RIVER VALLEY HIGH SCHOOL
JC2 PRELIM EXAMINATION

CANDIDATE NAME	

CLASS	18J		

CENTRE NUMBER	S	3	0	4	4	INDEX NUMBER					

H2 CHEMISTRY
9729/01

Paper 1 Multiple Choice

26 September 2019

1 hour

Additional Materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
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Write your name, class and index number on the Optical Answer Sheet in the spaces provided.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
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The use of an approved scientific calculator is expected, where appropriate.

This document consists of **16** printed pages

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

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What is the value of x?

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

2 10 cm^3 of an unknown hydrocarbon was combusted in excess oxygen gas. The gaseous mixture contracted by 30 cm^3. The gaseous mixture further contracted by 40 cm^3 when it was passed through aqueous sodium hydroxide. All volumes of gases were measured at room temperature and pressure.

1	cyclopropane
2	butane
3	cyclobutane
4	but-2-ene

What is the hydrocarbon?

A 1 and 2 only

B 2 and 3 only

C 3 and 4 only

D 2, 3 and 4

3 The successive ionisation energies, in kJ mol^{-1}, of elements **X** and **Y** are given below.

X	575	1820	2740	11600	14800	18400	23400
Y	1320	3390	5320	7470	11000	13330	71330

1 The element preceding **X** in the Periodic Table has a higher first ionisation energy.

2 Element **Y** has a lower first ionisation energy than the element preceding it in the Periodic Table.

3 **X** and **Y** forms a compound with the formula $\mathbf{X}_3\mathbf{Y}_2$.

4 Oxide of **X** dissolves in water to give an acidic solution.

Which statements about **X** and **Y** are true?

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4 *Use of Data Booklet is relevant to this question.*

Some isotopes are unstable and undergo beta decay (β-decay).

β-decay is a process where a neutron transforms into a proton by the emission of an electron. The proton is retained in the nucleus.

Which of the following change describes a β-decay?

A $^{40}\text{K} \rightarrow {}^{40}\text{Ca}$

B $^{32}\text{P} \rightarrow {}^{31}\text{P}$

C $^{11}\text{C} \rightarrow {}^{12}\text{C}$

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5 Which graph does **not** describe the behaviour of a fixed mass of ideal gas at constant temperature?

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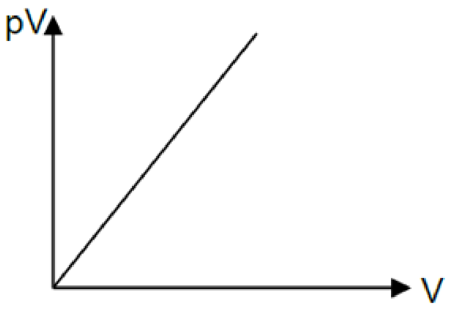

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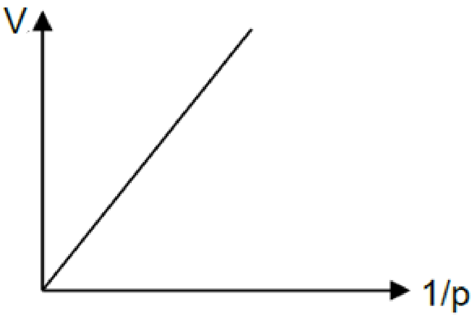

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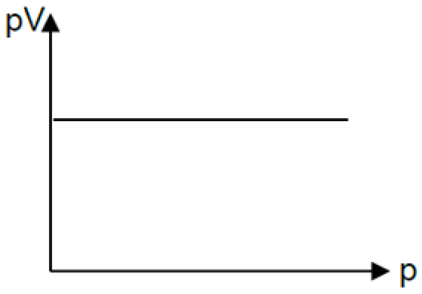

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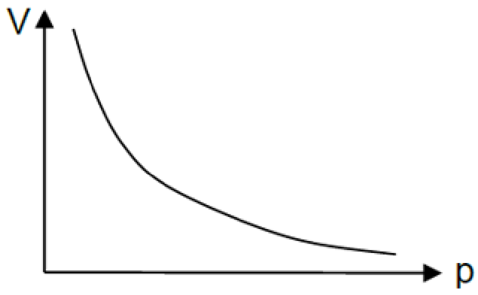

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2 Ionic bonds and covalent bonds can occur in the same compound.

3 An ionic compound will have the greatest degree of covalent character if both the cation and anion are large.

4 Ionic compounds can conduct electricity in both solid and liquid states.

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7 Which of the following shows a decrease in bond angle from left to right?

A	$SiCl_4$	H_2O	NF_3
B	$AlCl_3$	NH_3	PH_3
C	PCl_3	PF_3	PBr_3
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Compound	$\Delta H_{\text{hydrogenation}}$ /kJ mol^{-1}
benzene	−206
1,3,5−cyclohexatriene	−360
cyclohexene	−120

Which of the following statements is correct?

A 1,3,5−cyclohexatriene is more stable than benzene.

B Benzene has a lower energy content than 1,3,5−cyclohexatriene.

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10 A pure sample of SO_3(l) is introduced into an evacuated vessel. The vessel, of constant volume, is heated to a constant temperature such that the equilibrium below is established.

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

The value of pressure is found to be 27% greater than if only SO_3(g) were present.

What is the mole fraction of oxygen in the equilibrium mixture?

A 0.119 **B** 0.213 **C** 0.425 **D** 0.787

11 Equal volumes of 1.35×10^{-5} mol dm^{-3} $Bi(NO_3)_3$ and 2.00×10^{-5} mol dm^{-3} NaOH were added to a conical flask. Equilibrium was achieved within a few minutes and the following observations were made.

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	Precipitation of $Bi(OH)_3$	IP vs K_{sp} for the solution at equilibrium
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12 Caesium-137 is a radioactive isotope with a half-life of 30.2 years. Following the Fukushima Daiichi nuclear disaster in 2011, it was reported that about 8.4 kg of Caesium-137 was released into the sea.

What is the mass of Caesium-137 left in the sea after 100 years?

A 0.801 kg

B 0.846 kg

C 1.05 kg

D 6.73 kg

13 For the reaction: **A**(g) + **B**(g) → **C**(g) + **D**(g), the following experimental data was obtained.

Expt No.	[**A**] /mol dm^{-3}	[**B**] /mol dm^{-3}	Initial rate of reaction /mol dm^{-3} s^{-1}
1	0.20	0.20	3.00×10^{-4}
2	0.60	0.20	9.00×10^{-4}
3	0.80	0.40	4.80×10^{-3}

Which of the following conclusions can be drawn for the reaction?

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

2 The overall equation is the rate determining step.

3 The initial rate of reaction can be calculated from the initial rate of formation of **C**(g).

A 1 only **B** 1 and 2 only **C** 1 and 3 only **D** 2 and 3 only

14 The following equilibrium are studied at a fixed temperature T °C.

Equilibrium 1: $H_2PO_4^- + SO_4^{2-} \ll HSO_4^- + HPO_4^{2-}$

Equilibrium 2: $HSO_4^- \ll SO_4^{2-} + H^+$ $K_c = K_2$

Equilibrium 3: $H_2PO_4^- \ll HPO_4^{2-} + H^+$ $K_c = K_3$

Given that $K_2 > K_3$, which of the following statements is correct?

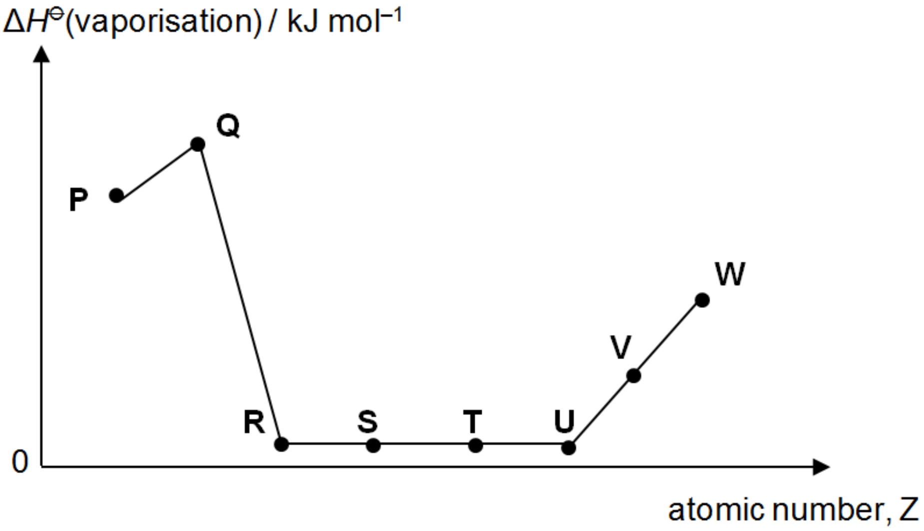
A HPO_4^{2-} is a stronger acid.

B $H_2PO_4^-$ is the conjugate base of HPO_4^{2-}.

C The position of Equilibrium 1 lies to the left.

D The rate of forward reaction for all three equilibrium decreases at (T+100) °C.

15 The graph below shows the variation in the standard enthalpy change of vaporisation, $\Delta H^\ominus$(vaporisation), for eight consecutive elements in the Periodic Table, all with atomic number, Z ≤ 20.



Which of the following statement is correct?

A Element **Q** forms an oxide which is amphoteric.

B Element **R** forms an oxide which is basic in aqueous solution.

C Element **V** forms a chloride which is neutral in aqueous solution.

D Element **W** forms a chloride which is basic in aqueous solution.

16 Element **E** is in the third period of the Periodic Table. The chloride of **E** has a simple molecular structure while the oxide of **E** has a giant ionic structure. Which of the following statements is **incorrect**?

A The atomic radius of **E** is larger than that of chlorine.

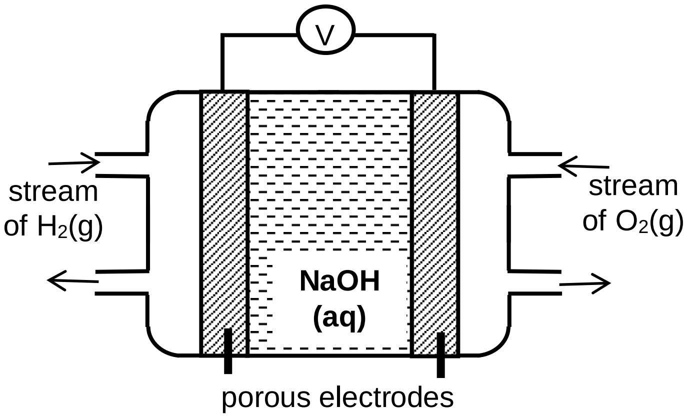
B The melting point of **E** is lower than its preceding element.

C The chloride of **E** dissolves in water to give an acidic solution.

D The oxide of **E** reacts with excess aqueous sodium hydroxide to form a colourless complex.

17 *Use of the Data Booklet is relevant in this question.*

A hydrogen-oxygen fuel cell is constructed using 1.00 mol dm^{-3} sodium hydroxide as the electrolyte. What is the change in pH of the solution around each electrode when the current is flowing?



	Cathode	Anode
A	increase	decrease
B	increase	increase
C	decrease	increase
D	decrease	decrease

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

An antique car bumper is to be chrome plated. The bumper is dipped into a Cr^{3+} solution where it serves as an electrode of an electrolytic cell. Oxygen is formed on the other electrode.

Which of the following statements is correct?

A The bumper is the anode of the electrolytic cell.

B Reduction of water occurs at the cathode.

C For every 52 g of chromium plated, 3 mole of oxygen is evolved.

D It takes about 8 hours to plate 52 g of chromium, if the current used is 10 A.

19 When a dilute sulfate solution of a metal **J** is electrolysed, metal **J** and a diatomic gas **K** are produced at the cathode and the anode respectively in the molar ratio 2:1. In another experiment, the same quantity of electricity is used to electrolyse a saturated sodium chloride solution and a gas **L** is evolved at the anode.

What is the molar ratio of **J** : **K** : **L**?

A 2:1:1

B 2:1:2

C 4:2:1

D 4:2:3

20 Covalent bonds are formed when orbitals overlap. The shape of many organic molecules can be explained by the hybridisation of orbitals.

Which bond is **not** present in the molecule, $\mathrm{HC}^{\sim}\mathrm{CCH}^{\wedge}\mathrm{CH_2}$?

A A σ bond formed by 1s-2sp overlap

B A σ bond formed by 2sp-2sp^2 overlap

C A σ bond formed by 2sp-2sp^3 overlap

D A π bond formed by 2p-2p overlap

21 In the 1960s, a certain class of organic compounds was widely used in aerosol sprays, refrigerants and making foamed plastics. However, they were found to destroy the ozone layer in the upper atmosphere and viable replacements were sought to minimise ozone depletion.

Which of the following compounds can be used safely as a replacement?

A $CHBr_3$

B CF_3CBr_3

C $CHC\mathit{l}FCC\mathit{l}F_2$

D $CH_3CH_2CH_2CH_3$

22 For which property of the alkanes does the numerical value decrease down the homologous series?

A Density

B Enthalpy change of vapourisation

C Number of isomers

D Vapour pressure

23 Hydrogen bromide reacts with but-1-ene to form bromobutane.

Which statements are possible descriptions of the organic intermediate in this reaction?

1 It contains carbon, hydrogen and bromine.

2 It has a positive charge.

3 It reacts with a nucleophile.

4 It has a plane of symmetry.

A 1 and 3 only

B 2 and 3 only

C 2 and 4 only

D 3 and 4 only

24 Which salt will be the most acidic in aqueous solution?

A $CH_3CH_2CH_2NH_3Cl$

B $C_6H_5NH_3Cl$

C $MgCl_2$

D NH_4Cl

25 When propene is bubbled through iodine monochloride, ICl, dissolved in water, which products could be formed?

1 $CH_3CH(OH)CH_2Cl$

2 CH_3CHICH_2OH

3 $CH_3CHClCH_2I$

4 CH_3CHICH_2Cl

A 1 and 2 only

B 2 and 3 only

C 3 and 4 only

D 2, 3 and 4

26 Tetrapeptide, **P**, is formed by an unknown amino acid. **P** has a relative molecular mass of *M*.

What is the relative molecular mass of the amino acid?

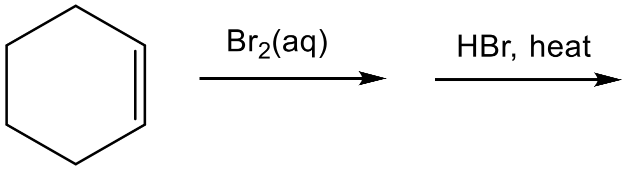
A $\frac{M}{4}$ **B** $\frac{M}{4} + 18$ **C** $\frac{M + 54}{4}$ **D** $\frac{M}{4} + 54$

27 Which reaction yields a carbon compound incorporating deuterium, D? [D = ^2H]

	Reactant	Reagents and conditions
A	CH_3CH_2CN	NaOD, D_2O, heat
B	$(CH_3)_3COH$	conc H_2SO_4, heat
C	CH_3COCI_3	NaOD, D_2O, warm
D	$CD_2(OH)CO_2H$	acidified $KMnO_4$, heat

28 Which two-step synthesis process will not give a good yield of 1,2-dibromocyclohexane?

A



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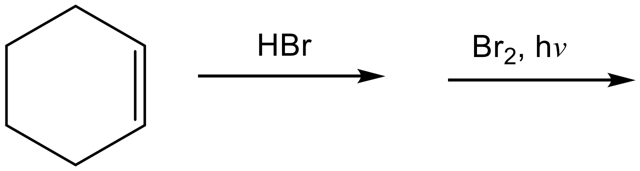
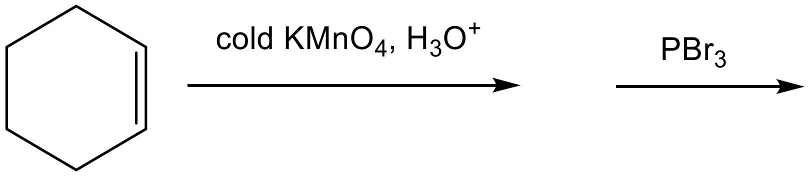


C



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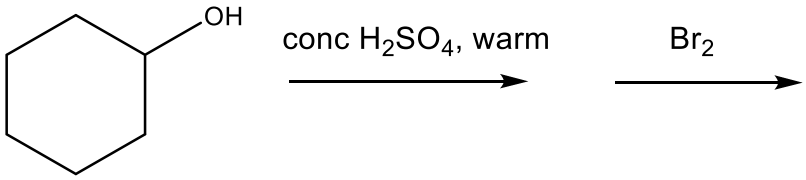
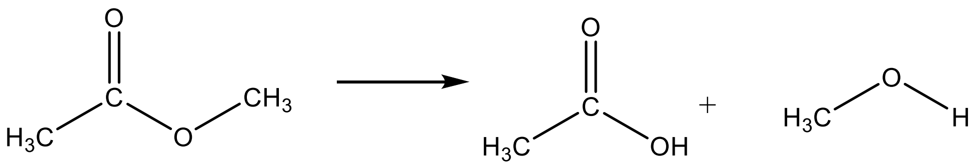


29 Which reaction will **not** take place in the presence of a suitable homogeneous catalyst?

A $CH_3CH{=}CH_2 \longrightarrow CH_3CH_2CH_3$

B



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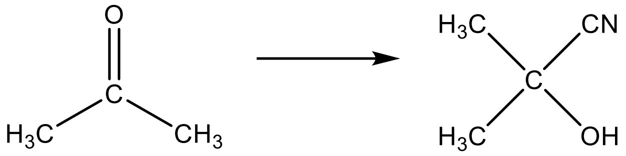

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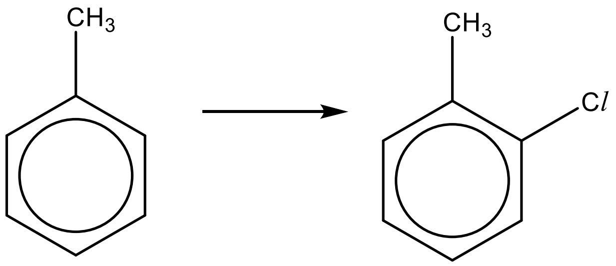
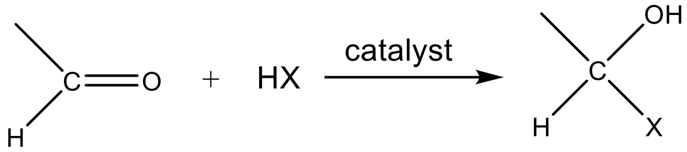


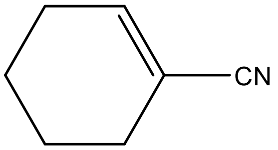
30 There is a range of reactions of the aldehyde group which have the pattern



of which the formation of a cyanohydrin (where X = CN) is one.

Which compounds could be obtained by such an addition to an aldehyde group, followed by a dehydration?

1



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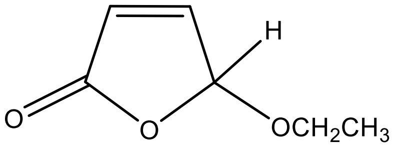

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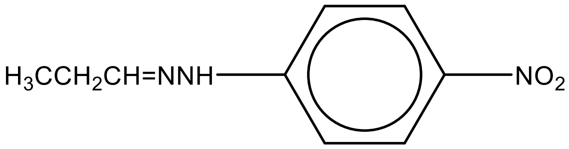

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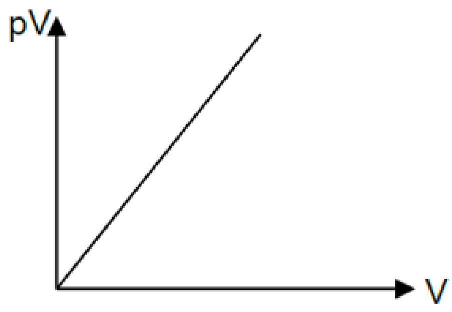

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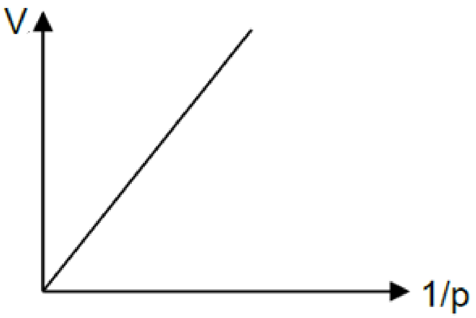

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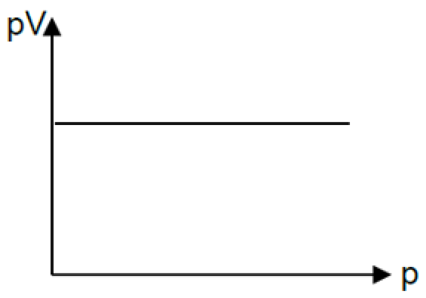

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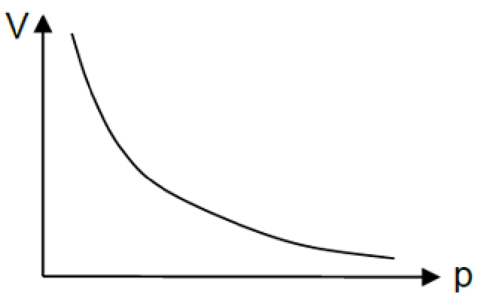

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13 For the reaction: **A**(g) + **B**(g) → **C**(g) + **D**(g), the following experimental data was obtained.

Expt No.	[**A**] /mol dm^{-3}	[**B**] /mol dm^{-3}	Initial rate of reaction /mol dm^{-3} s^{-1}
1	0.20	0.20	3.00×10^{-4}
2	0.60	0.20	9.00×10^{-4}
3	0.80	0.40	4.80×10^{-3}

Which of the following conclusions can be drawn for the reaction?

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

2 The overall equation is the rate determining step.

3 The initial rate of reaction can be calculated from the initial rate of formation of **C**(g).

A	1 only	**B**	1 and 2 only	**C**	1 and 3 only	**D**	2 and 3 only

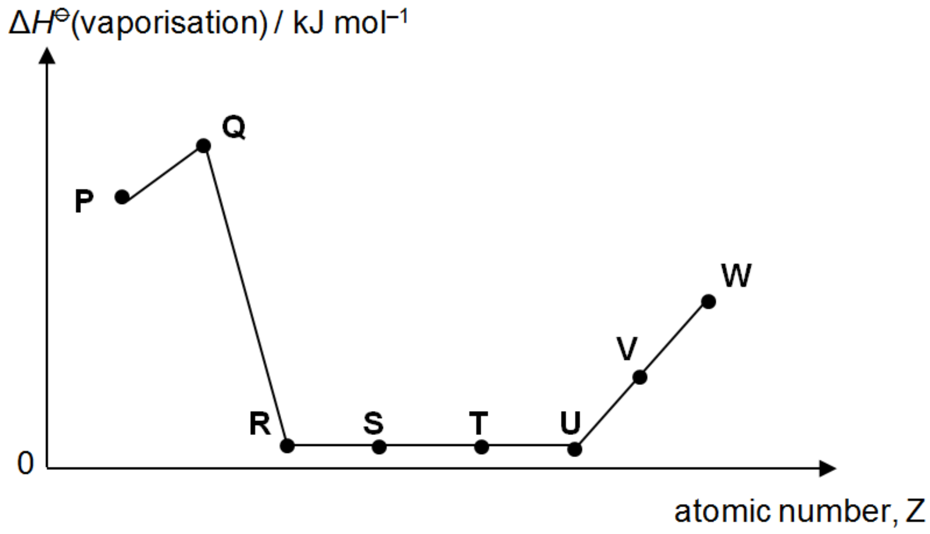
14 The following equilibrium are studied at a fixed temperature T °C.

Equilibrium 1:	$H_2PO_4^- + SO_4^{2-} \ll HSO_4^- + HPO_4^{2-}$	
Equilibrium 2:	$HSO_4^- \ll SO_4^{2-} + H^+$	$K_c = K_2$
Equilibrium 3:	$H_2PO_4^- \ll HPO_4^{2-} + H^+$	$K_c = K_3$

Given that $K_2 > K_3$, which of the following statements is correct?

A	HPO_4^{2-} is a stronger acid.
B	$H_2PO_4^-$ is the conjugate base of HPO_4^{2-}.
C	The position of Equilibrium 1 lies to the left.
D	The rate of forward reaction for all three equilibrium decreases at (T+100) °C.

15 The graph below shows the variation in the standard enthalpy change of vaporisation, $\Delta H^{\ominus}$(vaporisation), for eight consecutive elements in the Periodic Table, all with atomic number, Z $\leq$ 20.



Which of the following statement is correct?

A Element **Q** forms an oxide which is amphoteric.

B Element **R** forms an oxide which is basic in aqueous solution.

C Element **V** forms a chloride which is neutral in aqueous solution.

D Element **W** forms a chloride which is basic in aqueous solution.

16 Element **E** is in the third period of the Periodic Table. The chloride of **E** has a simple molecular structure while the oxide of **E** has a giant ionic structure. Which of the following statements is **incorrect**?

A The atomic radius of **E** is larger than that of chlorine.

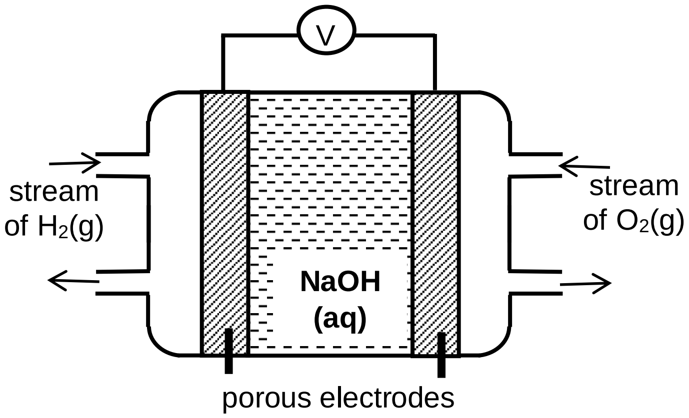
B The melting point of **E** is lower than its preceding element.

C The chloride of **E** dissolves in water to give an acidic solution.

D The oxide of **E** reacts with excess aqueous sodium hydroxide to form a colourless complex.

17 *Use of the Data Booklet is relevant in this question.*

A hydrogen-oxygen fuel cell is constructed using 1.00 mol dm^{-3} sodium hydroxide as the electrolyte. What is the change in pH of the solution around each electrode when the current is flowing?



	Cathode	Anode
A	increase	decrease
B	increase	increase
C	decrease	increase
D	decrease	decrease

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

An antique car bumper is to be chrome plated. The bumper is dipped into a Cr^{3+} solution where it serves as an electrode of an electrolytic cell. Oxygen is formed on the other electrode.

Which of the following statements is correct?

A	The bumper is the anode of the electrolytic cell.
B	Reduction of water occurs at the cathode.
C	For every 52 g of chromium plated, 3 mole of oxygen is evolved.
D	It takes about 8 hours to plate 52 g of chromium, if the current used is 10 A.

19	When a dilute sulfate solution of a metal **J** is electrolysed, metal **J** and a diatomic gas **K** are produced at the cathode and the anode respectively in the molar ratio 2:1. In another experiment, the same quantity of electricity is used to electrolyse a saturated sodium chloride solution and a gas **L** is evolved at the anode. What is the molar ratio of **J** : **K** : **L**?		
A	2:1:1	**B**	2:1:2
C	4:2:1	**D**	4:2:3

20	Covalent bonds are formed when orbitals overlap. The shape of many organic molecules can be explained by the hybridisation of orbitals. Which bond is **not** present in the molecule, HC˜CCHˆCH_2?
A	A σ bond formed by 1s-2sp overlap
B	A σ bond formed by 2sp-2sp^2 overlap
C	A σ bond formed by 2sp-2sp^3 overlap
D	A π bond formed by 2p-2p overlap

21	In the 1960s, a certain class of organic compounds was widely used in aerosol sprays, refrigerants and making foamed plastics. However, they were found to destroy the ozone layer in the upper atmosphere and viable replacements were sought to minimise ozone depletion. Which of the following compounds can be used safely as a replacement?
A	$CHBr_3$
B	CF_3CBr_3
C	$\text{CHC}l\text{FCC}l\text{F}_2$
D	$CH_3CH_2CH_2CH_3$

22	For which property of the alkanes does the numerical value decrease down the homologous series?	
	A	Density
	B	Enthalpy change of vapourisation
	C	Number of isomers
	D	Vapour pressure

23	Hydrogen bromide reacts with but-1-ene to form bromobutane. Which statements are possible descriptions of the organic intermediate in this reaction? 1 It contains carbon, hydrogen and bromine. 2 It has a positive charge. 3 It reacts with a nucleophile. 4 It has a plane of symmetry.	
	A	1 and 3 only
	B	2 and 3 only
	C	2 and 4 only
	D	3 and 4 only

24	Which salt will be the most acidic in aqueous solution?	
	A	$CH_3CH_2CH_2NH_3Cl$
	B	$C_6H_5NH_3Cl$
	C	$MgCl_2$
	D	NH_4Cl

25 When propene is bubbled through iodine monochloride, ICl, dissolved in water, which products could be formed?

1 $CH_3CH(OH)CH_2Cl$

2 CH_3CHICH_2OH

3 $CH_3CHClCH_2I$

4 CH_3CHICH_2Cl

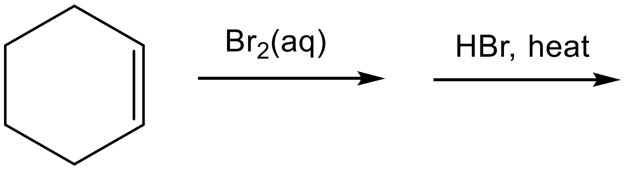
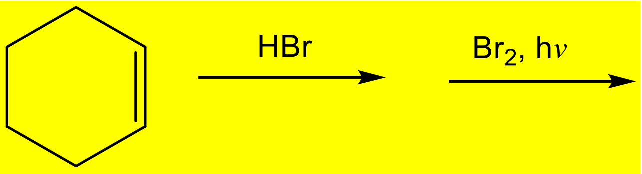
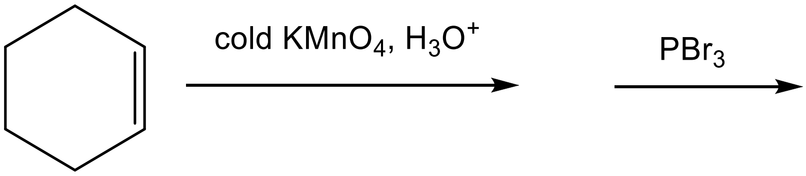
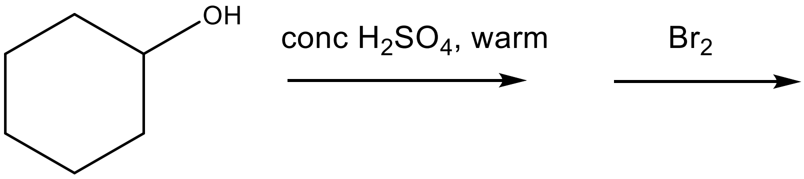
A	1 and 2 only
B	2 and 3 only
C	3 and 4 only
D	2, 3 and 4

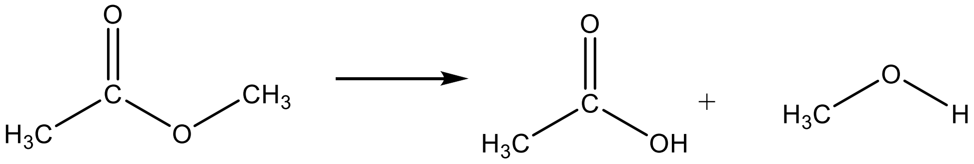
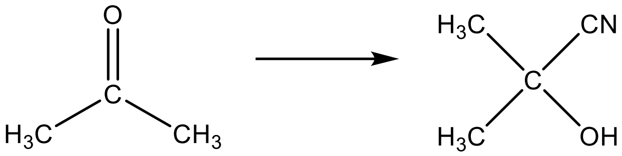
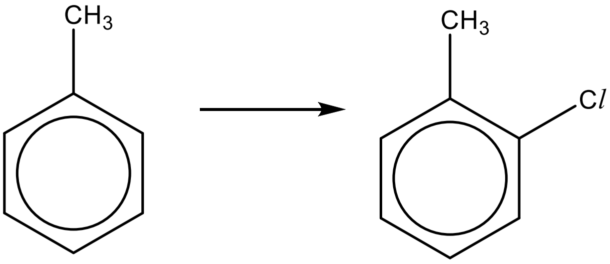
26 Tetrapeptide, **P**, is formed by an unknown amino acid. **P** has a relative molecular mass of *M*.

What is the relative molecular mass of the amino acid?

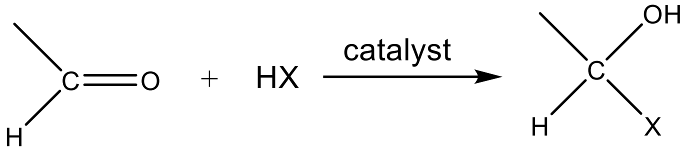
A	$\frac{M}{4}$	**B**	$\frac{M}{4}+18$	**C**	$\frac{M+54}{4}$	**D**	$\frac{M}{4}+54$

27	Which reaction yields a carbon compound incorporating deuterium, D? [D = ^2H]			
		Reactant	Reagents and conditions	
	A	CH_3CH_2CN	NaOD, D_2O, heat	
	B	$(CH_3)_3COH$	conc H_2SO_4, heat	
	C	CH_3COCI_3	NaOD, D_2O, warm	
	D	$CD_2(OH)CO_2H$	acidified $KMnO_4$, heat	

28	Which two-step synthesis process will not give a good yield of 1,2-dibromocyclohexane?	
	A	
	B	
	C	
	D	

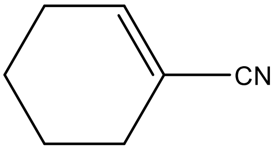
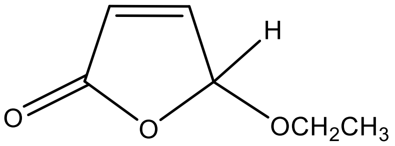
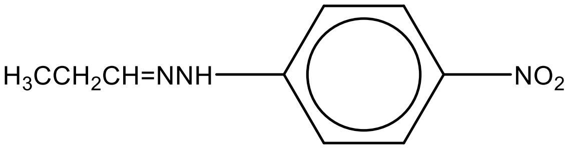
29	Which reaction will **not** take place in the presence of a suitable homogeneous catalyst?	
	A	$CH_3CH{=}CH_2 \longrightarrow CH_3CH_2CH_3$
	B	
	C	
	D	

30 There is a range of reactions of the aldehyde group which have the pattern



of which the formation of a cyanohydrin (where X = CN) is one.

Which compounds could be obtained by such an addition to an aldehyde group, followed by a dehydration?

1	
2	
3	

A 1 and 2 only

B 1 and 3 only

C 2 and 3 only

D 1, 2 and 3 only

END OF PAPER

Qn	Answer	Qn	Answer	Qn	Answer
1	D	11	B	21	D
2	C	12	B	22	D
3	A	13	C	23	B
4	A	14	C	24	B
5	A	15	C	25	D
6	A	16	B	26	C
7	B	17	A	27	C
8	B	18	D	28	B
9	A	19	B	29	A
10	B	20	C	30	C

RIVER VALLEY HIGH SCHOOL
JC 2 PRELIMINARY EXAMINATION

CANDIDATE NAME

CLASS 18J

CENTRE NUMBER S

INDEX NUMBER

H2 CHEMISTRY 9729/02

Paper 2 Structured Questions

18 September 2019

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, class, centre number and index number on all the work you hand in.
Write in dark blue or black pen on both sides of paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions in the space provided.
A Data Booklet is provided. Do NOT write anything on it.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner’s Use										
Paper 2										
Question Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total (Paper 2)**	**sf**	**Units**
Marks	/9	/9	/10	/12	/12	/10	/13	/75		
Paper 1		/30		**Paper 3**		/80		**Total**	/185	

This document consists of **21** printed pages and **3** blank pages.

1 Group 2 metals are also known as alkaline earth metals. The elements have similar properties and appearance. The metals are silvery-white and are reactive at room temperature and pressure.

(a) Ionisation energy of Group 2 varies down the group.

Explain how the 1st ionisation energy of beryllium and barium differs.

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………………………………………………………………………………….... **[3]**

(b) The nitrates, carbonates and hydroxides of Group 2 elements can undergo thermal decomposition.

(i) In the thermal decomposition of Group 2 nitrates, oxygen and a brown gas are also produced.

Write a balanced equation, with state symbols, for the decomposition of calcium nitrate.

……………………………………………………………………………… **[1]**

(ii) The nitrates of lead and zinc can undergo thermal decomposition similar to calcium nitrate. The decomposition temperatures of the three nitrates are given in the following table

Table 1.1

Compound	**Decomposition temperature /°C**
Lead(II) nitrate, $Pb(NO_3)_2$	290
Calcium nitrate, $Ca(NO_3)_2$	132
Zinc nitrate, $Zn(NO_3)_2$	105

Explain, with reference to the *Data Booklet,* the trend in the decomposition temperatures of the metal nitrates in the Table 1.1.

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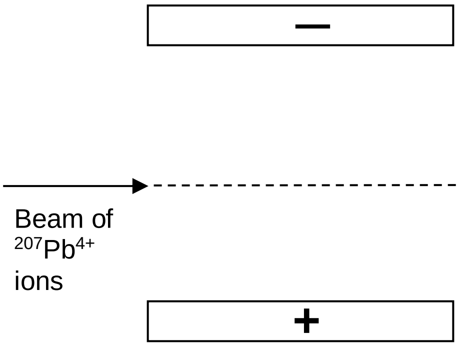
………………………………………………………………………………………… **[3]**

(c) Lead can exhibit variable oxidation states and its cation can exist either as $^{207}Pb^{2+}$ or $^{207}Pb^{4+}$. **[2]**

Given that the angle of deflection for $^{207}Pb^{2+}$ is 8°, calculate the angle of deflection for $^{207}Pb^{4+}$ and draw a labelled line to the figure below to represent the path of a beam of $^{207}Pb^{4+}$ ions, at high temperature, in an electric field.



[Total: 9]

2 Citric acid ($H_3C_6H_5O_7$) is a naturally occuring weak organic tribasic acid. It is found in a variety of vegetables and fruits. In a typical sample of lemon, the concentration of citric acid is about 0.300 mol dm^{-3}.

Table 2.1

	K_{a1}	K_{a2}	K_{a3}
$H_3C_6H_5O_7$	1.43×10^{-3}	1.74×10^{-5}	3.98×10^{-7}

(a) Calculate the pH of a typical sample of lemon. You may ignore K_{a2} and K_{a3} for this calculation.

[1]

(b) Calculated the pH of solution containing 46.0 g dm^{-3} of $Na_3C_6H_5O_7$.

[3]

(c) **(i)** A buffer solution can resist changes in pH when small amounts of acid or base is added to it. Suggest two conditions necessary to make a good buffer solution.

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…………………………………………………………………………………

[2]

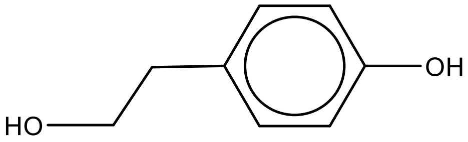
(ii) Calculate the mass of NaOH(s) required to be added to 50 cm^3 of 0.300 mol dm^{-3} citric acid for the preparation of buffer at pH = 6.40.

Clearly identify the acid and salt species in the buffer.

[3]

[Total: 9]

3 Olives are commonly used in foods and production of edible oils. In their natural state, olives contain organic compounds like tyrosol that make them unpalatable to people.



tyrosol

In order for olives to be made edible, their natural bitterness has to be removed in a process known as debittering. This is done by soaking olives in brine, followed by sodium hydroxide solution, which will react with tyrosol and extracted.

(a) **(i)** Write an equation for the reaction between tyrosol and sodium hydroxide.

.... **[1]**

(ii) State the different types of interaction that the product in **(a)(i)** will have with water molecules.

....

.... **[2]**

(iii) After treatment, tyrosol can be converted back to its original form. Outline a simple chemical test that could be carried out to check for the presence of tyrosol.

....

.... **[2]**

(iv) For this debittering process to be effective, the sodium hydroxide solution has to be changed frequently.

Suggest, using ideas behind Le Chatelier's principle, why the sodium hydroxide solution has to changed in order to remove tyrosol.

You may find it useful to use the equation $[T]_{olive} \rightleftharpoons [T]_{NaOH}$ where [T] refers to the concentration of tyrosol.

....

....

....

.... **[2]**

(b) **(i)** When tyrosol is heated with ethanoic acid with concentrated H_2SO_4, compound **D** is formed.

When bromine water is added to tyrosol, a brominated tyrosol, **E**, is formed.

Suggest a structure for compound **D** and **E**.

D	**E**

[2]

(ii) Explain how the acidity of brominated tyrosol might differ from that of tyrosol.

....

....

....

.... **[1]**

[Total: 10]

4 $SOCl_2$ and S_2Cl_2 are chlorine and sulfur containing compounds.

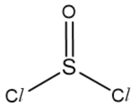
(a) Draw the dot-and-cross diagram of S_2Cl_2 and state its bond angle.

[2]

(b) The dipole moments and boiling points for $SOCl_2$ and S_2Cl_2 are shown in the table below.

The larger the dipole moment in Debye (*D*), the greater the difference in electrical charge in a species.

Table 4.1

Compound	M_r	Boiling point / ^oC	Net dipole moment / *D*
	119	74.6	1.44
S_2Cl_2	135.2	137.1	1.60

With reference to their structures and bonding and the information above, account for the large difference in their boiling points.

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………………………………………………………………………………….. **[3]**

(c) $SOCl_2$ is used in organic synthesis.

The following Synthetic Route A shows how a carboxylic acid can be converted into an amine.

Synthetic Route A

$$CH_3CO_2H \xrightarrow{SOCl_2} CH_3COCl \xrightarrow{\text{Step 2}} CH_3CONH_2 \xrightarrow{\text{Step 3}} CH_3CH_2NH_2$$

(i) State the reagents and conditions for Steps 2 and 3.

Step 2 ……………………………………..

Step 3 …………………………………….. **[2]**

(ii) Angelic acid, $C_5H_8O_2$, is a natural product isolated from the roots of the angelica plant.

- Angelic acid reacts with H_2 + Ni to form **T**, $C_5H_{10}O_2$.
- **T** undergoes the above Synthetic Route A to form the amine **U**, $C_5H_{13}N$.
- **U** can also be made by reacting 1-bromo-2-methylbutane with ammonia.

Both angelic acid and **T** can exhibit stereoisomerism.

Suggest structures for angelic acid, **T** and **U**.

angelic acid	**T**
U	

[3]

(iii) State the types of stereoisomerism shown by angelic acid and **T**.

angelic acid ……………………………………………..

T …………………………………………….. **[2]**

[Total: 12]

5 *Use of the Data Booklet and the information about the various oxidation states of vanadium from Table 5.1 are relevant to this question.*

Table 5.1

Example of Species	Oxidation State of Vanadium	Solution Colour	Wavelength / nm
V^{2+}	+2	violet	400
V^{3+}	+3	green	515
VO^{2+}	+4	blue	460
VO_2^+	+5	yellow	580

(a) In a solution containing V^{2+}(aq), water molecules act as ligands that bind to the vanadium cation in an octahedral arrangement and cause the 3d subshell in V^{2+} to split into two different energies. As a result, a solution of V^{2+}(aq) appears violet.

(i) Explain why a solution of V^{2+}(aq) is coloured.

……………………………………………………………………………...

……………………………………………………………………………...

……………………………………………………………………………...

……………………………………………………………………………... **[2]**

(ii) Given that the energy of light is inversely proportional to its wavelength, deduce which of the two solutions, V^{2+}(aq) or V^{3+}(aq), has a larger 3d-subshell splitting.

……………………………………………………………………………...

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……………………………………………………………………………... **[2]**

(b) Frost-Ebsworth diagrams are the most common graphical method of representing redox relationships for species of a given element in different oxidation states.

In a Frost-Ebsworth diagram, values of $-\Delta G$ /F for the formation of M(N) from M(0), where N is the oxidation state, are plotted with increasing oxidation states.

From the relationship:

$$\Delta G \; = -\mathrm{n}FE$$

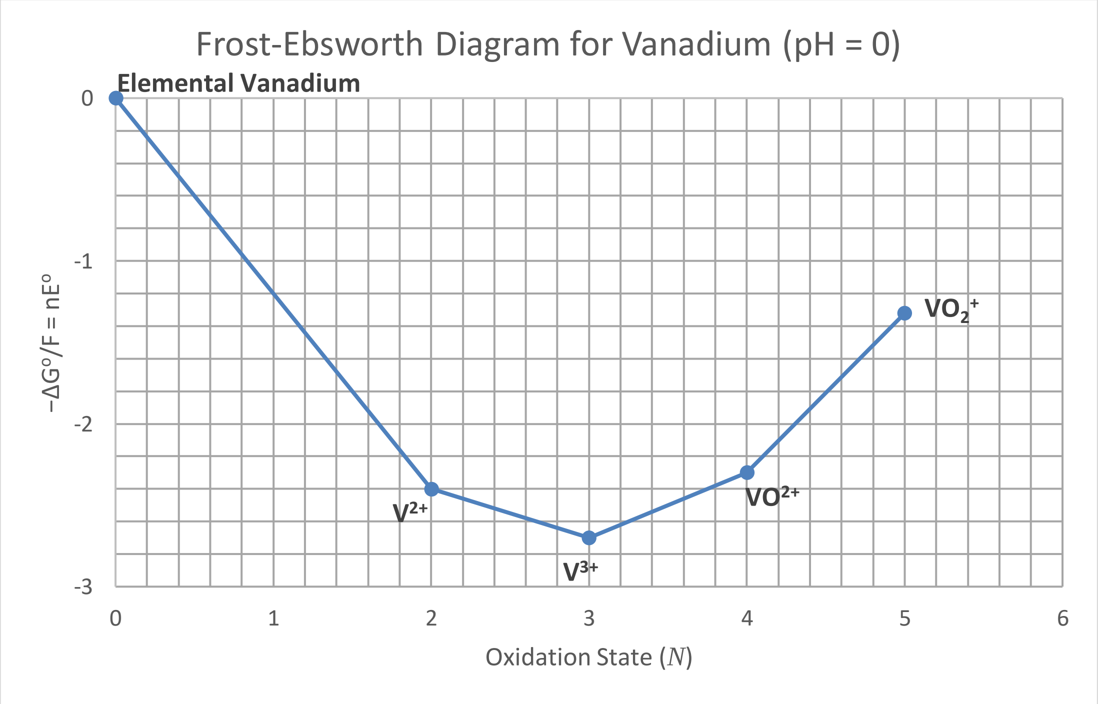
where n is the number of moles of electrons transferred during the redox reaction, it follows that $-\Delta G$ /F = nE , hence a Frost-Ebsworth diagram is essentially a plot of nE against oxidation states.

The ΔG for elements in their standard states is taken as zero.

The gradient of the line drawn between any two points on the plot corresponds to the E of the corresponding redox couple.

A Frost-Ebsworth diagram for vanadium in aqueous solution of pH 0 (i.e. [H^+] = 1 mol dm^{-3}) is shown below.

Fig. 5.1



(i) Fill in the blanks below the y-coordinates of the plotted points for V^{3+} and VO^{2+} to 1 decimal place.

V^{3+} : (3 , ……………)

VO^{2+}: (4 , ……………) **[1]**

(ii) For the V^{2+}/V redox couple, the coordinates for V^{2+} is (2, −2.40).

For the VO_2^+/VO^{2+} redox couple, the coordinates for VO_2^+ is (5, −1.32).

Calculate the E value for the VO_2^+/V^{2+} redox couple.

[1]

(iii) Suggest the significance of V^{3+} being the lowest point on the Frost-Ebsworth diagram.

…………………………………………………………………………………..........

[1]

…………………………………………………………………………………..........

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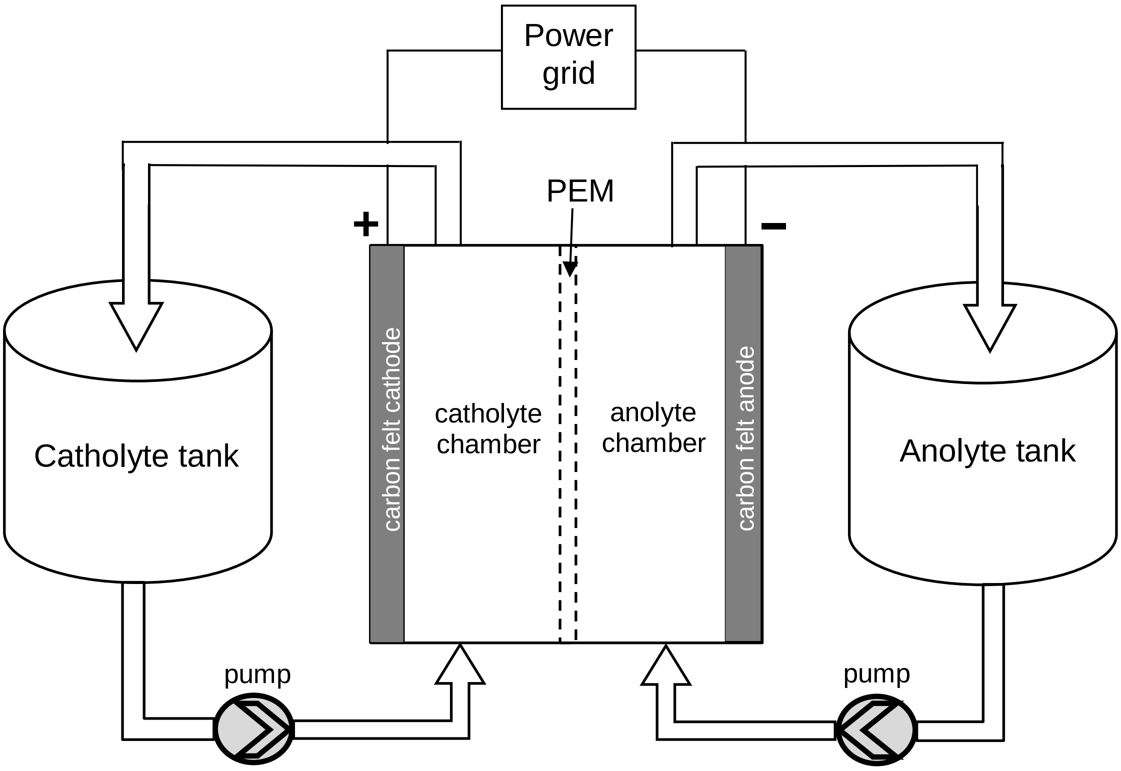
A recent exciting development in the energy storage industry is the vanadium redox flow battery (VRFB), a rechargeable electrochemical cell that employs aqueous vanadium ions in various oxidation states to store chemical potential energy. A 20-year-long cycle life and high energy efficiency are its key advantages, giving rise to its potential to power up cities in the near future.

A schematic diagram of a VRFB, during the discharge phase, is shown below, with the flow of the electrolytes in the connecting pipes shown in block arrows.

Fig. 5.2



Key Characteristics of the VRFB

1. The battery comprises of 2 electrolytes, a catholyte and an anolyte, that flow through the respective half-cells from separate storage tanks. Each electrolyte contains a redox couple, i.e. 2 vanadium species, dissolved in sulfuric acid.
2. The species in each redox couple differs from each other by **one oxidation state**.
3. These electrolytes are separated by a proton exchange membrane (PEM) whereby protons can migrate across to maintain electrical neutrality in the cell.
4. The predominant colours of the electrolytes flowing through the four connecting tubes are **all different**, based on the colours given in Table 5.1.

(c) **(i)** The e.m.f. of a single VRFB is 1.26 V.

With reference to the given information above and the *Data Booklet*, write down the relevant vanadium redox couples present in the catholyte and anolyte chambers in the schematic diagram above.

Catholyte chamber: ………………………….

Anolyte chamber: …………………………. **[2]**

(ii) Hence or otherwise, construct the overall equation of the redox process in the VRFB.

……………………………………………………………………………… **[1]**

(iii) Once a discharge cycle is completed, the VRFB will be connected to an external power supply to "charge up".

State the direction of proton transfer during the charging cycle.

……………………………………………………………………………… **[1]**

(iv) Suggest a suitable modification to the VRFB to increase the e.m.f without changing the species in the catholyte and anolyte chambers.

……………………………………………………………………………… **[1]**

[Total: 12]

6 When Group 1 metals are heated in an excess of air, alkali metal oxides, peroxides and superoxides are produced. The principal product obtained depends on the metal.

For potassium, its superoxide, KO_2, is formed predominantly.

(a) **(i)** The enthalpy change of formation of the oxides increases drastically as shown in Table 6.1. Suggest a reason for each of the following:

- $\Delta H_f(O_2^{2-})$ is more endothermic than $\Delta H_f(O_2^{-})$
- $\Delta H_f(O^{2-})$ is more endothermic than that of the other two anions

Table 6.1

	O_2^{-}	O_2^{2-}	O^{2-}
ΔH_f/ kJ mol^{-1}	–43.0	553	903

…………………………………………………………………………...

…………………………………………………………………………...

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…………………………………………………………………………...

…………………………………………………………………………... **[2]**

…………………………………………………………………………...

(ii) Define the term *lattice energy*.

…………………………………………………………………………....

…………………………………………………………………………....

………………………………………………………………………….... **[1]**

(iii) Explain how the magnitude of lattice energy changes from KO_2 to K_2O_2 to K_2O.

…………………………………………………………………………....

…………………………………………………………………………....

…………………………………………………………………………....

…………………………………………………………………………....

………………………………………………………………………….... **[2]**

(b) Potassium superoxide, KO_2, is a rare yet stable salt of superoxide anion. It is used in rebreathers as it reacts with carbon dioxide exhaled to generate oxygen and potassium carbonate.

Potassium superoxide is stable as long as it is kept dry. Upon contact with water, it hydrolyses extremely quickly to give potassium hydroxide.

Interestingly, the alkaline products from both reactions aforementioned also absorb the exhaled CO_2.

The following table lists the Δ*H* values of the reactions.

Table 6.2

reaction	ΔH / kJ mol^{-1}
$2KO_2(s) + CO_2(g) \rightarrow K_2CO_3(aq) + \frac{3}{2}O_2(g)$	–219
$2KO_2(s) + H_2O(l) \rightarrow 2KOH(aq) + \frac{3}{2}O_2(g)$	–113
$CO_2(g) + K_2CO_3(aq) + H_2O(l) \rightarrow 2KHCO_3(aq)$	–100
$KOH(aq) + CO_2(g) \rightarrow KHCO_3(aq)$	ΔH_r

Using the data given in Table 6.2, construct a fully labelled energy cycle to determine ΔH_r.

$$2KO_2(s) + H_2O(l) \longrightarrow 2KOH(aq) + \frac{3}{2}O_2(g)$$

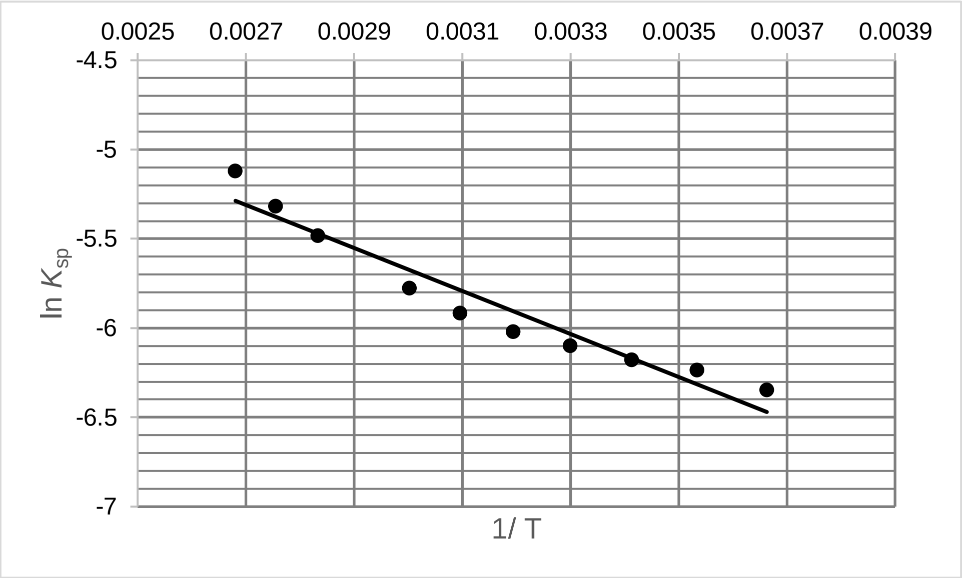
[3]

(c) The relationship between the thermodynamic functions, ΔG_{ppt}, ΔH_{ppt} and ΔS_{ppt} of a reaction and its equilibrium constant is given as follows.

$$\Delta G_{ppt} = \Delta H_{ppt} - T\Delta S_{ppt} = - RT \ln(K_{sp}).$$

An experiment was conducted to determine the entropy change of precipitation of potassium carbonate. The solubility product of potassium carbonate at various specific temperatures were determined and Figure 6.1 shows a plot of ln K_{sp} against 1/T which can be used to obtain ΔS_{ppt}.

Fig. 6.1



(i) Using the graph, determine ΔS_{ppt}.

[1]

(ii) Explain the significance of the sign of ΔS_{ppt} of K_2CO_3.

…………………………………………………………………………….…

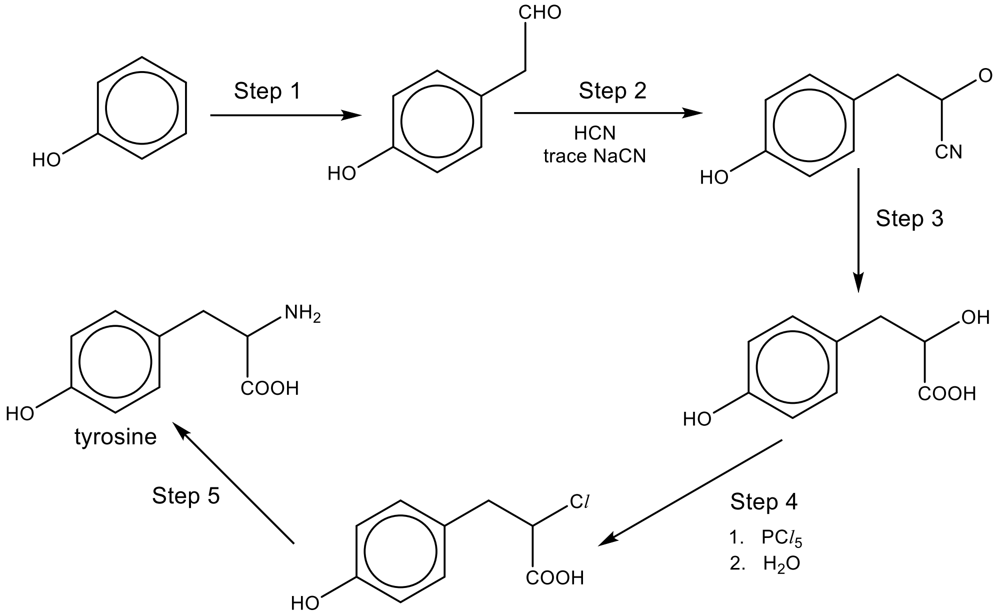
[1]

…………………………………………………………………………….…

[Total: 10]

7 **(a)** Tyrosine is a naturally occurring amino acid.

The amino acid tyrosine can be synthesised from phenol by the route shown.



(i) Describe the mechanism in Step 2.

[3]

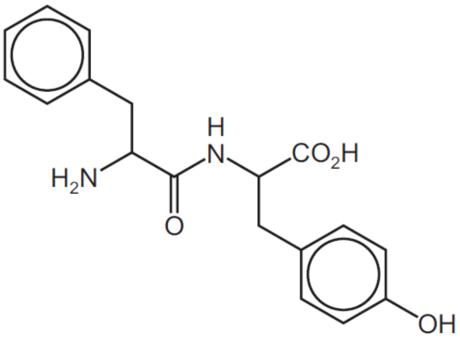
(ii) State the reagents and conditions for Steps 1, 3 and 5.

Step 1 ……………………………………………………

Step 3 ……………………………………………………

Step 5 …………………………………………………… **[3]**

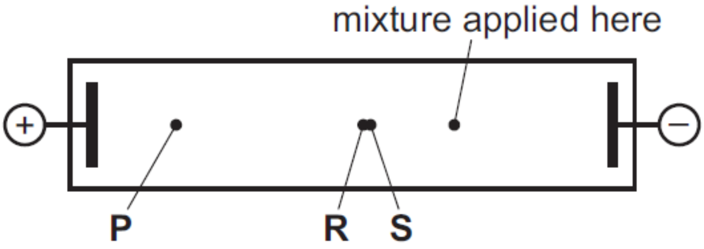
(b) The dipeptide phe-tyr has the following structure.



A mixture of this dipeptide (phe-tyr) and its two constituent amino acids (phe and tyr) was subjected to electrophoresis in a buffer at pH 12.

Electrophoresis is a technique commonly used in the lab to separate species like amino acids. The speed of migration of the amino acids depends on their charge and size.

At the end of the experiment the following results were seen. Spots **R** and **S** remained very close together.



(i) Draw the structure of the species responsible for spot **P**.

[1]

(ii) Suggest a simple modification to the electrophoresis setup to increase the separation for spots **R** and **S.**

……………………………………………………………………………..

…………………………………………………………………………….. **[1]**

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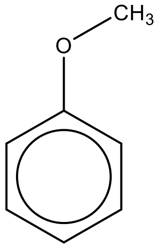
(c) Anisole, or methoxybenzene, is an organic compound with the formula $CH_3OC_6H_5$. It is a colorless liquid with a smell reminiscent of anise seed, and in fact many of its derivatives are found in natural and artificial fragrances. It is an ether and contain the C–O–C functional group.



anisole

Ether can be synthesised via Williamson ether synthesis which involves an alkoxide ion, R'O$^-$, reacting with an alkyl halide, RX.

$$R'O^- + RX \longrightarrow R'OR + X^-$$

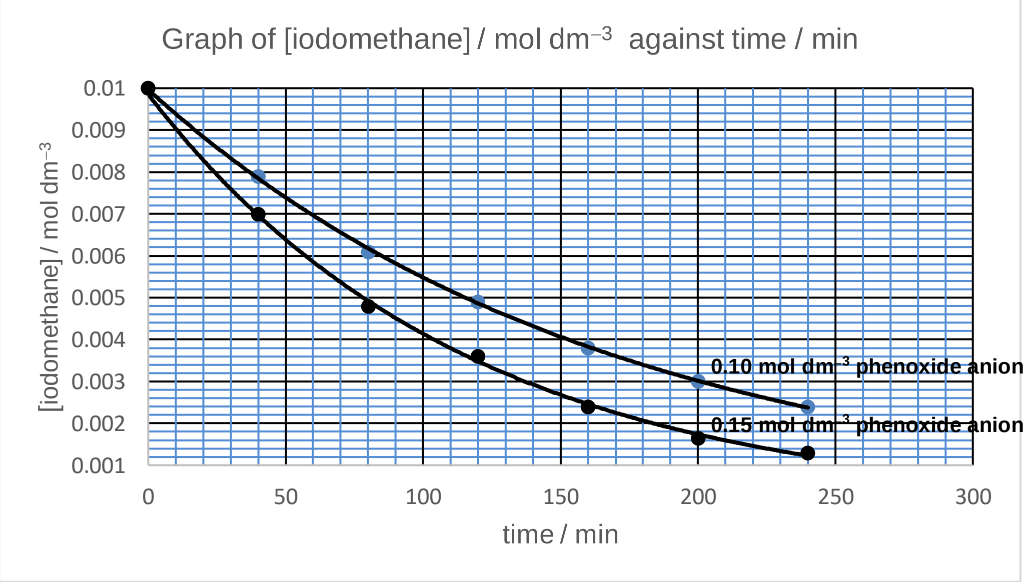
(i) To produce anisole, phenol is first reacted with sodium hydride, NaH, via an acid–base reaction to produce phenoxide ion.

Construct a balanced chemical equation for the reaction between phenol and NaH.

………………………………………………………………………………... **[1]**

(ii) The following graph shows the experimental findings of a Chemistry undergraduate student when iodomethane is reacted with 2 different concentrations of phenoxide ion.

Fig. 7.1



Using the graph, determine the order of reaction with respect to

- iodomethane
- phenoxide ion

Justify your answer in each case. **[4]**

Order of reaction with respect to iodomethane: ……………………………………………

Justification: ……………………………………………

……………………………………………

……………………………………………

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……………………………………………

Order of reaction with respect to phenoxide ion: ……………………………………………

Justification: ……………………………………………

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……………………………………………

[Total: 13]

~END OF PAPER~

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Suggested Answers for 9729 H2 CM 2019 JC 2 Prelim

Paper 2

1 **(a)** Barium has a larger nuclear charge and larger shielding effect than beryllium. Although there is an increase in nuclear charge in barium, it is cancelled out by the simultaneous increase in shielding effect by inner shells of electrons. Barium has a bigger atomic radius than beryllium. **[3]**

Hence the valence electrons become increasingly less attracted by the positive nucleus and less energy is required to remove the valence electrons. Therefore 1st IE of Ba is lower than the 1st IE of beryllium.

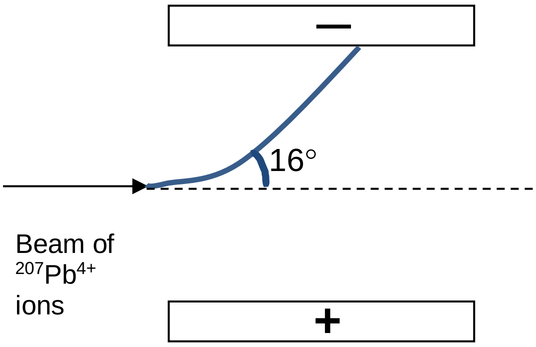
(b) **(i)** $Ca(NO_3)_2$ (s) → CaO (s) + $2NO_2$ (g) + $\frac{1}{2}O_2$ (g) **[1]**

(ii) **[3]**

cations	Ionic radius/nm
Pb^{2+}	0.120
Zn^{2+}	0.074
Ca^{2+}	0.099

The ionic radius of the metal cation increases from Zn^{2+} to Ca^{2+} to Pb^{2+} and its charge density decreases. As a result, the ability of M^{2+} to polarise the electron cloud of the large NO_3^- anion decreases and the N–O bonds are weakened to a smaller extent. Hence $Zn(NO_3)_2$ decomposes at the lowest temperature followed by $Ca(NO_3)_2$ and lastly $Pb(NO_3)_2$.

(c) **[2]**



$\frac{charge}{mass}$ for Pb^{2+} = $\frac{+2}{207.2}$= 0.00965

$\frac{charge}{mass}$ for Pb^{4+} = $\frac{+4}{207.2}$ = 0.01930

Angle of deflection= $\frac{0.01930}{0.00965}$ ×8 = 16°C

[Total: 9]

2 **(a)** $K_{a1} = X^2/(0.300 - X)$; assuming x is very small and 0.300 - X = 0.300

$X = 0.0207 \text{ mol dm}^{-3}$

pH = -lg 0.0207 = 1.68 **[1]**

(b) $[Na_3C_6H_5O_7] = 46/(23.0 \times 3 + 12.0 \times 6 + 16.0 \times 7 + 1.0 \times 5)$

$= 0.178 \text{ mol dm}^{-3}$

$K_b = K_w / K_a = 10^{-14} / (3.98 \times 10^{-7}) = 2.51 \times 10^{-8} \text{ mol dm}^{-3}$

$K_b = [OH^-]^2 / 0.178 = 2.51 \times 10^{-8}$

$[OH^-] = 6.69 \times 10^{-5} \text{ mol dm}^{-3}$

pH = 14 – pOH

pH = 9.82 **[3]**

(c) **(i)** [salt] = [acid] / Amount of acid = Amount of salt / Larger volume of buffer

Amounts of salt and acid are relatively higher than the amount of acid or alkali added. **[2]**

(ii) $pH = 6.40 = pK_{a3}$

buffer consist of $HC_6H_5O_7^{2-}$ and $C_6H_5O_7^{3-}$

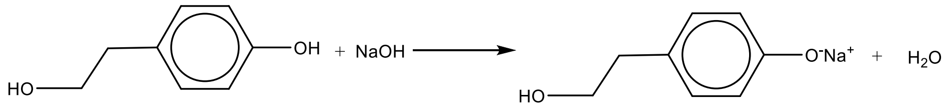
Amt of of citric acid = 0.300 x 0.05 = 0.0150 mol

Amt of NaOH needed = 0.0150 x 2.5 = 0.0375 mol

mass = 0.0375 x (23.0 + 16.0 + 1.0) = 1.50 g **[3]**

[Total: 9]

3 **(a)** **(i)** **[1]**



(ii) Ion-dipole interactions **[2]**

Hydrogen bonding

Instantaneous dipole-induced dipole forces

(iii) Neutral $FeCl_3$. Violet colouration will be observed if tyrosol is present. There will be no violet colouration if tyrosol is not present. **[2]**

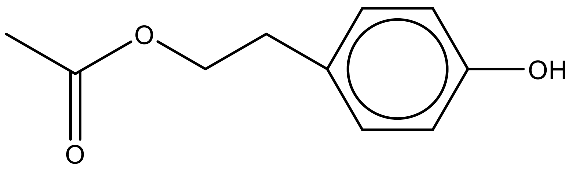
(iv) When the NaOH solution is changed, $[T]_{NaOH}$=0/ lowered. **[2]**

Equilibirum position shifts right to dissolve more tyrosol and counteract the change.

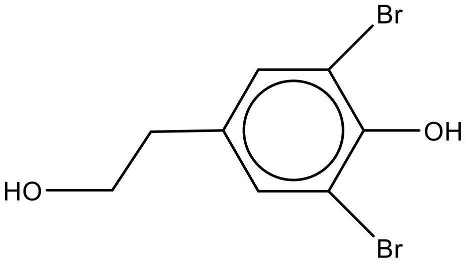
More tyrosol will be removed from the olives.

(b) (i) **[2]**

D:



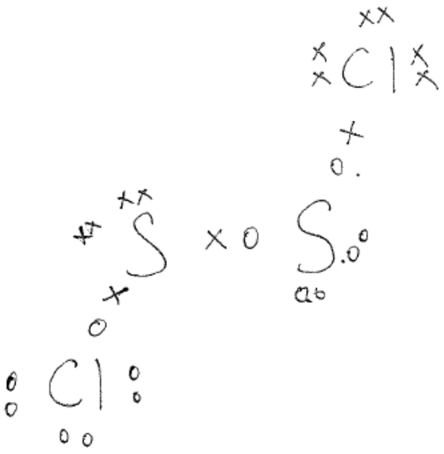
E:



(ii) The brominated tyrosol is a stronger acid than tyrosol. In the brominated phenoxide ion, the electron-withdrawing bromine atoms increase the delocalisation of the negative charge into the benzene ring, making the brominated phenoxide ion more stable than the phenoxide ion in tyrosol. **[1]**

[Total: 10]

4 (a)



Bond angle is 104.5^0 **[2]**

(b) All two compounds have simple covalent structures/ are simple covalent molecules.

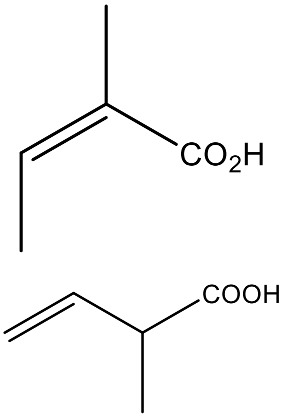
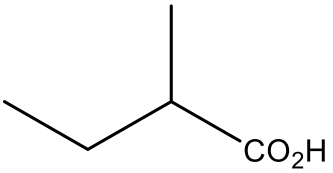
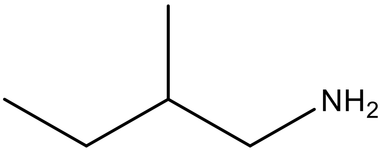
For $SOCl_2$ and S_2Cl_2, there exists permanent dipole-permanent dipole interactions and instantaneous dipole-induced dipole interactions between molecules. **[3]**

As S_2Cl_2 has a larger number of electrons/electron cloud and is more polar, more energy is required to overcome the stronger instantaneous dipole-induced dipole interactions and stronger permanent dipole-permanent dipole interactions between S_2Cl_2 molecules than $SOCl_2$ molecules. Therefore, S_2Cl_2 has a higher boiling point than $SOCl_2$.

(c) **(i)** Step 2: NH_3, rtp **[2]**

Step 3: $LiAlH_4$ in dry ether..

(ii)

	
angelic acid	**T**
	
U	

[3]

(iii)

angelic acid	cis – trans isomerism / enantiomerism
T	enantiomerism

[2]

[Total: 12]

5 **(a)** **(i)** The difference in energies (ΔE) between these 2 sets of 3d orbitals is small and radiation from the visible region of the electromagnetic spectrum is absorbed when an electron is promoted from a lower energy d orbital to another unfilled/partially-filled d orbital of higher energy.

The colour observed (violet) corresponds to the complement of the absorbed colours (yellow). **[2]**

(ii) Vanadium(II) / V^{2+}(aq). Because V^{2+}(aq) is violet and V^{3+}(aq) is green, which means that for V^{2+} and V^{3+}, the complement colours, yellow and red respectively, are absorbed.

Since the energy of light is inversely proportional to its wavelength, the energy gap between the 2 sets of d orbitals in V^{2+} will be larger as the wavelength of yellow light is shorter than that of red light. **[2]**

(b) **(i)** V^{3+} : (3 , −2.7)

VO^{2+}: (4 , −2.3) **[1]**

(ii) E (VO_2^+/V^{2+}) = gradient of line joining VO_2^+ and V^{2+} points

$$= \frac{-2.40-(-1.32)}{2-5} = \mathbf{+0.36\ V}$$ **[1]**

(iii) −Δ*G* /F is the most negative here, hence Δ*G* for V^{3+} is the most positive. Thus V^{3+} is the most (thermodynamically) stable species of vanadium / +3 is the most stable oxidation state of vanadium.

Or V^{3+} will not undergo redox (i.e. oxidation (to VO^{2+}) and reduction (to V^{2+})) easily **[1]**

(c) **(i)** Catholyte chamber: VO_2^+ / VO^{2+}

Anolyte chamber: V^{3+} / V^{2+} **[2]**

(ii) $V^{2+} + VO_2^+ + 2H^+ \rightarrow VO^{2+} + V^{3+} + H_2O$ **[1]**

(iii) From anolyte chamber towards catholyte chamber / Right to left **[1]**

(iv) Increase the concentration of VO_2^+ in the VO_2^+/VO^{2+} redox couple (i.e. catholyte) and/or increase the concentration of V^{2+} in the V^{3+}/V^{2+} redox couple (i.e. anolyte)

or

Attach a number of VRFB cells in series **[1]**

[Total: 12]

6 **(a)** **(i)** Energy is needed to overcome the repulsion to add an electron to a negatively charged O_2^-, hence the $\Delta H_f(O_2^{2-})$ is more positive than $\Delta H_f(O_2^-)$. **[2]**

ΔH_f (O^{2-}) is highly endothermic/ requires a lot of energy as it involves the breaking of a double bond and the addition of 2 electrons to a single atom/ single $^-O–O^-$ bond requires the addition of an electron to a negatively charged O^-.

(ii) *Enthalpy change* when **1 mole of the solid ionic compound** is formed **from** its **constituent gaseous ions** under standard conditions. **[1]**

(iil) $LE \propto \left|\frac{q_1.q_2}{r_1 + r_2}\right|$. As the charges of O^{2-} and O_2^{2-} are higher than O_2^-, the ionic size of O_2^{2-} is larger than that of O^{2-}**,** the magnitudes of LE of decreases in the order $K_2O > K_2O_2 > KO_2$. **[2]**

(b) **[3]**

$$\begin{tikzcd}
2KO_2(s) + H_2O(l) \arrow[r] \arrow[d, "\begin{array}{c}+CO_2(g)\\ -219\end{array}"'] & 2KOH(aq) + \frac{3}{2}O_2(g) \arrow[dd, "\begin{array}{c}+2CO_2(g)\\ \mathbf{2(\Delta H_r)}\end{array}"] \\
K_2CO_3(aq) + \frac{3}{2}O_2(g) + H_2O(l) \arrow[dr, "\begin{array}{c}+CO_2(g)\\ -100\end{array}"'] & \\
 & 2KHCO_3(aq) + \frac{3}{2}O_2(g)
\end{tikzcd}$$

By Hess' Law, $2(\Delta H_r) = (-113) + (-219) + (-100)$

$\Delta H_r = -103$ kJ mol^{-1}

(c) **(i)** $\Delta H_{ppt} - T\Delta S_{ppt} = -RT\ln(K_{sp})$ **[1]**

$$\ln(K_{sp}) = \frac{\Delta H}{-RT} + \frac{\Delta S}{R}$$

From graph, gradient = $\dfrac{-5.3-(-6.3)}{0.0027-0.0035} = -1250$ K

At (0.0027, –5.3), $-5.3 = -1250(0.0027) + \dfrac{\Delta S}{R}$

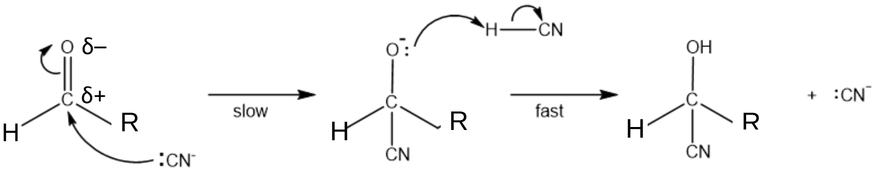
$$\frac{\Delta S}{R} = \frac{\Delta S}{8.31} = -1.925$$

$\Delta S = -1.925 \times 8.31 = -16.0$ J mol^{-1} K^{-1}

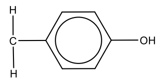
(ii) Entropy/ Disorder decreases because there are less ways to distribute the energy/ arrange the ions/ particles as they have to take up fixed positions in the lattice structure. **[1]**

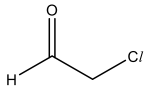
[Total: 10]

7 **(a)** **(i)** $NaCN \longrightarrow Na^+ + CN^-$ **[3]**



R is

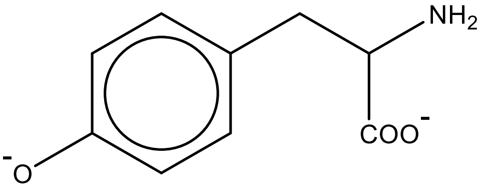


(ii) step 1 Anhydrous $AlCl_3$, 

step 3 H_2SO_4 (aq), heat (under reflux) **[3]**

step 5 (excess) alcoholic NH_3, heat in a sealed tube

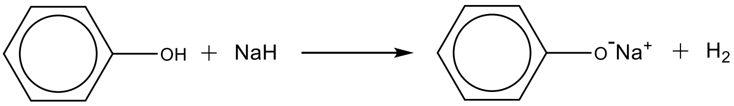
(b) **(i)**



[1]

(ii) Use a longer gel plate / Apply a higher voltage / Change the pH / Run for a longer time. **[2]**

(c) **(i)**



[1]

(ii)

Order of reaction with respect to iodomethane:	1
Justification:	[phenoxide] = 0.10 M, constant half life of 118.0 ± 5 min OR [phenoxide] = 0.15 M, constant half life of 80.0 ± 5 min
Order of reaction with respect to phenoxide:	1
Justification:	When concentration of phenoxide times 1.5, rate/ gradient times 1.5.

[4]

[Total: 15]

RIVER VALLEY HIGH SCHOOL
JC2 PRELIMINARY EXAMINATION

CANDIDATE NAME											
CLASS	18J										
CENTRE NUMBER	S					INDEX NUMBER					

H2 CHEMISTRY **9729/03**

Paper 3 Free Response **24 September 2019**

2 hours

Candidates answer on separate paper.

Additional Materials: Answer Booklet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, class, centre number and index number on all the work you hand in.
Write in dark blue or black pen on both sides of paper.
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** questions.

Section B
Answer **one** question.

Begin each question on a fresh page.
A Data Booklet is provided. Do not write anything on it.
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.
At the end of the examination, fasten all your work securely together.

This document consists of **15** printed pages and 1 blank page.

Section A

Answer **all** the questions from this section.

1 **(a)** **(i)** Hydrogen halide, HX, is soluble in both polar and nonpolar solvents. Describe the interactions formed when HX dissolves in polar solvents such as water. **[1]**

(ii) The boiling points of the first four hydrogen halides down Group 17 are listed in the following table.

Table 1.1

Hydrogen Halide	Boiling Point / °C
HF	20
HC*l*	−85
HBr	−67
HI	−35

Describe and explain the trend. **[2]**

(iii) Four gas jars containing a hydrogen halide from Table 1.1 were prepared. When a red-hot steel needle is introduced to the gas jars respectively, two of them showed intense colour changes while the other two showed no visible change.

With reference to the *Data Booklet*, describe and explain the observations. **[3]**

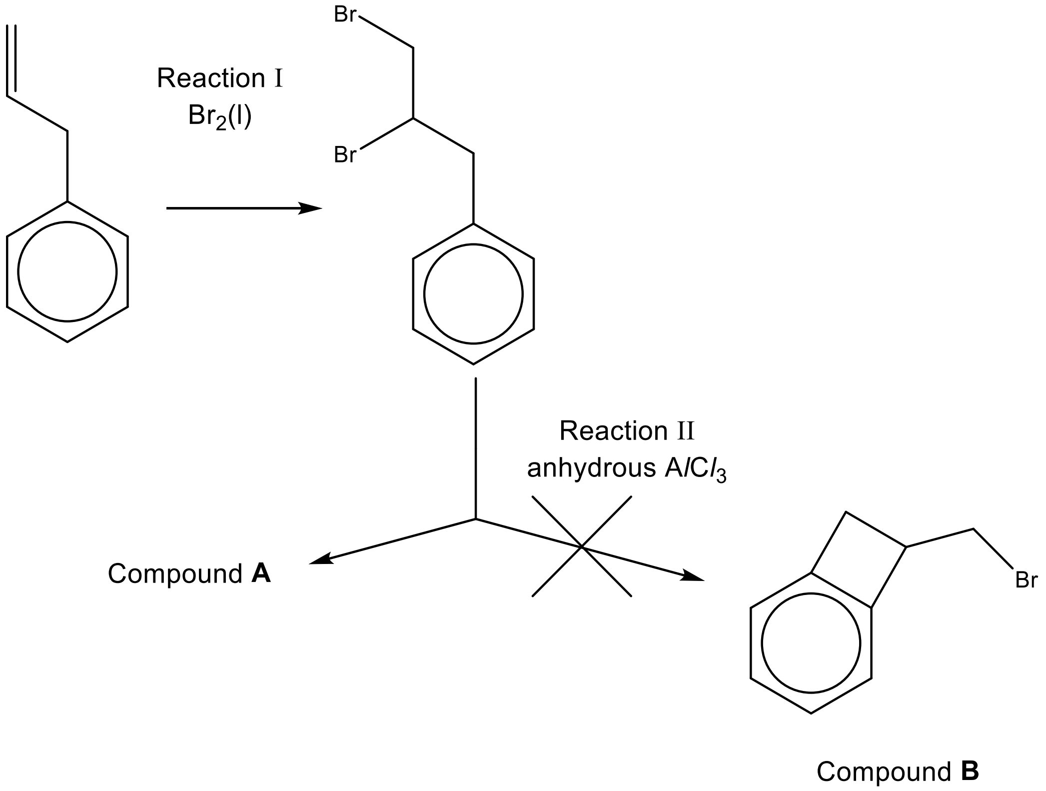
(b) **(i)** In an experiment, an excess of 5.00 g AgC*l*(s) was added to 1 dm^3 solution of 0.00100 mol dm^{-3} NaC*l* and allowed to reach equilibrium at 298 K. The mixture was then filtered and the residue was dried thoroughly. 100 cm^3 of the filtrate required the addition of 4.00×10^{-12} mol of NaBr for the first trace of AgBr to appear.

Given that solubility of AgBr in water is 0.140 mg L^{-1}, calculate the concentration of Ag^+ ions in the 100 cm^3 filtrate. **[2]**

(ii) Calculate the solubility of AgC*l* in mol dm^{-3}. **[2]**

(iii) Calculate the mass of residue collected from the filtration. **[1]**

(c)



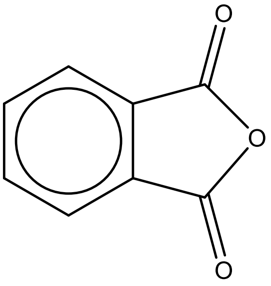
(i) There are two possible intermediates for Reaction I. Draw the structure of the more stable intermediate and explain its stability. **[2]**

(ii) Describe the mechanism of Reaction II to form Compound **A**. In your answer, use curly arrows to indicate the movement of electrons. **[2]**

(iii) With reference to the hybridisation of carbon atoms, explain why compound **B** is not a product from Reaction II. **[2]**

[Total: 17]

2 **(a)** Phthalic anhydride is the acid anhydride of phthalic acid. It is an important industrial chemical for the synthesis of phthalic esters, which are used as plasticisers to soften plastics

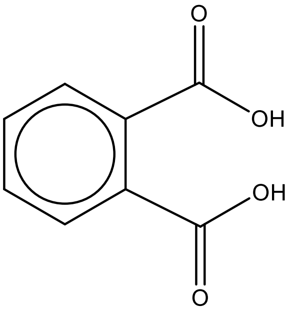


Phthalic anhydride

(i) Given that phthalic anhydride reacts with an alcohol to form a monoester as the only product, write an equation for the reaction of phthalic anhydride with propan-1-ol. **[1]**

(ii) The esterification of the monoester is more difficult to carry out and requires the removal of an inorganic by-product. Suggest the identity of the by-product. **[1]**

(b) Hydrolysis of phthalic anhydride produces phthalic acid, which is an aromatic dicarboxylic acid that can ionise in stages. Some information on phthalic acid and another aromatic acid are given below.



Phthalic acid

Table 2.1

	pK_1	pK_2
Phthalic acid	2.89	5.51
Benzoic acid	4.20	-

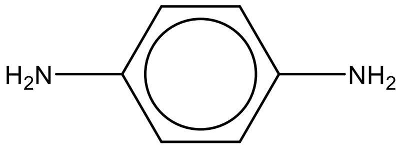
(i) Suggest a reason why the pK_2 of phthalic acid is higher than its pK_1. **[1]**

(ii) Calculate the pH of a solution that is obtained after 50 cm^3 of 0.1 mol dm^{-3} of NaOH is added to 10 cm^3 of 0.2 mol dm^{-3} phthalic acid. **[2]**

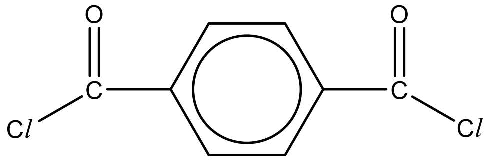
(iii) Sketch the pH-volume added curve you would expect to obtain when 50 cm^3 of 0.1 mol dm^{-3} of NaOH is added to 10 cm^3 of 0.2 mol dm^{-3} phthalic acid. Include relevant details from **(ii)** on your graph. **[3]**

(iv) Predict the structure of the ionic compound that will be formed when sodium benzoate is added to phthalic acid. **[1]**

(c) Kevlar is a heat resistant and strong synthetic polymer that is used in bullet-proof vests. Kevlar is synthesised in solution from the monomers of 1,4-phenylene-diamine and terephthaloyl chloride.



1,4-phenylene-diamine

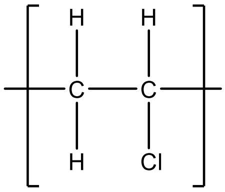


terephthaloyl chloride

(i) State the type of reaction that occurs between 1,4-phenylene-diamine and terephthaloyl chloride that will result in the formation of a polymer. **[1]**

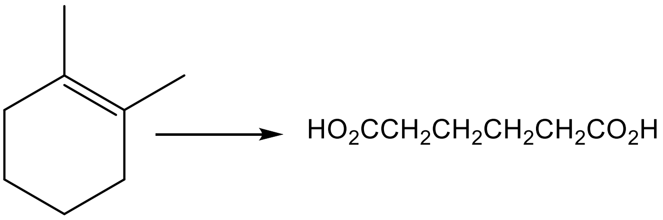
(ii) A repeating unit is a part of a polymer whose repetition would produce the complete polymer chain (except the end groups) by linking the repeating units together successively along the chain.

For example, the repeating unit of polyvinyl chloride is shown below.



Draw the structure of the repeating unit of Kevlar. **[1]**

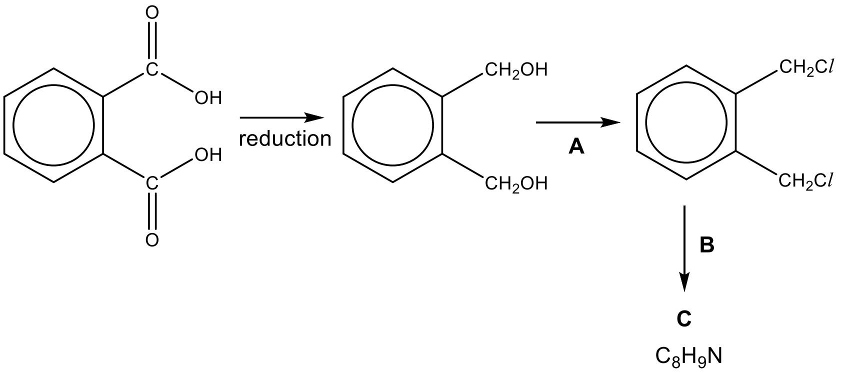
(d) Polyprotic organic acids are usual precursors in synthesis. Suggest how the polyprotic organic acid below can be synthesised. Indicate reagents and conditions you would use in each step, including the structure of the intermediate(s), if any.



$HO_2CCH_2CH_2CH_2CH_2CO_2H$

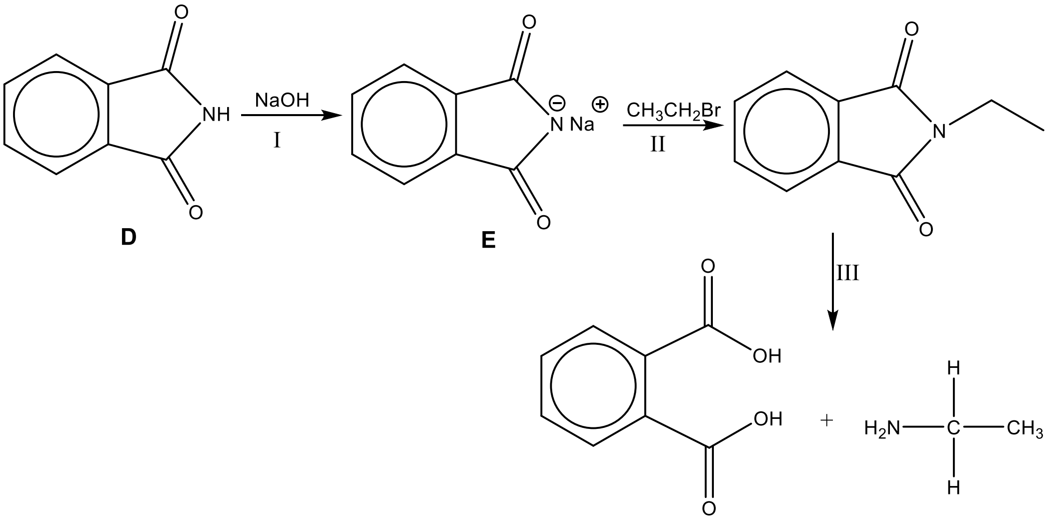
[2]

(e) Phthalic acid undergoes the reaction scheme below.



Suggest the reagents and conditions for Reactions **A** and **B** as well as the structure for Compound **C**. **[3]**

(f) Compound **D** is a useful intermediate for making primary amines from bromoalkanes, by the following method.



(i) State the types of reaction in Steps I, II and III. **[3]**

(ii) Suggest reagents and conditions for Step III. **[1]**

(iii) Draw a simple diagram to show how a water molecule can be attached to the anion in **E**. Label your diagram to show the dominant type of interaction involved. **[1]**

(iv) When **D** undergoes combustion, a student, Eugene, predicted that one of the likely products is either NO or N_2 gas. He carried out a simple experiment to determine the combustion equation for **D**.

First, he burnt 0.5 g of **D** in air. After combustion, he passed the gaseous mixture through potassium hydroxide and measured the volume of gas remaining at 30 °C and 1 atm. Eugene determined that the gaseous volume was 42.26 cm^3.

Using the information above, determine the identity of the gas and write an equation for the combustion reaction of **D**. **[3]**

[Total: 24]

3 Iron is the second most abundant metal in the earth's crust and is abundantly used in building materials such as steel. The two most common oxidation states of iron in its compounds are +2 and +3.

(a) When 5 cm^3 of 0.2 mol dm^{-3} iron(III) chloride solution was added to 10 cm^3 of 0.6 mol dm^{-3} sodium cyanide solution, the solution turned red.

When the resultant solution undergoes a redox reaction, the solution turned yellow and the complex **Y** formed has a M_r of 211.8.

Deduce, with the help of calculations and the *Data Booklet*, the formulae of the complexes formed when the solution turned red and yellow respectively. Write equations when appropriate. **[2]**

(b) Explain the following observations regarding iron and its compounds. Support your answers with data from the *Data Booklet* where appropriate.

(i) The electrical conductivity of iron is higher than that of calcium. **[1]**

(ii) The pH of a solution of iron(III) chloride is lower than the pH of a solution of iron(II) chloride of the same concentration. **[2]**

(c) Iron(III) ions catalyse the reaction between aqueous potassium peroxodisulfate, $K_2S_2O_8$, and aqueous potassium iodide.

(i) Explain, with the help of the *Data Booklet*, the role of Fe^{3+} in the reaction. **[2]**

(ii) Draw a fully-labelled energy profile diagram to show the above reaction, which is exothermic. **[3]**

(d) Compound **V**, with the molecular formula $C_8H_9NO_2$, is found to be able to relief pain and reduce fever. At room temperature, **V** is insoluble in water and dilute acids but soluble in aqueous sodium hydroxide. **V** reacts with aqueous bromine to form **W**, $C_8H_7NO_2Br_2$.

On heating **V** with dilute hydrochloric acid, compounds **X** and **Y** are formed. **X**, with the molecular formula C_6H_8NOCl, is soluble in water.

Y, on reduction with lithium aluminium hydride, forms **Z**. **Z** reacts with alkaline aqueous iodine to form a yellow precipitate.

Identify compounds **V** to **Z** and briefly explain the reactions described. **[9]**

[Total: 19]

Section B

Answer **one** question from this section.

4. Volatile organic compounds (VOCs) are carbon-containing chemical vapours that can come from both man-made and natural sources. VOCs generally have high vapour pressures at ordinary room temperatures.

The table below shows a list of the common VOCs found around us.

Table 4.1

VOC	Formula	ΔH_{vap} / kJ mol^{-1}	ΔS_{vap} / J mol^{-1} K^{-1}
Benzene	C_6H_6	+33.9	+113.6
Ethanol	C_2H_5OH	+38.6	+109.7
Methylbenzene	$C_6H_5CH_3$	+38.1	+87.3
Propanone	CH_3COCH_3	+31.3	+95.0

(a) **(i)** Using the Gibbs Equation,

$$\Delta G_{\text{vap}} = \Delta H_{\text{vap}} - T\Delta S_{\text{vap}},$$

explain whether the process of vaporisation is an enthalpy-driven or entropy-driven reaction. **[2]**

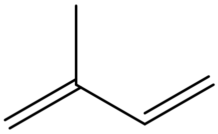
(ii) From Table 4.1, state the most volatile VOC at 330 K and calculate the corresponding ΔG_{vap}. **[1]**

(b) Dichloromethane, another common VOC of formula CH_2Cl_2, is synthesised industrially from methane via free radical chlorination.

(i) State the reagent and condition required to synthesise dichloromethane from methane. **[1]**

(ii) Describe the mechanism involved in this synthesis, showing the steps that produce dichloromethane. **[3]**

(c) Isoprene, C_5H_8, is one of the biologically generated VOCs by plants and algae. It is used to manufacture synthetic rubbers and elastomer plastics. It appears as a colourless, volatile liquid and is known to cause respiratory irritation from overexposure to its vapour.



(i) State the IUPAC nomenclature of isoprene. **[1]**

(ii) Yet, isoprene is the most abundant hydrocarbon measurable in human breath.

The estimated production rate of isoprene in the human body is 0.15 μmol kg^{-1} h^{-1}.

Calculate the mass, in mg, of isoprene estimated to be produced by a 65 kg person in a day.

[1 μmol = 10^{-6} mol] **[1]**

A gaseous mixture, made up of isoprene (C_5H_8) and carbon disulfide (CS_2), is prepared in a corresponding volume ratio of 1 : n.

The mixture is completely combusted with an excess of oxygen at 25 ^{o}C and 1 atm. After combustion, there was an overall volume contraction of 70 cm^3.

The resultant product mixture contains three gases, two of which are acidic, and water. Upon passing this mixture through aqueous sodium hydroxide, a further contraction of 170 cm^3 took place.

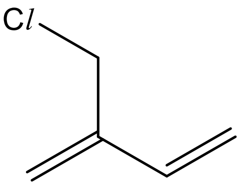
(iii) Given that complete combustion of carbon disulfide produces carbon dioxide and sulfur dioxide, write balanced equations for the complete combustion of isoprene and of carbon disulfide separately. **[2]**

(iv) Assuming that the volume of isoprene is x cm^3 in the gaseous mixture, find n using the balanced equations in **(c)(iii)**.

You may find proving the following expressions useful:

- $(n + 3)x = 70$ from the 1st contraction
- $(3n + 5)x = 170$ from the 2nd contraction **[3]**

(d) Compound **M**, a chlorinated form of isoprene of molecular formula C_5H_7Cl, is a liquid at room temperature.



Compound **M**

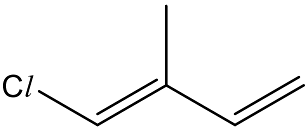
(i)

Enthalpy change of atomisation of carbon / kJ mol^{-1}	+715
Enthalpy change of vaporisation of compound **M /** kJ mol^{-1}	+30

Using the given data above and relevant data from the *Data Booklet*, construct a fully-labelled energy level diagram to calculate the enthalpy change of formation of compound **M**. **[4]**

(ii) Compound **N** is an isomer of compound **M**.

It is a liquid at room temperature and its enthalpy change of vaporisation is +30 kJ mol^{-1} as well.



Compound **N**

State the isomeric relationship between compounds **M** and **N**. **[1]**

(iii) It is found that the magnitude of its enthalpy change of formation is smaller than that of compound **M**. Suggest a possible reason for this. **[1]**

[Total: 20]

5 This question is about the chemistry of Period 3 elements.

(a) Describe the action of water on the oxides of magnesium, silicon and phosphorus.

Write equations for any reactions that occur, and suggest the pH for each of the resulting solutions.

[5]

(b) All wines contain sulfur dioxide for its anti-oxidant and anti-bacterial properties. However, if too much sulfur dioxide and sulfites are present, they would induce an unpleasant taste. Sulfur dioxide also contributes significantly to hangover.

The World Health Organisation recommends a maximum daily intake of 0.7 mg of SO_2 per kilogram of bodyweight.

Wineries use the Ripper titration to determine the concentration of SO_2 in mg L^{-1} in their wines. In a Ripper titration, 2 cm^3 of starch solution is added to 50 cm^3 of the wine in a conical flask. The wine is then titrated against a standard iodine solution.

17.70 cm^3 of 0.0100 mol dm^{-3} aqueous iodine is added until a dark colour appears and persists for at least 15 seconds.

(i) Write the balanced equation for the reaction between SO_2 and iodine. **[1]**

(ii) Determine the concentration of sulfur dioxide in the wine and state if it is advisable for a person of 70 kg to consume 400 mL of this bottle of wine. **[2]**

(c) Organometallic compounds, which contain a carbon-metal bond, are key intermediates in organic reactions to form a C–C bond. In general, when organometallic compounds are used on carbonyl compounds, alcohols are produced as shown in Fig 5.1.

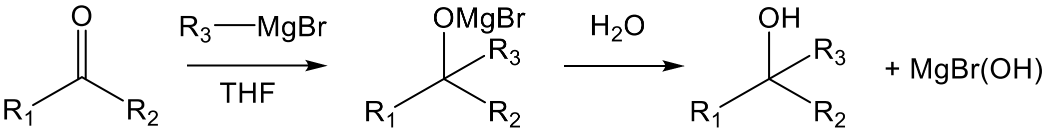


Fig 5.1

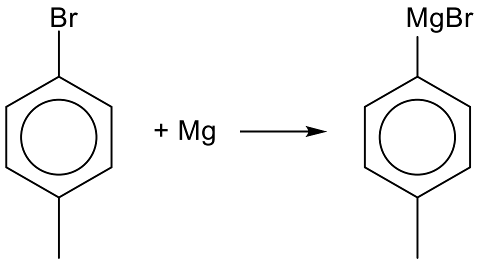
Common organometallic compounds are organolithium (contain carbon-lithium bond) and Grignard reagents (contain carbon-magnesium bond).

(i) In organolithium and Grignard reagents, carbon is a powerful nucleophile, which allows the formation of a C–C bond.

Explain how the nucleophilicity of carbon arises. **[1]**

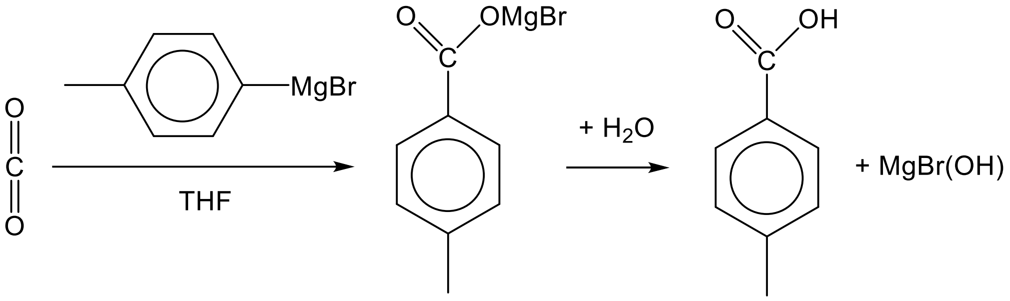
An experiment was conducted to synthesise 4-toluic acid from 4-bromotoluene using a Grignard reagent. The Grignard reagent is first synthesised by a reaction between 4-bromotoluene and magnesium. The Grignard reagent is then used on dry ice to form 4-toluic acid in tetrahydrofuran (THF) solvent.

Synthesis of Grignard reagent:



Grignard reagent

Reaction:



4-toluic acid

Fig 5.2 shows the reflux set-up of a Grignard reaction.

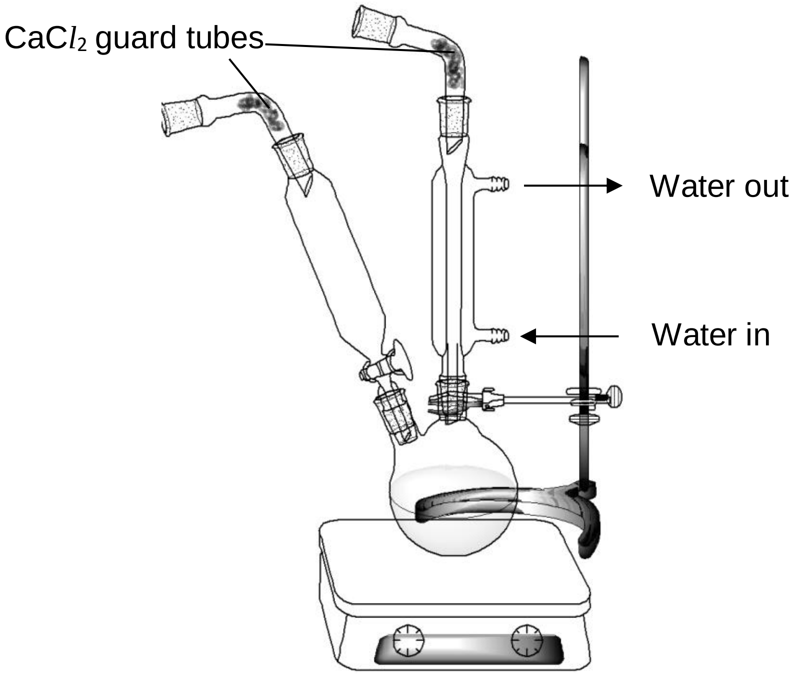


Fig 5.2

(ii) State the purpose of the calcium chloride guard tubes. **[1]**

(iii) Grignard reagents are destroyed readily upon the exposure to a small amount of moisture.

State the name of the reaction and draw the mechanism for this reaction using the Grignard reagent in Fig 5.2. **[2]**

A basic solvent extraction is used to purify the crude 4-toluic acid product. The crude product was dissolved in 20 cm^3 of dichloromethane (CH_2Cl_2) with 20 cm^3 of 10% NaOH.

The aqueous layer was extracted and combined before immersing in an ice-water bath. Concentrated hydrochloric acid was then added from a dispenser to the aqueous layer.

(iv) Explain the need for an ice-water bath in this step. **[1]**

In organic experiments, Thin Layer Chromatography (TLC) is often used to monitor the progress of a reaction and assess if the reaction is complete.

Fig. 5.3 shows a typical chromatography paper made up of silica (SiO_2) with the presence of hydroxyl groups on their surface.

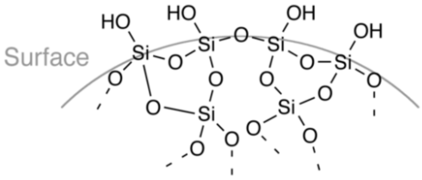
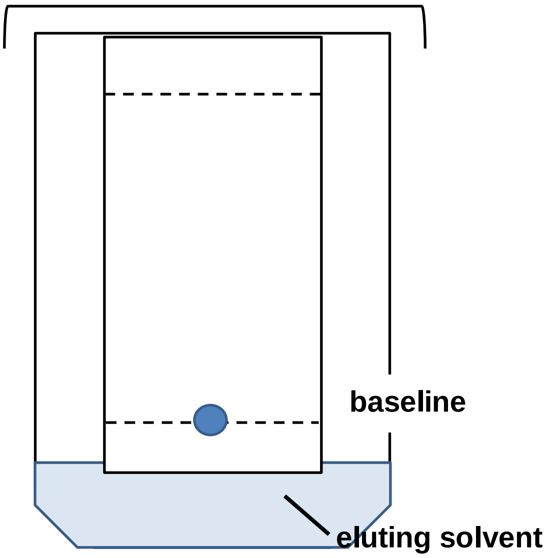


Fig. 5.3

When the reaction has proceeded for 60 minutes, a small portion of the reaction mixture, containing 4-bromotoluene and 4-toluic acid, was loaded on the TLC plate as shown in Fig. 5.4.



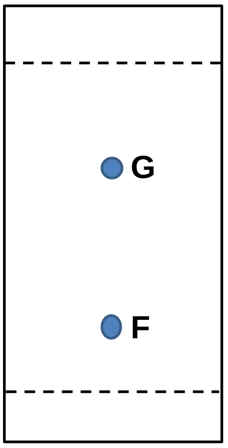


Fig. 5.4 TLC plate placed in TLC developing chamber

Fig. 5.5 TLC plate developed

The TLC plate was placed in a TLC developing chamber which contains an eluting solvent made up of ethyl acetate and hexane in a 1:2 volume ratio. As the eluting solvent passed through the spots on the baseline, depending on the interactions with the chromatogram and eluting solvent, the solute molecules travelled at different rates up the chromatogram. Each compound has a different retention factor, R_f, in the eluting solvent.

(v) The TLC plate is developed and the result is shown in Fig. 5.5.

Determine the R_f value of **F** in this TLC, given that the R_f is calculated as:

$$R_f = \frac{distance\ moved\ by\ solute}{migration\ distance\ moved\ by\ solvent}$$

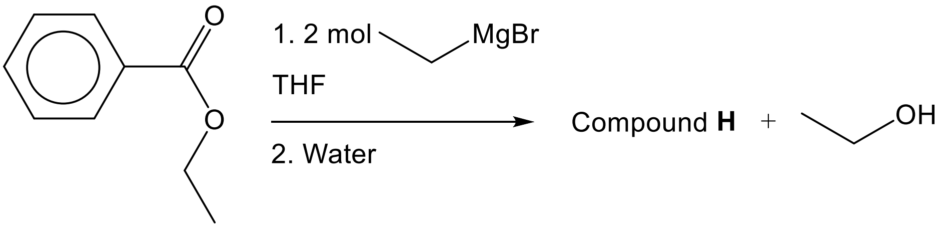
[1]

(vi) Consider the interactions between silica and 4-toluic acid, and between silica and 4-bromotoluene, identify **F** and **G**. Hence, explain the difference in the migration distance between 4-toluic acid and 4-bromotoluene.

[2]

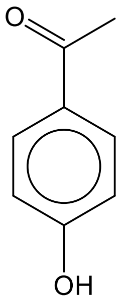
(vii) Suggest how the R_f value of 4-toluic acid will change when the eluting solvent is changed to ethyl acetate : hexane in a 2:1 volume ratio. **[1]**

(viii)

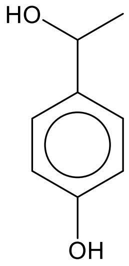


Suggest the structure for compound **H**. **[1]**

(ix) Compounds **J** and **K** are isomers of 4-toluic acid. Describe a simple chemical test to distinguish between compounds **J** and **K**.



Compound **J**



Compound **K**

[2]

[Total: 20]

– **End of Paper** –

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Suggested Answers for 9729 H2 CM 2019 JC 2 Prelim

Paper 3

1 **(a)** **(i)** When dissolved in a polar solvent such as water, they dissociate to form strong acids, releasing <u>H^+ and X^- ions</u> forming <u>ion-dipole interactions</u> with water. **[1]**

(ii) HF has an <u>exceptionally high boiling point</u> compared to the other hydrogen halides as <u>hydrogen bonds</u> exist between HF molecules but not between the rest of the HX molecules. <u>More energy is needed to overcome the stronger hydrogen bonds</u>.

Boiling point of the hydrogen halides <u>increases from HC*l* to HBr to HI.</u>

The strength of instantaneous dipole-induced dipole interactions between the hydrogen halide molecules increases as <u>the number of electrons in the molecules increases. More energy is needed to overcome the stronger id-id interactions.</u> **[2]**

(iii) When a red-hot steel needle is introduced, HBr produces <u>red brown bromine vapour.</u> HI gives <u>violet fumes of iodine</u>. <u>HF and HC*l* do not/show little tendency to decompose.</u>

Bond	Bond Energies/ kJ mol^{-1}
H–F	+562
H–C*l*	+431
H–Br	+366
H–I	+299

<u>Less energy is required to break the weaker H–X bond</u>.

<u>The thermal stability of hydrogen halides decreases down the Group</u> due to decreasing H–X bond energy. **[3]**

(b) **(i)** Solubility of AgBr = $0.140 \times 10^{-3} / (107.9 + 79.9)$

$= 7.45 \times 10^{-7}$ mol dm^{-3}

$[Br^-] = 4.00\times 10^{-12} / 0.100 = 4.00\times 10^{-11}$ mol dm^{-3}

$[Ag^+]\,[Br^-] = K_{sp}$

$[Ag^+]\,(4.00\times 10^{-11}) = (7.45 \times 10^{-7})^2$

$[Ag^+] = 0.0139$ mol dm^{-3} **[2]**

(ii) In the saturated AgC*l*,

$[Ag^+]\,[Cl^-] = K_{sp}$

$(0.0139)(0.0139 + 0.001) = K_{sp}$

$K_{sp} = 0.000206$ mol^2 dm^{-6}

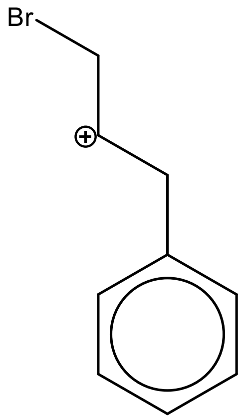
Solubility = $(0.00206)^{1/2} = 0.0144$ mol dm^{-3} **[2]**

(iii) Mass of AgC*l* dissolved in 1 dm^3 = (0.0139)(107.9 + 35.5)

= 1.99 g

Mass of residue = 5.00 – 1.99 = <u>3.01 g</u> **[1]**

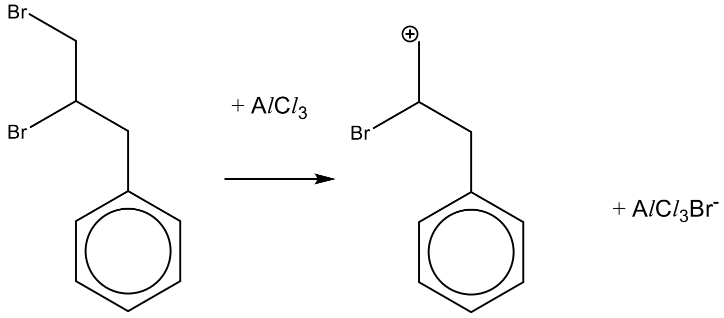
(c) **(i)**

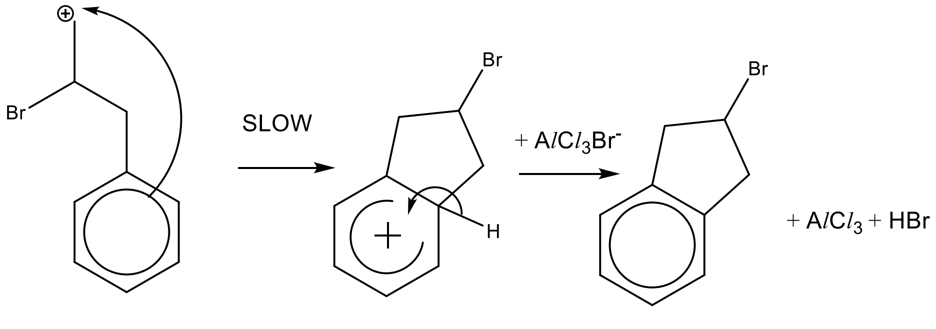


The higher the number of electron donating groups attached to carbocation, the more stable the carbocation.

As the 2 possible intermediate contains a primary carbocation and secondary carbocation respectively, intermediate with the secondary carbocation is more stable. **[2]**

(ii)





[2]

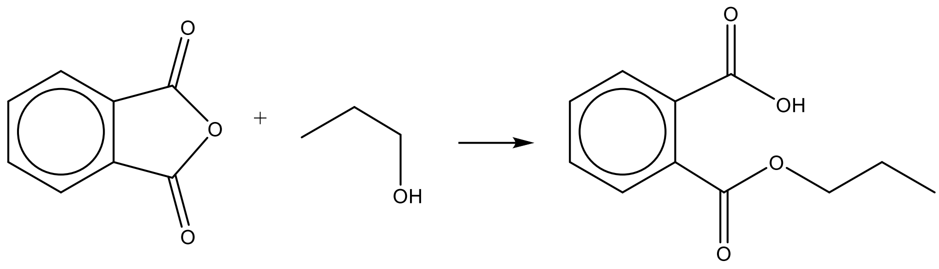
(iii) Compound **B** has a 4 membered ring form in place of the 5 membered ring presented in the reaction scheme.

The 4 membered ring consist of 2 carbon atoms with sp^2 hybridised orbitals 120° from each other and 2 carbon atoms with sp^3 hybridised orbitals at 109.5° from each other.

To fit into 4 membered ring, all 4 carbons are forced into 90° bond angle which exerts high angle strains making the 4 membered ring formation unfavourable. **[2]**

[Total: 17]

2 **(a)** **(i)**



[1]

(ii) H_2O/Water **[1]**

(b) **(i)** For pK_1, the H^+ is removed from a neutral molecule. For pK_2, the <u>removal of a H^+ from the anion</u> that already carries a negative charge is electrostatically unfavourable.

OR <u>Favourable intramolecular hydrogen bonding</u> in the anion will be <u>disrupted</u> when it dissociates in pK_2. **[1]**

(ii) Phthalic acid is the limiting reagent/NaOH is in excess

Amount of excess NaOH = $\frac{50}{1000} \times 0.1 - \left(\frac{10}{1000} \times 0.2 \times 2\right)$

$= 1.0\times10^{-3}$ mol

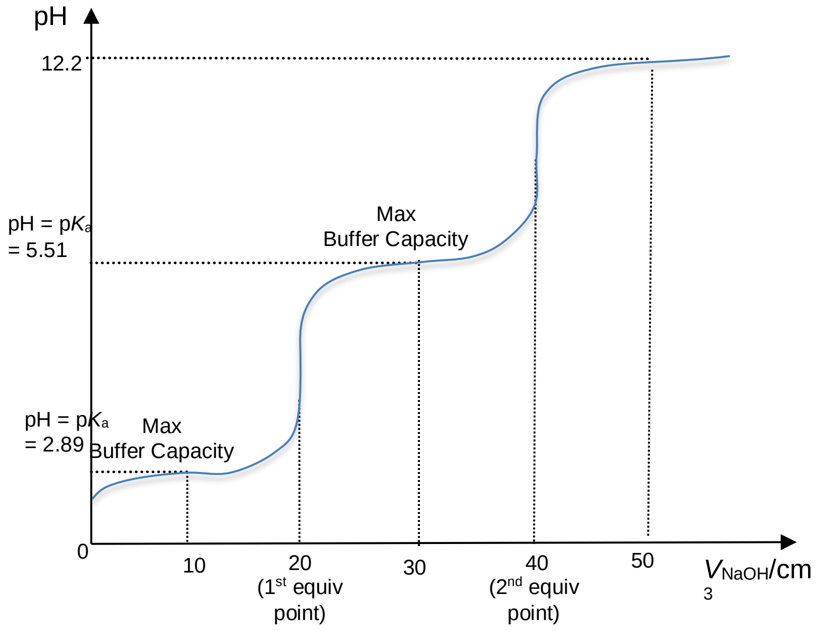
$[OH^-] = \frac{1.0\times10^{-3}}{\frac{60}{1000}} = 1.667 \times 10^{-2}$ mol dm^{-3}

pOH = $-\lg(1.667 \times 10^{-2}) = 1.78$

pH = $14 - 1.78 = 12.2$

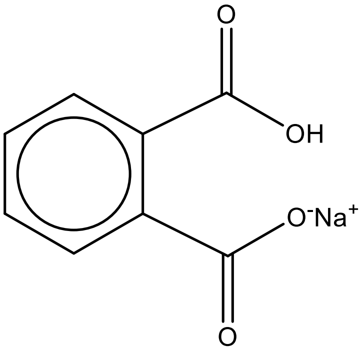
[2]

(iii)



[3]

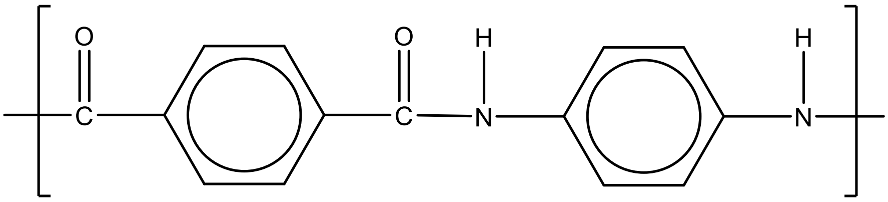
(iv)



[1]

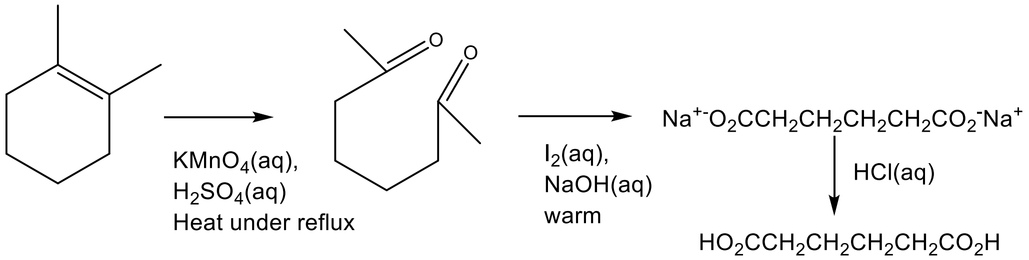
(c) **(i)** Condensation **[1]**

(ii)



[1]

(d)

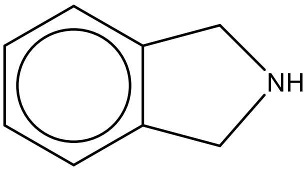


[2]

(e) Reaction **A**: PCl_5, room temperature

Reaction **B**: limited ethanolic NH_3, heat in a sealed tube

Structure of **C**:



[3]

(f) **(i)** I: acid-base reaction (alkaline hydrolysis is not accepted)

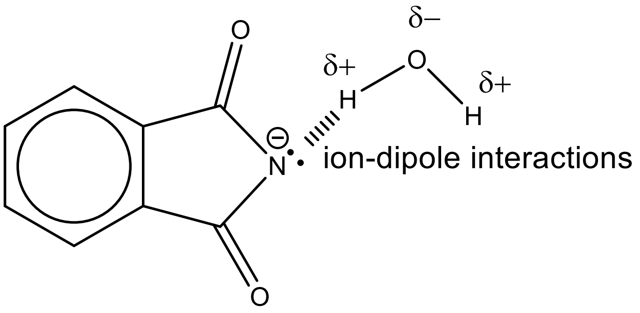
II: nucleophilic substitution

III: hydrolysis **[3]**

(ii) H_2SO_4(aq) and heat under reflux, followed by controlled amount of strong base.

Or NaOH(aq) and heat under reflux, followed by controlled amount of strong acid **[1]**

(iii)



[1]

(iv) Amt of **D** = $\frac{0.5}{147}$ = 3.401 × $10^{`3}$ mol

Amt of gaseous product = $\frac{pV}{RT} = \frac{(101325)(42.26\times10^{-6})}{8.31\times303}$ = 1.701× $10^{`3}$ mol

Since mole ratio of **D**: Gaseous Product = 2:1, gaseous product is N_2 gas.

$4C_8H_5O_2N + 33O_2 \rightarrow 32CO_2 + 10H_2O + 2N_2$ **[3]**

[Total: 24]

3 **(a)** Amt of Fe^{3+} = $\frac{5}{1000}\times0.2 = 0.00100$ mol

Amt of CN– = $\frac{6}{1000}\times0.6 = 0.00600$ mol

Since ratio of Fe^{3+} : CN^{-} = 1:6,

H_2O ligand is displaced.

Complex in red solution : $[Fe(CN)_6]^{3-}$

Formation of red solution : $[Fe(H_2O)_6]^{3+} + 6CN^{-} \rightarrow [Fe(CN)_6]^{3-} + 6H_2O$

Complex in yellow solution : $[Fe(CN)_6]^{4-}$ **[2]**

(b) **(i)** 3d and 4s electrons have similar energies. More valence electrons from Fe is contributed to the sea of delocalised (mobile) electrons then Ca, thus Fe has a higher electrical conductivity. **[1]**

(ii) Both aqueous Fe^{2+} and Fe^{3+} exist as aqua complexes with formulae $[Fe(H_2O)_6]^{2+}$ and $[Fe(H_2O)_6]^{3+}$ respectively.

Ionic radius of Fe^{2+} = 0.061 nm

ionic radius of Fe^{3+} is 0.055 nm

With a smaller radius and a higher charge, Fe^{3+} has a higher charge density**,** water molecules in $[Fe(H_2O)_6]^{3+}$ is polarised and the O–H bonds are weakened to a greater extent, $[H^+]/[H_3O^+]$ increases. Hence, the pH is lower.

$[Fe(H_2O)_6]^{3+}(aq) + H_2O(l) \rightleftharpoons [Fe(H_2O)_5(OH)]^{2+}(aq) + H_3O^+(aq)$ **[2]**

(c) **(i)** Role of Fe^{3+} : Homogeneous catalyst

The reaction between peroxodisulfate ions $S_2O_8^{2-}$ and iodide ions I^- can be catalysed by either Fe^{2+} or Fe^{3+}.

$$S_2O_8^{2-} + 2e^- \rightleftharpoons 2SO_4^{2-} \quad E^\ominus = +2.01\text{ V}$$

$$Fe^{3+} + e^- \rightleftharpoons Fe^{2+} \quad E^\ominus = +0.77\text{ V}$$

$$I_2 + 2e^- \rightleftharpoons 2I^- \quad E^\ominus = +0.54\text{ V}$$

Reaction catalysed by $Fe^{3+}(aq)$:

Step 1: Formation of an intermediate

$$2Fe^{3+}(aq) + 2I^-(aq) \rightarrow 2Fe^{2+}(aq) + I_2(aq)$$

$$E^\ominus_{cell} = +0.77 - (+0.54) = +0.23\text{ V}$$

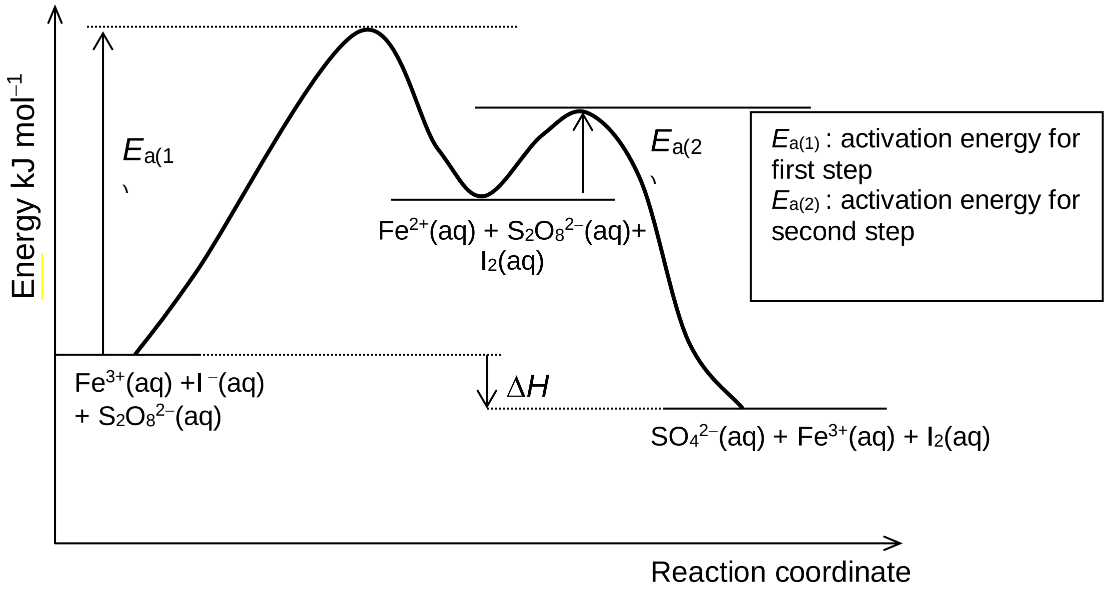
Step 2: Regeneration of catalyst

$$S_2O_8^{2-}(aq) + 2Fe^{2+}(aq) \rightarrow 2SO_4^{2-}(aq) + 2Fe^{3+}(aq)$$

$$E^\ominus_{cell} = +2.01 - (+0.77) = +1.24\text{ V}$$

[2]

(ii) **[3]**



(c) **V** has a molecular formula of $C_8H_9NO_2$.

The C:H ratio is ≈ 1:1.

⇒**V** contains a benzene ring

V is insoluble in water and acids

⇒**V** contains an amide

V undergoes acid-base reaction in NaOH

⇒**V** contains a phenol or carboxylic acid group

V undergoes electrophilic substitution with aq Br_2 to form **W**

⇒ **W** has a side chain in either position 2, 4 w.r.t. OH

V undergoes acidic hydrolysis to form compound **X** and **Y**

⇒ salt and carboxylic acid is formed.

X is soluble in water

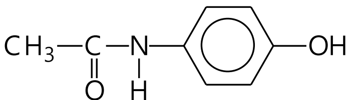
⇒ **X** is an ammonium salt

Y on reduction with $LiAlH_4$ forms **Z**

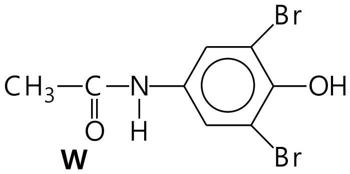
⇒ **Z** is an alcohol

Z undergoes positive iodoform test/oxidation to form a yellow precipitate.

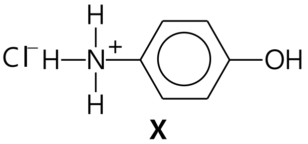
⇒ **Z** is $–CH(CH_3)(OH)$ group



V



W



X

CH_3COOH

Y

CH_3CH_2OH

Z

[9]

[Total: 19]

4 **(a)** **(i)** ΔH_{vap} positive due to the energy required to overcome the intermolecular forces between molecules.

ΔS_{vap} positive due to the changing from liquid to gaseous state, hence $-T\Delta S_{vap}$ negative

For vaporisation to be spontaneous, $|-T\Delta S_{vap}| > |\Delta H_{vap}|$, hence it is an entropy-driven reaction. **[2]**

(ii) Benzene is the most volatile VOC.

$$\Delta G_{vap} = 33.9 - 330(\frac{113.6}{1000}) = \underline{-3.59 \text{ kJ mol}^{-1}}$$

(For the others: ethanol +2.40 , methylbenzene +9.29 , propanone −0.05) **[1]**

(b) **(i)** Excess chlorine, uv light, (limited methane) **[1]**

(ii) Initiation

U

$Cl_2 \rightarrow 2Cl\bullet$ **[3]**

Propagation

$CH_4 + Cl\bullet \rightarrow \bullet CH_3 + HCl$

$\bullet CH_3 + Cl_2 \rightarrow CH_3Cl + Cl\bullet$

$CH_3Cl + Cl\bullet \rightarrow \bullet CH_2Cl + HCl$

$\bullet CH_2Cl + Cl_2 \rightarrow CH_2Cl_2 + Cl\bullet$ (must show)

Termination

$\bullet CH_2Cl + Cl\bullet \rightarrow CH_2Cl_2$ (must show)

$2Cl\bullet \rightarrow Cl_2$

$\bullet CH_3 + \bullet CH_3 \rightarrow CH_3CH_3$

$\bullet CH_3 + Cl\bullet \rightarrow CH_3Cl$

$\bullet CH_2Cl + \bullet CH_2Cl \rightarrow ClCH_2CH_2Cl$ (Any 1 of these other 4)

(c) **(i)** 2-methyl-buta-1,3-diene or 2-methyl-1,3-butadiene **[1]**

(ii) Mass produced = $(0.15 \times 10^{-6} \times 68.0 \times 1000) \times 65 \times 24$

= 15.9 mg **[1]**

(iii) $C_5H_8 + 7O_2 \rightarrow 5CO_2 + 4H_2O$

$CS_2 + 3O_2 \rightarrow CO_2 + 2SO_2$ **[2]**

(iv)

Let x be the volume of C_5H_8 and nx be the volume of CS_2 initially.

Combining the eqns: $C_5H_8 + 7O_2 \rightarrow 5CO_2 + 4H_2O$ & $nCS_2 + 3nO_2 \rightarrow nCO_2 + 2nSO_2$

Combustion Process:

$$C_5H_8 + nCS_2 + (3n+7)O_2 \rightarrow (n+5)CO_2 + 2nSO_2 + 4H_2O$$

	C_5H_8	nCS_2	$(3n+7)O_2$	$(n+5)CO_2$	$2nSO_2$	$4H_2O$
Initial vol	x	nx	excess V_{O2}	-	-	-
Change	*–x*	*–nx*	*–(3n+7)x*	*+(n+5)x*	*+2nx*	-
After rxn	0	0	(excess V_{O2} – 3nx – 7x)	(n+5)x	2nx	-

Volume of gas before combustion = excess V_{O2} + x + nx

Volume of gas after combustion = excess V_{O2} – 3nx – 7x + nx + 5x + 2nx

= excess V_{O2} – 2x

(Volume before combustion) – (Volume after combustion) = 1st volume contraction (excess V_{O2} + x + nx) – (excess V_{O2} – 2x) = 1st volume contraction

$x + nx + 2x = 70$

$3x + nx = 70$

$\mathbf{(n + 3)x = 70}$ **------- (1)**

Volume of CO_2 and SO_2 in resultant mixture = 2nd volume contraction

$5x + nx + 2nx = 170$

$\mathbf{(3n + 5)x = 170}$ **------ (2)**

$$\frac{(1)}{(2)}: \quad \frac{n+3}{3n+5} = \frac{70}{170}$$

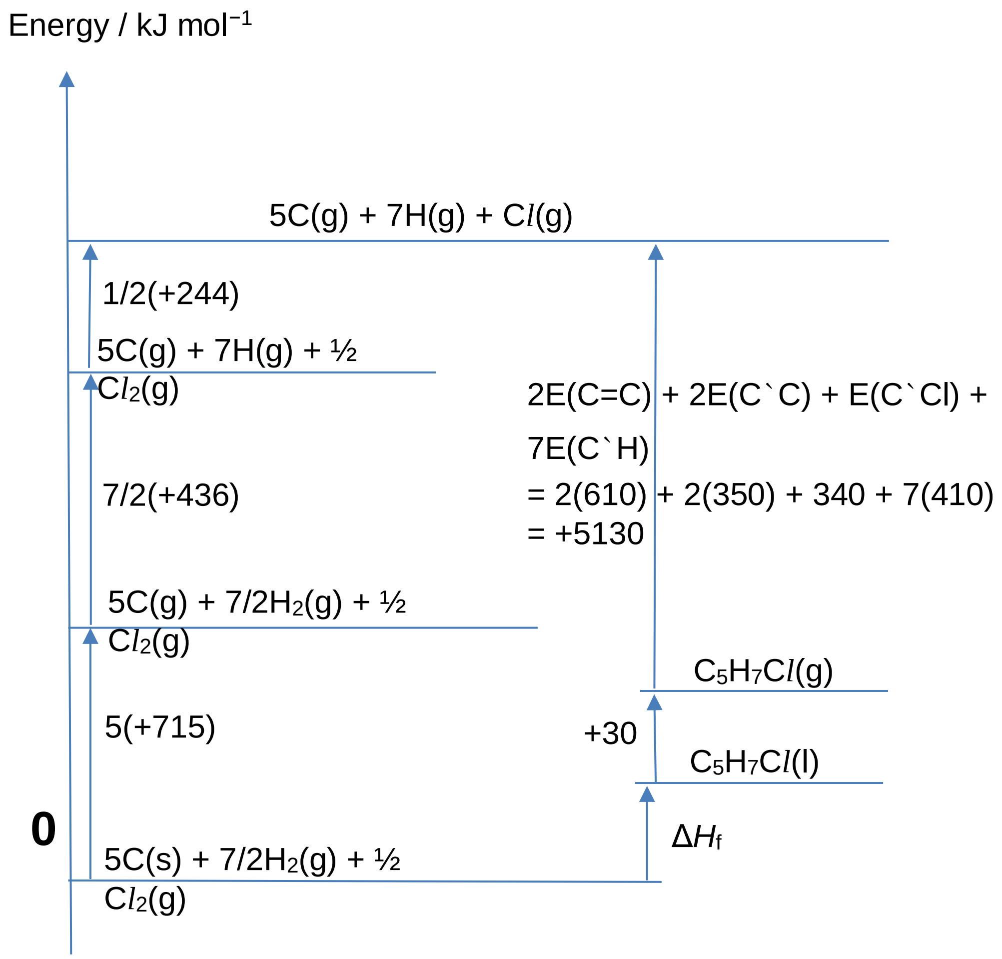
[3]

$170n + 510 = 210n + 350$

$210n – 170n = 510 – 350$

$40n = 160$ ➔ **n = 4**

(d) (i) **[4]**



ΔH_f = +(5223 – 5160) = <u>+63</u> kJ mol^{-1}

(d) **(ii)** constitutional / structural / functional group isomerism. **[1]**

(iii) The C`C*l* bond in compound **N** has a partial double bond character due to the delocalisation of lone pair on C*l* into the neighbouring C^C π electron system.

Hence the C`C*l* bond energy will be larger than +340 kJ mol^{-1} and will in turn decrease the magnitude of compound **N**'s enthalpy change of formation. **[1]**

[Total: 20]

5 **(a)** MgO(s) reacts with water to form $Mg(OH)_2(s)$, which dissolves sparingly in water to give a weakly alkaline (pH = 8) solution. **[5]**

$MgO(s) + H_2O(l) \rightarrow Mg(OH)_2(s)$

$Mg(OH)_2(s) \rightleftharpoons Mg^{2+}(aq) + 2OH^-(aq)$

$SiO_2(s)$ is insoluble in water as a large amount of energy is required to break the many strong covalent bonds in the giant covalent structure. Since the oxide does not dissolve in water, it will not affect the pH (*i.e.* pH = 7).

$P_4O_{10}(s)$ react violently/vigorously with water to give an acidic solution (pH = 2).

$P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)$
OR $P_4O_6(s) + 6H_2O(l) \rightarrow 4H_3PO_3(aq)$

(b) **(i)** $SO_2(aq) + 2H_2O(l) + I_2(aq) \rightarrow SO_4^{2-}(aq) + 4H^+(aq) + 2I^-(aq)$ **[1]**

(ii) Amount of I_2 = $\frac{17.70}{1000} \times 0.0100 = 1.77 \times 10^{-4}$ mol **[2]**

Amount of SO_2 in 50 cm^3 = 1.77×10^{-4} mol

$[SO_2] = \frac{1.77 \times 10^{-4}}{50 \times 10^{-3}} = 3.54 \times 10^{-3}$

Concentration of SO_2 in mg L^{-1} = $3.54 \times 10^{-3} \times 64.1 = 227$ mg L^{-1}

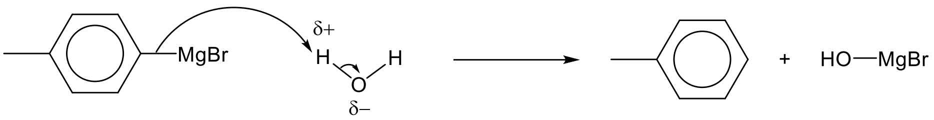
Amount of SO_2 per kg $= \frac{227 \times \frac{400}{1000}}{70} = 1.30 > 0.7$

Exceeded the maximum daily intake of SO_2 so it is not advisable.

(c) **(i)** Lithium and magnesium are highly electropositive, polarised the bond towards carbon. **[1]**

(ii) It is used to avoid prolonged exposure to the moisture in the air/ as a dehydrating agent. **[1]**

(iii) Hydrolysis/ nucleophilic substitution **[2]**



Accept OH^- $MgBr^+$

(iv) Acidification of benzoate/4-toluate ion is a highly exothermic process as O–H bonds are formed and no bonds are broken. **[1]**

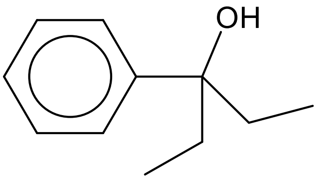
(v) $R_f = \frac{0.85}{4.35} = 0.195$ **[1]**

(vi) **F**: 4-toluic acid, **G**: 4-bromotoluene **[2]**

4-toluic acid forms stronger hydrogen bonding with the hydroxyl group of the silica surface, hence, 4-bromotoluene travels further than 4-toluic acid.

(vii) The R_f value will increase. **[1]**

(viii)



[1]

(ix) Test: Acidified $K_2Cr_2O_7$, heat **[2]**

Observation: Orange dichromate turned green for Compound **K** but not **J**.

Or

Test: 2,4-DNPH

Observation: Orange ppt is formed for Compound **J** but not **K**.

Or

Test: PCl_5 or PCl_3 or $SOCl_2$

Observation: White fumes of HCl evolved for Compound **K** but not **J**.

[Total: 20]

RIVER VALLEY HIGH SCHOOL
JC 2 PRELIM PRACTICAL EXAMINATION

H2 CHEMISTRY 9729

26 AUGUST 2019

2 HOURS 30 MINUTES

NAME ____________________________________

CLASS 18J (   )

INDEX NO. ____________________________________

INSTRUCTIONS TO CANDIDATES

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

Read these notes carefully.

Write your name, class and index number in the spaces at the top of this page.
Give details of the practical shift and laboratory where appropriate, in the boxes provided.
Write in dark blue or black pen.
You may use a 2B pencil for any diagrams or graph.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer ***all*** *questions in the spaces provided on the Question Paper.*

The use of an approved scientific calculator is expected, where appropriate.

You may lose marks if you do not show your working or if you do not use appropriate units.

Shift
Laboratory

For Examiner's Use	
3 s.f.	
Units	
Total	55

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

1 An experiment to investigate the behaviour of acids and bases in aqueous solution

FA 1 is 1.00 mol dm^{-3} sodium hydrogencarbonate, $NaHCO_3$

FA 2 is sodium hydroxide, NaOH, between 1.5 to 2.5 mol dm^{-3}

FA 3 is 2.00 mol dm^{-3} sulfuric acid, H_2SO_4

According to the *Arrhenius* theory of acids and bases, an acid produces $H^+(aq)$ ions and a base produces $OH^-(aq)$ ions, in aqueous solution.
Using the *Arrhenius* theory, an acid-base neutralisation reaction involves reacting together these two ions to produce water molecules.

The equation for this neutralisation reaction is given below.
$H^+(aq) + OH^-(aq) \longrightarrow H_2O(l)$ $\Delta H_{neutralisation} = -57.1$ kJ mol^{-1}

The reaction between $H^+(aq)$ and $OH^-(aq)$ involves bond formation and is exothermic. It is possible to make use of this fact to perform a thermometric titration. This task involves two different acid-base reactions.

The first reaction is between sodium hydrogencarbonate, **FA 1**, and sodium hydroxide, **FA 2**.

Reaction 1:
$NaHCO_3(aq) + NaOH(aq) \longrightarrow Na_2CO_3(aq) + H_2O(l)$ $\Delta H_{reaction\ 1}$

The molar enthalpy change for **Reaction 1**, $\Delta H_{reaction\ 1}$, is the enthalpy change when 1.00 mol of $NaHCO_3$ reacts completely with NaOH.

Instead of using an indicator to determine the endpoint, you will perform a thermometric titration to determine the equivalence point of the reaction. The equivalence point is that point where $H^+(aq)$ from the acid and $OH^-(aq)$ from the base are present in equal molar amounts.

The second reaction is between sodium hydrogencarbonate, **FA 1**, and sulfuric acid, **FA 3**.

Reaction 2:
$NaHCO_3(aq) + \frac{1}{2}H_2SO_4(aq) \longrightarrow \frac{1}{2}Na_2SO_4(aq) + H_2O(l) + CO_2(g)$
$\Delta H_{reaction\ 2}$

The molar enthalpy change for **Reaction 2**, $\Delta H_{reaction\ 2}$, is the enthalpy change when 1.00 mol of $NaHCO_3$ reacts completely with H_2SO_4.

In your first experiment, you will perform a thermometric titration by adding portions of **FA 2** progressively to a known volume of **FA 1**. You will continue adding **FA 2** until the equivalence point is reached and passed. Throughout the experiment, you will note and record the temperature of the mixture after each addition.

You will then analyse your results graphically in order to determine the
- titration volume at the equivalence point, $V_{\text{equivalence}}$,
- maximum temperature change, $\Delta T_{\text{maximum 1}}$,
- molar enthalpy change, $\Delta H_{\text{reaction 1}}$, for **Reaction 1**.

In your second experiment, you will mix together a given volume of **FA 1** with a suitable volume of **FA 3**.

You will then determine the
- maximum temperature change, $\Delta T_{\text{maximum 2}}$,
- molar enthalpy change, $\Delta H_{\text{reaction 2}}$, for **Reaction 2**.

Reaction between FA 1 and FA 2

(a) **(i)** In this task you will need to record the maximum temperature of the reaction mixture when specified volumes of **FA 2** have been added. It is important that the volume of **FA 2** recorded is the total volume you have added up to that point when the temperature reading was made.

Note:
If you overshoot on an addition, record the **actual** total volume of **FA 2** added up to that point.

In an appropriate format in the space provided, record all values of temperature, T, to 0.1 °C, and each total volume of **FA 2** added to 0.05 cm^3.

1. Fill a burette with **FA 2**.
2. Place a Styrofoam cup inside a second Styrofoam cup which is held in a glass beaker to prevent it tipping over.
3. Using a pipette, transfer 25.0 cm^3 of **FA 1** to the first Styrofoam cup.
4. Stir the **FA 1** solution in the cup with the thermometer. Read and record its temperature.
5. From the burette, add 2.00 cm^3 of **FA 2** to the cup and stir the mixture thoroughly.
6. Read and record the maximum temperature of the mixture, T, and the volume of **FA 2** added.
7. Repeat points 5 and 6 until a total of 30.00 cm^3 of **FA 2** has been added. After each addition of **FA 2**, record the maximum temperature of the mixture and the total volume of **FA 2** added up to that point.

Results

For Examiner's Use

1	
2	

(a) **(ii)** On the grid below, plot a graph of temperature, T against volume of **FA 2** added.

For Examiner's Use

3	
4	
5	

(iii) Draw **two** smooth lines of best fit. Extrapolate these lines until they cross. Extrapolate these lines until they cross.

6	
7	
8	

(iv) Determine from your graph,

- the maximum temperature reached, T_{maximum},
- the maximum temperature change, $\Delta T_{\text{maximum 1}}$,
- the volume, $V_{\text{equivalence}}$, of **FA 2** needed to completely react with 25.0 cm^3 of **FA 1**.

Show on your graph how you obtained these values.

Record these values in the spaces provided below.

Maximum temperature reached, T_{maximum} = ...

Volume of **FA 2** used, $V_{\text{equivalence}}$ = ...

Supervisor
Student
Difference

Hence, calculate the maximum temperature change, $\Delta T_{\text{maximum 1}}$ = ...

Supervisor
Student
Difference

Reaction between FA 1 and FA 3

(b) The molar enthalpy change for **Reaction 2**, $\Delta H_{\text{reaction 2}}$, is the enthalpy change when 1.00 mol of $NaHCO_3$ reacts completely with H_2SO_4.

In this task you will calculate a value for the molar enthalpy change, $\Delta H_{\text{reaction 2}}$. To do this you will need to determine the maximum temperature change produced when measured volumes of **FA 1** and **FA 3** are mixed. After considering the concentrations of **FA 1** and **FA 3**, you will select a suitable volume of **FA 3** to add to 40 cm^3 of **FA 1**.

(i) Choose a suitable volume of **FA 3**, $V_{\textbf{FA 3}}$, to be added to 40 cm^3 of **FA 1**. Explain your answer.

……………………………………………………………………………

……………………………………………………………………………

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10	

(ii) Identify the apparatus you intend to use to measure the volume of **FA 1**.

Explain your choice.

……………………………………………………………………………

……………………………………………………………………………

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11	

(iii) In an appropriate format in the space provided below, record all values of measured temperature for this experiment.

1. Label one Styrofoam cup, **A**. Label a second Styrofoam cup, **B**.
2. Place cup **A** inside a Styrofoam cup which is held in a glass beaker to prevent it from tipping over.
3. Transfer 40 cm^3 of **FA 1** into cup **A**.
4. Stir the **FA 1** solution in cup with the thermometer. Read and record its temperature, $T_{\textbf{FA 1}}$. This is the initial temperature of **FA 1**.
5. Wash and dry the thermometer.
6. Transfer your chosen volume of **FA 3** into cup **B**. Stir the **FA 3** solution with the thermometer. Read and record its temperature, $T_{\textbf{FA 3}}$. This is the initial temperature of **FA 3**.
7. Carefully add the contents of cup **B** to cup **A** in **small** portions to avoid too much frothing.
8. Place the lid on the cup and insert the thermometer through the lid. Stir the mixture.
9. Continue to stir the mixture. Measure and record the temperature, T_{mixture} that shows the maximum change from the initial temperature.

Results

For Examiner's Use

12	
13	

Calculations

(c) For the purposes of these calculations, you should assume that the reaction mixture has a density of 1.00 g cm^{-3} and a specific heat capacity, *c*, of 4.18 J g^{-1} K^{-1}.

(i) Calculate the concentration of sodium hydroxide, [NaOH], in **FA 2**.

14	

[NaOH] in **FA 2** = ...

(ii) Calculate the heat change, *q*, for the reaction occurring in **(a)(i)**, and hence determine a value for the molar enthalpy change for **Reaction 1**, $\Delta H_{\text{reaction 1}}$.

15	
16	

q =..............................

$\Delta H_{\text{reaction 1}}$= ....

(d) Use your results from **(b)(iii)** to calculate a value for the molar enthalpy change for **Reaction 2**, $\Delta H_{\text{reaction 2}}$. For the experiment in **(b)(iii)**, the weighted average initial temperature, T_{average}, of **FA 1** and **FA 3** may be calculated using the formula given below.

For Examiner's Use

$$T_{average} = \frac{(V_{FA1} \times T_{FA1}) + (V_{FA3} \times T_{FA3})}{(V_{FA1} + V_{FA3})}$$

17	
18	
19	

T_{average} = ...

q =.............................

$\Delta H_{\text{reaction 2}}$ = ...

(e) Ionic equations for neutralisation, **Reaction 1**, and **Reaction 2** are shown below.

HCO_3^{-} (aq) + OH^{-} (aq) $\longrightarrow$ CO_3^{2-} (aq) + H_2O (l) $\Delta H_{\text{reaction 1}}$

HCO_3^{-}(aq) + H^{+} (aq) $\longrightarrow$ H_2O (l) + CO_2 (g) $\Delta H_{\text{reaction 2}}$

Use your answers in **(c)(ii)** and **(d)**, draw an energy cycle to determine a value for the molar enthalpy change, $\Delta H_{\text{reaction 3}}$, for **Reaction 3**.

Reaction 3:

H_2O(l) + CO_2(g) + OH^{-}(aq) $\longrightarrow$ CO_3^{2-}(g) + H_2O(l) + H^{+}(aq) $\Delta H_{\text{reaction 3}}$

20	
21	

(f) An alternative definition of acid-base behaviour was proposed by Brønsted and Lowry. **Reaction 1** and **Reaction 2** are both acid-base reactions involving hydrogencarbonate ions, HCO_3^{-}.

In terms of the *Brønsted-Lowry* theory of acids and bases, suggest the role of hydrogencarbonate ions, HCO_3^{-}, in **Reaction 1**.

Explain your answer.

Reaction 1

Role of HCO_3^{-} : ……………………………………………………………………

22	

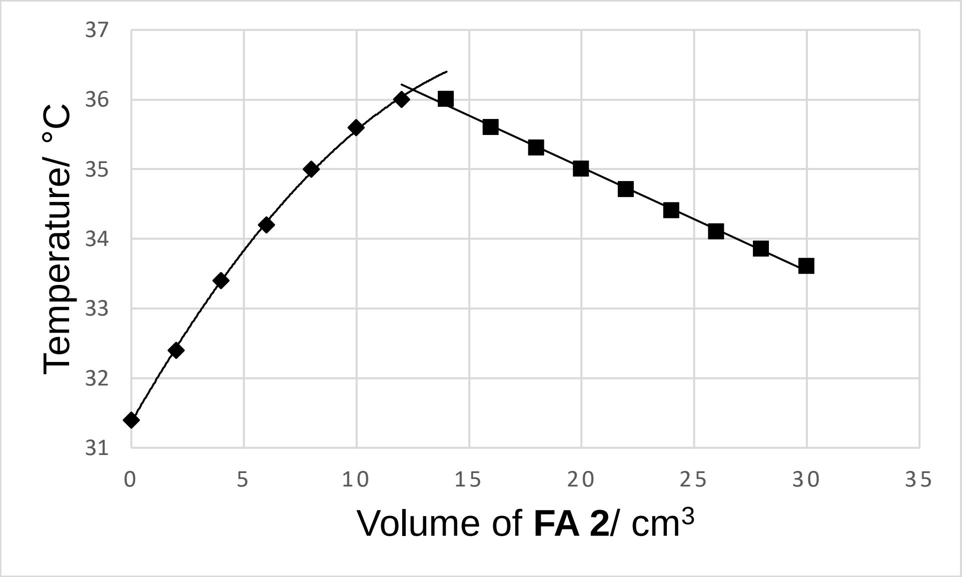
Explanation : ……………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

For Examiner's Use

(g) A student conducted the same experiment using a digital thermometer and obtained the graph as shown below.



Explain the shape of the graph.

....

....

....

....

....

....

....

....

23	
24	
25	

(h) In the calculation of **(d)**, explain why the weighted average initial temperature was used.

……………………………………………………………………………………… **26**

………………………………………………………………………………………

(h) With reference to the reaction between **FA 1** and **FA 2**, if the volume of NaOH is doubled, explain how it will affect the maximum temperature change?

………………………………………………………………………………………

……………………………………………………………………………………… **27**

………………………………………………………………………………………

………………………………………………………………………………………

[Total: 27]

2 To determine the proticity of an unknown acid

For Examiner's Use

Acid base titration is commonly used to determine the concentration of an acid or base. In this experiment, the concentration of the acid is given and the aim of this investigation is to determine its proticity.

Acids are defined as substances that can donate hydrogen ions, H^+, to bases. Monoprotic acids contain one H^+ that can be donated per molecule. Diprotic acids contain two H^+ that can be donated per molecule.

You will determine using a titration method whether acid **Z** is monoprotic or diprotic.

- **FA 4** is a solution containing 11.55 g dm^{-3} of acid **Z**.
- **FA 5** is 0.105 mol dm^{-3} aqueous sodium hydroxide, NaOH.
- Thymol blue indicator

(a) Method

1. Pipette 25.0 cm^3 of solution **FA 4** into a conical flask.
2. Fill a burette with **FA 5**.
3. Add 3 drops of thymol blue indicator to the conical flask.
4. The colour change at the endpoint is yellow to blue.
5. Carry out as many accurate titrations as you think necessary to obtain consistent results.
6. Record, in a suitable form below, all of your burette readings and the volume of **FA 5** added in each accurate titration.

Results

28	
29	
30	
31	

For Examiner's Use

(b) From your titration results, obtain a suitable value for the volume of **FA 5** to be used in your calculations. Show clearly how you obtained this value.

32	

Volume of **FA 5** =............................

(c) Calculations

(i) Calculate the amount of H^+ present in 25.0 cm^3 of **FA 4**.

33	

Amount of H^+ in 25.0 cm^3 of **FA 4** = ...

(ii) Calculate the amount of H^+ present in 1 dm^3 of **FA 4**.

34	

Amount of H^+ in 1 dm^3 of **FA 4** = ...

(iii) **FA 4** contains 11.55 g dm^{-3} of acid **Z**. The relative molecular mass of **Z** is 126. Calculate amount of **Z** in 1 dm^3 of **FA 4**.

35	

Amount of **Z** in 1 dm^3 of **FA 4** = ...

(iv) Use your answers to **(ii)** and **(iii)** to determine whether **Z** is a monoprotic or a diprotic acid. Explain your answer.

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(v) Student **A** conducted this experiment on the day when the chemicals were freshly prepared. His average titre value was found to be *h* cm^3.

Three days later, he conducted the same experiment using the same chemicals but he found that the bottle of NaOH(aq) was left uncovered.

37	

Suggest how his new titre value would compare to *h* cm^3 and explain your answer.

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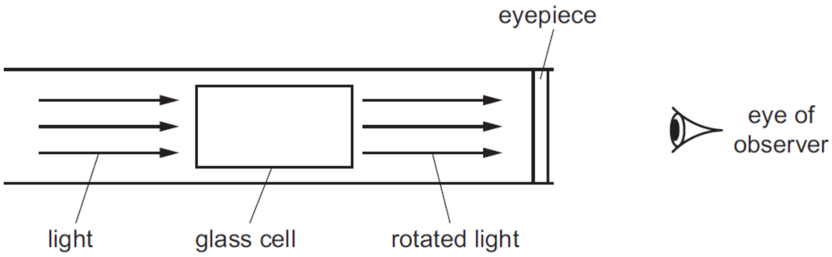
(d) Planning

Sucrose, $C_{12}H_{22}O_{11}$, is a sugar. The concentration of a solution of sucrose can be measured by the optical rotation, α, of a sucrose solution instead of acid–base titration. The more concentrated the solution, the greater the optical rotation of the solution.

A polarimeter is used to measure optical rotation. Plane–polarised light is passed through a sample of the sucrose solution in a glass cell, and the observed angle of rotation, α_{obs}, is measured.

A simplified diagram of a polarimeter is shown.



If a glass cell of length 1 cm is filled with a solution of sucrose of concentration 1 g cm^{-3}, the measured angle of rotation is known as the specific rotation, [α].

The observed angle of rotation, α_{obs}, measured by the polarimeter is related mathematically to the concentration of the sucrose solution by the equation shown.

$$\alpha_{obs} = [\alpha]lc$$

α_{obs} is the observed angle of rotation.

[α] is a constant and is known as the specific rotation of sucrose solution.

l is path length which is 1 cm in the above description.

c is the concentration of sucrose, in g cm^{-3}

(i) Explain why a sucrose solution is able to rotate plane–polarised light.

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(ii) Using the information given above, you are required to write a plan to determine the concentration of sucrose in a solution **X**.

You may assume that you are provided with:

- solid sucrose, $C_{12}H_{22}O_{11}$;
- solution **X**, of an unknown sucrose concentration less than 0.0800 g cm^{-3};
- access to a polarimeter and instructions for use;
- graph paper;
- the apparatus and chemicals normally found in a school or college laboratory.
- glass cell of length 10 cm.

Your plan should include details of:

- the preparation of 250 cm^3 0.0800 g cm^{-3} sucrose solution using solid sucrose provided;
- the preparation of a suitable range of diluted solutions of accurate concentrations;
- an outline of how the results would be obtained;
- a sketch of the calibration curve you would expect to obtain;
- how the calibration line would be used to determine the concentration of sucrose in solution **X**.

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For Examiner's Use

(iv) The glass cell of 10 cm length is expensive, so one cell is used for all the solutions that are placed in the polarimeter.

Suggest how you would ensure that the concentration of solution in the cell is accurate each time the cell is used for the different sucrose solutions.

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(v) Concentration of sucrose is the independent variable in this polarimeter experiment.

The glass cell of 10 cm length is replaced by a glass cell of 20 cm length. The 20 cm glass cell is filled with 0.0750 g cm^{-3} sucrose solution.

Given that α_{obs} of 0.0750 g cm^{-3} sucrose solution is $+6.11^{o}$, predict the value for the observed angle of rotation, α_{obs}, for the sucrose solution of concentration 0.0750 g cm^{-3} when the 20 cm cell is used.

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Predicted angle = …………………………..

[Total: 20]

3 Inorganic qualitative analysis

For Examiner's Use

(a) **FA 6** and **FA 7** each contain one anion and one cation.

Carry out the following tests and record your observations. For each test you should use a small spatula measure of **FA 6** or **FA 7**

	observations	
test	**FA 6**	**FA 7**
Add a small spatula measure to a 1 cm depth of deionised water in a test-tube and shake. Add 2 drops of universal indicator. Record the pH of the mixture.		
Heat a small spatula measure in a dry boiling tube until no further change is observed.		
Add a small spatula measure in a 2 cm depth of dilute hydrochloric acid in a boiling tube. Decant 1 cm depth of this solution into two test-tubes.	☒	☒

48	
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To one test-tube, add aqueous sodium hydroxide.		
To the second test-tube, add aqueous ammonia.		

(b) Mix a spatula measure of **FA 6** with a spatula measure of **FA 7**. Heat the mixture in a boiling tube. Record your observations.

State the type of reaction that has occurred.

Observations: ………………………………………………………………

………………………………………………………………………………

………………………………………………………………………………

Type of reaction: …………………………………………………………

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53	

(c) From your observations in **(a)** and **(b)**, identify the possible ions present in **FA 6** and **FA 7**.

If you are unable to identify an ion, write 'unknown'.

	cation	anion
FA 6		
FA 7		

54	
55	

[Total: 8]

END OF PAPER

9 Qualitative Analysis Notes

[ppt. = precipitate]

9(a) Reactions of aqueous cations

cation	***reaction with***	
	NaOH(aq)	**NH_3(aq)**
aluminium, Al^{3+}(aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH_4^+ (aq)	ammonia produced on heating	–
barium, Ba^{2+}(aq)	no ppt. (if reagents are pure)	no ppt.
calcium, Ca^{2+}(aq)	white. ppt. with high [Ca^{2+}(aq)]	no ppt.
chromium(III), Cr^{3+}(aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu^{2+}(aq),	pale blue ppt. insoluble in excess	blue ppt. soluble in excess giving dark blue solution
iron(II), Fe^{2+}(aq)	green ppt., turning brown on contact with air insoluble in excess	green ppt., turning brown on contact with air insoluble in excess
iron(III), Fe^{3+}(aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
magnesium, Mg^{2+}(aq)	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), Mn^{2+}(aq)	off-white ppt., rapidly turning brown on contact with air insoluble in excess	off-white ppt., rapidly turning brown on contact with air insoluble in excess
zinc, Zn^{2+}(aq)	white ppt. soluble in excess	white ppt. soluble in excess

9(b) Reactions of anions

anion	*reaction*
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, Cl^-(aq)	gives white ppt. with Ag^+(aq) (soluble in NH_3(aq))
bromide, Br^-(aq)	gives pale cream ppt. with Ag^+(aq) (partially soluble in NH_3(aq))
iodide, I^-(aq)	gives yellow ppt. with Ag^+(aq) (insoluble in NH_3(aq))
nitrate, NO_3^- (aq)	NH_3 liberated on heating with OH^-(aq) and Al foil
nitrite, NO_2^- (aq)	NH_3 liberated on heating with OH^-(aq) and Al foil; NO liberated by dilute acids (colourless NO → (pale) brown NO_2 in air)
sulfate, SO_4^{2-} (aq)	gives white ppt. with Ba^{2+}(aq) (insoluble in excess dilute strong acids)
sulfite, SO_3^{2-} (aq)	SO_2 liberated with dilute acids; gives white ppt. with Ba^{2+}(aq) (soluble in dilute strong acids)

9(c) Tests for gases

gas	*test and test result*
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater (ppt. dissolves with excess CO_2)
chlorine, Cl_2	bleaches damp litmus paper
hydrogen, H_2	"pops" with a lighted splint
oxygen, O_2	relights a glowing splint
sulfur dioxide, SO_2	turns aqueous acidified potassium manganate(VII) from purple to colourless

9(d) Colour of halogens

halogen	*colour of element*	*colour in aqueous solution*	*colour in hexane*
chlorine, Cl_2	greenish yellow gas	pale yellow	pale yellow
bromine, Br_2	reddish brown gas / liquid	orange	orange-red
iodine, I_2	black solid / purple gas	brown	purple

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Suggested Solutions for 9729 2019 Prelim Practical Examinations

1 An experiment to investigate the behaviour of acids and bases in aqueous solution

FA 1 is 1.00 mol dm^{-3} sodium hydrogencarbonate, $NaHCO_3$

FA 2 is sodium hydroxide, NaOH, between 1.5 to 2.5 mol dm^{-3}

FA 3 is 2.00 mol dm^{-3} sulfuric acid, H_2SO_4

According to the *Arrhenius* theory of acids and bases, an acid produces H^+(aq) ions and a base produces OH^-(aq) ions, in aqueous solution.
Using the *Arrhenius* theory, an acid-base neutralisation reaction involves reacting together these two ions to produce water molecules.

The equation for this neutralisation reaction is given below.
$H^+(aq) + OH^-(aq) \longrightarrow H_2O(l) \qquad \Delta H_{neutralisation} = -57.1 \text{ kJ mol}^{-1}$

The reaction between H^+(aq) and OH^-(aq) involves bond formation and so is exothermic. It is possible to make use of this fact to perform a thermometric titration. This task involves two different acid-base reactions.

The first reaction is between sodium hydrogencarbonate, **FA 1**, and sodium hydroxide, **FA 2**.

Reaction 1:
$NaHCO_3(aq) + NaOH(aq) \longrightarrow Na_2CO_3(aq) + H_2O(l) \qquad \Delta H_{reaction\ 1}$

The molar enthalpy change for **Reaction 1**, $\Delta H_{reaction\ 1}$, is the enthalpy change when 1.00 mol of $NaHCO_3$ reacts completely with NaOH.

Instead of using an indicator to determine the endpoint, you will perform a thermometric titration to determine the equivalence point of the reaction. The equivalence point is that point where H^+(aq) from the acid and OH^-(aq) from the base are present in equal molar amounts.

The second reaction is between sodium hydrogencarbonate, **FA 1**, and sulfuric acid, **FA 3**.

Reaction 2:
$NaHCO_3(aq) + ½H_2SO_4(aq) \longrightarrow ½Na_2SO_4(aq) + H_2O(l) + CO_2(g)$
$\Delta H_{reaction\ 2}$

The molar enthalpy change for **Reaction 2**, $\Delta H_{reaction\ 2}$, is the enthalpy change when 1.00 mol of $NaHCO_3$ reacts completely with H_2SO_4.

In your first experiment, you will perform a thermometric titration by adding portions of **FA 2** progressively to a known volume of **FA 1**. You will continue adding **FA 2** until the equivalence point is reached and passed. Throughout the experiment you will note and record the temperature of the mixture after each addition.

You will then analyse your results graphically in order to determine the
- titration volume at the equivalence point, $V_{\text{equivalence}}$,
- maximum temperature change, $\Delta T_{\text{maximum 1}}$,
- molar enthalpy change, $\Delta H_{\text{reaction 1}}$, for **Reaction 1**.

In your second experiment, you will mix together a given volume of **FA 1** with a suitable volume of **FA 3**.

You will then determine the
- maximum temperature change, $\Delta T_{\text{maximum 2}}$,
- molar enthalpy change, $\Delta H_{\text{reaction 2}}$, for **Reaction 2**.

Reaction between FA 1 and FA 2

(a) **(i)** In this task you will need to record the maximum temperature of the reaction mixture when specified volumes of **FA 2** have been added. It is important that the volume of **FA 2** recorded is the total volume you have added up to that point when the temperature reading was made.

Note:
If you overshoot on an addition, record the **actual** total volume of **FA 2** added up to that point.

In an appropriate format in the space provided, record all values of temperature, *T,* to 0.1 °C, and each total volume of **FA 2** added to 0.05 cm^3.

1. Fill a burette with **FA 2**.
2. Place a Styrofoam cup inside a second Styrofoam cup which is held in a glass beaker to prevent it tipping over.
3. Using a pipette, transfer 25.0 cm^3 of **FA 1** to the first Styrofoam cup.
4. Stir the **FA 1** solution in the cup with the thermometer. Read and record its temperature.
5. From the burette, add 2.00 cm^3 of **FA 2** to the cup and stir the mixture thoroughly.
6. Read and record the maximum temperature of the mixture, *T,* and the volume of **FA 2** added.
7. Repeat points 5 and 6 until a total of 30.00 cm^3 of **FA 2** has been added. After each addition of **FA 2**, record the maximum temperature of the mixture and the total volume of **FA 2** added up to that point.

Results

For Examiner's Use

Volume of FA2 added/cm^3	*Maximum temperature/°C*
0.00	*31.8*
2.00	*33.0*
4.00	*34.0*
6.00	*34.8*
8.00	*35.4*
10.00	*36.0*
12.00	*36.4*
14.00	*36.6*
16.00	*36.4*
18.00	*36.2*
20.00	*35.8*
22.00	*35.3*
24.00	*35.0*
26.00	*34.8*
28.00	*34.6*
30.00	*34.4*

1	
2	

Note:

- *Correct headers and units (Final Temp not accepted as header);*
- *Proper tabulation of volumes and temperatures*
- *Thermometer readings to 1dp*
- *Total volume of FA2 to 2dp*

(a) **(ii)** On the grid below, plot a graph of temperature, T against volume of **FA 2** added.

For Examiner's Use

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(iii) Draw **two** smooth lines of best fit. Extrapolate these lines until they cross. Extrapolate these lines until they cross.

Note:

- *Axes correct way round* **+** *correct labels* **+** *units* **+** *scale.*
- *Awkward scales (e.g. 3:10) are not allowed.*
- *The plotted points must occupy at least half of the grid in both directions.*
- *All points must be correctly plotted within ±½ small square.*
- *Graph lines may be* ***curved/ straight*** *best-fit lines, drawn so as to best reflect the distribution of points* ***before*** *and* ***after*** *the equivalence point. These lines should be extrapolated until they* ***cross****.*

6	
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Supervisor
Student
Difference

(iv) Determine from your graph,

- the maximum temperature reached, T_{maximum},
- the maximum temperature change, $\Delta T_{\text{maximum 1}}$,
- the volume, $V_{\text{equivalence}}$, of **FA 2** needed to completely react with 25.0 cm^3 of **FA 1**.

Show on your graph how you obtained these values.

Record these values in the spaces provided below.

Maximum temperature reached, T_{maximum} = ...

Volume of **FA 2** used, $V_{\text{equivalence}}$ = ...

Supervisor
Student
Difference

Hence, calculate the maximum temperature change, $\Delta T_{\text{maximum 1}}$

= ....

Note:

- *Correct reading, to ±½ small square, of Tmaximum; correct calculation of ΔTmaximum**;** correct reading, to ±½ small square, of Vequivalence.*
- *Accuracy based on difference between Supervisor's and Student's values*

Reaction between FA 1 and FA 3

For Examiner's Use

(b) The molar enthalpy change for **Reaction 2**, $\Delta H_{\text{reaction 2}}$, is the enthalpy change when 1.00 mol of $NaHCO_3$ reacts completely with H_2SO_4.

In this task you will calculate a value for the molar enthalpy change, $\Delta H_{\text{reaction 2}}$. To do this you will need to determine the maximum temperature change produced when measured volumes of **FA 1** and **FA 3** are mixed. After considering the concentrations of **FA 1** and **FA 3**, you will select a suitable volume of **FA 3** to add to 40 cm^3 of **FA 1**.

(i) Choose a suitable volume of **FA 3**, $V_{\mathbf{FA\ 3}}$, to be added to 40 cm^3 of **FA 1**. Explain your answer.

Volume should be between $10cm^3 \leq V_{FA3} \leq 20cm^3$ to add sufficient **FA3** for complete reaction/provide an excess of acid for reaction. (Adding too much **FA3** will result in larger percentage uncertainty due to lower temperature rise)

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(ii) Identify the apparatus you intend to use to measure the volume of **FA 1**.

Explain your choice.

Burette. Since **FA1** is the limiting reagent, exact measurement is required. So precise/ accurate measurement of ±0.05 cm^3 is required.

11	

(iii) In an appropriate format in the space provided below, record all values of measured temperature for this experiment.

1. Label one styrofoam cup, **A**. Label a second Styrofoam cup, **B**.
2. Place cup **A** inside a styrofoam cup which is held in a glass beaker to prevent it tipping over.
3. Transfer 40 cm^3 of **FA 1** into cup **A**.
4. Stir the **FA 1** solution in cup with the thermometer. Read and record its temperature, $T_{\mathbf{FA\ 1}}$. This is the initial temperature of **FA 1**.
5. Wash and dry the thermometer.

6. Transfer your chosen volume of **FA 3** into cup **B**. Stir the **FA 3** solution with the thermometer. Read and record its temperature, $T_{\mathbf{FA\,3}}$. This is the initial temperature of **FA 3**.
7. Carefully add the contents of cup **B** to cup **A** in **small** portions to avoid too much frothing.
8. Place the lid on the cup and insert the thermometer through the lid. Stir the mixture.
9. Continue to stir the mixture. Measure and record the temperature, T_{mixture} that shows the maximum change from the initial temperature.

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Results

T_{FA1}/°C	T_{FA3}/°C	$T_{mixture}$/°C
31.6	*31.0*	*31.8*

For Examiner's Use

Note:

- *Correct headers and units*
- *Proper tabulation of temperature of FA1, FA3 and maximum temperature change in a table.*
- *Recording of thermometer readings to 1dp*

Calculations

(c) For the purposes of these calculations, you should assume that the reaction mixture has a density of 1.00 g cm^{-3} and a specific heat capacity, *c*, of 4.18 J g^{-1} K^{-1}.

(i) Calculate the concentration of sodium hydroxide, [NaOH], in **FA 2**.

$$[NaOH] = \frac{25.0 \ x\ 10^{-3}}{Vequivalence\ x\ 10^{-3}} = XXX$$

[NaOH] in **FA 2** = ...

14	

(ii) Calculate the heat change, *q*, for the reaction occurring in **(a)(i)**, and hence determine a value for the molar enthalpy change for **Reaction 1**, $\Delta H_{\text{reaction 1}}$.

$m = 25.0 + V_{\text{equivalence}}$

$q = mc\Delta T_{\text{maximum}}$

$nNaHCO_3 = 25.0 \times 10^{-3}$

$\Delta H\text{reaction 1} = -\frac{q}{25.0\ x\ 10^{-3}}$

Note: – sign must be present.

15	
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(d) Use your results from **(b)(iii)** to calculate a value for the molar enthalpy change for **Reaction 2**, $\Delta H_{\text{reaction 2}}$. For the experiment in **(b)(iii)**, the weighted average initial temperature, T_{average}, of **FA 1** and **FA 3** may be calculated using the formula given below.

For Examiner's Use

$$T_{average} = \frac{(V_{FA1} \times T_{FA1}) + (V_{FA3} \times T_{FA3})}{(V_{FA1} + V_{FA3})}$$

Calculation of T_{average} using formula given

$\Delta T_{\text{maximum 2}} = |T_{\text{mixture}} - T_{\text{average}}|$
$q = (V_{\textbf{FA 1}} + V_{\textbf{FA 3}}) \times 4.18 \times$ temperature change

$\Delta H_{\text{reaction 2}} = -\frac{q}{40.0\ x\ 10^{-3}}$

17	
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19	

T_{average} = ...

q =..............................

$\Delta H_{\text{reaction 2}}$ = ...

(e) Ionic equations for neutralisation, **Reaction 1**, and **Reaction 2** are shown below.

For Examiner's Use

$HCO_3^- + OH^- \longrightarrow CO_3^{2-} + H_2O \qquad \Delta H_{\text{reaction 1}}$

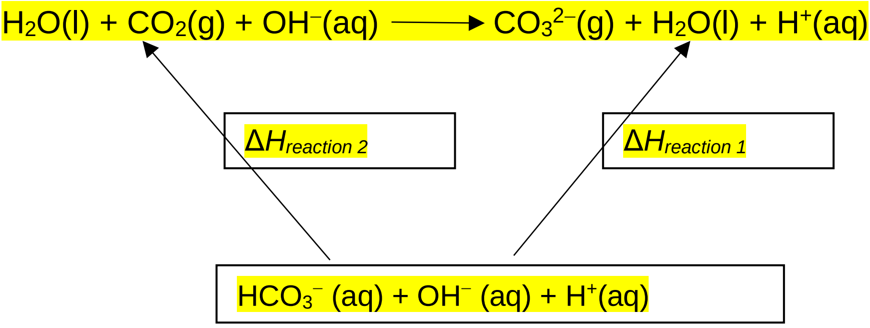
$HCO_3^- + H^+ \longrightarrow H_2O + CO_2 \qquad \Delta H_{\text{reaction 2}}$

An equation for this reaction is given below.

Reaction 3:

$H_2O(l) + CO_2(g) + OH^-(aq) \longrightarrow CO_3^{2-}(g) + H_2O(l) + H^+(aq) \quad \Delta H_{\text{reaction 3}}$

Use your answers in **(c)(ii)** and **(d)**, draw an energy cycle to determine a value for the molar enthalpy change for this reaction, $\Delta H_{\text{reaction 3}}$.



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21	

$\Delta H_{\text{reaction 3}} = \Delta H_{reaction\ 1} - \Delta H_{reaction2}$

(f) An alternative definition of acid-base behaviour was proposed by Brønsted and Lowry. **Reaction 1** and **Reaction 2** are both acid-base reactions involving hydrogencarbonate ions, HCO_3^-.

In terms of the *Brønsted-Lowry* theory of acids and bases, suggest the role of hydrogencarbonate ions, HCO_3^-, in **Reaction 1**.

Explain your answer in each case.

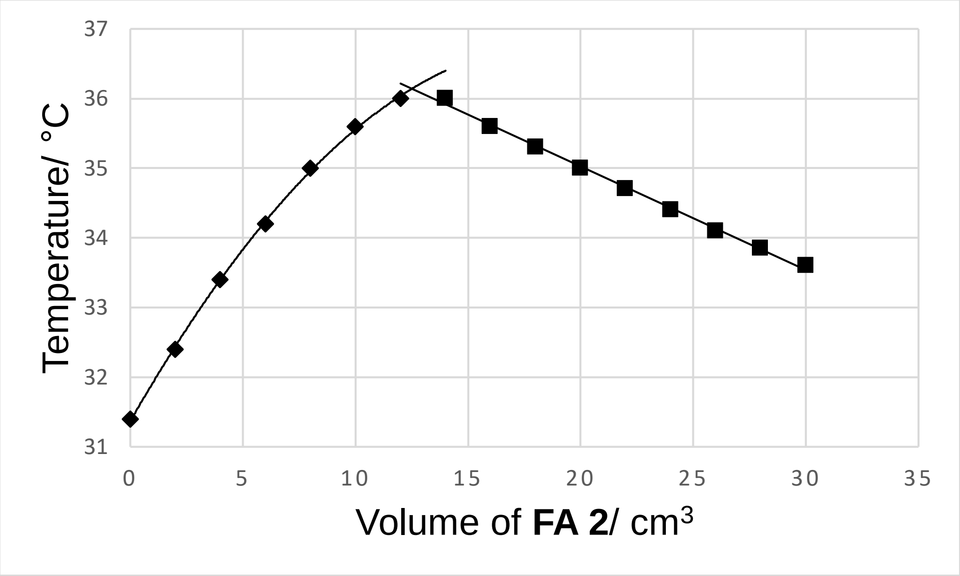
Reaction 1

Role : acid

Explanation : HCO_3^- loses an H^+ ion

22	

(g) A student conducted the same experiment using a digital thermometer and obtained the graph as shown below.



Explain the shape of the graph.

Before equivalence point, T rises/ gradient is positive with each addition of NaOH as reaction is exothermic.

Nearing equivalence point, T rise is smaller / gradient is less positive/ becoming gentler
as the same amount of heat is used to heat up a larger volume of reaction mixture / greater heat loss to surroudings due to steeper temperature gradient.

23	
24	
25	

After equivalence point, T decreases OR gradient is negative with each addition of NaOH. No heat is evolved/ Reaction is completed and addition of **FA 2** cools the solution. (**FA 2** is at a lower temperature than the reaction mixture)

(h) In the calculation of **(d)**, explain why the weighted average initial temperature was used.

The initial temperature and volume of sodium hydrogencarbonate and NaOH is different. Hence by considering the mass of the solution, the average initial temperature is calculated with respect to its mass and the average initial temperature will be more accurate.

26	

(h) With reference to the reaction between **FA 1** and **FA 2**, if the volume of NaOH is doubled, explain how it will affect the maximum temperature change?

No effect on the maximum temperature change. FA 1 is the limiting reagent OR the same amount of heat released at equivalence point is used to heat up the same total volume of solution.

27	

[Total: 27]

2 To determine the proticity of an unknown acid

For Examiner's Use

Acid base titration is commonly used to determine the concentration of an acid or base. In this experiment, the concentration of the acid is given and the aim of this investigation is to determine its proticity.

Acids are defined as substances that can donate hydrogen ions, H^+, to bases. Monoprotic acids contain one H^+ that can be donated per molecule. Diprotic acids contain two H^+ that can be donated per molecule.

You will determine using a titration method whether acid **Z** is monoprotic or diprotic.

- **FA 4** is a solution containing 11.55 g dm^{-3} of acid **Z**.
- **FA 5** is 0.105 mol dm^{-3} aqueous sodium hydroxide, $NaOH$.
- Thymol blue indicator

(a) **Method**

- Pipette 25.0 cm^3 of solution **FA 4** into a conical flask.
- Fill a burette with **FA 5**.
- Add 3 drops of thymol blue indicator to the conical flask.
- The colour change at the endpoint is yellow to blue.
- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Record, in a suitable form below, all of your burette readings and the volume of **FA 5** added in each accurate titration.

Results

Titration number	1	2	3	
Final burette reading /cm^3	24.50	49.00		
Initial burette reading /cm^3	0.00	24.50		
Volume of **FA 5**(used) /cm^3	24.50	24.50		

28	
29	
30	
31	

Note:

- *Correct headers and units*
- *Proper tabulation of burette readings*
- *Burette readings in the table recorded to the nearest 0.05 cm^3*
- *Check consistency of two uncorrected titres $\leq$ 0.10 cm^3*
- *Accuracy based on difference between Supervisor's and Student's values*

(b) From your titration results, obtain a suitable value for the volume of **FA 5** to be used in your calculations. Show clearly how you obtained this value.

Average of any two volume of **FA 1** to 2dp.

Volume of **FA 5** =............................ **32**

(c) Calculations

(i) Calculate the amount of H^+ present in 25.0 cm^3 of **FA 4**.

Amt of H^+ = **(b)** × 0.105 / 1000

Amt of H^+

$= (24.50/1000) \times 0.105$

$= 2.573 \times 10^{-3}$

$= 2.57 \times 10^{-3}$ mol **33**

Amount of H^+ in 25.0 cm^3 of **FA 4** = ...

(ii) Calculate the amount of H^+ present in 1 dm^3 of **FA 4**.

Amt of H^+ = Amt of H^+ from **(c)(i)** × (1000 / 25)

Amt of H^+

$= 2.573 \times 10^{-3} \times (1000 / 25)$

$= 1.029 \times 10^{-1}$

$= 1.03 \times 10^{-1}$ mol **34**

Amount of H^+ in 1 dm^3 of **FA 4** = ...

For Examiner's Use

(iii) **FA 4** contains 11.55 g dm^{-3} of acid **Z**. The relative molecular mass of **Z** is 126. Calculate amount of **Z** in 1 dm^3 of **FA 4**.

Amt of Z = 11.15 / 126 = 9.17×10^{-2} mol

Amount of **Z** in 1 dm^3 of **FA 4** = ... **35**

(iv) Use your answers to **(ii)** and **(iii)** to determine whether **Z** is a monoprotic or a diprotic acid. Explain your answer.

Z is a monoprotic acid as the amount of H^+ in 1 dm^3 of **FA 4** is similar to the amount of **Z** in 1 dm^3 of **FA 4**.

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(v) Student **A** conducted this experiment on the day when the chemicals were freshly prepared. His average titre value was found to be *h* cm^3.

Three days later, he conducted the same experiment using the same chemicals but he found that the bottle of NaOH(aq) was left uncovered.

Suggest how his new titre value would compare to *h* cm^3 and explain your answer.

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New titre value is lower. Water evaporated from the NaOH (aq). Concentration of NaOH (aq) is higher.

OR

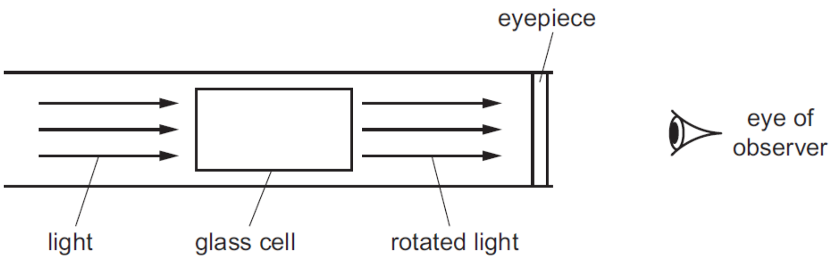
New titre value is higher. NaOH (aq) reacted with CO_2 in the air via acid-base reaction. Concentration of NaOH (aq) is lower.

(d) Planning

Sucrose, $C_{12}H_{22}O_{11}$, is a sugar. The concentration of a solution of sucrose can be measured by the optical rotation, α, of a sucrose solution instead of acid–base titration. The more concentrated the solution, the greater the optical rotation of the solution.

A polarimeter is used to measure optical rotation. Plane–polarised light is passed through a sample of the sucrose solution in a glass cell, and the observed angle of rotation, α_{obs}, is measured.

A simplified diagram of a polarimeter is shown.



If a glass cell of length 10 cm is filled with a solution of sucrose of concentration 1 g cm^{-3}, the measured angle of rotation is known as the specific rotation, [α].

The observed angle of rotation, α_{obs}, measured by the polarimeter is related mathematically to the concentration of the sucrose solution by the equation shown.

$$\alpha_{obs} = [\alpha]lc$$

α_{obs} is the observed angle of rotation.

[α] is a constant and is known as the specific rotation of sucrose solution.

l is path length which is 10 cm in the above description.

c is the concentration of sucrose, in g cm^{-3}

(i) Explain why a sucrose solution is able to rotate plane–polarised light.

Sucrose contains at least 1 chiral C/ Sucrose is optically active.

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For Examiner's Use

(ii) Using the information given above, you are required to write a plan to determine the concentration of sucrose in a solution **X**.

You may assume that you are provided with:

- solution **X**, of unknown sucrose concentration less than 0.0800 g cm^{-3};
- access to a polarimeter and instructions for use;
- graph paper;
- the apparatus and chemicals normally found in a school or college laboratory.

Your plans should include details of:

- the preparation of 250 cm^3 0.0800 g cm^{-3} sucrose solution using your answer in **(d)(ii);**
- the preparation of a suitable range of diluted solutions of accurate concentrations;
- an outline of how the results would be obtained;
- a sketch of the calibration curve you would expect to obtain;
- how the calibration line would be used to determine the concentration of sucrose in solution **X**.

Note:

- *Calculate mass of sucrose to use (20.0g)*
- *Proper weighing of sucrose (using electronic balance and reweighing vessel with residual solid)*
- *Procedure to prepare homogenous standard solution of 250 cm^3 0.0800 g cm^{-3} sucrose solution using volumetric flask.*
- *Description of procedure and apparatus (with stated volumes) to prepare diluted solutions.*
- *Concentrations chosen must be well spread out*
- *State the volumes of DI water and stock solution to be added to prepare diluted solutions (min. 3 sets)*
- *Note that total volume of stock solution used cannot exceed volume of stock solution prepared (i.e. 250cm^3)*
- *Scan/ Measure/ Record for each concentration.*
- *Sketch of α_{obs} against concentration. (straight line passing through origin)*
- *Measuring of α_{obs} of solution X and intrapolation to find accurate concentration.*

Example:

Weigh accurately a clean dry empty 100 cm^3 beaker using a weighing balance and record the mass.

Place about 20.00 g sucrose solid in the beaker and reweigh.

Calculate the accurate mass of the sucrose by subtracting the mass of the empty beaker from the mass of beaker and sucrose.

Dissolve the sucrose in deionised water.

Transfer the sucrose solution and its rinsings to a 250.0 cm^3 volumetric flask.

Make-up to the mark with deionised water adding dropwise close to mark and shake the flask well to obtain a homogenous solution.

	100 cm^3 volumetric flask
Concentration of sucrose solution / g dm^{-3}	Volume of 0.0800 g dm^{-3} sucrose solution / cm^3
0.0800	NA
0.0400	50.00
0.0200	25.00
0.0100	12.50
0.0050	6.25

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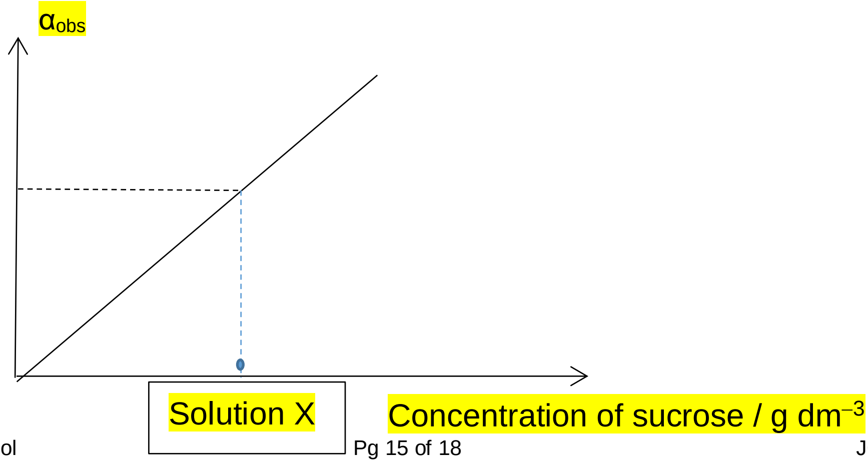
To prepare the diluted sucrose solutions, the appropriate volume of 0.0800 g dm^{-3} sucrose(aq) as shown in the table above is transferred using a burette to a 100 / 250 cm^3 volumetric flask and topped up to the mark with deionised water.

The flask is then well shaken to produce a homogeneous solution.

Measure the rotation values for each sucrose concentration.

A graph of rotation against concentration of the sucrose(aq) used is plotted. A straight line passing through the origin should be obtained.



The rotation value given by the sucrose solution prepared from solution X is measured and the corresponding concentration read off from the calibration graph.

(iv) The glass cell of 10 cm length is expensive, so one cell is used for all the solutions that are placed in the polarimeter.

Suggest how you would ensure that the concentration of solution in the cell is accurate each time the cell is used for the different sucrose solutions.

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Rinse/ wash out with small volume of solution of concentration to be used.

(v) Concentration of sucrose is the independent variable in this polarimeter experiment.

The glass cell of 10 cm length is replaced by a glass cell of 20 cm length. The 20 cm glass cell is filled with 0.0750 g cm^{-3} sucrose solution.

Given that α_{obs} of 0.0750 g cm^{-3} sucrose solution is +6.11^o, predict the value for the observed angle of rotation, α_{obs}, for the sucrose solution of concentration 0.0750 g cm^{-3} when the 20 cm cell is used. Explain your answer.

Predicted angle = +12.22^o

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[Total: 20]

3 Inorganic qualitative analysis

For Examiner's Use

(a) **FA 6** and **FA 7** each contain one anion and one cation.

Carry out the following tests and record your observations. For each test you should use a small spatula measure of **FA 6 or FA 7**

	observations	
test	**FA 6**	**FA 7**
Add a small spatula measure to a 1 cm depth of deionised water in a test-tube and shake. Add 2 drops of universal indicator.	**FA 6** is a white solid (ppt not accepted) **FA 6** is sparingly soluble/ insoluble Green to Blue/Purple	**FA 7** is a white solid (ppt not accepted) **FA 7** dissolves to give a colourless solution.

Record the pH of the mixture.	pH 10–14	Green to Orange/ Red pH 1–3
Heat a small spatula measure in a dry boiling tube until no further change.	Water vapour /condensation / steam observed on cooler part of boiling tube.	White solid forms on cold part or top of tube / white fumes/ smoke. Moist red litmus paper turned blue* On strong heating, moist blue litmus paper turned to red. Water vapour/ condensation/ steam observed on cooler part of boiling tube.
Add a small spatula measure in a 2 cm depth of dilute hydrochloric acid in a boiling tube. Decant 1 cm depth of this solution into two test-tubes.		

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To one test-tube, add aqueous sodium hydroxide.	White ppt formed; insoluble in excess NaOH	No (observable) reaction / no change / no ppt
To the second test-tube, add aqueous ammonia.	White ppt formed; insoluble in excess NH_3(aq)	No (observable) reaction / no change / no ppt

(b) Mix a spatula measure of **FA 6** with a spatula measure of **FA 7**. Heat the mixture in a boiling tube. Record your observations.

State the type of reaction that has occurred.

Observations:

Colourless, pungent gas evolved that turns **moist red litmus blue**. The gas is NH_3.

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Type of reaction: Acid-base

(c) From your observations in **(a)** and **(b)**, identify the possible ions present in **FA 6** and **FA 7**.

If you are unable to identify an ion, write 'unknown'.

	cation	anion
FA 6	Mg^{2+}	OH^-/ strong conjugate base
FA 7	NH_4^+	Unknown

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[Total: 8]

END OF PAPER