SECTION A – Multiple choice questions

Instructions for Section A

Answer all questions in pencil on the answer sheet provided for multiple-choice questions.

Choose the response that is correct or that best answers the question.

A correct answer scores 1, an incorrect answer scores 0.

Marks will not be deducted for incorrect answers.

No marks will be given if more than one answer is completed for any question.

Question 1

A titration between 0.15 M nitric acid and sodium hydroxide was carried out. A weighing bottle was used to weigh out 0.15 g of sodium hydroxide. This was dissolved in 20.00 mL of water and then titrated with the nitric acid. The titrator expected a titre of 25.00 mL but instead the indicator changed colour when 19.45 mL had been added. The discrepancy between the expected titre and the actual titre can be explained if

A. more than 20.00 mL of water was used to dissolve the sodium hydroxide.

B. thymol blue indicator was used instead of bromothymol blue.

C. the sodium hydroxide has absorbed water from the atmosphere before weighing.

D. more than 0.15 g of sodium hydroxide was weighed out.

Question 2

A 100 mL solution of 0.01 M HCl is diluted to a volume of 10 L. The pH of the resulting solution is

A. 2

B. 3

C. 4

D. 5

Question 3

The oxidation numbers of oxygen in ozone (O_3) and iodine in triiodide ion (I_3^-) are

A. 0 and -⅓

B. -2 and -⅓

C. 0 and -1

D. -2 and -1

Question 4

Which of the following statements about chromatography is true?

A. In high performance liquid chromatography the more strongly adsorbed a component, the higher the R_f value.

B. R_f values allow identification of components in a thin layer chromatograph.

C. The area under peaks allows identification of components in a gas chromatograph.

D. In gas chromatography, retention times are greater for lighter components.

Question 5

Both UV-visible and Atomic Absorption Spectroscopy (AAS) can be used to identify the concentration of the metal ion in

A. sodium nitrate.

B. copper sulfate.

C. zinc sulfate.

D. aluminium chloride.

Question 6

How many peaks would you expect to find in the ^1H NMR spectrum and ^{13}C NMR spectrum of CH_3COOCH_3?

A. Two ^1H NMR peaks and two ^{13}C NMR peaks

B. Two ^1H NMR peaks and three ^{13}C NMR peaks

C. One ^1H NMR peaks and three ^{13}C NMR peaks

D. One ^1H NMR peaks and three ^{13}C NMR peaks

Question 7

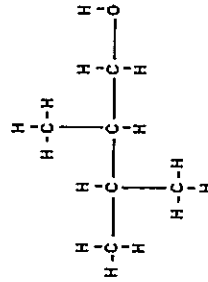Which of the following is not an isomer of ethyl ethanoate?

A. butanoic acid

B. propyl methanoate

C. methyl propanoate

D. butan-1,4-diol

Question 8

How many structural isomers of $C_3H_6ClCOOH$ are there?

A. 3

B. 4

C. 5

D. 6

Question 9

What is the correct IUPAC name for this molecule?

A. 2-methylpentan-1-ol.

B. 3,3-dimethyl,2-methylpropan-1-ol.

C. 2,3,3-trimethylpropan-1-ol.

D. 2,3-dimethylbutan-1-ol.

Question 10

Alkenes are reactive compounds. Which of the following is **not** a property of alkenes?

A. They turn bromine solution colourless.

B. The lighter alkenes burn readily.

C. The first three alkenes are gases.

D. They are soluble in water.

Question 11

Which of the following statements about all primary alkanols are true?

I   The hydroxyl group is always at the end of the alkyl chain.

II They may oxidise to aldehydes or alkanoic acids.

III They react with alkanoic acids to form esters.

IV They are always soluble in water.

A. All the statements above are true.

B. I and III are true

C. I, III and IV are true.

D. II, III and IV are true.

Question 12

Some of the 20 common amino acids have basic R groups. Which of the following would all be considered to be basic?

A. Lysine, arginine and histidine.

B. Phenylalanine, tryptophan and tyrosine.

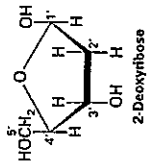C. Alanine, glycine and valine.

D. Serine, threonine and tyrosine.

Question 13

Which of the following can act as a monomer in the formation of a polysaccharide?

A. Glycine

B. Glycogen

C. Glycerol

D. Glucose

Question 14

In the deoxyribose molecule below, the carbon atoms are numbered C1' to C5'. When a DNA strand forms

2-Deoxyribose

A. the base bonds to C1' and the phosphate bonds to C5'.

B. the base bonds to C2' and the phosphate bonds to C4'.

C. the base bonds to C5' and the phosphate bonds to C1'.

D. the base bonds to C2' and the phosphate bonds to C3'.

Question 15

In the energy profile diagram below, the activation energy, E_A is 243 kJ and ΔH is +190 kJ mol⁻¹.
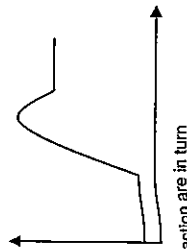
The E_A and ΔH for the reverse reaction are in turn

A. 53 kJ and +190 kJ mol⁻¹

B. 53 kJ and -190 kJ mol⁻¹

C. -243 kJ and -190 kJ mol⁻¹

D. 243 kJ and 433 kJ mol⁻¹

Question 16

If a catalyst is applied to the reaction in **Question 15**, the E_A would

A. decrease in both the forward reaction and the reverse reaction.

B. decrease in the forward reaction but not the reverse reaction.

C. increase in both the forward reaction and the reverse reaction.

D. increase in the forward reaction but not the reverse reaction.

Question 17

The rate of a chemical reaction usually increases with higher temperatures. This is because at higher temperatures

A. the activation energy increases.

B. the activation energy decreases.

C. more molecules collide with enough energy to react.
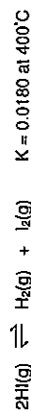
D. enthalpy of reaction increases.

Question 18

Which acid-base indicator that is red at low pH is the strongest acid?

A. Phenolphthalein

B. Methyl red

C. Phenol red

D. Thymol blue

Question 19

Hydrogen iodide decomposes according to the following equation:
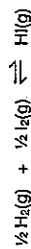
$$2HI(g) \rightleftharpoons H_2(g) + I_2(g) \qquad K = 0.0180 \text{ at } 400°C$$

1.0 mol of HI, 1.0 mol of $H_2(g)$ and 1.0 mol of $I_2(g)$ are placed in a sealed container at 400°C.

At equilibrium, the concentration of HI

A. increases.

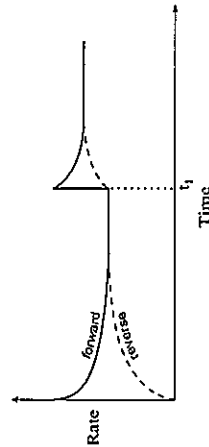B. decreases.

C. increases, then decreases.

D. stays constant.

Question 20

Using the information from **Question 19** above, calculate the value of K' for the following reaction

$$½ H_2(g) + ½ I_2(g) \rightleftharpoons HI(g)$$

A. -0.009

B. -0.018

C. 7.45

D. 55.6

Question 21

Rate

forward

reverse

Time t_1

The graph above shows the rate against time for the reaction in **Question 19**.
Which of the following occurs at time t_1?

A. addition of H_2

B. addition of HI

C. addition of a catalyst

D. decrease in volume

Question 22

Consider the following statements about the equilibrium constant.

The value of the equilibrium constant K depends on the

I temperature of the system

II concentration of the reactants

III concentration of the products

IV ΔH of the reaction

Which of the following is true?

A. I

B. II and III

C. I, II and III

D. I, II, III and IV

Question 23

A student sets up the equipment for a galvanic cell similar to the diagram below using 1.0 M solutions.
The student is uncertain which solution has been placed in the cell containing the platinum electrode.
The voltage reading for the cell is 0.46 volts.

Pt

V

Cu

$Cu(NO_3)_2(aq)$
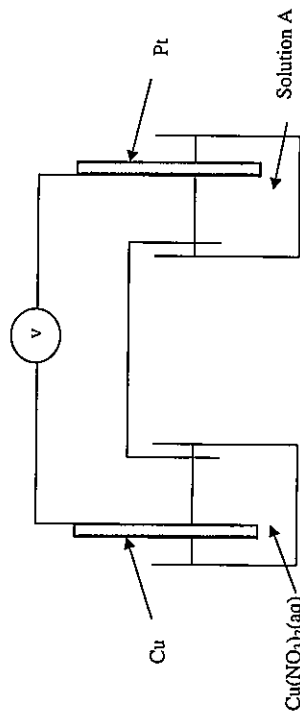
Solution A

From this information, solution A is most likely

A. $AgNO_3$

B. $Pb(NO_3)_2$

C. $Sn(NO_3)_2$

D. $Fe(NO_3)_2$

Question 24

The student then changed the experimental set up, replacing the platinum electrode with a silver electrode and using a new solution for this half-cell. However the student is still not sure what solution has been used. The cell voltage is read as 0.43 volts. The solution in the silver electrode half-cell is

A. water

B. $Zn(NO_3)_2$

C. $Fe(NO_3)_2$

D. $Fe(NO_3)_3$

Question 25

Which of the following is **not** an important consideration for waste management principles in the chemical industry?

A. Recycling the reactants

B. Re-using the waste products

C. Properties of the waste products

D. Uses of the main products

Question 26

0.7246 g of a tin salt is dissolved in 25.00 mL of distilled water. The solution is titrated against 0.100 M $K_2Cr_2O_7$. The average titre is 12.78 mL.

Given $Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$

What is the name of the tin salt?

A. tin(II) sulfate ($M_r = 214.8$)

B. tin(II) chloride ($M_r = 189.7$)

C. tin(IV) chloride ($M_r = 260.7$)

D. tin(II) nitrate ($M_r = 242.7$)

Question 27

A 10.0 mL solution of ammonium sulfate has a pH of 5.0. What is the concentration of the ammonium sulfate?

A. 1.0×10^{-5} M

B. 0.089 M

C. 0.18 M

D. 0.36 M

Question 28

Industry attempts to minimise the cost of production of a chemical by

A. using a catalyst which lowers the ΔH of the chemical reaction.

B. selecting endothermic reactions which use less energy.

C. recycling unused reactants.

D. operating at the highest pressures to increase the reaction rates..

Question 29

A beaker contains a mixture of the following 1.0 M solutions, $Mn(NO_3)_2$, $Mg(NO_3)_2$, $Ni(NO_3)_2$ and $Cu(NO_3)_2$.

Two platinum rods are placed in the beaker and connected to a 6 V battery.

Which of the above metals will be plated last onto the cathode?

A. Cu

B. Mn

C. Ni

D. Mg

Question 30

The Environmental Protection Authority determines the concentration of ozone in the air by passing the air sample through a solution containing iodide ions. These react according to the equation

$$O_3(g) + 2I^-(aq) + H_2O(l) \rightarrow O_2(g) + I_2(aq) + 2OH^-(aq)$$
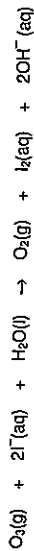
From the equation above, the half reaction for the reductant is

A. $2I^-(aq) + 2e^- \rightarrow I_2(aq)$

B. $2I^-(aq) \rightarrow I_2(aq) + 2e^-$

C. $O_3(g) + H_2O(l) \rightarrow O_2(g) + 2OH^-(aq) + 2e^-$

D. $O_3(g) + H_2O(l) + 2e^- \rightarrow O_2(g) + 2OH^-(aq)$

SECTION B – Short answer questions

Instructions for Section B
Answer all questions in the spaces provided.
To obtain full marks for your responses you should

- give simplified answers with an appropriate number of significant figures to all numerical questions; unsimplified answers will not be given full marks.
- show all working in your answers to numerical questions. No credit will be given for an incorrect answer unless it is accompanied by details of the working.
- make sure chemical equations are balanced and that the formulas for individual substances include an indication of state; for example, $H_2(g)$; $NaCl(aq)$

Question 1

The discovery of the ship wreck *Titanic* showed that the rusting process that normally occurs in shallow, oxygenated water does not occur at great depths in the ocean. Instead, the steel is consumed by a range of different bacteria including anaerobic bacteria. One class of anaerobic bacteria is the sulfate-reducing bacteria. They obtain their energy for metabolism by oxidation of iron and reduction of sulfate ions.
Under acidic conditions the following reaction may occur

$$4Fe(s) + SO_4^{2-}(aq) + 2H_2O(l) + 2H^+(aq) \rightarrow FeS(s) + 3Fe(OH)_2(s)$$
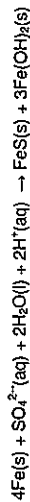
a. Write a balanced ionic equation for the reduction of sulfate ions to sulfide ions.

1 mark

A 1.000 g sample of a piece of corroded iron found deep under the ocean is analysed to determine the percentage of iron that had corroded. The sample is dissolved in excess sulfuric acid, converting all Fe(s) to Fe^{2+}(aq). The rust does not react with the acid. The solution is then titrated with 0.1100 M potassium dichromate, $K_2Cr_2O_7$. An average litre volume of 21.10 mL is required to reach the equivalence point.

b. Write a balanced ionic equation for the reaction of Fe^{2+}(aq) with dichromate ion, $Cr_2O_7^{2-}$(aq).

c. Calculate the amount, in moles, of dichromate ions $Cr_2O_7^{2-}$(aq) used in the titration.

2 marks

d. Calculate the amount, in moles, of Fe^{2+}(aq) reacted.

1 mark

e. Calculate the percentage mass of iron in the sample.

1 mark

f. Name a volumetric analytical piece of equipment used in the above determination and state its uncertainty...

2 marks

Question 2

Samples of various concentrations of benzyl ethanoate, $CH_3COOCH_2C_6H_5$, are run through a chromatograph and the areas under their peaks recorded. A 10.00 mL sample containing an unknown concentration of benzyl ethanoate is diluted to 100.0 mL and its area also measured. The results are listed below.

Mass per sample (μg)	Area under the peak
0.00	0
1.22	2010
1.70	2840
3.23	5230
3.90	6410
unknown sample	3450

a. On the grid below draw a calibration curve.
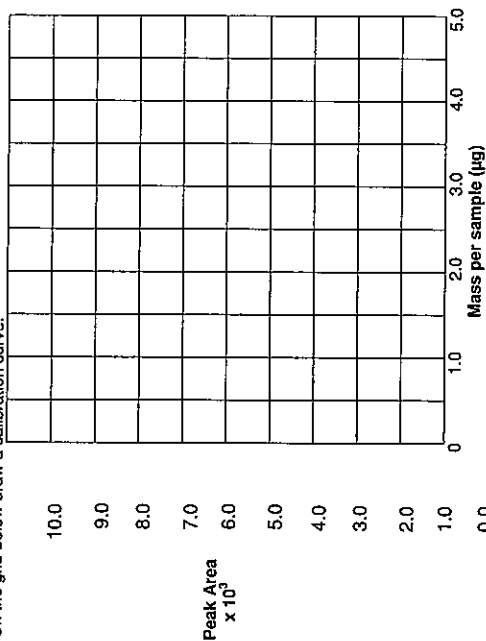
a. Determine the mass of benzyl ethanoate in the diluted unknown sample.

1 mark

b. Determine the mass in grams of benzyl ethanoate in the original sample.

1 mark

c. Why was the dilution step carried out?

1 mark

Question 3

An unknown molecule has a molecular formula $C_4H_8O_2$ and is not an aldehyde, ketone or diol.
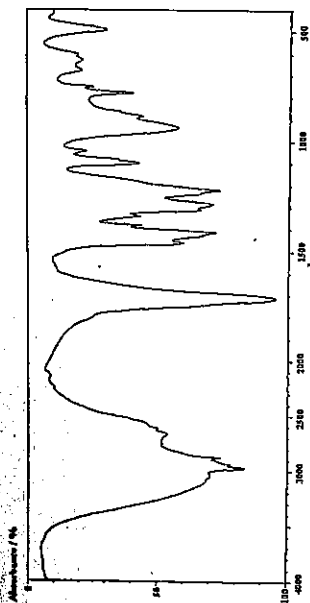
a. Name the two possible functional groups in $C_4H_8O_2$.

2 marks

b. Give the names of four possible structures of $C_4H_8O_2$.

2 marks

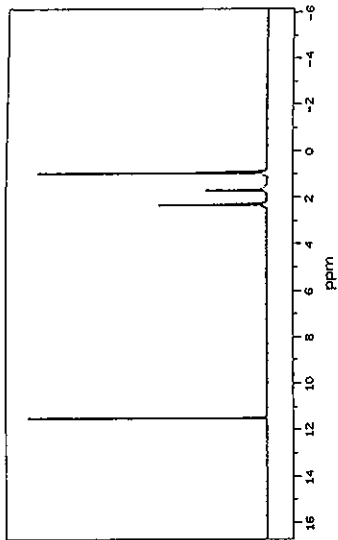The IR spectrum of the unknown molecule is shown below

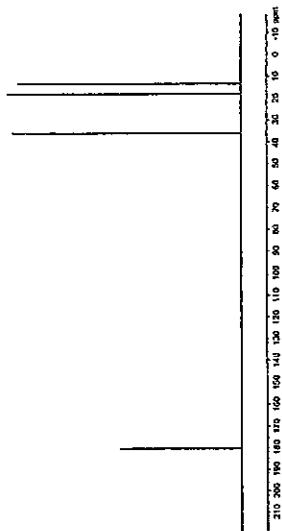c. On the diagram, circle each of the areas indicating an oxygen atom is present in the compound.

1 mark

The ^1H NMR and ^{13}C NMR spectra of the compound are shown below:

^1H NMR $C_4H_8O_2$

^{13}C NMR $C_4H_8O_2$

d. How many different hydrogen environments are present in the compound?

1 mark

e. Give a probable mass spectrum fragment m/e and write the formula of the fragment.

2 marks

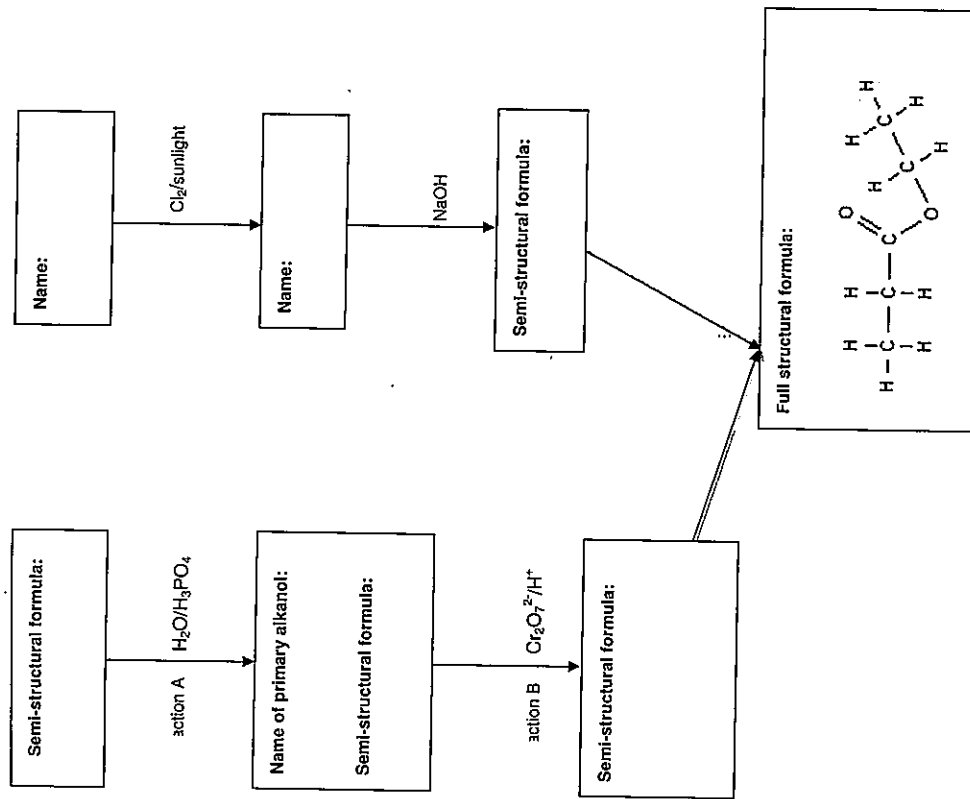f. Give a structural formula for the compound.

g. Give the IUPAC systematic name of the compound.

1 mark

Question 4

Ethyl propanoate is an ester that has a pineapple-like smell. Kiwifruit and strawberries both contain small quantities of ethyl propanoate. Complete the flow chart below working back from the molecule in the last box.

Name:

↓ Cl_2/sunlight

Name:

↓ NaOH

Semi-structural formula:

Semi-structural formula:

action A H_2O/H_3PO_4

Name of primary alkanol:

Semi-structural formula:

action B $Cr_2O_7^{2-}/H^+$

Semi-structural formula:

Full structural formula:

7 marks

c. Which of the above reactions are substitution reactions?

1 mark

d. Why was $H_2SO_4(l)$ and not $H_2SO_4(aq)$ used in the esterification reaction?

1 mark

Question 5

a. There are two naturally occurring lactotripeptides in milk: Ile – Pro – Pro (IPP) and Val – Pro – Pro (VPP). For a while clinical studies seemed to prove that they might be useful in lowering blood pressure but a recent European review has cast doubt on these claims.

i. Draw the structure of Val – Pro – Pro.

2 marks

ii. What is the molecular formula of proline?

1 mark

b. When glycerol reacts with three linolenic acid molecules, a triglyceride forms. Circle the correct answers in the following:

i. The reaction may be described as

condensation   alkylation   hydrolysis   hydrogenation

1 mark

ii. The resulting triglyceride is

saturated   monounsaturated   polyunsaturated

1 mark

iii. The functional group is

an amide link   a peptide link   an ester link   a glycosidic link

1 mark

c. For each of the following statement indicate whether they are True or False. Give a reason for your answer.

True or False

i. Uranium can be considered to be a sustainable resource because compared with coal, a huge quantity of energy is produced from very small amounts.
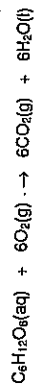
Reason:

2 marks

ii. Bonding between the guanine and cytosine bases in DNA are stronger than the bonds between adenine and thymine.
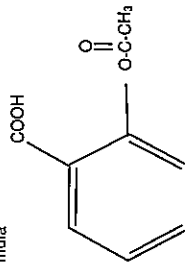
Reason:

2 marks

iii. Grain can be used to produce bioethanol. The starch in the grain is first hydrolysed then the glucose produced is fermented according to the equation

$$C_6H_{12}O_6(aq) + 6O_2(g) \longrightarrow 6CO_2(g) + 6H_2O(l)$$

Reason:

2 marks

d. Aspirin has the following formula

i. It has long been known that salicylic acid reduced pain and inflammation. Explain why salicylic acid was 'acetylated'.

1 mark

ii. Write an equation for the formation of aspirin from salicylic acid.

1 mark

iii. Soluble aspirin works much faster than aspirin. Redraw the formula above so that it becomes soluble aspirin.

1 mark

SECTION B – continued

Question 6

Give concise explanations for the following:

a. Methane gas mixed with air does not explode until a spark or flame is applied.

1 mark

b. Small pieces of wood burn faster than a large piece.

1 mark

c. When ammonium nitrate powder is dissolved in water, the temperature of the solution decreases.

1 mark

d. Milk becomes sour after a few hours at 25°C but this process takes days in a refrigerator.

1 mark

e. Carbon monoxide is extremely toxic.
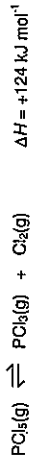
1 mark

f. A buffer solution resists change in pH.

1 mark

g. Equilibrium can be described as a dynamic state.

1 mark

SECTION B – continued
TURN OVER

Question 7

PCl₅ decomposes according to the following equation:

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g) \qquad \Delta H = +124 \text{ kJ mol}^{-1}$$

A 2.00 L container initially contained 0.0175 mol of PCl₅ and 0.600 mol of PCl₃ only.
At equilibrium, 0.00401 mol of Cl₂ was found in the flask at the same temperature.

a. Calculate the equilibrium concentrations of each of the three molecules

3 marks

b. Calculate the value of the equilibrium constant at this temperature

1 mark

c. Complete the following table by describing **two** changes needed to achieve each desired effect without adding or removing any gas:

Desired effect	Changes needed
Produce more Cl₂	1.
	2.
Increase the reaction rate	1.
	2.
Decrease the total pressure in the flask	1.
	2.

3 marks

A gas sample of PCl₅ has a greenish colour. Explain this observation.

2 marks

d. Explain why changing the volume of the container does not disturb the equilibrium of some reactions.

1 mark

SECTION B – continued

Question 8 (9 marks)

a. In thermochemistry two types of calorimeter are commonly used, the solution calorimeter and the bomb calorimeter.

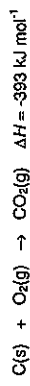i. Name two differences that these calorimeters have.

1 mark

ii. Write an equation for an experiment that could be carried out in a solution calorimeter.

1 mark

iii. Write a thermochemical equation for an experiment that could only be carried out in a bomb calorimeter but not a solution calorimeter.

1 mark

b. Listed below are three thermochemical equations.

$$CH_3OH(g) + 1\tfrac{1}{2}O_2(g) \rightarrow CO_2(g) + 2H_2O(l) \qquad \Delta H = -754 \text{ kJ mol}^{-1}$$
$$C(s) + O_2(g) \rightarrow CO_2(g) \qquad \Delta H = -393 \text{ kJ mol}^{-1}$$
$$C(s) + \tfrac{1}{2}O_2(g) \rightarrow CO(g) \qquad \Delta H = -115 \text{ kJ mol}^{-1}$$

Using the equations above, calculate the change in enthalpy for the following equation.

$$CH_3OH(g) + O_2(g) \rightarrow CO(g) + 2H_2O(l)$$
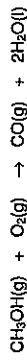
2 marks

c. A bomb calorimeter is calibrated using benzoic acid (C₆H₅COOH) and the following information recorded:
The molar enthalpy for the combustion of benzoic acid is -3227 kJ mol⁻¹.
Mass of benzoic acid = 1.71 g.
After ignition the temperature of the water rose by 4.89°C.
Calculate the calibration factor for the calorimeter under these conditions.

2 marks

SECTION B – continued
TURN OVER

d. The Russian Soyuz-2 rocket has launched several communications, navigation and weather satellites. Where a third stage of the launch is required, a fuel mix of N_2O_4 / UDMH is used. UDMH is unsymmetrical dimethylhydrazine. This mixture is self-igniting. The reliability of the Soyuz-2 rocket is in part because UDMH is stable and can be loaded in rocket systems for long periods of time.

$$H_2NN(CH_3)_2(l) + 1.5N_2O_4(l) \rightarrow 2.5N_2(g) + 2CO(g) + 4H_2O(g) \quad \Delta H = -1208 \text{ kJ mol}^{-1}$$

Assuming that all the N_2O_4 is consumed, calculate the heat, in MJ, produced if the rocket is carrying 3.4 tonnes of N_2O_4?

_____

_____

2 marks

Question 9 (5 marks)

a. Complete the following table identifying where there is a reaction and therefore the half-equation for the reduction reaction.

| Substances present in the test-tube	Reaction Yes/No	Half equation for the reduction occurring
copper metal in a silver nitrate solution		
hydrogen peroxide and tin(IV) chloride solution		
chlorine bubbled into a tin(II) nitrate solution		

3 marks

b. How are E° values determined?

_____

_____

1 mark

c. A particular cell is expected to produce electricity but no reaction is observed. Give a reason why this might happen.

_____

_____

1 mark

Question 10 (7 marks)

The diagram below represents a phosphoric acid fuel cell (PAFC). PAFCs operate at temperatures of 150–200°C.

Phosphoric Acid Fuel Cell
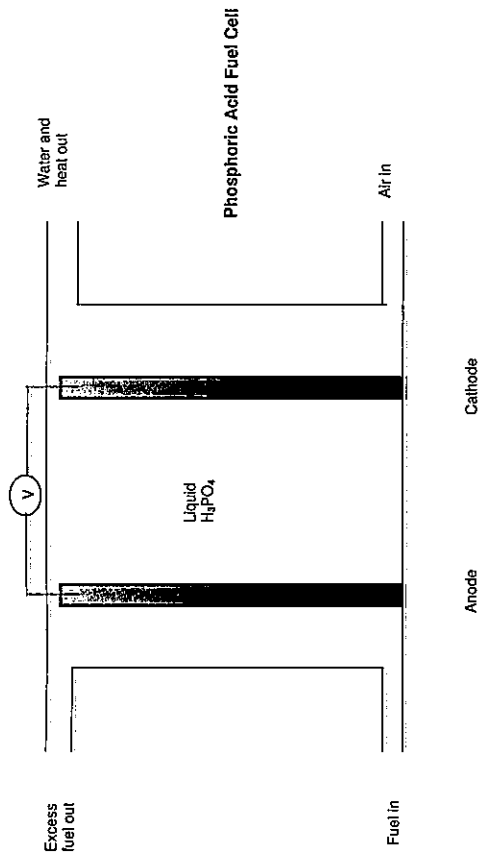
a. What polarity is the cathode?

_____

1 mark

b. Water is produced when the cell is in operation. Write a balanced half equation for the production of water.

_____

1 mark

c. Calculate the volume of 1.0 kg of H_2O at 200°C and 1.5 atm.

_____

_____

2 marks

d. Calculate the current produced when 1 kg of H_2O is produced in 1 hour.

_____

_____

_____

2 marks

e. Name two essential properties of electrodes in fuel cells.

_____

_____

1 mark

CHEM EXAM

Question 11

An aluminium can weighs 15.0 g. Aluminium can be produced industrially from electrolysis of a non-aqueous solution of aluminium ions, Al^{3+}, at a voltage of 5.0 volts.

a.   Write a complete balanced half-equation for the reaction where aluminium is produced during electrolysis.

_____

1 mark

b.   Calculate how much energy in joules is needed to produce one aluminium can from electrolysis of a non-aqueous solution of aluminium ions.

_____

_____

_____

2 marks

c.   During the industrial production of aluminium in a particular type of cell, carbon electrodes are used and consumed in the process of making aluminium. Oxide ions in the electrolyte react at the electrode to produce oxygen gas which reacts immediately with the carbon atoms in the electrode producing carbon dioxide, according to the reactions below.

$$2O^{2-}(l) \rightarrow O_2(g) + 4e^-$$

$$C(s) + O_2(g) \rightarrow CO_2(g)$$
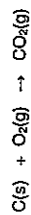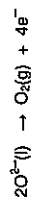
How many moles of carbon dioxide are produced in the production of one aluminium can?

_____

_____

_____

_____

3 marks

d.   Give one environmental advantage of recycling aluminium.

_____

_____

_____

1 mark

END OF SECTION B
END OF QUESTION AND ANSWER BOOK