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2023 Trial Examination

STUDENT NUMBER | | | | | | | | | Letter |

CHEMISTRY

Units 3&4 – Written examination

Reading time: 15 minutes
Writing time: 2 hour and 30 minutes

QUESTION & ANSWER BOOK

Structure of book

Section	*Number of questions*	*Number of questions to be answered*	*Number of marks*
A	30	30	30
B	8	8	90
			Total 120

- Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, rulers and a scientific calculator.
- Students are NOT permitted to bring into the examination room: blank sheets of paper and/or white out liquid/tape.

Materials supplied

- Question and answer book of 29 pages.

Instructions

- Print your name in the space provided on the top of this page.
- All written responses must be in English.

Students are NOT permitted to bring mobile phones and/or any other unauthorised electronic communication devices into the examination room.

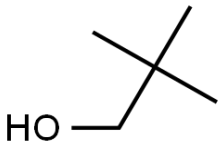
SECTION A – Multiple-choice questions

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.
Unless otherwise indicated, the diagrams in this book are not drawn to scale.

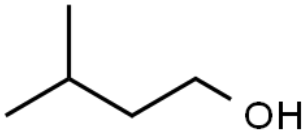
Question 1

Which of the following structures contains a chiral carbon?

A.



B.



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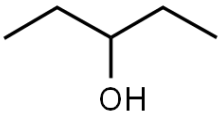
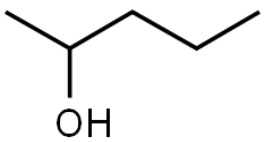


D.



Question 2

Which of the following is **not** true of a fuel cell?

A. Fuel cells convert chemical energy into electrical energy

B. Fuel cells have a continual supply of reactants

C. Fuel cells are rechargeable

D. Fuel cells use porous electrodes.

SECTION A - continued

Question 3

$$CH_3CH_2NH_2\ (l) + CH_3COOH\ (l) \rightarrow CH_3COONHCH_2CH_3(l) + H_2O(l)$$

The equation above is an example of what type of reaction?

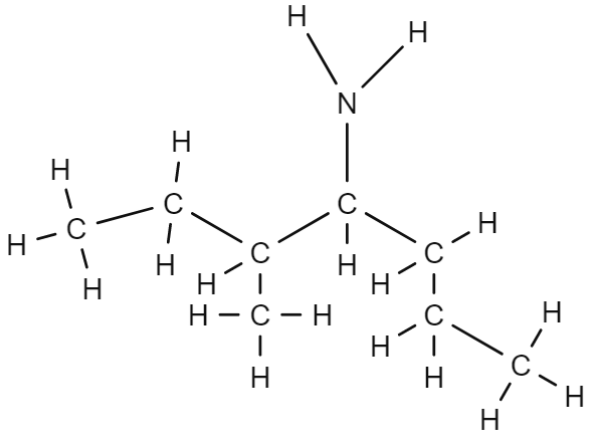
A. esterification
B. condensation
C. hydrolysis
D. addition

Question 4

The thermochemical equation for the complete combustion of methanol at SLC is

A. $2CH_3OH\ (l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(g)$ $\Delta H = -726\ kJ\ mol^{-1}$
B. $CH_3OH\ (l) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$ $\Delta H = -1452\ kJ\ mol^{-1}$
C. $2CH_3OH\ (l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(g)$ $\Delta H = -726\ kJ\ mol^{-1}$
D. $2CH_3OH\ (l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(l)$ $\Delta H = -1452\ kJ\ mol^{-1}$

Question 5



What is the IUPAC name for the molecule above?

A. 2-ethylhex-3-amine
B. 3-methylhept-4-amine
C. 5-methylhept-4-amine
D. 5-ethylhex-3-amine

SECTION A – continued
TURN OVER

Question 6

Steam methane reforming is a process that is often used to produce hydrogen gas. The equation for the reaction is:

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \qquad \Delta H = 206 \text{ kJ mol}^{-1}$$

The conditions that would produce the highest yield of hydrogen are

A. High pressure and high temperature

B. Low pressure and high temperature

C. High pressure and low temperature

D. Low pressure and low temperature

Question 7

A sample of food that contains 1.2g of carbohydrate, 0.30g of protein and 0.50g of fat was burned in a bomb calorimeter and the temperature of the water rose 15.2ºC. The calibration factor of the calorimeter is:

A. 2.8 kJ $^oC^{-1}$

B. 0.65 kJ $^oC^{-1}$

C. 2.9 kJ $^oC^{-1}$

D. 0.67 kJ $^oC^{-1}$

Question 8

The overall equation for an ethanol fuel cell is:

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

The equation for the reaction that occurs at the anode of this fuel cell is:

A. $CH_3CH_2OH(aq) + 12OH^-(aq) \rightarrow 2CO_2(g) + 9H_2O(l) + 12\ e^-$

B. $4OH^-(aq) \rightarrow 2H_2O(l) + O_2(g) + 4e^-$

C. $2CO_2(g) + 9H_2O(l) + 12\ e^- \rightarrow CH_3CH_2OH(aq) + 12OH^-(aq)$

D. $2H_2O(l) + O_2(g) + 4e^- \rightarrow 4OH^-(aq)$

Question 9

Which of the following is an omega-6 fatty acid?

A. Linolenic acid

B. Linoleic acid

C. Oleic acid

D. Stearic acid

SECTION A - continued

Question 10

Which of the following combinations of standard half-cell pairs would produce a cell potential closest to 1.0V?

A. $Ni(s)/Ni^{2+}(aq)$ and $Zn(s)/Zn^{2+}(aq)$

B. $Sn^{2+}(aq)/Sn^{4+}(aq)$ and $Mn(s)/Mn^{2+}(aq)$

C. $Ag(s)/Ag^{+}(aq)$ and $Ni(s)/Ni^{2+}(aq)$

D. $Cu(s)/Cu^{2+}(aq)$ and $Zn(s)/Zn^{2+}(aq)$

Question 11

How many structural isomers are there of $C_4H_{11}Cl$?

A. 4

B. 6

C. 8

D. 10

Question 12

Which of the following would increase the reliability of a practical experiment?

A. Increase the resolution of the equipment being used

B. Repeat the experiment

C. Calibrate the equipment before use

D. Have another scientist complete the experiment

Question 13

Electrolytic cells were set up with Nal(l), $CuCl_2(aq)$ and $AlF_3(aq)$ electrolytes. Which of the cells would produce gases at the cathode?

A. NaI(l) only

B. NaI(l) and $CuCl_2(aq)$

C. $AlF_3(aq)$ only

D. NaI(l) and $AlF_3(aq)$

Question 14

Which one of the following molecules has enantiomers?

A. C_2H_4

B. C_3H_8O

C. C_3H_6

D. C_4H_8

SECTION A – continued
TURN OVER

Question 15

Find the enthalpy for the following reaction:

$$C_2H_2(g) \rightarrow 2C(s) + H_2(g)$$

Given the following thermochemical equations:

$2C_2H_2(g) + 5O_2(g) \rightarrow 4CO_2(g) + 2H_2O(l)$ $\quad \Delta H = -2999 kJ\ mol^{-1}$

$CO_2(g) \rightarrow C(s) + O_2(g)$ $\quad \Delta H = 394\ kJ\ mol^{-1}$

$2H_2(g) + O_2(g) \rightarrow H_2O(l)$ $\quad \Delta H = -570\ kJ\ mol^{-1}$

A. $-141.5\ kJ\ mol^{-1}$

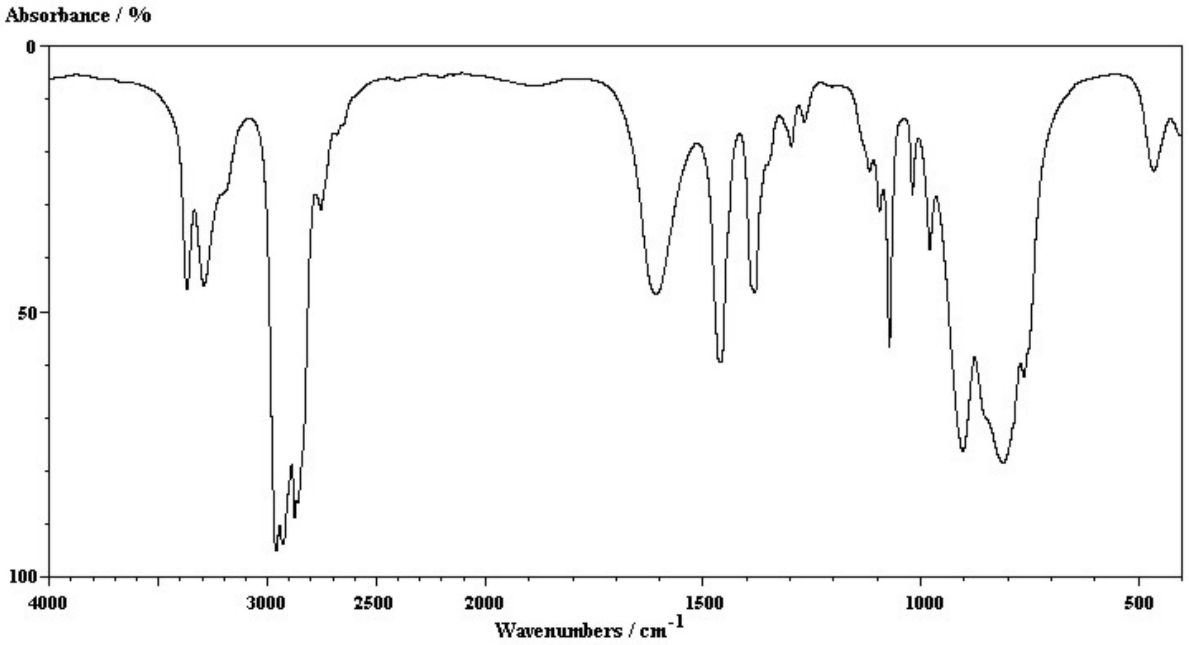
B. $428.5\ kJ\ mol^{-1}$

C. $-1071\ kJ\ mol^{-1}$

D. $-1675.5\ kJ\ mol^{-1}$

Question 16

The following is the infra-red spectrum of an organic compound



The compound is an

A. Ester

B. Carboxylic acid

C. Amide

D. Alcohol

SECTION A – continued

Question 17

A mixture of propanol, butanol and butanoic acid was put through a HPLC with a polar stationary phase and a non-polar mobile phase. The order of chemicals from shortest to longest retention time is:

A. Propanol, butanol, butanoic acid

B. Propanol, butanoic acid, butanol

C. Butanoic acid, butanol, propanol

D. Butanol, butanoic acid, propanol

Question 18

Sulfur trioxide dissociates into sulfur dioxide and oxygen according to the equation:

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

2.0 mol of SO_3 was placed in an evacuated 5.0L container, after the system reached equilibrium the concentration of O_2 was found to be 0.15M. The equilibrium constant for the reaction is

A. $0.74M^{-1}$

B. $1.35M^{-1}$

C. 0.74M

D. 1.35M

Question 19

Fats highest in which of the following fatty acids would be most likely to undergo oxidative rancidity.

A. Oleic acid

B. Arachidonic acid

C. Linolenic acid

D. Palmitic acid

Question 20

An electrolytic cell with an unknown electrolyte is run for 300 seconds with a current of 4.00 amps. The mass of the electrode increased by 1.25g, the electrolyte was:

A. $AgNO_3$

B. $Pb(NO_3)_2$

C. $Hg(NO_3)_2$

D. $CsNO_3$

Question 21

A student completed a practical investigation into the energy released from a sample of ethanol through bomb calorimetry. Which of the following changes to the practical investigation is matched to the correct practical element?

A. Increase the uncertainty by calibrating the equipment

B. Increase the precision by repeating the experiment multiple times

C. Increase the repeatability by repeating the experiment using different alcohols

D. Increase the resolution by replacing the thermometer with a digital thermometer that reads to two decimal places

Question 22 and 23 refer to the following information

Prior to the introduction of natural gas, coal gas was used as a fuel in many cities. Coal gas is a mixture of carbon monoxide and hydrogen gas, formed by passing steam over coal. This mixture of carbon monoxide and hydrogen can then be burnt in the presence of oxygen to produce carbon dioxide and water.

$C(s) + H_2O(g) \rightarrow CO(g) + H_2(g)$ $\quad \Delta H = 131.3 kJ\ mol^{-1}$

$2CO(g) + O_2(g) \rightarrow 2CO_2(g)$ $\quad \Delta H = -563.4 kJ\ mol^{-1}$

$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$ $\quad \Delta H = -483.6 kJ\ mol^{-1}$

Question 22

How much energy is required to produce 100L of town gas stored at SLC?

A. 265 kJ

B. 529 kJ

C. 916 kJ

D. 1060 kJ

Question 23

How much energy would the complete combustion of 100L of town gas produce at SLC?

A. 528 kJ

B. 784 kJ

C. 1055 kJ

D. 2111 kJ

Question 24

Which of the following statements is true about biodiesel?

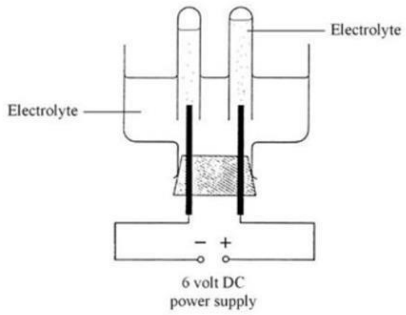
A. Biodiesel has a higher energy content per gram and lower hygroscopicity than petrodiesel.

B. Biodiesel has a higher energy content per gram and higher hygroscopicity than petrodiesel.

C. Biodiesel has a lower energy content per gram and lower hygroscopicity than petrodiesel.

D. Biodiesel has a lower energy content per gram and higher hygroscopicity than petrodiesel.

Question 25



A student electrolysed a sample of water using the above apparatus. When he tested the gas above the cathode he found.

A. There was twice as much gas as the anode and it caused a glowing splint to relight

B. There was half as much gas as the anode and it caused a glowing splint to relight

C. There was half as much gas as the anode and it emitted a pop when tested with a splint

D. There was twice as much gas as the anode and it emitted a pop when tested with a splint

Question 26

The percentage of amylose and amylopectin in samples of carbohydrates is shown in the table below. Which carbohydrate would have the lowest glycaemic index (GI)?

	Food	Amylose (%)	Amylopectin (%)
A.	Carbohydrate A	32	68
B.	Carbohydrate B	27	73
C.	Carbohydrate C	37	63
D.	Carbohydrate D	21	79

Question 27

Which of the following statements about indicators is correct?

A. Phenolphthalein is a suitable indicator for titrating a strong acid against a weak base

B. Methyl red is a suitable indicator for titrating ethanol with acidified permanganate

C. Bromothymol blue is a suitable indicator for titrating a strong base against a strong acid

D. Methyl orange is a suitable indicator for titrating a strong base against a weak acid

Question 28

In HPLC, which would be the most suitable pairing of stationary and mobile phases would give the best separation of a mixture of hydrocarbons

	Stationary phase	Mobile phase
A.	Polar	Polar
B.	Polar	Non-polar
C.	Non-polar	Non-polar
D.	Non-polar	polar

Question 29

Which of the following does **not** describe the action of a coenzyme?

A. A coenzyme can bind with the enzyme to change the shape of the active site

B. A coenzyme is a protein molecule

C. A coenzyme is not used up in the reaction

D. A coenzyme can carry electrons to assist in the reaction

Question 30

The lead-acid battery is a rechargeable battery found in most cars. The overall reaction for the discharge of a lead-acid battery is:

$$Pb(s) + PbO_2(s) + 2H_2SO_4(aq) \rightarrow 2PbSO_4(s) + 2H_2O(l)$$

What would be observed at the positive electrode during recharge?

A. The pH will decrease

B. Lead will accumulate on the electrode

C. The pH will increase

D. Lead sulfate will accumulate on the electrode

END OF SECTION A

SECTION B - Short-answer questions

Instructions for Section B

Answer all questions in the spaces provided.

Give simplified answers to all numerical questions, with an appropriate number of significant figures; non-simplified answers will not be given full marks.

Show all working in your answers to numerical questions; no marks will be given for an incorrect answer unless it is accompanied by details of the working.

Ensure chemical equations are balanced and that the formulas for individual substances include an indication of state, for example, $H_2(g)$, NaCl(s).

Unless otherwise indicated, the diagrams in this book are not drawn to scale.

Question 1 (11 marks)

Nutrition Facts

Serving Size 100 grams

	% Daily Value*
Total Fat 10.5g	**16%**
Saturated Fat 2.7g	**13%**
Trans Fat 0g	
Cholesterol 61mg	**20%**
Sodium 414mg	**17%**
Potassium 341mg	**10%**
Total Carbohydrate 0.7g	**0%**
Dietary Fiber 0.1g	**0%**
Sugars 0.4g	
Protein 20.9g	**42%**

Vitamin A 3%	Vitamin C 2%
Calcium 24%	Iron 13%
Thiamin 3%	Riboflavin 14%
Vitamin B6 6%	Vitamin B12 150%
Niacin 21%	Magnesium 9%
Phosphorus 37%	Zinc 9%
Copper 14%	Pantothenic Acid 7%
Vitamin D 120%	

The nutrition information for a can of sardines in tomato sauce is shown above

a. Calculate the energy content of a 100g serve of sardines. 2 marks

SECTION B – Question 1 – continued

TURN OVER

b. A 100g serve of sardines contains 120% of the daily requirement of vitamin D. Explain whether it would be suitable for a person to consume more than one serve of sardines a day, with reference to the structure of vitamin D. 2 marks

c. A 100g serve of sardines contains 42% of the daily requirement of protein.

i. Proteins are long chains of alpha (α-) or 2-amino acids. Describe the structure of an alpha or 2-amino acid. 2 mark

ii. Sardines contain all essential amino acids, explain what the term "essential amino acids" means. 2 mark

d. Sardines are also a good source of omega-3 fats.

i. Give an example of an omega-3 fatty acid. 1 mark

ii. Draw the structure of an omega-3 fatty acid and circle the omega-3 carbon. 2 mark

SECTION B – continued

Question 2 (8 marks)

Liquid petroleum gas (LPG) can be used as an alternative to octane-based petrol in motor vehicles. A sample of LPG was found to contain 60% propane and 40% butane by mass.

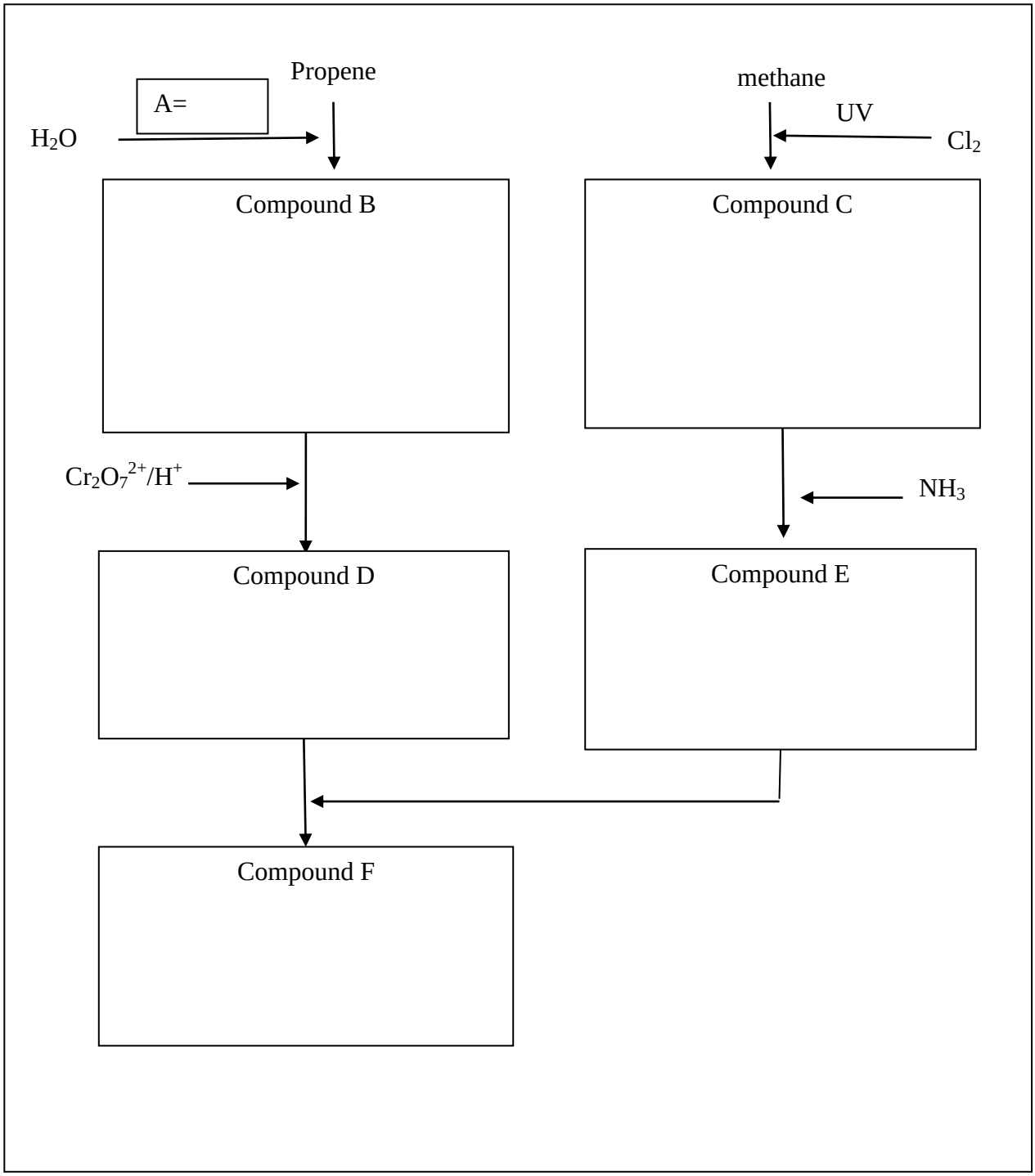
a. Write the balanced thermochemical equations for the complete combustion of propane and butane at SLC. 2 marks

b. Find the energy released when 500g of the LPG sample was fully combusted at SLC. 3 marks

c. Find the volume of carbon dioxide released when 500g of the LPG sample was fully combusted at SLC. 3 marks

SECTION B – continued
TURN OVER

Question 3 (12 marks)
The diagram below shows a reaction pathway starting with propene and methane.



SECTION B – Question 3 – continued

a. Name a suitable catalyst in the box on page 14, that would allow water to react with propene. 1 mark

b. Compound B is a primary organic compound, draw the structural formula in the box on page 14. 1 mark

c. Methane has undergone a single substitution to form compound C.

i. Draw the structural formula of compound C in the box on page 14. 1 mark

ii. Calculate the atom economy of the reaction that forms compound C. 2 marks

d. Compound D turns blue litmus red. Draw the skeletal structure of D in the box on page 14. 1 mark

e. The reaction that converts compound B into compound D is a two-step redox reaction. Write balanced oxidation, reduction and full equations for both steps in the reaction. 4 marks

f. Draw the structural formula of E in the box on page 14. 1 mark

g. Draw the skeletal formula of F, the product of a reaction of compound D and E in the box on page 14. 1 mark

SECTION B – continued
TURN OVER

Question 4 (17 marks)

The Haber Process is used to produce ammonia from nitrogen and hydrogen, according to the equation.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92.4kJ/mol$$

a. 4.00 mol of nitrogen, N_2, and 4.00 mol of hydrogen, H_2, are placed in an evacuated 500mL container. The concentration of ammonia when the system reached was 5.2M.
Calculate the equilibrium constant, K_c. 3 marks

b. After a period of time, the container was expanded to 2.00L

i. Explain the effect of the **rate** of the forward reaction after the container was expanded using collision theory. 2 marks

ii. Find the value of reaction quotient, Qc, immediately after the container was expanded. 2 marks

SECTION B - Question 4 - continued

iii. Explain the change in the position of equilibrium in relation to the reaction quotient and equilibrium constant. 2 marks

c. The Haber process is conducted at 500°C, 250 atm in the presence of an iron or osmium catalyst.

i. Explain the effect of the high temperature on the rate of reaction and position of equilibrium, with reference to collision theory and Le Chatelier's principle. 2 marks

ii. Explain the effect of the high pressure on the rate of reaction and position of equilibrium, with reference to collision theory and Le Chatelier's principle. 2 marks

SECTION B – Question 4 – continued

TURN OVER

iii. Explain the effect of the catalyst on the rate of reaction and position of equilibrium, with reference to collision theory and Le Chatelier's principle. 2 marks

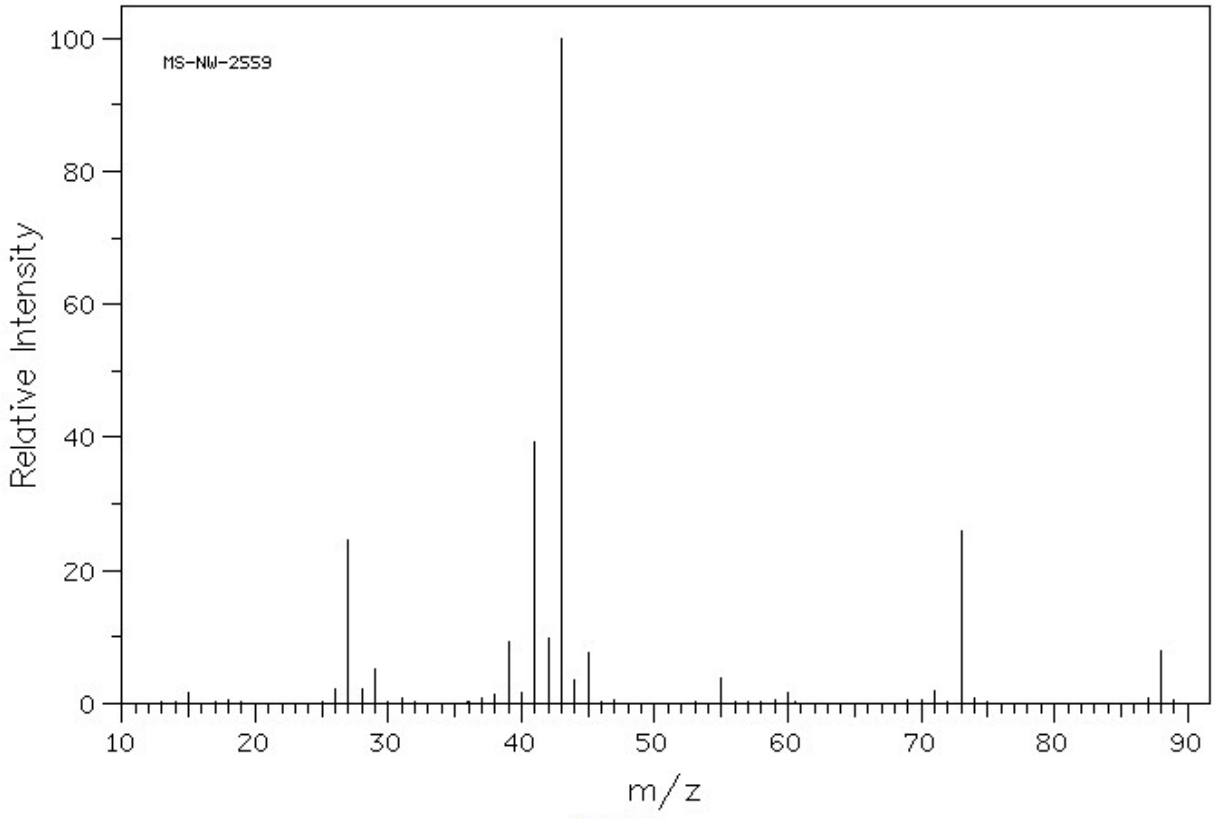
iv. The yield of the Haber process under these conditions is between 10-20%. Explain why these conditions are favoured over conditions that may produce a higher yield. 2 marks

SECTION B - continued

Question 5 (10 marks)

An unknown organic compound contains only carbon, hydrogen, and oxygen.

a. The mass spectra of the compound is shown below.



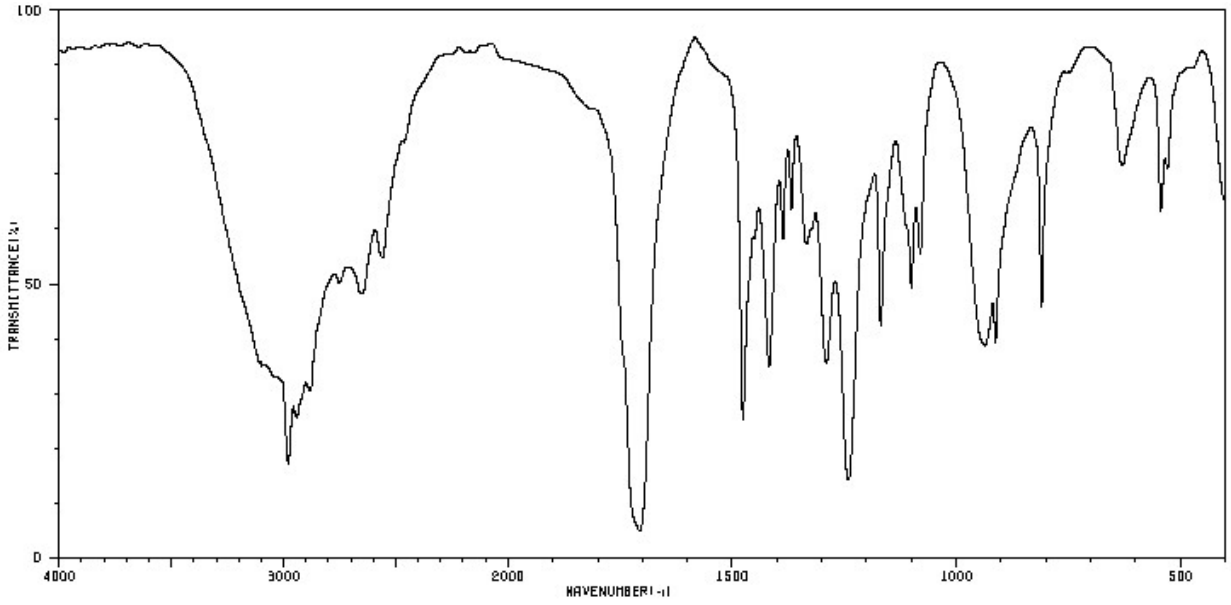
i. The parent ion has a mass charge ratio of 88. Explain the presence of the small peak with a m/z of 89. 1 mark

ii. Give two possible molecular formulas that would give a molecular mass of 88. 2 marks

SECTION B – Question 5 - continued
TURN OVER

iii. Suggest a possible species that would account for the base peak. 1 mark

b. The IR spectra of the compound is shown below



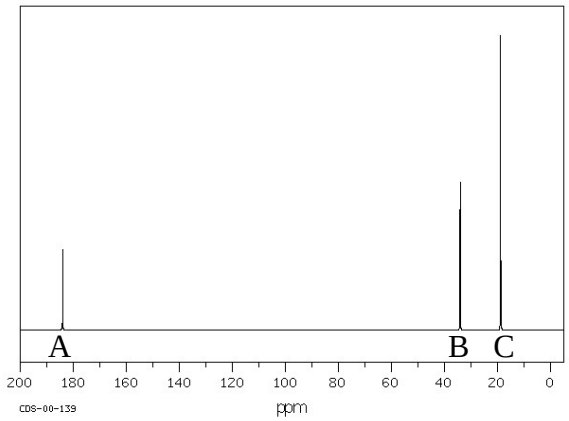
i. Identify the key absorbance regions present in the IR spectra. 2 marks

ii. Based on the IR spectra, what is the molecular formula of the compound? 1 mark

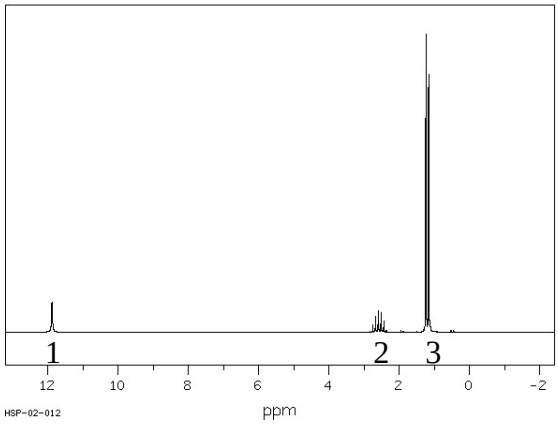
SECTION B – Question 5 – continued

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

^{13}C NMR



H NMR



i. Draw the structural formula of the compound that is consistent with the spectral data.

1 mark

ii. Label the carbons A, B and C on your diagram. 1 mark

iii. Label the hydrogen environments 1, 2 and 3 on your diagram. 1 mark

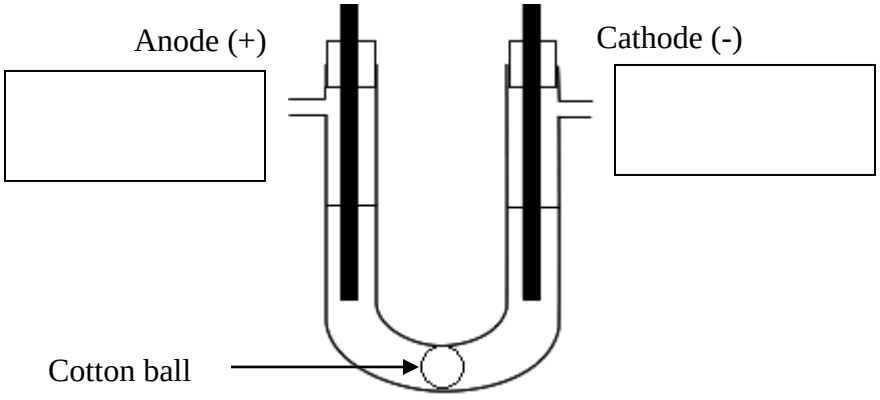
SECTION B – continued

TURN OVER

Question 6 (16 marks)

The electrolysis of sodium chloride will produce different products depending on the state and concentration of the electrolyte.

a. In the school laboratory a 0.1M sodium chloride solution can be electrolysed using the apparatus shown below.



i. Write the names of the gases produced at the anode and the cathode in the boxes above. 2 marks

ii. What is the purpose of the cotton ball at the bottom of the U tube? 1 mark

b. The Nelson cell uses a 20% m/v sodium chloride electrolyte to produce chlorine gas, Cl_2, and sodium hydroxide, NaOH.

i. Write balanced half equations and the full equation for the Nelson cell, showing the production of OH^- ions. 3 marks

SECTION B – Question 6 – continued

}

ii. Find the concentration of the sodium chloride solution. 2 marks

iii. Explain why chlorine gas is produced at the anode of the Nelson cell.

2 marks

iv. Find the volume of chlorine gas in mL produced at 400ºC and 250kPa when the Nelson cell operates for a day at 10,000 amps.

3 marks

SECTION B – Question 6 – continued
TURN OVER

c. A Downs cell uses molten $NaCl/CaCl_2$ electrolyte to produce sodium metal.

i. Explain why calcium chloride is added to the sodium chloride electrolyte. 2 marks

ii. Explain why calcium chloride does not affect the products of the electrolysis reaction. 2 marks

SECTION B – continued

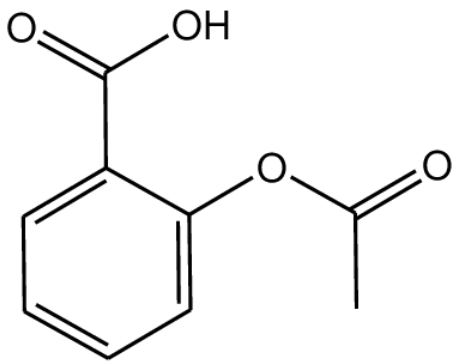
Question 7 (8 marks)

A group of students designed a titration to test the amount of aspirin in 100mg aspirin tablets. Aspirin is a weak acid, due to the carboxy group and will react with sodium hydroxide in a 1:1 ratio.

Research

Aspirin (acetylsalicylic acid) is a pain reliever and anti-inflammatory drug. It's precursor, salicylic acid, is found in willow bark, which has been used for around 2500 years

Skeletal structure



Reaction: $C_9H_8O_4(aq) + NaOH(aq) \rightarrow NaC_9H_7O_4(aq) + H_2O(l)$

Aim: To determine the amount of aspirin in a 100mg aspirin tablet

Predicted titre: $n(C_9H_8O_4) = \frac{0.100}{180} = 0.000556$ mol

$V(NaOH) = \frac{0.00556}{0.025} \times 1000 = 22.22mL$

Method

1. Dilute stock 1M sodium hydroxide to 0.025M by adding 25mL 1M NaOH to 1L volumetric flask and filling to line.
2. Crush aspirin tablet and transfer to conical flask
3. Add 20mL of deionised water and wait for tablet to swell and fall apart
4. Add 20mL of ethanol to dissolve aspirin tablet
5. Add 5 drops of phenolphthalein
6. Titrate against 0.25M NaOH, repeat until there are 3 concordant titres.

Results

Trial	Initial Reading	Final Reading	Titre
1	0.56	23.27	22.71
2	23.27	45.83	22.56
3	0.24	22.85	22.61
4	22.85	45.59	22.74
5	0.68	23.3	22.62

Calculations

Average titre = $\frac{22.56+22.61+22.62}{3} = 22.597\text{mL}$

n(NaOH) = $0.025 \times \frac{22.597}{1000} = 0.000565$ = n($C_9H_8O_4$)

m($C_9H_8O_4$) = $0.000565 \times 180 = 0.102\text{g}$

Conclusion

Through direct titration of aspirin tablets with sodium hydroxide, it was found that the 100mg aspirin tablets contains 102mg of aspirin.

a. Identify the independent variable in the experiment 1 mark

_____

b. Identify a systematic error in the practical investigation 1 mark

_____

_____

c. Identify the appropriate solution to rinse out the following instruments prior to use. 2 marks

burette: _____

conical flask: _____

SECTION B – Question 7 - continued

d. Consider the method undertaken by the student in this experiment to determine the amount of aspirin in the tablets. Identify specific steps in the method that affect the accuracy and reliability of the data and how they could be addressed. 4 marks

Question 8 (8 marks)

Octane is a major component of petrol. In the presence of excess oxygen it produces large amounts of energy, with the by-products being carbon dioxide and water. However if there is not sufficient oxygen octane will undergo the following reaction:

$$2C_8H_{18}(l) + 17O_2(g) \rightarrow 16CO(g) + 18H_2O(l) \qquad \Delta H = -6413 \text{ kJ mol}^{=1}$$

a. Compare the environmental impact of incomplete combustion of octane with the complete combustion of octane. In your response you should compare the energy produced by the two reactions and the environmental impacts of the products of the reactions.

In addition to the environmental impact of the release of carbon monoxide into the environment, there are also major health implications to the release of carbon monoxide into the environment.

b. Explain the health implications of the release of carbon monoxide by the incomplete combustion of fuels. In your response include equations of the reactions and treatments.

4 marks

END OF QUESTION & ANSWER BOOK