Write your name here

Surname	Other names

Pearson Edexcel Level 3 GCE

Centre Number	Candidate Number

Chemistry

Advanced

Paper 3: General and Practical Principles in Chemistry

Tuesday 27 June 2017 – Morning

Time: 2 hours 30 minutes

Paper Reference **9CH0/03**

Candidates must have: Data Booklet
Scientific calculator
Ruler

Total Marks

Instructions

- Use **black** ink or **black** ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided – *there may be more space than you need.*

Information

- The total mark for this paper is 120.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- For the question marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically showing the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.
- Show all your working in calculations and include units where appropriate.

Turn over ▶

Pearson

Answer ALL questions.

Write your answers in the spaces provided.

1 This question is about transition metal chemistry.

(a) The **amphoteric** character of solid chromium(III) hydroxide is shown by the fact that it reacts separately with both dilute hydrochloric acid and dilute sodium hydroxide solution.

(i) Write an **ionic** equation for the reaction of solid chromium(III) hydroxide with dilute hydrochloric acid, showing the formula of the complex ion formed. Include state symbols in your answer.

(2)

(ii) Describe the changes you would **see** when the reaction in (a)(i) is carried out.

(2)

(iii) Write an **ionic** equation for the reaction of solid chromium(III) hydroxide with dilute sodium hydroxide solution, showing the formula of the complex ion formed. Include state symbols in your answer.

(2)

(iv) State the final appearance of the reaction mixture in (a)(iii).

(1)

(b) Dilute aqueous ammonia is added, drop by drop, to an aqueous solution of copper(II) sulfate until the aqueous ammonia is in excess.

(i) Describe what you would **see** during this experiment.

(2)

(ii) The reaction between aqueous copper(II) sulfate and **excess** aqueous ammonia is an example of a **ligand substitution** reaction.

Write an equation for the ligand substitution reaction that occurs, showing the formulae of the complex ions involved. State symbols are not required.

(2)

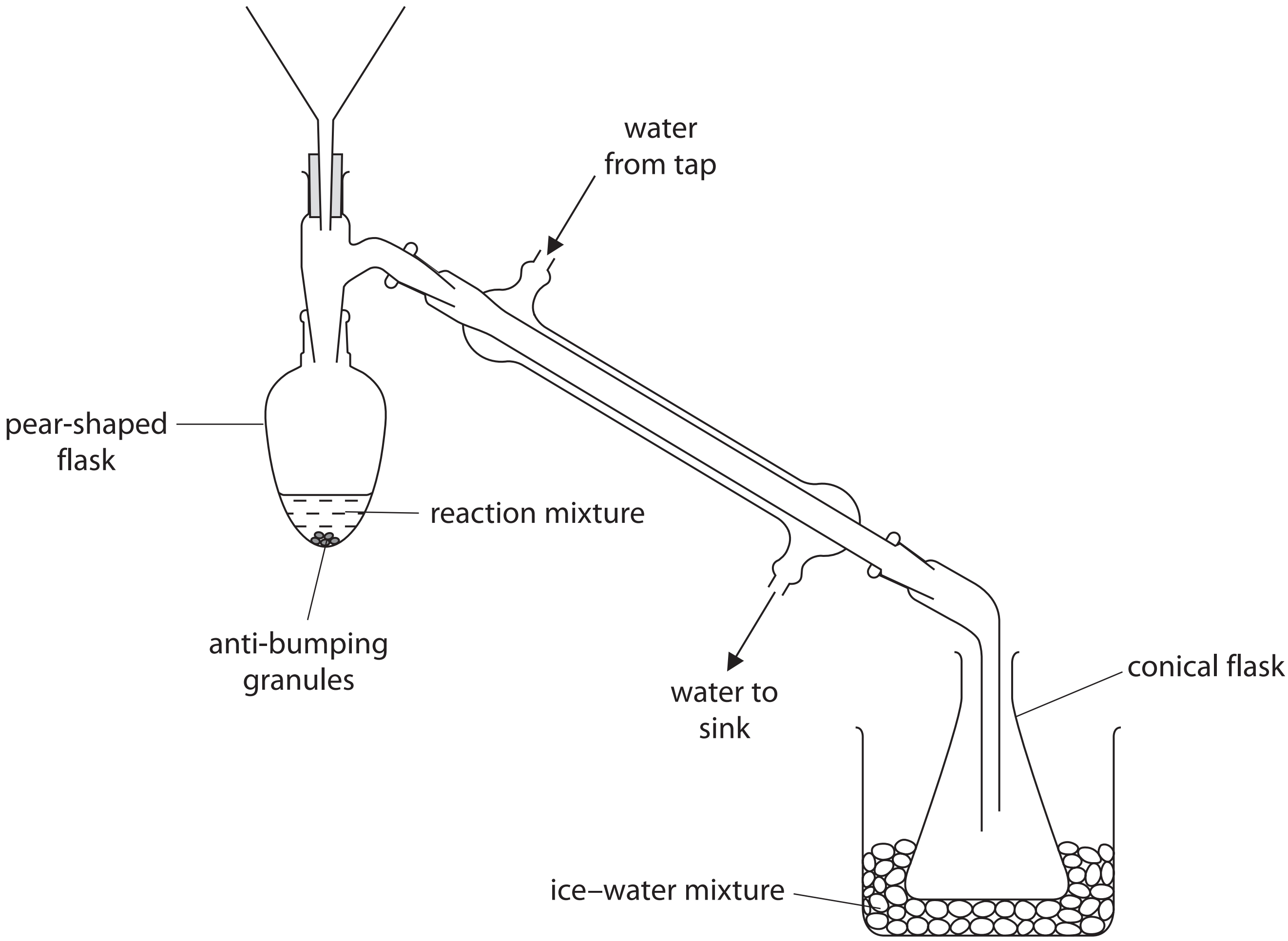
(Total for Question 1 = 11 marks)

2 This question is about the preparation of a sample of the ketone, 3-methylbutan-2-one.

A student's research suggested that 3-methylbutan-2-one may be prepared by oxidising 3-methylbutan-2-ol with acidified potassium dichromate(VI) solution.

The student sets up the apparatus as shown in the diagram. You may assume that all the equipment is suitably clamped.

The student adds dilute sulfuric acid to the pear-shaped flask. A mixture of potassium dichromate(VI) and 3-methylbutan-2-ol is then added slowly to the dilute sulfuric acid in the flask.



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(a) Identify the **two** changes that must be made to the apparatus before heating the pear-shaped flask, giving a reason for each change.

(4)

(b) Draw the **skeletal** formulae for 3-methylbutan-2-ol and 3-methylbutan-2-one.

(2)

3-methylbutan-2-ol

3-methylbutan-2-one

(c) Once the essential changes are made to the apparatus, the pear-shaped flask is heated. The distillate formed is collected in the conical flask.

On testing the distillate with pH paper, it is found that its pH is 2.
The student suggests that this pH is due to the formation of 3-methylbutanoic acid.

(i) Give a reason why 3-methylbutanoic acid cannot be formed in the reaction.

(1)

(ii) Deduce the **formula** of the compound that could cause the distillate to have a pH value of 2.

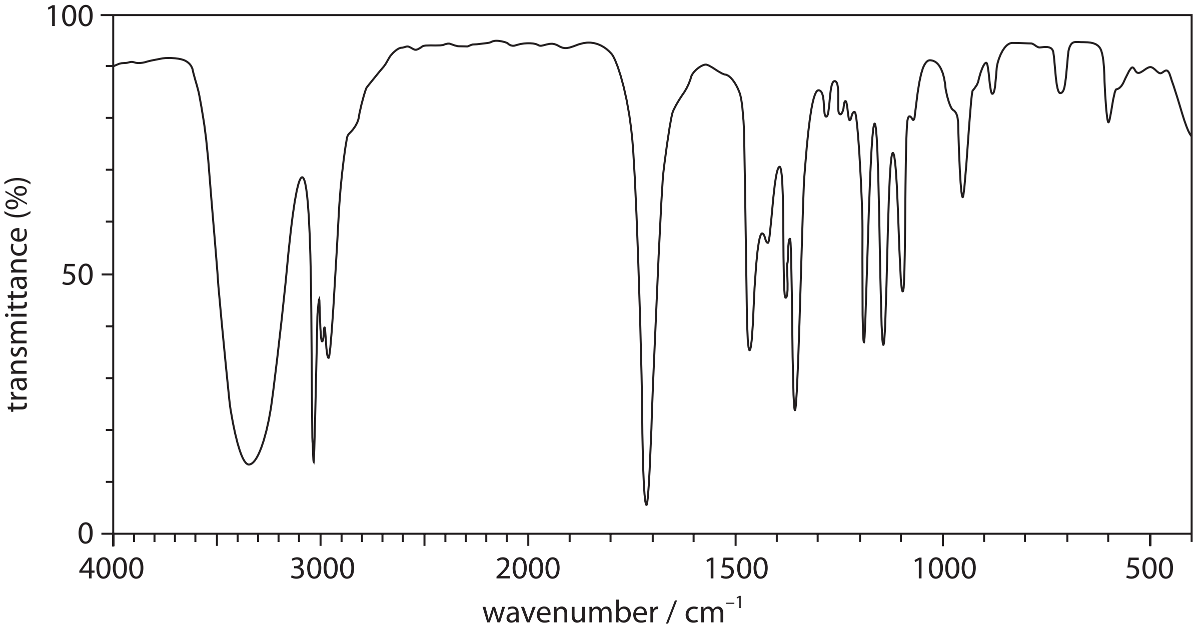
(1)

(iii) Solid sodium carbonate is added to the distillate. The sodium carbonate disappears and fizzing occurs.

Write an equation, including state symbols, for the reaction that occurs between sodium carbonate and the compound you have identified in (c)(ii).

(2)

(d) The organic mixture was separated from the aqueous layer and dried. The infrared spectrum of the organic mixture is shown.



(i) By reference to any relevant peak(s), deduce how the infrared spectrum shows that the mixture contains 3-methylbutan-2-one.

(2)

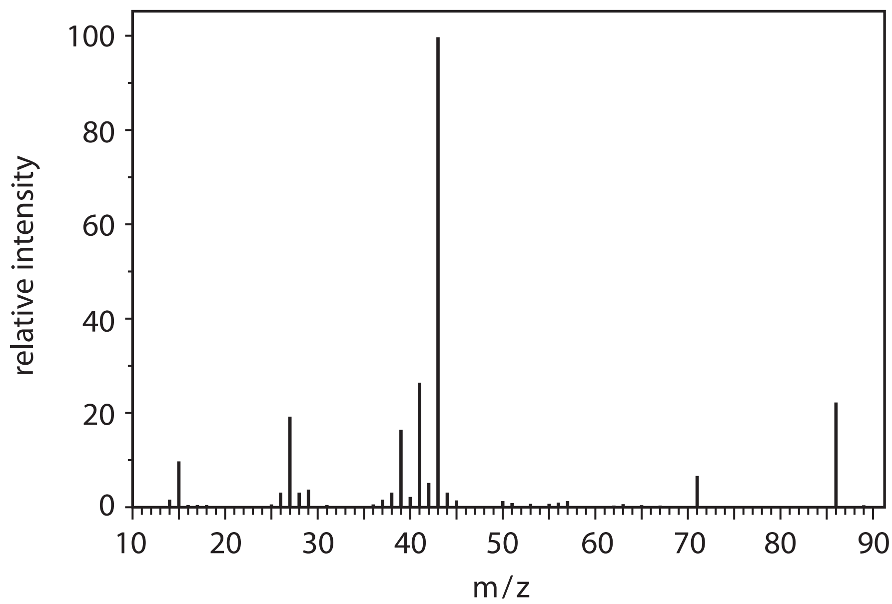
(ii) From the infrared spectrum, the student concludes that the mixture contains another organic compound.

The mixture is redistilled and the fraction that boils in the range 93–95 °C is collected. The boiling temperature of 3-methylbutan-2-one is 94 °C.

Predict any change(s) you would see in the infrared spectrum after redistillation, justifying your answer.

(2)

(e) The mass spectrum of pure 3-methylbutan-2-one is shown.



(i) State how you would find the molar mass of 3-methylbutan-2-one from the mass spectrum.

(1)

(ii) The mass spectrum shows a peak at m/z = 43.

Draw the **displayed** formulae of two fragment **ions** that might be responsible for this peak.

(2)

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(f) The sample of purified 3-methylbutan-2-one is found to have a mass of 2.15 g.
This mass of 3-methylbutan-2-one represents a yield of 62.5% by mass.

(i) Write an equation, using **molecular** formulae, for the oxidation of 3-methylbutan-2-ol to 3-methylbutan-2-one.
Use [O] to represent the oxidising agent.

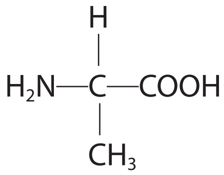
(2)

(ii) Calculate the mass of 3-methylbutan-2-ol that the student uses at the start of the preparation.

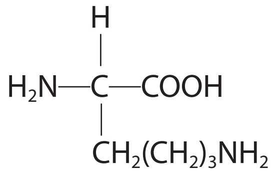
(2)

(Total for Question 2 = 21 marks)

3 Alanine and lysine are amino acids.



alanine



lysine

(a) Give the systematic (IUPAC) name for **lysine**.

(1)

(b) Draw the **structure** of the organic product formed when **lysine** reacts with the following reagents:

(3)

aqueous sodium hydroxide, NaOH(aq)

excess dilute hydrochloric acid, HCl(aq)

methanol, with warming, in the presence of a few drops of concentrated sulfuric acid.

(c) Draw the structure of a dipeptide formed when one molecule of alanine reacts with one molecule of lysine.

(1)

(d) The dipeptide formed in part (c) is hydrolysed under **acidic** conditions and the resulting mixture is analysed by column chromatography. The column uses a polar stationary phase.

Explain why lysine leaves the chromatography column after alanine.

(2)

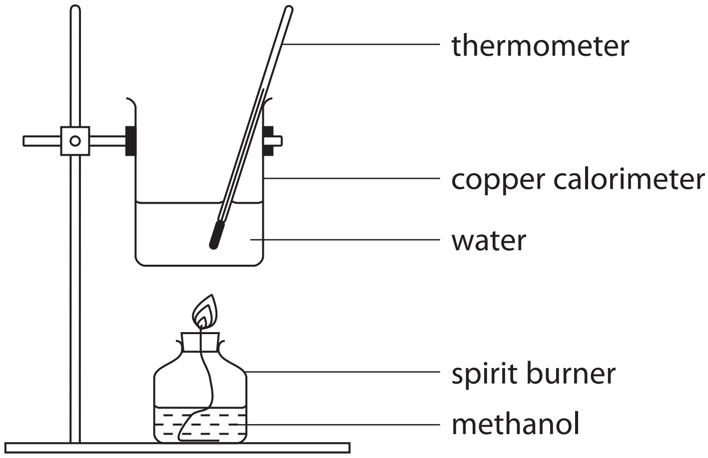
(Total for Question 3 = 7 marks)

4 This question is about the enthalpy change of combustion of methanol.

A teacher asked two students to carry out a practical task to determine the enthalpy change of combustion of methanol.
Both students were provided with the same apparatus and chemicals.
The following procedure was provided for the students.

Procedure

- Measure out 150 cm^3 of distilled water, using a 250 cm^3 measuring cylinder.
- Transfer the water to a copper calorimeter and note the initial temperature of the water (to the nearest 0.5 °C) in **Table 1**.
- Weigh the spirit burner containing methanol and record its mass in **Table 1**.
- Place the spirit burner under the copper calorimeter, as shown in the diagram.
- Ignite the spirit burner and burn the methanol, whilst stirring the water with the thermometer.
- After heating the water for three minutes, extinguish the flame and immediately record the **highest** temperature reached by the water.
- As soon as possible, reweigh the spirit burner containing the methanol and record its mass in **Table 1**.



The results of Student 1 are recorded in **Table 1**.

Mass of spirit burner plus methanol before burning / g	213.47
Mass of spirit burner plus methanol after burning / g	211.87
Mass of methanol burned / g	
Highest temperature of the water / °C	64.5
Initial temperature of the water / °C	22.0
Temperature change of the water / °C	

Table 1

(a) Complete **Table 1**, giving the values to an appropriate number of decimal places.

(2)

(b) Write the equation that represents the reaction that occurs when the standard enthalpy change of combustion of methanol, $CH_3OH(l)$, is measured. Include state symbols.

(2)

(c) Use Student 1's result to calculate the enthalpy change of combustion of methanol in kJ mol^{-1}.
Give your answer to an appropriate number of significant figures.

Specific heat capacity of water = 4.18 J g^{-1} °C^{-1}
Density of water = 1.00 g cm^{-3}

(4)

(d) Student 1 compared the experimental value for the enthalpy change of combustion of methanol obtained in part (c) with the standard value given on the internet. The student's value was **less exothermic** than the standard value.

Student 1 decided to evaluate the uncertainty in the measurements made in this experiment.

(i) Student 1 used a 250 cm^3 measuring cylinder to measure the volume of 150 cm^3 distilled water. The uncertainty in this volume measurement is ± 1 cm^3.

Calculate the percentage uncertainty in the volume of distilled water that Student 1 measured in the experiment.

(1)

(ii) Compare and contrast the use of a 250 cm^3 measuring cylinder to measure out the 150 cm^3 distilled water with the use of a 25 cm^3 measuring cylinder (uncertainty ± 0.2 cm^3 for each volume measurement) six times to measure the same volume.

(3)

(iii) Student 1 calculated the uncertainties in the remaining measurements. However, Student 1 realised that the measurement uncertainties did **not** explain the difference between the experimental value for the enthalpy change of combustion of methanol calculated in part (c) and the value obtained from the internet.

Other than human error, give **three** reasons for the difference in the values.

(3)

(e) Student 1 decided to repeat the experiment.

Student 1 used the copper calorimeter and water from the first experiment and recorded the initial temperature as 60.0 °C.
Student 1 burned **exactly** the same mass of methanol as in the first experiment.

Explain, with a reason, how the value for the enthalpy change of combustion of methanol from this experiment would differ, if at all, from the value obtained in the first experiment.

(2)

(f) Student 2 followed the **original** instructions provided, but extinguished the flame after **four** minutes rather than after three minutes.

Explain how the value calculated by Student 2 for the enthalpy change of combustion of methanol compared with that obtained in Student 1's first experiment.

(2)

(g) Another student, Student 3, used the results from Student 1's first experiment to find the enthalpy change of combustion of methanol. Student 3 incorrectly used a value of 46.0 g mol^{-1} for the molar mass of methanol.

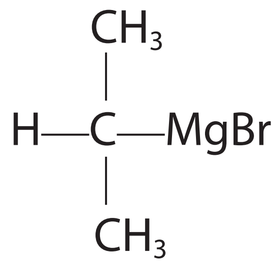
State and justify how this mistake would affect the calculated value for the enthalpy change of combustion of methanol.

(2)

(Total for Question 4 = 21 marks)

5 Grignard reagents are used in organic synthesis as a way of increasing the length of the carbon chain in a molecule.

(a) The structure of the Grignard reagent formed by the reaction between 2-bromopropane and magnesium is



On the diagram, draw the permanent dipole involving the central carbon atom.

(1)

(b) The Grignard reagent in part (a) reacts with propanal.

(i) Draw the **fully displayed** formula of the final organic product of this reaction.

(1)

(ii) Name the organic product in (b)(i).

(1)

(c) Identify, by using ticks, **two** boxes in the table to select appropriate terms that describe a Grignard reagent.

(2)

acid	
electrophile	
nucleophile	
oxidising agent	
reducing agent	

(d) The solvent used for Grignard reagents has to be completely **dry**.

By considering the dipole on the O—H bonds in water, predict the identity of the organic product that forms if water is added to the Grignard compound in part (a).

(1)

(Total for Question 5 = 6 marks)

6 A student carried out an investigation to determine the value of $\boldsymbol{x}$ in hydrated magnesium nitrate(III), $Mg(NO_2)_2{\bullet}\boldsymbol{x}H_2O$, using three different methods.

Method 1

- The student prepared an aqueous solution by dissolving 1.15 g of $Mg(NO_2)_2{\bullet}\boldsymbol{x}H_2O$ in distilled water, making up the solution to 250.0 cm^3 in a volumetric flask and shaking the mixture.
- The student titrated this solution against 25.0 cm^3 portions of an acidified solution of 0.0200 mol dm^{-3} potassium manganate(VII), $KMnO_4$(aq).

Method 2

- The student mixed a solution of $Mg(NO_2)_2{\bullet}\boldsymbol{x}H_2O$ with an excess of aqueous sodium carbonate solution, Na_2CO_3(aq).
- The student obtained a precipitate of magnesium carbonate, $MgCO_3$(s), and determined the mass of this precipitate.

Method 3

- The student heated a known mass of $Mg(NO_2)_2{\bullet}\boldsymbol{x}H_2O$(s).
- The student determined the mass of the anhydrous residue formed.

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Method 1 – Titration

The student filled the burette with the solution made from $Mg(NO_2)_2 \cdot \boldsymbol{x}H_2O$.

In each titration

- 25.0 cm^3 of 0.0200 mol dm^{-3} $KMnO_4$(aq) was transferred to a conical flask using a pipette.
- An excess of dilute sulfuric acid was added to the conical flask and the mixture heated.
- $Mg(NO_2)_2$(aq) was added from the burette until the end-point was reached.

The student's titration results are shown in the table (the rough titration results have **not** been included in the table).

Titration number	**1**	**2**	**3**
Final burette reading / cm^3	23.95	48.05	23.85
Initial burette reading / cm^3	0.80	24.50	0.65
Titre / cm^3			
Concordant titres (✓)	☐	☐	☐
Mean titre / cm^3			

(a) Complete the table.

(2)

(b) Deduce the colour change that the student would see at the end-point in this titration.

(1)

From .... to ....

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(c) In the titration reaction, 2 mol MnO_4^- react with 5 mol NO_2^-.
Calculate the number of moles of NO_2^-, in the 250 cm^3 of solution prepared by the student and hence the value of ***x*** in $Mg(NO_2)_2 \cdot \boldsymbol{x}H_2O$.
Give your answer to the nearest whole number.

(5)

(d) The half-equations for the reaction in the titration are

$$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$$

$$NO_2^- + H_2O \rightarrow NO_3^- + 2H^+ + 2e^-$$

Use these half-equations to derive the overall ionic equation for the reaction between manganate(VII) and nitrate(III) ions in acidic conditions.
State symbols are not required.

(2)

Method 2 – Precipitation

The student used the following procedure.

- Dissolve a known mass of $Mg(NO_2)_2 \cdot \boldsymbol{x}H_2O$ in distilled water.
- Add an excess of aqueous sodium carbonate solution, $Na_2CO_3(aq)$, to obtain a precipitate of magnesium carbonate, $MgCO_3(s)$.

$$Mg^{2+}(aq) + CO_3^{2-}(aq) \rightarrow MgCO_3(s)$$

- Weigh a piece of filter paper.
- Filter the mixture from the above reaction through the pre-weighed filter paper.
- Wash the precipitate of $MgCO_3(s)$ with distilled water.
- Dry the filter paper and precipitate in a desiccator.
- Reweigh the filter paper and the precipitate.
- Calculate the value of ***x*** from the results obtained.

The student found that the value of ***x*** calculated using **Method 2** was different from that obtained using **Method 1**. This difference occurred despite having used a pure sample of the hydrated salt and without making any errors in technique during the experiment.

The student found out from a data book that the compound magnesium carbonate is very slightly soluble in water.

(e) Explain how, if at all, the very slight solubility of magnesium carbonate in water would affect the value calculated for ***x***.

(2)

(f) The student planned to obtain any dissolved magnesium carbonate by evaporating the filtrate, and then weighing the residue.

Criticise this student's plan.

(2)

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Method 3 – Thermal decomposition

NOTE: On heating, $Mg(NO_2)_2 \cdot \boldsymbol{x}H_2O(s)$ loses its water of crystallisation and **then** undergoes further decomposition to give magnesium oxide, MgO.

The student used the following procedure.

- Weigh an empty crucible.
- Add some $Mg(NO_2)_2 \cdot \boldsymbol{x}H_2O(s)$ and then reweigh the crucible plus contents.
- Heat the crucible plus contents and allow to cool.
- Weigh the crucible plus magnesium oxide residue.
- Use these data to calculate a value for ***x***.

The student's results are shown in the table.

Mass of crucible / g	18.02
Mass of crucible + $Mg(NO_2)_2 \cdot \boldsymbol{x}H_2O$ / g	18.84
Mass of crucible + MgO residue / g	18.27

(g) Identify how the student should ensure that the hydrated salt was fully decomposed.

(1)

(h) The student carried out an evaluation of the results obtained from **Method 3**

Identify **two** modifications to the method that would enable the student to lower the percentage uncertainty in the measurement of the mass of the solid residue.

(2)

(Total for Question 6 = 17 marks)

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7 This question is about the chemistry of elements in the *d*-block of the Periodic Table.

*(a) Many of the *d*-block elements are also classified as transition metals.

Explain why two of the *d*-block elements within Period 4 (scandium to zinc) are **not** classified as transition metals.

You should include **full** electronic configurations where relevant.

(6)

(b) Under certain conditions, dichromate(VI) ions, $Cr_2O_7^{2-}$, can oxidise manganese(II) ions, Mn^{2+}.

In this reaction, dichromate(VI) ions are reduced to chromium(III) ions, in acidic conditions, according to the half-equation

$$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightleftharpoons 2Cr^{3+}(aq) + 7H_2O(l)$$

In an experiment it was found that 20.0 cm^3 of 0.100 mol dm^{-3} potassium dichromate(VI) was required to oxidise 30.0 cm^3 of 0.200 mol dm^{-3} manganese(II) sulfate solution.

Use these data to calculate the final oxidation state of the manganese.

(5)

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(c) A student constructed an electrochemical cell as follows:

- a half-cell was made from a strip of chromium metal and a solution of aqueous chromium(III) sulfate
- a second half-cell was made from a piece of metal, **X**, and a solution of its sulfate, **X**SO_4(aq)
- the two half-cells were connected and a current allowed to pass for some time.

Results

- the chromium electrode increased in mass by 1.456 g
- the electrode made of metal **X** decreased in mass by 1.021 g.

Use these data to determine the identity of the metal, **X**.

(4)

(Total for Question 7 = 15 marks)

8 The chemistry of organic compounds containing a chlorine atom is affected by the presence of other groups.

Consider the reaction of ammonia, NH_3, with $CH_3CH_2CH_2Cl$ and with CH_3CH_2COCl.

(a) Draw the mechanism for the reaction of $CH_3CH_2CH_2Cl$ with an **excess** of ammonia to form the primary amine. Include curly arrows and relevant lone pairs.

(3)

(b) Predict the mechanism for the reaction of CH_3CH_2COCl with ammonia. Include curly arrows and relevant lone pairs.

(3)

(Total for Question 8 = 6 marks)

9 The gas phase reaction between hydrogen and iodine is reversible.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

(a) (i) Write the expression for the equilibrium constant, K_c, for this reaction.

(1)

(ii) If the starting concentration of both hydrogen and iodine was **a** mol dm^{-3} and it was found that 2**y** mol dm^{-3} of hydrogen iodide had formed once equilibrium had been established, write the K_c expression in terms of **a** and **y**.

(2)

(b) The expression for the equilibrium constant in (a)(ii) can be rearranged as shown.

$$\mathbf{y} = \frac{\mathbf{a}\sqrt{K_c}}{2+\sqrt{K_c}}$$

In an experiment, air was removed from a 1 dm^3 flask and amounts of hydrogen and iodine gases were mixed together such that their initial concentrations were both **a** mol dm^{-3}. This mixture was allowed to reach equilibrium at 760 K. The equilibrium concentration of iodine was then measured.

The experiment was repeated for various initial concentrations, **a** mol dm^{-3}, and the results recorded in the table.

(i) Complete the table to give the two remaining values of **y** mol dm^{-3}, to **two** decimal places.

(1)

a / mol dm^{-3}	$[I_2]_{eq}$ / mol dm^{-3}	y / mol dm^{-3}
0.20	0.02	0.18
0.80	0.25	0.55
1.50	0.37	
2.10	0.57	1.53
2.80	0.65	2.15
3.80	0.87	
4.90	1.15	3.75

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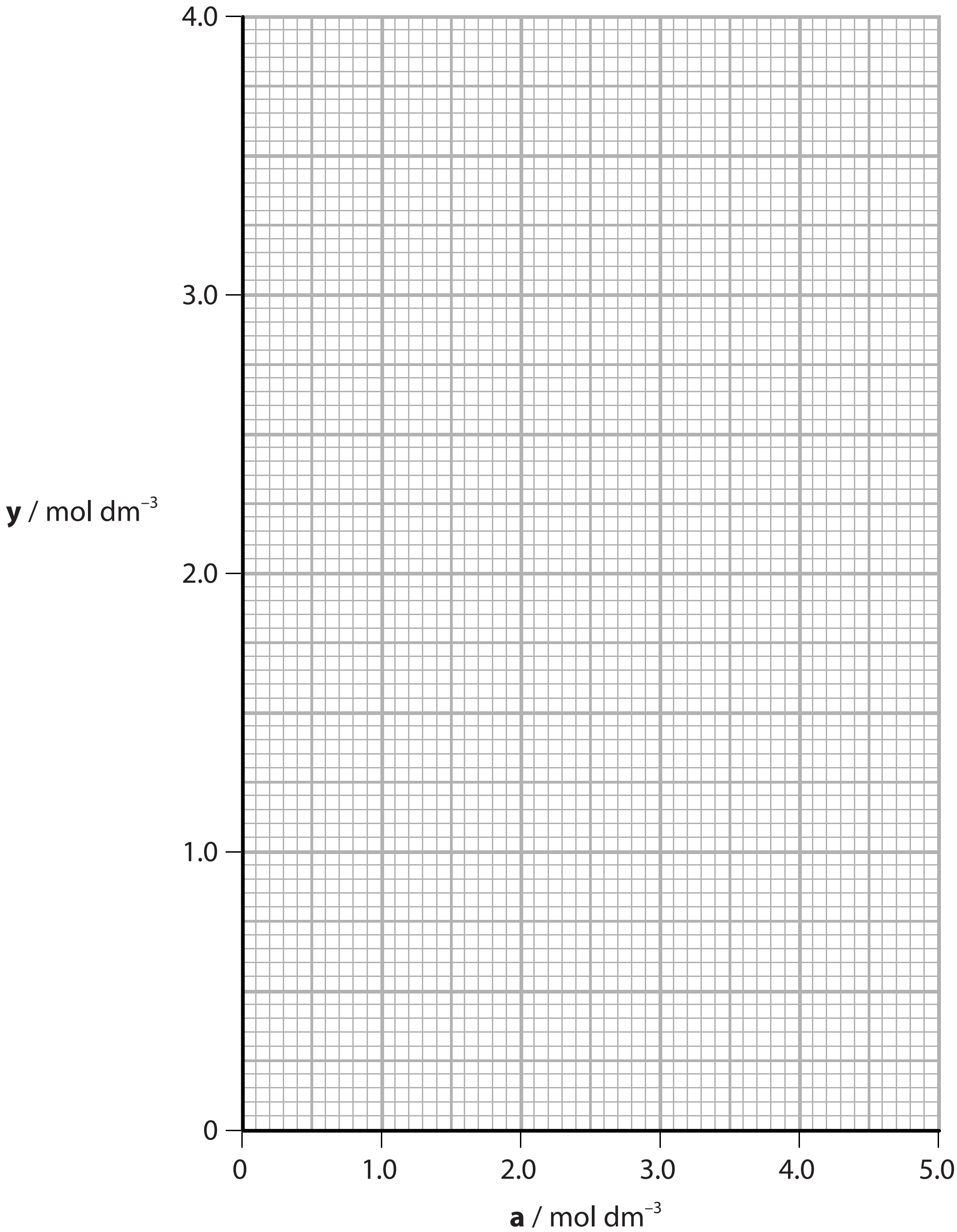
(ii) Plot a graph to show how **y** mol dm^{-3} varies with the initial concentrations of hydrogen and iodine, **a** mol dm^{-3}.

(2)



(iii) Determine the gradient of your graph.
Show your working on the graph.

(2)

(iv) Use your answer to (b)(iii) and the expression $\mathbf{y = \dfrac{a\sqrt{K_c}}{2 + \sqrt{K_c}}}$ to calculate the value of K_c.

(2)

(c) Identify a safety issue associated with this experiment.

(1)

(d) One of the experiments in part (b) was repeated using the same molar quantities of hydrogen and iodine but in a 500 cm^3 flask instead of the 1 dm^3 flask.

Deduce the effect, if any, that this would have on the rate of reaction and on the value of K_c calculated.

(2)

(e) The equation for the reaction between hydrogen and iodine is

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad \Delta H = -9.6 \text{ kJ mol}^{-1}$$

(i) Explain the effect, if any, on the value of K_c when the temperature is increased.

(2)

(ii) On your graph in (b)(ii), draw and label the line you would expect if the experiment was carried out at 1000 K instead of 760 K.

(1)

(Total for Question 9 = 16 marks)

TOTAL FOR PAPER = 120 MARKS

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The Periodic Table of Elements

Key

relative atomic mass **atomic symbol** name atomic (proton) number

1 *(1)*	**2** *(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*	**3** *(13)*	**4** *(14)*	**5** *(15)*	**6** *(16)*	**7** *(17)*	**0 (8)** *(18)*
							1.0 **H** hydrogen 1										4.0 **He** helium 2
6.9 **Li** lithium 3	9.0 **Be** beryllium 4											10.8 **B** boron 5	12.0 **C** carbon 6	14.0 **N** nitrogen 7	16.0 **O** oxygen 8	19.0 **F** fluorine 9	20.2 **Ne** neon 10
23.0 **Na** sodium 11	24.3 **Mg** magnesium 12											27.0 **Al** aluminium 13	28.1 **Si** silicon 14	31.0 **P** phosphorus 15	32.1 **S** sulfur 16	35.5 **Cl** chlorine 17	39.9 **Ar** argon 18
39.1 **K** potassium 19	40.1 **Ca** calcium 20	45.0 **Sc** scandium 21	47.9 **Ti** titanium 22	50.9 **V** vanadium 23	52.0 **Cr** chromium 24	54.9 **Mn** manganese 25	55.8 **Fe** iron 26	58.9 **Co** cobalt 27	58.7 **Ni** nickel 28	63.5 **Cu** copper 29	65.4 **Zn** zinc 30	69.7 **Ga** gallium 31	72.6 **Ge** germanium 32	74.9 **As** arsenic 33	79.0 **Se** selenium 34	79.9 **Br** bromine 35	83.8 **Kr** krypton 36
85.5 **Rb** rubidium 37	87.6 **Sr** strontium 38	88.9 **Y** yttrium 39	91.2 **Zr** zirconium 40	92.9 **Nb** niobium 41	95.9 **Mo** molybdenum 42	[98] **Tc** technetium 43	101.1 **Ru** ruthenium 44	102.9 **Rh** rhodium 45	106.4 **Pd** palladium 46	107.9 **Ag** silver 47	112.4 **Cd** cadmium 48	114.8 **In** indium 49	118.7 **Sn** tin 50	121.8 **Sb** antimony 51	127.6 **Te** tellurium 52	126.9 **I** iodine 53	131.3 **Xe** xenon 54
132.9 **Cs** caesium 55	137.3 **Ba** barium 56	138.9 **La*** lanthanum 57	178.5 **Hf** hafnium 72	180.9 **Ta** tantalum 73	183.8 **W** tungsten 4	186.2 **Re** rhenium 75	190.2 **Os** osmium 76	192.2 **Ir** iridium 77	195.1 **Pt** platinum 78	197.0 **Au** gold 79	200.6 **Hg** mercury 80	204.4 **Tl** thallium 81	207.2 **Pb** lead 82	209.0 **Bi** bismuth 83	[209] **Po** polonium 84	[210] **At** astatine 85	[222] **Rn** radon 86
[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac*** actinium 89	[261] **Rf** rutherfordium 104	[262] **Db** dubnium 105	[266] **Sg** seaborgium 106	[264] **Bh** bohrium 107	[277] **Hs** hassium 108	[268] **Mt** meitnerium 109	[271] **Ds** darmstadtium 110	[272] **Rg** roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

	140 **Ce** cerium 58	141 **Pr** praseodymium 59	144 **Nd** neodymium 60	[147] **Pm** promethium 61	150 **Sm** samarium 62	152 **Eu** europium 63	157 **Gd** gadolinium 64	159 **Tb** terbium 65	163 **Dy** dysprosium 66	165 **Ho** holmium 67	167 **Er** erbium 68	169 **Tm** thulium 69	173 **Yb** ytterbium 70	175 **Lu** lutetium 71
* Lanthanide series														
* Actinide series	232 **Th** thorium 90	[231] **Pa** protactinium 91	238 **U** uranium 92	[237] **Np** neptunium 93	[242] **Pu** plutonium 94	[243] **Am** americium 95	[247] **Cm** curium 96	[245] **Bk** berkelium 97	[251] **Cf** californium 98	[254] **Es** einsteinium 99	[253] **Fm** fermium 100	[256] **Md** mendelevium 101	[254] **No** nobelium 102	[257] **Lr** lawrencium 103