Catholic Junior College

JC 2 Preliminary Examinations

Higher 1

CHEMISTRY

8872/01

Paper 1 Multiple Choice

Tuesday 29 August 2017

50 minutes

Additional Materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, HT group and NRIC/FIN number on the Answer Sheet in the spaces provided.
Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of **10** printed pages

[Turn over

Section A

For each question there are four possible answers, **A**, **B**, **C** and **D**. Choose the **one** you consider to be correct.

1 A giant molecule contains a large amount of carbon; mainly of isotopes ^{12}C and ^{13}C. It was found that the relative atomic mass of carbon in the molecule is 12.2.
What is the ratio of ^{12}C to ^{13}C?

A 4:1 **B** 3:1 **C** 3:4 **D** 1:4

2 10 cm^3 of a pure hydrocarbon **X** was completely burnt in 80 cm^3 of excess oxygen to give carbon dioxide gas and water vapour. After cooling to room temperature, the volume of gaseous mixture decreased from 105 cm^3 to 55 cm^3. A further reduction of 40 cm^3 was observed when the residual gas was passed through aqueous sodium hydroxide.
All gas volumes were measured at the same temperature and pressure.
What is the formula of **X**?

A C_2H_6 **B** C_3H_8 **C** C_4H_{10} **D** C_5H_{12}

3 A plasma is a gaseous mixture in which atoms have been completely stripped of their electrons, leaving bare nuclei. When passed through an electric field, the ^1H nucleus is deflected at an angle of $+4^o$. What will be the angle of deflection for the ^3H nucleus in the same plasma?

A $+0.75^o$ **B** $+1.3^o$ **C** $+4^o$ **D** $+12^o$

4 *Use of the Data Booklet is relevant to this question.*
What do the ions $^{23}Na^+$ and $^{24}Mg^{2+}$ have in common?

A Both ions have more electrons than neutrons.
B Both ions have 12 neutrons in their nuclei.
C Both ions contain the same number of nucleons in their nuclei.
D Both ions have an outer electronic configuration of $3s^2\,3p^6$.

5 *Use of the Data Booklet is relevant to this question.*

Which of the following particles would, on losing an electron, have a half-filled set of p orbitals?

A C^- **B** N **C** N^- **D** O^+

6 The first seven successive ionisation energies (in kJ mol^{-1}) of an element **J** are given below:

1020 1950 2730 4580 6020 12300 15400

Which of the following statements about **J** is correct?

A It has a valence shell electronic configuration of $ns^2\ np^4$

B Its atomic radius is larger than its ionic radius.

C It has a lower second ionisation energy than that of its preceding element.

D It can form a chloride that has a trigonal pyramidal shape.

7 In which of the following pairs of compounds is the bond angle in particle **I** greater than that in particle **II**?

	I	**II**
A	PH_3	BH_3
B	NO_3^-	ClO_2^-
C	SF_6	I_3^-
D	ClF_3	$BeCl_2$

8 Which one of the following statements about aluminium chloride is correct?

A $AlCl_3$ is pyramidal.

B $AlCl_3$ has a higher melting point than Al_2O_3.

C The Al_2Cl_6 dimer contains hydrogen bonding.

D The $AlCl_3$ is known as a halogen carrier in the chlorination of benzene.

9 Which of the following processes is endothermic?

A $H_2O(l) \rightarrow H^+(aq) + OH^-(aq)$

B $SO_2(g) + ½O_2(g) \rightarrow SO_3(g)$

C $2KOH(aq) + H_2SO_4(aq) \rightarrow K_2SO_4(aq) + 2H_2O(l)$

D $Li^+(g) + Cl^-(g) \rightarrow LiCl(s)$

10 Iron can be obtained by the reduction of its oxide by carbon monoxide:

$$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g) \qquad \Delta H = -27 \text{ kJ mol}^{-1}$$

By using the data (enthalpy change of formation) given in the table, find the enthalpy change of formation of $Fe_2O_3(s)$.

	ΔH_f / kJ mol^{-1}
CO(g)	–111
CO_2(g)	–394

A –310 kJ mol^{-1}

B –411 kJ mol^{-1}

C –822 kJ mol^{-1}

D –849 kJ mol^{-1}

11 Which of the following options is correct for the following equilibrium?

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \qquad \Delta H = -950 \text{ kJ mol}^{-1}$$

	Condition	**Position of equilibrium**	K_c
A	Increase in temperature	Right	Increase
B	Addition of catalyst	Right	No change
C	Addition of HC*l*(g)	No change	No change
D	Decrease in pressure	Right	No change

12 The Haber process is the industrial manufacture of ammonia. The following equilibrium exists at the expected conditions needed for the Haber process:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

Which of the following changes would increase both the proportion of ammonia present at equilibrium and the value of equilibrium constant, K_c?

A adding more finely divided iron

B changing the temperature to 100 ^oC.

C changing the temperature to 600 ^oC.

D setting the total pressure to 400 atm

13 0.100 moles of HC*l* was mixed with 0.300 moles of NaOH and the total volume was 2 dm^3. What is the pH of the resulting solution?

A 13.3 **B** 13.0 **C** 1.0 **D** 0.7

14 For the reaction **L**(aq) + **2M**(aq) → **N**(aq), the rate equation is

$$\text{Rate} = k\,[H^+][\mathbf{M}]^2$$

Which of the following is **false**?

A H^+ is a catalyst in the reaction.

B When the concentration of **L** is halved, the rate remains unchanged.

C The unit for the rate constant is $mol^{-2}\ dm^6\ s^{-1}$.

D If the concentration of **M** is doubled, the rate of the experiment increases by two times.

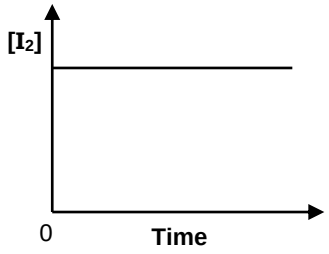
15 Iodine reacts with propanone according to the following equation.

$$I_2 + CH_3COCH_3 \rightarrow CH_3COCH_2I + HI$$

The reaction of iodine with propanone is found to be zero order with respect to iodine.

Which graph correctly shows how the $[I_2]$ changes with time?

A



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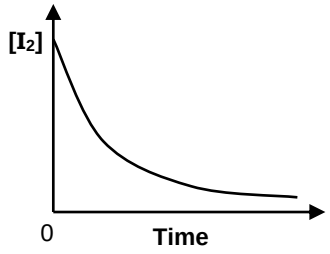

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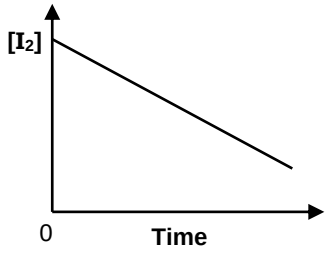

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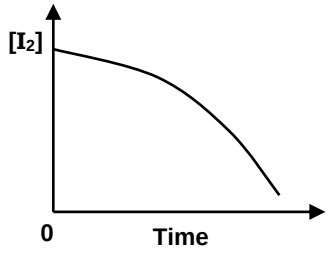


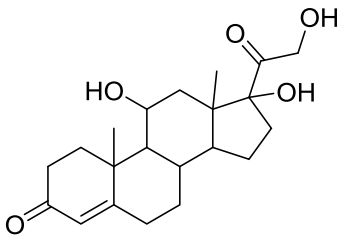
16 An unknown element **X** undergoes radioactive decay to form element **Y**. The radioactive decay is a first-order reaction with a half-life of 47.0 minutes.
How long will it take for the molar proportion of **X** to **Y** to be 1:7?

A 23.5 min **B** 47.0 min **C** 94.0 min **D** 141.0 min

17 The proton number of the element **E** is less than 20.
When the chloride of **E** is dissolved in water, a slightly acidic solution is obtained.
When the oxide of **E** is dissolved in water, an alkaline solution is obtained.
In which Group of the Periodic Table is **E** likely to be found?

A 1 **B** 2 **C** 13 **D** 14

18 Cortisol is a hormone that can increase blood sugar and aids in the metabolism of fat, protein, and carbohydrates.



cortisol

Which of the following will not react with cortisol?

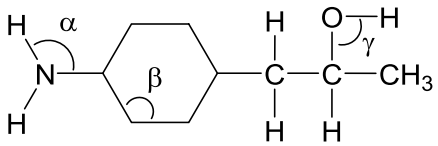
A solid sodium carbonate

B red phosphorus and excess Br_2

C cold, alkaline potassium managate(VII)

D 2,4-dinitrophenylhydrazine

19 What are the angles α, β and γ in the following molecule?



	α	β	γ
A	120	120	90
B	109	109	107
C	107	120	105
D	107	109	105

20 A catalytic converter is part of the exhaust system of many modern cars. Which one of the following reactions occurs in the catalytic converter?

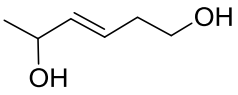
A $2C_xH_y + (4x + y)NO \rightarrow 2xCO_2 + yH_2O + (2x + \frac{y}{2})N_2$

B $2SO_2 + 2NO \rightarrow 2SO_3 + N_2$

C $CO_2 + NO \rightarrow CO + NO_2$

D $2C + O_2 \rightarrow 2CO$

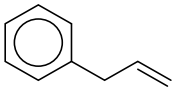
21 Hex-3-en-1,5-diol has the following structure.



How many moles of PCl_5 will react with the products formed from heating 1 mole of hex-3-en-1,5-diol in the presence of acidified potassium manganate(VII)?

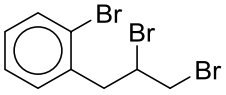
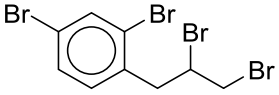
A 1 **B** 2 **C** 3 **D** 4

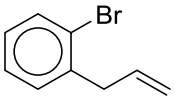
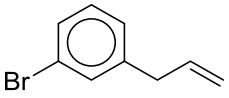
22 Bromine, along with iron(III) bromide, is dissolved in compound **P** and left to stand in the dark.

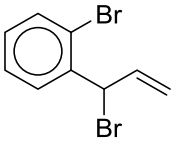
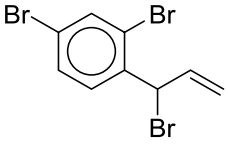


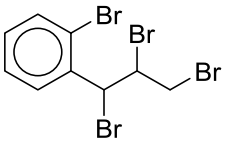
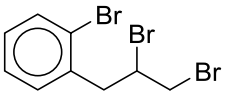
compound **P**

Which of the following pairs is likely to be the major products formed?

A  and 

B  and 

C  and 

D  and 

23 Chlorofluorocarbons (CFCs) have been widely used in aerosol sprays, refrigerators and in making foamed plastics, but are now known to destroy ozone in the upper atmosphere. Which of the following will not destroy ozone, and therefore can be used as a replacement for CFCs?

A $CHBr_2CH_2CH_2CCl_3$

B $CH_3CHFCH_2CH_2F$

C $CH_2ClCH_2CHFCH_3$

D $CHF_2CH_2CH_2CHBr_2$

24 A glass of wine was exposed to air for a period of time. This causes the wine to have a sour taste. A student proposed that a portion of ethanol present in the wine has been oxidised, thus giving rise to the sour taste.

Which of the following reagents can be used to confirm the above hypothesis?

A Na **B** NaOH **C** K_2CO_3 **D** $KMnO_4$

25 Butanoic acid was heated under reflux with a mixture of ethanol and propanol in the presence of concentrated sulfuric acid. Which of the following is a possible product of this reaction?

A ethyl propanoate

B propyl butanoate

C butyl butanoate

D propyl ethanoate

Section B

For each of the questions in this section, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct).

The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

26 Chlorine gas reacts with sodium hydroxide according to the following equation.

$$3Cl_2 + 6OH^- \rightarrow 5Cl^- + ClO_3^- + 3H_2O$$

Which of the following statements is true for this reaction?

1 C*l* is oxidised.

2 C*l* is reduced.

3 Oxidation state of O does not change.

27 Which of the following shows a correct example of a conjugate acid / base pair?

1 CH_3CO_2H, $CH_3CO_2^-Na^+$

2 CH_3NH_2, $CH_3NH_3^+Cl$

3 H_2O, OH^-

28 *Use of the Data Booklet is relevant to this question.*

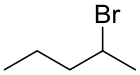
Based on its position in the Periodic Table, which properties will element **X** (atomic number 14) have?

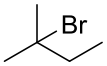
1 Its oxide has a simple molecular structure.

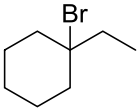
2 Its chloride hydrolyses in water to give an acidic solution.

3 Element **X** has high melting and boiling point.

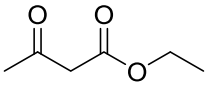
29 An unknown halogen derivative, **Q**, was heated with alcoholic potassium hydroxide. A product that exhibits geometric isomerism is obtained. Which of the following is a possible identity of compound **Q**?

1 

2 

3 

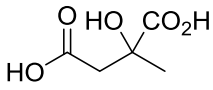
30 Compound **Y** is reacted with aqueous hydrogen cyanide in alkaline condition at 20 °C to produce compound **Z**. Compound **Z** is then heated under reflux with dilute sulfuic acid and the products isolated.

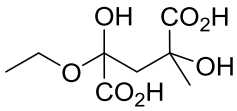


Compound **Y**

Which of the following are the possible products from the above reaction?

1 CH_3CH_2OH

2 

3 

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Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

WORKED SOLUTIONS

Section A

For each question there are four possible answers, **A**, **B**, **C** and **D**. Choose the **one** you consider to be correct.

1 A giant molecule contains a large amount of carbon; mainly of isotopes ^{12}C and ^{13}C. It was found that the relative atomic mass of carbon in the molecule is 12.2.
What is the ratio of ^{12}C to ^{13}C?

A 4:1 **B** 3:1 **C** 3:4 **D** 1:4

Answer: A

Let the percentage of ^{12}C be x.

Hence, the percentage of ^{13}C is $(100 - x)$

$\left(\frac{x}{100} \times 12\right) + \left(\frac{100-x}{100} \times 13\right) = 12.2$

x = 80%

Hence, ^{12}C to ^{13}C is 80:20 which is 4:1

2 10 cm^3 of a pure hydrocarbon **X** was completely burnt in 80 cm^3 of excess oxygen to give carbon dioxide gas and water vapour. After cooling to room temperature, the volume of gaseous mixture decreased from 105 cm^3 to 55 cm^3. A further reduction of 40 cm^3 was observed when the residual gas was passed through aqueous sodium hydroxide.
All gas volumes were measured at the same temperature and pressure.
What is the formula of **X**?

A C_2H_6 **B** C_3H_8 **C** C_4H_{10} **D** C_5H_{12}

Answer: C

$$C_xH_y(g) + (x + \tfrac{y}{4})O_2(g) \rightarrow xCO_2(g) + \tfrac{y}{2}H_2O(l)$$

Initial (cm^3)	10	80	0	0
Final (cm^3)	0	55-40 = 15	40	105-55 = 50 cm^3 after cooling
Vol used (cm^3)	10	80-15=65	40	50
Ratio	1	6.5	4	5

By inspection, x = 4.

$\therefore \frac{y}{2} = 5 \quad \therefore y = 10$

$\therefore$ molecular formula of the hydrocarbon is C_4H_{10}.

3 A plasma is a gaseous mixture in which atoms have been completely stripped of their electrons, leaving bare nuclei. When passed through an electric field, the ^{1}H nucleus is deflected at an angle of $+4^{o}$. What will be the angle of deflection for the ^{3}H nucleus in the same plasma?

A $+0.75^{o}$ **B** $+1.3^{o}$ **C** $+4^{o}$ **D** $+12^{o}$

Answer: B

angle of deflection = $k\left(\frac{\text{charge}}{\text{mass}}\right)$

For the ^{1}H nucleus, $4 = k\left(\frac{+1}{1}\right)$. Hence k is 4.

For the ^{3}H nucleus, angle = $4\left(\frac{+1}{3}\right) = 1.3^{o}$.

4 *Use of the Data Booklet is relevant to this question.*
What do the ions $^{23}Na^{+}$ and $^{24}Mg^{2+}$ have in common?

A Both ions have more electrons than neutrons.
B Both ions have 12 neutrons in their nuclei.
C Both ions contain the same number of nucleons in their nuclei.
D Both ions have an outer electronic configuration of $3s^2\,3p^6$.

Answer: B

	$^{23}Na^{+}$	$^{24}Mg^{2+}$
No. of protons	11	12
No. of electrons	11 – 1 = 10	12 – 2 = 10
No. of neutrons	23 – 11 = 12	24 – 12 = 12
No. of nucleons (protons + neutrons)	23	24
Electronic Configuration	$1s^2\ 2s^2 2p^6$	$1s^2\ 2s^2 2p^6$

5 *Use of the Data Booklet is relevant to this question.*

Which of the following particles would, on losing an electron, have a half-filled set of p orbitals?

A C^- **B** N **C** N^- **D** O^+

Answer: C

	Full electronic configuration of species	Full electronic configuration after losing an electron
C^-	$1s^2\ 2s^2 2p_x^1 2p_y^1 2p_z^1$ (already has half filled set of p orbitals)	$1s^2\ 2s^2 2p_x^1 2p_y^1 2p_z^0$
N	$1s^2\ 2s^2 2p_x^1 2p_y^1 2p_z^1$ (already has half filled set of p orbitals)	$1s^2\ 2s^2 2p_x^1 2p_y^1 2p_z^0$
N^-	$1s^2\ 2s^2 2p_x^2 2p_y^1 2p_z^1$	$1s^2\ 2s^2\ \mathbf{2p_x^1 2p_y^1 2p_z^1}$ (has half filled set of p orbitals)
O^+	$1s^2\ 2s^2 2p_x^1 2p_y^1 2p_z^1$ (already has half filled set of p orbitals)	$1s^2\ 2s^2 2p_x^1 2p_y^1 2p_z^0$

6 The first seven successive ionisation energies (in kJ mol^{-1}) of an element **J** are given below:

1020 1950 2730 4580 6020 12300 15400

Which of the following statements about **J** is correct?

A It has a valence shell electronic configuration of $ns^2\ np^4$

B Its atomic radius is larger than its ionic radius.

C It has a lower second ionisation energy than that of its preceding element.

D It can form a chloride that has a trigonal pyramidal shape.

Answer: D

Most significant increase in IE is between 6020 and 12300 (5^{th} and 6^{th} IE). Hence element **J** is from Group 15 with 5 valence electrons.

A Incorrect. The valence shell configuration is **ns^2np^3.** (5 valence electrons)

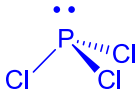
B Incorrect. It is likely to gain 3 electrons to form $\mathbf{J^{3-}}$ anion and hence the atomic radius is expected to be smaller than the anionic radius.

C Electronic configuration of $\mathbf{J^+}$(g): **ns^2np^2**

Electronic configuration of the singly charged preceding element: **ns^2np^1**

Element **J** is NOT expected to have a lower second ionisation energy than that of its preceding element.

D Correct. With 5 valence electrons, **J** is likely to form a chloride with 3 bond pairs and 1 lone pair (for central atom **J** to achieve octet). Hence **J** can form a chloride that has as trigonal pyramidal shape. Eg: phosphorus is a group 15 element:



7 In which of the following pairs of compounds is the bond angle in particle **I** greater than that in particle **II**?

	I	II
A	PH_3	BH_3
B	NO_3^-	ClO_2^-
C	SF_6	I_3^-
D	ClF_3	$BeCl_2$

Answer: B

This qns can be done by counting the number of bond pairs and lone pair of electrons.

	I	Bp and lp	Shape and angle	II	Bp and lp	Shape and angle
A	PH_3	3 bp 1 lp	Trigonal pyramidal < 109º	BH_3	3 bp 0 lp	Trigonal planar 120º
B	NO_3^-	3 bp 0 lp	Trigonal planar 120º	ClO_2^-	2 bp 2 lp	Bent < 109º
C	SF_6	6 bp 0 lp	Octahedral 90º	I_3^-	2 bp 3 lp	Linear 180º
D	ClF_3	3 bp 2 lp	T shaped < 90º	$BeCl_2$	2 bp 0 lp	Linear 180º

8 Which one of the following statements about aluminium chloride is correct?

A $AlCl_3$ is pyramidal.

B $AlCl_3$ has a higher melting point than Al_2O_3.

C The Al_2Cl_6 dimer contains hydrogen bonding.

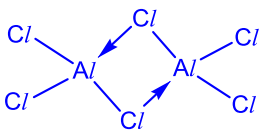
D The $AlCl_3$ is known as a halogen carrier in the chlorination of benzene.

Answer: D

A $AlCl_3$ has 3 bond pairs and no lone pairs. It is trigonal planar in shape.

B $AlCl_3$ is simple molecular and hence will have a lower melting point than Al_2O_3 which is giant ionic.

C The Al_2Cl_6 dimer **<u>contains</u>** two co-ordinate bonds, not hydrogen bonds.



D The $AlCl_3$ catalyst is also known as a halogen carrier in the chlorination of benzene.

9 Which of the following processes is endothermic?

A $H_2O(l) \rightarrow H^+(aq) + OH^-(aq)$

B $SO_2(g) + ½O_2(g) \rightarrow SO_3(g)$

C $2KOH(aq) + H_2SO_4(aq) \rightarrow K_2SO_4(aq) + 2H_2O(l)$

D $Li^+(g) + Cl^-(g) \rightarrow LiCl(s)$

Answer: A

A This shows bond breaking / dissociation which is endothermic.

B SO_2 undergoes combustion and combustion reactions are exothermic.

C Neutralisation reaction is exothermic as the ionic eqution is $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$. Bond formation (to form the molecule from the ions) is exothermic.

D Electrostatic forces of attraction between oppositely charged ions result in the formation of ionic bonds. Bond formation is exothermic. Also, the equation represent lattice energy of LiCl where 1 mol of ionic solid LiCl is formed from its separate gaseous ions.

10 Iron can be obtained by the reduction of its oxide by carbon monoxide:

$$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g) \qquad \Delta H = -27 \text{ kJ mol}^{-1}$$

By using the data (enthalpy change of formation) given in the table, find the enthalpy change of formation of $Fe_2O_3(s)$.

	ΔH_f / kJ mol^{-1}
CO(g)	–111
CO_2(g)	–394

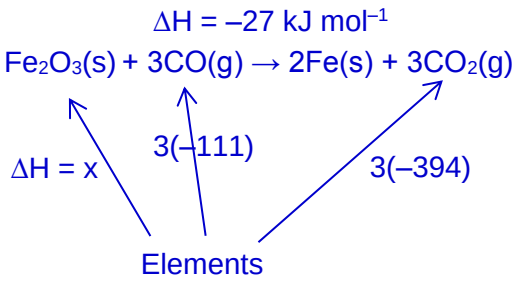
A –310 kJ mol^{-1}

B –411 kJ mol^{-1}

C –822 kJ mol^{-1}

D –849 kJ mol^{-1}

Answer: C



Using Hess' Law,

$x + 3(-111) + (-27) = 3(-394)$

$x = -822$ kJ mol^{-1}

11 Which of the following options is correct for the following equilibrium?

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \qquad \Delta H = -950 \text{ kJ mol}^{-1}$$

	Condition	Position of equilibrium	K_c
A	Increase in temperature	Right	Increase
B	Addition of catalyst	Right	No change
C	Addition of HC*l*(g)	No change	No change
D	Decrease in pressure	Right	No change

Answer: D

	Condition	Position of equilibrium	K_c
A	Increase in temperature	Right (False) Position of eqm will shift to favour the endothermic side which is the left hand side.	Increase (False) K_c should decrease.
B	Addition of catalyst	Right (False) No change in position of equilibrium	No change (True) K_c is independent of catalyst.
C	Addition of HCl (g)	Right (False) Basic NH_3 gas reacts with HCl gas to form a white solid of NH_4Cl. Hence, some $NH_3(g)$ is removed from the equilibrium mixture and the position of equilibrium shifts left.	No change (True)
D	Decrease in pressure	Right (True) Position of eqm will shift to favour the side with greater no. of moles of gaseous molecules which is the right hand side.	No change (True)

12 The Haber process is the industrial manufacture of ammonia. The following equilibrium exists at the expected conditions needed for the Haber process:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

Which of the following changes would increase both the proportion of ammonia present at equilibrium and the value of equilibrium constant, K_c?

A adding more finely divided iron

B changing the temperature to 100 ^oC.

C changing the temperature to 600 ^oC.

D setting the total pressure to 400 atm

Answer: B

As this reaction is in the syllabus, students are expected to know that the reaction is exothermic.

Typical conditions used in the Haber process are

- a pressure of 200-300 atm.
- a moderate temperature of *about* 450 - 500 ^{o}C.
- Iron *catalyst* (finely-divided)

	Change	Proportion of ammonia present	K_c
A	adding more finely divided iron	Not affected	Not affected
B	changing the temperature to 100 ^{o}C	The drop in temperature would favour the forward exothermic reaction and hence increase the proportion of ammonia	Increases
C	changing the temperature to 600 ^{o}C.	The increase in temperature would favour the backward endothermic reaction and hence decrease the proportion of ammonia	Decreases
D	setting the total pressure to 400 atm	The increase in pressure would favour the formation of newer number of moles of gas (forward reaction) and hence increase the proportion of ammonia.	Not affected

13 0.100 moles of HC*l* was mixed with 0.300 moles of NaOH and the total volume was 2 dm^3. What is the pH of the resulting solution?

A 13.3 **B** 13.0 **C** 1.0 **D** 0.7

Answer: B

HC*l* + NaOH → NaC*l* + H2O

Since HC*l* ≡ NaOH, NaOH is present in excess by 0.300 – 0.100 = 0.200 moles.

NaOH → $Na^+ + OH^-$

$[OH^-] = \frac{0.200}{2} = 0.100$ mol dm^{-3}

pOH = -lg(0.100) = 1.0

pH = 14 – pOH (at 25 ^{o}C) = 13.0

14 For the reaction **L**(aq) + **2M**(aq) → **N**(aq), the rate equation is

$$\text{Rate} = k\,[H^+][\mathbf{M}]^2$$

Which of the following is **false**?

A H^+ is a catalyst in the reaction.

B When the concentration of **L** is halved, the rate remains unchanged.

C The unit for the rate constant is mol^{-2} dm^6 s^{-1}.

D If the concentration of **M** is doubled, the rate of the experiment increases by two times.

Answer: D

A True. It is not a reagent as seen in the overall reaction, but it affects the rate.

B True. Reaction is zero order wrt [**L**] as [**L**] is not involved in the rate equation. Hence, any change in [**L**] will not affect the rate.

C True.

$$\text{Rate} = k\,[H^+][\mathbf{M}]^2$$

$$\text{mol dm}^{-3}\ \text{s}^{-1} \qquad \text{mol dm}^{-3} \qquad (\text{mol dm}^{-3})^2$$

Hence units of k has to be $\text{mol}^{-2}\ \text{dm}^6\ \text{s}^{-1}$ in order for the units on the left and the right of the equal sign to be the same.

D False. Reaction is second order wrt [**M**]. So when [**M**] is doubled, the rate of the reaction should increase by 4 times.

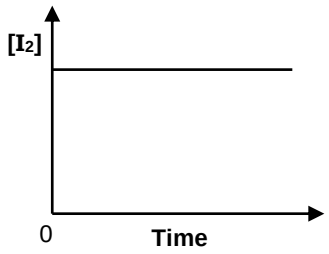
15 Iodine reacts with propanone according to the following equation.

$$I_2 + CH_3COCH_3 \rightarrow CH_3COCH_2I + HI$$

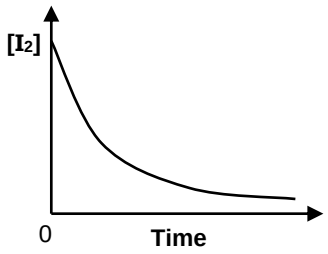
The reaction of iodine with propanone is found to be zero order with respect to iodine.

Which graph correctly shows how the $[I_2]$ changes with time?

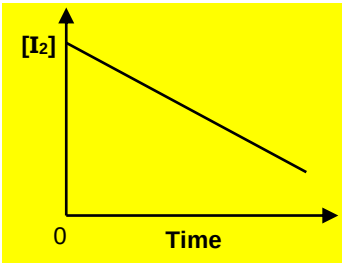
A



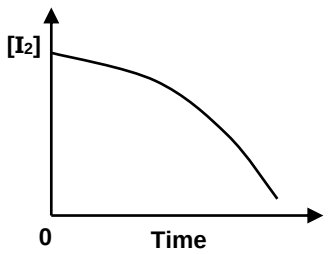
C



B



D



Answer: B

Zero order with respect to iodine means that the rate of the reaction (gradient in the $[I_2]$ – time graph) is constant.

Incorrect answers:

A Gradient is zero. It means that rate of reaction is zero.

C Gradient (rate) is decreasing as [I_2] decreases.

D Gradient (rate) is increasing as [I_2] decreases.

16 An unknown element **X** undergoes radioactive decay to form element **Y**. The radioactive decay is a first-order reaction with a half-life of 47.0 minutes.
How long will it take for the molar proportion of **X** to **Y** to be 1:7?

A 23.5 min **B** 47.0 min **C** 94.0 min **D** 141.0 min

Answer: D

Let a be the initial amt of X

X: $a \longrightarrow \frac{1}{2}a \longrightarrow \frac{1}{4}a \longrightarrow \frac{1}{8}a$

Y: $0 \longrightarrow \frac{1}{2}a \longrightarrow \frac{3}{4}a \longrightarrow \frac{7}{8}a$

Thus, 3 half-lives have passed. Time taken = 47 × 3 = 141 min

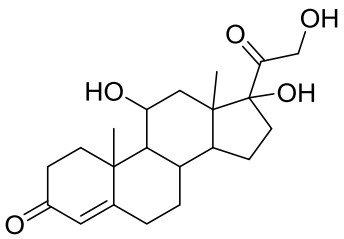
17 The proton number of the element **E** is less than 20.
When the chloride of **E** is dissolved in water, a slightly acidic solution is obtained.
When the oxide of **E** is dissolved in water, an alkaline solution is obtained.
In which Group of the Periodic Table is **E** likely to be found?

A 1 **B** 2 **C** 13 **D** 14

Answer: B

Chlorides that dissolve to give acidic solution → $MgCl_2$, $AlCl_3$, $SiCl_4$, PCl_5
Oxides that dissolves to give alkaline solution → Na_2O MgO
Thus the element E is most likely Mg, a Group 2 element.

18 Cortisol is a hormone that can increase blood sugar and aids in the metabolism of fat, protein, and carbohydrates.



cortisol

Which of the following will not react with cortisol?

A solid sodium carbonate

B red phosphorus and excess Br_2

C cold, alkaline potassium managate(VII)

D 2,4-dinitrophenylhydrazine

Answer: A

Cortisol contains alcoholic –OH groups, ketone functional groups and an alkene functional group. It does not have a carboxylic acid functional group. Thus,

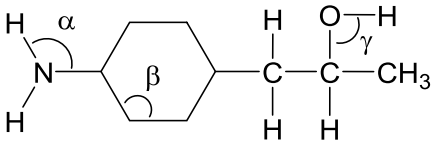
A no reaction

B PBr_3 formed will react with –OH groups

C mild oxidation of alkene functional group to form diol

D condensation reaction with ketone to form orange crystals

19 What are the angles α, β and γ in the following molecule?



	α	β	γ
A	120	120	90
B	109	109	107
C	107	120	105
D	107	109	105

Answer: D

α: There are 3 bond pairs, 1 lone pair around N central atom $\rightarrow$ 107°
β: There are 4 bond pairs, no lone pair around C central atom $\rightarrow$ 109°
γ: There are 2 bond pairs, 2 lone pair around O central atom $\rightarrow$ 105°

20 A catalytic converter is part of the exhaust system of many modern cars. Which one of the following reactions occurs in the catalytic converter?

A $2C_xH_y + (4x + y)NO \rightarrow 2xCO_2 + yH_2O + (2x + \frac{y}{2})N_2$

B $2SO_2 + 2NO \rightarrow 2SO_3 + N_2$

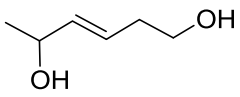
C $CO_2 + NO \rightarrow CO + NO_2$

D $2C + O_2 \rightarrow 2CO$

Answer: A

Catalytic converters convert harmful exhaust gases into inert ones, such as carbon dioxide and water vapor. Thus options **B** – **C** are incorrect as harmful gases such as SO_3, NO_2 and CO are formed.

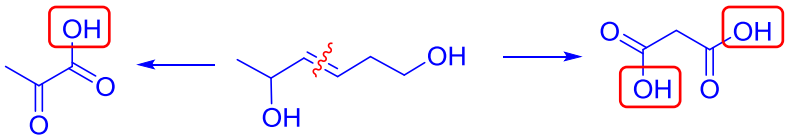
21 Hex-3-en-1,5-diol has the following structure.



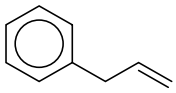
How many moles of PCl_5 will react with the products formed from heating 1 mole of hex-3-en-1,5-diol in the presence of acidified potassium manganate(VII)?

A 1 **B** 2 **C** 3 **D** 4

Answer: C

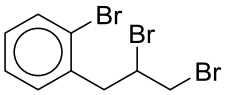
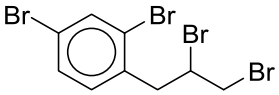


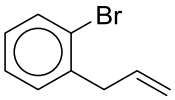
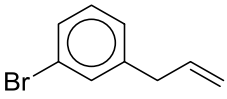
22 Bromine, along with iron(III) bromide, is dissolved in compound **P** and left to stand in the dark.

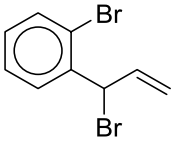
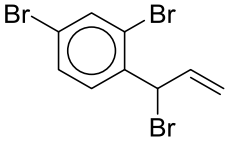


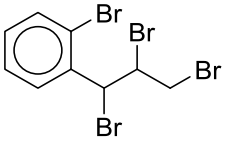
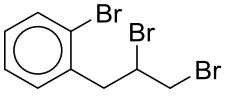
compound **P**

Which of the following pairs is likely to be the major products formed?

A  and 

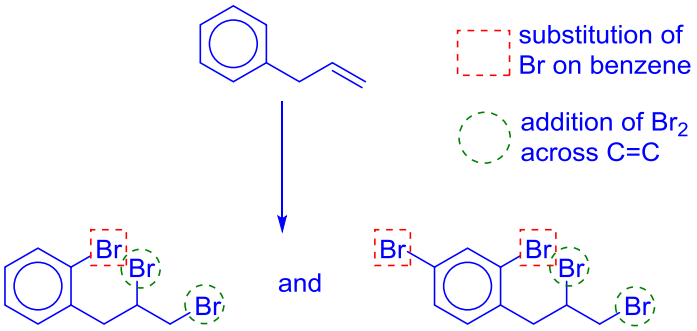
B  and 

C  and 

D  and 

Answer: A

When **P** is reacted with bromine in the dark, addition across the C=C occurrs. In the presence of $FeBr_3$ catalyst, substitution of the benzene will occur too. To form the major product from the substitution of Br on the benzene, Br has to be at position 2 and/or 4 with respect to the alkyl sidechain. Substitution of the alkyl group will not occur due to the absence of UV light.



23 Chlorofluorocarbons (CFCs) have been widely used in aerosol sprays, refrigerators and in making foamed plastics, but are now known to destroy ozone in the upper atmosphere. Which of the following will not destroy ozone, and therefore can be used as a replacement for CFCs?

A $CHBr_2CH_2CH_2CCl_3$

B $CH_3CHFCH_2CH_2F$

C $CH_2ClCH_2CHFCH_3$

D $CHF_2CH_2CH_2CHBr_2$

Answer: B

CFCs will release C*l* or Br radicals when exposed to UV light in the upper atmosphere (stratosphere) as the C-C*l* bonds and C-Br bonds will break (homolytically). These radicals are responsible for the breaking down of the ozone layer. Only C-F bonds are not broken when exposed to UV light in the stratosphere. Thus, a suitable CFC replacement would be option B where there is no C*l* or Br in the molecule.

24 A glass of wine was exposed to air for a period of time. This causes the wine to have a sour taste. A student proposed that a portion of ethanol present in the wine has been oxidised, thus giving rise to the sour taste.

Which of the following reagents can be used to confirm the above hypothesis?

A Na **B** NaOH **C** K_2CO_3 **D** $KMnO_4$

Answer: C

To prove the hypothesis correct, the student has to test for the presence of carboxylic acid (ethanol is oxidised to ethanoic acid, giving rise to the sour taste).

A Na : both ethanol and ethanoic acid will result in effervescence of $H_2(g)$

B NaOH : only ethanoic acid will react, however, there is no observable change and thus cannot be used as a distinguishing test

C K_2CO_3 : ethanoic acid reacts and the effervescence released (CO_2) produce white ppt when passed through $Ca(OH)_2$ solution.

D $KMnO_4$: only ethanol will decolourise purple $KMnO_4$

25 Butanoic acid was heated under reflux with a mixture of ethanol and propanol in the presence of concentrated sulfuric acid. Which of the following is a possible product of this reaction?

A ethyl propanoate

B propyl butanoate

C butyl butanoate

D propyl ethanoate

Answer: B

The only two possible products are ethyl butanoate and propyl butanoate.

alcohol carboxylic acid

alcohol carboxylic acid

Section B

For each of the questions in this section, one or more of the three numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct).

The responses **A** to **D** should be selected on the basis of

A	B	C	D
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

26 Chlorine gas reacts with sodium hydroxide according to the following equation.

$$3Cl_2 + 6OH^- \rightarrow 5Cl^- + ClO_3^- + 3H_2O$$

Which of the following statements is true for this reaction?

1 C*l* is oxidised.

2 C*l* is reduced.

3 Oxidation state of O does not change.

Answer: A

Statement 1 is true. C*l* is oxidised from 0 in Cl_2 to +5 in ClO_3^-.

Statement 2 is true. C*l* is reduced from 0 in Cl_2 to –1 in Cl^-.

Statement 3 is true. Oxidation state of O is is –2 in OH^-, H_2O and ClO_3^-.

27 Which of the following shows a correct example of a conjugate acid / base pair?

1 CH_3CO_2H, $CH_3CO_2^-Na^+$

2 CH_3NH_2, $CH_3NH_3^+Cl$

3 H_2O, OH^-

Answer: A (1, 2 and 3)

1 CH_3CO_2H (acid), $CH_3CO_2^-Na^+$ (conjugate base)

2 CH_3NH_2 (base), $CH_3NH_3^+Cl$ (conjugate acid)

3 H_2O (acid), OH^- (conjugate base)

28 *Use of the Data Booklet is relevant to this question.*

Based on its position in the Periodic Table, which properties will element **X** (atomic number 14) have?

1 Its oxide has a simple molecular structure.

2 Its chloride hydrolyses in water to give an acidic solution.

3 Element **X** has high melting and boiling point.

Answer: C (2 and 3 only)

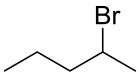
Element X is silicon.

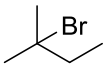
Statement 1: False. SiO_2 is a giant covalent compound.

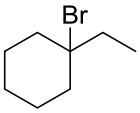
Statement 2: True. $SiCl_4$ hydrolyses complete in water to give a pH 2 solution.

Statement 3: True. Si has a giant covalent structure, thus have high m.p. and b.p.

29 An unknown halogen derivative, **Q**, was heated with alcoholic potassium hydroxide. A product that exhibits geometric isomerism is obtained. Which of the following is a possible identity of compound **Q**?

1 

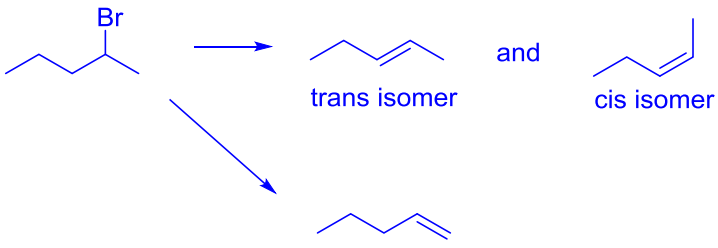
2 

3 

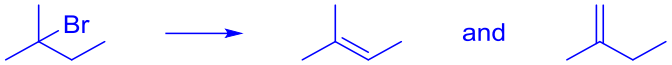
Answer: D (1 only)

Compound Q undergoes elimination to form alkene.

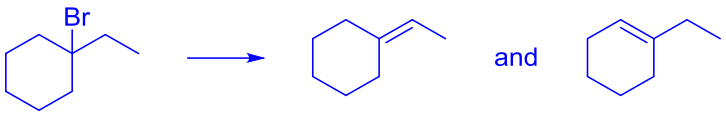
Option 1: 2 different alkenes are produced. One of the alkenes exhibits geometric isomerism.



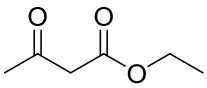
Option 2: Both alkenes formed do not exhibit geometric isomerism.



Option 3: Both alkenes formed do not exhibit geometric isomerism.



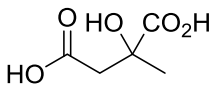
30 Compound **Y** is reacted with aqueous hydrogen cyanide in alkaline condition at 20 °C to produce compound **Z**. Compound **Z** is then heated under reflux with dilute sulfuic acid and the products isolated.

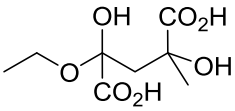


Compound **Y**

Which of the following are the possible products from the above reaction?

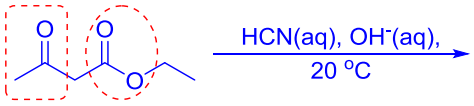
1 CH_3CH_2OH

2 

3 

Answer: B

addition of HCN across C=O (nucleophilic addition)

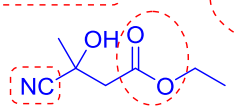


Y

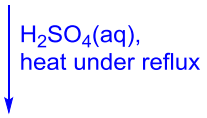
ester does not undergo addition with HCN

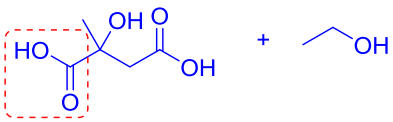
acid hydrolysis of nitrile to form carboxylic acid

acid hydrolysis of ester to form carboxylic acid and alcohol



Z





Catholic Junior College
JC2 Preliminary Examinations
Higher 1

CANDIDATE NAME	
CLASS	**2T**

CHEMISTRY

8872/02

Paper 2

Friday 18 August 2017
2 hours

Candidates answer Section A on the Question Paper.
Additional Materials: Data Booklet
Answer paper

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A – Answer **all** the questions**.**
Section B – Answer **two** questions on separate answer paper.

The use of an approved scientific calculator is expected where appropriate.
You are reminded of the need for good English and clear presentation in your answers.

At the end of the examination, fasten all your answer scripts securely together.

The number of marks is given in brackets [ ] at the end of each question or part of the question.

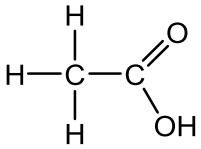
	For Examiner's Use		
Section A	**Q1**	/9	
	Q2	/12	
	Q3	/7	
	Q4	/6	
	Q5	/6	/40
Section B	**Q6**	/20	
	Q7	/20	
	Q8	/20	/40
Total			/80

This document consists of **14** printed pages

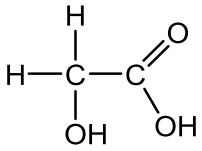
Section A

Answer **all** the questions in this section in the spaces provided.

1 Ethanoic acid and 2-hydroxyethanoic acid are weak acids containing two carbons each.



ethanoic acid



2-hydroxyethanoic acid

Ethanoic acid is a component in antiseptic that can be used to treat skin infections, whereas 2-hydroxyethanoic acid is commonly used in skincare products.

(a) Ethanoic acid dissociates according to the following equation:

$$CH_3CO_2H \rightleftharpoons CH_3CO_2^- + H^+$$

Write an expression for the acid dissociation constant, K_a, of ethanoic acid.

[1]

(b) The K_a of ethanoic acid is 1.74×10^{-5} mol dm^{-3}.
Given that the $[H^+]$ = [conjugate base], calculate the $[H^+]$ and hence the pH of 0.100 mol dm^{-3} of ethanoic acid.

[2]

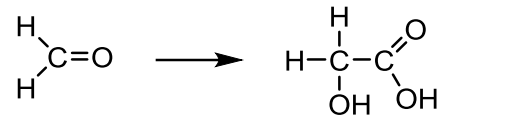
(c) The K_a of 2-hydroxyethanoic acid is 1.48×10^{-4} mol dm^{-3}.
Explain why 2-hydroxyethanoic acid has a higher K_a value than ethanoic acid.

.....

.....

..... [2]

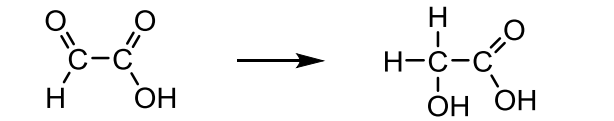
(d) Propose a simple reaction scheme to obtain 2-hydroxyethanoic acid from methanal.



methanal 2-hydroxyethanoic acid

[3]

(e) 2-hydroxyethanoic acid can also be obtained from oxoethanoic acid in a one-step reaction. State the reagents and conditions for this conversion.



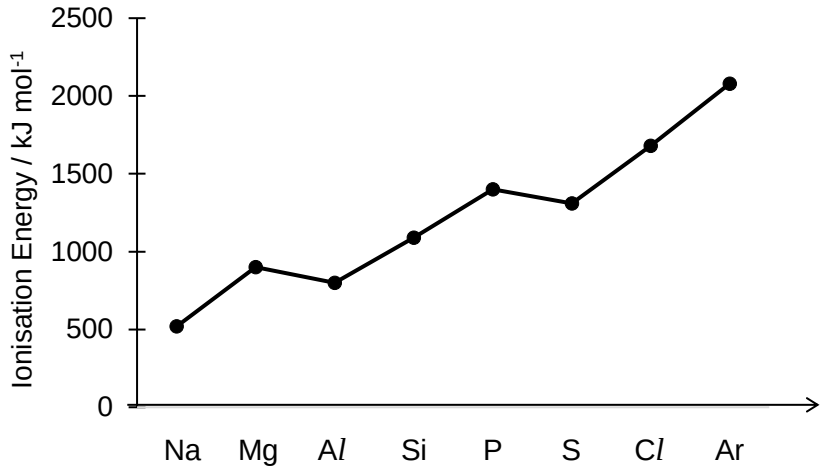
oxoethanoic acid 2-hydroxyethanoic acid

Reagents and conditions:

..... [1]

[Total: 9]

2 **(a)** The diagram below shows the first ionisation energies of the Period 3 elements from Na to Ar.



(i) Write an equation to represent the *first ionisation energy* of S.

.....[1]

(ii) Explain why the first ionisation energy generally increases across Period 3.

.....

.....

.....

.....

.....

.....[2]

(iii) With the aid of electronic configurations, predict whether the **second** ionisation energy of Si will be higher or lower than the second ionisation of A*l*. Give your reasoning.

.....

.....

.....

.....

.....[2]

(b) Sodium and magnesium are elements from Period 3 of the Periodic Table.

(i) State and explain two reasons why the melting point of magnesium is higher than that of sodium.

……

……

……

……

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……

..……[2]

Magnesium can react with oxygen gas to form magnesium oxide, MgO, which is often used as a refractory material in the lining of furnaces.

(ii) Draw a dot-and-cross diagram to show the bonding in MgO.

[1]

(iii) Explain why the lattice energy of MgO is less exothermic than that of Mg_3N_2.

……

……

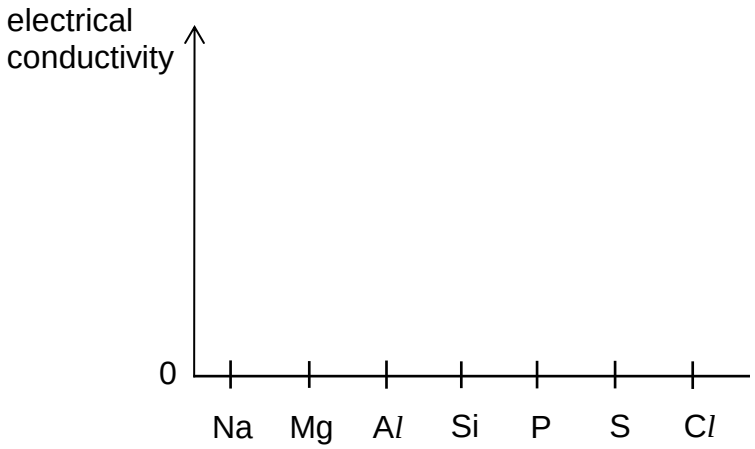
……

……

……

..……[3]

(c) Using the axes below, sketch the graph to show the electrical conductivity of the Period 3 elements from Na to C*l*.



[1]

[Total: 12]

3 An aromatic ester with the molecular formula $C_8H_8O_2$ was synthesised in the laboratory using suitable reactants and heated under reflux with concentrated sulfuric acid catalyst for about 6 hours.
The enthalpy change for this esterification reaction can be regarded as 0 kJ mol^{-1}.

(a) Draw a Boltzmann distribution curve for the reactants at this temperature and use it to explain why the reaction is significantly slower when the catalyst is removed.

.....

.....

.....

.....

.....

..... [3]

(b) The esterification reaction is reversible and hence has an equilibrium constant, K_c. Explain briefly how the equilibrium position and K_c are expected to change when the temperature is increased.

…….....

..... [2]

(c) When the aromatic ester is hydrolysed with H_2SO_4(aq), methanoic acid, HCO_2H, is not among the products.
Suggest two possible structural formulae for the ester.

[2]
[Total: 7]

4 **(a)** Hexa-1,4-diene, $CH_2CHCH_2CHCHCH_3$, has geometrical isomers.

(i) Draw the structural formula of each of the isomers so as to identify this isomerism and label each structure. [2]

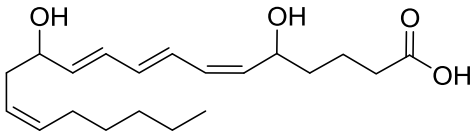
(ii) Explain how this isomerism arises.

……

……

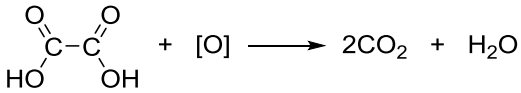
……[1]

(b) Leukotriene B4 is a biomolecule in the human body.



Leukotriene B4

Draw **all possible organic products** formed when leukotriene B4 is subjected to heating under reflux in the presence of acidified $KMnO_4(aq)$. Note that any ethanodioic acid formed is further oxidised according to the following equation.



[3]

[Total: 6]

5 In March 2017, residents in a small town in Alberta, Canada, received a shock when pink coloured water flowed from their taps. The colour was due to potassium manganate(VII), $KMnO_4$, used in the early stages of water treatment to remove pathogens and metal ions such as iron and manganese ions. $KMnO_4$ should have been removed before the treated water reached the homes of the consumers, but a water treatment valve malfunctioned which caused the incident to happen.

$KMnO_4$ has a relative formula mass of 158 and it exists as black crystals at room condition. When dissolved in water, small quantities of the solid are sufficient to give very intense shades of pink and purple solutions.

(a) Define the term *relative formula mass*.

.....

..... [1]

$KMnO_4$ is used to remove Mn^{2+} present in water. $KMnO_4$ will oxidise Mn^{2+} to MnO_2 precipitate which can easily be filtered from the water.

The half equation that shows the reduction of MnO_4^- under the treatment conditions is:

$$MnO_4^- + 4H^+ + 3e^- \rightarrow MnO_2 + 2H_2O$$

(b) With reference to the *Data Booklet*, write down the oxidation half equation.

..... [1]

(c) Hence, give the overall equation that shows the removal of Mn^{2+} during the treatment of water.

..... [1]

(d) During treatment, the concentration of $KMnO_4$ used is 1 mg dm^{-3}. Convert this concentration value into mol dm^{-3} and hence calculate the maximum mass of MnO_2 that can be precipitated per cubic metre of water.
(1 g = 1000 mg; 1 cubic metre = 1000 dm^3)

[3]

[Total: 6]

Section B

Answer **two** questions from this section on separate answer paper.

6 Hydrogen peroxide and acidified potassium iodide can react according to the equation below.

$$H_2O_2 + 2I^- + 2H^+ \rightarrow 2H_2O + I_2$$

The rate of reaction can be followed by measuring the amount of iodine produced after various times, from which the concentration of H_2O_2 remaining can be calculated.

In one such study, the following reaction mixture was prepared.

initial $[H^+] = 0.200$ mol dm^{-3}
initial $[I^-] = 0.200$ mol dm^{-3}
initial $[H_2O_2] = 0.0200$ mol dm^{-3}

The table below shows $[H_2O_2]$ at various times.

time / s	$[H_2O_2] \times 10^{-3}$ / mol dm^{-3}
0	20.0
80	16.7
183	13.5
315	10.3
490	7.10
760	3.90

(a) **(i)** Explain the term *rate of reaction*. [1]

(ii) Explain why the initial concentration of H_2O_2 used is much lower than the concentrations of H^+ and I^- used. [1]

(iii) Plot a graph of the above results. [2]

(iv) Use your graph to determine:

I the order of reaction with respect to $[H_2O_2]$,

II the initial rate, in mol dm^{-3} s^{-1}.

Show all working and construction lines clearly on your graph. [4]

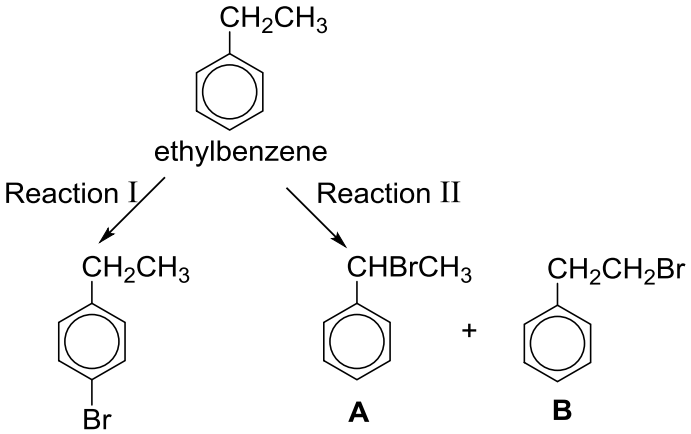
(v) Further experiments were carried out by changing $[H^+]$ and $[I^-]$, but keeping the initial $[H_2O_2]$ constant. The following results were obtained.

Experiment	initial $[H^+]$ / mol dm^{-3}	initial $[I^-]$ / mol dm^{-3}	initial rate/ mol dm^{-3} s^{-1}
1	0.400	0.200	1.0×10^{-4}
2	0.200	0.100	2.5×10^{-5}
3	0.100	0.200	2.5×10^{-5}

Determine the orders with respect to $[H^+]$ and $[I^-]$. Explain your reasoning. [2]

(b) Describe the reactions, if any, of the oxides P_4O_{10} and SiO_2 with water. State the approximate pH values of the resulting solutions and explain your answer with the aid of relevant equations for any reactions that occur. [3]

(c) Ethylbenzene can undergo substitution reactions to give three different products as shown in the scheme below.



(i) Explain why ethylbenzene does not undergo addition reactions readily. [1]

(ii) State the reagents and conditions for reactions **I** and **II**. [2]

(iii) Suggest the ratio in which **A** and **B** might be formed, assuming that the ease of substitution of H is the same for the formation of both compounds. [1]

(d) An alkaline solution of $Cu^{2+}(aq)$ is used in organic chemistry to test for a particular functional group.

(i) Describe the appearance of a positive result of this test. [1]

(ii) Compounds **X** and **Y** both have the molecular formula $C_5H_{10}O$ and give an orange precipitate with 2,4-dinitrophenylhydrazine. However, compound **X** shows a positive result in the test in **(d)(i)** while compound **Y** does not. Suggest a possible structure for compound **X** and for compound **Y**, showing the skeletal formula in your answers. [2]

[Total: 20]

7 **(a)** Ethanol, CH_3CH_2OH, is manufactured in the industry by reacting ethene with steam in the presence of a catalyst. The reaction is reversible and the equation is as follows:

$$CH_2{=}CH_2(g) + H_2O(g) \rightleftharpoons CH_3CH_2OH(g) \qquad \Delta H = -45 \text{ kJ mol}^{-1}$$

(i) Draw a labelled reaction pathway diagram for this reaction. [2]

For every 1.0 mol dm^{-3} of ethene and 0.6 mol dm^{-3} of steam reacted and allowed to reach equilibrium, only 5% of the ethene is converted into ethanol at each pass through the reactor. To increase the overall yield of ethanol, ethanol is regularly removed from the equilibrium mixture as it is formed, and more ethene is added into the reaction mixture.

(ii) Using the information given above, calculate K_c (including units) at this temperature. [2]

(iii) Calculate the amount, in moles, of ethene (in every dm^3) that must be added to increase the equilibrium concentration of ethanol to 0.20 mol dm^{-3}. [2]

(iv) State the catalyst used for the reaction. [1]

(v) Apart from the methods mentioned above, suggest one other method which will result in an increase in the conversion of ethene into ethanol without changing the temperature and without adding more steam. Explain your answer briefly. [2]

(b) Ethanol is one of several compounds used as an ‘anti-knock’ agent that is added to unleaded petrol to prevent damage to car engines. Prior to the use of ethanol as an anti-knocl

To prevent accumulation of lead deposits in the engines, a small quantity of 1,2-dichloroethane was added to the gasoline to form $PbCl_2$ that can be flushed from the engine and into the air, but the compound quickly solidifies at atmospheric temperature. The accumulation of toxic lead compounds in the environment quickly resulted in a worldwide ban of leaded petrol.

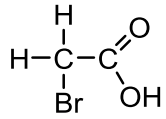
(i) Catalytic converters were fitted in cars to minimise the emissions of undesirable exhaust gases emitted such as carbon monoxide, oxides of nitrogen and unburnt hydrocarbons. State the environmental damage of one of the gases listed. [1]

(ii) The oxidation state of Pb in $PbCl_2$ is +2. What is the maximum oxidation state Pb is able to obtain and explain why this is so. [1]

(iii) Write an equation to show how the chloride of lead (where lead is at its maximum oxidation state) reacts with water. [1]

(iv) Explain why the reaction stated in **(b)(iii)** proceeds with greater ease than a similar reaction involving the chloride of silicon. [1]

(c) Ethene can be used as a starting material to synthesise 2-bromoethanoic acid.



2-bromoethanoic acid

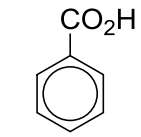
(i) Propose a reaction scheme that will convert ethene to 2-bromoethanoic acid, bearing in mind that each step should result in a fairly good yield of products. [3]

(ii) State the functional groups present in 2-bromoethanoic acid. [2]

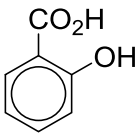
(iii) Describe a simple chemical test to show the presence of bromine in 2-bromoethanoic acid. [2]

[Total: 20]

8 **(a)** Benzoic acid and salicylic acid are both important precursors for the industrial synthesis of many other organic substances.



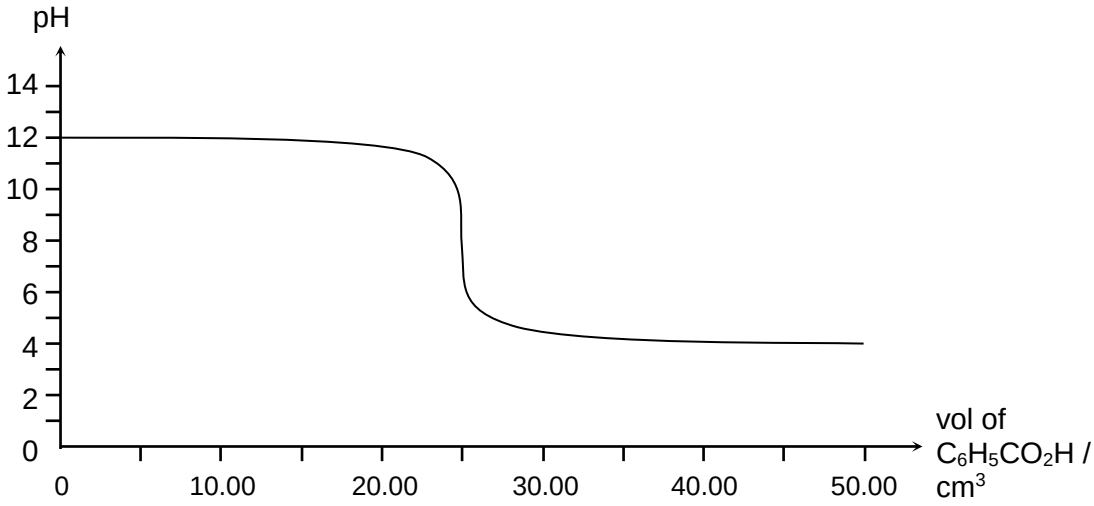
benzoic acid



salicylic acid

It was observed that salicylic acid has a lower solubility in water compared to benzoic acid in water. This is due to salicylic acid forming less extensive hydrogen bonding with water molecules. With the aid of a labelled diagram, suggest a reason for this observation. [2]

(b) In a titration carried out under standard conditions, a solution of benzoic acid is added to 20.00 cm^3 of aqueous sodium hydroxide. The change in pH was measured and the following titration curve was obtained.



(i) Using the titration curve, calculate the concentration of OH^- at the beginning of the reaction. [1]

(ii) Suggest a suitable indicator for the above reaction, stating the expected colour change. [2]

(iii) Explain your choice of indicator. [1]

(iv) Using the answer in **(b)(i)**, calculate the concentration of the solution of benzoic acid. [2]

(c) *Use of Data Booklet is relevant to this question.*

In another experiment, 60.00 cm^3 of 0.600 mol dm^{-3} benzoic acid is added to 40.00 cm^3 of 0.800 mol dm^{-3} aqueous sodium hydroxide and the increase in temperature is measured.

Given that the enthalpy change of this reaction is –56.9 kJ mol^{-1}, calculate the increase in temperature. [3]

(d) In the 1940s, it was difficult to oxidise methylbenzene to benzoic acid using the oxygen present in air. Many methods resulted in incomplete oxidation or produced low yields of benzoic acid. It was later discovered that aluminium oxide is able to support controlled oxidation of methylbenzene to benzoic acid in the presence of air.

Aluminium oxide is amphoteric. Write balanced equations to illustrate this fact. [2]

(e) Compound **X** is a four carbon organic molecule. Upon addition of aqueous silver nitrate, a yellow precipitate was observed almost immediately. The yellow precipitate was then filtered off and the solution was left to stand. After a period of time, white precipitate was observed in the filtrate.

In a separate experiment, compound **X** was heated under reflux with aqueous sodium hydroxide to give compound **Y**. When compound **Y** was reacted with phosphorus(V) chloride, steamy fumes were observed. When one mole of compound **Y** was reacted with alkaline aqueous iodine, only one mole of yellow precipitate **Z** was produced.

Using the information given, deduce the structures of **X**, **Y** and **Z**. In your answer, state clearly the types of reactions that occurred. [7]

[Total: 20]

Catholic Junior College
JC2 Preliminary Examinations
Higher 1

CANDIDATE NAME	
CLASS	**2T**

CHEMISTRY

Paper 2

8872/02
Friday 18 August 2017
2 hours

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Additional Materials: Data Booklet
Answer paper

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Answer Scheme

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Section A	Q1	9	
	Q2	12	
	Q3	7	
	Q4	6	
	Q5	6	40
Section B	Q6	20	
	Q7	20	
	Q8	20	40
Total			80

This document consists of **19** printed pages and 1 blank page

Section A

Answer **all** the questions in this section in the spaces provided.

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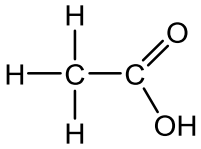
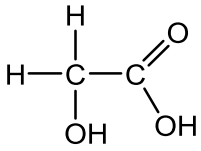


ethanoic acid



2-hydroxyethanoic acid

Ethanoic acid is a component in antiseptic that can be used to treat skin infections, whereas 2-hydroxyethanoic acid is commonly used in skincare products.

(a) Ethanoic acid dissociates according to the following equation:

$$CH_3CO_2H \rightleftharpoons CH_3CO_2^- + H^+$$

Write an expression for the acid dissociation constant, K_a, of ethanoic acid.

$$K_a = \frac{[CH_3CO_2^-][H^+]}{[CH_3CO_2H]}$$

[1]

(b) The K_a of ethanoic acid is 1.74×10^{-5} mol dm^{-3}.
Given that the $[H^+]$ = [conjugate base], calculate the $[H^+]$ and hence the pH of 0.100 mol dm^{-3} of ethanoic acid.

$$K_a = \frac{[CH_3CO_2^-][H^+]}{[CH_3CO_2H]}$$

$$1.74 \times 10^{-5} = \frac{[H^+]^2}{(0.100)}$$

$[H^+] = 1.32 \times 10^{-3}$ mol dm^{-3}

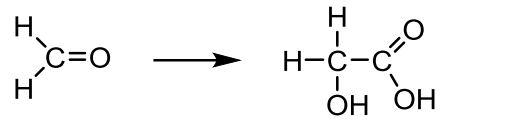
pH = -lg (1.32×10^{-3}) =2.88

[2]

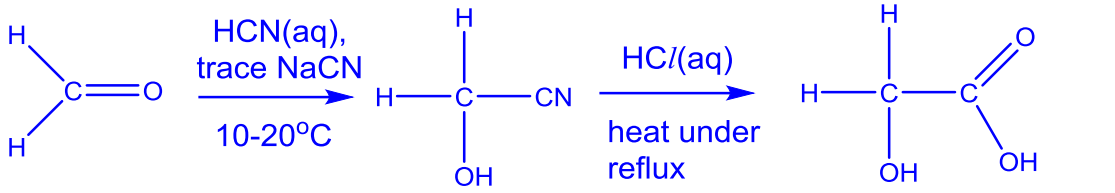
(c) The K_a of 2-hydroxyethanoic acid is 1.48×10^{-4} mol dm^{-3}.
Explain why 2-hydroxyethanoic acid has a higher K_a value than ethanoic acid.

The –OH group (on the α-carbon) is electron withdrawing. This stabilises the conjugate base by dispersing the negative charge on O, decreasing the tendency to recombine with H^+ OR weakens the O-H bond of the $–CO_2H$ group allowing for greater ease of dissociation of H^+. Hence, 2-hydroxyethanoic acid is a stronger acid, resulting is a higher K_a value. [2]

(d) Propose a simple reaction scheme to obtain 2-hydroxyethanoic acid from methanal.



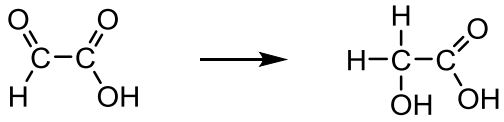
methanal 2-hydroxyethanoic acid



methanal 2-hydroxyethanoic acid

[3]

(e) 2-hydroxyethanoic acid can also be obtained from oxoethanoic acid in a one-step reaction. State the reagents and conditions for this conversion.



oxoethanoic acid 2-hydroxyethanoic acid

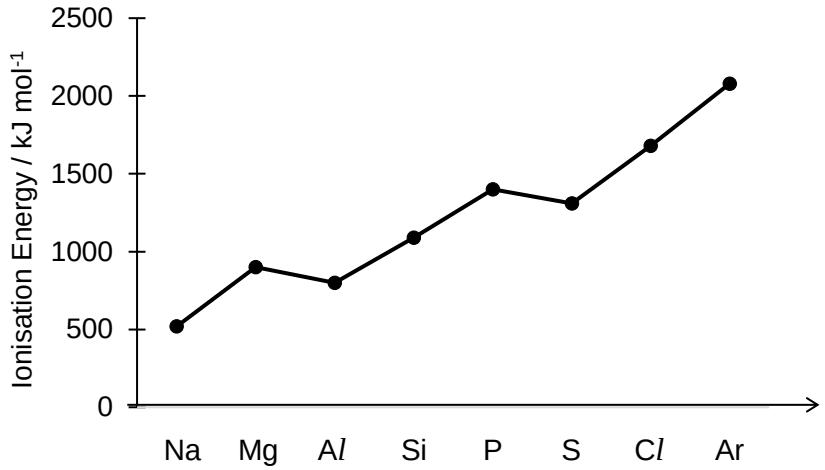
Reagents and conditions:

$NaBH_4$ in methanol ..... [1]

Note: $LiAlH_4$ in dry ether cannot be used as this will reduce the carboxylic acid group as well.

[Total: 9]

2 **(a)** The diagram below shows the first ionisation energies of the Period 3 elements from Na to Ar.



(i) Write an equation to represent the *first ionisation energy* of S.

$S(g) \rightarrow S^+(g) + e^-$

.....[1]

(ii) Explain why the first ionisation energy generally increases across Period 3.

The nuclear charge increases (due to the increase in number of protons).

The atomic radius decreases (thus the outermost electron is nearer to the nucleus).

The screening/shielding effect remains almost the same (as the electron is "added" to the same outermost electron shell).

Therefore, the outermost electron becomes more strongly attracted by the positive nucleus and thus, more energy is required to remove the electron.

.....[2]

(iii) With the aid of electronic configurations, predict whether the **second** ionisation energy of Si will be higher or lower than the second ionisation of A*l*. Give your reasoning.

Al^+: $1s^2\,2s^2\,2p^6\,3s^2$; Si^+: $1s^2\,2s^2\,2p^6\,3s^2\,3p^1$

The second I.E. of Si will be lower than the second I.E. of A*l*.

Less energy is required to remove a 3p electron in Si^+ than a 3s electron in Al^+ since the 3p subshell has a higher energy than the 3s subshell.

.....[2]

(b) Sodium and magnesium are elements from Period 3 of the Periodic Table.

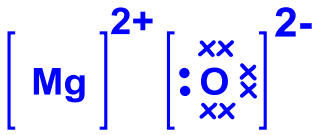
(i) State and explain two reasons why the melting point of magnesium is higher than that of sodium.

Mg has stronger metallic bond strength compared to Na as Mg has a greater number of valence electrons contributed to the 'sea' of delocalised electrons, than Na. As more energy is required to overcome the stronger metallic bonds in Mg, Mg has a higher melting point. Mg^{2+} has a larger ionic charge and smaller cationic size than Na. This results in higher charge density of Mg^{2+} and stronger metallic bond strength.

[2]

Magnesium can react with oxygen gas to form magnesium oxide, MgO, which is often used as a refractory material in the lining of furnaces.

(ii) Draw a dot-and-cross diagram to show the bonding in MgO.



[1]

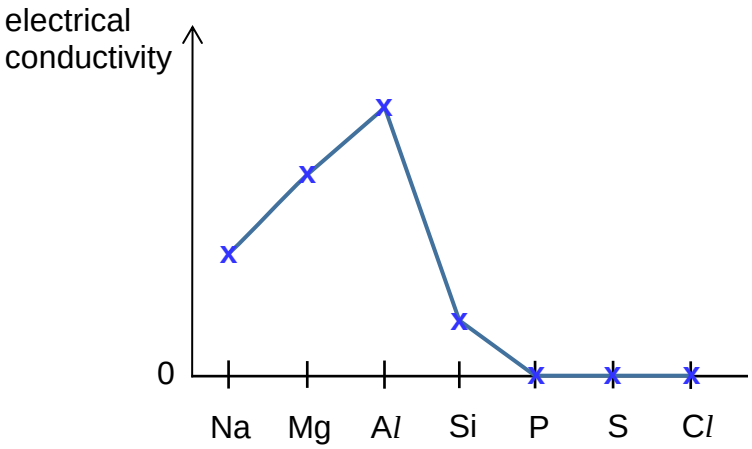
(iii) Explain why the lattice energy of MgO is less exothermic than that of Mg_3N_2.

Both MgO and Mg_3N_2 contain the same cation, Mg^{2+}. Although O^{2-} has a smaller ionic radius than N^{3-}, O^{2-} has a smaller ionic charge than N^{3-}.

$\Delta H_{latt} \propto \frac{q_+ q_-}{r_+ + r_-}$**; as charge is more dominant than radius in affecting lattice energy, lattice energy of MgO is less exothermic than Mg_3N_2.**

[3]

(c) Using the axes below, sketch the graph to show the electrical conductivity of the Period 3 elements from Na to C*l*.

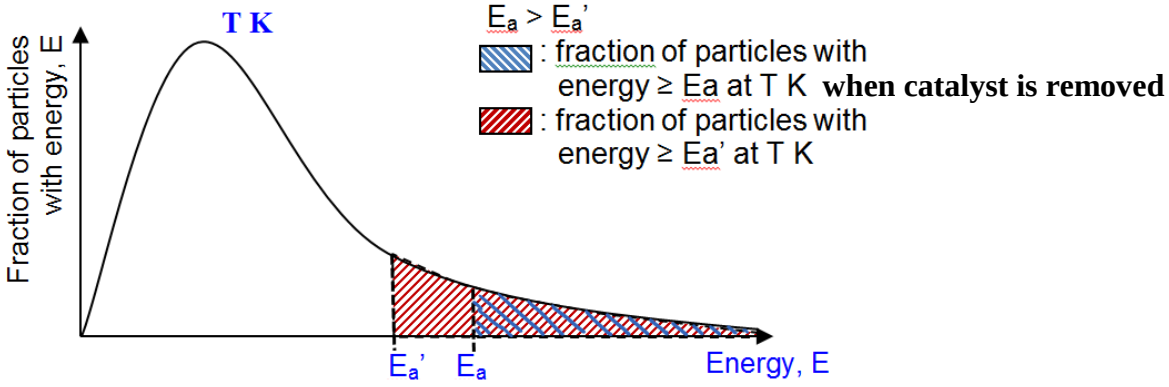


[1]

[Total: 12]

3 An aromatic ester with the molecular formula $C_8H_8O_2$ was synthesised in the laboratory using suitable reactants and heated under reflux with concentrated sulfuric acid catalyst for about 6 hours.
The enthalpy change for this esterification reaction can be regarded as 0 kJ mol^{-1}.

(a) Draw a Boltzmann distribution curve for the reactants at this temperature and use it to explain why the reaction is significantly slower when the catalyst is removed.



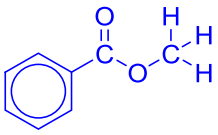
The catalyst speeds up the rate of reaction **by lowering the activation energy** of the reaction by providing an **alternative reaction pathway** with lower activation energy.

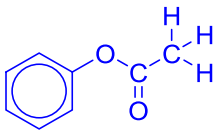
When a catalyst is removed, as shown by the Boltzmann distribution, **there is a lower fraction of molecules with energy ≥ activation energy**, this also reduces the frequency of **effective** collisions between molecules, and the rate of reaction falls. [3]

(b) The esterification reaction is reversible and hence has an equilibrium constant, K_c. Explain briefly how the equilibrium position and K_c are expected to change when the temperature is increased.

As the enthalpy change is 0 kJ mol^{-1}, a temperature increase will not have any effect on the equilibrium position and the K_c will not change. [2]

(c) When the aromatic ester is hydrolysed with H_2SO_4(aq), methanoic acid, HCO_2H, is not among the products.
Suggest two possible structural formulae for the ester.



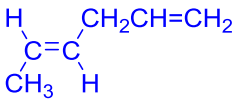


[2]

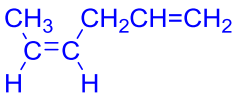
[Total: 7]

4 **(a)** Hexa-1,4-diene, $CH_2CHCH_2CHCHCH_3$, has geometrical isomers.

(i) Draw the structural formula of each of the isomers so as to identify this isomerism and label each structure. [2]



trans isomer

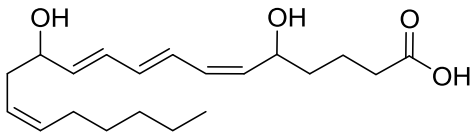


cis isomer

(ii) Explain how this isomerism arises.

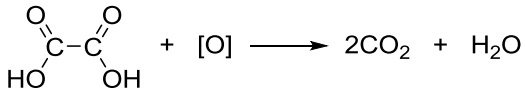
Geometric isomerism arises in alkenes due to the **restricted rotation about π bond in the C=C** and **each carbon in the C=C have 2 different groups attached to it.** [1]

(b) Leukotriene B4 is a biomolecule in the human body.

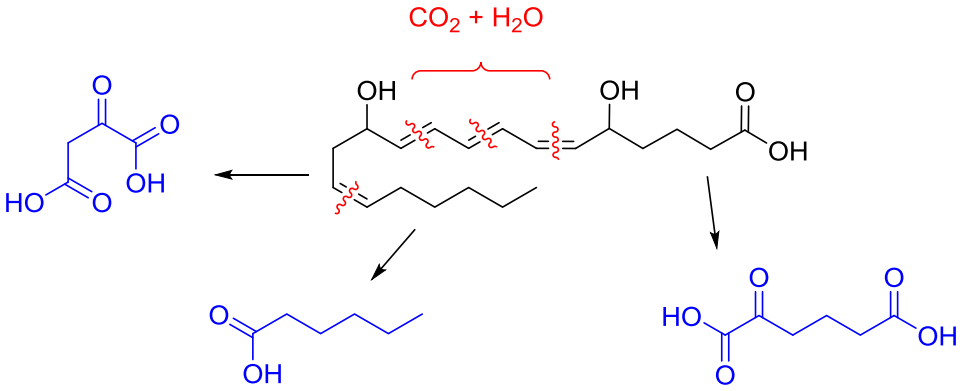


Leukotriene B4

Draw **all possible organic products** formed when leukotriene B4 is subjected to heating under reflux in the presence of acidified $KMnO_4$(aq). Note that any ethanodioic acid formed is further oxidised according to the following equation.



[3]



[Total: 6]

5 In March 2017, residents in a small town in Alberta, Canada, received a shock when pink coloured water flowed from their taps. The colour was due to potassium manganate(VII), $KMnO_4$, used in the early stages of water treatment to remove pathogens and metal ions such as iron and manganese ions. $KMnO_4$ should have been removed before the treated water reached the homes of the consumers, but a water treatment valve malfunctioned which caused the incident to happen.

$KMnO_4$ has a relative formula mass of 158 and it exists as black crystals at room condition. When dissolved in water, small quantities of the solid are sufficient to give very intense shades of pink and purple solutions.

(a) Define the term *relative formula mass*.

It is the ratio of the average mass of one formula unit of the compound to $\frac{1}{12}$ the mass of an atom of ^{12}C isotope, expressed on the ^{12}C scale. [1]

$KMnO_4$ is used to remove Mn^{2+} present in water. $KMnO_4$ will oxidise Mn^{2+} to MnO_2 precipitate which can easily be filtered from the water.

The half equation that shows the reduction of MnO_4^- under the treatment conditions is:

$$MnO_4^- + 4H^+ + 3e^- \rightarrow MnO_2 + 2H_2O$$

(b) With reference to the *Data Booklet*, write down the oxidation half equation.

$Mn^{2+} + 2H_2O \rightarrow MnO_2 + 4H^+ + 2e^-$ [1]

(c) Hence, give the overall equation that shows the removal of Mn^{2+} during the treatment of water.

$3Mn^{2+} + 2H_2O + 2MnO_4^- \rightarrow 5MnO_2 + 4H^+$ [1]

(d) During treatment, the concentration of $KMnO_4$ used is 1 mg dm^{-3}. Convert this concentration value into mol dm^{-3} and hence calculate the maximum mass of MnO_2 that can be precipitated per cubic metre of water.
(1 g = 1000 mg; 1 cubic metre = 1000 dm^3)

Concentration of $KMnO_4$ in mol dm^{-3} = $\frac{1\times10^{-3}}{158} = 6.329 \times 10^{-6}$

Maximum amount of solid MnO_2 that forms in 1 dm^3 = $\frac{5}{2} \times (6.329 \times 10^{-6})$
= 1.582 x 10^{-5}

Mass of MnO_2 formed in 1 dm^3 = (1.582 x 10^{-5})(54.9 + 2(16.0))
= 1.375 x 10^{-3}g

Mass of MnO_2 formed per cubic metre of water = 1.375 x 10^{-3} x 1000
= 1.375g [3]

[Total: 6]

Section B

Answer **two** questions from this section on separate answer paper.

6 Hydrogen peroxide and acidified potassium iodide can react according to the equation below.

$$H_2O_2 + 2I^- + 2H^+ \rightarrow 2H_2O + I_2$$

The rate of reaction can be followed by measuring the amount of iodine produced after various times, from which the concentration of H_2O_2 remaining can be calculated.

In one such study, the following reaction mixture was prepared.

initial $[H^+] = 0.200$ mol dm^{-3}
initial $[I^-] = 0.200$ mol dm^{-3}
initial $[H_2O_2] = 0.0200$ mol dm^{-3}

The table below shows $[H_2O_2]$ at various times.

time / s	$[H_2O_2] \times 10^{-3}$ / mol dm^{-3}
0	20.0
80	16.7
183	13.5
315	10.3
490	7.10
760	3.90

(a) (i) Explain the term *rate of reaction*. [1]

The rate of reaction is defined as the change in the concentration of reactants or products per unit time.

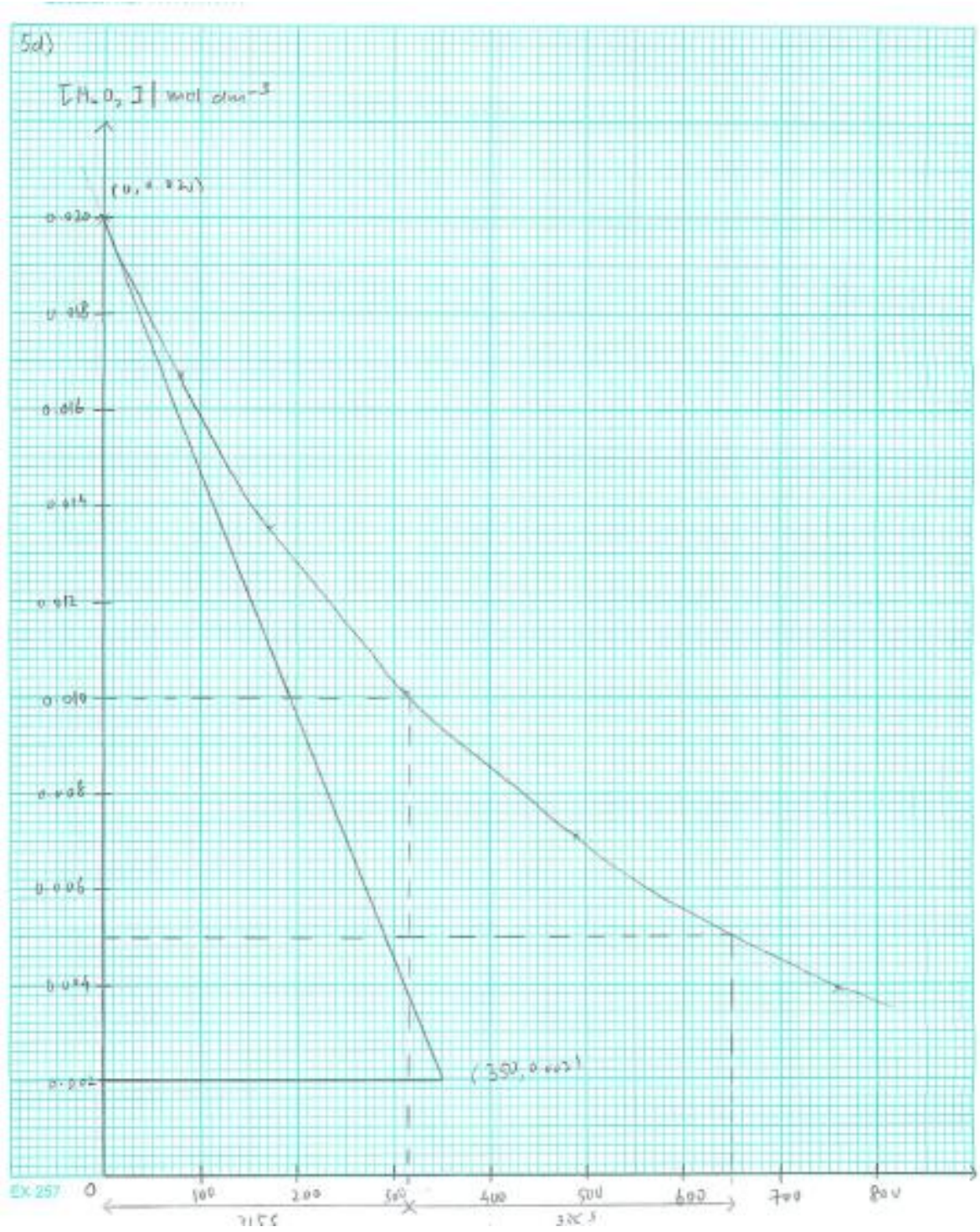
(ii) Explain why the initial concentration of H_2O_2 used is much lower than the concentrations of H^+ and I^- used. [1]

This is to ensure that concentrations of H^+ and I^- are effectively constant and only the concentration of H_2O_2 varies with time.

OR

This is to ensure that the order of reaction with respect to H^+ and I^- is pseudo-zero order.

(iii) Plot a graph of the above results. [2]



(iv) Use your graph to determine:

I the order of reaction with respect to $[H_2O_2]$,

Using half-life,

1st half-life = 315 s

2nd half-life = 335 s

Since both half-lives are fairly constant, the order of reaction with respect to $[H_2O_2]$ is 1.

II the initial rate, in mol dm^{-3} s^{-1}.

From the graph,

Initial rate = $\frac{0.02 - 0.002}{350}$ = 5.14 x 10^{-5} mol dm^{-3} s^{-1}

Show all working and construction lines clearly on your graph. [4]

(v) Further experiments were carried out by changing $[H^+]$ and $[I^-]$, but keeping the initial $[H_2O_2]$ constant. The following results were obtained.

Experiment	initial $[H^+]$ / mol dm^{-3}	initial $[I^-]$ / mol dm^{-3}	initial rate/ mol dm^{-3} s^{-1}
1	0.400	0.200	1.0 x 10^{-4}
2	0.200	0.100	2.5 x 10^{-5}
3	0.100	0.200	2.5 x 10^{-5}

Determine the orders with respect to $[H^+]$ and $[I^-]$. Explain your reasoning. [2]

By inspection,using experiments 1 and 3, when $[I^-]$ is constant at 0.200 mol dm^{-3}, and $[H^+]$ is decreased by 4 times, the reaction rate also decreased by 4 times. Therefore, the order of reaction with respect to $[H^+]$ is 1.

Using experiments 1 and 2, when $[I^-]$ is halved and $[H^+]$ is also halved, the reaction rate decreased by 4 times. Since the order with respect to $[H^+]$ is 1, by inspection, the order of reaction with respect to $[I^-]$ is 1.

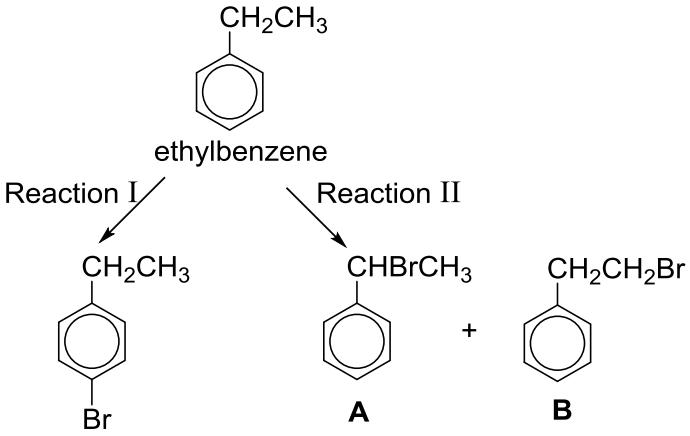
(b) Describe the reactions, if any, of the oxides P_4O_{10} and SiO_2 with water. State the approximate pH values of the resulting solutions and explain your answer with the aid of relevant equations for any reactions that occur. [3]

$P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)$

P_4O_{10} completely hydrolyses in water to give a strongly acidic solution of pH = 2

SiO_2 does not dissolve in water due to strong covalent bonds between atoms, thus the solution remains at pH = 7

(c) Ethylbenzene can undergo substitution reactions to give three different products as shown in the scheme below.



(i) Explain why ethylbenzene does not undergo addition reactions readily. [1]

Ethylbenzene does not undergo addition reactions readily but undergoes substitution reactions so as to retain the stable ring structure.

(ii) State the reagents and conditions for reactions **I** and **II**. [2]

Reaction I: Br_2, anhydrous $FeBr_3$ catalyst or Br_2, Fe catalyst

Reaction II: limited Br_2, *uv* light

(iii) Suggest the ratio in which **A** and **B** might be formed, assuming that the ease of substitution of H is the same for the formation of both compounds. [1]

A : B = 2 : 3

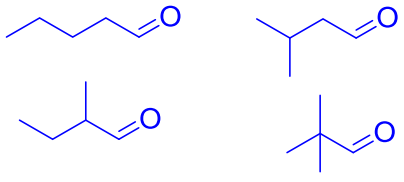
(d) An alkaline solution of $Cu^{2+}(aq)$ is used in organic chemistry to test for a particular functional group.

(i) Describe the appearance of a positive result of this test. [1]

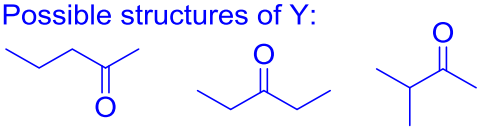
Red precipitate of Cu_2O seen

(ii) Compounds **X** and **Y** both have the molecular formula $C_5H_{10}O$ and give an orange precipitate with 2,4-dinitrophenylhydrazine. However, compound **X** shows a positive result in the test in **(d)(i)** while compound **Y** does not. Suggest a possible structure for compound **X** and for compound **Y**, showing the skeletal formula in your answers. [2]

Possible structures of X:



Possible structures of Y:

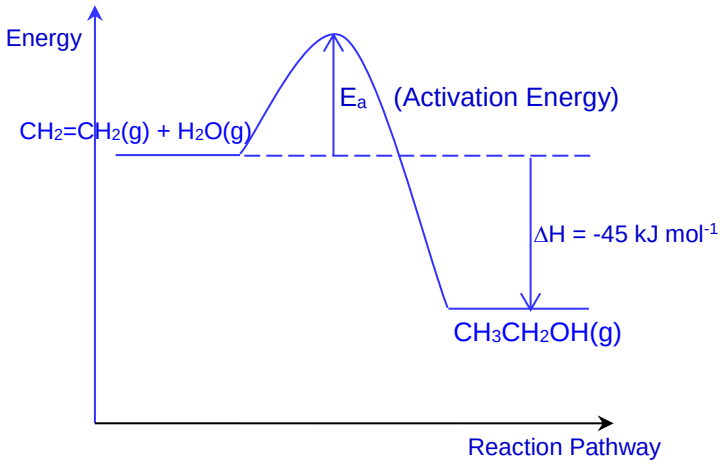


[Total: 20]

7 **(a)** Ethanol, CH_3CH_2OH, is manufactured in the industry by reacting ethene with steam in the presence of a catalyst. The reaction is reversible and the equation is as follows:

$$CH_2{=}CH_2(g) + H_2O(g) \rightleftharpoons CH_3CH_2OH(g) \qquad \Delta H = -45 \text{ kJ mol}^{-1}$$

(i) Draw a labelled reaction pathway diagram for this reaction. [2]



For every 1.0 mol dm^{-3} of ethene and 0.6 mol dm^{-3} of steam reacted and allowed to reach equilibrium, only 5% of the ethene is converted into ethanol at each pass through the reactor. To increase the overall yield of ethanol, ethanol is regularly removed from the equilibrium mixture as it is formed, and more ethene is added into the reaction mixture.

(ii) Using the information given above, calculate K_c (including units) at this temperature. [2]

	$CH_2{=}CH_2(g)$ +	$H_2O(g)$ ⇌	$CH_3CH_2OH(g)$
Initial / mol dm^{-3}	1.0	0.6	0.0
Change / mol dm^{-3}	-0.05	-0.05	+0.05
Eqm / mol dm^{-3}	0.95	0.55	0.05

$$K_c = \frac{[CH_3CH_2OH]}{[CH_2{=}CH_2][H_2O]} = \frac{0.05}{0.95 \times 0.55} = 0.0957 \text{ mol}^{-1} \text{ dm}^3$$

(iii) Calculate the amount, in moles, of ethene (in every dm^3) that must be added to increase the equilibrium concentration of ethanol to 0.20 mol dm^{-3}. [2]

Let the amount of ethene to be added be x.

	$CH_2{=}CH_2(g)$ +	$H_2O(g)$ ⇌	$CH_3CH_2OH(g)$
Initial / mol dm^{-3}	1.0 + x	0.6	0.0
Change / mol dm^{-3}	-0.20	-0.20	+0.20
Eqm / mol dm^{-3}	0.8 + x	0.40	0.20

$K_c = \frac{0.20}{(0.80+x)\times 0.40} = 0.0957$; x = 4.42 moles

(iv) State the catalyst used for the reaction. [1]

Concentrated H_3PO_4

(v) Apart from the methods mentioned above, suggest one other method which will result in an increase in the conversion of ethene into ethanol without changing the temperature and without adding more steam. Explain your answer briefly. [2]

Increasing the pressure will shift equilibrium to favour the production of **fewer number of moles of gas molecules**. Hence the equilibrium shifts forward and more ethanol is produced.

(b) Ethanol is one of several compounds used as an 'anti-knock' agent that is added to unleaded petrol to prevent damage to car engines. Prior to the use of ethanol as an anti-knocking agent, a compound called tetraethyl lead was used.

To prevent accumulation of lead deposits in the engines, a small quantity of 1,2-dichloroethane was added to the gasoline to form $PbCl_2$ that can be flushed from the engine and into the air, but the compound quickly solidifies at atmospheric temperature. The accumulation of toxic lead compounds in the environment quickly resulted in a worldwide ban of leaded petrol.

(i) Catalytic converters were fitted in cars to minimise the emissions of undesirable exhaust gases emitted such as carbon monoxide, oxides of nitrogen and unburnt hydrocarbons. State the environmental damage of one of the gases listed. [1]

Carbon monoxide: toxic gas that binds to human haemoglobin to inhibit the transport of oxygen
Oxides of nitrogen: Contributes to acid rain
Unburnt hydrocarbons: cause the environmental damage of photochemical smog.

(ii) The oxidation state of Pb in $PbCl_2$ is +2. What is the maximum oxidation state Pb is able to obtain and explain why this is so. [1]

+4. This corresponds to the maximum number of valence electrons Pb has / used for bonding.

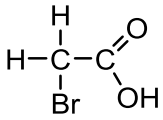
(iii) Write an equation to show how the chloride of lead (where lead is at its maximum oxidation state) reacts with water. [1]

$PbCl_4 + 2H_2O \rightarrow PbO_2 + 4HCl$

(iv) Explain why the reaction stated in **(b)(iii)** proceeds with greater ease than a similar reaction involving the chloride of silicon. [1]

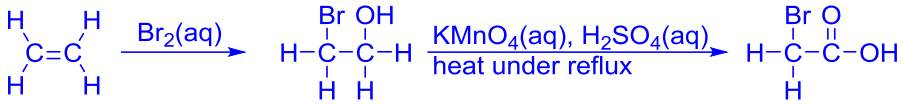
Pb is a larger atom than Si hence the Pb-C*l* covalent bond is longer and weaker than the Si-C*l* bond.

(c) Ethene can be used as a starting material to synthesise 2-bromoethanoic acid.



2-bromoethanoic acid

(i) Propose a reaction scheme that will convert ethene to 2-bromoethanoic acid, bearing in mind that each step should result in a fairly good yield of products. [3]



(ii) State the functional groups present in 2-bromoethanoic acid. [2]

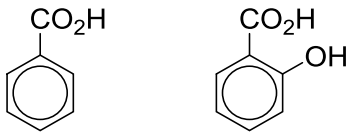
Primary bromoalkane and carboxylic acid

(iii) Describe a simple chemical test to show the presence of bromine in 2-bromoethanoic acid. [2]

To a sample of 2-bromoethanoic acid, add aqueous NaOH and heat.
Allow to cool and add dilute nitric acid, followed by aqueous $AgNO_3$.
Cream ppt of AgBr formed confirms the presence of bromine.

[Total: 20]

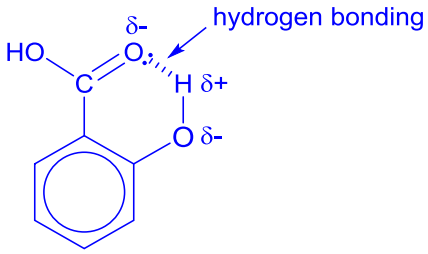
8 **(a)** Benzoic acid and salicylic acid are both important precursors for the industrial synthesis of many other organic substances.



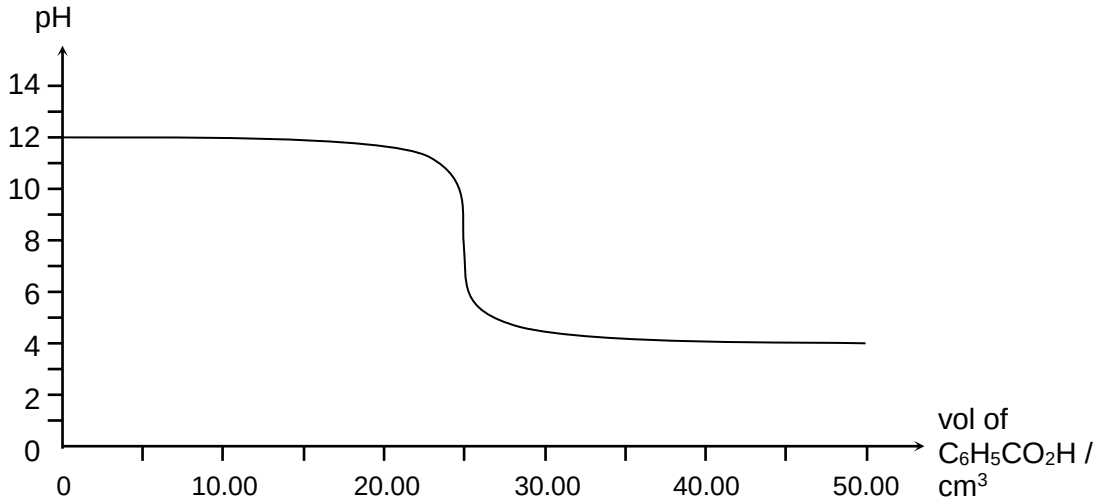
benzoic acid salicylic acid

It was observed that salicylic acid has a lower solubility in water compared to benzoic acid in water. This is due to salicylic acid forming less extensive hydrogen bonding with water molecules. With the aid of a labelled diagram, suggest a reason for this observation. [2]

Salicylic acid forms <u>intramolecular hydrogen bonding</u>, reducing the extensiveness of intermolecular hydrogen bonding. Thus, salicylic acid is less soluble in water than benzoic acid.



(b) In a titration carried out under standard conditions, a solution of benzoic acid is added to 20.00 cm^3 of aqueous sodium hydroxide. The change in pH was measured and the following titration curve was obtained.



(i) Using the titration curve, calculate the concentration of OH^- at the beginning of the reaction. [1]

Since pH = 12, pOH = 14 – 2 = 2

$[OH^-] = 10^{-2} = 0.0100$ mol dm^{-3}

(ii) Suggest a suitable indicator for the above reaction, stating the expected colour change. [2]

Phenolphthalein, pink to colourless

(iii) Explain your choice of indicator. [1]

The pH range for colour change that lies within the pH range of rapid change of the titration.

(iv) Using the answer in **(b)(i)**, calculate the concentration of the solution of benzoic acid. [2]

Amt of NaOH used = $0.01 \times \frac{20.00}{1000} = 0.000200$ mol

Thus amt of benzoic acid reacted = 0.000200 mol

[benzoic acid] = $\frac{0.002}{25}$ × 1000 = 0.00800 mol dm^{-3}

(c) *Use of Data Booklet is relevant to this question.*

In another experiment, 60.00 cm^3 of 0.600 mol dm^{-3} benzoic acid is added to 40.00 cm^3 of 0.800 mol dm^{-3} aqueous sodium hydroxide and the increase in temperature is measured.

Given that the enthalpy change of this reaction is –56.9 kJ mol^{-1}, calculate the increase in temperature. [3]

Amt of NaOH used = 0.8 × $\frac{40.00}{1000}$ = 0.0320 mol

Amt of benzoic acid used = 0.6 × $\frac{60.00}{1000}$ = 0.0360 mol

Thus amt of water produced = 0.0320 mol

Thus heat released = 56.9 × 1000 × 0.0320 = 1821 J (4.s.f.)

Thus increase in T = $\frac{1821}{100 \times 4.18}$ = 4.36 K

(d) In the 1940s, it was difficult to oxidise methylbenzene to benzoic acid using the oxygen present in air. Many methods resulted in incomplete oxidation or produced low yields of benzoic acid. It was later discovered that aluminium oxide is able to support controlled oxidation of methylbenzene to benzoic acid in the presence of air.

Aluminium oxide is amphoteric. Write balanced equations to illustrate this fact. [2]

$Al_2O_3 + 6H^+ \rightarrow 2Al^{3+} + 3H_2O$

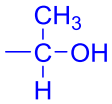
$Al_2O_3 + 2OH^- + 3H_2O \rightarrow 2[Al(OH)_4]^-$

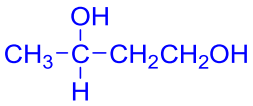
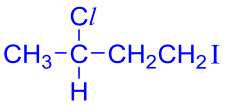
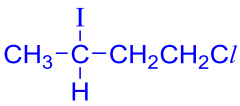
(e) Compound **X** is a four carbon organic molecule. Upon addition of aqueous silver nitrate, a yellow precipitate was observed almost immediately. The yellow precipitate was then filtered off and the solution was left to stand. After a period of time, white precipitate was observed in the filtrate.

In a separate experiment, compound **X** was heated under reflux with aqueous sodium hydroxide to give compound **Y**. When compound **Y** was reacted with phosphorus(V) chloride, steamy fumes were observed. When one mole of compound **Y** was reacted with alkaline aqueous iodine, only one mole of yellow precipitate **Z** was produced.

Using the information given, deduce the structures of **X**, **Y** and **Z**. In your answer, state clearly the types of reactions that occurred. [7]

Clues / observations	Type of reaction	Deduction
X, a four carbon organic	Substitution /	Since **X** has only 4 C and two

molecule, was reacted with $AgNO_3$(aq) and yellow precipitate was observed almost immediately. After a period of time, white precipitate was observed	hydrolysis	different silver halides are precipitated, **X** contains an **iodobutane**. **X** also contains a **chlorobutane**
X is heated under reflux with aqueous sodium hydroxide to give compound **Y**	(nucleophilic) substitution	**Y** has two **–OH groups** / **Y** is a **diol**
Y is reacted with PCl_5, steamy fumes are observed	(nucleophilic) substitution	
1 mole of **Y** is reacted with alkaline I_2(aq) to give 1 mole of yellow precipitate **Z**	Triiodomethane test or mild oxidation	**Z is CHI_3.**  Thus **Y** has **1 group.**

Thus **Y** is  and **X** is  or 

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