THE SCHOOL FOR EXCELLENCE 2007

UNIT 3 – CHEMISTRY

WRITTEN EXAMINATION 1

Reading Time: 15 minutes
Writing Time: 1 hour 30 minutes

QUESTION AND ANSWER BOOK

Structure of Book

Section		*Number of Questions*	*Number of Questions to be Answered*	*Number of Marks*	*Suggested Times (min)*
A	Multiple choice questions	20	20	20	20
B	Short answer questions	7	7	70	70
				Total 90	Total 90

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SECTION A

Specific Instructions For Section A

Section A consists of 20 multiple-choice questions. Section A is worth approximately 22% of the marks available. You should spend approximately 20 minutes on this section.

Choose the response that is **correct** or **best answers the question**, and shade the square on the multiple-choice answer sheet according to the instructions on that sheet.

A correct answer is worth 1 mark, an incorrect answer is worth no marks. No mark will be given if more than one answer is shown for any question. Marks will **not** be deducted for incorrect answers. You should attempt every question.

Item 1

A $0.150\ L$ flask contains Neon gas at $20.0^{o}C$ and at atmospheric pressure. When the flask is heated to $40.0^{o}C$, the pressure of the gas will increase by a factor of

A 0.3
B 0.5
C 2
D 8

Item 2

$4.86\ g$ of magnesium reacts in excess dilute hydrochloric acid.

$$Mg_{(s)} + 2HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$$

The volume of dry hydrogen gas evolved at $25^{o}C$ and $101.3\ kPa$ is

A $2.45\ L$
B $4.89\ L$
C $9.79\ L$
D $12.23\ L$

Item 3

$5.00\ g$ of $AgNO_3$ and $10.00\ g$ of $MgCl_2$ were dissolved in $200.00\ ml$ of water. Assuming that complete ionisation occurs, the number of ions in solution is

A 1.11×10^{23}
B 1.63×10^{23}
C 1.89×10^{23}
D 2.27×10^{23}

Item 4

The pH of a $0.1\ M$ solution of acetic acid, which is a weak acid, is approximately

A 1
B 4
C 10
D 13

Item 5

$20\ ml$ of $0.20\ M$ HCl reacts with $10\ ml$ of $0.10\ M$ sodium hydroxide solution. The pH of the resultant solution is closest to

A 1
B 3
C 8
D 11.5

Item 6

A compound is known to contain only sodium, sulphur and oxygen. A $100\ g$ sample of the compound contains $17.04\ g$ of sodium and $47.1\ g$ of sulphur. The empirical formula of the compound is

A NaS_2O_3
B $Na_2S_4O_6$
C Na_2SO_4
D $Na_2S_2O_3$

Item 7
What is the percentage by mass of oxygen in hydrated iron oxide, $Fe_2O_3.2H_2O$?

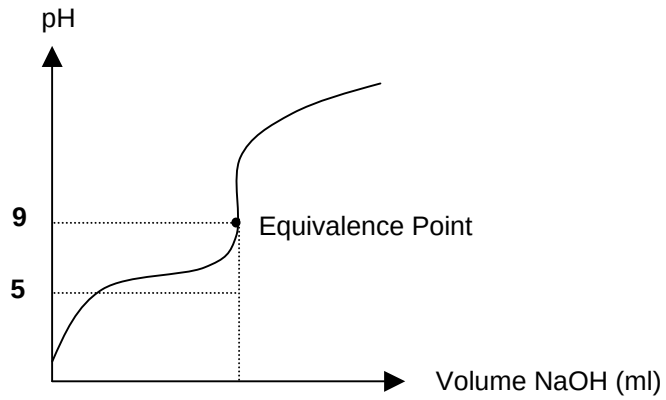
A 25%
B 27%
C 30%
D 41%

The following information relates to Items 8 and 9.

Benzoic acid, a weak acid, dissociates according to the following equation:

$$C_6H_5COOH_{(aq)} \rightleftharpoons C_6H_5COO^-_{(aq)} + H^+_{(aq)}$$

The diagram below shows the pH changes which occur when $20.0\ ml$ of $0.100M$ benzoic acid is titrated with $0.200M$ sodium hydroxide solution.



Item 8
Methyl orange indicator changes colour from red to yellow between a pH of 2.1 and 4.4. How would the calculated concentration compare to the true value if methyl orange were used as the indicator for this reaction?

A There would be no difference between the two concentrations.
B The calculated concentration will be higher than the true value.
C The calculated concentration will be lower than the true value.
D The difference in concentrations cannot be determined from the given information.

Item 9
In another reaction, $20.0\ ml$ of $0.100M$ hydrochloric acid is titrated with $0.200M$ sodium hydroxide.

How would the pH and volume of $NaOH$ solution required to reach the equivalence point compare to that for the benzoic acid solution?

	pH at Equivalence Point	**Volume at End Point**
A	Lower	The Same
B	Lower	Lower
C	Higher	The Same
D	Higher	Lower

Item 10
Which one of the following reactions is **not** a redox process?

A $FeO_{(s)} + CO_{(g)} \rightarrow Fe_{(s)} + CO_{2(g)}$

B $C_6H_{12}O_{6(s)} + 6H_2SO_{4(l)} \rightarrow 6C_{(s)} + 6H_3O^+_{(aq)} + 6HSO^-_{4(aq)}$

C $(NH_4)_2Cr_2O_{7(s)} \rightarrow N_{2(g)} + 4H_2O_{(g)} + Cr_2O_{3(s)}$

D $Cu^{2+}_{(aq)} + 2I^-_{(aq)} \rightleftharpoons CuI_{(s)} + \frac{1}{2}I_{2(aq)}$

Item 11
The oxidation number of nitrogen in NH_4NO_2 is

A 0
B -3
C $+3$
D ± 3

Item 12
Which of the following statements relating to paper chromatography is incorrect?

A R_f values increase as the temperature increases.

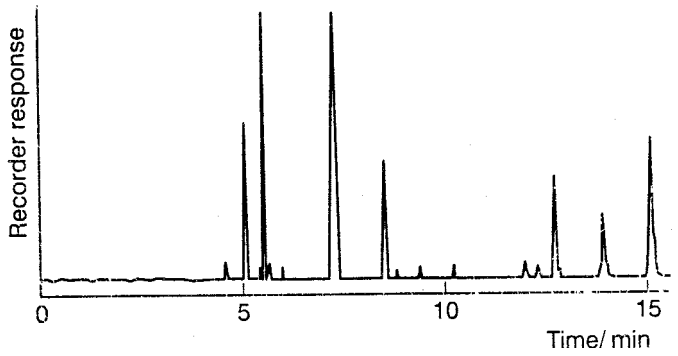
B Better resolution of sample components may be obtained by increasing the length of the chromatogram.

C Components of a sample separate due to differences in their rates of absorption and desorption.

D Paper chromatography may be used to separate components of mixtures.

Item 13
A sample of a mixture of alcohols was analysed using Gas Chromatography. The spectrum obtained is given below. Which of the following statements is false?

A The components separate according to their affinities for the two different phases.
B The smallest molecular weight alcohol will have an R_T value of 15 minutes.
C The area under each curve represents the amount of alcohol.
D The gas used as the mobile phase in this process is most likely to be helium.



Item 14
According to Le Chatelier's principle, when disrupted by a change at constant temperature, an equilibrium system

A Will restore original conditions.
B Will not reach equilibrium again.
C Will reach a new equilibrium but with a different value for the equilibrium constant, K.
D Will reach a new equilibrium with the same value for the equilibrium constant, K.

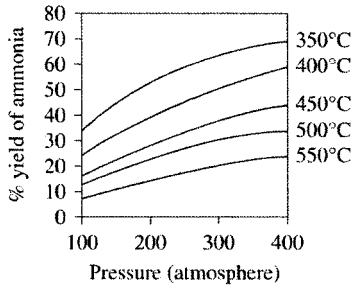
Item 15

Ammonia is produced on a large scale using the Haber Process.

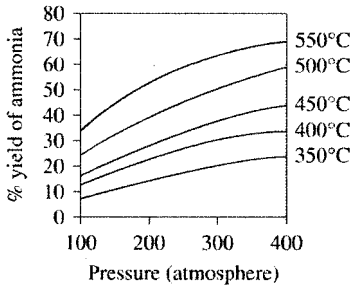
$$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)} \quad \Delta H = -108\ kJ / mol$$

Which of the following graphs best describes how pressure and temperature affect the yield of ammonia produced?

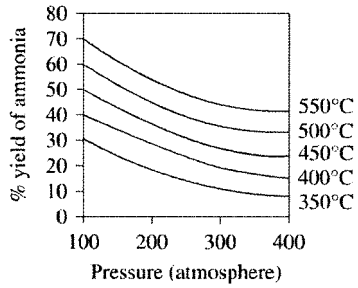
A



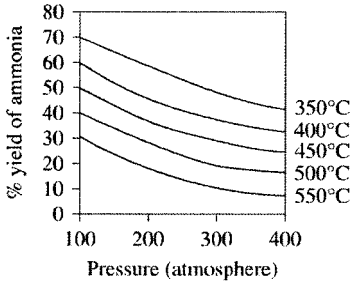
B



C



D



Item 16

The equilibrium constants for the reaction of $1\,M\ \ HCl$ and $1\,M\ \ CH_3COOH$ as equal volumes of acid are slowly added to $20.00\ ml$ of water are given below.

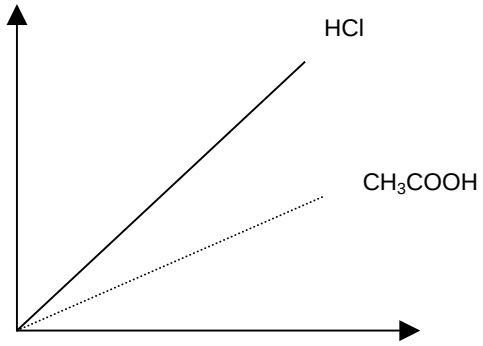
$1\,M\ \ HCl \qquad K = 3\times10^{10}$

$1\,M\ \ CH_3COOH \qquad K = 2\times10^{-2}$

Which of the following graphs best describes the changes in electrical conductivity for each of the above reactions?

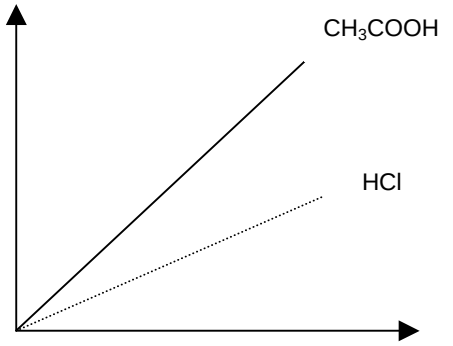
A

Conductivity



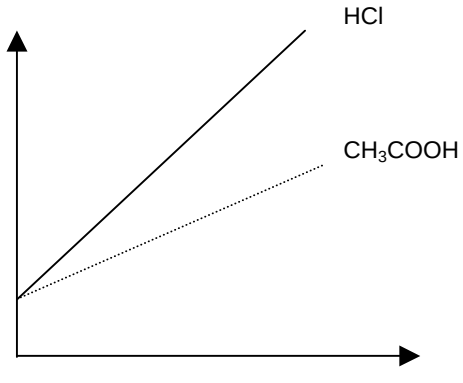
B

Conductivity



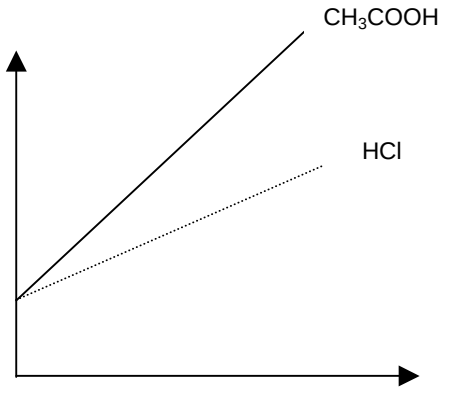
C

Conductivity



D

Conductivity



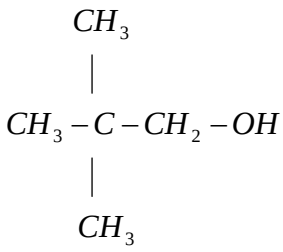
Item 17
The organic compound with the highest boiling point is

A Propane
B Propanoic acid
C Propene
D Propanol

Item 18
The organic compound in with the lowest solubility in water is

A Methanoic acid
B Ethanoic acid
C Propanoic acid
D Butanoic acid

Item 19
The structural formula of a compound is



The systematic name of this compound is:

A 2,2-dimethyl-1-propanol
B 2,2-dimethyl-1-propanoic acid
C 2,2-dimethyl-3-propanol
D 2,2-dimethyl-3-propanoic acid

Item 20
2-methyl-2-butanol is an isomer of:

A 2-butanol
B pentanoic acid
C 1-pentanol
D 2,3-dimethyl-2-butanol

SECTION B

Specific Instructions For Section B

Section B consists of six short-answer questions numbered 1 to 6; you must answer all of these questions. This section is worth 70 marks which is approximately 78 per cent of the total available marks You should spend approximately 70 minutes on this section.

The marks allotted to each question are shown at the end of each question.

Questions must be answered in the spaces provided in this book.

To obtain full marks for your responses you should

- Give simplified answers with an appropriate number of significant figures for 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 that all chemical equations are balanced and that the formulas for individual substances include an indication of state (for example, $H_{2(g)}$; $NaCl_{(s)}$).

QUESTION 1
The equation describing the production of butyl ethanoate is given below.

$$C_4H_9OH_{(aq)} + CH_3COOH_{(aq)} \overset{\text{Catalyst}}{\rightleftharpoons} CH_3COOC_4H_{9(aq)} + H_2O_{(l)}$$

$0.0500\ mol$ of ethanoic acid and $0.0500\ mol$ of butanol were allowed to reach equilibrium at 90^0C for 2 hours, and then quickly cooled in an ice bath to 25^0C. The reaction was carried out at a constant volume of $1.00\ dm^3$.

$50.00\ cm^3$ of $1.00\ M\ \ NaOH$ was added to the mixture, and was then titrated with $1.00\ M$ hydrochloric acid using phenolphthalein as the indicator.
$33.30\ cm^3$ of acid was required for this reaction.

$$CH_3COOH_{(aq)} + NaOH_{(aq)} \rightarrow CH_3COONa_{(aq)} + H_2O_{(l)}$$

$$NaOH_{(aq)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$$

a. (i) Calculate the amount, in mol, of $NaOH$ that reacted with the $1.00\ M$ hydrochloric acid solution.

_____

_____

1 mark

(ii) Calculate the amount, in mol, of CH_3COOH that reacted with the $1.00\ M\ \ NaOH$ solution.

_____

_____

_____

_____

2 marks

(iii) Calculate the amount, in mol, of butanol, C_4H_9OH , that reacted in the initial mixture.

_____

_____

_____

_____

2 marks

(iv) Hence calculate the amount, in mol, of each species at equilibrium at $25^0 C$.

2 marks

b. (i) Write an expression for the equilibrium constant for this reaction.

1 mark

(ii) Hence determine the equilibrium constant at $25^0 C$.

1 mark

c. The table below describes some features relating to the organic molecules involved in the production of butyl ethanoate.

$$C_4H_9OH_{(aq)} + CH_3COOH_{(aq)} \overset{\text{Catalyst}}{\rightleftharpoons} CH_3COOC_4H_{9(aq)} + H_2O_{(l)}$$

	Molar Mass (g/mol)	Boiling Point (^oC)
Ethanoic Acid	60.1	118.0
Butanol	74.1	117.3
Butyl ethanoate	116	126

(i) Explain how heating the equilibrium mixture to $110^o C$ will improve the yield of ester.

2 marks

(ii) What catalyst is typically used in the production of esters and why?

_____

_____

1 mark

(ii) The reactants used to make small chain esters are highly soluble in aqueous solutions, but the esters themselves are not. Explain.

_____

_____

_____

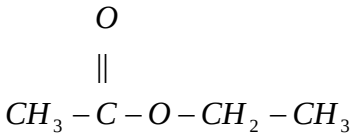
_____

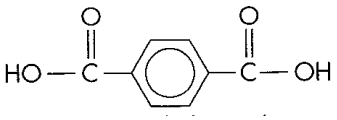
_____

_____

2 marks

d. Esters may be linked to produce long chains known as polyesters. Could the molecules below be used to produce a polyester? Explain your answer.





_____

_____

_____

_____

2 marks

Total 16 marks

QUESTION 2

The equilibrium constant for the dissociation of a weak acid is described by the acidity constant, K_a. The equilibrium constant for the dissociation of a weak base is described in the same way using the term K_b.

a. Calculate the hydroxide ion concentration that arises when $0.100\ M$ ammonia reacts with water, given that K_b for ammonia is $1.79 \times 10^{-5}\ M$ at 25^oC.

3 marks

b. Calculate the pH of a solution containing $0.100\ M$ of NH_3 at 25^oC.

2 marks

c. Which species, ammonia or $OH^-_{(aq)}$ is the stronger base?
Give one reason for your answer.

2 marks

Total 7 marks

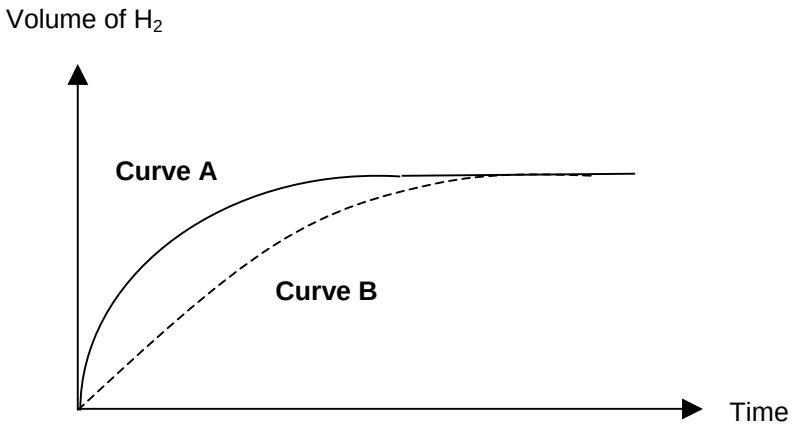
QUESTION 3

$5\ cm$ of magnesium ribbon was added to $20\ ml$ of $1.00\ M$ hydrochloric acid in a closed system and the volume of hydrogen gas evolved at 10 second intervals was recorded.

$$Mg_{(s)} + 2HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$$

The experiment was then repeated using a fresh $5\ cm$ of magnesium ribbon, using $20\ ml$ of $2.00\ M$ hydrochloric acid.

The following graphs were obtained.



a. (i) Which curve, A or B, best describes the reaction occurring in $2.00\ M$ hydrochloric acid?

_____

_____

1 mark

(ii) Give one reason why the two reactions produce the same volume of hydrogen.

_____

_____

_____

1 mark

b. $10\ cm$ of magnesium ribbon was added separately to $20\ ml$ of $1.00\ M$ and $2.00\ M$ hydrochloric acid in a closed system.

It was observed that in both cases, the initial rate of H_2 evolution was increased as compared to when just $5\ cm$ of magnesium ribbon was used. Explain why the greater mass of magnesium increased the reaction rate.

_____

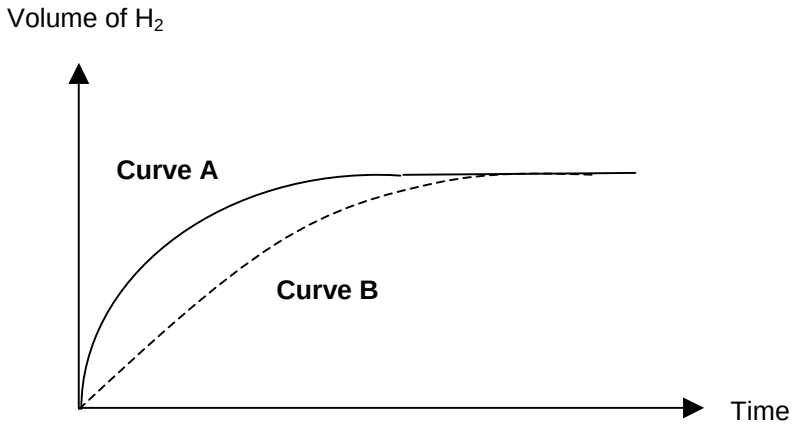
_____

_____

1 mark

c. $5\ cm$ of magnesium ribbon was added separately to $20\ ml$ and $40\ ml$ of $1.00\ M$ hydrochloric acid at constant temperature in a closed vessel.

The following graphs were obtained.



Which curve, A or B, best describes the reaction occurring in the greater volume of hydrochloric acid? Give a reason for your answer.

_____

_____

_____

_____

_____

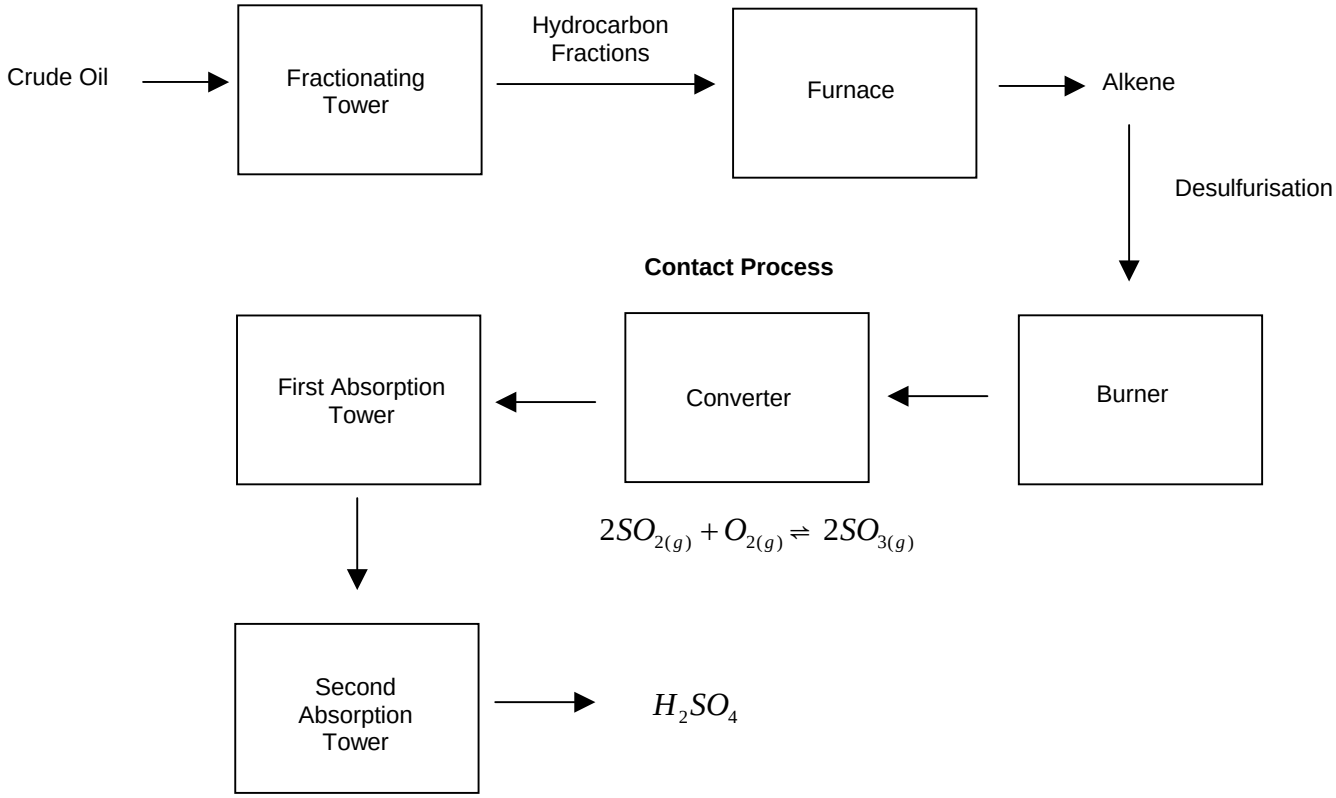
_____

2 marks

Total 5 marks

QUESTION 4

Industries often exist as integrated complexes, being located within close proximity of one another. An schematic of an integrated industry is illustrated below.



One advantage of integrated industries lies in the fact that the by products of one industry can be used as a raw material for another industry; reducing wastage, environmental pollution and costs.

One example involves the desulfurisation process employed in petrochemical industries. The sulfur that is removed during the desulfurisation process is used as a raw material for the production of chemicals such as sulfuric acid.

a. State one reason why desulfurisation is carried out before fractions are sent to a refinery.

_____

_____

_____

1 mark

b. (i) Briefly explain how hydrocarbons are separated in the fractionating tower.

_____

_____

_____

_____

_____

_____

2 marks

(ii) What process occurs in the Furnace?

_____

_____

1 mark

(iii) Why does this process result in the production of unsaturated hydrocarbons such as ethene?

_____

_____

1 mark

c. (i) Give the name and molecular formula of the catalyst used in the converter.

_____

_____

1 mark

(ii) Give the equation describing the process that occurs in the absorption towers.

_____

_____

1 mark

(iii) Why is $SO_{3(g)}$ passed through two absorption towers?

_____

_____

_____

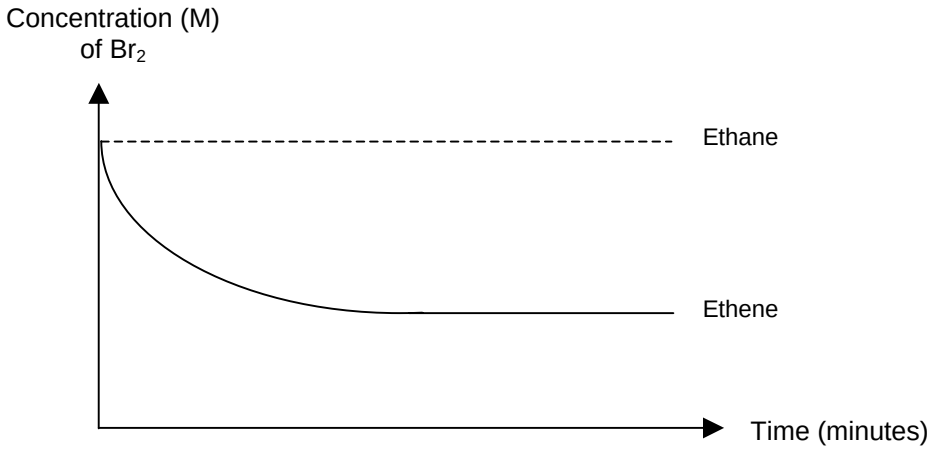
1 mark

Total 8 marks

QUESTION 5

Br_2 is added to a sample of ethene, and separately, to a sample of ethane.

The variation in $Br_{2(aq)}$ concentration was monitored using colorimetry, and the following graph was obtained.



a. (i) Explain why the concentration of bromine decreases when it is reacted with ethene. In your answer, give an equation to describe the reaction occurring.

_____

_____

_____

_____

_____

_____

2 marks

(ii) What needs to be added/introduced to the reaction mixture involving ethane before the concentration of bromine is observed to decrease.

_____

_____

1 mark

b. Explain why alkanes and their corresponding alkenes have similar physical properties, but very different chemical properties.

_____

_____

_____

_____

2 marks

c. (i) Write equations using structural formulae to illustrate the production of propanoic acid from propene. In your answer, give the name of any catalysts used in the process.

3 marks

(ii) Ethene reacts in the presence of acidified $MnO^{-}_{4(aq)}$ to produce $C_2H_4(OH)_{2(l)}$ and $Mn^{2+}_{(aq)}$. Write the equation describing this reaction.

3 marks

Total 11 marks

QUESTION 6
The oxidation of sulfur dioxide to sulfur trioxide is an equilibrium process described by the equation:

$$2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}, \quad \Delta H = -198\ kJ / mol\ .$$

a. (i) The pressure in the $SO_{2(g)} / SO_{3(g)}$ equilibrium mixture is increased by halving the volume of the vessel keeping temperature constant. The mass of SO_2 in the new equilibrium mixture will be

Higher than Lower than Equal to

the mass of SO_2 in the initial equilibrium mixture. Circle the correct response from the options above.

1 mark

(ii) O_2 is added to the $SO_{2(g)} / SO_{3(g)}$ equilibrium mixture at constant temperature and volume. The mass of SO_2 in the new equilibrium mixture will be

Higher than Lower than Equal to

the mass of SO_2 in the initial equilibrium mixture. Circle the correct response from the options above.

1 mark

(iii) How does the addition of oxygen change the extent of the reaction?

_____

_____

_____

1 mark

b. (i) Oxygen is added to the equilibrium system at constant volume. As a result, the temperature of the reaction vessel should

Rise Fall Remain constant

1 mark

(i) SO_3 is removed from the equilibrium system at constant temperature and volume. As the system re-establishes equilibrium, the rate of the forward reaction will

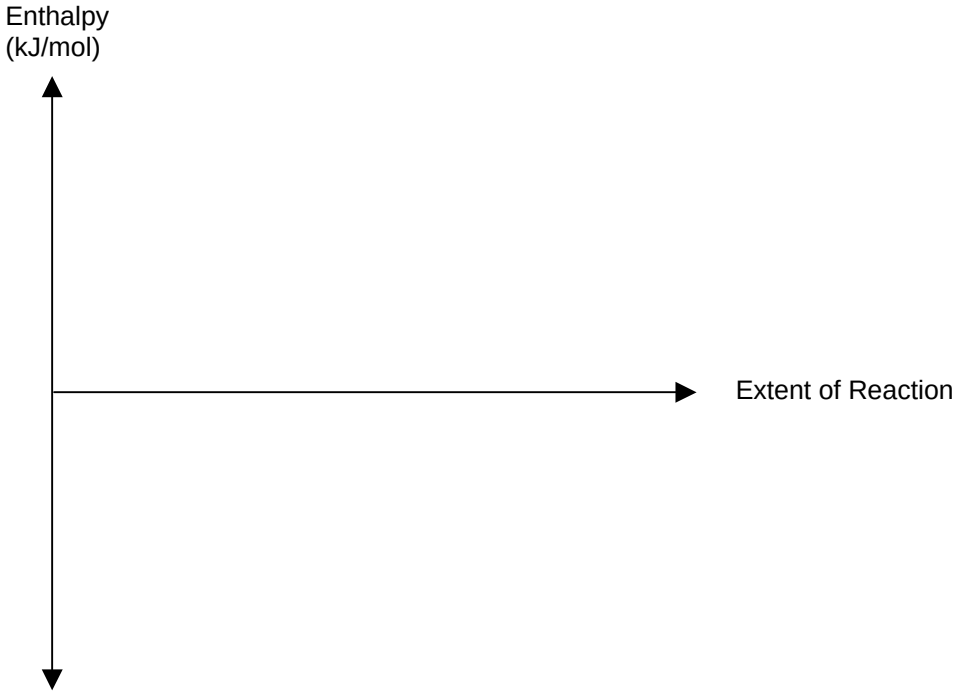
Increase Decrease Remain the same

1 mark

c. (i) Draw a potential energy diagram for the reaction

$2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}, \quad \Delta H = -198\ kJ/mol$

given that the activation energy requirement is $250\,kJ/mol$ and taking the enthalpy of the reactants as zero.



3 marks

(ii) Calculate the activation energy for the reverse reaction.

_____

_____

_____

1 mark

(iii) Determine the enthalpy change for the reaction involving 1 mole of sulphur dioxide.

_____

_____

_____

1 mark

Total 10 marks

QUESTION 7

A brand of canned peaches claims that a $100.00\ g$ serving contains $5.00\ mg$ of sodium. Atomic Absorption Spectroscopy (AAS) was used to test this claim.

A $50.00\ g$ sample of the peaches was treated with acids and other solvents in order to extract all of the sodium from the fruit. The resultant mixture was filtered producing $25.00\ ml$ of filtrate. A $10\ ml$ sample of this solution was diluted to $100.00\ ml$ for analysis.

The absorption of the diluted peach solution and of several standard solutions were measured under identical conditions. The results are shown in the table below.

Sodium Concentration (ppm)	Absorbance Reading
0	0.000
5	0.160
10	0.360
15	0.500
20	0.660
Test Sample	0.420

a. (i) Apart from the cathode lamp, state the names of two (2) important component "parts" found within an atomic absorption spectrophotometer.

_____

_____

1 mark

(ii) Briefly describe the function of one of these components in **i.** above.

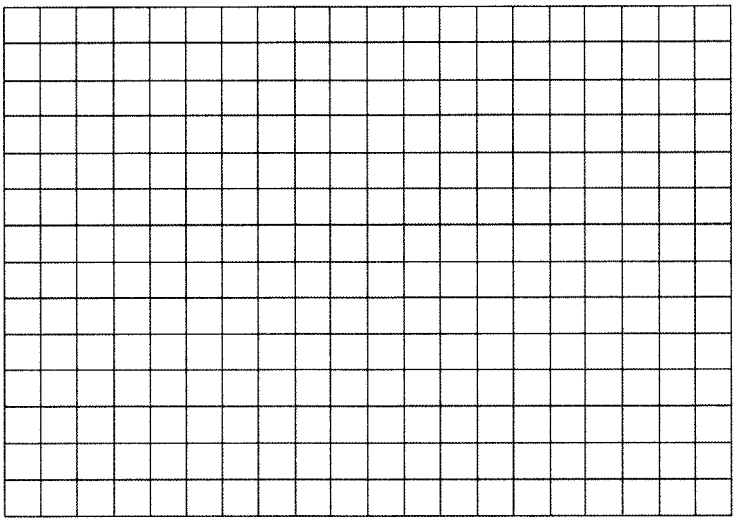
_____

_____

_____

1 mark

b. (i) Use the given data to sketch a calibration curve.



2 marks

(ii) Calculate the concentration of sodium in the undiluted sample in ppm.

_____

_____

1 mark

c. (i) By what percentage does the calculated concentration in $mg/100\ g$ of sodium differ from the stated claim?

_____

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3 marks

(ii) If the sodium in peaches is present as $NaCl$, calculate the mass of $NaCl$ per $100.00\ g$ of peach.

3 marks

d. The concentration of lead in peaches may also be determined by atomic absorption spectroscopy. After the peach solution has been tested for sodium, some changes need to be made to test for lead.

(i) State one change that would need to be made to the set up of the atomic absorption spectrometer.

1 mark

(ii) State one change that would need to be made to the calibration of the atomic absorption spectrometer.

1 mark

Total 13 marks

END OF PAPER