Name:		Class:	

ST ANDREW'S JUNIOR COLLEGE

JC2 Preliminary Examinations

Chemistry **8872/1**

Higher 1 **18 Sep 2017**

Paper 1 **1300 – 1350**

Candidates answer on separate paper.

Additional Materials: Writing paper, Data Booklet, OAS

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write you name, civics group and index number on the OAS provided unless this has been done for you.

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 OAS.

Read the instructions on the OAS 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.

This document consists of **12** pages including a blank page.

[BLANK]

Section A

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

1 How many carbon atoms are present in 4.0 g of ethanoic acid? [L = Avogradro constant]

A L/12

B L/15

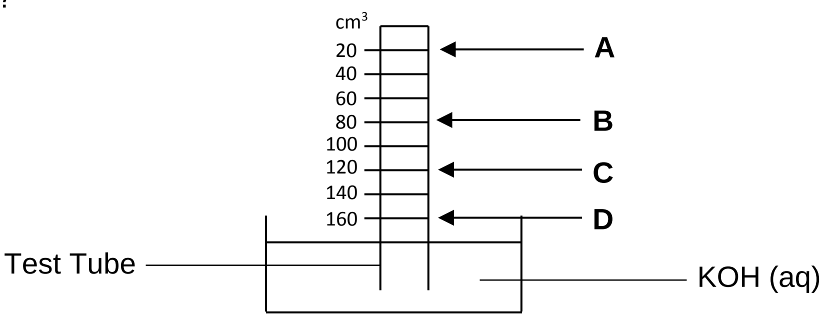
C 2L/15

D 2/15L

2 A test tube is filled with 20 cm^3 of propane and 160 cm^3 of oxygen at room temperature. The open end of the test tube is placed in a beaker of KOH (aq) as shown. The gas mixture was sparked according to the following reaction.

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$$

What will be the final level of liquid in the test tube after it has cooled back to room temperature?



3 A sample containing ammonium sulfate (M_r = 132) was warmed with 100 cm^3 of 0.500 mol dm^{-3} sodium hydroxide. When the evolution of ammonia ceased, the excess sodium hydroxide solution was neutralised with 25.00 cm^3 of 0.500 mol dm^{-3} hydrochloric acid. What was the mass of ammonium sulfate in the sample?

A 2.48 g

B 4.95 g

C 6.60 g

D 13.20 g

4 Which of the following ions has two more electrons in the third quantum shell than in the second quantum shell?

A Ca^{2+}

B K^{+}

C Ti^{+}

D V^{2+}

5 Which of the following ions would be deflected in an electric field to the same extent as CO^{+} under the same conditions?

A OF^{-}

B Ca^{2+}

C OH^{-}

D BeF^{+}

6 Which of the following sets of compounds consists of a simple molecular structure, giant ionic structure and giant molecular structure?

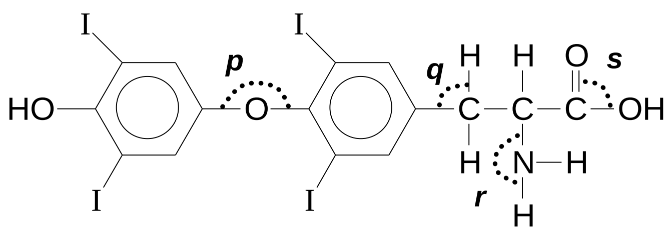
A SiO_2, HBr, $BeCl_2$

B $SiCl_4$, AlF_3, $C_{(graphite)}$

C SrO, ICl_3, $SnCl_2$

D $C_6H_5CO_2H$, P_4O_{10}, SiO_2

7 The thyroid gland concentrates iodine and uses it to produce thyroxine, which is a hormone that controls the metabolic rate.



Thyroxine

What are the values of the bond angles ***p***, ***q***, ***r*** and ***s***?

	p	*q*	*r*	*s*
A	180°	90°	180°	90°
B	105°	90°	107°	180°
C	180°	90°	120°	180°
D	105°	109.5°	107°	120°

8 Which of the following reactions can the bond energy of the Si–C*l* bond be determined by using the standard enthalpy change of the reaction?

A $SiCl_4\ (l) \rightarrow SiCl_4\ (g)$

B $SiCl_4\ (g) \rightarrow Si\ (g) + 4Cl\ (g)$

C $SiCl_4\ (g) \rightarrow SiCl_2\ (g) + Cl_2\ (g)$

D $2Cl_2\ (g) + Si\ (s) \rightarrow SiCl_4\ (g)$

9 Which of the following shows the sequence of the magnitude of lattice energies of the following compounds in ascending order?

I NaC*l*

II RbC*l*

III MgS

IV BaS

A I, II, III, IV

B II, I, IV, III

C III, IV, I, II

D IV, III, II, I

10 The table below shows the standard enthalpy change of neutralisation, ΔH, for the various acids and bases listed.

Acid	**Base**	**ΔH / kJ mol^{-1}**
hydrobromic acid	sodium hydroxide	–57.0
P	sodium hydroxide	less exothermic than –57.0
hydrofluoric acid	potassium hydroxide	less exothermic than –57.0
Q	potassium hydroxide	–57.0

What could be **P** and **Q**?

	P	**Q**
A	hydrochloric acid	nitric acid
B	ethanoic acid	hydrofluoric acid
C	hydrogen cyanide	ethanoic acid
D	ethanoic acid	hydrobromic acid

11 A chemical plant illegally dumped two radioactive isotopes **P** and **Q** in a landfill. The amount of **P** is 4 times the amount of **Q**. The radioactive decay of isotopes follows first-order kinetics. The half-life of **P** is 2 days whereas that of **Q** is 8 days. By the time the authorities found out about this illegal dumping and analysed a sample of the waste, the ratio of **P** to **Q** was found to be **1**:**2**. How long was the waste in the landfill before the authorities arrived?

A 8 days

B 16 days

C 32 days

D 64 days

12 The table below gives data for the reaction between **A** and **B** at a constant temperature.

Experiment	**[A] / mol dm^{-3}**	**[B] / mol dm^{-3}**	**Initial rate / mol dm^{-3} s^{-1}**
1	0.3	0.2	4.0×10^{-4}
2	0.6	0.2	4.0×10^{-4}
3	0.6	0.8	6.4×10^{-3}

Which of the following correctly represents the units of the rate constant, *k,* in the rate equation?

A mol^{-1} dm^{3} s^{-1}

B mol dm^{-3} s^{-1}

C mol s^{-1}

D s^{-1}

13 At 298 K, 0.20 mol dm^{-3} of propanone reacts with 0.30 mol dm^{-3} of methanol to form 0.04 mol dm^{-3} of acetal as shown below.

$$CH_3COCH_3\,(l) + 2CH_3OH\,(l) \overset{H^+}{\rightleftharpoons} CH_3C(OCH_3)_2CH_3\,(l) + H_2O\,(l)$$

acetal

What is the equilibrium constant of the reaction at 298 K?

A 0.0385

B 0.0455

C 0.148

D 0.207

14 Fe^{3+} and SCN^- react in a closed system to give the complex, $[Fe(SCN)]^{2+}$, which is blood-red in colour.

$Fe^{3+}\,(aq) + SCN^-\,(aq) \rightleftharpoons [Fe(SCN)]^{2+}\,(aq)$ $\Delta H < 0$

Which one of the following changes will result in the solution turning pale red?

A Increase the concentration of SCN^-

B Decrease the pressure of the system

C Decrease the temperature of the system

D Add a small amount of dilute NaOH to the resulting mixture

15 A mixture was made by adding 10 cm^3 of a solution of pH 1 to 30 cm^3 of another solution of pH 5. What is the final pH of the mixture?

A 1.6

B 2.5

C 3.0

D 4.0

16 Which of the following is a general trend from left to right of the elements in the third period of the Periodic Table?

A The radii of the atoms increase.

B The melting points of the chlorides decrease.

C The electrical conductivity of the elements decrease.

D The first ionisation energies of the elements increase.

17 Which element has a chloride with a simple molecular structure that is readily hydrolysed in water?

A sodium

B magnesium

C aluminium

D silicon

18 Which property decreases from Na_2O to P_4O_{10} for the oxides of period 3 elements?

A melting point

B covalent character

C solubility in aqueous alkali

D pH when mixed with water

19 Linoleic acid is an essential fatty acid with the structural formula.

$CH_3(CH_2)_4CH{=}CHCH_2CH{=}CH(CH_2)_7CO_2H$

Which of the following statements about linoleic acid is correct?

A It undergoes electrophilic substitution with liquid bromine.

B It undergoes oxidation with acidified potassium dichromate(VI) solution.

C 1 mole of linoleic acid requires 48 dm^3 of hydrogen for hydrogenation at room temperature.

D 1 mole of linoleic acid reacts with 1 mole of sodium carbonate to form 24 dm^3 of carbon dioxide at room temperature.

20 Which property of benzene is reflected as a consequence of the delocalised electrons in its molecule?

A Benzene is a planar molecule.

B Benzene is a good conductor of electricity.

C Substitution in benzene takes place at a carbon atom.

D Addition reactions of benzene take place more easily than substitution.

21 The volatile liquid, fluothane, $CF_3CHBrCl$, is a widely used anaesthetic.

Which statement about fluothane is **incorrect**?

A It has a simple molecular structure.

B It may cause depletion of ozone layer.

C It may undergo substitution with chlorine.

D It can form hydrogen bonds between its molecules.

22 A compound **V** gives yellow precipitate with alkaline aqueous iodine. One mole of **V** liberates one mole of hydrogen when it reacts with excess sodium.

What could be the formula of **V**?

A $CH_3CH(OH)CHO$

B $CH_3CH(OH)CO_2H$

C $HOCH_2CH_2CO_2H$

D $HOCH_2CH(CH_3)CH_2OH$

23 A compound, **W**, has the following properties.

- It reacts with hydrogen in the presence of nickel catalyst.
- It reacts with phosphorus pentachloride to give off HCl fumes.
- It reacts with sodium hydroxide to form an ionic compound.
- It reacts with ethanol.

What formula could represent **W**?

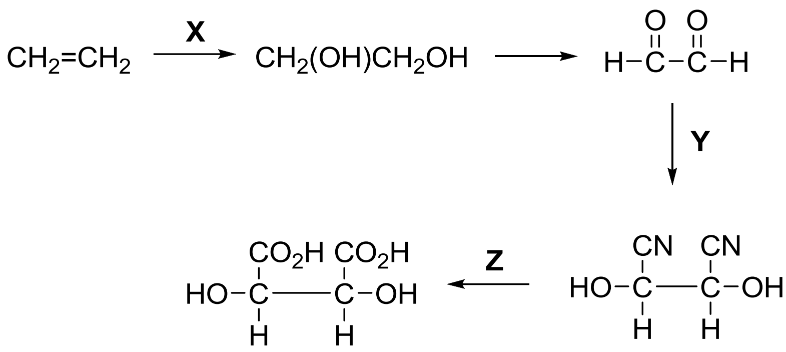
A CH_3CHO

B CH_3COCH_3

C $CH_2{=}CHCO_2H$

D $CH_2{=}CHCH_2OH$

24 The following is a method of synthesising tartaric acid, a compound found in wine.



Which set of reagents and conditions can be used for the synthesis?

	X	Y	Z
A	cold concentrated H_2SO_4, followed by boiling H_2O	cold HCN, NaOH(aq)	hot $K_2Cr_2O_7$, H_2SO_4(aq)
B	cold $KMnO_4$, H_2SO_4(aq)	cold HCN, NaOH(aq)	HC*l*(aq), heat
C	cold concentrated H_2SO_4, followed by boiling H_2O	ethanolic KCN, heat	hot $K_2Cr_2O_7$, H_2SO_4(aq)
D	cold $KMnO_4$, NaOH(aq)	ethanolic KCN, heat	HC*l*(aq), heat

25 Which of the following shows the descending order of acid strength?

A CH_3CO_2H > CH_2ClCO_2H > CH_3CH_2OH

B CH_3CH_2OH > CH_2ClCO_2H > CH_3CO_2H

C CH_2ClCO_2H > CH_2FCO_2H > CH_3CH_2OH

D CH_2ClCO_2H > CH_2BrCO_2H > CH_3CO_2H

[Turn Over

Section B

For each of the following questions, 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 Materials are insulators when the outer shells of electrons of all the constituent particles are completely filled and there is a considerable energy gap before the next unoccupied shell.

Which compounds have completely filled shells and might therefore act as insulators?

1 MgO

2 SiO_2

3 SiC (diamond structure)

27 Calcium reacts with water to form calcium hydroxide and hydrogen.

$Ca(s) + 2H_2O\,(l) \rightarrow Ca(OH)_2\,(s) + H_2\,(g)$

The standard enthalpy change for this reaction can be determined experimentally.

What further information are needed to calculate the standard enthalpy change of formation of calcium hydroxide, $\Delta H_f^{\ominus}$?

1 $\Delta H_f^{\ominus}$ for $H_2O(l)$

2 $\Delta H_f^{\ominus}$ for $H_2(g)$

3 First and second ionisation energies for Ca

28 Which of the following pairs would form an acidic buffer when mixed together?

1 CH_3CO_2H and $NaCl$

2 HCN and KCN

3 $C_6H_5CO_2H$ and $(C_6H_5CO_2)_2Ca$

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

29 A halogenoalkane has the formula of $C_3H_5Cl_3$.

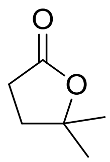
Which of the isomers have the correct IUPAC name?

1 1,1,1-trichloropropane

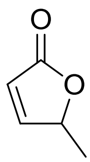
2 1,2,2-trichloropropane

3 2,2,3-trichloropropane

30 Below are the structures of compounds **X** and **Y**.



X



Y

Which sets of reagents and conditions can be used to distinguish between them?

1 aqueous bromine

2 acidified $K_2Cr_2O_7$, heat

3 alkaline aqueous iodine, heat

--- End of Paper ---

Name:		Class:	

ST ANDREW'S JUNIOR COLLEGE

JC2 Preliminary Examinations

Chemistry	**8872/1**
Higher 1	**18 Sep 2017**
Paper 1	**1300 − 1350**

Candidates answer on separate paper.

Additional Materials: Writing paper, Data Booklet, OAS

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write you name, civics group and index number on the OAS provided unless this has been done for you.

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 OAS.

Read the instructions on the OAS 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.

This document consists of **12** printed pages including this page.

[BLANK]

Section A

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

1 How many carbon atoms are present in 4.0 g of ethanoic acid? [L = Avogradro constant]

A L/12

B L/15

C 2L/15

D 2/15L

Mr of ethanoic acid (CH_3COOH) = (12.0 x 2) + (1.0 x 4) + (16.0 x 2) = 60.0

Amount of ethanoic acid = 4.0 / 60.0

Amount of carbon present = 2 x 4 / 60 = 2 /15

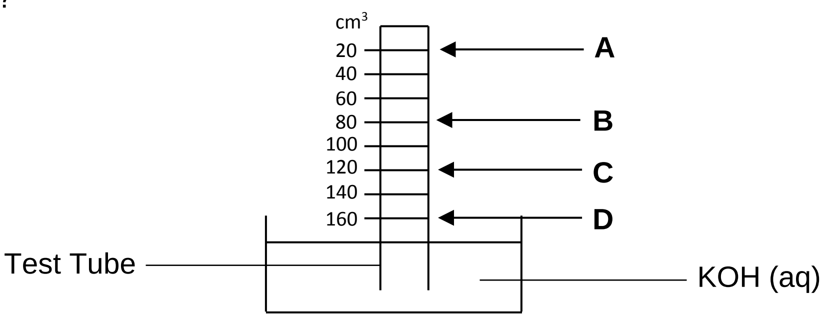
No. of C atoms = (2 / 15) x L = 2L / 15

Ans: (C)

2 A test tube is filled with 20 cm^3 of propane and 160 cm^3 of oxygen at room temperature. The open end of the test tube is placed in a beaker of KOH (aq) as shown. The gas mixture was sparked according to the following reaction.

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$$

What will be the final level of liquid in the test tube after it has cooled back to room temperature?



Volume of O_2 used = 100 cm^3

Volume of CO_2 formed = 60 cm^3

Volume of O_2 remained = 160 - 100 = 60 cm^3

Final volume of gas = vol of CO_2 + vol of O_2 remained = 60 + 60 = 120cm^3

Ans: (C)

3 A sample containing ammonium sulfate (M_r = 132) was warmed with 100 cm^3 of 0.500 mol dm^{-3} sodium hydroxide. When the evolution of ammonia ceased, the excess sodium hydroxide solution was neutralised with 25.00 cm^3 of 0.500 mol dm^{-3} hydrochloric acid. What was the mass of ammonium sulfate in the sample?

A 2.48 g

B 4.95 g

C 6.60 g

D 13.20 g

$(NH_4)_2SO_4 + 2NaOH \rightarrow 2NH_3 + Na_2SO_4 + 2H_2O$

Volume of NaOH reacts with $(NH_4)_2SO_4$ = 100 - 25 = 75.00 cm^3

Amount of $(NH_4)_2SO_4$ present = ½ (75 / 1000 x 0.500) = 0.01875 mol

Mass of $(NH_4)_2SO_4$= 0.01875 x 132.1 =2.475 = 2.48 g

Ans: (A)

4 Which of the following ions has two more electrons in the third quantum shell than in the second quantum shell?

A Ca^{2+}

B K^+

C Ti^+

D V^{2+}

$_{22}Ti$: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^2\ 4s^2$

Ti^+ : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^2\ 4s^1$

Third quantum shell has 10 electrons, second quantum shell has 8 electrons.

Ans: (C)

5 Which of the following ions would be deflected in an electric field to the same extent as CO^+ under the same conditions?

A OF^-

B Ca^{2+}

C OH^-

D BeF^+

Angle of deflection α charge/mass

CO^+ = 1/ (12+16) = 1 / 28

BeF^+ = 1 / (9+19) = 1 / 28

Ans: (D)

6 Which of the following sets of compounds consists of a simple molecular structure, giant ionic structure and giant molecular structure?

A SiO_2, HBr, $BeCl_2$

B $SiCl_4$, AlF_3, $C_{(graphite)}$

C SrO, ICl_3, $SnCl_2$

D $C_6H_5CO_2H$, P_4O_{10}, SiO_2

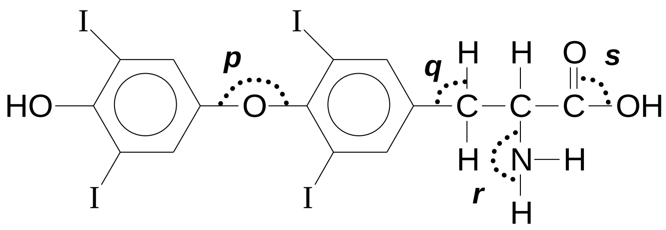
HBr, $BeCl_2$, ICl_3, $SiCl_4$, $C_6H_5CO_2H$, P_4O_{10} – simple molecular

SiO_2, $C_{(graphite)}$ – giant molecular

SrO, AlF_3, $SnCl_2$ – giant ionic

Ans: (B)

7 The thyroid gland concentrates iodine and uses it to produce thyroxine, which is a hormone that controls the metabolic rate.



Thyroxine

What are the values of the bond angles ***p***, ***q***, ***r*** and ***s***?

	p	***q***	***r***	***s***
A	180°	90°	180°	90°
B	105°	90°	107°	180°
C	180°	90°	120°	180°
D	105°	109.5°	107°	120°

p – oxygen has 2 b.p, 2 *l*.p, bond angle = 105°

q – carbon has 4 b.p, no *l*.p, bond angle = 109.5°

r – nitrogen has 3 b.p, 1 *l*.p, bond angle = 107°

s – carbon has 3 b.p, no *l*.p, bond angle = 120°

Ans: (D)

8 Which of the following reactions can the bond energy of the Si–C*l* bond be determined by using the standard enthalpy change of the reaction?

A $SiCl_4\ (l) \rightarrow SiCl_4\ (g)$

B $SiCl_4\ (g) \rightarrow Si\ (g) + 4Cl\ (g)$

C $SiCl_4\ (g) \rightarrow SiCl_2\ (g) + Cl_2\ (g)$

D $2Cl_2\ (g) + Si\ (s) \rightarrow SiCl_4\ (g)$

ΔH for B = 4 x BE(Si-C*l*)

Ans: (B)

9 Which of the following shows the sequence of the magnitude of lattice energies of the following compounds in ascending order?

I NaC*l*

II RbC*l*

III MgS

IV BaS

A I, II, III, IV

B II, I, IV, III

C III, IV, I, II

D IV, III, II, I

$|\text{Lattice Energy}| \propto \left|\frac{q^+q^-}{r_+ + r_-}\right|$

MgS, BaS has a bigger q^+q^- than NaC*l* and RbC*l*.

Rb^+ has a bigger ionic radius than Na^+, hence RbC*l* has the smallest magnitude of L.E.

Mg^{2+} has a smaller ionic radius than Ba^{2+}, hence MgS has the largest magnitude of L.E.

Ans: (B)

10 The table below shows the standard enthalpy change of neutralisation, Δ*H*, for the various acids and bases listed.

Acid	Base	Δ*H* / kJ mol^{-1}
hydrobromic acid	sodium hydroxide	–57.0
P	sodium hydroxide	less exothermic than –57.0
hydrofluoric acid	potassium hydroxide	less exothermic than –57.0
Q	potassium hydroxide	–57.0

What could be **P** and **Q**?

	P	Q
A	hydrochloric acid	nitric acid
B	ethanoic acid	hydrofluoric acid
C	hydrogen cyanide	ethanoic acid
D	ethanoic acid	hydrobromic acid

Hydrobromic acid is a strong acid since it reacts with NaOH gives an enthalpy change of –57.0 kJ mol^{-1}. Hydrofluoric acid is a weak acid since it reacts with NaOH that gives an enthalpy change that is less exothermic than –57.0 kJ mol^{-1}. P must be a weak acid, ethanoic acid and Q must be a strong acid, hydrobromic acid.

Ans: (D)

11 A chemical plant illegally dumped two radioactive isotopes **P** and **Q** in a landfill. The amount of **P** is 4 times the amount of **Q**. The radioactive decay of isotopes follows first-order kinetics. The half-life of **P** is 2 days whereas that of **Q** is 8 days. By the time the authorities found out about this illegal dumping and analysed a sample of the waste, the ratio of **P** to **Q** was found to be **1**:**2**. How long was the waste in the landfill before the authorities arrived?

A 8 days

B 16 days

C 32 days

D 64 days

4P → 2P → 1P → 1/2 P → 1/4 P

= 4 half-lives = 4 x 2 = 8 days

Q → 1/2 Q = 1 half-lives = 1 x 8 = 8 days

Ratio of P : Q = 1/4: 1/2 = 1: 2

Ans : (A)

12 The table below gives data for the reaction between **A** and **B** at a constant temperature.

Experiment	**[A] / mol dm^{-3}**	**[B] / mol dm^{-3}**	**Initial rate / mol dm^{-3} s^{-1}**
1	0.3	0.2	4.0×10^{-4}
2	0.6	0.2	4.0×10^{-4}
3	0.6	0.8	6.4×10^{-3}

Which of the following correctly represents the units of the rate constant, *k,* in the rate equation?

A mol^{-1} dm^{3} s^{-1}

B mol dm^{-3} s^{-1}

C mol s^{-1}

D s^{-1}

Comparing between experiment 1 and 2, when [B] is constant, [A] x 2, rate is the same, therefore it is zero order with respect to [A].

Comparing between experiment 2 and 3, when [A] constant, [B] x 4, rate increases 16 times, therefore it is second order with respect to [B].

Rate = k $[B]^2$

mol dm^{-3} s^{-1}= k(mol dm^{-3})^2

k= mol^{-1} dm^{3} s^{-1}

Ans: (A)

13 At 298 K, 0.20 mol dm^{-3} of propanone reacts with 0.30 mol dm^{-3} of methanol to form 0.04 mol dm^{-3} of acetal as shown below.

$$CH_3COCH_3\ (l) + 2CH_3OH\ (l) \xrightleftharpoons{H^+} CH_3C(OCH_3)_2CH_3\ (l) + H_2O\ (l)$$

acetal

What is the equilibrium constant of the reaction at 298 K?

A 0.0385

B 0.0455

C 0.148

D 0.207

	CH_3COCH_3 (*l*)	CH_3OH (*l*)	$CH_3C(OCH_3)_2CH_3$ (*l*)	H_2O (*l*)
Initial conc	0.20	0.30	0	0
Change in conc	0.20 – 0.04	0.30 – 2(0.04)	+0.04	+0.04
Equilibrium conc	0.16	0.22	0.04	0.04

$K_c = [CH_3C(OCH_3)_2CH_3]\ [H_2O]\ /\ [CH_3COCH_3]\ [CH_3OH]^2$

$= (0.04)^2 / [0.16 \times (0.22)^2]$

$= 0.207$ mol^{-1}dm^{3}

Ans: (D)

14 Fe^{3+} and SCN^{-} react in a closed system to give the complex, $[Fe(SCN)]^{2+}$, which is blood-red in colour.

Fe^{3+} (aq) + SCN^{-} (aq) $\rightleftharpoons$ $[Fe(SCN)]^{2+}$ (aq) $\Delta H < 0$

Which one of the following changes will result in the solution turning pale red?

A Increase the concentration of SCN^{-}

B Decrease the pressure of the system

C Decrease the temperature of the system

D Add a small amount of dilute NaOH to the resulting mixture

The NaOH added will react with Fe^{3+} to form $Fe(OH)_3$, causing $[Fe^{3+}]$ to be decreased. By L.C.P, position of equilibrium shift to the left to replenish the $[Fe^{3+}]$, hence the colour becomes less blood-red.

Ans: (D)

15 A mixture was made by adding 10 cm^3 of a solution of pH 1 to 30 cm^3 of another solution of pH 5. What is the final pH of the mixture?

A 1.6

B 2.5

C 3.0

D 4.0

$[H^+]$ in 10 cm^3 = 10^{-1} = 0.1

$[H^+]$ in 30 cm^3 = 10^{-5} = 0.00001

Total amount of H^+ = (10/1000 x 0.1) + (30/1000 x 0.00001) = 0.0010003 mol

$[H^+]$ = 0.0010003 / (40/1000)

= 0.0250 mol dm^{-3}

pH = $-\log_{10}[H^+]$ = $-\log_{10}$ (0.0250) = 1.6

Ans: (A)

16 Which of the following is a general trend from left to right of the elements in the third period of the Periodic Table?

A The radii of the atoms increase.

B The melting points of the chlorides decrease.

C The electrical conductivity of the elements decrease.

D The first ionisation energies of the elements increase.

Across the period, the effective nuclear charge of the element increases, Hence, more energy is required to remove the valence electrons and ionisation energies increases.

Ans: (D)

17 Which element has a chloride with a simple molecular structure that is readily hydrolysed in water?

A sodium

B magnesium

C aluminium

D silicon

$SiCl_4$ has a simple molecular structure and is completely hydrolysed in water.

18 Which property decreases from Na_2O to P_4O_{10} for the oxides of period 3 elements?

A melting point

B covalent character

C solubility in aqueous alkali

D pH when mixed with water

pH of Na_2O in water = 13; pH of MgO in water = 9; pH of Al_2O_3 and SiO_2 = 7, P_4O_{10} = 3

Ans: (D)

19 Linoleic acid is an essential fatty acid with the structural formula.

$CH_3(CH_2)_4CH{=}CHCH_2CH{=}CH(CH_2)_7CO_2H$

Which of the following statements about linoleic acid is correct?

A It undergoes electrophilic substitution with liquid bromine.

B It undergoes oxidation with acidified potassium dichromate(VI) solution.

C 1 mole of linoleic acid requires 48 dm^3 of hydrogen for hydrogenation at room temperature.

D 1 mole of linoleic acid reacts with 1 mole of sodium carbonate to form 24 dm^3 of carbon dioxide at room temperature.

1 mole of linoleic acid reacts with 2 mole of H_2. 1 mole of gas at r.t.p is 24 dm^3. Hence 24 dm^3 of H_2 is needed.

Ans: (C)

20 Which property of benzene is reflected as a consequence of the delocalised electrons in its molecule?

A Benzene is a planar molecule.

B Benzene is a good conductor of electricity.

C Substitution in benzene takes place at a carbon atom.

D Addition reactions of benzene take place more easily than substitution.

Benzene is resonance stabilised by the delocalised electrons present in its molecule. Hence it will undergo substitution instead of addition reaction.

Ans: (C)

21 The volatile liquid, fluothane, $CF_3CHBrCl$, is a widely used anaesthetic.

Which statement about fluothane is **incorrect**?

A It has a simple molecular structure.

B It may cause depletion of ozone layer.

C It may undergo substitution with chlorine.

D It can form hydrogen bonds between its molecules.

The hydrogen is not bonded to F,O and N hence it is not able to form hydrogen bonds between its molecules.

Ans: (D)

22 A compound **V** gives yellow precipitate with alkaline aqueous iodine. One mole of **V** liberates one mole of hydrogen when it reacts with excess sodium.

What could be the formula of **V**?

A $CH_3CH(OH)CHO$

B $CH_3CH(OH)CO_2H$

C $HOCH_2CH_2CO_2H$

D $HOCH_2CH(CH_3)CH_2OH$

$CH_3CH(OH)$- gives yellow ppt with alkaline aqueous iodine. It has –OH and –COOH group which reacts with 2 moles of sodium to form 1 mole of H_2.

Ans: (B)

23 A compound, **W**, has the following properties.

- It reacts with hydrogen in the presence of nickel catalyst.
- It reacts with phosphorus pentachloride to give off HCl fumes.
- It reacts with sodium hydroxide to form an ionic compound.
- It reacts with ethanol.

What formula could represent **W**?

A CH_3CHO

B CH_3COCH_3

C $CH_2{=}CHCO_2H$

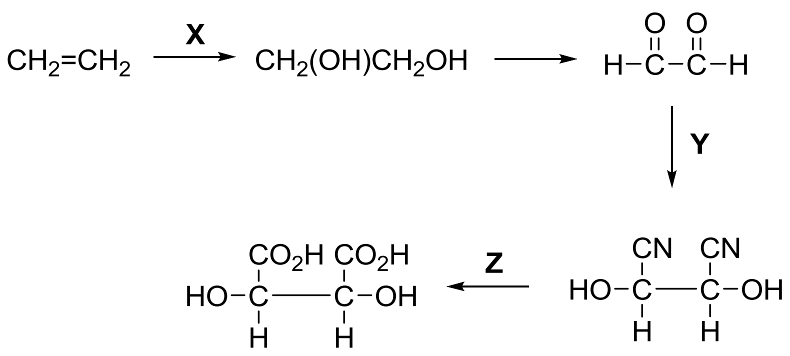
D $CH_2{=}CHCH_2OH$

- Carboxylic acid functional group reacts with NaOH to form $–CO_2^-Na^+$ an ionic compound.
- Carboxylic acid functional group reacts with PCl_5 to form $RCOCl$ and HCl.
- Alkene functional group present to reacts with H_2 in the presence of Ni catalyst.
- Carboxylic acid functional group reacts with alcohol to form ester.

X has both carboxylic acid and alkene functional groups.

Ans: (C)

24 The following is a method of synthesising tartaric acid, a compound found in wine.



Which set of reagents and conditions can be used for the synthesis?

	X	Y	Z
A	cold concentrated H_2SO_4, followed by boiling H_2O	cold HCN, NaOH(aq)	hot $K_2Cr_2O_7$, H_2SO_4(aq)
B	cold $KMnO_4$, H_2SO_4(aq)	cold HCN, NaOH(aq)	HCl(aq), heat
C	cold concentrated H_2SO_4, followed by boiling H_2O	ethanolic KCN, heat	hot $K_2Cr_2O_7$, H_2SO_4(aq)
D	cold $KMnO_4$, NaOH(aq)	ethanolic KCN, heat	HCl(aq), heat

Mild oxidation of **X** with cold $KMnO_4$, H_2SO_4(aq) to form diol.

Addition of carbonyl functional group with cold HCN, NaOH(aq) to form cyanohydrin.

Acidic hydrolysis of nitrile group to form carboxylic acid.

Ans: (B)

25 Which of the following shows the descending order of acid strength?

A CH_3CO_2H > $CH_2C\mathit{l}CO_2H$ > CH_3CH_2OH

B CH_3CH_2OH > $CH_2C\mathit{l}CO_2H$ > CH_3CO_2H

C $CH_2C\mathit{l}CO_2H$ > CH_2FCO_2H > CH_3CH_2OH

D $CH_2C\mathit{l}CO_2H$ > CH_2BrCO_2H > CH_3CO_2H

F being more electronegative than C*l* can better disperse the negative charge on the conjugate base, hence stabilising the conjugate base more, therefore CH_2FCO_2H is the most acidic.

C*l* being more electronegative than Br can better disperse the negative charge on the conjugate base, hence stabilising the conjugate base more, therefore $CH_2C\mathit{l}CO_2H$ is more acidic.

CH_3CO_2H is more acidic than CH_3CH_2OH due to the negative charge being able to delocalise over the O-C-O bond in the conjugate base, hence forming a resonance structure.

Acid strength:

CH_2FCO_2H > $CH_2C\mathit{l}CO_2H$ > CH_2BrCO_2H > CH_3CO_2H > CH_3CH_2OH

Section B

For each of the following questions, 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 Materials are insulators when the outer shells of electrons of all the constituent particles are completely filled and there is a considerable energy gap before the next unoccupied shell.

Which compounds have completely filled shells and might therefore act as insulators?

1 MgO

2 SiO_2

3 SiC (diamond structure)

MgO has completely filled outer shells as Mg has transferred 2 electrons to oxygen. Ionic compounds in solid states are insulators as there are no free mobile electrons. MgO is sparingly soluble in water, hence no ions are formed.

SiO_2 and SiC are giant molecular structure in a tetrahedral network. Therefore the outer shells are completely filled. They are insulators as there are no free mobile electrons.

Ans: (A)

27 Calcium reacts with water to form calcium hydroxide and hydrogen.

$Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2(s) + H_2(g)$

The standard enthalpy change for this reaction can be determined experimentally.

What further information are needed to calculate the standard enthalpy change of formation of calcium hydroxide, $\Delta H_f^{\ominus}$?

1 $\Delta H_f^{\ominus}$ for $H_2O(l)$

2 $\Delta H_f^{\ominus}$ for $H_2(g)$

3 First and second ionisation energies for Ca

$$Ca(s) + 2H_2O(l) \xrightarrow{\Delta H_r^{\ominus}} Ca(OH)_2(s) + H_2(g)$$

$\Delta H_r^{\ominus} = \sum n\Delta H_f^{\ominus}(\text{products}) - \sum n\Delta H_f^{\ominus}(\text{reactants})$

$= [\Delta H_f^{\ominus}(Ca(OH)_2) + \Delta H_f^{\ominus}(H_2)] - [\Delta H_f^{\ominus}(Ca) + 2\Delta H_f^{\ominus}(H_2O)]$

$= [\Delta H_f^{\ominus}(Ca(OH)_2) - 2\Delta H_f^{\ominus}(H_2O)$

$\Delta H_f^{\ominus}(Ca(OH)_2) = \Delta H_r^{\ominus} + 2\Delta H_f^{\ominus}(H_2O)$

Ans: (D)

28 Which of the following pairs would form an acidic buffer when mixed together?

1 CH_3CO_2H and NaC*l*

2 HCN and KCN

3 $C_6H_5CO_2H$ and $(C_6H_5CO_2)_2Ca$

An acidic buffer is made up of weak acid and its conjugate base. HCN and $C_6H_5CO_2H$ are both weak acid. KCN and $(C_6H_5CO_2)_2Ca$ are the respective conjugate base.

Ans: (C)

29 A halogenoalkane has the formula of $C_3H_5Cl_3$.

Which of the isomers have the correct IUPAC name?

1 1,1,1-trichloropropane

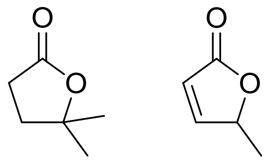
2 1,2,2-trichloropropane

3 2,2,3-trichloropropane

2,2,3- trichloropropane is the same as 1,2,2-trichloropropane. Smaller numbers are preferred on the IUPAC name.

Ans: (B)

30 Below are the structures of compounds **X** and **Y**.



X **Y**

Which sets of reagents and conditions can be used to distinguish between them?

1 aqueous bromine

2 acidified $K_2Cr_2O_7$, heat

3 alkaline aqueous iodine, heat

For **1**, C=C in **Y** will decolourise orange-red Br_2(aq). No decolouisation of Br_2(aq) for **X**.

For **2**, ester group in **X** undergoes acid hydrolysis to form tertiary alcohol which cannot be oxidised by $K_2Cr_2O_7$. There is no change in the colour of solution. However, the acid hydrolysis of **Y** formed secondary alcohol which can be oxidised by $K_2Cr_2O_7$. The colour of solution changes from orange to green.

For **3**, both the ester groups in **X** and **Y** undergo base hydrolysis. However, only **Y** shows a positive iodoform test due to presence of $CH_3CH(OH)$– group after hydrolysis.

Ans: (A)

--- End of Paper ---

Name:		Class:	

ST ANDREW'S JUNIOR COLLEGE

Preliminary Examinations

Chemistry **8872/2**

Higher 1 **11 Sep 2017**

Paper 2 **1300 – 1500**

Candidates answer on separate paper.

Additional Materials: Writing paper, graph paper, Data Booklet

READ THESE INSTRUCTIONS FIRST
Write your name and civics group on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A:
Answer **all** the questions in this section in the spaces provided.

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

You are reminded of the need for good English and clear presentation in your answers. The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiners use only:

Section A		Section B	
Question	**Marks**	**Question**	**Marks**
1	/ 9	1	/ 20
2	/ 14	2	/ 20
3	/ 7	3	/ 20
4	/ 10		
Total	/ 40	**Total**	/ 40
TOTAL (Section A + Section B)			/ 80

This document consists of **17** pages including a blank page.

[BLANK]

Section A

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

1. Apricot kernels containing glycoside amygdalin turns into deadly hydrogen cyanide acid, HCN, when the kernel is crushed. High doses of hydrogen cyanide can cause coma with seizures and cardiac arrest, leading to death in a matter of minutes. A fatal dose for a human can be as low as 1.50 mg kg^{-1} of body weight.

(1 mg = 1.00 x 10^{-3} g)

The forensics department of the local law enforcement agency was trying to determine the cause of death of a 90 kg deceased man who was found at home on the couch with a few empty packets of apricot kernels lying on the ground.

A typical human has 70 cm^3 of blood per kg of body mass. A 10 cm^3 sample of blood was obtained from the body and dissolved to form 25 cm^3 of solution. The amount of HCN can be determined through the amount of Fe^{2+} present in the blood. The Fe^{2+} required 1.70 cm^3 of 0.00100 mol dm^{-3} acidified $Na_2Cr_2O_7$ solution for complete reaction.

(a) Write a balanced redox equation between Fe^{2+} and $Cr_2O_7^{2-}$. **[1]**

……………………………………………………………………………………………

(b) Show by oxidation number that the reaction in **(a)** is a redox reaction. **[2]**

……………………………………………………………………………………………

……………………………………………………………………………………………

(c) Calculate the number of moles of hydrogen cyanide, HCN, in the 25 cm^3 of solution. **[2]**

1 **(d)** Calculate the number of moles of hydrogen cyanide, HCN, in the body of the deceased man. **[1]**

(e) Calculate the concentration of HCN in mg kg^{-1} and hence determine if the cause of death was due to hydrogen cyanide poisoning. **[3]**

[Total: 9]

2. This question is about nitrogen and its compounds.

(a) NO_2 is highly reactive and usually exists in the more stable form of N_2O_4.

(i) Draw a diagram to illustrate the shape of the molecule, N_2O_4, and state the bond angle about the N atom. **[2]**

Bond angle: …………………………….....

(ii) Draw the dot-and-cross diagram of NO_2 and hence suggest a reason why NO_2 is expected to be highly reactive. **[2]**

……………………………………………………………………………………..

……………………………………………………………………………………..

(iii) Explain why the bond angle for NO_2 is greater than 120°. **[2]**

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

2 **(b)** At room temperature and pressure, NO_2 dimerises to form dinitrogen tetraoxide, N_2O_4, as shown below:

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta H < 0$$

(i) Write the expression for the equilibrium constant, K_c, for the above equilibrium, stating its units. **[2]**

Units: ………………………

(ii) At 298 K and 101 kPa, 1.00 g of NO_2 was placed in the reaction chamber initially. When equilibrium was established, the gaseous mixture was found to occupy a volume of 0.317 dm^3 and showed an average M_r of 77.3. The average M_r of the mixture can be calculated using the following expression, **[2]**

$$\text{Ave } M_r = \frac{[n_{eqm}(NO_2) \times M_r(NO_2)] + [n_{eqm}(N_2O_4) \times M_r(N_2O_4)]}{\text{Total number of moles at equilibrium}}$$

where n_{eqm} = number of moles at equilibrium

Fill in the table below and use the expression given above to solve for the value of y.

	NO_2	N_2O_4
Initial/ mol		
Change/ mol	$-2y$	$+y$
Equilibrium/ mol		y

2 **(b)** **(iii)** Hence, calculate the value of K_c. **[2]**

(iv) Describe how the average M_r will be affected when pressure decreases. **[2]**

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

[Total: 14]

3. Many biological processes only occur within a narrow range of pH values. The pH of different fluids found in the body is given below:

Body Fluid	**pH**
Saliva	6.8
Blood	7.4
Stomach juices	1.0 - 3.0
Intestinal juices	8.5

(a) Calculate the hydroxide ion concentration in intestinal juices. **[2]**

(b) The low pH in the human stomach is due to the existence of hydrochloric acid, which is known to be a *strong Brønsted-Lowry acid*. Explain the terms in italics. **[2]**

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

(c) The body maintains the pH of blood within a narrow range of values. Death could result if the blood pH decreases below 6.8 or increases above 7.8. The need to maintain the pH within a narrow range of values requires the use of a buffer. In blood, the main buffering system is the H_2CO_3 / HCO_3^- buffer.

(i) What do you understand by the term *buffer* solution? **[1]**

…………………………………………………………………………………..

…………………………………………………………………………………..

3 (c) (ii) Write equations to show how the H_2CO_3/HCO_3^- buffer system regulates the acidity on the addition of a small amount of H^+ and OH^-. [2]

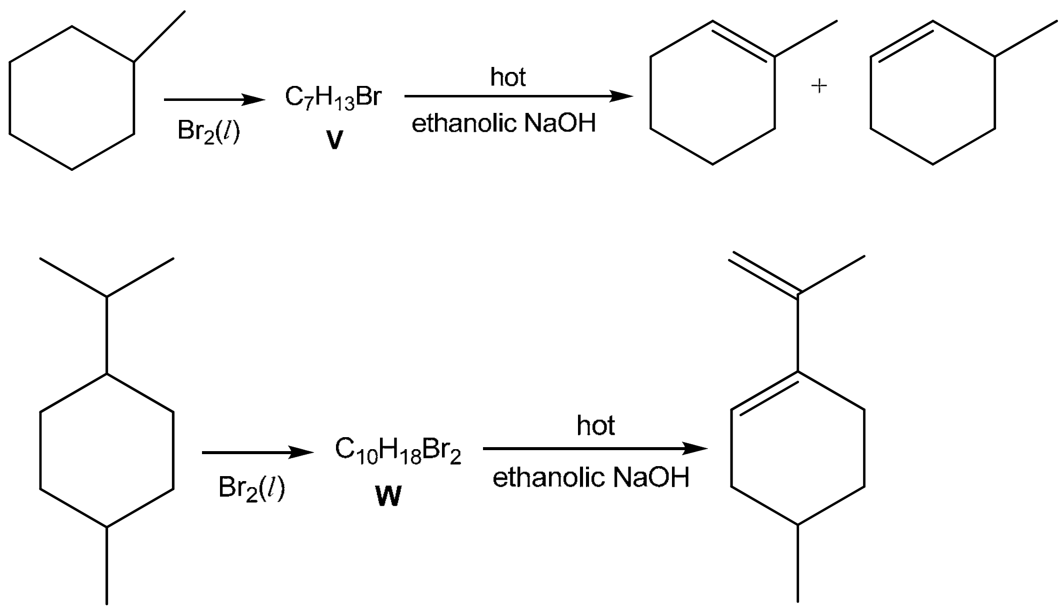
…………………………………………………………………………………….

…………………………………………………………………………………….

…………………………………………………………………………………….

[Total: 7]

4. Alkenes are very useful compounds and can be used as fuels and in the manufacture of a wide variety of polymers. The following reactions involve the formation of some alkenes.



only 1 product formed

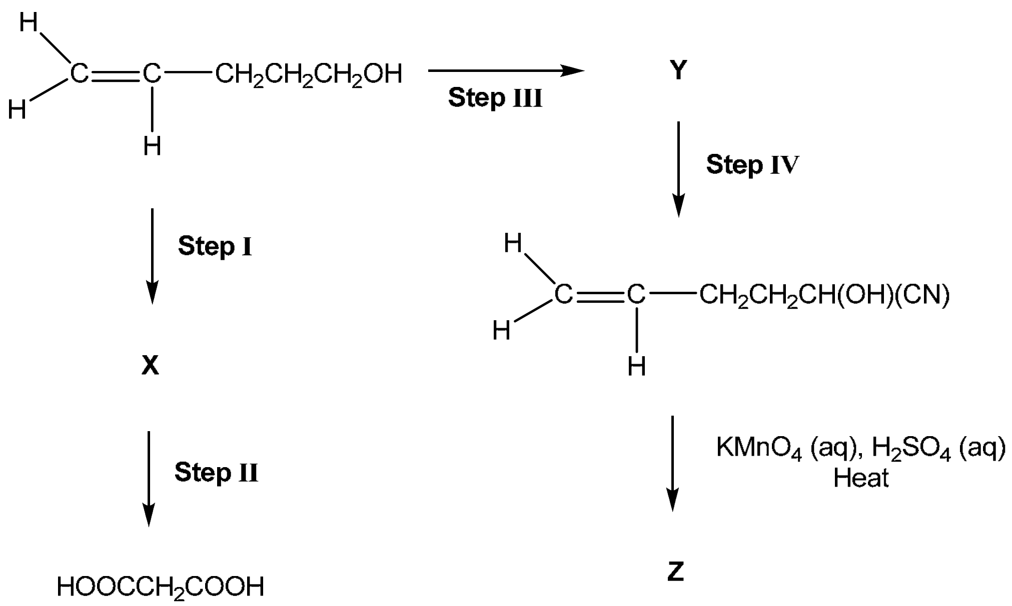
(a) What is the type of reaction for the reaction of the hydrocarbons with $Br_2(l)$ to form **V** and **W?** **[1]**

……………………………………………………………………………………………

4 **(b)** Suggest the skeletal structure of **V** and **W.** **[2]**

Structure **V**	Structure **W**

(c) The flow chart below involves the reaction of pent-4-en-1-ol.



4 (c) (i) Draw the structural formulae of **X**, **Y** and **Z**. **[3]**

Structure **X**	Structure **Y**
Structure **Z**	

(ii) State the reagents and conditions for steps **I – IV** in the spaces provided. **[4]**

	Reagents and Conditions
Step I	
Step II	
Step III	
Step IV	

[Total: 10]

--- END OF SECTION A ---

Section B

Answer 2 out of 3 questions.

1. The Andrussow oxidation is invented by Leonid Andrussow in which methane and ammonia react in the presence of oxygen, over platinum catalyst, to produce hydrogen cyanide.

$$2CH_4(g) + 2NH_3(g) + 3O_2(g) \rightarrow 2HCN(l) + 6H_2O(l)$$

(a) Draw the dot-and-cross diagram for HCN. State the shape and bond angle. **[3]**

(b) **(i)** Calculate the standard enthalpy change of the above reaction using the data below. **[2]**

	$\Delta H_f^\ominus$ / kJ mol^{-1}
CH_4	–74.9
NH_3	–45.9
HCN	+130.5
H_2O	–285.8

(ii) Using data from the *Data Booklet*, calculate another value for the standard enthalpy change of the above reaction. **[3]**

(iii) Explain why the two values differ in **(b)(i)** and **(b)(ii)**. **[1]**

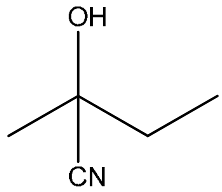
(c) The data below shows the boiling points of HCN and NaCN, and their solubility in water.

	Boiling Point / °C	Solubility in water
HCN	25.6	Miscible
NaCN	1496	Miscible

(i) Explain, in terms of structure and bonding, the difference between the boiling points of HCN and NaCN. **[3]**

(ii) Explain with the aid of a diagram the solubility of NaCN in water. **[3]**

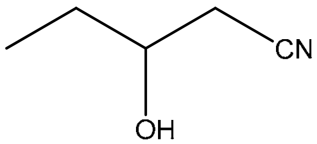
1 **(d)** Hydrogen cyanide is used as a reagent in the formation of cyanohydrin. The structure below shows an example of a cyanohydrin.



(i) Draw the structure of the organic compound that forms the cyanohydrin above. **[1]**

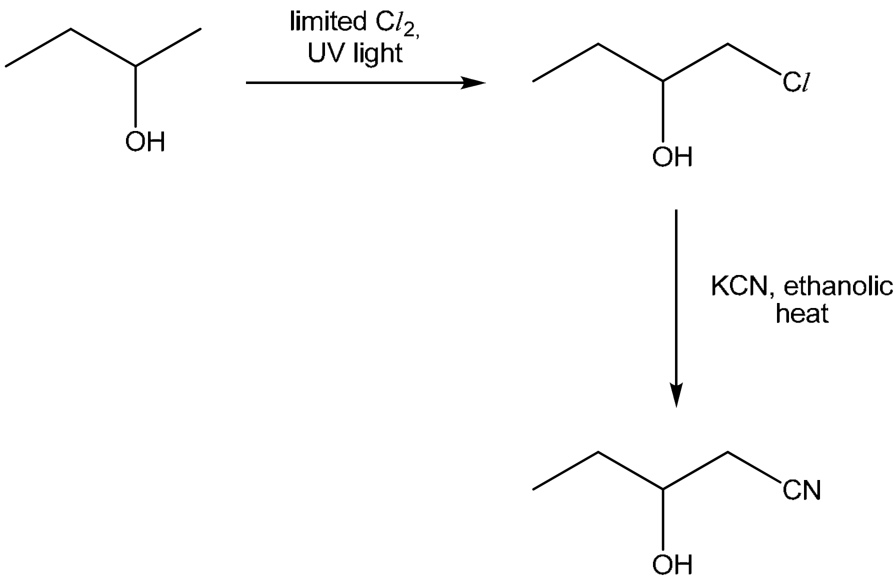
(ii) Suggest why the reaction needs to be performed at a low temperature. **[1]**

(iii) The structure below is an isomer of the cyanohydrin above. **[2]**



Outline a simple chemical test to distinguish between the two compounds.

(iv) A student suggested that the isomer can be synthesised in the following reaction scheme. Suggest why this synthesis is not the best method. **[1]**



[Total: 20]

2. Rocket propellant is a high oxygen containing fuel, whose combustion takes place, in a definite and controlled manner with the evolution of a huge volume of gas. There are four main types of chemical rocket propellants: solid, storable liquid, cryogenic liquid and liquid monopropellant. Solid propellant rocket has a higher propellant density than liquid propellant rocket.

(a) Suggest an advantage of using a solid propellant rocket rather than a liquid propellant rocket. **[1]**

During the 1950s, researchers in the United States developed ammonium perchlorate composite propellant, a type of solid propellant. This mixture is made up of finely ground ammonium perchlorate, fine aluminium powder and polybutadiene acrylonitrile.

(b) Ammonium perchlorate undergoes mild heating according to the equation below.

$$4NH_4ClO_4(s) \rightarrow 4HCl(g) + 2N_2(g) + 5O_2(g) + 6H_2O(l)$$

(i) Calculate the volume of gases formed when 25 g of ammonium perchlorate is heated. (All volumes are measured at room temperature and pressure.) **[2]**

(ii) Suggest why strong heating may lead to an explosion. **[1]**

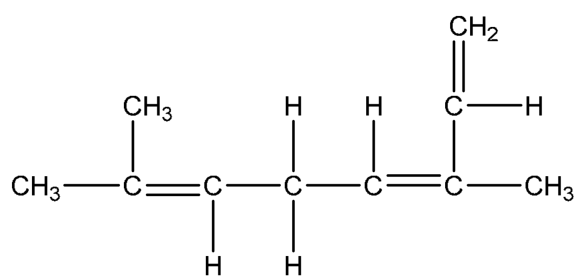
(c) **(i)** Explain why the first ionisation energy of magnesium is higher than that of aluminium. **[2]**

(ii) Explain the difference in electrical conductivity of magnesium, aluminium and silicon. **[2]**

The Soviet utilised syntin, a liquid propellant, for Soyuz U2, is a type of carrier rocket, until 1995. Syntin comprises of synthetic cyclopropane, $C_{10}H_{16}$.

(d) When 0.75 g of cyclopropane undergoes complete combustion, the increase in temperature of 250 cm^3 of water is 18°C and has an efficiency is 85%. Calculate the standard enthalpy change of combustion of cyclopropane. **[3]**

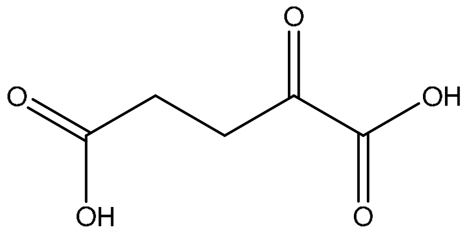
(e) Ocimene is an isomer of syntin with the following structure.



(i) Draw the cis and trans isomers of Ocimene. **[2]**

(ii) Explain why ocimene is able to exhibit cis-trans isomerism. **[2]**

2 (f) **W** is another isomer of syntin, with a molecular formula of $C_{10}H_{16}$. When **W** reacts with hot acidified potassium manganate(VII), it forms 2 moles of gas **X**, **Y**, and the product shown below [5]



X forms a white precipitate when it reacts with aqueous calcium hydroxide.

Y, C_3H_6O, forms a yellow precipitate when it reacts with aqueous alkaline iodine. **Y** also forms an orange precipitate when it reacts with 2,4–dinitrophenylhydrazine. However, **Y** does not form a sliver mirror when it is warmed with Tollens' Reagent.

Deduce the structures of **W**, **X** and **Y**.

[Total: 20]

3 **(a)** A solution of hydrogen peroxide in aqueous HC*l* slowly oxidises bromide ions according to the equation below.

$$H_2O_2 + 2Br^- + 2H^+ \rightarrow Br_2 + 2H_2O$$

The rate of reaction was followed by measuring the concentration of the remaining hydrogen peroxide after fixed time intervals. Two experiments were carried out, starting with different concentrations of bromide ions. The following results were obtained.

Time / min	Experiment 1 $[Br^-]$ = 1.00 mol dm^{-3}	Experiment 2 $[Br^-]$ = 1.50 mol dm^{-3}
	$[H_2O_2]$/ mol dm^{-3}	$[H_2O_2]$/ mol dm^{-3}
0	0.0100	0.0100
40	0.0078	0.0069
80	0.0061	0.0048
120	0.0048	0.0033
160	0.0037	0.0023
200	0.0028	0.0016

(i) Using the same axes, plot graphs of $[H_2O_2]$ against time for the two experiments. **[2]**

(ii) Use your graphs to determine the order of reaction with respect to $[H_2O_2]$ and to $[Br^-]$, showing your workings clearly. **[4]**

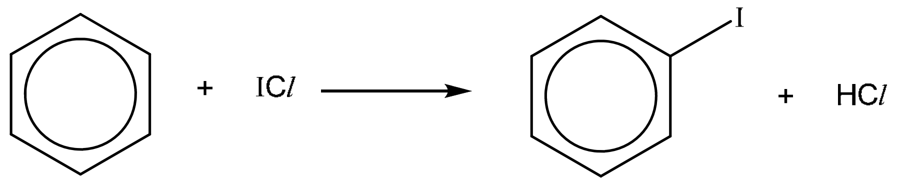
(iii) In another separate experiment, it was found that the order of reaction with respect to [HC*l*] is zero, write the rate equation for the reaction. **[1]**

(iv) Sketch a graph of rate against concentration of H_2O_2. **[1]**

(v) Explain, with an appropriate sketch of the Boltzmann distribution, how an increase in temperature affects the rate of reaction. **[3]**

(b) Explain the difference in ionic radius between Br^- and I^-. **[2]**

3 (c) Aromatic halogenation with iodine monochloride, ICl, produces aryl iodide.



This reaction is typically catalysed by aluminium chloride when it reacts with iodine monochloride to produce the electrophile I^+.

$$ICl + AlCl_3 \longrightarrow [AlCl_4]^- + I^+$$

(i) Draw the structure of $[AlCl_4]^-$ and suggest in terms of bonding how $[AlCl_4]^-$ is formed from $AlCl_3$. **[2]**

(ii) When sodium carbonate is added to a solution of $AlCl_3$, effervescence was seen. Explain the observation with the aid of relevant equations. **[3]**

(iii) Ethanolic silver nitrate is added to iodobenzene and iodopropane in two separate test tubes. Yellow precipitate is seen immediately in one of the test tubes, whereas no precipitate is seen in the other test tube. Explain the observations. **[2]**

[Total: 20]

--- THE END ---

Name:		Class:	

ST ANDREW'S JUNIOR COLLEGE

Preliminary Examinations

Chemistry **8872/2**

Higher 1 **11 Sep 2017**

Paper 2 **1300 – 1500**

Candidates answer on separate paper.

Additional Materials: Writing paper, graph paper, Data Booklet

READ THESE INSTRUCTIONS FIRST
Write your name and civics group on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A:
Answer **all** the questions in this section in the spaces provided.

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

You are reminded of the need for good English and clear presentation in your answers. The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiners use only:

Section A		Section B	
Question	**Marks**	**Question**	**Marks**
1	9	1	20
2	14	2	20
3	7	3	20
4	10		
Total	40	**Total**	40
TOTAL (Section A + Section B)			80

This document consists of **17** pages including a blank page.

[BLANK]

Section A

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

1. Apricot kernels containing glycoside amygdalin turns into deadly hydrogen cyanide acid, HCN, when the kernel is crushed. High doses of hydrogen cyanide can cause coma with seizures and cardiac arrest, leading to death in a matter of minutes. A fatal dose for a human can be as low as 1.50 mg kg^{-1} of body weight.

(1 mg = 1.00 x 10^{-3} g)

The forensics department of the local law enforcement agency was trying to determine the cause of death of a 90 kg deceased man who was found at home on the couch with a few empty packets of apricot kernels lying on the ground.

A typical human has 70 cm^3 of blood per kg of body mass. A 10 cm^3 sample of blood was obtained from the body and dissolved to form 25 cm^3 of solution. The amount of HCN can be determined through the amount of Fe^{2+} present in the blood. The Fe^{2+} required 1.70 cm^3 of 0.00100 mol dm^{-3} acidified $Na_2Cr_2O_7$ solution for complete reaction.

(a) Write a balanced redox equation between Fe^{2+} and $Cr_2O_7^{2-}$. **[1]**

$6Fe^{2+} + Cr_2O_7^{2-} + 14H^+ \rightarrow 6Fe^{3+} + 7H_2O + 2\ Cr^{3+}$ [1]

(b) Show by oxidation number that the reaction in **(a)** is a redox reaction. **[2]**

Fe changed from +2 in Fe^{2+} to +3 in Fe^{3+} (oxidation) [1]

Cr changed from +6 in $Cr_2O_7^{2-}$ to +3 in Cr^{3+} (reduction) [1]

(c) Calculate the number of moles of hydrogen cyanide, HCN, in the 25 cm^3 of solution. **[2]**

Amount of $Cr_2O_7^{2-}$ reacted = (1.70/1000) x 0.001 = 1.70 x 10^{-6} mol [1]

Amount of Fe^{2+} in 25 cm^3 of solution

= 6 x 1.70 x 10^{-6}

= 1.02 x 10^{-5} mol

= Amount of HCN [1]

(d) Calculate the number of moles of hydrogen cyanide, HCN, in the body of the deceased man. **[1]**

Amount of HCN in the body = (70/10) x 90 x 1.02 x 10^{-5} = 0.006426 mol [1]

(e) Calculate the concentration of HCN in mg kg^{-1} and hence determine if the cause of death was due to hydrogen cyanide poisoning. **[3]**

Mass of HCN in the body

= 0.006426 x (1.0 + 12.0 + 14.0) = 0.1735 g = 173.5 mg [1]

[HCN] = 173.5 / 90.0 = 1.93 mg kg^{-1} [1]

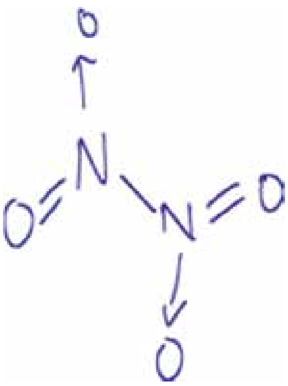
Since 1.93 mg kg^{-1} > 1.50 mg kg^{-1}, therefore the death is due to HCN poisoning. [1]

[Total: 9]

2. This question is about nitrogen and its compounds.

(a) NO_2 is highly reactive and usually exists in the more stable form of N_2O_4.

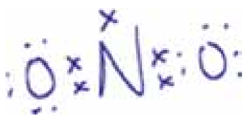
(i) Draw a diagram to illustrate the shape of the molecule, N_2O_4, and state the bond angle about the N atom. **[2]**



[1]

120° about N [1]

(ii) Draw the dot-and-cross diagram of NO_2 and hence suggest a reason why NO_2 is expected to be highly reactive. **[2]**



[1]

There is an unpaired electron on N / NO_2 is a radical. [1]

(iii) Explain why the bond angle for NO_2 is greater than 120°. **[2]**

NO_2 has a <u>lone electron and two bond pairs</u> [1]. The <u>lone electron-bond pair repulsion is lesser than the bond pair-bond pair repulsion</u> [1] in a trigonal planar shape, hence the angle is larger than 120°.

(b) At room temperature and pressure, NO_2 dimerises to form dinitrogen tetraoxide, N_2O_4, as shown below:

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta H < 0$$

(i) Write the expression for the equilibrium constant, K_c, for the above equilibrium, stating its units. **[2]**

$K_c = [N_2O_4] / [NO_2]^2$ [1]

Units: $mol^{-1}\ dm^3$ [1]

(ii) At 298 K and 101 kPa, 1.00 g of NO_2 was placed in the reaction chamber initially. When equilibrium was established, the gaseous mixture was found to occupy a volume of 0.317 dm^3 and showed an average M_r of 77.3. The average M_r of the mixture can be calculated using the following expression, **[2]**

$$\text{Ave } M_r = \frac{[n_{eqm}(NO_2) \times M_r(NO_2)] + [\, n_{eqm}(N_2O_4) \times M_r(N_2O_4)]}{\text{Total number of moles at equilibrium}}$$

where n_{eqm} = number of moles at equilibrium

Fill in the table below and use the expression given above to solve for the value of y.

	NO_2	N_2O_4
Initial/ mol	1/46	0
Change/ mol	$-2y$	$+y$
Equilibrium/ mol	$1/46 - 2y$	y

[1]

$$\frac{[(1/46 - 2y) \times 46] + [y \times 92]}{(1/46 - y)} = 77.3$$

y = 0.00880 [1]

(iii) Hence, calculate the value of K_c. **[2]**

$n_{eqm}(N_2O_4)$ = y = 0.00880 mol

$n_{eqm}(NO_2)$ = 0.00414 mol

$[N_2O_4]$ = 0.00880 / 0.317 = 0.0278 mol dm^{-3}

$[NO_2]$ = 0.00414 / 0.317 = 0.0131 mol dm^{-3} [1]

$K_c = 0.0278 / (0.0131)^2 = 162\ mol^{-1}\ dm^3$ [1]

(iv) Describe how the average M_r will be affected when pressure decreases. **[2]**

Average M_r will decrease [1]. Equilibrium position shifts to the left to form more gaseous particles [1], hence more NO_2 will be formed, leading to lower average M_r.

[Total: 14]

3. Many biological processes only occur within a narrow range of pH values. The pH of different fluids found in the body is given below:

Body Fluid	**pH**
Saliva	6.8
Blood	7.4
Stomach juices	1.0 - 3.0
Intestinal juices	8.5

(a) Calculate the hydroxide ion concentration in intestinal juices. **[2]**

$[H^+] = 10^{-8.5} = 3.16 \times 10^{-9}$ [1]

$[OH^-] = 10^{-14} / 3.16 \times 10^{-9} = 3.16 \times 10^{-6}$ mol dm^{-3} [1]

(b) The low pH in the human stomach is due to the existence of hydrochloric acid, which is known to be a *strong Brønsted-Lowry acid*. Explain the terms in italics. **[2]**

A strong Brønsted-Lowry acid is a substance that dissociates fully [1] to donate H^+ [1].

(c) The body maintains the pH of blood within a narrow range of values. Death could result if the blood pH decreases below 6.8 or increases above 7.8. The need to maintain the pH within a narrow range of values requires the use of a buffer. In blood, the main buffering system is the H_2CO_3 / HCO_3^- buffer.

(i) What do you understand by the term *buffer* solution? **[1]**

A buffer solution is one that can resist a change in pH (pH changes only very slightly) when a small amount of acid or base is added to it. [1]

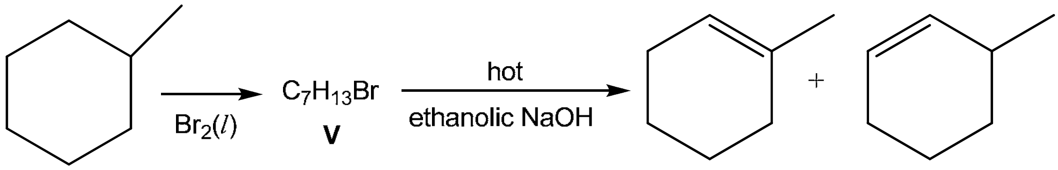
(ii) Write equations to show how the H_2CO_3/HCO_3^- buffer system regulates the acidity on the addition of a small amount of H^+ and OH^-. **[2]**

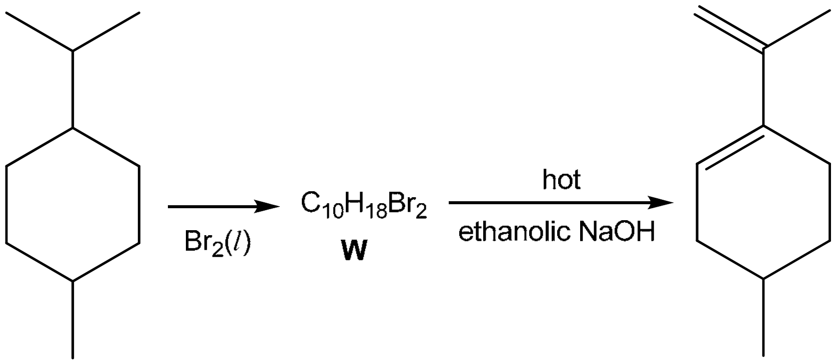
$H_2CO_3(aq) + OH^-(aq) \rightarrow H_2O(l) + HCO_3^-(aq)$ [1]

$HCO_3^-(aq) + H^+(aq) \rightarrow H_2CO_3(aq)$ [1]

[Total: 7]

4. Alkenes are very useful compounds and can be used as fuels and in the manufacture of a wide variety of polymers. The following reactions involve the formation of some alkenes.



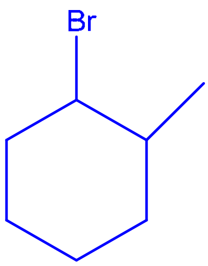


only 1 product formed

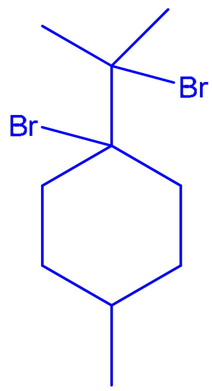
(a) What is the type of reaction for the reaction of the hydrocarbons with $Br_2(l)$ to form **V** and **W?** **[1]**

Free Radical <u>Substitution</u> [1]

(b) Suggest the skeletal structure of **V** and **W.** **[2]**

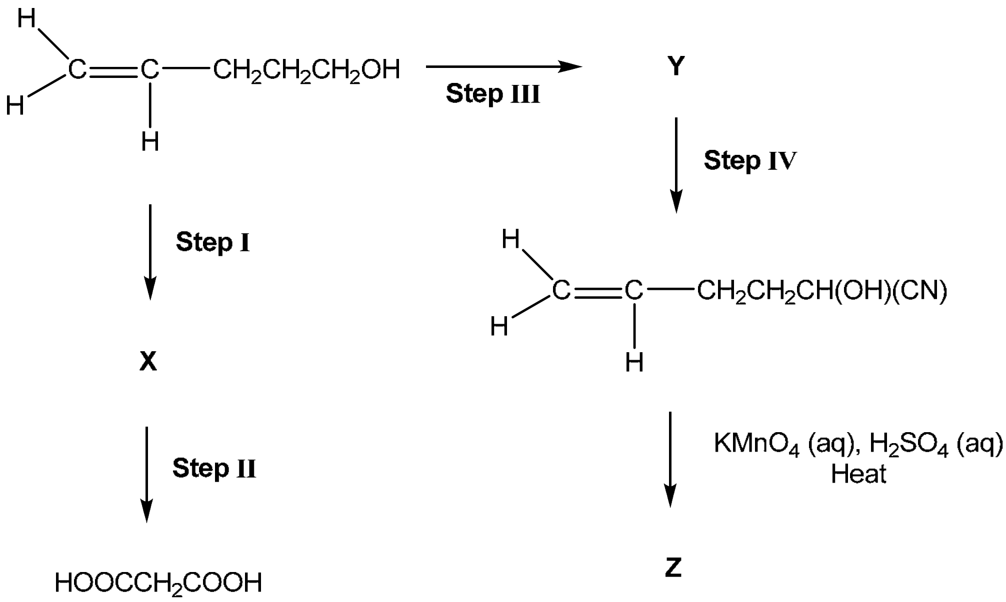


V [1]

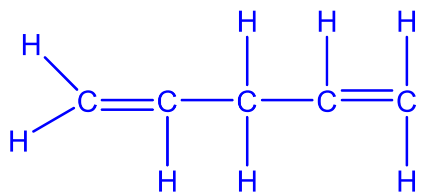


W [1]

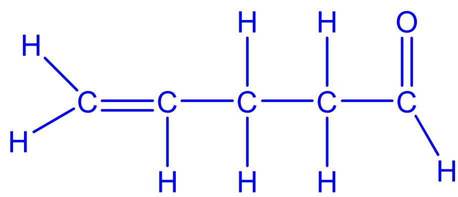
(c) The flow chart below involves the reaction of pent-4-en-1-ol.



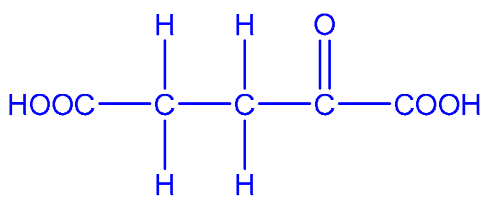
(i) Draw the structural formulae of **X**, **Y** and **Z**. **[3]**



X [1]



Y [1]



Z [1]

(ii) State the reagents and conditions for steps **I – IV** in the spaces provided. **[4]**

	Reagents and Conditions
Step I	Excess conc H_2SO_4, 170°C [1]
Step II	$KMnO_4$ (aq), H_2SO_4 (aq), heat [1]
Step III	$K_2Cr_2O_7$ (aq), H_2SO_4 (aq), heat with distillation [1]
Step IV	HCN, trace NaOH/NaCN, 10 – 20 °C [1]

[Total: 10]

--- END OF SECTION A ---

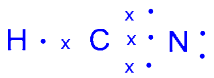
Section B

Answer 2 out of 3 questions.

1. The Andrussow oxidation is invented by Leonid Andrussow in which methane and ammonia react in the presence of oxygen, over platinum catalyst, to produce hydrogen cyanide.

$$2CH_4(g) + 2NH_3(g) + 3O_2(g) \rightarrow 2HCN(l) + 6H_2O(l)$$

(a) Draw the dot-and-cross diagram for HCN. State the shape and bond angle. **[3]**



[1]

Linear [1]

180° [1]

(b) **(i)** Calculate the standard enthalpy change of the above reaction using the data below. **[2]**

	$\Delta H_f^\ominus$ / kJ mol^{-1}
CH_4	–74.9
NH_3	–45.9
HCN	+130.5
H_2O	–285.8

$\Delta H_r^\ominus = \sum n\Delta H_f^\ominus(\text{products}) - \sum n\Delta H_f^\ominus(\text{reactants})$

$= [2(+130.5) + 6(-285.8)] - [2(-74.9) + 2(-45.9)]$ [1]

$= -1212.2$ kJ mol^{-1} [1]

(ii) Using data from the *Data Booklet*, calculate another value for the standard enthalpy change of the above reaction. **[3]**

BE of reactants = 8(C-H) + 6(N-H) + 3(O=O)

= 8(410) + 6(390) + 3(496)

= +7108 kJ mol^{-1} [1]

BE of products = 2(C-H) + 2(C≡N) + 12(O-H)

= 2(410) + 2(890) + 12(460)

= +8120 kJ mol^{-1} [1]

$\Delta H_r^{\ominus}$ = BE (reactants) – BE (products)

= 7108 – 8120

= –1012 kJ mol^{-1} [1]

(iii) Explain why the two values differ in **(b)(i)** and **(b)(ii)**. **[1]**

The enthalpy of reaction calculated using bond energies in the data booklet is for gaseous reactants and products, but in the above calculation, HCN and H_2O is a liquid. [1]

OR

The bond energies values in the data booklet are average values. [1]

(c) The data below shows the boiling points of HCN and NaCN, and their solubility in water.

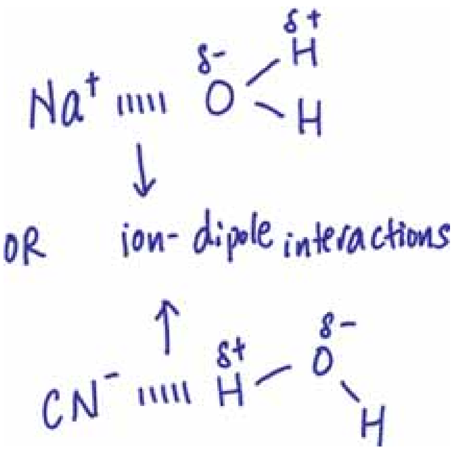
	Boiling Point / °C	Solubility in water
HCN	25.6	Miscible
NaCN	1496	Miscible

(i) Explain, in terms of structure and bonding, the difference between the boiling points of HCN and NaCN. **[3]**

HCN is a polar simple covalent molecule with permanent dipole-permanent dipole interactions [1]. NaCN is a giant ionic lattice structure with electrostatic forces of attraction between Na^+ and CN^- [1]. A greater amount of energy is required the stronger ionic bonds in NaCN. [1]

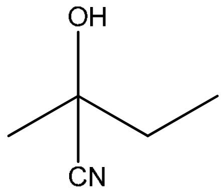
(ii) Explain with the aid of a diagram the solubility of NaCN in water. **[3]**

The energy released from the ion-dipole interactions between NaCN and water is sufficient [1] to overcome the ionic bonds in NaCN and the hydrogen bonds in water [1].

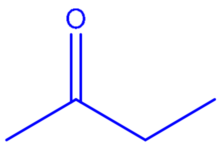


[1]

(d) Hydrogen cyanide is used as a reagent in the formation of cyanohydrin. The structure below shows an example of a cyanohydrin.



(i) Draw the structure of the organic compound that forms the cyanohydrin above. **[1]**

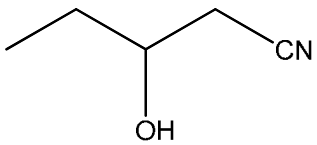


[1]

(ii) Suggest why the reaction needs to be performed at a low temperature. **[1]**

If a high temperature is used, HCN will become a gas which is toxic and it will be difficult to contain the gas. [1]

(iii) The structure below is an isomer of the cyanohydrin above. **[2]**



Outline a simple chemical test to distinguish between the two compounds.

Reagents and conditions: $KMnO_4$ (aq), H_2SO_4 (aq), heat [1]

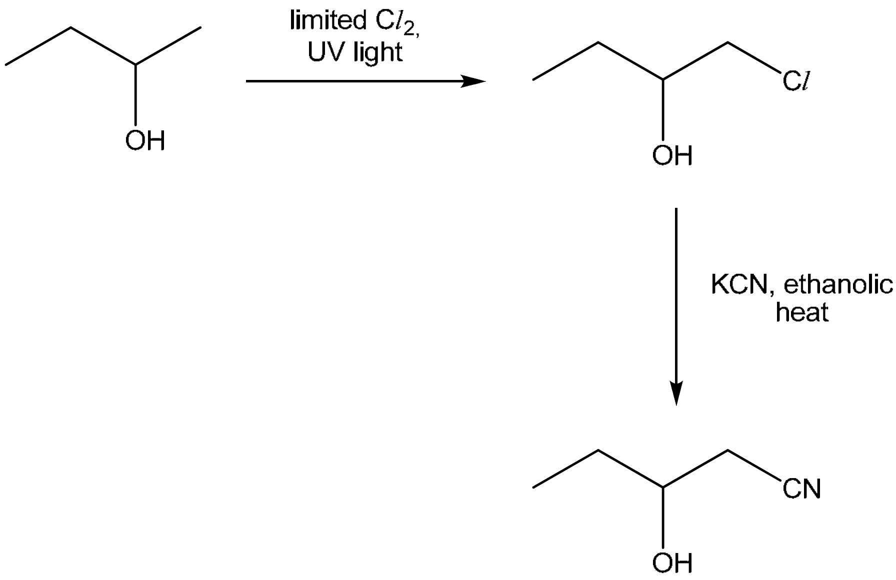
Observation: Purple $KMnO_4$ decolourised for the isomer but purple $KMnO_4$ remains for the cyanohydrin [1]

OR

Reagents and conditions: $K_2Cr_2O_7$ (aq), H_2SO_4 (aq), heat [1]

Observation: Orange $K_2Cr_2O_7$ turned green for the isomer but orange $K_2Cr_2O_7$ remains for the cyanohydrin [1]

(iv) A student suggested that the isomer can be synthesised in the following reaction scheme. Suggest why this synthesis is not the best method. **[1]**



Cl can substitute any of the hydrogen, hence producing a low yield of the product. [1]

[Total: 20]

2. Rocket propellant is a high oxygen containing fuel, whose combustion takes place, in a definite and controlled manner with the evolution of a huge volume of gas. There are four main types of chemical rocket propellants: solid, storable liquid, cryogenic liquid and liquid monopropellant. Solid propellant rocket has a higher propellant density than liquid propellant rocket.

(a) Suggest an advantage of using a solid propellant rocket rather than a liquid propellant rocket. **[1]**

Due to a higher density, the solid propellant rocket has a compact size and thus easier to store. [1]

OR

Solid fuel is able to last longer. [1]

During the 1950s, researchers in the United States developed ammonium perchlorate composite propellant, a type of solid propellant. This mixture is made up of finely ground ammonium perchlorate, fine aluminium powder and polybutadiene acrylonitrile.

(b) Ammonium perchlorate undergoes mild heating according to the equation below.

$$4NH_4ClO_4(s) \rightarrow 4HCl(g) + 2N_2(g) + 5O_2(g) + 6H_2O(l)$$

(i) Calculate the volume of gases formed when 25 g of ammonium perchlorate is heated. (All volumes are measured at room temperature and pressure.) **[2]**

Amount of ammonium perchlorate

= 25 / [14 + 4 + 35.5 + 4(16)] = 0.2127 mol

Amount of gases formed = 0.2127 x 11/4 = 0.5849 mol [1]

Volume of gases formed = 0.5849 x 24 = 14.0 dm^3 [1]

(ii) Suggest why strong heating may lead to an explosion. **[1]**

A large volume of gases are produced. [1]

(c) **(i)** Explain why the first ionisation energy of magnesium is higher than that of aluminium. **[2]**

Mg: $1s^2\ 2s^2\ 2p^6\ 3s^2$

Al: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$

The first electron of A*l* is removed from the 3p orbital is further from the nucleus and also experiences additional screening effect by the two 3s electrons [1]. These factors outweigh the effect of increase in nuclear charge from Mg to A*l*, resulting in a weaker attraction by the nucleus and hence less energy required to remove an electron from 3p than the 3s orbital [1].

Alternative:

The first electron of Mg is removed from the 3s orbital which is closer to the nucleus [1], resulting in a stronger attraction by the nucleus and hence more energy required to remove an electron from the 3s orbital [1].

(ii) Explain the difference in electrical conductivity of magnesium, aluminium and silicon. **[2]**

Aluminium has 3 delocalised valence electrons whereas magnesium has only 2, thus aluminium is a better electrical conductor than magnesium [1]. Silicon is a metalloid thus it is not a good electrical conductor [1].

The Soviet utilised syntin, a liquid propellant, for Soyuz U2, is a type of carrier rocket, until 1995. Syntin comprises of synthetic cyclopropane, $C_{10}H_{16}$.

(d) When 0.75 g of cyclopropane undergoes complete combustion, the increase in temperature of 250 cm^3 of water is 18°C and has an efficiency is 85%. Calculate the standard enthalpy change of combustion of synthetic cyclopropane. **[3]**

Heat absorbed by water = $mc\Delta T$ = 250 x 4.18 x 18 = 18810 J [1]

Heat released by combustion of synthetic cyclopropane

= 100 / 85 x 18810 = 22129 J [1]

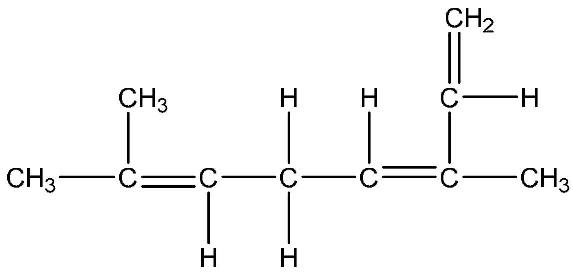
Amount of synthetic cyclopropane = 0.75 / [(10 x 12) + 16] = 0.005514

Standard enthalpy change of combustion of synthetic cyclopropane

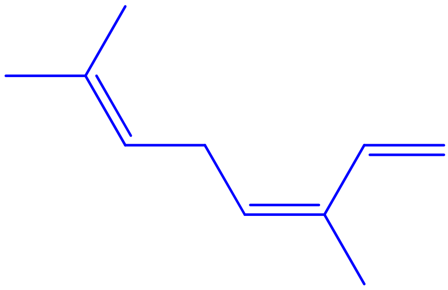
= – 22129 / 0.005514

= – 4013 kJ mol^{-1} [1]

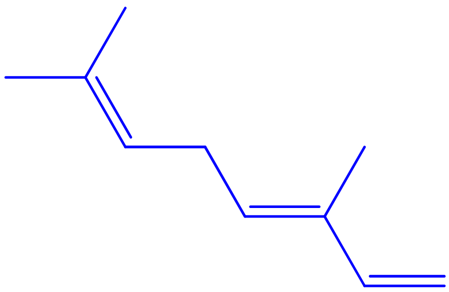
(e) Ocimene is an isomer of syntin with the following structure.



(i) Draw the cis and trans isomers of Ocimene. **[2]**



Cis [1]



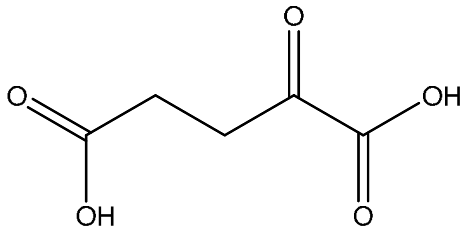
Trans [1]

(ii) Explain why ocimene is able to exhibit cis-trans isomerism. **[2]**

There is <u>restriction of rotation</u> due to the <u>presence of C=C</u>. [1]

There are <u>no two identical atoms or groups of atoms</u> that are bonded to the <u>same carbon on the C=C</u>. [1]

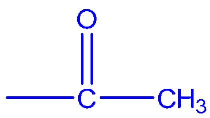
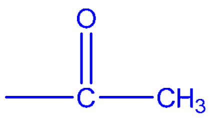
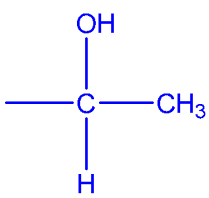
(f) **W** is another isomer of syntin, with a molecular formula of $C_{10}H_{16}$. When **W** reacts with hot acidified potassium manganate(VII), it forms 2 moles of gas **X**, **Y**, and the product shown below **[5]**



X forms a white precipitate when it reacts with aqueous calcium hydroxide.

Y, C_3H_6O, forms a yellow precipitate when it reacts with aqueous alkaline iodine. **Y** also forms an orange precipitate when it reacts with 2,4–dinitrophenylhydrazine. However, **Y** does not form a sliver mirror when it is warmed with Tollens' Reagent.

Deduce the structures of **W**, **X** and **Y**.

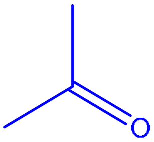
Observations	**Deductions**
X forms a white precipitate when it reacts with aqueous calcium hydroxide.	**X** undergoes acid-base reaction and it is CO_2. [1]
W reacts with hot acidified potassium manganate(VII), it forms 2 moles of gas **X**	**W** undergoes oxidation. Presence of 2 terminal C=C in **W** since **X** is CO_2. [1]
Y, C_3H_6O, forms a yellow precipitate when it reacts with aqueous alkaline iodine.	**Y** undergoes oxidation and contains  . [1] (Do not accept if student gave both  and )
Y also forms an orange precipitate when it react with 2,4–dinitrophenylhydrazine.	**Y** undergoes condensation and is a carbonyl compound. [1]

Y does not form a sliver mirror when it is warmed with Tollens' Reagent.	**Y** does not undergo oxidation and is a ketone. [1]

Deductions total [5], max [2]

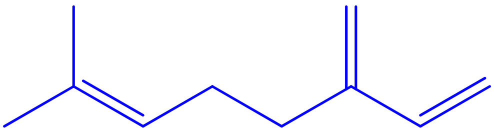
X: CO_2 [1]

Y:



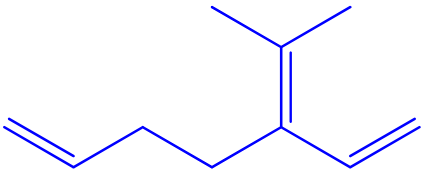
[1]

W:



[1]

OR



[Total: 20]

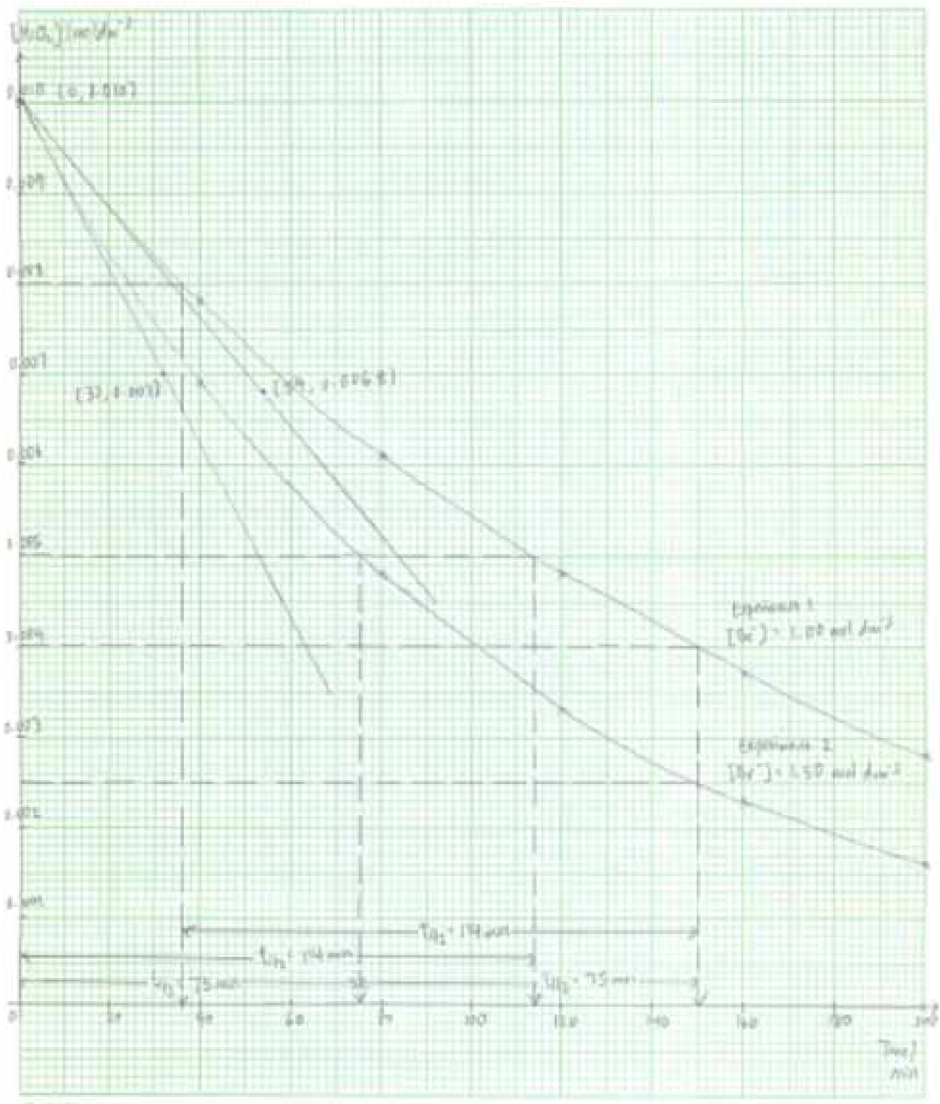
3 **(a)** A solution of hydrogen peroxide in aqueous HC*l* slowly oxidises bromide ions according to the equation below.

$$H_2O_2 + 2Br^- + 2H^+ \rightarrow Br_2 + 2H_2O$$

The rate of reaction was followed by measuring the concentration of the remaining hydrogen peroxide after fixed time intervals. Two experiments were carried out, starting with different concentrations of bromide ions. The following results were obtained.

Time / min	Experiment 1 $[Br^-]$ = 1.00 mol dm^{-3}	Experiment 2 $[Br^-]$ = 1.50 mol dm^{-3}
	$[H_2O_2]$/ mol dm^{-3}	$[H_2O_2]$/ mol dm^{-3}
0	0.0100	0.0100
40	0.0078	0.0069
80	0.0061	0.0048
120	0.0048	0.0033
160	0.0037	0.0023
200	0.0028	0.0016

(i) Using the same axes, plot graphs of [H_2O_2] against time for the two experiments. **[2]**



Each graph [1] x 2

Graph must have the following:

- correct axis with units
- labelling of experiment 1 and 2
- graph plotted accurately
- uses proper scale
- occupy ½ of the graph paper

Minus 1 mark if any of the above is missing.

(ii) Use your graphs to determine the order of reaction with respect to [H_2O_2] and to [Br^-], showing your workings clearly. **[4]**

Two sets of half-life clearly drawn on the graph for experiment 1 or 2.

Experiment 1:

$t_{1/2}$ = 114 min [1]

OR

Experiment 2:

$t_{1/2}$ = 75 min

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

Draw tangent at t = 0.

Initial rate for experiment 1

= |0.010 - 0.0068 / 0 - 54| = 5.926×10^{-5} mol dm^{-3} min^{-1}

Initial rate for experiment 2

= |0.010 - 0.007 / 0 - 32| = 9.375×10^{-5} mol dm^{-3} min^{-1}

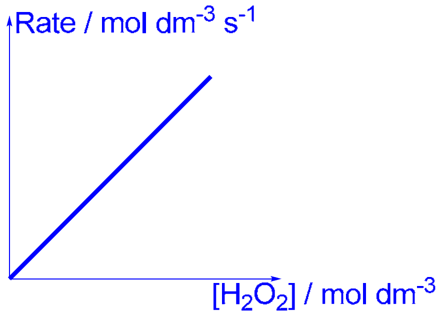
Calculation of 2 initial rates [1]

When $[Br^-]$ increases 1.5 times, the rate increases approximately 1.5 times. Hence the order of reaction with respect to $[Br^-]$ is one. [1]

(iii) In another separate experiment, it was found that the order of reaction with respect to [HC*l*] is zero, write the rate equation for the reaction. **[1]**

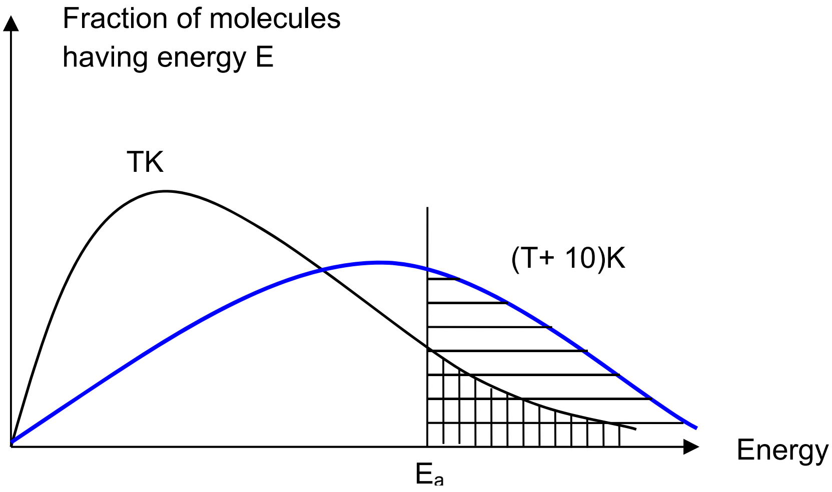
Rate = $k[H_2O_2][Br^-]$ [1]

(iv) Sketch a graph of rate against concentration of H_2O_2. **[1]**



[1]

(v) Explain, with an appropriate sketch of the Boltzmann distribution, how an increase in temperature affects the rate of reaction. **[3]**



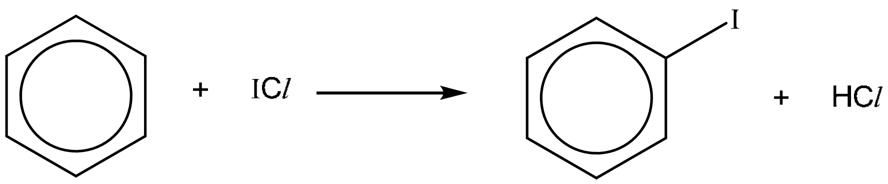
[1]

When temperature is increased, the molecules gain kinetic energy and move about faster. The number of molecules having energy greater than or equal to the activation energy increases. [1] Frequency of effective collisions increases. Reaction rate thus increases. [1]

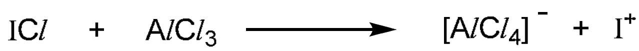
(b) Explain the difference in ionic radius between Br^- and I^-. **[2]**

I^- has more number of principal quantum shells than Br^-, thus the distance of the valence electrons is further away from its nucleus. [1] The valence electrons are less strongly attracted to the nucleus. Therefore the ionic radius of I^- is bigger than Br^-. [1]

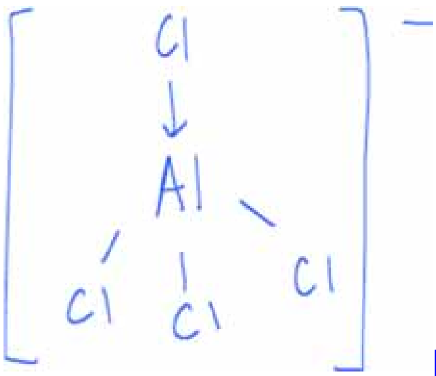
(c) Aromatic halogenation with iodine monochloride, IC*l*, produces aryl iodide.



This reaction is typically catalysed by aluminium chloride when it reacts with iodine monochloride to produce the electrophile I^+.



(i) Draw the structure of $[AlCl_4]^-$ and suggest in terms of bonding how $[AlCl_4]^-$ is formed from $AlCl_3$. **[2]**



[1]

Lewis structure (with correct shape) or dot-and-cross diagram is accepted.

The empty orbital of Al in $AlCl_3$ accepts a lone pair of electrons from Cl^-, forming a dative bond [1].

(ii) When sodium carbonate is added to a solution of $AlCl_3$, effervescence was seen. Explain the observation with the aid of relevant equations. **[3]**

$[Al(H_2O)_6]^{3+}(aq) + H_2O(l) \rightleftharpoons [Al(H_2O)_5OH]^{2+}(aq) + H_3O^+(aq)$ [1]

$2H^+(aq) + CO_3^{2-}(aq) \rightarrow CO_2(g) + H_2O(l)$ [1]

Al^{3+} hydrolyses in water to form H^+ which reacts with carbonate ions to give carbon dioxide gas. [1]

(iii) Ethanolic silver nitrate is added to iodobenzene and iodopropane in two separate test tubes. Yellow precipitate is seen immediately in one of the test tubes, whereas no precipitate is seen in the other test tube. Explain the observations. **[2]**

The yellow precipitate is AgI in the test tube containing iodopropane. [1]

No precipitate is seen in the test tube with iodobenzene as the lone pair of electrons on I is delocalised into the benzene ring, resulting in a partial double bond character in the C–I bond [1]. Hence the C–I bond is very strong to be broken to form AgI.

[Total: 20]

--- THE END ---