radicals combine with molecular oxygen to form ozone.

(a) Write balanced equations for the formation of ozone in high-voltage appliances. **2**

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(b) Write balanced equations for the formation of ozone when NO_2 reacts with UV light. **1**

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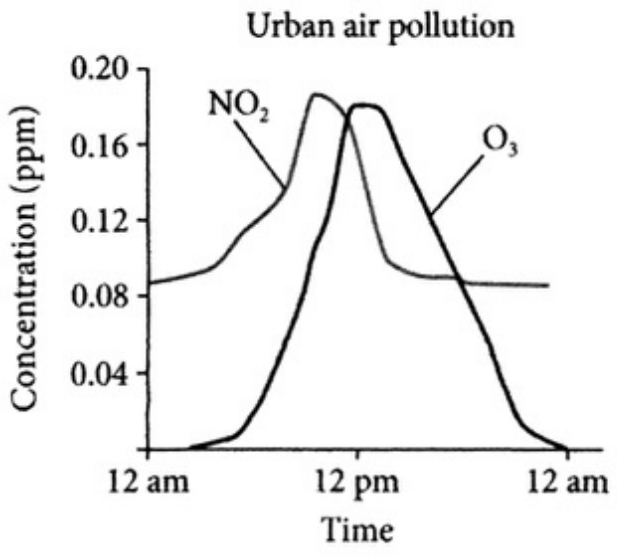
(c) The following diagram shows how the levels of NO_2 and O_3 change during a day in a city.



Explain why the maximum of the ozone graph occurs later than the maximum of the nitrogen dioxide graph. **1**

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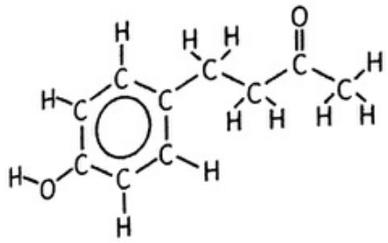
Question 37 (2 marks) **Marks**

The following diagram shows the structure of a natural molecule that is used as a raspberry food-flavouring.



(a) Classify this molecule. **1**

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(b) Draw the structural formula of a molecule that can be oxidised by acidified potassium dichromate to form the raspberry flavoured molecule. **1**

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Excel

Sample HSC Examination Paper 2

Sample Answers

Section I

1 D There is no common ion that can cause the equilibrium to shift. The crystals are dissolved in the existing solution, so no water has been added that could cause an equilibrium shift to the left.

2 B Alcohol-tolerant yeast causes the fermentation of sugars in molasses under anaerobic conditions. The rate of the reaction is higher at 35–37 °C. Above that temperature, the yeasts die.

3 C At equilibrium $[A^-] = [H^+] = 0.0010$ mol/L

$pH = -\log_{10}[H^+] = -\log_{10}[0.0010] = 3.0$

$$\% \text{ dissociation} = [H^+]/[HA] \times 100/1 = \frac{0.0010}{0.050} \times \frac{100}{1} = 2.0\ \%$$

4 A The hydrogen sulfate ion is a weak Brønsted–Lowry acid. Solutions of this ion are quite acidic due to the production of hydronium ions in the hydrolysis equilibrium. Methyl orange turns red at pH values less than 3.1.

5 C Thiocyanate ions react with Fe^{3+} ions to form the blood-red iron thiocyanate ion:

$$Fe^{3+}(aq) + SCN^-(aq) \rightarrow FeSCN^{2+}(aq)$$

6 C Methanol is the most polar molecule of the compounds listed. Water is polar and dipole–dipole attractions exist between methanol and water, which promotes solubility.

7 A Chloride ions are precipitated by silver ions to form white silver chloride. Carbonate ions are absent because no effervescence occurred on acidification. No sulfate is present because no precipitate formed on the addition of barium ions. Nitrates do not precipitate.

8 B Propanone is the organic molecule.

Parent molecular ion = $CH_3COCH_3^+$; $M = 58$

The m/z peak at 43 corresponds with the ion fragment CH_3CO^+.

The m/z peak at 15 corresponds with the ion fragment CH_3^+.

9 B Ethanol burns more cleanly and produces less soot and carbon monoxide. The carbon dioxide released contributes to global warming. The heat of combustion of ethanol is less than that for petrol.

10 A In alkenes the covalent bonds around the carbon atoms forming the double bond are arranged in a trigonal-planar orientation. One s orbital and two p orbitals hybridise to form three sp^2 molecular orbitals. The C=C double bond forms when one sp^2 orbital and the remaining p orbital from each carbon atom interact.

11 D Although the pH has increased as temperature decreased ($[H^+]^2 = 3.0 \times 10^{-15}$; $[H^+] = 5.5 \times 10^{-8}$ mol/L; $pH = -\log_{10}(5.5 \times 10^{-8}) = 7.3$), the water remains neutral because equal amounts of hydrogen ions and hydroxide ions are present. Only under standard conditions is the neutral pH equal to 7.

12 C Formic acid is a weak alkanoic acid, whereas nitric acid is a strong acid. Weak acids are incompletely dissociated in water. Concentrated and diluted acid solutions depend on the amount of solute and the amount of water present in the solution.

13 B Boiling chips have a high surface area, which leads to small vapour bubbles forming. This minimises bumping. Concentrated sulfuric acid is used as the catalyst but there is no change to the yield. The vessel is open to avoid pressure build-up. The reflux condenser cools vapours back to liquids and returns them to the flask. Ester yield is maximised by adding an excess of one reactant to push the equilibrium to the right.

14 C The soap anions at the water surface break some of the normal hydrogen-bonding forces that exist between water molecules. New ion–dipole forces result between the soap anion and the water. The surface tension of the water surface then decreases.

15 A Cellulose polymers can be broken down to glucose monomers by heating in acid solution or by using cellulase enzyme. The glucose can be anaerobically fermented to produce ethanol. The ethanol can be dehydrated with concentrated sulfuric acid to form ethylene.

16 C In the termination step, two radicals react to produce a longer hydrocarbon chain that is no longer a free radical. In the equation a polymer radical composed of x monomers combines with another polymer radical composed of y monomers to produce a polymer chain composed of $(x + y)$ monomers:

$$RO(CH_2CH_2)_x\cdot + RO(CH_2CH_2)_y\cdot \rightarrow RO(CH_2CH_2)_x(CH_2CH_2)_yOR$$

17 B HBr adds across the double bond via an addition reaction. Two isomeric products will form. They are 2-bromoheptane and 3-bromoheptane.

18 B There are three peaks. The condensed structural formula is $CH_3CH_2COOCH_3$. This shows H atoms in three different chemical environments.

19 D There is a strong absorbance in the green, blue and violet region of the visible spectrum. Therefore the light transmitted is orange-red (570–700 nm).

20 A $M(COOH)_2 \cdot 2H_2O) = (2 \times 12.01) + (6 \times 16.00) + (6 \times 1.008) = 126.068$ g/mol

$c = n/V$

$0.250 = n/0.500$

$n = 0.125$ mol

$n = m/M$

$0.125 = m/126.068$

$m = 15.8$ g

Section II

Question 21 (Total 6 marks)

(a) $Cu_3(CO_3)_2(OH)_2(s) + 6HCl(aq) \rightarrow 3CuCl_2(aq) + 4H_2O(l) + 2CO_2(g)$ *(1 mark)*

(b) (i) Molar volume of gas = $V_M = 24.79$ L at 25 °C (see Data Sheet)

$$n(CO_2) = V/V_M = \frac{0.440}{24.79} = 0.0177 \text{ mol}$$ *(1 mark)*

(ii) Stoichiometry: $Cu_3(CO_3)_2(OH)_2 : CO_2 = 1 : 2$

$$n(Cu_3(CO_3)_2(OH)_2) = \frac{0.0177}{2} = 0.008\,87 \text{ mol}$$ *(1 mark)*

(iii) $M(Cu_3(CO_3)_2(OH)_2) = (63.55 \times 3) + (12.01 \times 2) + (16.00 \times 8) + (1.008 \times 2)$
$= 344.71$ g/mol

$m(Cu_3(CO_3)_2(OH)_2) = nM = 0.008\,87 \times 344.71 = 3.06$ g

$$\% \text{ by weight of azurite in mineral sample} = \frac{3.06}{3.50} \times \frac{100}{1} = 87.4\%$$ *(3 marks)*

Question 22 (Total 7 marks)

$Fe_2O_3(s) + 6HCl(aq) \rightarrow 2FeCl_3(aq) + 3H_2O(l)$

$KOH(aq) + HCl(aq) \rightarrow KCl(aq) + H_2O(l)$

$n(KOH)$ reacted $= cV = (0.100)(0.015\,25) = 0.001\,525$ mol

Reaction stoichiometry in the titration = 1 : 1

$n(HCl)$ unreacted = 0.001 525 mol

$n(HCl)$ initial $= cV = (0.100)(0.040\,00) = 0.004\,000$ mol

$n(HCl)$ reacted with haematite = 0.004 000 – 0.001 525 = 0.002 475 mol

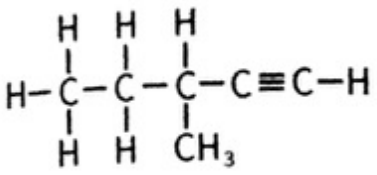
Reaction stoichiometry: $Fe_2O_3 : HCl = 1 : 6$

$$n(Fe_2O_3) = \frac{0.002\,475}{6} = 0.000\,4125 \text{ mol}$$

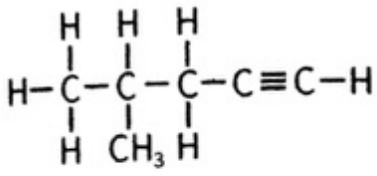
$m(Fe_2O_3) = nM = (0.000\,4125)((2 \times 55.85) + (3 \times 16.00))$
$= (0.000\,4125)(159.7) = 0.0659$ g

$$\% \text{ } Fe_2O_3 = \frac{0.0659}{0.0750} \times 100 = 87.8 \text{ \%w/w}$$ *(7 marks)*

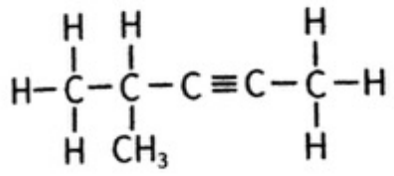
Question 23 (Total 3 marks)



3-methylpent-1-yne



4-methylpent-1-yne



4-methylpent-2-yne

(3 marks)

Question 24 (Total 4 marks)

(a) $CH_3CH_2CH_2COOH + CH_3CH_2NH_2$
$\rightarrow CH_3CH_2CH_2CONHCH_2CH_3 + H_2O$

N-ethylbutanamide *(2 marks)*

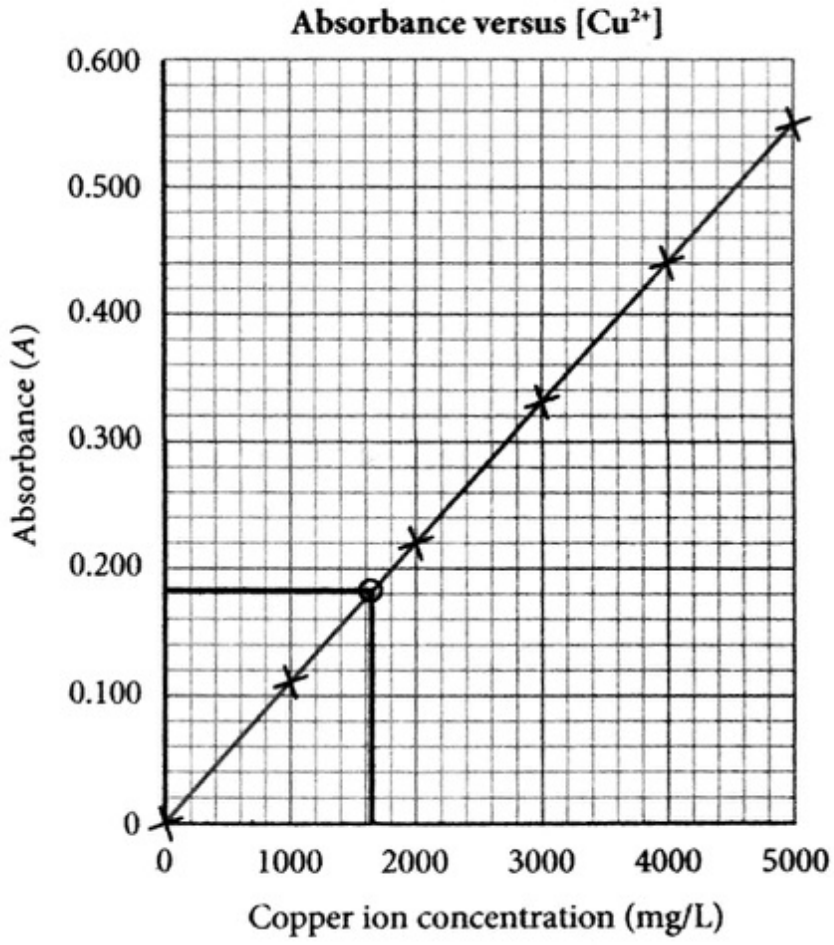
(b) $CH_3CH_2CH_2CH_2CONH_2(aq) + HCl(aq) + H_2O(l)$
$\rightarrow CH_3CH_2CH_2CH_2COOH(aq) + NH_4Cl(aq)$

Pentanoic acid *(2 marks)*

Question 25 (Total 6 marks)

(a) The hollow copper cathode only emits wavelengths of light characteristic of copper. The zinc ions in the AAS flame do not absorb these wavelengths, whereas the copper ions do. *(1 mark)*

(b) (i)



(3 marks)

(ii) From the graph, $[Cu^{2+}] = 1700$ mg/L *(1 mark)*

(iii) In 100 mL, $m(Cu^{2+}) = 170$ mg

$$\% \text{ Cu in brass} = \frac{170}{300} \times 100 = 56.7\%$$ *(1 mark)*

Question 26 (Total 5 marks)

(a) Water and phosphoric acid catalyst.

W = butan-1-ol *(2 marks)*

(b) $MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$ *(1 mark)*

(c) $CH_3CH_2CH_2COOH(aq) + KOH(aq) \rightarrow KCH_3CH_2CH_2COO(aq) + H_2O(l)$

Potassium butanoate *(2 marks)*

Question 27 (Total 5 marks)

(a) $q = mc\Delta T = (0.100)(4.18 \times 10^3)(16.0) = 6688\ J = 6.69\ kJ$ *(1 mark)*

(b) $n(\text{ethanol}) = m/M = \dfrac{1.85}{46.068} = 0.0402$ mol ethanol

$q = -n\Delta H = -(0.0402)(-1367) = 54.9$ kJ *(2 marks)*

(c) Considerable heat is lost to the surrounding air.

The combustion is not complete and less heat is released on incomplete combustion.

(2 marks)

Question 28 (Total 4 marks)

(a) 2-hydroxyethanoic acid or 2-hydroxyacetic acid. *(1 mark)*

(b) (i) $2CH_2(OH)COOH(aq) + Na_2CO_3(s)$

$\rightarrow 2NaCH_2(OH)COO(aq) + H_2O(l) + CO_2(g)$ *(1 mark)*

(ii) $n(CH_2(OH)COOH) = cV = (0.200)(0.040) = 0.0080$ mol

Stoichiometry: $CH_2(OH)COOH : Na_2CO_3 = 2 : 1$

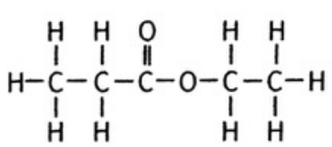
$n(Na_2CO_3) = \dfrac{0.0080}{2} = 0.0040$ mol

$m(Na_2CO_3) = nM = 0.0040 \times 105.99 = 0.43$ g *(2 marks)*

Question 29 (Total 8 marks)

Ethyl propanoate has the following structural and condensed structural formulae.

Structural formula:



Condensed structural formula: $CH_3CH_2COOCH_2CH_3$

The C-13 NMR spectrum shows five peaks, which indicates that the five carbon atoms are in different chemical environments as demonstrated by the structural formula.

Esters typically have chemical shifts in C-13 NMR spectra at 50–90 ppm and 160–185 ppm.

The low-resolution proton NMR spectrum shows four peaks, which indicates that the hydrogen atoms are in four different chemical environments, as demonstrated by the structural formula.

Esters typically have chemical shifts in proton NMR spectra at 3.5–5.5 ppm.

The infrared spectrum is typical of an ester, as indicated by the following stretch frequency of is bonds: C–H stretch (2850–2960 cm^{-1}); C=O stretch (1735–1770 cm^{-1}); C–O stretch (1000–1300 cm^{-1})

The mass spectrum shows a peak at m/z = 102. This is consistent with the parent ion $CH_3CH_2COOCH_2CH_3^+$.

The large peak at m/z = 57 is consistent with the fragment ion $CH_3CH_2CO^+$. The strongest peak at m/z = 29 is consistent with the fragment ion $CH_3CH_2^+$. *(8 marks)*

Question 30 (Total 5 marks)

(a) Roasting: $2PbS(s) + 3O_2(g) \rightarrow 2PbO(s) + 2SO_2(g)$

Smelting: $2PbO(s) + C(s) \rightarrow 2Pb(s) + CO_2(g)$ *(2 marks)*

(b) B, G, D; A, E, I; H, J, F, C *(3 marks)*

Question 31 (Total 2 marks)

The cycasin molecule has the following polar functional groups: O–H; $^+N–O^-$

These polar groups increase the solubility of the cycasin molecule in the polar water molecules via dipole–dipole attractions. *(2 marks)*

Question 32 (Total 8 marks)

(a) $N_2(g) + O_2(g) \rightarrow 2NO(g)$ *(1 mark)*

(b) The Gibbs free energy change is negative for a reaction to be spontaneous.

$\Delta G = \Delta H - T\Delta S < 0$

$180 - T(0.025) < 0$

$$T > \frac{180}{0.025}$$

$T > 7200$ K *(3 marks)*

(c) $2NO(g) + 2CO\ (g) \rightarrow N_2(g) + 2CO_2(g)$ *(1 mark)*

(d) (i) $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$ *(1 mark)*

(ii) Acid rain forms when nitrogen dioxide reacts with water in rain drops. Iron and steel structures in the urban environment are attacked by acid rain, leading to more rapid corrosion.

$Fe(s) + 2H^+(aq) \rightarrow Fe^{2+}(aq) + H_2(g)$

Acid rain drainage into lakes may lead to significant acidification of these lakes. Increasing levels of acidification causes the populations of aquatic organisms to become stressed. Acid rain also damages forests, especially those at higher elevations. Leaves are damaged by the acid rain. Thus no photosynthesis can occur and the trees die. *(2 marks)*

Question 33 (Total 4 marks)

(a) $HI(g) \rightarrow H^+(aq) + I^-(aq)$

According to the Arrhenius theory, the HI dissociates in water to form hydrogen ions that cause the indicator to turn red. *(2 marks)*

(b) $2HI(aq) + Ca(OH)_2(aq) \rightarrow CaI_2(aq) + H_2O(l)$

$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$ *(2 marks)*

Question 34 (Total 3 marks)

(a) $CO_3^{2-}(aq) + H_2O(l) \rightleftarrows HCO_3^-(aq) + OH^-(aq)$ *(1 mark)*

(b) The solution is a buffer as it contains a weak Brønsted–Lowry base and its conjugate acid.

The hydronium ion in the HCl reacts with the carbonate ions in the buffer solution.

$CO_3^{2-}(aq) + H_3O^+(aq) \rightarrow HCO_3^-(aq) + H_2O(l)$

The removal of the hydronium ions by the carbonate ions and the production of the weaker conjugate acid (hydrogen carbonate ions) is the main reason why the pH decreases very little, as shown in the pH graph. The pH does not stay constant but drops by a very small amount. *(2 marks)*

Question 35 (Total 4 marks)

(a) Bromocresol green is the most suitable indicator because this is a strong acid–weak base titration where the equivalence point is in the pH range of 4–6.

The colour change will be blue-green to green-yellow. *(2 marks)*

(b) Thymolphthalein is the most suitable indicator because this is a weak acid–strong base titration where the equivalence point is in the pH range of 8–10.

The colour change will be colourless to pale-blue. *(2 marks)*

Question 36 (Total 4 marks)

(a) $O_2(g) \rightarrow 2O\cdot(g)$

$O\cdot(g) + O_2(g) \rightarrow O_3(g)$ *(2 marks)*

(b) $NO_2(g) + UV \rightarrow NO(g) + O\cdot(g)$

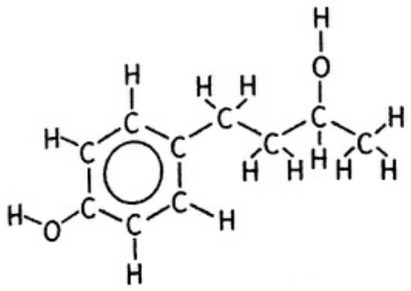
$O\cdot(g) + O_2(g) \rightarrow O_3(g)$ *(1 mark)*

(c) Levels of nitrogen dioxide rise during peak-hour traffic in the city. Ozone only forms when nitrogen dioxide reacts with UV light. The intensity of UV light reaches its maximum after midday and so the ozone levels reach a maximum after midday. *(1 mark)*

Question 37 (Total 2 marks)

(a) Ketone *(1 mark)*

(b) Secondary alcohols can be oxidised to form ketones.



(1 mark)