RIVER VALLEY HIGH SCHOOL
YEAR 6 PRELIMINARY EXAMINATION II

CANDIDATE NAME	

CLASS	6	

CENTRE NUMBER	S 3 0 4 4	INDEX NUMBER	0 0	

H2 CHEMISTRY   9729/01

Paper 1 Multiple Choice

21 Sep 2017

1 hour

Additional Materials: Multiple Choice Answer Sheet

Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
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**.
Choose the one you consider correct and record your choice in **soft pencil** on the Optical Answer Sheet.

**Read the instructions on the Answer Sheet very carefully.**

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

This document consists of **16** printed pages and **0** blank pages.

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

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

At room temperature and pressure, a sample of 2 dm^3 of polluted air was passed through limewater so that all the carbon dioxide present was precipitated as calcium carbonate. The mass of calcium carbonate formed was 0.05 g.

What is the percentage, by volume, of carbon dioxide in the air sample?

A   0.30%   **B**   0.57%

C   0.60%   **D**   1.20%

2   When Tl^+(aq) reacts with VO_3^-(aq), Tl^{3+}(aq) and V^{2+}(aq) are formed.

Assuming the reaction goes to completion, how many moles of Tl^+(aq) and VO_3^-(aq) would result in a mixture containing equal number of moles of VO_3^-(aq) and V^{2+}(aq) once the reaction had taken place?

	Moles of Tl^+(aq)	Moles of VO_3^-(aq)
A	1	2
B	1	3
C	2	3
D	3	4

3   Which of the following statements about the carbonate ion, CO_3^{2-}, are correct?

1   The carbon atom is sp^2-hybridised.

2   The carbon in CO_3^{2-} has an octet electronic configuration.

3   It has the same bond angle as the nitrate ion, NO_3^-.

A   1 only

B   1 and 2 only

C   2 and 3 only

D   1, 2 and 3 only

4 The diagram represents the melting points of four consecutive elements in the third period of the Periodic Table.

.

melting point / K

0   proton number
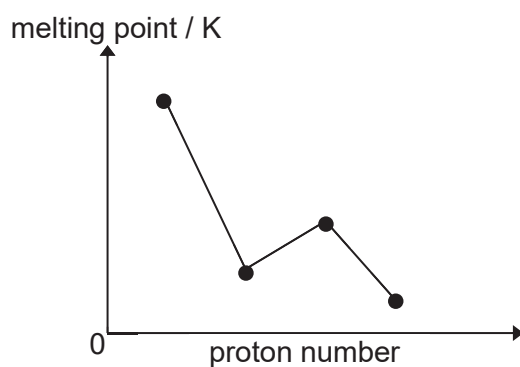
The sketches below represent another two properties, *m* and *n*, of the elements.

m

0   proton number

n

0   proton number
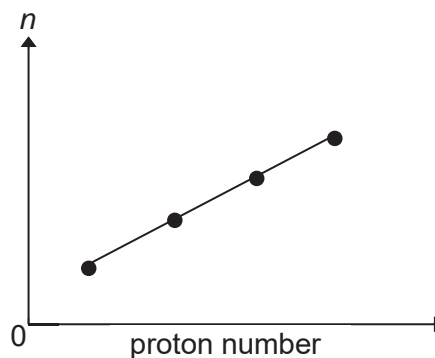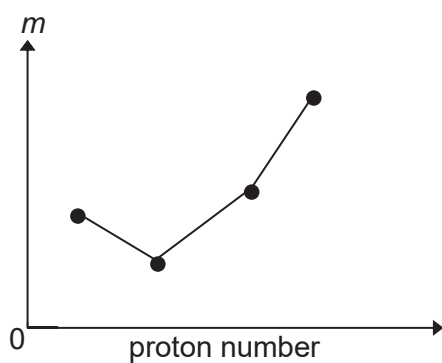
What are the properties *m* and *n*?

	Property *m*	Property *n*
A	third ionisation energy	electronegativity
B	number of valence electrons	boiling point
C	ionic radius	effective nuclear charge
D	electrical conductivity	atomic radius

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

Species containing one or more unpaired electrons are said to be paramagnetic as they can be attracted by an external magnetic field.

Which of the following species are paramagnetic?

1 Cr^{3+}

2 Fe^{2+}

3 Cu^+

A   1 only

B   1 and 2 only

C   1 and 3 only

D   2 and 3 only

6   Which pair of compounds meets the criteria below?

- The first compound has a larger bond angle than the second compound.
- The second compound is more polar than the first compound.

A CO_2, BCl_3 **B** $IClF_2$, ClO_2 **C**   HCN, SO_3 **D** CO_2, NCl_3

7   Flask **X** contains 1 dm^3 of helium at a pressure of 2 kPa and flask **Y** contains 2 dm^3 of neon at a pressure of 1 kPa.

If the flasks are connected at constant temperature, what is the final pressure?

A   1.00 kPa   **B**   1.33 kPa   **C**   1.67 kPa   **D**   2.00 kPa

8 When water is stirred with glucose, strong hydrogen bonds are initially formed between glucose molecules and water molecules, but as more water is added, these hydrogen bonds are broken.

Which graph best represents the observed temperature changes?

A

temp

Volume of water added

B

temp

Volume of water added

C

temp

Volume of water added

D

temp

Volume of water added
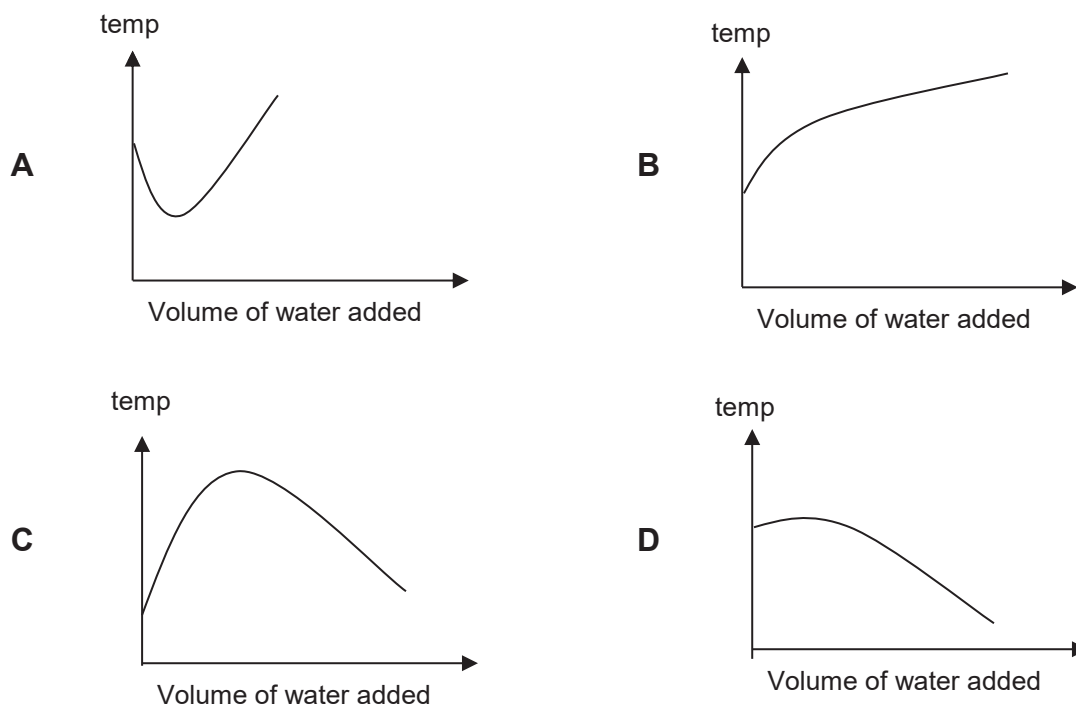
9 *Use of the Data Booklet is relevant to this question.*

A student dissolved 8.4 g of sodium fluoride in 250 g of water.

Given the following thermodynamic data,

Lattice energy of NaF $= -918$ kJ mol^{-1}

Enthalpy change of hydration of F$^-$ $= -457$ kJ mol^{-1}

Enthalpy change of hydration of Na$^+$ $= -390$ kJ mol^{-1}

What would be the initial temperature of the water if the final temperature of the solution is 20.00 °C?

Assume that the specific heat capacity of water is 4.2 J g^{-1}K^{-1}.

A 6.48 °C   **B** 33.08 °C   **C** 33.52 °C   **D** 47.62 °C

10 Ammonia gas and hydrogen chloride gas react to form ammonium chloride as shown in the equation below:

$$NH_3(g) + HCl(g) \rightarrow NH_4Cl(s) \qquad \Delta H = -176 \text{ kJ mol}^{-1}$$
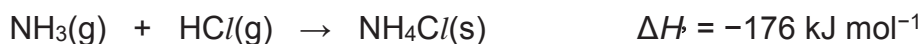
The standard entropy change of this reaction is -284 J K^{-1} mol^{-1}.

Which of the following statements is **not** correct?

A The reaction is spontaneous at 500 K.

B There is an increase in order due to the formation of a solid from gases.

C The reaction becomes non-spontaneous at temperatures higher than 620 K.

D Under standard conditions, $\Delta G = +8.4 \times 10^7$ J mol^{-1}.

11 The graph below shows how the fraction of a substance, **X**, in an equilibrium mixture varies with temperature at pressures of 2×10^7 Pa and 5×10^7 Pa.

Fraction of **X**

2×10^7 Pa

5×10^7 Pa

Temperature
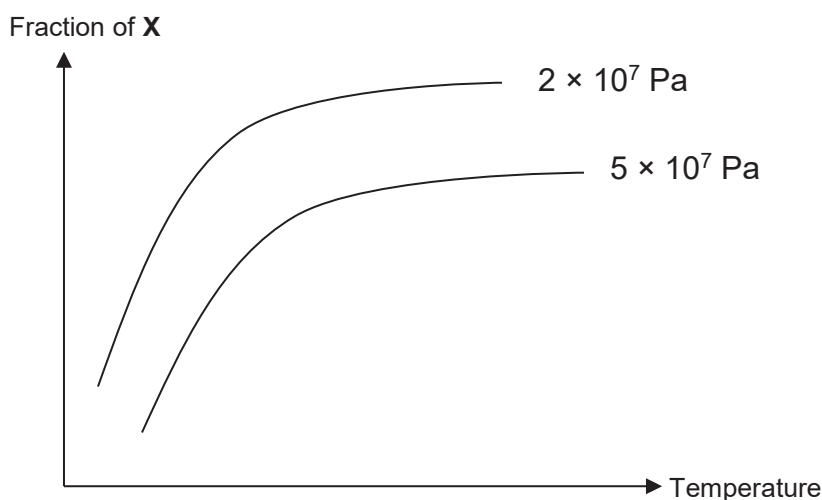
Which underlined compound represents **X**?

A $2N_2(g) + 6\underline{H_2O}(g) \rightleftharpoons 4NH_3(g) + 3O_2(g)$ $\Delta H = +1267$ kJ mol^{-1}

B $C(s) + H_2O(g) \rightleftharpoons H_2(g) + \underline{CO}(g)$ $\Delta H = +131$ kJ mol^{-1}

C $2SO_2(g) + O_2(g) \rightleftharpoons 2\underline{SO_3}(g)$ $\Delta H = -197$ kJ mol^{-1}

D $N_2(g) + 3H_2(g) \rightleftharpoons 2\underline{NH_3}(g)$ $\Delta H = -92$ kJ mol^{-1}

12 The solubility products of some sparingly soluble silver compounds are shown below.

Which compound, in saturated solution, contains the lowest concentration of silver ions?

	Compound	Solubility Product
A	silver arsenate(V), Ag_3AsO_4	1.0×10^{-22} mol^4 dm^{-12}
B	silver bromide, $AgBr$	5.0×10^{-13} mol^2 dm^{-6}
C	silver carbonate, Ag_2CO_3	8.1×10^{-12} mol^3 dm^{-9}
D	silver chromate(VI), Ag_2CrO_4	1.1×10^{-12} mol^3 dm^{-9}

13 The kinetics of the reaction between iodide and peroxodisulfate can be investigated by varying the volume of the reactants used. The two reactants are mixed in the presence of a known amount of $Na_2S_2O_3$ and a little starch. The time taken for an intense blue colour to be observed is then determined.

Experiment	Volume used/cm^3			t/s
	1.0 mol dm^{-3} KI	0.040 mol dm^{-3} $Na_2S_2O_8$	H_2O	
1	10.0	5.0	25.0	170
2	15.0	5.0	20.0	113
3	15.0	10.0	15.0	57
4	20.0	20.0	0.0	x

What is the value of x?

A   21   **B**   28   **C**   85   **D**   63

14 **L**, **M** and **N** react to form **P** and **Q** as shown.

$$L + M + N \rightarrow P + Q$$

The rate equation for this reaction is rate = $k[M][N]$.

Which of the following graphs is correct of the above reaction, when **N** is in excess?

A

B

C

D
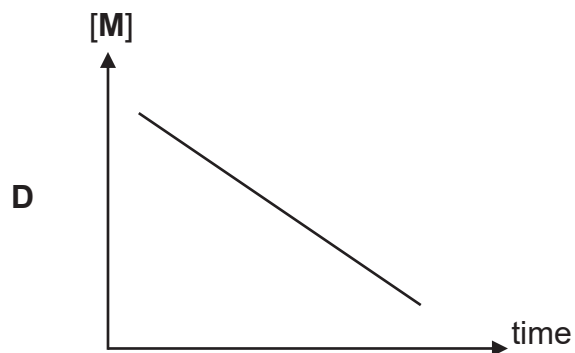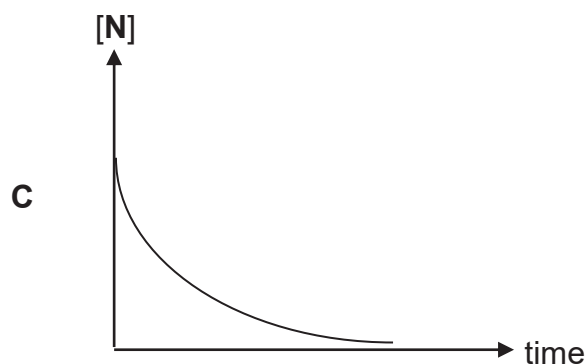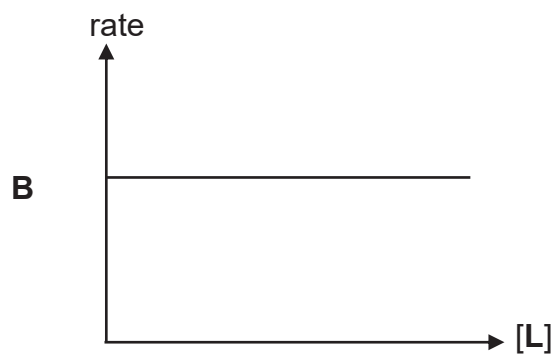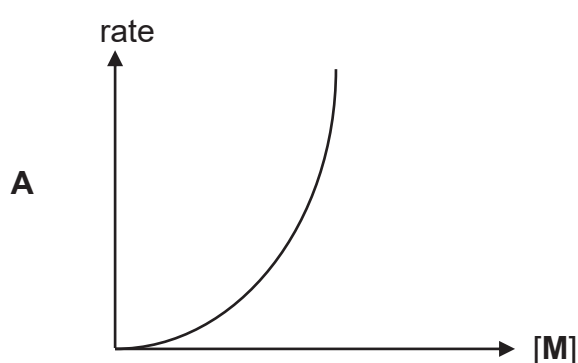
15 The silver halides, AgCl and AgBr, are both sparingly soluble in water. AgCl dissolves in dilute NH_3(aq) but AgBr can only dissolve in concentrated NH_3.

Which statement helps to explain this observation?

A The complex ion in $[Ag(NH_3)_2]Br$ is more stable than the complex ion in $[Ag(NH_3)_2]Cl$.

B A higher concentration of NH_3 ligand is required to form $[Ag(NH_3)_2]Br$.

C The lattice energy of AgBr(s) is numerically larger than that of AgCl(s).

D The solubility product of AgBr(s) is smaller than that of AgCl(s).

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

Hydroxyapatite, a basic calcium phosphate, $Ca(OH)_2.3Ca_3(PO_4)_2$, is the mineral found in bone.

Older people may lose calcium ions from the hydroxyapatite, weakening the bone structure. For such cases, strontium salts are administered to strengthen the bone. The strontium ions replace the lost calcium ions in the hydroxyapatite.

Which statements are correct?

1 Strontium ions have similar ionic radii as calcium ions and so may easily replace them in hydroxyapatite.

2 Strontium hydroxide is more soluble than calcium hydroxide and so will precipitate better in the bone structure.

3 There is ionic and covalent bonding in hydroxyapatite which gives it strength.

A 1 only

B 2 only

C 1 and 3 only

D 1, 2 and 3 only

17 Given weighed samples of the same mixture of magnesium carbonate and barium carbonate, which method will **not** allow the mole fraction of magnesium carbonate in the mixture to be estimated?

A Add a known volume of 0.1 mol dm^{-3} HNO$_3$(aq) in excess and back titrate the excess acid.

B Add an excess of HCl(aq) followed by an excess of H$_2$SO$_4$(aq); filter, dry and weigh the precipitate.

C Add an excess of HNO$_3$(aq) and measure, at room temperature and pressure, the volume of CO$_2$ liberated.

D Heat the mixture at 170°C for 10 minutes. Cool and weigh the mass of residue.

18 When aqueous ammonia is added to a solution containing hexaaquairon(III) ions, $[Fe(H_2O)_6]^{3+}$, a red-brown precipitate is formed which does not dissolve when excess ammonia is added.

What is the role of ammonia molecules in this reaction?

A   Brønsted-Lowry base

B   Lewis acid

C   Ligand

D   Reducing agent

19 Adding concentrated $HCl(aq)$ to $CuSO_4(aq)$ causes the colour of the solution to change from blue to yellow.

Which row best explains this observation? You are given that in the visible spectrum, red light has the lowest energy and violet light has the highest energy.

	Number of d-electrons around copper	Energy gap between the d-orbitals
A	Remains the same	Increase
B	Remains the same	Decrease
C	Changes	Increase
D	Changes	Decrease

20 Scandium, Sc, is the first of the d-block elements in the Periodic Table.

Which properties of scandium are consistent with this fact?

1   Scandium has an ionic chloride.

2   Scandium readily forms oxidation states of +3 and +4.

3   Compounds containing Sc^{3+} are coloured.

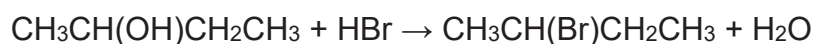A   1 only

B   2 only

C   1 and 2 only

D   2 and 3 only

21 Alkynes are a series of non-cyclic hydrocarbons with the general formula, C_nH_{2n-2} containing one carbon-carbon triple bond per molecule.

How many alkynes with 6 carbon atoms satisfies the above formula?

A   5

B   6

C   7

D   8

22 During the preparation of many organic compounds, by-products are formed. This usually occurs because the reagents can react in more than one way, depending on the conditions used, or because the products formed may react with the reactants.

2-bromobutane may be prepared by slowly adding concentrated sulfuric acid to sodium bromide to form hydrogen bromide which reacts with butan-2-ol. The reaction mixture is kept cool to optimise the reaction yield.

$$CH_3CH(OH)CH_2CH_3 + HBr \rightarrow CH_3CH(Br)CH_2CH_3 + H_2O$$

What could be a by-product of this reaction if the temperature is allowed to rise?

1 $CH_2{=}CHCH_2CH_3$

2 $CH_2BrCH_2CH_2CH_3$

3 $CH_3CBr_2CH_2CH_3$

A   1 only

B   1 and 2 only

C   2 and 3 only
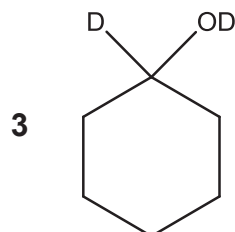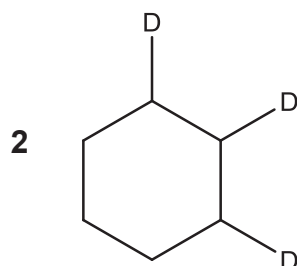
D   1, 2 and 3 only

23 Which method is able to separate benzene from a mixture of benzene and an amine?

    A Extracting the amine with ethanol

    B Nitrating the benzene with a nitrating agent to precipitate the solid

    C Shaking the mixture with dilute aqueous acid

    D Extracting the benzene with hexane

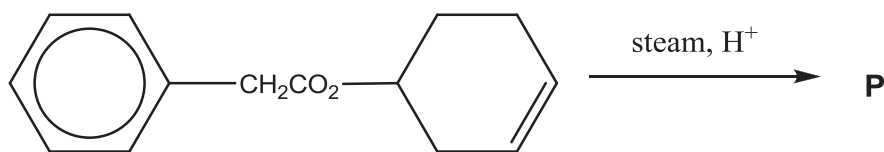**24** Deuterium is an isotope of hydrogen, $^{2}_{1}H$.

Which compound can be formed by the addition of D_2 to another molecule, in the presence of platinum catalyst?
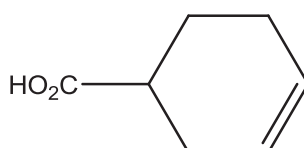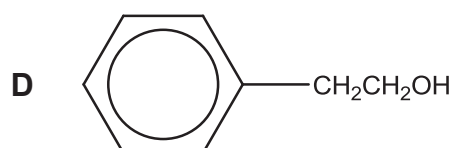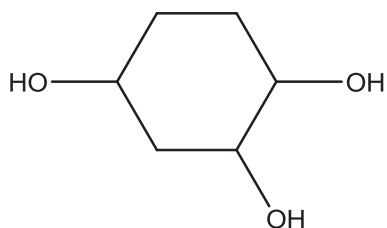
    1 $CH_3CD_2ND_2$

    2

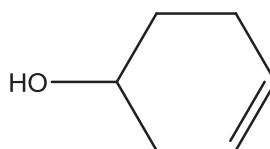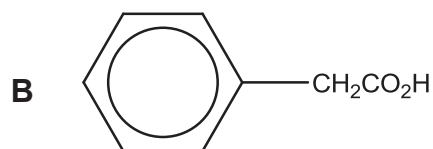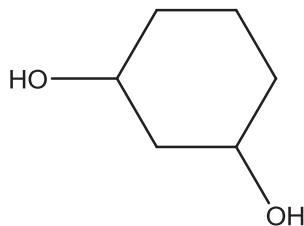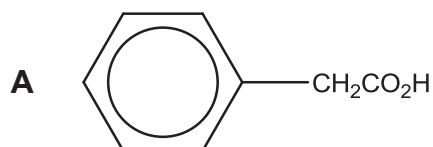   **3**

    A 1 only

    B 1 and 2 only

    C 1 and 3 only

    D 2 and 3 only

25 The diagram shows a reaction.

What could be the final products, **P**?

A

B

C

D
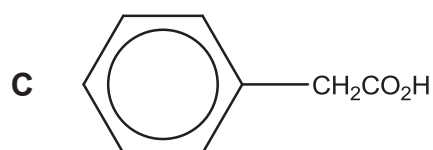
26 Which salt will give a solution with the lowest pH in aqueous solution?

A $C_2H_5NH_3{}^+Cl^-$

B $NH_4{}^+Cl^-$

C $C_6H_5NH_3{}^+Cl^-$

D K^+Cl^-

27 Which transformations involve a nucleophile?
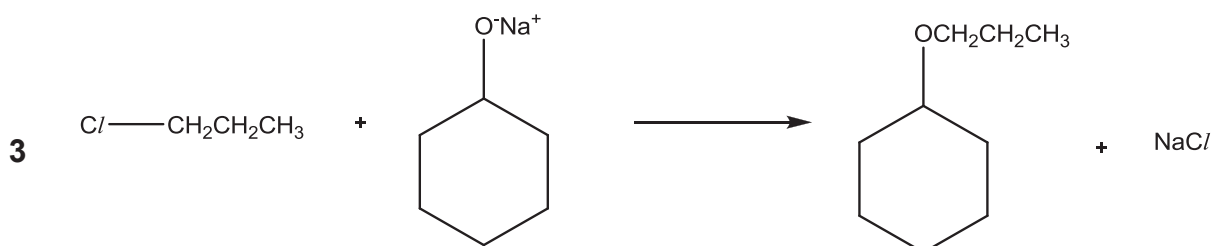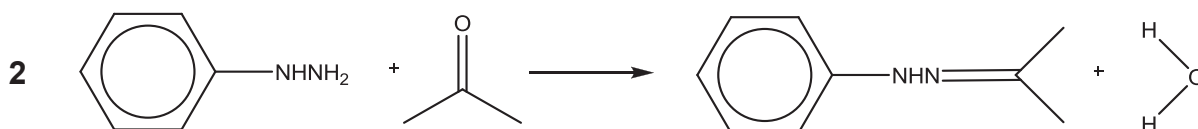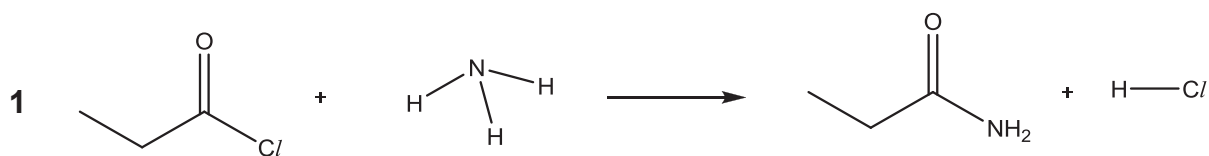
A 1 only

B 3 only

C 1 and 3 only

D 1, 2 and 3 only

Use of the Data Booklet is relevant to Questions 28 - 30.

28 When a dilute sulfate solution of a metal **J** is electrolysed, the 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

29 Iron(II) salts are often used as a dietary supplement to help cure some forms of anaemia. The amount of iron in such a pill may be estimated by titration with $KMnO_4$ (aq).

A dietary supplement pill was dissolved in 10 cm^3 of dilute sulfuric acid and titrated using 0.0200 mol dm^{-3} $KMnO_4$. The E_{cell} was measured against a standard hydrogen electrode and the following graph was obtained.
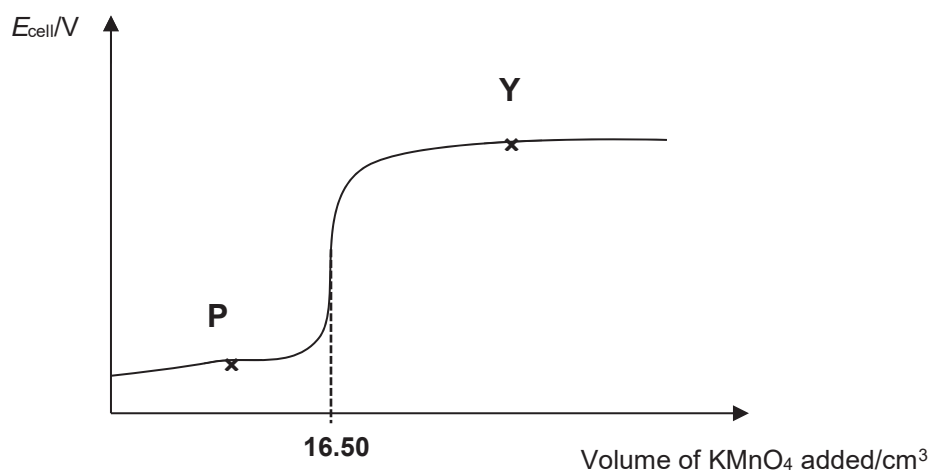
Which of the following lists appropriate approximate E values, in volts, for the points **P** and **Y**?

	Point **P**	Point **Y**
A	1.52	1.96
B	0.77	1.52
C	0.75	0.77
D	0.75	1.52

[Turn over

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

An electrolytic cell containing Mn^{2+} and another metal ion, **Y**$^{3+}$, is connected to Mn and Pt electrodes. The reactions that took place are

$$Mn \rightarrow Mn^{2+} + 2e^-$$

$$\mathbf{Y}^{3+} + 3e^- \rightarrow \mathbf{Y}$$

Which of the following statements are correct?

1   The Mn electrode is the anode.

2   A possible identity of **Y** is aluminium.

3   The number of moles of **Y** deposited is 1.5 times the number of moles of Mn^{2+} formed.

A   1 only

B   2 only

C   1 and 2 only

D   1 and 3 only

RIVER VALLEY HIGH SCHOOL
YEAR 6 PRELIMINARY EXAMINATION II

CANDIDATE NAME

CLASS

CENTRE NUMBER: S 3 0 4 4

INDEX NUMBER: 0 0

H2 CHEMISTRY 9729/02

Paper 2 Structured Questions 13 Sep 2017

2 hours

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST.

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

Write your name, class and index number in the spaces at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
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.
A Data Booklet is provided.

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									
P2	1	2	3	4	5	SF	UNITS	Total (P2)	
	17	14	14	15	15				75
P1	30	**P3**	80	**Total**	185	**P4**	55	**Grade**	

This paper consists of **18** printed pages.

1 Among the many pharmaceutical drugs manufactured worldwide, one of the most important types is the painkillers. The structures of three such painkillers are shown.

ibuprofen	paracetamol	aspirin
(M_r = 206)	(M_r = 151)	(M_r = 180)

Ibuprofen is used to treat arthritis and relieve pain, fever and swelling. It is available over-the-counter in 200 and 400 mg tablets. The recommended dosage varies with body mass and indication, but 1.20 g is considered the maximum daily adult dosage. Long term use of ibuprofen can lead to stomach ulcers. Ibuprofen can be synthesised via the following process:

(a) A man bought some ibuprofen tablets of dosage 200 mg over the counter and consumed one pill 4 times a day. Explain if this level of consumption safe for the man.

....

.... **[1]**

(b) State the *type of reaction* that converts Compound **A** to **B**.

.... **[1]**

(c) In the laboratory, Compound **C** can be converted to ibuprofen using a 3-step synthesis route.

Suggest reagents and conditions for each step, and draw the structures of all intermediates.

[5]

(d) Young children often find it difficult to swallow tablets. Thus, ibuprofen is supplied as an "infant formula" emulsion.

Given that ibuprofen and water are immiscible, an emulsifier such as polysorbate 80 is used to create a homogeneous mixture.
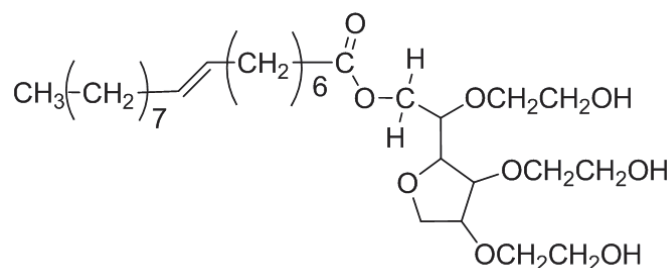
polysorbate 80

Explain why this molecule is able to act as an emulsifier.

....

....

....

[1]

4

(e) A certain pharmaceutical brand claims that the ibuprofen tablets it manufactures are 95.0% pure by mass.

To investigate this claim, 5.00 g of a sample was crushed and dissolved in 250 cm^3 of 0.450 mol dm^{-3} aqueous KOH. 25.0 cm^3 of this solution was withdrawn and titrated against sulfuric acid. The unreacted KOH in this solution required 25.50 cm^3 of 0.180 mol dm^{-3} of sulfuric acid for complete neutralisation.

Showing relevant calculations, deduce if the claim is valid.

[3]

(f) Compare the acidity of ibuprofen and aspirin. Explain your answer.

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

……………………………………………………………………………………………… [2]

(g) Describe two simple chemical tests to distinguish between ibuprofen, paracetamol and aspirin.

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

……………………………………………………………………………………… **[4]**

[Total: 17]

2 **(a)** Gaseous ethane can be used as a fuel for campers. A company manufactures compressed gaseous ethane in 400 cm³ metal canisters. A typical metal canister at room temperature contains compressed gaseous ethane at a pressure of 4.00 atm.

   (i) Suggest a reason why gaseous ethane in the metal canister does not behave like an ideal gas.

   …………………………………………………………………………………

   …………………………………………………………………………………

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

   (ii) One metal canister is used for heating water and the pressure decreases from 4.00 atm to 1.50 atm. Assuming that the compressed ethane behaves ideally, calculate the mass of water at room temperature that could be brought to boiling if the process is 80% efficient. The enthalpy change of combustion of ethane is -1420 kJ mol⁻¹.

   [3]

   (iii) Suggest a reason why butane is a better fuel for campers compared to ethane.

   …………………………………………………………………………………

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

(b) Calcium fluoride is used for dental protection. It dissolves readily in water with an enthalpy change of solution of −125 kJ mol⁻¹. It is given that the lattice energy of calcium fluoride is −2350 kJ mol⁻¹ while the enthalpy change of hydration of calcium ion is −1560 kJ mol⁻¹.

With the aid of a labelled energy level diagram, calculate the enthalpy change of hydration of fluoride ion.

[4]

(c) Liquid hydrazine reacts with oxygen to form nitrogen and steam which could involve the following energy cycle shown below.

$$N_2H_4(l) + O_2(g) \longrightarrow N_2(g) + 2H_2O(g)$$

$$N_2H_4(g) + O_2(g) \longrightarrow 2N(g) + 4H(g) + 2O(g)$$
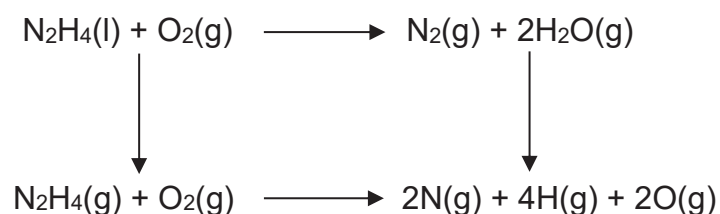
(i) Given that the enthalpy change of vapourisation of hydrazine is +58.0 kJ mol⁻¹, use appropriate bond energies from the *Data Booklet* to calculate the enthalpy change of reaction between liquid hydrazine and oxygen.

[2]

(ii) The reaction shown above has a positive ΔS value. Account for its significance.

………………………………………………………………………………………

………………………………………………………………………………………

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

(iii) Hence, under what conditions of temperature will the reaction be spontaneous?

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

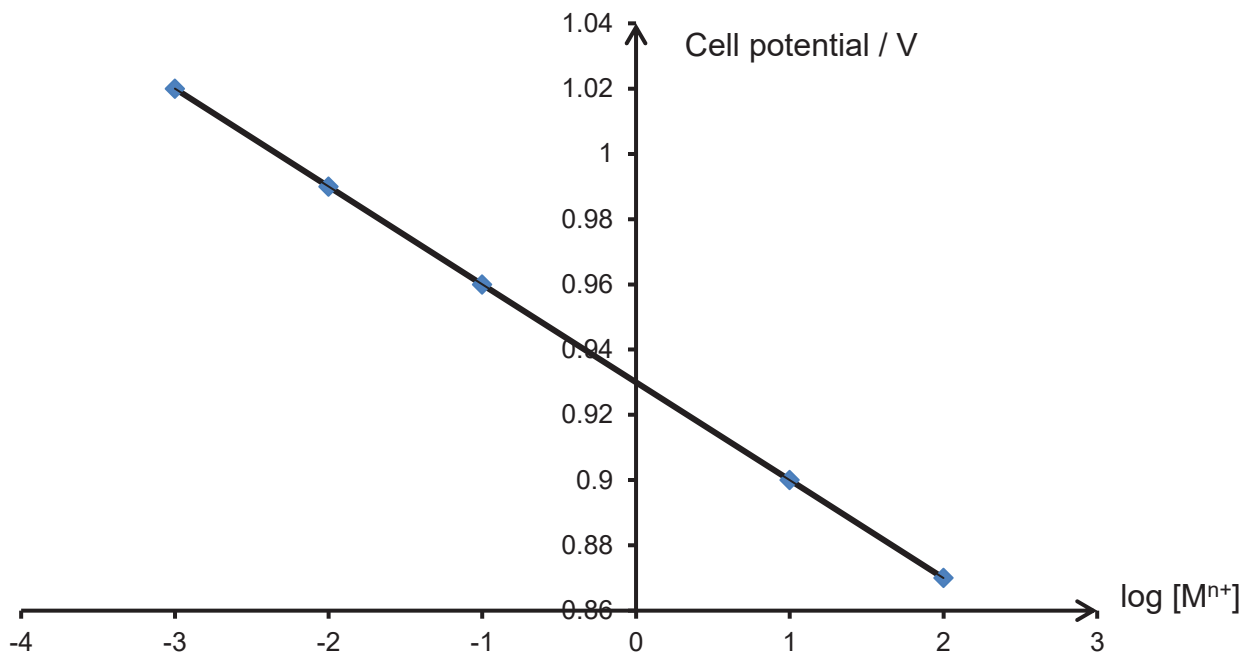……………………………………………………………………………… **[2]**

[Total: 14]

3 An experiment was set up to investigate how the cell potential of a cell containing a metal, M, in contact with an aqueous solution of its ions, $M^{n+}(aq)$, changed as $M^{n+}(aq)$ was diluted.

Since a standard hydrogen half-cell was not available, a half-cell consisting of Cl^-, ClO^- in alkaline medium under standard conditions was used to connect to the half-cell with M in contact with $M^{n+}(aq)$.

(a) Draw the setup of the galvanic cell as described above.

[3]

The cell potential was measured for various concentrations of M^{n+}(aq) and the results of cell potential against log $[M^{n+}]$ obtained are plotted in the graph as shown below.

(b) It is known that the cell potential of a cell, E_{cell}, is related to the standard electrode potential, $E^{\ominus}_{cell}$, by the equation:

$$E_{cell} = E^{\ominus}_{cell} - \frac{0.06\,\lg[M^{n+}]}{n}$$

(i) Use your graph to determine the gradient and the charge, n, of the M^{n+} ions.

[2]

(ii) Use your graph to determine the $E^{\ominus}_{cell}$, showing your working clearly.

[2]

(iii) In the determination of standard electrode potential of a half-cell, the polarity of standard hydrogen electrode can either be positive or negative.

The standard electrode potential for Cl^-, ClO^- in alkaline conditions is +0.80 V.

Hence, calculate the standard electrode potential of the metal, M, and suggest its identity.

[2]

(iv) Suggest one purpose of a salt bridge in a galvanic cell.

....

.... **[1]**

(v) A student suggested the use of aqueous potassium sulfate in the salt bridge. Do you think his choice is wise? Explain your reasoning.

....

.... **[2]**

(c) Using Le Chatelier's Principle and relevant equations, explain why $AgCl$ is soluble in excess aqueous ammonia.

....

....

....

....

....

.... **[2]**

[Total: 14]

4 Viridian is a blue-green pigment used commonly in paints, inks, and stained glasses. The major constituent of viridian is the compound chromium(III) oxide, Cr_2O_3, that gives its characteristic colour.

Alumina, which is the common name for the chemical aluminium oxide (Al_2O_3), is a white solid which is commonly used as abrasive owing to its high hardness rating.

(a) Define the term *transition element.*

....

.... **[1]**

(b) In terms of structure and bonding, explain why alumina has a high hardness rating.

....

....

....

.... **[2]**

(c) Both Cr_2O_3 and Al_2O_3 are amphoteric oxides. Describe the observations and write balanced equations when Cr_2O_3 is dissolved in HC*l*(aq) and NaOH(aq). You can assume that the coordination number of chromium in NaOH(aq) is 6.

In HC*l*(aq)

Equation:

....

Observation:

....

In NaOH(aq)

Equation:

....

Observation:

.... **[4]**

(d) Explain why the resultant solution is coloured when Cr_2O_3 is dissolved in acid.

....

....

....

....

....

....

....

.... **[3]**

(e) Another chromium-containing compound, $CrCl_3$, also exhibits similar properties to $AlCl_3$.

Predict the pH of the solution when a solid sample of $CrCl_3$ is dissolved in water. Use equations to justify your answer where possible.

....

....

....

.... **[2]**

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

The element chromium shows a relatively similar increase in the 1st, 2nd, 3rd and 4th ionisation energy. Aluminium, however, shows a significant difference between its 3rd and 4th ionisation energy.

   (i) By means of an equation, express the 2nd ionisation energy of chromium.

   .... **[1]**

(ii) Explain fully why the 4th ionisation energy of aluminium has a significantly larger magnitude compared to its 3rd ionisation energy.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

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

[Total: 15]

5 Caftaric acid is a compound found in grapes and is responsible for the yellowish-gold colour seen in some white wines.
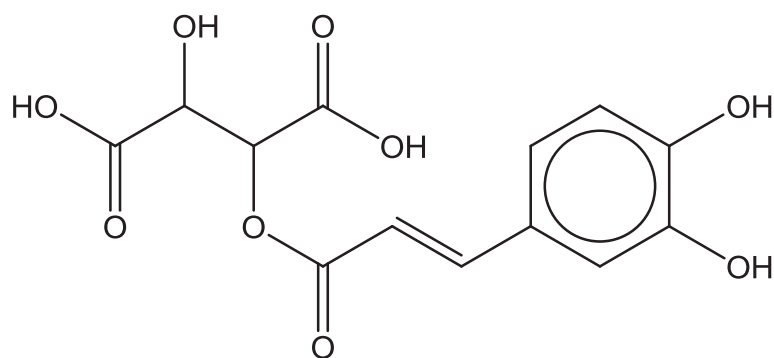
caftaric acid

(a) Deduce the molecular formula of caftaric acid.

.... **[1]**

(b) **(i)** State the type(s) of stereoisomerism exhibited by caftaric acid.

.... **[1]**

(ii) Hence, state the total number of stereoisomers of caftaric acid.

.... **[1]**

(c) The level of caftaric acid can be used to estimate the oxidation levels that a wine has undergone. Wines that undergo a high degree of oxidation, such as pressed wine, will have little to no caftaric acid in them.

Suggest the carbon-containing products formed when caftaric acid is heated with excess acidified $KMnO_4$(aq).

[3]

(d) On heating with dilute aqueous acid, caftaric acid produces two compounds **A** and **B**.
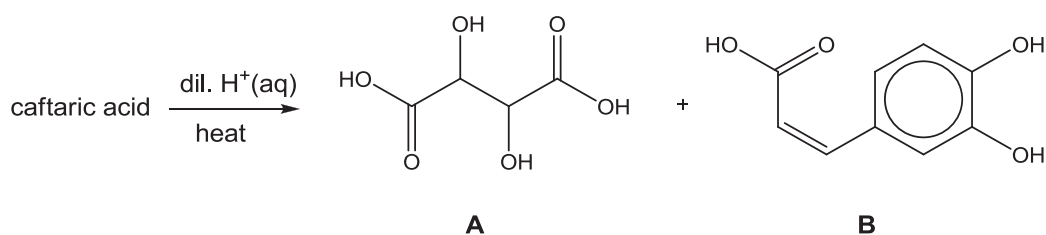
(i) State the *type of reaction* caftaric acid is undergoing when **A** and **B** are formed.

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

(ii) There are three types of molecules of **A**, one of which has no effect on plane polarised light.

Suggest the structure of the molecule and explain why it has no effect on plane polarised light.

……………………………………………………………………………………

……………………………………………………………………………………

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

(e) Under suitable conditions, the carboxylic acid functional group in compound **B** can be converted to its methyl ester.

B
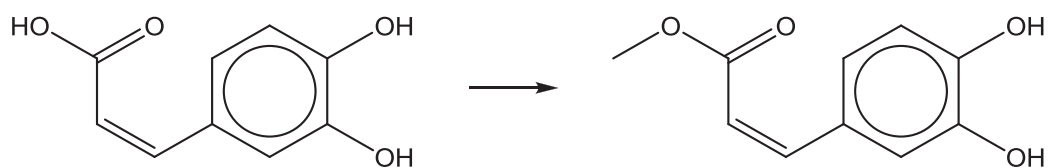
(i) State the *type of reaction* undergone by **B** above.

.... **[1]**

(ii) Suggest the reagents and conditions for the above reaction.

.... **[1]**

(f) Another method for conversion of carboxylic acids to their methyl esters involves the reaction with diazomethane, $:\overset{-}{C}H_2 \!\!-\!\! \overset{+}{N}\!\!\equiv\!\!N$, in an inert solvent.

$$RCO_2H + CH_2N_2 \rightarrow RCO_2CH_3 + N_2$$

This reaction occurs via a two-step mechanism.

- The carboxylic acid reacts with diazomethane to form a carboxylate ion intermediate in the first step.
- N_2 is formed in the second step.

Suggest the mechanism for this reaction. Show any relevant lone pairs, dipoles and charges, and indicate the movement of electron pairs with curly arrows.

[4]

[Total: 15]

END OF PAPER

CANDIDATE NAME

CLASS | 6 | |

CENTRE NUMBER | S | | | | | INDEX NUMBER | | | | |

H2 CHEMISTRY

9729/03

Paper 3 Free Response

19 September 2017

2 hours

Candidates answer on separate paper.

Additional Materials: Answer Paper

Cover Page

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 sheet of paper.
The use of an approved scientific calculator is expected, where appropriate.
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, with the cover page on top.

This document consists of **14** printed pages and **2** blank pages.

Section A
Answer **all** the questions in this section.

1 **(a)** Under suitable conditions, SCl_2 reacts with water to produce a yellow solid and an acidic solution **A**. Solution **A** contains a mixture of $SO_2(aq)$ and another compound.

  (i) State the oxidation number of S in SCl_2 . **[1]**

  (ii) Construct an equation for the reaction between SCl_2 and water. **[1]**

  (iii) In the Contact Process, one important step is the conversion of SO_2 to SO_3 as shown below.
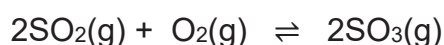
$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

  A 2.00 L flask was filled with 0.0400 mol SO_2 and 0.0200 mol O_2. At equilibrium, the flask contained 0.0296 mol of SO_3. Determine the value of K_c, stating its unit. **[3]**

(b) During the electrolysis of dilute sulfuric acid using a current of 0.75 A for 90 min and platinum electrodes, the volume of oxygen gas collected was recorded and is shown in Table 1.1 below.

Table 1.1

Time / min	Volume of O_2 gas / cm^3
20	55
40	110
60	165
80	220

  (i) Plot a graph of volume of O_2 gas over time.
  Use x axis: 2 cm for 10 min ; y axis: 2 cm for 50 cm^3 **[2]**

  (ii) Give equations for the reactions that occur at each electrode in the electrolysis of sulfuric acid. **[2]**

  (iii) On the same graph, draw and label a line (H_2) to predict the volume of hydrogen that would be given off during the same experiment. **[1]**

  (iv) On the same graph, draw and label a line (O_2) to predict the volume of oxygen that would be given off if a current of 0.3 A was used instead in the original experiment. **[1]**

(v) In a second experiment, the platinum electrodes were replaced with graphite electrodes. The volume of gas collected at the anode was 150 cm^3 while the volume of hydrogen gas collected was 220 cm^3.

The difference in volume of gas collected at the anode between the two experiments was due to the production of CO gas at the anode.

Calculate the volume of CO gas produced at the anode. **[2]**

(c) About 100 years ago, in a reaction discovered by German chemist Karl Fries, compound **B** was converted into compound **C** when heated with AlCl_3.

B
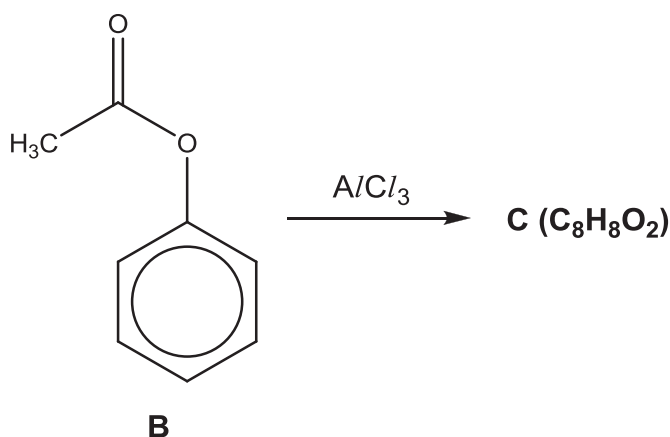
Compound **C** is a structural isomer of **B**.

It is insoluble in water but dissolves in aqueous sodium hydroxide.

It gives a yellow ppt with alkaline aqueous iodine and a white ppt with aqueous bromine.

(i) Suggest the structure for compound **C**. **[1]**

The various reactions of compound **C** can be represented as follows:
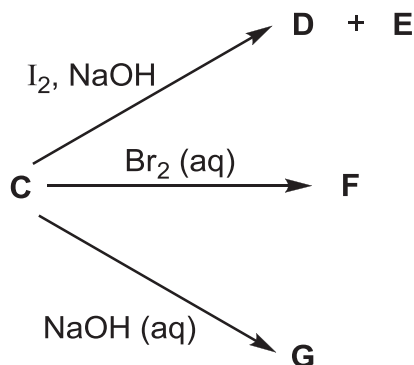
(ii) Suggest the structures for **D** to **G**. **[4]**

Compound **H**, as shown below, is another structural isomer of **B.**

It has a ether functional group whose general formula is R−O−R'.

Compound **H** can be formed via a reaction between a substituted phenoxide ion and an alkyl halide molecule.
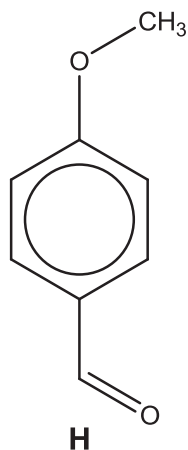
(iii) Describe the mechanism when compound **H** is formed as described above. **[3]**

[Total: 21]

BLANK PAGE

2   In the late 1940s, Willard Libby developed the radiocarbon dating method for determining the age of an object containing organic material by using the properties of radiocarbon (^{14}C), a radioactive isotope of carbon. The principle of carbon dating is as such:

During its life, a plant or animal is exchanging carbon with its surroundings, so the carbon it contains will have the same proportion of ^{14}C as the atmosphere. Once it dies, it ceases to acquire ^{14}C, but the ^{14}C within its biological material at that time will continue to decay, and so the ratio of ^{14}C to ^{12}C in its remains will gradually decrease.

Because ^{14}C decays with first order kinetics, the proportion of radiocarbon can be used to determine how long it has been since a given sample stopped exchanging carbon – the older the sample, the less ^{14}C will be left.

(a)   A sample of carbon dioxide gas (that contained both $^{12}CO_2$ and $^{14}CO_2$) was analysed to determine the proportion of $^{14}CO_2$ found within. Analysis results showed that there is one $^{14}CO_2$ molecule for every 10^{12} CO_2 molecules.

(i)   Calculate the number of $^{14}CO_2$ molecules in a 10.0 dm^3 carbon dioxide gas sample, measured under s.t.p.   **[2]**

(ii)   Calculate the mass of $^{14}CO_2$ in the 10.0 dm^3 sample.   **[1]**

(iii)   Hence, explain why it would be difficult to determine the proportion of $^{14}CO_2$ by means of mass measurement.   **[1]**

(b)   To more accurately determine the proportion of ^{14}C in a sample of graphite, the graphite is vaporised and ionised to $C^+(g)$ ions. These ions were then passed through 2 electric plates.

Given that H^+ is deflected with an angle of 8.4°, what is the angle of deflection for $^{14}C^+$ ions under the same experimental set-up?   **[1]**

(c)   The half-life of ^{14}C is 5730 years. Determine the time that has elapsed for a piece of wood from a dead tree to contain 30.0% of its original ^{14}C.   **[2]**

(d) The age of crude oil is far older than what could be determined from radiocarbon dating.

To measure the age of a crude oil sample, a method involving the measurement of the relative amount of oleanane is used instead.
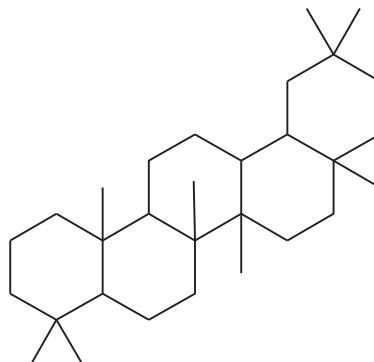
Oleanane

(i) What is the number of chiral carbons in an oleanane molecule? **[1]**

(ii) Free radical substitution of oleanane with Cl_2 produces a mixture of various products.

Given that tertiary hydrogen atoms are the most reactive towards free radical substitution, suggest the structures of two possible mono-chlorinated oleanane which are formed in high proportions. **[2]**

(e) Benzene is obtained from the fractional distillation of crude oil. It can be converted to a series of different useful chemicals such as phenylamine. The formation of phenylamine involves the direct reaction of nitrobenzene and hydrogen gas in the presence of a heterogeneous catalyst.

A series of experiments were carried out at a specific temperature to investigate the kinetics of this reaction:

Experiment	[nitrobenzene] / mol dm^{-3}	[H$_2$] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.010	0.010	4.50×10^{-5}
2	0.015	0.010	6.74×10^{-5}
3	0.020	0.020	1.80×10^{-4}
4	0.030	x	4.05×10^{-4}

    (i) Define the term *heterogeneous catalyst*. **[2]**

    (ii) Determine the order of reaction with respect to nitrobenzene and H$_2$. **[2]**

    (iii) Calculate the rate constant, stating its units. **[1]**

    (iv) Hence, determine the value of x. **[1]**

(f) Benzene is made to undergo a series of reactions as shown:
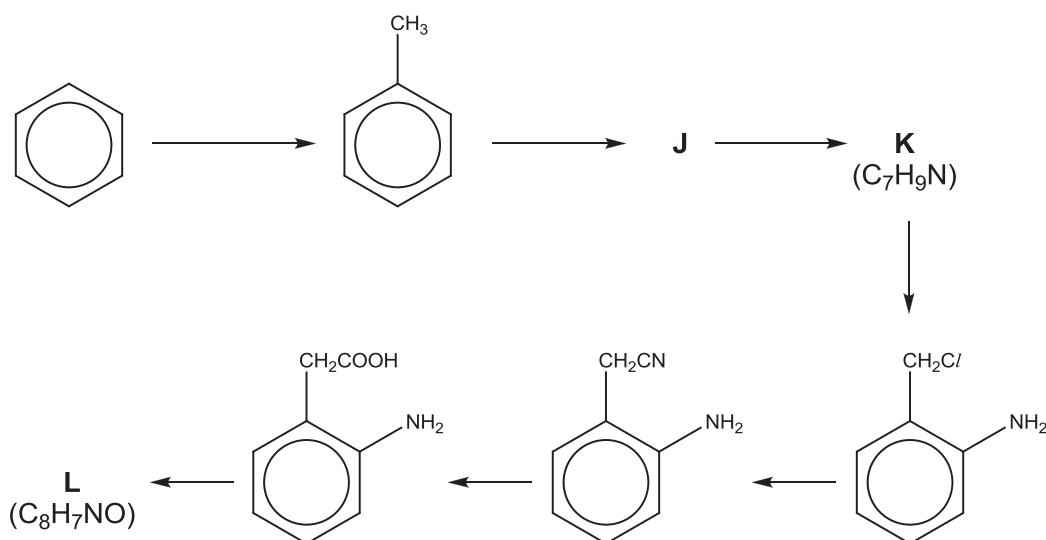
    (i) Suggest the structures of **J** and **K**. **[2]**

    (ii) Given that compound **L** is neutral, suggest the reagent used in the final step and the structure of **L**. **[2]**

[Total: 20]

BLANK PAGE

3 Chromium is a transition metal commonly found in the earth's crust. It is usually mined as chromite.

Period 4 Element	Ti	V	Cr	Mn	Fe	Co	Ni	Cu
Atomic radius / nm	0.132	0.122	0.117	0.117	0.116	0.116	0.115	0.117

(a) Explain why the atomic radius for transition elements remains relatively constant. **[2]**

(b) (i) Write the electronic configuration for Cr^{3+} ion. **[1]**

(ii) Chromium forms octahedral complexes with the general formula $CrCl_3.6H_2O$. One of them dissolves in water to form a violet solution which turned green upon warming. An excess of aqueous silver nitrate was added separately to solutions containing 0.0100 mol of each complex. The violet complex gave 1.50 g of precipitate, while the green complex gave 4.40 g of precipitate.

Deduce the formulae of the two complex ions.

Write the equation for the conversion of the violet complex to the green complex. **[3]**

(iii) Using the Cartesian axes, like those shown below,

draw **fully-labelled** diagrams of the following :

- One of the d orbital at the lower energy level in an octahedral complex. Label this diagram "Lower energy level".
- One of the d orbital at the upper energy level in an octahedral complex. Label this diagram "Upper energy level". **[2]**

(c) When sodium carbonate is added to a dichromate(VI) solution, the solution turned yellow.

$$Cr_2O_7{}^{2-}(aq) + 2OH^-(aq) \rightleftharpoons 2CrO_4{}^{2-}(aq) + H_2O(l)$$

  orange   yellow

Using a relevant equation, explain the above observation. **[2]**

(d) Ethylenediamine tetraacetate, $[EDTA]^{4-}$, is a ligand that acts as a chelating agent. It is widely used to remove transition metal ions such as those of chromium from aqueous solutions.

A possible reaction scheme used to synthesise $[EDTA]^{4-}$ from methanal is given below.

(i) Suggest the reagents and conditions in steps I, II and III. **[3]**

(ii) Draw the displayed formulae of intermediates **Q** and **R**. **[2]**

(iii) State the type of reaction when **T** is converted to $[EDTA]^{4-}$.

Give a reason why a limited amount of 1,2-diaminoethane is used. **[2]**

(iv) Define the term *ligand*. State the number of coordinate bonds that a $[EDTA]^{4-}$ ligand can form with a central metal ion. **[2]**

[Total: 19]

Section B

Answer **one** question from this section.

4   This question concerns the chemistry of the oxides of some elements.

(a)   The oxides of Period 3 show different reactions with water.

Describe the reactions, if any, of the oxides SiO_2 and SO_3 with water.

Include the approximate pH value of any resulting solutions, and write equations for any reactions that occur.   **[3]**

(b)   Carbon combusts in oxygen to form two common oxides, CO and CO_2. These oxides are also formed when solid magnesium oxalate, MgC_2O_4, is heated strongly.

(i)   Write an equation, with state symbols, to represent the thermal decomposition of solid magnesium oxalate.   **[1]**

(ii)   Explain why magnesium oxalate decomposes at a lower temperature than barium oxalate, BaC_2O_4.   **[2]**

Carbon also forms compounds with other Group 16 elements like sulfur and selenium. The properties of some of these compounds, along with CO_2, are given in Table 4.1.

Table 4.1

Compound	Structure	Dipole moment	Boiling point / $^\circ$C
CO_2	O=C=O	0	sublimes
CS_2	S=C=S	0	46
COS	S=C=O	0.71	−50
COSe	Se=C=O	0.73	−22

(iii)   Explain, in terms of structure and bonding, the difference in the boiling point of CS_2 and COS.   **[2]**

(iv)   Explain why

- CO_2 has no overall dipole moment.

- COSe has a greater dipole moment than COS.   **[2]**

(c) Aside from the common oxides, carbon forms a series of reactive oxocarbons. One such compound is tricarbon monoxide, C_3O, a reactive molecule found in space.

(i) Suggest a structure of tricarbon monoxide. Indicate clearly any lone pairs present. **[1]**

Tricarbon monoxide is isoelectronic to cyanogen, $(CN)_2$. The molecule of cyanogen contains a C–C single bond.

(ii) Draw the dot-and-cross diagram of cyanogen. In your diagram, you should distinguish the electrons originating from each of the two carbon atoms and those from the two nitrogen atoms. **[1]**

(iii) Suggest the shapes of tricarbon monoxide and cyanogen. **[1]**

(d) Another oxycarbon is pentacarbon dioxide, C_5O_2. It can be obtained by heating compound **X**, $C_6H_6O_3$, at a high temperature. **X** exists in equilibrium with its isomer, **Y**.

X does not react with aqueous bromine. **X** also gives an orange precipitate with 2,4-DNPH but does not give a silver mirror with Tollens' reagent. When reacted with limited bromine under ultraviolet light, **X** produced **only one** mono-brominated compound.

Y reacts with dilute nitric acid to form **only one** mono-nitrated compound, **Z**.

Suggest the structures of compounds **X**, **Y** and **Z**. Explain your reasoning. **[7]**

[Total: 20]

5 **(a)** Hydroformylation is an industrial process for the formation of aldehydes from alkenes.
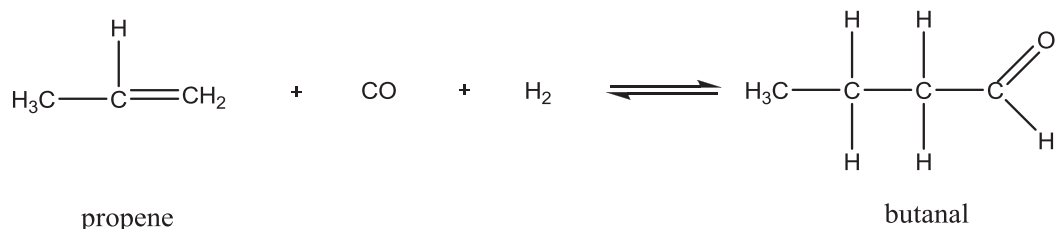
propene   butanal

(i) Determine the oxidation numbers of carbon-1, carbon-2 and carbon-4 in butanal. **[1]**

(ii) The hydroformylation of propene can result in the formation of two isomeric products. Given that the mechanism of hydroformylation resembles the electrophilic addition of alkenes, suggest the structure of the other isomer apart from butanal. **[1]**

(iii) Write the K_p expression for the reaction above, stating its units. **[1]**

(iv) When an equimolar mixture of propene, CO and H_2 at an initial pressure of 120 Pa was allowed to reach equilibrium at 550 K, the partial pressure of butanal was found to be 38.5 Pa.

Calculate a value of K_p at 550 K. **[2]**

(v) Hence, predict the sign of ΔG for the reaction. Explain your reasoning taking into account the thermodynamic considerations of the reaction. **[2]**

(b) Other important use of hydrocarbons include fuels, plastics, paints and solvents. In some countries, where crude oil is either scarce or expensive, biofuels such as ethanol are also increasingly being used for fuels instead of hydrocarbons.

(i) James carried out an experiment to determine the enthalpy change of combustion of octane, C_8H_{18}, using the apparatus shown in the diagram.
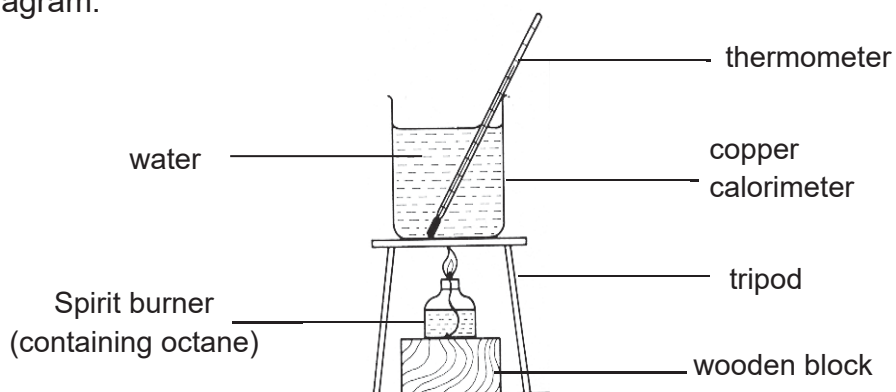
These are the results that James obtained:

Volume of water = 1000 cm^3

Initial temperature of water = 29.6 °C

Highest temperature of water = 50.0 °C

Initial mass of burner and octane = 59.35 g

Final mass of burner and octane = 53.77 g

Heat capacity of calorimeter = 770 J K^{-1}

Use these results and data from the *Data Booklet* to determine the experimental enthalpy change of combustion of octane. [3]

(ii) The accurate experimental enthalpy change of combustion of three hydrocarbons are given in Table 5.1.

Table 5.1

Alkane	Formula	ΔH_c/ kJ mol^{-1}
Heptane	C$_7$H$_{16}$	–4817
Octane	C$_8$H$_{18}$	–5470
Nonane	C$_9$H$_{20}$	–6125

Suggest what the regular increase in the values of ΔH_c given in the table represents. [1]

(iii) Draw a pair of enantiomers of heptane. [1]

(iv) Alkanes are also used in dry cleaning of clothing and textiles. Dry cleaning involves soaking the clothes in a solvent other than water. Recently, the use of supercritical carbon dioxide as a dry cleaning solvent has also been gaining popularity. Supercritical carbon dioxide is a fluid state of carbon dioxide which is maintained at or above its critical temperature.

Suggest two possible reasons why supercritical carbon dioxide is a better solvent than organic solvents like hexane. [2]

(c) Many modern methods of chemical analysis rely on the use of sophisticated instruments. For many years, scientists relied on traditional laboratory apparatus for chemical analysis.

Many qualitative tests and some volumetric analysis used depended on an application of the principles of solubility product.

Data for use in this question are given in Table 5.2.

Table 5.2

	Colour	Solubility / mol dm^{-3}	K_{sp} (25 °C)
AgCl	White	1.42×10^{-5}	2.02×10^{-10}
AgI	Yellow	8.95×10^{-9}	8.01×10^{-17}
Ag$_2$CrO$_4$	Red	9.10×10^{-5}	3.01×10^{-12}

(i) Aqueous AgNO$_3$ is added to solutions containing 0.100 mol dm^{-3} Cl^-(aq) or 0.0100 mol dm^{-3} CrO$_4^{2-}$(aq). What concentration of Ag$^+$ must be present to cause the precipitation of

I: AgCl

II: Ag$_2$CrO$_4$? **[2]**

(ii) Standard solutions of silver nitrate can be used in volumetric analysis to determine the concentration of chloride ions in a sample of water. When the titration is carried out, AgNO$_3$(aq) of known concentration is added slowly to the solution that contains Cl^- ions. A small quantity of aqueous potassium chromate(VI), K$_2$CrO$_4$ (0.01 mol dm^{-3}) is also added as an indicator.

Using the data given in Table 5.2 and your answers in **(c)(i)**, predict using calculations what you would see at the beginning of the titration and at the end-point and explain why K$_2$CrO$_4$(aq) can be used as an indicator in this titration. **[4]**

[Total: 20]

- End of Paper –

RIVER VALLEY HIGH SCHOOL

YEAR 6 PRACTICAL EXAMINATION

H2 CHEMISTRY 9729

23RD AUG 2017

2 hour 30 minutes

NAME

CLASS   6 (   )

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 an HB 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.
Qualitative Analysis Notes are printed on pages 15 and 16.

Shift
Laboratory

For Examiner's Use	
1	/ 21
2	/ 15
3	/ 9
4	/ 10
Total	/ 55

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

1 Determine the the percentage by mass of sodium ethanedioate in a mixture of sodium ethanedioate and ethanedioic acid.

This experiment involves **two steps**.
In step one, you will carry out a titration to find the amount of acid, $H_2C_2O_4$, present in **FB 3**.
In step two, you will carry out a second titration to find the total amount of ethanedioate ion, $C_2O_4^{2-}$, present in **FB 3**.
Finally, you will use the values found in the two steps to calculate the percentage by mass of sodium ethanedioate in **FB 3**.

FB 1 is 0.100 mol dm^{-3} sodium hydroxide, NaOH
FB 2 is 0.0200 mol dm^{-3} potassium manganate(VII), $KMnO_4$
FB 3 is a mixture of aqueous sodium ethanedioate, $Na_2C_2O_4$, and ethanedioic acid, $H_2C_2O_4$
FB 4 is approximately 2 mol dm^{-3} sulfuric acid
thymolphthalein indicator

Read through the whole method before starting any practical work.

(a)   Method

Step 1

1. Fill the burette labelled **FB 1** with **FB 1**.

2. Pipette 25.0 cm^3 of **FB 3** into a conical flask.

3. Add 1 dropper full of thymolphthalein.

4. Titrate **FB 3** in the conical flask with **FB 1** until a pale blue colour is seen.

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 **FB 1** added in each accurate titration.

Step 2

1. Pipette 25.0 cm^3 of **FB 3** into a conical flask.

2. Using a measuring cylinder, add about 25 cm^3 of 2 mol dm^{-3} sulfuric acid, **FB 4**, to the flask.

3. Place the conical flask on a hotplate and heat to about 65°C.

4. Fill the burette labelled **FB 2** with **FB 2**.

5. Use an appropriate method to carefully transfer the hot conical flask onto a white tile under the burette.

6. Titrate the mixture in the conical flask with **FB 2** until a permanent pale pink colour is seen. If a permanent brown colour is seen, stop the titration and begin **Step 2** again.

7. Carry out as many accurate titrations as you think necessary to obtain consistent results.

8. Record in a suitable form below all of your burette readings and the volume of **FB 2** added in each accurate titration.

M1	
M2	
M3	

[3]

(b) (i) From your titration results in **Step 1**, obtain a suitable value to be used in your calculations. Show clearly how you have obtained this value.

M4	
M5	

25.0 cm^3 of **FB 3** required ………….. cm^3 of **FB 1**

[2]

(b) (ii) Write an equation for the reaction between sodium hydroxide and ethanedioic acid to give sodium ethanedioate and water.   [1]

M6	

……………………………………………………………………………………..

(b) (iii) Use your answer from **(b)(i)** to calculate the amount of sodium hydroxide, **FB 1**, required to react with 25.0 cm³ of **FB 3** in **Step 1**.

Amount of NaOH = ………………………..

[1]

(b) (iv) Use your answer to **(b)(iii)** to determine the amount of ethanedioic acid in 25.0 cm³ of **FB 3**.

Amount of $H_2C_2O_4$ in 25.0 cm³ of **FB 3** = …………………………..

[1]

(c) (i) From your titration results in **Step 2**, obtain a suitable value to be used in your calculations. Show clearly how you have obtained this value.

25.0 cm³ of **FB 3** required ………….. cm³ of **FB 2**.

[3]

(c) (ii) Use your answer from **(c)(i)** to calculate the amount of potassium manganate(VII), **FB 2**, required to react with 25.0 cm^3 of **FB 3** in **Step 2**.

<div align="right">

M12 ☐

</div>

Amount of KMnO$_4$ = ...
[1]

(c) (iii) The equation for the reaction between acidified manganate(VII) ions and ethanedioate ions is shown below.

$$2MnO_4^- \text{ (aq)} + 5C_2O_4^{2-} \text{ (aq)} + 16H^+ \text{(aq)} \rightarrow 2Mn^{2+} \text{(aq)} + 10CO_2\text{(g)} + 8H_2O\text{(l)}$$
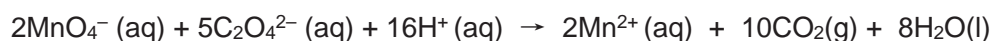
Calculate the total amount of ethanedioate ions in 25.0 cm^3 of **FB 3**.

<div align="right">

M13 ☐

</div>

Total amount of C$_2$O$_4^{2-}$ in 25.0 cm^3 of **FB 3** = ...
[1]

(c) (iv) Use your answers to **(b)(iv)** and **(c)(iii)** to calculate the amount of ethanedioate ions which came from the sodium ethanedioate dissolved in 25.0 cm^3 of **FB 3**.

<div align="right">

M14 ☐

</div>

Amount of C$_2$O$_4^{2-}$ from Na$_2$C$_2$O$_4$ in 25.0 cm^3 of **FB 3** = ...
[1]

(d) (i) Use your answer to **(b)(iv)** to calculate the mass of ethanedioic acid, H$_2$C$_2$O$_4$, in 25.0 cm^3 of **FB 3**.   [A_r: H, 1.0; C, 12.0; O, 16.0]
(If you were unable to answer **(b)(iv)**, you may assume that the amount of ethanedioic acid is 6.51×10^{-4} mol.)

<div align="right">

M15 ☐

</div>

Mass of ethanedioic acid = ...
[1]

(d) (ii) Use your answer to **(c)(iv)** to calculate the mass of sodium ethanedioate, $Na_2C_2O_4$ in 25.0 cm³ of **FB 3**. [A_r: C, 12.0; O, 16.0; Na, 23.0]
(If you were unable to answer **(c)(iv)**, you may assume that the amount of sodium ethanedioate is 4.13×10^{-4} mol.)

M16

Mass of sodium ethanedioate = ...
[1]

(d) (iii) Calculate the percentage by mass of sodium ethanedioate in **FB 3**.

M17

Percentage by mass of sodium ethanedioate is ....
[1]

(e) (i) A student suggested that using a burette to measure the 25.0 cm³ of acid would give a more accurate result than using a pipette.

The percentage error of a 25.0 cm³ pipette is 0.24 %. Is the student correct? Explain your answer. [2]

………………………………………………………………………………..

M18

………………………………………………………………………………..

M19

………………………………………………………………………………..

………………………………………………………………………………

(e) (ii) A student decided to use a 25.0 cm³ pipette instead of a measuring cylinder to measure the volume of **FB 4** in **Step 2**.

State and explain whether this alteration will improve the accuracy of the calculation of the percentage by mass of sodium ethanedioate in the mixture. [2]

………………………………………………………………………………..

M20

………………………………………………………………………………..

M21

………………………………………………………………………………..

[Total: 21]

BLANK PAGE

2 **Investigate how the rate of the following reaction varies with the concentration of sodium thiosulfate, Na₂S₂O₃.**

$$Na_2S_2O_3 (aq) + H_2SO_4 (aq) \rightarrow S (s) + Na_2SO_4 (aq) + SO_2 (g) + H_2O (l)$$
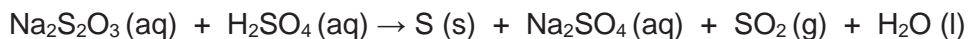
The rate of the reaction above can be found by measuring how long it takes for the solid sulfur formed to obscure the printing on the insert provided.

Care should be taken to avoid inhalation of SO₂(g) that is given off during this reaction.

FC 5 is 1.0 mol dm⁻³ sulfuric acid, H_2SO_4
FC 6 is 0.10 mol dm⁻³ sodium thiosulfate, $Na_2S_2O_3$

(a) **Method**

1. Using the 50 cm³ measuring cylinder, transfer 45 cm³ of **FC 6** into a 100 cm³ beaker.
2. Using the 25 cm³ measuring cylinder, measure 10 cm³ of **FC 5**.
3. Tip the **FC 5** into the **FC 6** in the beaker and **immediately** start the stopwatch.
4. Stir the mixture once with a glass rod and place the beaker on top of the printed insert. Cover the beaker with a petri dish.
5. View the printed insert from above so that it is seen through the mixture.
6. Record the time, to the nearest second, when the printing on the insert **just** disappears.
7. Empty and rinse the beaker. Shake out as much of the water as possible and dry the inside of the beaker.

You will repeat the experiment to find out how the time for the printing on the insert to disappear changes when a different volume of **FC 6** is used.

8. Using the 50 cm³ measuring cylinder, transfer 20 cm³ of **FC 6** and 25 cm³ of distilled water into the 100 cm³ beaker.
9. Using the 25 cm³ measuring cylinder, add 10 cm³ of **FC 5** to the mixture and **immediately** start timing.
10. Stir the mixture once with a glass rod and place it on top of the printed insert.
11. View the printed insert from above so that it is seen through the mixture.
12. Record the time, to the nearest second, when the printing on the insert **just** disappears.
13. Select suitable volumes of **FC 6 and** distilled water for **two** further experiments to investigate the effect of volume of sodium thiosulfate on the time taken for the printing on the insert to **just** disappear. The volume of **FC 6** used should range from 0 cm³ to 45 cm³.

In the space below, record, in an appropriate form, all measurements of volume, time, and 1/time.

M1	
M2	
M3	
M4	
M5	

[5]

(b) Plot 1/time against the volume of **FC 6**. Draw the most appropriate line, taking into account all the points. [3]
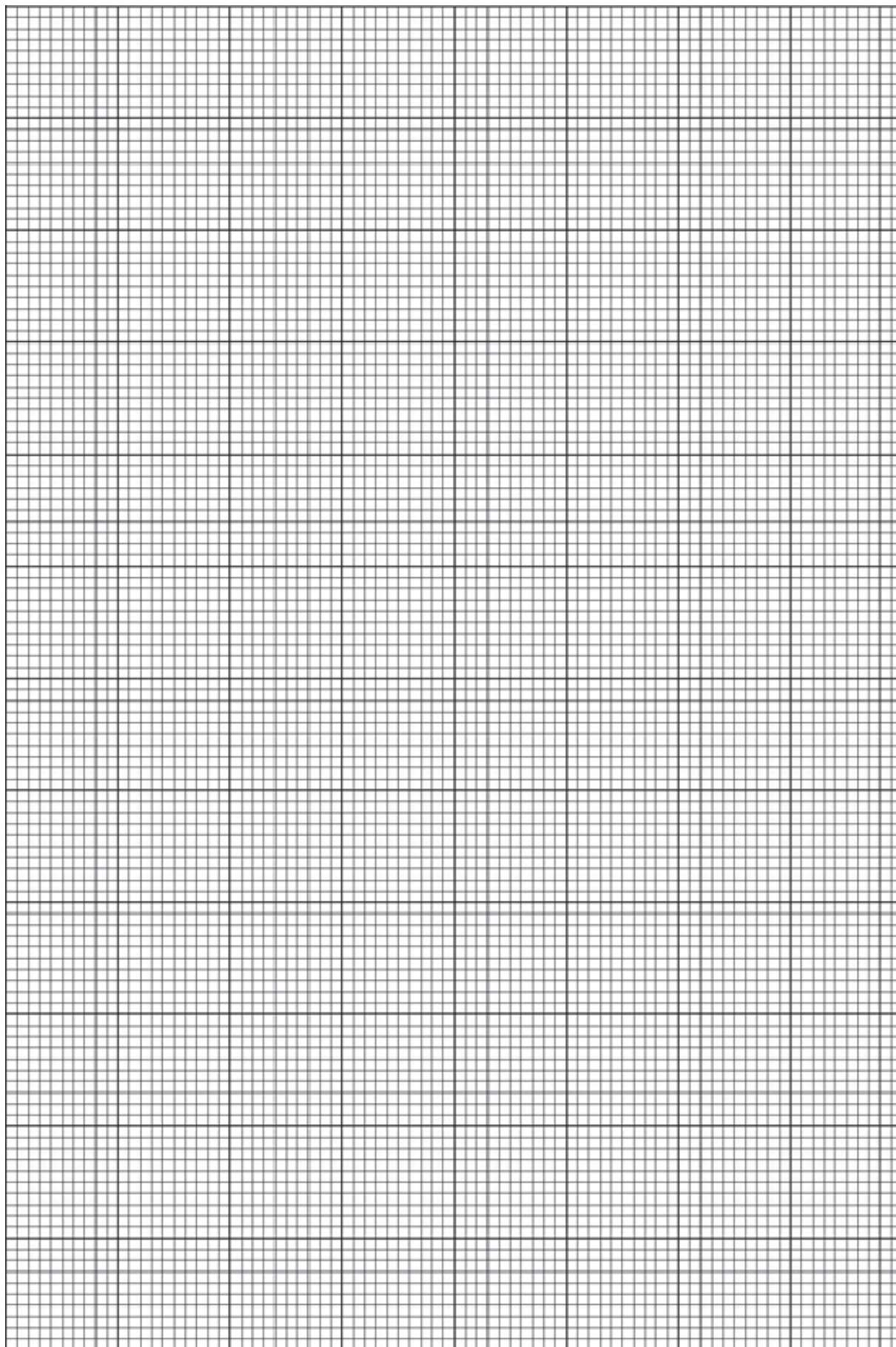
M6	M7	M8

(c) Why was the total volume of solution kept constant in the experiments? [1]

……………………………………………………………………………………….. M9

………………………………………………………………………………………..

(d) Using the graph of 1/time against the volume of **FC 6,** draw a conclusion about the relationship between the concentration of sodium thiosulfate used and the rate of reaction. Hence, state the order of reaction with respect to sodium thiosulfate. [2]

……………………………………………………………………………………….. M10

M11

………………………………………………………………………………………..

………………………………………………………………………………………..

(e) In the four experiments, which value of the time measured had the greatest error? Explain your answer. [2]

……………………………………………………………………………………….. M12

M13

………………………………………………………………………………………..

(f) Another student conducts another experiment for the same reaction where the sodium thiosulfate is in large excess. The concentration of acid is monitored as the reaction progresses. His results are as shown below.
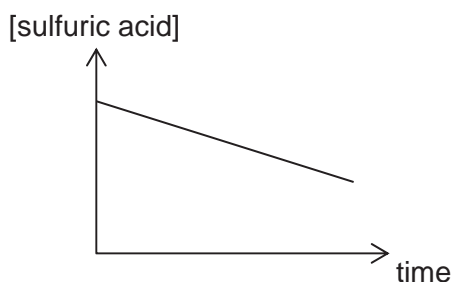
M14

M15

Deduce the order of reaction with respect to sulfuric acid. [2]

………………………………………………………………………………………..

………………………………………………………………………………………..

………………………………………………………………………………………..

[Total: 15]

3   Organic Analysis

Before starting parts (a) and (b), half-fill a 250 cm³ beaker with water and heat with a hotplate to approximately 60 ⁰C. You will use this as a hot water bath.

(a)   **FD 7**, **FD 8** and **FD 9** are solutions each containing a single compound which could be ethanol, ethanal or propanone. To identify each compound you will react the samples with Tollens' reagent and with acidified potassium manganate(VII).

<u>Preparation of Tollens' reagent</u>

1.   To approximately 2 cm depth of aqueous silver nitrate in a boiling tube, add approximately 0.5 cm depth of aqueous sodium hydroxide.
2.   Add aqueous ammonia a little at a time with continuous shaking until the brown precipitate just dissolves. Do not add an excess of ammonia.

Complete the table below.

test	observations		
	FD 7	**FD 8**	**FD 9**
To a 1 cm depth of each solution in a clean test-tube, add a few drops of the Tollens' reagent that you have prepared. **Do not shake the tube**. If no reaction is seen, warm the tube in the hot water bath.			
To a 1 cm depth of each solution in a test-tube, add 1 cm depth of dilute sulfuric acid. Then add a few drops of aqueous potassium manganate(VII). If no reaction is seen, warm the tube in the hot water bath.			
Identity			

[4]

M1	M2	M3	M4

(b) **FD 10** is an aqueous solution of an organic compound. Carry out the following tests.

test	observations
To a 1 cm depth of **FD 10** in a test-tube, add 1 cm depth of dilute sulfuric acid. Then add a few drops of aqueous potassium manganate(VII). If no reaction is seen, place the test-tube in the hot water bath and leave to stand.	
To a 1 cm depth of **FD 10** in a test-tube, carefully add a small spatula measure of sodium hydrogen carbonate.	

[2]

M5	M6

(c) State the type(s) of reactions that **FD 10** have undergone in **(b)**. [2]

…………………………………………………………………………………………..

M7	
M8	

…………………………………………………………………………………………..

(d) You are given that the M_r of **FD 10** is 46.0. State the identity of **FD 10.** [1]
[A_r: C, 12.0; O, 16.0; H, 1.0; Cl, 35.5; N, 14.0]

…………………………………………………………………………………………..

M9	

[Total: 9]

4 Planning

When heated, aqueous hydrogen peroxide, H_2O_2, decomposes to form oxygen and water.

$$2H_2O_2 \,(aq) \; \rightarrow \; 2H_2O \,(l) \; + \; O_2 \,(g)$$

The decomposition can also occur at room temperature if a suitable catalyst is added. Both of the solids, manganese(IV) oxide and lead(IV) oxide, will catalyse the decomposition.

You are provided with:
- 0.150 mol dm^{-3} solution of hydrogen peroxide
- a syringe with a capacity of 100 cm^3
- apparatus normally found in a school laboratory

(a) (i) Using the information given above, you are required to write a plan to determine the more efficient catalyst for the decomposition of aqueous hydrogen peroxide. Your plan should include:

- a fully labelled diagram of the apparatus to be used

- a calculation of the volume in cm^3 of the aqueous hydrogen peroxide that could be used such that an appropriate volume of oxygen could be collected.

- the measurements you would take that and how you would use them to deduce which catalyst is more efficient.

The molar volume of a gas at 20 °C is 24.0 dm^3.

....

....

....

....

....

....

....

....

....

....

....

[9]

M1	M2	M3	M4	M5	M6	M7	M8	M9

(ii) What other feature of the catalyst should be controlled during the experiment? [1]

....

M10	

[Total : 10]

~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 $\rightarrow$ (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

For each candidate

- 1 × 25 cm³ pipette
- 2 × 50 cm³ burette
- 1 × burette stand and clamp
- 1 × funnel (for filling burette)
- 2 × 250 cm³ conical flask
- 2 × 250 cm³ beaker
- 1 × 100 cm³ beaker
- 1 × 50 cm³ measuring cylinder
- 1 × 25 cm³ measuring cylinder
- 1 × white tile
- 1 × white insert with cross
- 1 × petri dish
- 1 × hotplate
- 1 × spatula
- 6 clean test-tubes
- 1 × boiling tube
- 1 × test-tube rack
- 1 × test-tube holder
- 1 × glass rod
- 4 × teat/dropping pipette
- 1 × wash bottle containing distilled water
- 1 × thermometer (−10 °C to +110 °C at 1 °C)
- 1 × stopwatch
- paper towels
- access to a balance reading to at least 0.1 g

For each candidate

hazard	label	per candidate	identity	notes (hazards given in this column are for the raw materials)
[H]	FB 1	100 cm³	0.1 mol dm⁻³ sodium hydroxide	Dissolve 4.0 g NaOH [C] in each dm³ of solution.
[N]	FB 2	120 cm³	0.02 mol dm⁻³ potassium manganate(VII)	Dissolve 3.16 g KMnO₄ [N] [O] [H] in each dm₃ of solution.
	FB 3	230 cm³	solution containing a mixture of ethanedioic acid and sodium ethanedioate	Dissolve 3.80 g HOOCCOOH.2H₂O [H] and 2.00 g Na₂C₂O₄ [H] in each dm³ of solution.
[C]	FB 4	150 cm³	2.0 mol dm⁻³ sulfuric acid	Cautiously pour 110 cm³ of concentrated (98 %) sulfuric acid [C] into 800 cm³ of distilled water with continuous stirring. Make the solution up to 1 dm³ with distilled water. **Care** – *concentrated H₂SO₄ is very corrosive.*
[F]	thymolphthalein indicator	5 cm³	thymolphthalein	.
[H]	FC 5	100 cm³	1.0 mol dm⁻³ sulfuric acid	Cautiously pour 55 cm³ of concentrated (98%) sulfuric acid [C] into 500 cm³ of distilled water with continuous stirring. Make the solution up to 1 dm³ with distilled water Care: concentrated H₂SO₄ is very corrosive.
	FC 6	180 cm³	0.1 mol dm⁻³ sodium thiosulfate	Dissolve 24.8 g of Na₂S₂O₃.5H₂O in each dm³ of solution. The solid should be dissolved in boiled distilled water that has been cooled in a closed vessel. This prevents oxidation of the thiosulfate by dissolved oxygen.
	FD 7	10 cm³	0.10 mol dm⁻³ magnesium sulfate	Dissolve 24.6 g of MgSO₄.7H₂O in each dm³ of solution.
*[F] [H]	FE 8	5 cm³	1.0 mol dm⁻³ glucose	Dissolve 180 g of glucose in each dm³ of solution. This should be provided in a stoppered container.
*[F] [H]	FE 9	5 cm³	distilled water	Provided in a stoppered container.
[F] [H]	FE 10	5 cm³	ethanol	Ethanol [F], or IMS, Industrial Methylated Spirits [F] [H]. Provided in a stoppered container.
[C]	FE 11	5 cm³	3.0 mol dm⁻³ methanoic acid	Dilute 126 cm³ of HCOOH, methanoic acid (90%) [C] to 1 dm³ with distilled water.

Bench reagents

hazard	Label	notes
[H]	dilute hydrochloric acid	All concentrations to be around 2.0 mol dm^{-3}
[C]	dilute nitric acid	Except sulfuric acid (1.0 mol dm^{-3})
[H]	dilute sulfuric acid	
[H]	aqueous ammonia	
[C]	aqueous sodium hydroxide	
[H]	0.1 mol dm^{-3} barium nitrate	
[H] [N]	0.05 mol dm^{-3} silver nitrate	
[H]	limewater	
[N]	0.02 mol dm^{-3} potassium manganate(VII)	
	0.1 mol dm^{-3} potassium iodide	
	Red & Blue litmus paper	

Answers to Paper 1

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

RIVER VALLEY HIGH SCHOOL
YEAR 6 PRELIMINARY EXAMINATION II

CANDIDATE NAME

CLASS

CENTRE NUMBER   S 3 0 4 4

INDEX NUMBER   0 0

H2 CHEMISTRY

Paper 2 Structured Questions

9729/02

13 Sep 2017

2 hours

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST.

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

Write your name, class and index number in the spaces at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
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.
A Data Booklet is provided.

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.

<table>
<tr><th colspan="10">For Examiner's Use</th></tr>
<tr><th colspan="10">Paper 2</th></tr>
<tr><th rowspan="2">P2</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>SF</th><th>UNITS</th><th colspan="2">Total (P2)</th></tr>
<tr><td>17</td><td>14</td><td>14</td><td>15</td><td>15</td><td></td><td></td><td colspan="2">75</td></tr>
<tr><td>P1</td><td>30</td><td>P3</td><td>80</td><td>Total</td><td>185</td><td>P4</td><td>55</td><td>Grade</td><td></td></tr>
</table>

This paper consists of **XX** printed pages.

1 Among the many pharmaceutical drugs manufactured worldwide, one of the most important types is the painkillers. The structures of three such painkillers are shown.

ibuprofen
(M_r = 206)

paracetamol
(M_r = 151)

aspirin
(M_r = 180)

Ibuprofen is used to treat arthritis and relieve pain, fever and swelling. It is available over-the-counter in 200 and 400 mg tablets. The recommended dosage varies with body mass and indication, but 1.20 g is considered the maximum daily adult dosage. Long term use of ibuprofen can lead to stomach ulcers.

Ibuprofen can be synthesised via the following process:

A

B

3 steps

ibuprofen

C

(a) A man bought some ibuprofen tablets of dosage 200 mg over the counter and consumed one pill 4 times a day. Explain if this level of consumption safe for the man.

Since 4 x 200 = 800 mg is lower than the maximum dosage of 1200 mg, the level of consumption is safe for the man. **[1]**

(b) State the *type of reaction* that converts Compound **A** to **B**.

Electrophilic substitution **[1]**

(c)	In the laboratory, Compound **C** can be converted to ibuprofen using a 3-step synthesis route. Suggest reagents and conditions for each step, and draw the structures of all intermediates.	
		[5]
(d)	Young children often find it difficult to swallow tablets. Thus, ibuprofen is supplied as an "infant formula" emulsion. Given that ibuprofen and water are immiscible, an emulsifier such as polysorbate 80 is used to create a homogeneous mixture. **polysorbate 80** Explain why this molecule is able to act as an emulsifier.	
	The -OH polar groups allow the molecule to be soluble in water, while the non-polar hydrocarbon groups allow the molecule to be soluble in oil / non-polar liquids.	**[1]**
(e)	A certain pharmaceutical brand claims that the ibuprofen tablets it manufactures are 95.0% pure by mass.	

To investigate this claim, 5.00 g of a sample was crushed and dissolved in 250 cm^3 of 0.450 mol dm^{-3} aqueous KOH. 25.0 cm^3 of this solution was withdrawn and titrated against sulfuric acid. The unreacted KOH in this solution required 25.50 cm^3 of 0.180 mol dm^{-3} of sulfuric acid for complete neutralisation.

Showing relevant calculations, deduce if the claim is valid.

Amount of H$_2$SO$_4$ = $\frac{25.50}{1000} \times 0.180$

$\qquad\qquad$ = 0.00459 mol

Amount of unreacted KOH = 0.00459 x 2

$\qquad\qquad$ = 0.00918 mol

Amount of unreacted KOH (in 250 cm^3) = 0.0918 mol

Amount of KOH reacted with ibuprofen sample = $\frac{250}{1000} \times 0.450 - 0.0918$

$\qquad\qquad$ = 0.0207 mol

Since ibuprofen $\equiv$ KOH,

Amount of ibuprofen = 0.0207 mol

Mass of ibuprofen = 0.0207 x [13(12.0) + 18(1.0) + 2(16.0)]

$\qquad\qquad$ = 4.26 g

Percentage purity = $\frac{4.26}{5.00} \times 100\%$

$\qquad\qquad$ = 85.2%

Hence, the claim is invalid.

[3]

(f) Compare the acidity of ibuprofen and aspirin. Explain your answer.

Aspirin is a stronger acid than ibuprofen.

The anion of aspirin, , is more stable than the anion of

ibuprofen, , as the negative charge is delocalised over the COO⁻ group and into the benzene ring.

[2]

(g) Describe two simple chemical tests to distinguish between ibuprofen, paracetamol and aspirin.

Test: Add neutral FeCl_3(aq)

[4]

		Observations: Violet colouration forms for paracetamol. No violet colouration forms for ibuprofen and aspirin.		
		Test: Heat with acidified $KMnO_4(aq)$		
		Observations: Purple $KMnO_4$ turns colourless for ibuprofen. $KMnO_4$ remains purple for paracetamol and aspirin.		
				[Total: 17]

2	**(a)**		Gaseous ethane can be used as a fuel for campers. A company manufactures compressed gaseous ethane in 400 cm³ metal canisters. A typical metal canister at room temperature contains compressed gaseous ethane at a pressure of 4.00 atm.	
		(i)	Suggest a reason why gaseous ethane in the metal canister does not behave like an ideal gas.	
			Due to high pressure in the canister, volume of the ethane molecules is not negligible compared to volume of the metal canister / intermolecular forces of attraction between ethane molecules are not negligible.	**[1]**
		(ii)	One metal canister is used for heating water and the pressure decreases from 4.00 atm to 1.50 atm. Assuming that the compressed ethane behaves ideally, calculate the mass of water at room temperature that could be brought to boiling if the process is 80% efficient. The enthalpy change of combustion of ethane is -1420 kJ mol⁻¹.	

			Using pV = nRT, $(2.50 \times 101325)(400 \times 10^{-6}) = n(8.31)(293)$
			n = amount of ethane used
			  = 0.0416 mol
			Heat evolved from combustion of ethane = 0.0416 x 1420
			                                       = 59.1 kJ
			$0.80 \times 59.1 \times 10^3$ = Mass of water x 4.18 x (100 − 20)
			Mass of water = 141 g
				[3]

		(iii)	Suggest a reason why butane is a better fuel for campers compared to ethane.	

		Butane has a higher magnitude of enthalpy change of combustion / More heat is produced per mole of butane combusted / Butane is more compressible, and therefore more portable.	[1]
	(b)	Calcium fluoride is used for dental protection. It dissolves readily in water with an enthalpy change of solution of −125 kJ mol⁻¹. It is given that the lattice energy of calcium fluoride is −2350 kJ mol⁻¹ while the enthalpy change of hydration of calcium ion is −1560 kJ mol⁻¹. With the aid of a labelled energy level diagram, calculate the enthalpy change of hydration of fluoride ion.	

Energy

$Ca^{2+}(g) + 2F^-(g)$

$LE(CaF_2)$

$\Delta H_{hyd}(Ca^{2+}) + 2\Delta H_{hyd}(F^-)$

$CaF_2(s)$

$\Delta H_{soln}(CaF_2)$

$Ca^{2+}(aq) + 2F^-(aq)$

By Hess' Law,

$\Delta H_{soln}(CaF_2) = -LE(CaF_2) + \Delta H_{hyd}(Ca^{2+}) + 2\Delta H_{hyd}(F^-)$

$-125 = -(-2350) + (-1560) + 2\Delta H_{hyd}(F^-)$

$\Delta H_{hyd}(F^-) = -458$ kJ mol⁻¹ [4]

(c) Liquid hydrazine reacts with oxygen to form nitrogen and steam which could involve the following energy cycle shown below.

$$N_2H_4(l) + O_2(g) \longrightarrow N_2(g) + 2H_2O(g)$$

$$N_2H_4(g) + O_2(g) \longrightarrow 2N(g) + 4H(g) + 2O(g)$$

	(i)	Given that the enthalpy change of vapourisation of hydrazine is +58.0 kJ mol^{-1}, use appropriate bond energies from the *Data Booklet* to calculate the enthalpy change of reaction between liquid hydrazine and oxygen.	
		$\Delta H_r = \Delta H_{vap}(N_2H_4) + [BE(N-N) + 4BE(N-H) + BE(O=O)]$ $- [BE(N\equiv N) + 4BE(O-H)]$ $= +58 + [(+160) + 4(+390) + (+496)] - [(+944) + 4(+460)]$ $= -510$ kJ mol^{-1}	[2]
	(ii)	The reaction shown above has a positive ΔS value. Account for its significance.	
		There is an increase in disorder of the system. The amount of gaseous molecules increases from 1 mol to 3 mol as the reaction proceeds.	[1]
	(iii)	Hence, under what conditions of temperature will the reaction be spontaneous?	
		$\Delta G = \Delta H - T\Delta S$ Since ΔS is positive, $-T\Delta S$ is negative. Given that the calculated ΔH is negative, ΔG is negative and the reaction is spontaneous at all temperatures.	[2]
			[Total: 14]

3	An experiment was set up to investigate how the cell potential of a cell containing a metal, M, in contact with an aqueous solution of its ions, M^{n+}(aq), changed as M^{n+}(aq) was diluted.	

Since a standard hydrogen half-cell was not available, a half-cell consisting of Cl^-, ClO^- in alkaline medium under standard conditions was used to connect to the half-cell with M in contact with $M^{n+}(aq)$.

(a) Draw the setup of the galvanic cell as described above.

[3]

The cell potential was measured for various concentrations of $M^{n+}(aq)$ and the results of cell potential against log $[M^{n+}]$ obtained are plotted in the graph as shown below.

(b) It is known that the cell potential of a cell, E_{cell}, is related to the standard electrode potential, $E^{\ominus}_{cell}$, by the equation:

$$E_{cell} = E^{\ominus}_{cell} - \frac{0.06\,lg[M^{n+}]}{n}$$

		(i)	Use your graph to determine the gradient and the charge, n, of the M^{n+} ions.	
			Gradient = −0.0300 **− 0.06 / n = -0.0300** **n = 2**	**[2]**
		(ii)	Use your graph to determine the $E^{\ominus}_{cell}$, showing your working clearly.	
			$\log_{10}1 = 0$ **y-intercept = 0.93 V or uses equation to calculate**	**[2]**
		(iii)	In the determination of standard electrode potential of a half-cell, the polarity of standard hydrogen electrode can either be positive or negative. The standard electrode potential for Cl^-, ClO^- in alkaline conditions is +0.80 V. Hence, calculate the standard electrode potential of the metal, M, and suggest its identity.	
			$E^{\ominus}$ for M = 0.80 − 0.93 **= −0.13 V** **M is Pb.**	**[2]**
		(iv)	Suggest one purpose of a salt bridge in a galvanic cell.	
			To allow movement of ions / complete the circuit **OR** **To maintain electrical neutrality / charge or ion balance**	**[1]**
		(v)	A student suggested the use of aqueous potassium sulfate in the salt bridge. Do you think his choice is wise? Explain your reasoning.	
			Not wise **$PbSO_4$ is insoluble/ is a ppt. Will affect E values.**	**[2]**
	(c)		Using Le Chatelier's Principle and relevant equations, explain why $AgCl$ is soluble in excess aqueous ammonia.	
			$AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq)$ ---------- (1) **$Ag^+(aq) + 2NH_3(aq) \rightleftharpoons [Ag(NH_3)_2]^+(aq)$** **When excess NH_3 is added, diammine silver complex is formed.**	**[2]**

		POE in (1) is shifted to the right as [Ag+] decreases. AgCl dissolves.	
			[Total: 14]

4		Viridian is a blue-green pigment used commonly in paints, inks, and stained glasses. The major constituent of viridian is the compound chromium(III) oxide, Cr_2O_3, that gives its characteristic colour.	
		Alumina, which is the common name for the chemical aluminium oxide (Al_2O_3), is a white solid which is commonly used as abrasive owing to its high hardness rating.	
	(a)	Define the term *transition element.*	
		A transition element is a d-block element which forms at least one stable ion (compound) with a partially filled d subshell.	**[1]**
	(b)	In terms of structure and bonding, explain why alumina has a high hardness rating.	
		Alumina has a giant ionic structure. Strong electrostatic forces of attractions between Al^{3+} and O^{2-} ions which is difficult to overcome.	**[2]**
	(c)	Both Cr_2O_3 and Al_2O_3 are amphoteric oxides. Describe the observations and write balanced equations when Cr_2O_3 is dissolved in HCl(aq) and NaOH(aq). You can assume that the coordination number of chromium in NaOH(aq) is 6.	
		In HCl(aq) Equation: $Cr_2O_3 + 6HCl \rightarrow 2CrCl_3 + 3H_2O$ Observation: (Blue)-green solid dissolves in HCl(aq) to give a green solution In NaOH(aq) Equation: $Cr_2O_3 + 6NaOH + 3H_2O \rightarrow 2Na_3[Cr(OH)_6]$ Observation: (Blue)-green solid dissolves in NaOH(aq) to give a dark green solution	**[4]**
	(d)	Explain why the resultant solution is coloured when Cr_2O_3 is dissolved in acid.	
		The solution contains Cr^{3+} which has a partially filled 3d subshell. In the presence of H_2O ligands, the 3d orbitals are split into 2 sets of orbitals with	**[3]**

different energy level. The difference in energies (ΔE) between these 2 sets of non-degenerate 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 is the complement of the colour absorbed.

(e) Another chromium-containing compound, $CrCl_3$, also exhibits similar properties to $AlCl_3$.

Predict the pH of the solution when a solid sample of $CrCl_3$ is dissolved in water. Use equations to justify your answer where possible.

pH of solution = 3.0

$CrCl_3 + 6H_2O \rightarrow [Cr(H_2O)_6]^{3+} + 3Cl^-$

$[Cr(H_2O)_6]^{3+} \rightleftharpoons [Cr(H_2O)_5(OH)]^{2+} + H^+$

OR

$[Cr(H_2O)_6]^{3+} + H_2O \rightleftharpoons [Cr(H_2O)_5(OH)]^{2+} + H_3O^+$

[2]

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

The element chromium shows a relatively similar increase in the 1st, 2nd, 3rd and 4th ionisation energy. Aluminium however, shows a significant difference between its 3rd and 4th ionisation energy.

(i) By means of an equation, express the 2nd ionisation energy of chromium.

$Cr^+(g) \rightarrow Cr^{2+}(g) + e^-$ $\Delta H = $ 2nd IE

[1]

(ii) Explain fully why the 4th ionisation energy of aluminium has a significantly larger magnitude compared to its 3rd ionisation energy.

Al^{2+}: $1s^2\ 2s^2\ 2p^6\ 3s^1$

Al^{3+}: $1s^2\ 2s^2\ 2p^6$

Fourth electron is removed from an inner principal quantum shell which is closer to the nucleus while the 3rd electron is removed from the outermost shell. The fourth electron in the inner shell (2p subshell) also experiences a greater effective nuclear charge/ less shielding effect compared to the electron in the outermost shell (3p subshells).

[2]

[Total: 15]

5	Caftaric acid is a compound found in grapes and is responsible for the yellowish-gold colour seen in some white wines. **caftaric acid**			
	(a)	Deduce the molecular formula of caftaric acid.		
		$C_{13}H_{12}O_9$		**[1]**
	(b)	**(i)**	State the type(s) of stereoisomerism exhibited by caftaric acid.	
			Enantiomerism and cis-trans isomerism	**[1]**
		(ii)	Hence, state the total number of stereoisomers of caftaric acid.	
			8 (2^2 enantiomers × 2 cis-trans)	**[1]**
	(c)	The level of caftaric acid can be used to estimate the oxidation levels that a wine has undergone. Wines that undergo a high degree of oxidation, such as pressed wine, will have little to no caftaric acid in them. Suggest **the carbon-containing products formed** when caftaric acid is heated **with excess acidified KMnO₄(aq).**		
		and CO_2		**[3]**

(d) On heating with dilute aqueous acid, caftaric acid produces two compounds **A** and **B**.

(i) State the *type of reaction* caftaric acid is undergoing when **A** and **B** are formed.

(Acidic) Hydrolysis [1]

(ii) There are three types of molecules of **A**, one of which has no effect on plane polarised light.

Suggest the structure of the molecule and explain why it has no effect on plane polarised light.

(Accept if OH and H are swapped on both carbon)

There is a plane of symmetry in the molecule so the rotation of plane polarised light by the two chiral centres will cancel each other out. [2]

(e) Under suitable conditions, the carboxylic acid functional group in compound **B** can be converted to its methyl ester.

B

		(i)	State the *type of reaction* undergone by B above.	
			Condensation	[1]
		(ii)	Suggest the reagents and conditions for the above reaction.	
			Methanol, (a few drops of) concentrated H_2SO_4, heat (under reflux)	[1]

(f) Another method for conversion of carboxylic acids to their methyl esters involves the reaction with diazomethane, $:\bar{C}H_2 － \overset{+}{N} ≡ N$, in an inert solvent.

$$RCO_2H + CH_2N_2 \rightarrow RCO_2CH_3 + N_2$$

This reaction occurs via a two-step mechanism.

- The carboxylic acid reacts with diazomethane to form a carboxylate ion intermediate in the first step.
- N_2 is formed in the second step.

Suggest the mechanism for this reaction. Show any relevant lone pairs, dipoles and charges, and indicate the movement of electron pairs with curly arrows.

[4]

[Total: 15]

END OF PAPER

RIVER VALLEY HIGH SCHOOL
YEAR 6 PRELIMINARY EXAMINATION II

CANDIDATE
NAME

CLASS   6

CENTRE
NUMBER   S

INDEX
NUMBER

H2 CHEMISTRY   9729/03

Paper 3 Free Response   **19 September 2017**

                                                2 hours

Candidates answer on separate paper.

Additional Materials: Answer Paper

                             Cover Page

                             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 sheet of paper.
The use of an approved scientific calculator is expected, where appropriate.
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, with the cover page on top.

This document consists of **XX** printed pages.

Section A
Answer **all** the questions in this section.
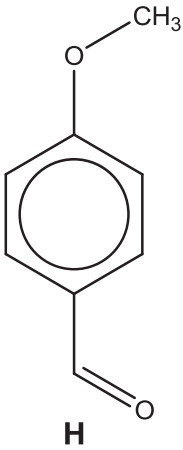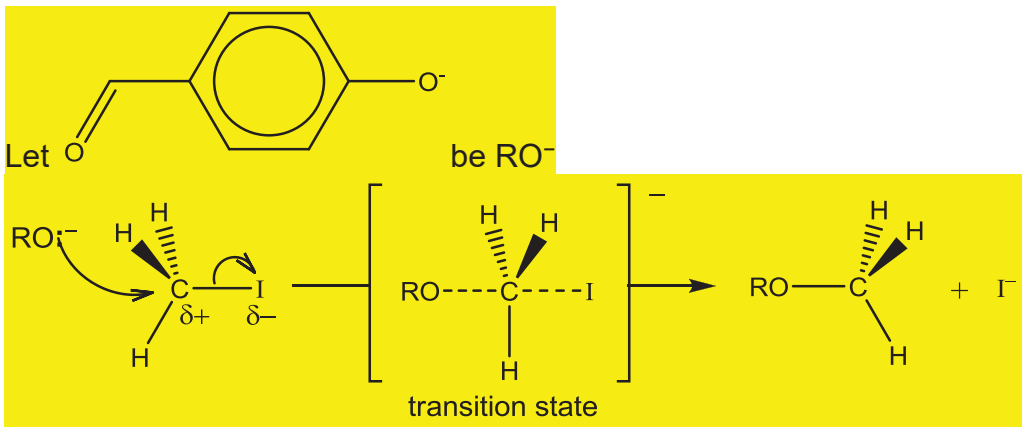
1	(a)		Under suitable conditions, SCl_2 reacts with water to produce a yellow solid and an acidic solution **A**. Solution **A** contains a mixture of $SO_2(aq)$ and another compound.	
		(i)	State the oxidation number of S in SCl_2 .	**[1]**
			+2	
		(ii)	Construct an equation for the reaction between SCl_2 and water.	**[1]**
			$2SCl_2 + 2H_2O \rightarrow S + SO_2 + 4HCl$	
		(iii)	In the Contact Process, one important step is the conversion of SO_2 to SO_3 as shown below. $$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$ A 2.00 L flask was filled with 0.0400 mol SO_2 and 0.0200 mol O_2. At equilibrium, the flask contained 0.0296 mol of SO_3. Determine the value of K_c, stating its unit.	**[3]**

	2SO₂	+	O₂	⇌	2SO₃
I / mol	0.04		0.02		0
C / mol	−0.0296		−0.0148		+0.0296
E / mol	0.0104		0.0052		0.0296

K_c

$$= \frac{[^{0.0296}/_2]^2}{[^{0.0104}/_2]^2[^{0.0052}/_2]}$$

$= 3116$

$= 3120 \text{ mol}^{-1} \text{ dm}^3$

	(b)	During the electrolysis of dilute sulfuric acid using a current of 0.75 A for 90 min and platinum electrodes, the volume of oxygen gas collected was recorded and is shown in the Table 1.1 below.	

Table 1.1

Time / min	Volume of O_2 gas / cm^3
20	55
40	110
60	165
80	220

		(i)	Plot a graph of volume of O_2 gas over time. Use x axis: 2 cm for 10 min ; y axis: 2 cm for 50 cm^3	**[2]**
			See graph paper	
		(ii)	Give equations for the reactions that occur at each electrode in the electrolysis of sulfuric acid.	**[2]**
			Cathode: $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$ Anode: $2H_2O(l) \rightarrow 4H^+(aq) + O_2(g) + 4e^-$	
		(iii)	On the same graph, draw and label a line (H_2) to predict the volume of hydrogen that would be given off during the same experiment.	**[1]**
			See graph paper. Each point is twice the value of graph in (ii).	
		(iv)	On the same graph, draw and label a line (O_2) to predict the volume of oxygen that would be given off if a current of 0.3 A was used instead in the original experiment.	**[1]**
			See graph paper. Each point is (3/7.5) the value of graph in (ii).	
		(v)	In a 2nd experiment, the platinum electrodes were replaced with graphite electrodes. The volume of gas collected at the anode was 150 cm^3 while the volume of hydrogen gas collected was 220 cm^3. The difference in volume of gas collected at the anode between the two experiments was due to production of CO gas at the anode. Calculate the volume of CO gas produced at the anode.	**[2]**
			$C + \frac{1}{2} O_2(g) \longrightarrow CO(g)$ If no reaction with anode, volume of gas is 110 cm^3 Let volume of O_2 reacted to form CO be x $110 - x + 2x = 150$ $x = 40 \ cm^3$	

		$V_{CO} = 2(40) = \textbf{80 cm}^3$	
(c)		About 100 years ago, in a reaction discovered by German chemist Karl Fries, compound **B** was converted into compound **C** when heated with AlCl$_3$. Compound **C** is a structural isomer of **B**. It is insoluble in water but dissolves in aqueous sodium hydroxide. It gives a yellow ppt with alkaline aqueous iodine and a white ppt with aqueous bromine.	
	(i)	Suggest the structure for compound **C**.	**[1]**
		Accept 1,2 and 1,3 isomers.	
		The various reactions of compound **C** can be represented as follows: 	

| | | (ii) | Suggest the structures for **D** to **G**. | | | [4] |

O⁻Na⁺ structure (benzene ring with O⁻Na⁺ at top and carboxylate O=C–O⁻Na⁺ at bottom)	CHI₃	**D** and **E** are interchangeable.
D	**E**	
OH structure (benzene ring with OH at top, Br and Br at 2,6 positions, and C(=O)CH₃ at bottom)	O⁻Na⁺ structure (benzene ring with O⁻Na⁺ at top and C(=O)CH₃ at bottom)	
F	**G**	

Accept 1,2- and 1,3 isomers for all.

Compound **H**, as shown below, is another structural isomer of **B.**

It has a ether functional group whose general formula is R–O–R'.

Compound **H** can be formed via a reaction between a substituted phenoxide ion and an alkyl halide molecule.

H

| | | (iii) | Describe the mechanism when compound **H** is formed as described above. | [3] |

Let $\text{(O=CH–C}_6\text{H}_4\text{–O}^-)$ be RO^-

transition state

[Total: 21]

| **2** | In the late 1940s, Willard Libby developed the radiocarbon dating method for determining the age of an object containing organic material by using the properties of radiocarbon (^{14}C), a radioactive isotope of carbon. The principle of carbon dating is as such: |

During its life, a plant or animal is exchanging carbon with its surroundings, so the carbon it contains will have the same proportion of ^{14}C as the atmosphere. Once it dies, it ceases to acquire ^{14}C, but the ^{14}C within its biological material at that time will continue to decay, and so the ratio of ^{14}C to ^{12}C in its remains will gradually decrease.

Because ^{14}C decays with first order kinetics, the proportion of radiocarbon can be used to determine how long it has been since a given sample stopped exchanging carbon – the older the sample, the less ^{14}C will be left.

	(a)	A sample of carbon dioxide gas (that contained both $^{12}CO_2$ and $^{14}CO_2$) was analysed to determine the proportion of $^{14}CO_2$ found within. Analysis results showed that there is one $^{14}CO_2$ molecule for every 10^{12} CO_2 molecules.	
		(i) Calculate the number of $^{14}CO_2$ molecules in a 10.0 dm^3 carbon dioxide gas sample, measured under s.t.p.	[2]
		Number of moles of CO_2 $= \frac{10}{22.7}$ $= 0.441$ mol Number of $^{14}CO_2$ molecules $= 0.441 \times \frac{6.02 \times 10^{23}}{10^{12}}$ $= 2.65 \times 10^{11}$ molecules	
		(ii) Calculate the mass of $^{14}CO_2$ in the 10.0 dm^3 sample.	[1]
		Mass of $^{14}CO_2 = \frac{2.65 \times 10^{11}}{6.02 \times 10^{23}} \times (14.0 + 16.0 \times 2)$ $= 2.03 \times 10^{-11}$ g	
		(iii) Hence, explain why it would be difficult to determine the proportion of $^{14}CO_2$ by means of mass measurement.	[1]
		The amount/mass of $^{14}CO_2$ is too small to be accurately measured.	
	(b)	To more accurately determine the proportion of ^{14}C in a sample of graphite, the graphite is vaporised and ionised to $C^+(g)$ ions. These ions were then passed through 2 electric plates. Given that H^+ is deflected with an angle of 8.4°, what is the angle of deflection for $^{14}C^+$ ions under the same experimental set-up?	[1]
		$^{14}C^+$ deflected by $\left(\frac{1}{14}\right)(8.4) = 0.60°$	
	(c)	The half-life of ^{14}C is 5730 years. Determine the time that has elapsed for a piece of wood from a dead tree to contain 30.0% of its original ^{14}C.	[2]
		Let the number of half-life be n $\frac{30.0}{100} = \left(\frac{1}{2}\right)^n$ $n = \frac{lg\left(\frac{30.0}{100}\right)}{lg\left(\frac{1}{2}\right)}$ $n = 1.74$ [1] Time taken = 5730 × 1.74 = **9970 years**	
	(d)	The age of crude oil is far older than what could be determined from radiocarbon dating.	

To measure the age of a crude oil sample, a method involving the measurement of the relative amount of oleanane is used instead.
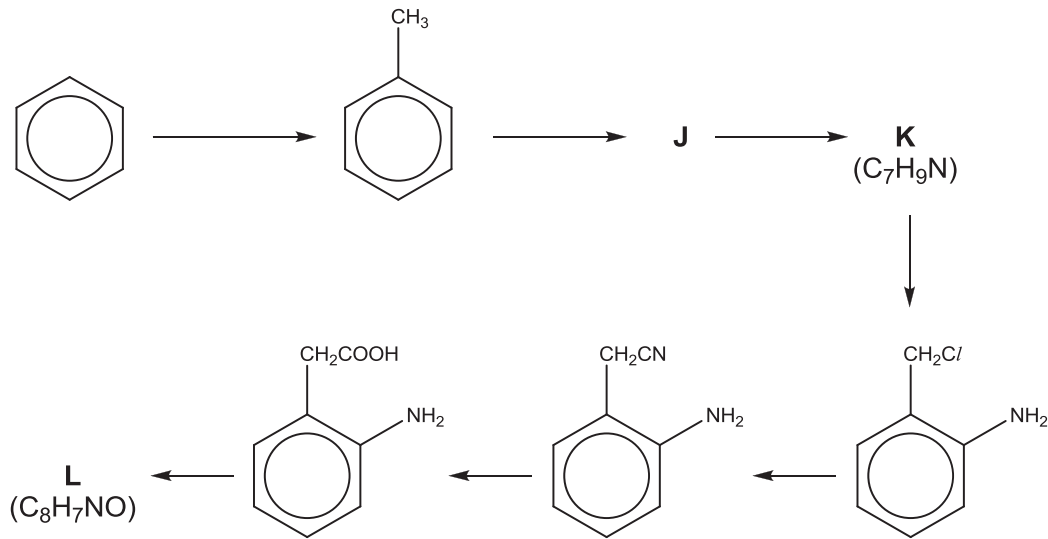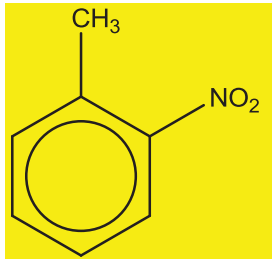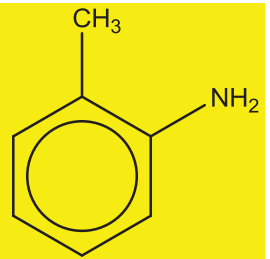
Oleanane

(i)	What is the number of chiral carbons in an oleanane molecule?		**[1]**

8

(ii)	Free radical substitution of oleanane with Cl_2 produces a mixture of various products. Given that tertiary hydrogen atoms are the most reactive towards free radical substitution, suggest the structures of two possible mono-chlorinated oleanane which are formed in high proportions.		**[2]**

	(e)	Benzene is obtained from the fractional distillation of crude oil. It can be converted to a series of different useful chemicals such as phenylamine. The formation of phenylamine involves the direct reaction of nitrobenzene and hydrogen gas in the presence of a heterogeneous catalyst. A series of experiments were carried out at a specific temperature to investigate the kinetics of this reaction:	

Experiment	[nitrobenzene] / mol dm^{-3}	[H$_2$] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.010	0.010	4.50 × 10^{-5}
2	0.015	0.010	6.74 × 10^{-5}
3	0.020	0.020	1.80 × 10^{-4}
4	0.030	x	4.05 × 10^{-4}

	(i)	Define the term *heterogeneous catalyst*.	[2]
		A catalyst is a substance that <u>increases the rate of reaction</u> by providing an <u>alternative reaction pathway of lowered activation energy</u>, and is <u>regenerated at the end of the reaction</u>. A heterogeneous catalyst is one that is <u>not in the same phase</u> as the reactants.	
	(ii)	Determine the order of reaction with respect to nitrobenzene and hydrogen.	[2]
		Comparing experiment 1 and 2, when [nitrobenzene] is increased to 1.5 times, the reaction rate is increased to 1.5 times. Hence, it is first order with respect to nitrobenzene. Let the rate equation be: Rate = k[nitrobenzene][H$_2$]^a Comparing experiment 2 and 3: $\frac{6.74 \times 10^{-5}}{1.80 \times 10^{-4}} = \frac{k(0.015)(0.01)^a}{k(0.02)(0.02)^a}$ $\left(\frac{6.74 \times 10^{-5}}{1.80 \times 10^{-4}}\right)\left(\frac{0.02}{0.015}\right) = \left(\frac{0.01}{0.02}\right)^a$ $a = 1$	
	(iii)	Calculate the rate constant, stating its units.	[1]
		Using experiment 1:	

			$4.50 \times 10^{-5} = k(0.01)(0.01)$ k = 0.450 mol^{-1} dm^3 s^{-1}	
		(iv)	Hence, determine the value of x.	**[1]**
			$4.05 \times 10^{-4} = (0.45)(0.03)x$ $x = 0.0300$ (mol dm^{-3})	
(f)			Benzene is made to undergo a series of reactions as shown:	
		(i)	Suggest the structures of **J** and **K**.	**[2]**
			J: **K:**	
		(ii)	Given that compound **L** is neutral, suggest the reagent used in the final step and the structure of **L**.	**[2]**
			PCl_5 or SOCl_2 Structure of **L:**	

[Total: 20]

3 Chromium is a transition metal commonly found in the earth's crust. It is usually mined as chromite.

Period 4 Element	Ti	V	Cr	Mn	Fe	Co	Ni	Cu
Atomic radius / nm	0.132	0.122	0.117	0.117	0.116	0.116	0.115	0.117

(a) Explain why the atomic radius for transition elements remains relatively constant. **[2]**

Across the transition elements, nuclear charge increases but screening effect also increases due to electrons added to the inner 3d subshell. Therefore, the effective nuclear charge is approximately the same. The attraction between the nucleus and the valence electrons remain about the same. Thus, atomic radius remains almost constant.

(b) (i) Write the electronic configuration for Cr^{3+} ion. **[1]**

Cr^{3+} : $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3$

(ii) Chromium forms octahedral complexes with the general formula $CrCl_3.6H_2O$. One of them dissolves in water to form a violet solution which turned green upon warming. An excess of aqueous silver nitrate was added separately to solutions containing 0.0100 mol of each complex. The violet complex gave 1.50 g of precipitate, while the green complex gave 4.40 g of precipitate.

Deduce the formulae of the two complex ions. **[3]**

Write the equation for the conversion of the violet complex to the green complex.

Amt of chloride from the green complex = 4.40 / 143.5

$= 0.0306$ mol

Ratio of chloride: complex = 3:1

Formula of green complex: $[Cr(H_2O)_6]^{3+}$

Amt of chloride from violet complex = 1.50 / 143.5 = 0.0105 mol

Ratio of chloride : complex = 1:1

Formula of violet complex: $[Cr(H_2O)_4(Cl)_2]^+$

$[Cr(H_2O)_4(Cl)_2]^+(aq) + 2H_2O(l) \rightarrow [Cr(H_2O)_6]^{3+}(aq) + 2Cl^-(l)$

(iii) Using the Cartesian axes, like those shown below,

draw **fully-labelled** diagrams of the following :

- One of the d orbital at the lower energy level in an octahedral complex. Label this diagram "Lower energy level".
- One of the d orbital at the upper energy level in an octahedral complex. Label this diagram "Upper energy level".

[2]

dxz   or   dxy   or

dzy

Lower energy level

dz² or   dx²-y²

Upper energy level

(c) When sodium carbonate is added to a dichromate(VI) solution, the solution turned yellow.

$$Cr_2O_7^{2-}(aq) + 2OH^-(aq) \rightleftharpoons 2CrO_4^{2-}(aq) + H_2O(l)$$

   orange   yellow

Using a relevant equation, explain the above observation.   **[2]**

When Na_2CO_3 is added, the concentration of OH^- increased.

$$CO_3^{2-}(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + OH^-(aq)$$

The equilibrium position will shift to the right to remove some of the added OH^-, changing the solution to yellow.

(d) Ethylenediamine tetraacetate, $[EDTA]^{4-}$, is a ligand that acts as a chelating agent. It is widely used to remove transition metal ions such as those of chromium from aqueous solutions.

A possible reaction scheme used to synthesise $[EDTA]^{4-}$ from methanal is given below.

(i) Suggest the reagents and conditions in steps I, II and III. [3]

Step I : HCN with small amount of NaCN

Step II : PCl$_5$/PCl$_3$/SOCl$_2$

Step III : H$_2$SO$_4$(aq) heat under reflux

(ii) Draw the displayed formulae of intermediates **Q** and **R**. [2]

Q **R**

(iii) State the type of reaction when **T** is converted to [EDTA]$^{4-}$.

Give a reason why a limited amount of 1,2-diaminoethane is used. [2]

Nucleophilic substitution

To enable multiple substitution on the amine group.

(iv) Define the term *ligand*. State the number of coordinate bonds that a [EDTA]$^{4-}$ ligand can form with a central metal ion. [2]

			A ligand is an ion or molecule which contains at least one atom bearing a lone pair of electrons which can be donated into the low-lying vacant orbital of the central metal atom or ion forming a co-ordinate (dative) bond. 6 coordinate bonds.	
				[Total: 19]
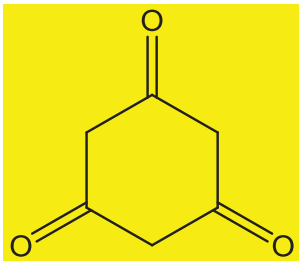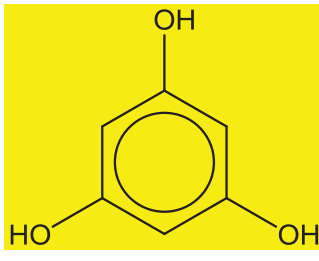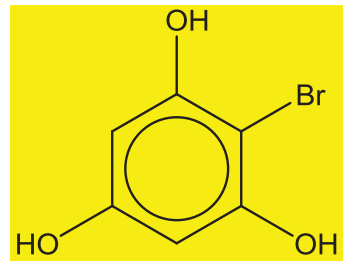
Section B
Answer **one** question from this section.
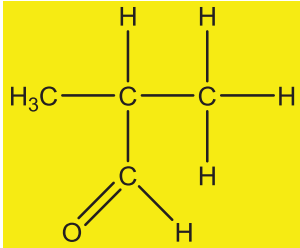
4		This question concerns the chemistry of the oxides of some elements.	
	(a)	The oxides of Period 3 show different reactions with water. Describe the reactions, if any, of the oxides SiO_2 and SO_3 with water. Include the approximate pH value of any resulting solutions, and write equations for any reactions that occur.	**[3]**
		SiO_2 does not react with water/is insoluble in water. Hence, pH remains at 7. SO_3 reacts/hydrolyse with water to give acidic solutions (pH = 2). $SO_3(l) + H_2O(l) \rightarrow H_2SO_4(aq)$	
	(b)	Carbon combusts in oxygen to form two common oxides, CO and CO_2. These oxides are also formed when solid magnesium oxalate, MgC_2O_4, is heated strongly.	

		(i)	Write an equation, with state symbols, to represent the thermal decomposition of solid magnesium oxalate.	[1]
			$MgC_2O_4(s) \rightarrow MgO(s) + CO_2(g) + CO(g)$	
		(ii)	Explain why magnesium oxalate decomposes at a lower temperature than barium oxalate, BaC_2O_4.	[2]
			Mg^{2+} is smaller/has a smaller ionic radius and has a higher charge density, and hence a greater polarising power, than Ba^{2+}. It weakens the bonds in the $C_2O_4^{2-}$ anion to a greater extent and hence MgC_2O_4 is less thermally stable.	

Carbon also forms compounds with other Group 16 elements like sulfur and selenium. The properties of some of these compounds, along with CO_2, are given in Table 4.1.

Table 4.1

Compound	Structure	Dipole moment	Boiling point / °C
CO_2	O=C=O	0	sublimes
CS_2	S=C=S	0	46
COS	S=C=O	0.71	–50
COSe	Se=C=O	0.73	–22

		(iii)	Explain, in terms of structure and bonding, the difference in the boiling point of CS_2 and COS.	[2]
			Both CS_2 and COS have simple molecular structures. CS_2 has a larger number of electrons (or larger electron cloud) than COS. More energy is required to overcome the stronger instantaneous dipole-induced dipole interactions between CS_2 molecules than the permanent dipole-induced dipole interactions between COS molecules. Hence, CS_2 has a higher boiling point.	
		(iv)	Explain why	
			• CO_2 has no overall dipole moment.	
			• COSe has a greater dipole moment than COS.	[2]
			• CO_2 is linear and hence the dipoles cancel out.	
			• C=S bond is more polar than C=Se (since S is more electronegative than Se). There is smaller difference between	

			the dipole moment of C=O and C=S than that between C=O and C=Se.	

(c)		Aside from the common oxides, carbon forms a series of reactive oxocarbons. One such compound is tricarbon monoxide, C_3O, a reactive molecule found in space.	

	(i)	Suggest a structure of tricarbon monoxide. Indicate clearly any lone pairs present.	[1]

:C≡≡C≡≡C≡≡Ö:

Tricarbon monoxide is isoelectronic to cyanogen, $(CN)_2$. The molecule of cyanogen contains a C–C single bond.

	(ii)	Draw the dot-and-cross diagram of cyanogen. In your diagram, you should distinguish the electrons originating from each of the two carbon atoms and those from the two nitrogen atoms.	[1]

:N ⦂ ×ₓ C ×ₓ C ⦂ ×ₓ N ×ₓ

	(iii)	Suggest the shapes of tricarbon monoxide and cyanogen.	[1]

They are both **linear**.

(d)		Another oxycarbon is pentacarbon dioxide, C_5O_2. It can be obtained by heating compound **X**, $C_6H_6O_3$, at a high temperature. **X** exists in equilibrium with its isomer, **Y**.	

X does not react with aqueous bromine. **X** also gives an orange precipitate with 2,4-DNPH but does not give a silver mirror with Tollens' reagent. When reacted with limited bromine under ultraviolet light, **X** produced **only one** mono-brominated compound.

Y reacts with dilute nitric acid to form **only one** mono-nitrated compound, **Z**.

Suggest the structures of compounds **X**, **Y** and **Z**. Explain your reasoning. [7]

Information/Reaction	Deduction
X/Y has C:H ratio of 1:1	X/Y might contain a benzene ring.
X does not undergo electrophilic substitution nor electrophilic addition with $Br_2(aq)$	X does not contain a phenol nor a C=C.
X undergoes condensation with 2,4-DNPH but does not undergo oxidation with Tollens' reagent.	X is a ketone.

	X undergoes free-radical substitution with Br$_2$ to give only one monobromo compound.	X is highly symmetrical.
	Y undergoes electrophilic substitution with HNO$_3$(aq) to give only one mono-nitrated compound.	Y is a phenol. Y is also highly symmetrical.

Structures:

X	Y	Z

[Total: 20]

5	(a)		Hydroformylation is an industrial process for the formation of aldehydes from alkenes.	
			propene butanal	
		(i)	Determine the oxidation numbers of carbon-1, carbon-2 and carbon-4 in butanal.	[1]
			C1: +1 C2: -2 C4: -3	
		(ii)	The hydroformylation of propene can result in the formation of two isomeric products. Given that the mechanism of hydroformylation resembles the electrophilic addition of alkenes, suggest the structure of the other isomer apart from butanal.	[1]

		(iii)	Write the K_p expression for the reaction above, stating its units.	**[1]**
			$K_p = \dfrac{P_{CH_3CH_2CH_2CHO}}{P_{CH_3CH=CH_2} P_{CO} P_{H_2}}$ Units: atm^{-2} / Pa^{-2}	
		(iv)	When an equimolar mixture of propene, CO and H_2 at an initial pressure of 120 atm was allowed to reach equilibrium at 550 K, the partial pressure of butanal was found to be 38.5 atm. Calculate a value of K_p at 550 K.	**[2]**
			C₃H₆ + CO + H₂ ⇌ CH₃CH₂CH₂CHO Initial partial pressure / Pa: 40 40 40 0 Eqm partial pressure / Pa: 40–38.5 = 1.5 40–38.5 = 1.5 40–38.5 = 1.5 38.5 $K_p = \dfrac{38.5}{1.5 \times 1.5 \times 1.5} = 11.4 \; Pa^{-2}$	
		(v)	Hence, predict the sign of ΔG for the reaction. Explain your reasoning taking into account the thermodynamic considerations of the reaction.	**[2]**
			ΔG is negative due to K_p is large (greater than 1) and position of equilibrium lies very much to the right.	
	(b)		Other important use of hydrocarbons include fuels, plastics, paints and solvents. In some countries, where crude oil is either scarce or expensive, biofuels such as ethanol are also increasingly being used for fuels instead of hydrocarbons.	

		(i)	James carried out an experiment to determine the enthalpy change of combustion of octane, C_8H_{18}, using the apparatus shown in the diagram.	
			These are the results that James obtained:	
			Volume of water = 1000 cm^3	
			Initial temperature of water = 29.6 °C	
			Highest temperature of water = 50.0 °C	
			Initial mass of burner and octane = 59.35 g	
			Final mass of burner and octane = 53.77 g	
			Heat capacity of calorimeter = 770 J K^{-1}	
			Use these results and data from the *Data Booklet* to determine the experimental enthalpy change of combustion of octane.	[3]
			Heat evolved = 1000 × 4.18 × 20.4 + 770 × 20.4 = 101000 J	
			Amount of octane reacted = $\frac{59.35 - 53.77}{8 \times 12.0 \ + \ 18 \times 1.0}$ = 4.89 × 10^{-2} mol	
			Enthalpy change of combustion of octane = $- \frac{101000}{4.89 \times 10^{-2}}$	
			= –2060 kJ mol^{-1}	
		(ii)	The accurate experimental enthalpy change of combustion of three hydrocarbons are given in Table 5.1.	

Table 5.1

Alkane	Formula	ΔH_c/ kJ mol^{-1}	
Heptane	C_7H_{16}	–4817	
Octane	C_8H_{18}	–5470	[1]

Nonane	C_9H_{20}	−6125

Suggest what the regular increase in the values of ΔH_c given in the table represents.

The regular increase in the ΔH_c (~650kJ mol^{-1}) is due to the combustion of the $-CH_2-$ group.

(iii) Draw a pair of enantiomers of heptane. **[1]**

(iv) Alkanes are also used in dry cleaning of clothing and textiles. Dry cleaning involves soaking the clothes in a solvent other than water. Recently, the use of supercritical carbon dioxide as a dry cleaning solvent has also been gaining popularity. Supercritical carbon dioxide is a fluid state of carbon dioxide which is maintained at or above its critical temperature.

Suggest two possible reasons why supercritical carbon dioxide is a better solvent than organic solvents like hexane. **[2]**

CO_2 is:

- cheap
- non-flammable
- readily available
- easily vaporised under low pressure/high temperature
- safe/non-toxic.
- odourless

(c) Many modern methods of chemical analysis rely on the use of sophisticated instruments. For many years, scientists relied on traditional laboratory apparatus for chemical analysis.

Many qualitative tests and some volumetric analysis used depended on an application of the principles of solubility product.

Data for use in this question are given in Table 5.2.

Table 5.2

	Colour	Solubility/ mol dm^{-3}	K_{sp} (25 °C)
AgCl	White	1.42×10^{-5}	2.02×10^{-10}
AgI	Yellow	8.95×10^{-9}	8.01×10^{-17}
Ag$_2$CrO$_4$	Red	9.10×10^{-5}	3.01×10^{-12}

(i) Aqueous AgNO$_3$ is added to solutions containing 0.100 mol dm^{-3} Cl^-(aq) or 0.0100 mol dm^{-3} CrO$_4{}^{2-}$(aq). What concentration of Ag$^+$ must be present to cause the precipitation of

I: AgCl

II: Ag$_2$CrO$_4$? **[2]**

I: $[Ag^+] = \dfrac{2.02 \times 10^{-10}}{0.1} = 2.02 \times 10^{-9}$ mol dm^{-3}

II: $[Ag^+] = \sqrt{\dfrac{3.01 \times 10^{-12}}{0.01}} = 1.73 \times 10^{-5}$ mol dm^{-3}

(ii) Standard solutions of silver nitrate can be used in volumetric analysis to determine the concentration of chloride ions in a sample of water. When the titration is carried out, AgNO$_3$(aq) of known concentration is added slowly to the solution that contains Cl^- ions. A small quantity of aqueous potassium chromate(VI), K$_2$CrO$_4$ (0.01 mol dm^{-3}) is also added as an indicator.

Using the data given in Table 5.2 and your answers in **(c)(i)**, predict using calculations what you would see at the beginning of the titration and at the end-point and explain why K$_2$CrO$_4$(aq) can be used as an indicator in this titration. **[4]**

At the beginning, a white ppt AgCl is observed

At the end point, a red ppt of Ag$_2$CrO$_4$ is observed

When all AgCl is precipitated, $[Ag^+] = 1.42 \times 10^{-5}$ when IP of Ag$_2$CrO$_4$ = $[Ag^+]^2[CrO_4{}^{2-}]$ = $(1.42 \times 10^{-5})^2(0.01) = 2.02 \times 10^{-12}$ which is lower than K_{sp} of Ag$_2$CrO$_4$.

So, at the end point, Ag$_2$CrO$_4$ only precipitates when all AgCl has precipitated.

[Total: 20]

- End of Paper -

RIVER VALLEY HIGH SCHOOL

YEAR 6 PRACTICAL EXAMINATION

H2 CHEMISTRY 9729

23RD AUG 2017

2.5 HOURS

NAME _____

CLASS   6 (   )

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 an HB 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.
Qualitative Analysis Notes are printed on pages 14 and 15.

Shift
Laboratory

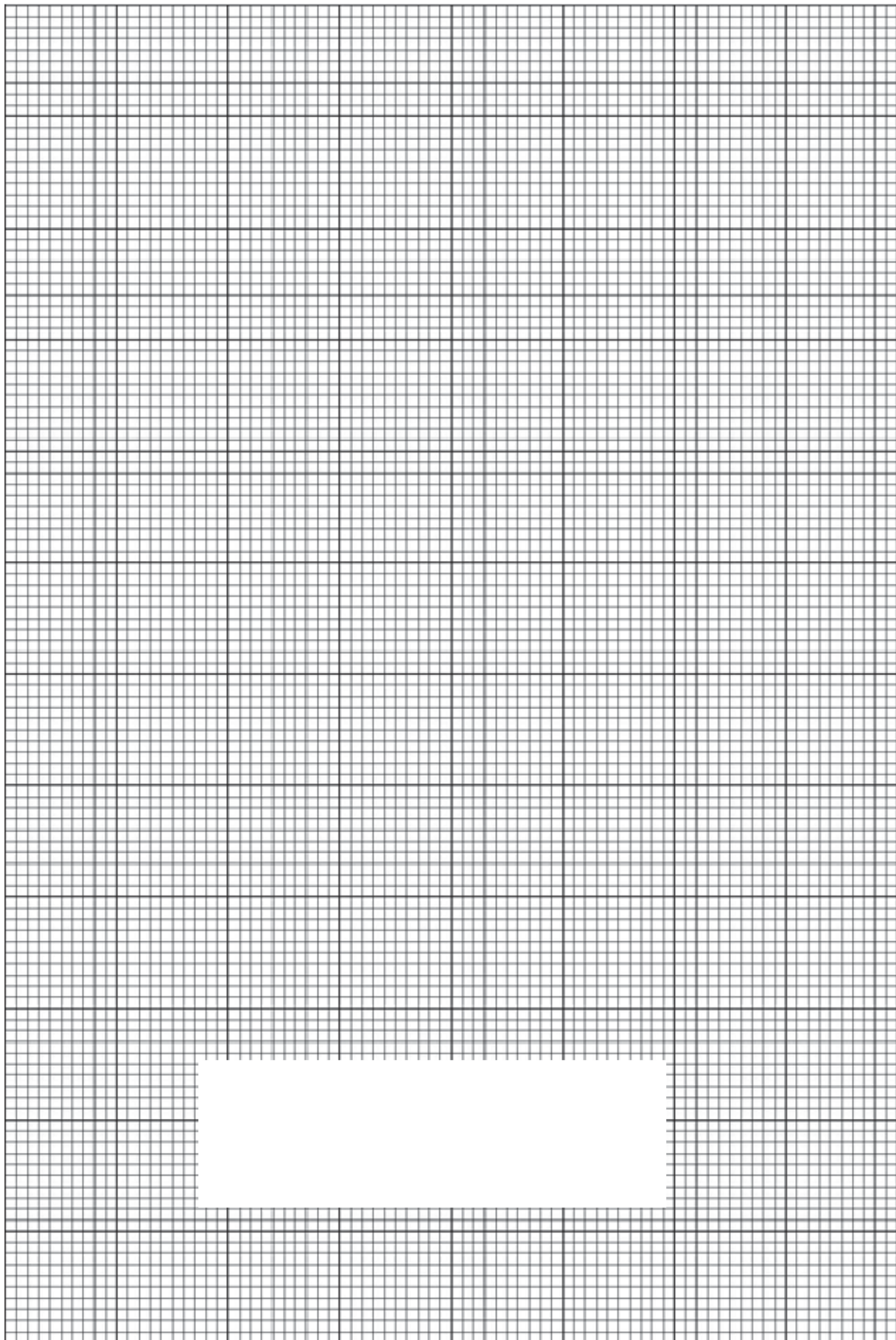| For Examiner's Use	
1	/ 21
2	/ 15
3	/ 9
4	/ 10
Total	/ 55

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

1	**Determine the the percentage by mass of sodium ethanedioate in a mixture of sodium ethanedioate and ethanedioic acid.**

This experiment involves **two steps**.

In step one, you will carry out a titration to find the amount of acid, $H_2C_2O_4$, present in **FB 3**.

In step two, you will carry out a second titration to find the total amount of ethanedioate ion, $C_2O_4^{2-}$, present in **FB 3**.

Finally, you will use the values found in the two steps to calculate the percentage by mass of sodium ethanedioate in **FB 3**.

FB 1 is 0.100 mol dm^{-3} sodium hydroxide, NaOH.

FB 2 is 0.0200 mol dm^{-3} potassium manganate(VII), $KMnO_4$.

FB 3 is a mixture of aqueous sodium ethanedioate, $Na_2C_2O_4$, and ethanedioic acid, $H_2C_2O_4$.

FB 4 is approximately 2 mol dm^{-3} sulfuric acid.

thymolthalein indicator

Read through the whole method before starting any practical work.

(a)   Method

Step 1
1. Fill the burette labelled **FB 1** with **FB 1**.
2. Pipette 25.0 cm^3 of **FB 3** into a conical flask.
3. Add 1 dropper full of thymolphthalein.
4. Titrate **FB 3** in the conical flask with **FB 1** until a pale blue colour is seen.
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 **FB 1** added in each accurate titration.

Step 2
1. Pipette 25.0 cm^3 of **FB 3** into a conical flask.
2. Using a measuring cylinder, add about 25 cm^3 of 2 mol dm^{-3} sulfuric acid, **FB 4**, to the flask.
3. Place the conical flask on a hotplate and heat to about 65°C.
4. Fill the burette labelled **FB 2** with **FB 2**.
5. Use an appropriate method to carefully transfer the hot conical flask onto a white tile under the burette.
6. Titrate the mixture in the conical flask with **FB 2** until a permanent pale pink colour is seen. If a permanent brown colour is seen, stop the titration and begin **Step 2** again.
7. Carry out as many accurate titrations as you think necessary to obtain consistent results.
8. Record in a suitable form below all of your burette readings and the volume of **FB 2** added in each accurate titration.

[3]

(b) (i)   From your titration results in **Step 1**, obtain a suitable value to be used in your calculations. Show clearly how you have obtained this value.

Shift 1	Shift 2	Shift 3
15.20 cm^3	15.20 cm^3	15.20 cm^3

		25.0 cm³ of **FB 3** required ………….. cm³ of **FB 1** [2]
(b) (ii)	Write an equation for the reaction between sodium hydroxide and ethanedioic acid to give sodium ethanedioate and water. $H_2C_2O_4 + 2NaOH \rightarrow Na_2C_2O_4 + 2H_2O$ ………………………………………………………………………………...... [1]	
(b) (iii)	Use your answer from **(b)(i)** to calculate amount of sodium hydroxide, **FB 1**, required to react with 25.0 cm³ of **FB 3** in **Step 1**. (b)(i) × 0.10}/1000 Amount of NaOH = ……………………… [1]	
(b) (iv)	Use your answer to **(b)(iii)** to determine the amount of ethanedioic acid in 25.0 cm³ of **FB 3**. (iii)/2 Amount of $C_2O_4H_2$ in 25.0 cm³ of **FB 3** = …………………… [1]	

(c) (i) From your titration results in **Step 2**, obtain a suitable value to be used in your calculations. Show clearly how you have obtained this value.

Shift 1	Shift 2	Shift 3
22.60 cm³	22.75 cm³	22.60 cm³

25.0 cm³ of **FB 3** required ………….. cm³ of **FB 2**.
[3]

(c) (ii) Use your answer from **(c)(i)** to calculate amount of potassium manganate(VII), **FB 2**, required to react with 25.0 cm³ of **FB 3** in **Step 2**.

(c)(i) × 0.02/1000

Amount of KMnO₄ = ……………………
[1]

(c) (iii) The equation for the reaction between acidified manganate(VII) ions and ethanedioate ions is shown below.

$2MnO_4^- (aq) + 5C_2O_4^{2-} (aq) + 16H^+ (aq) \rightarrow 2Mn^{2+} (aq) + 10CO_2(g) + 8H_2O(l)$

Calculate the total amount of ethanedioate ions in 25.0 cm³ of **FB 3**.

(c)(ii) × 5/2

Total amount of $C_2O_4^{2-}$ in 25.0 cm³ of **FB 3** = ………………
[1]

(c) (iv) Use your answers to **(b)(iv)** and **(c)(iii)** to calculate the amount of ethanedioate ions which came from the sodium ethanedioate dissolved in 25.0 cm³ of **FB 3**.

(c)(iii) – (b)(iv)

		Amount of $C_2O_4^{2-}$ from $C_2O_4Na_2$ in 25.0 cm³ of **FB 3** = ……………… [1]
(d) (i)	Use your answer to **(b)(iv)** to calculate the mass of ethanedioic acid, $H_2C_2O_4$, in 25.0 cm³ of **FB 3**. [*Ar*: H, 1.0; C, 12.0; O, 16.0] (If you were unable to answer **(b)(iv)**, you may assume that the amount of ethanedioic acid is 6.51×10^{-4} mol.) (b)(iv) × 90.0	
	Mass of ethanedioic acid = …………………… [1]	
(d) (ii)	Use your answer to **(c)(iv)** to calculate the mass of sodium ethanedioate, $Na_2C_2O_4$ in 25.0 cm³ of **FB 3**. [*Ar*: C, 12.0; O, 16.0; Na, 23.0] (If you were unable to answer **(c)(iv)**, you may assume that the amount of sodium ethanedioate is 4.13×10^{-4} mol.) (c)(iv) × 134.0	
	Mass of sodium ethanedioate = …………………… [1]	
(d) (iii)	Calculate the percentage by mass of sodium ethanedioate present in **FB 3**. {mass $Na_2C_2O_4$ in (ii)/total mass} × 100 [total mass = (d)(i) + (d)(ii)]	
	Percentage by mass of sodium ethanedioate present is …………………… [1]	
(e) (i)	A student suggested that using a burette to measure the 25.0 cm³ of acid would give a more accurate result than using a pipette. The percentage error of a 25.0 cm³ pipette is 0.24 %. Is the student correct? Explain your answer. [2] Student is incorrect use of burette: {0.10/25} × 100 = 0.40% compared to 0.24% or apparatus error of pipette is ±0.06 compared with apparatus error of burette is ±0.10	
(e) (ii)	A student decided to use a 25.0 cm³ pipette instead of a measuring cylinder to measure the volume of **FB 4** in **Step 2**. State and explain whether this alteration will improve the accuracy of the calculation of the percentage by mass of sodium ethanedioate in the mixture. [2] No improvement as acid in excess	

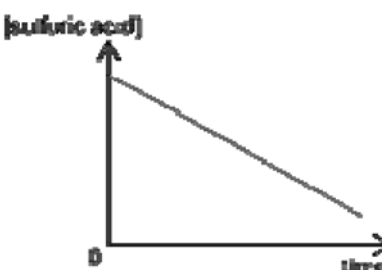| 2	**Investigate how the rate of the following reaction varies with the concentration of sodium thiosulfate, Na₂S₂O₃.**
	$$Na_2S_2O_3\,(aq)\;+\;H_2SO_4\,(aq) \rightarrow S\,(s)\;+\;Na_2SO_4\,(aq)\;+\;SO_2\,(g)\;+\;H_2O\,(l)$$ The rate can be found by measuring how long it takes for the solid sulfur formed to obscure the printing on the insert provided. **Care should be taken to avoid inhalation of SO₂(g) that is given off during this reaction.** **FC 5** is 1.0 mol dm^{-3} sulfuric acid, H_2SO_4 **FC 6** is 0.10 mol dm^{-3} sodium thiosulfate $Na_2S_2O_3$ **(a) Method** 1. Using the 50 cm³ measuring cylinder transfer 45 cm³ of **FC 6** into a 100 cm³ beaker. 2. Using the 25 cm³ measuring cylinder measure 10 cm³ of **FC 5**. 3. Tip the **FC 5** into the **FC 6** in the beaker and **immediately** start timing. 4. Stir the mixture once with a glass rod and place the beaker on top of the printed insert. Cover the beaker with a petri dish. 5. View the printed insert from above so that it is seen through the mixture. 6. Record the time, to the nearest second, when the printing on the insert **just** disappears. 7. Empty and rinse the beaker. Shake out as much of the water as possible and dry the outside of the beaker. You will repeat the experiment to find out how the time for the printing on the insert to disappear changes when a different volume of **FC 6** is used. 8. Using the 50 cm³ measuring cylinder transfer 20 cm³ of **FC 6** and 25 cm³ of distilled water into the 100 cm³ beaker. 9. Using the 25 cm³ measuring cylinder, add 10 cm³ of **FC 5** to the mixture and **immediately** start timing. 10. Stir the mixture once with a glass rod and place it on top of the printed insert. 11. View the printed insert from above so that it is seen through the mixture. 12. Record the time, to the nearest second, when the printing on the insert **just** disappears. 13. Select suitable volumes of **FC 6 and** distilled water for **two** further experiments to investigate the effect of volume of sodium thiosulfate on the time taken for the printing on the insert to **just** disappear. The volume of **FC 6** used should range from 0 cm³ to 45 cm³. In the space below, record, in an appropriate form, all measurements of volume, time, and 1/time. [5]
(b)	Plot 1/time against the volume of **FC 6**. Draw the most appropriate line, taking into account all the points.

[3]

(c) Why was the total volume of solution kept constant in the experiments? [

		Volume of FC 6 is directly proportional to its concentration (if total volume is constant)
(d)		Using the graph of 1/time against the volume of **FC 6,** draw a conclusion about the relationship between the concentration of sodium thiosulfate used and the rate of reaction. Hence, state the order of reaction with respect to sodium thiosulfate. [2] Rate of reaction is proportional to concentration of FC 6 (allow directly proportional). Order of reaction is 1.
(e)		In the four experiments, which value of the time measured had the greatest error? Explain your answer. [2] Either shortest time as greatest percentage/ fractional error or longest time as greatest uncertainty in judging when printing is obscured
(f)		Another student conducts another experiment for the same reaction where the sodium thiosulfate is in large excess. The concentration of acid is monitored as the reaction progresses. His results are as shown below. Deduce the order of reaction with respect to sulfuric acid. [2] The constant gradient indicates a constant rate of reaction. Zero order with respect to sulfuric acid
		[Total: 13]

3   **Organic Analysis**

Before starting parts (a) and (b), half-fill a 250 cm³ beaker with water and heat with a hotplate to approximately 60 °C. You will use this as a hot water bath.

(a)   **FD 7**, **FD 8** and **FD 9** are solutions each containing a single compound which could be ethanol, ethanal or propanone. To identify each compound you will react the samples with Tollens' reagent and with acidified potassium manganate(VII).

Preparation of Tollens' reagent
1.   To approximately 2 cm depth of aqueous silver nitrate in a boiling tube, add approximately 0.5 cm depth of aqueous sodium hydroxide.

2. Add aqueous ammonia a little at a time with continuous shaking until the brown precipitate just dissolves. Do not add an excess of ammonia.

Complete the table below

test	observations		
	FD 7	**FD 8**	**FD 9**
To a 1 cm depth of each solution in a clean, dry test-tube add a few drops of the Tollens' reagent that you have prepared. **Do not shake the tube**. If no reaction is seen, warm the tube in the hot water bath.	silver mirror/black or brown or grey ppt	No ppt	No ppt
To a 1 cm depth of each solution in a test-tube, add a 1 cm depth of dilute sulfuric acid. Then add a few drops of aqueous potassium manganate(VII). If no reaction is seen, warm the tube in the hot water bath.	Purple $KMnO_4$ turns colourless/ decolourised	Purple $KMnO_4$ remains purple	Purple $KMnO_4$ turns colourless/ decolourised
Identity	ethanal	propanone	ethanol

[4]

(b) **FD 10** is an aqueous solution of an organic compound. Carry out the following tests. You do not need to identify **FD 10**.

test	observations
To a 1 cm depth of **FD 10** in a test-tube add a 1 cm depth of dilute sulfuric acid. Then add a few drops of aqueous potassium manganate(VII). If no reaction is seen, place the test-tube in the hot water bath and leave to stand.	Purple $KMnO_4$ turns colourless/ decolourises
To a 1 cm depth of **FD 10** in a test-tube, carefully add a small spatula measure of sodium hydrogen carbonate.	Effervescence/fizzing/bubbles Colourless, odourless gas evolved that gives a white ppt with limewater

[2]

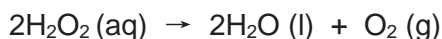| **(c)** | State the type(s) of reactions that **FD 10** have undergone in **(b)**. | [2] |

	Oxidation	
	Acid-carbonate	
(d)	Given that the Mr of **FD 10** is 46.0. State its identity. [Ar: C, 12.0; O, 16.0; H, 1.0; C*l*, 35.5; N, 14.0]	[1]
	HCOOH	

[Total: 9]

4   Planning

When heated, aqueous hydrogen peroxide, H_2O_2, decomposes to form oxygen and water.

$$2H_2O_2 \, (aq) \; \rightarrow \; 2H_2O \, (l) \; + \; O_2 \, (g)$$

The decomposition can also occur at room temperature if a suitable catalyst is added. Both of the solids, manganese(IV) oxide and lead(IV) oxide, will catalyse the decomposition.

You are provided with:
- 0.150 mol dm^{-3} solution of hydrogen peroxide
- a syringe with a capacity of 100 cm^3
- apparatus normally found in a school laboratory

(a)   (i)   Using the information given above, you are required to write a plan to determine the more efficient catalyst for the decomposition of aqueous hydrogen peroxide. Your plan should include:

- a fully labelled diagram of the apparatus to be used

- a calculation of the volume in cm^3 of the aqueous hydrogen peroxide that could be used such that an appropriate volume of oxygen could be collected.

- the measurements you would take and how you would use them to deduce which catalyst is more efficient.

The molar volume of a gas at 20 °C is 24.0 dm^3.

- Diagram shows a container with both chemicals named and attached to a syringe connected without leaks.
- Container shows the catalyst and hydrogen peroxide separated and ready to mix.
- Rubber bung
- Well-greased 100 cm^3 syringe (labelled)
- 250 cm^3 conical flask (labelled)
- Delivery tube

At least half the capacity of syringe for M4
Amt of oxygen in 100 cm^3 of oxygen = 100/24000 = 0.00417 mol
Amt of H_2O_2 = 2 × 0.00417 = 0.00834 mol
Volume of hydrogen peroxide = (0.00834 × 1000)/0.15 = 55.6 cm^3

1.   Measure 55.0 cm^3 of aqueous hydrogen peroxide into a 250 cm^3 conical flask using a 100 cm^3 measuring cylinder.

2.   Weigh accurately 0.10 g (acceptable range: 0.1 to 1 g) of solid manganese(IV)

oxide into a plastic vial using the weighing balance.

3. Setup the experiment as shown in the diagram above.

4. Shake the conical flask to topple the solid into the aqueous hydrogen peroxide and start the stopwatch.

5. Record the time taken when 90 cm^3 (at least half the capacity of the collecting vessel) of gas is collected (when solid manganese(IV) oxide is used.)

6. Repeat the above steps using lead(IV) oxide instead.

7. The more efficient catalyst is the solid that requires the shorter time to collect 90.0 cm^3 of gas.

Alternative method:

- Record volume of gas in time intervals of less than 1 min and plot graphs

[9]

(ii) What other feature of the catalyst should be controlled?

Surface area

[1]

[Total : 10]

~END OF PAPER~