

AS CHEMISTRY (7404/1)

Paper 1: Inorganic and Physical Chemistry

Specimen 2015

Session

Time allowed: 1 hour 30 minutes

Materials

For this paper you must have:

- the Data Sheet, provided as an insert
- a ruler
- a calculator.

Instructions

- Answer **all** questions.
- Show **all** your working.

Information

- The maximum mark for this paper is 80.

Please write clearly, in block capitals, to allow character computer recognition.

Centre number

Candidate number

Surname

Forename(s)

Candidate signature _____

There are no questions printed on this page

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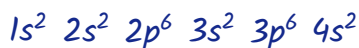
Section A

Answer **all** questions in this section.

1 This question is about the elements in Group 2 and their compounds.

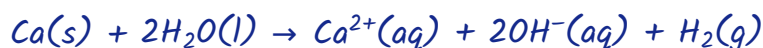
0 1 . **1** Use the Periodic Table to deduce the full electron configuration of calcium.

[1 mark]



0 1 . **2** Write an ionic equation, with state symbols, to show the reaction of calcium with an excess of water.

[1 mark]



0 1 . **3** State the role of water in the reaction with calcium.

[1 mark]

Oxidising agent (water is reduced to hydrogen)

0 1 . **4** Write an equation to show the process that occurs when the first ionisation energy of calcium is measured.

[1 mark]



0 1 . **5** State and explain the trend in the first ionisation energies of the elements in Group 2 from magnesium to barium.

[3 marks]

Trend Decreases (from Mg to Ba)

Explanation The atoms / ions get bigger, with more (energy) shells,
so the outer electron is further from the nucleus and more shielded by
inner electrons.

So there is a weaker attraction between the nucleus and the electron
being lost, so less energy is needed to remove it.

0 2 .

1

A sample of sulfur consisting of three isotopes has a relative atomic mass of 32.16
Table 1 gives the relative abundance of two of these isotopes.

Table 1

Mass number of isotope	32	33
Relative abundance / %	91.0	1.8

Use this information to determine the relative abundance and hence the mass number of the third isotope.

Give your answer to the appropriate number of significant figures.

[4 marks]

$$\text{Abundance of third isotope} = 100 - 91.0 - 1.8 = 7.2\%$$

$$[(32 \times 91.0) + (33 \times 1.8) + (y \times 7.2)] / 100 = 32.16$$

$$7.2y = (32.16 \times 100) - (32 \times 91.0) - (33 \times 1.8)$$

$$7.2y = 3216 - 2912 - 59.4 = 244.6$$

$$y = 244.6 / 7.2 = 33.97$$

Mass number = 34

0 2 .

2

Describe how ions are formed in a time of flight (TOF) mass spectrometer.

[2 marks]

The sample is dissolved in a volatile (polar) solvent and sprayed from
a fine needle that has a high voltage applied to it (electrospray
ionisation).

The molecules lose an electron to form positive ions: $M(g) \rightarrow M^+(g) +$
 e^-

0 2 . 3 A TOF mass spectrometer can be used to determine the relative molecular mass of molecular substances.

Explain why it is necessary to ionise molecules when measuring their mass in a TOF mass spectrometer.

[2 marks]

*Only ions (charged particles), not neutral molecules, will interact with
and be accelerated by the electric field, so they can travel through the
flight tube.*

*Also, only ions create a current when they hit the detector, so neutral
molecules would not be detected.*

Turn over for the next question

- 0 3** . **1** Write an equation, including state symbols, for the reaction with enthalpy change equal to the standard enthalpy of formation for $\text{CF}_4(\text{g})$.

[1 mark]



- 0 3** . **2** Explain why CF_4 has a bond angle of 109.5° .

[2 marks]

Around the carbon atom there are 4 bonding pairs of electrons and no lone pairs.

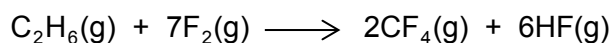
These electron pairs repel each other equally, so they spread out as far apart as possible, giving a tetrahedral shape with bond angles of 109.5° .

- 0 3** . **3** **Table 2** gives some values of standard enthalpies of formation ($\Delta_f H^\ominus$).

Table 2

Substance	$\text{F}_2(\text{g})$	$\text{CF}_4(\text{g})$	$\text{HF}(\text{g})$
$\Delta_f H^\ominus / \text{kJ mol}^{-1}$	0	-680	-269

The enthalpy change for the following reaction is $-2889 \text{ kJ mol}^{-1}$.



Use this value and the standard enthalpies of formation in **Table 2** to calculate the standard enthalpy of formation of $\text{C}_2\text{H}_6(\text{g})$.

[3 marks]

$$\Delta H = \Sigma \Delta_f H(\text{products}) - \Sigma \Delta_f H(\text{reactants})$$

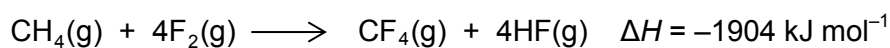
$$-2889 = [(2 \times -680) + (6 \times -269)] - [\Delta_f H(\text{C}_2\text{H}_6) + (7 \times 0)]$$

$$-2889 = -1360 - 1614 - \Delta_f H(\text{C}_2\text{H}_6) = -2974 - \Delta_f H(\text{C}_2\text{H}_6)$$

$$\Delta_f H(\text{C}_2\text{H}_6) = -2974 + 2889 = -85$$

Standard enthalpy of formation of $\text{C}_2\text{H}_6(\text{g}) = \underline{\quad -85 \quad} \text{ kJ mol}^{-1}$

0 3 . 4 Methane reacts violently with fluorine according to the following equation.



Some mean bond enthalpies are given in **Table 3**.

Table 3

Bond	C-H	C-F	H-F
Mean bond enthalpy / kJ mol ⁻¹	412	484	562

A student suggested that one reason for the high reactivity of fluorine is a weak F-F bond .

Is the student correct? Justify your answer with a calculation using these data.

[4 marks]

$$\text{Bonds broken} = 4(\text{C-H}) + 4(\text{F-F}) = (4 \times 412) + 4(\text{F-F})$$

$$\text{Bonds formed} = 4(\text{C-F}) + 4(\text{H-F}) = (4 \times 484) + (4 \times 562) = 4184$$

$$\Delta H = \Sigma(\text{bonds broken}) - \Sigma(\text{bonds formed})$$

$$-1904 = [1648 + 4(\text{F-F})] - 4184$$

$$4(\text{F-F}) = -1904 - 1648 + 4184 = 632$$

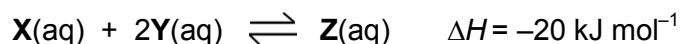
$$\text{F-F} = 632 / 4 = 158 \text{ kJ mol}^{-1}$$

Yes, correct: F-F (158 kJ mol⁻¹) is much weaker than the C-H, C-F and H-F bonds (412 to 562), so F-F is easily broken.

Turn over for the next question

4

Colourless solutions of X(aq) and Y(aq) react to form an orange solution of Z(aq) according to the following equation.



A student added a solution containing 0.50 mol of X(aq) to a solution containing 0.50 mol of Y(aq) and shook the mixture.

After 30 seconds, there was no further change in colour.

The amount of Z(aq) at equilibrium was 0.20 mol.

0 4 . **1** Deduce the amounts of X(aq) and Y(aq) at equilibrium.

[2 marks]

$$\text{X: } 0.50 - 0.20 = 0.30 \text{ mol}$$

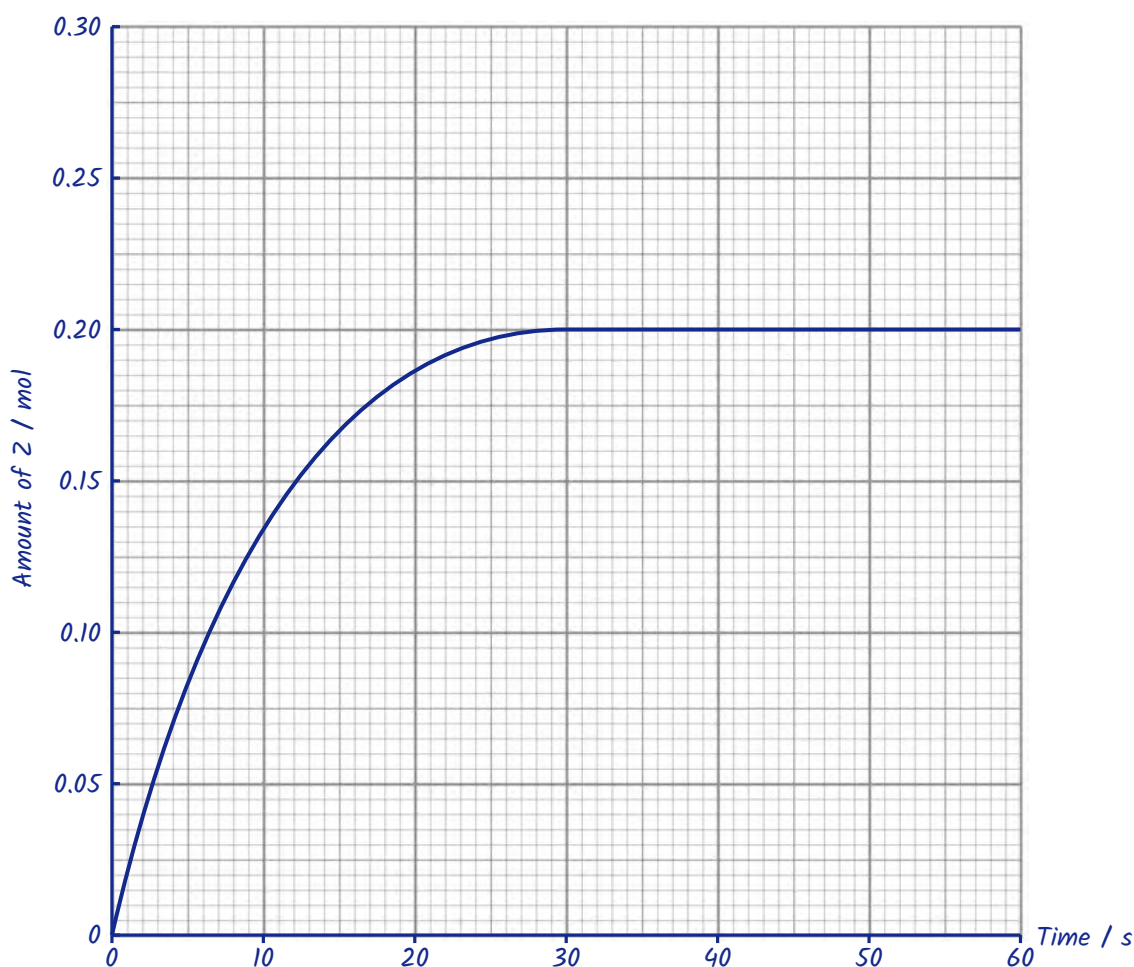
$$\text{Y: } 0.50 - (2 \times 0.20) = 0.10 \text{ mol}$$

Amount of X(aq) = 0.30 mol

Amount of Y(aq) = 0.10 mol

0 4 . **2** On the grid below, draw a graph to show how the amount of Z(aq) changed from the time of initial mixing until 60 seconds had elapsed.

[3 marks]



- 0 4 . 3** The student prepared another equilibrium mixture in which the equilibrium concentrations of **X** and **Z** were:
X(aq) = 0.40 mol dm⁻³ and **Z**(aq) = 0.35 mol dm⁻³.

For this reaction, the equilibrium constant $K_c = 2.9 \text{ mol}^{-2} \text{ dm}^6$.
Calculate a value for the concentration of **Y** at equilibrium.
Give your answer to the appropriate number of significant figures.

[3 marks]

$$K_c = [Z] / ([X][Y]^2)$$

$$[Y]^2 = [Z] / ([X] \times K_c) = 0.35 / (0.40 \times 2.9) = 0.3017$$

$$[Y] = \sqrt{0.3017} = 0.5493$$

$$[Y] = \underline{0.55} \text{ mol dm}^{-3}$$

- 0 4 . 4** The student added a few drops of **Y**(aq) to the equilibrium mixture of **X**(aq), **Y**(aq) and **Z**(aq) in Question 4.3.

Suggest how the colour of the mixture changed. Give a reason for your answer.

[3 marks]

Colour change Went darker / more orange

Reason The equilibrium moves to the right

to oppose the increased concentration of Y, so more orange Z is formed.

- 0 4 . 5** The student warmed the equilibrium mixture from Question 4.3.

Predict the colour change, if any, when the equilibrium mixture was warmed.

[1 mark]

The orange colour fades (becomes paler): the forward reaction is
exothermic, so the equilibrium moves to the left.

5

This question is about the chemical properties of chlorine, sodium chloride and sodium bromide.

0 5

. 1

Sodium bromide reacts with concentrated sulfuric acid in a different way from sodium chloride.

Write an equation for this reaction of sodium bromide and explain why bromide ions react differently from chloride ions.

[3 marks]

Equation $2\text{NaBr} + 2\text{H}_2\text{SO}_4 \rightarrow \text{Na}_2\text{SO}_4 + \text{Br}_2 + \text{SO}_2 + 2\text{H}_2\text{O}$

Explanation Br^- ions are bigger than Cl^- ions,

so Br^- ions are more easily oxidised (lose an electron more easily)

than Cl^- ions. Br^- is a stronger reducing agent and reduces H_2SO_4 to

SO_2 .

0 5

. 2

A colourless solution contains a mixture of sodium chloride and sodium bromide.

Using aqueous silver nitrate and any other reagents of your choice, develop a procedure to prepare a pure sample of silver bromide from this mixture.

Explain each step in the procedure and illustrate your explanations with equations, where appropriate.

[6 marks]

Stage 1: Add an excess of aqueous silver nitrate to the solution.

Precipitates of silver chloride (white) and silver bromide (cream) form together:



Stage 2: Add an excess of dilute ammonia to the mixture of

precipitates and stir. The silver chloride precipitate dissolves, forming a soluble complex, but silver bromide does not dissolve in dilute ammonia:



Stage 3: Filter off the remaining silver bromide precipitate. Wash it

with distilled water to remove soluble compounds (the silver ammonia complex, NaNO_3 and NH_3). Then dry it (e.g. in a warm oven or a

desiccator) to remove the water, leaving pure AgBr.

- 0 5 . 3** Write an ionic equation for the reaction between chlorine and cold dilute sodium hydroxide solution.
Give the oxidation state of chlorine in each of the chlorine-containing ions formed.
[2 marks]



Oxidation state of Cl: in $\text{OCl}^- = +1$, in $\text{Cl}^- = -1$

Turn over for the next question

6

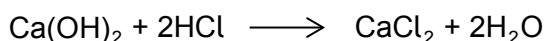
This question is about reactions of calcium compounds.

06

1

A pure solid is thought to be calcium hydroxide. The solid can be identified from its relative formula mass.

The relative formula mass can be determined experimentally by reacting a measured mass of the pure solid with an excess of hydrochloric acid. The equation for this reaction is



The unreacted acid can then be determined by titration with a standard sodium hydroxide solution.

You are provided with 50.0 cm³ of 0.200 mol dm⁻³ hydrochloric acid.

Outline, giving brief practical details, how you would conduct an accurate experiment to calculate the relative formula mass of the solid using this method.

[8 marks]

Stage 1: The acid must be in excess. Moles of HCl = 50.0 × 0.200 /

1000 = 1.00 × 10⁻² mol. 2 mol HCl react with 1 mol Ca(OH)₂, so the

moles of solid must be less than 0.5 × 1.00 × 10⁻² = 5.00 × 10⁻³ mol,

so the mass of solid must be less than 5.00 × 10⁻³ × 74.1 = 0.371 g

(use about 0.25 g).

Stage 2: Weigh about 0.25 g of the solid accurately on a balance

(weigh by difference). Use a pipette to measure 50.0 cm³ of the acid

into a conical flask and add the weighed solid; swirl until it has all reacted.

Add a few drops of indicator (e.g. phenolphthalein) and titrate against

0.100 mol dm⁻³ NaOH added from a burette, swirling, until the

indicator just changes colour. Record the volume of NaOH added, v cm³.

Stage 3: Moles of HCl left over = v × 0.100 / 1000. Moles of HCl that

reacted = 1.00 × 10⁻² - (v × 0.100 / 1000), so moles of Ca(OH)₂ = z

= ½ × [1.00 × 10⁻² - (v × 0.100 / 1000)] mol.

M_r = mass of solid / z

06 . 2

A 3.56 g sample of calcium chloride was dissolved in water and reacted with an excess of sulfuric acid to form a precipitate of calcium sulfate.

The percentage yield of calcium sulfate was 83.4%.

Calculate the mass of calcium sulfate formed.

Give your answer to an appropriate number of significant figures.

[3 marks]

$$\text{Moles of CaCl}_2 = 3.56 / 111.1 = 3.204 \times 10^{-2} \text{ mol}$$



$$\text{Moles of CaSO}_4 = 3.204 \times 10^{-2} \times 83.4 / 100 = 2.672 \times 10^{-2} \text{ mol}$$

$$\text{Mass} = 2.672 \times 10^{-2} \times 136.2 = 3.640 \text{ g}$$

Mass of calcium sulfate formed = 3.64 g

Turn over for the next question

7

A sample of pure $\text{Mg}(\text{NO}_3)_2$ was decomposed by heating as shown in the equation below.



0 7 . **1** A 3.74×10^{-2} g sample of $\text{Mg}(\text{NO}_3)_2$ was completely decomposed by heating.

Calculate the total volume, in cm^3 , of gas produced at 60.0°C and 100 kPa .

Give your answer to the appropriate number of significant figures.

The gas constant $R = 8.31\text{ J K}^{-1}\text{ mol}^{-1}$.

[5 marks]

$$M_r \text{ of } \text{Mg}(\text{NO}_3)_2 = 24.3 + 2(14.0 + 3 \times 16.0) = 148.3$$

$$n(\text{Mg}(\text{NO}_3)_2) = 3.74 \times 10^{-2} / 148.3 = 2.522 \times 10^{-4} \text{ mol}$$

$$2 \text{ mol } \text{Mg}(\text{NO}_3)_2 \rightarrow 5 \text{ mol gas } (4\text{NO}_2 + \text{O}_2), \text{ so}$$

$$n(\text{gas}) = 5/2 \times 2.522 \times 10^{-4} = 6.305 \times 10^{-4} \text{ mol}$$

$$pV = nRT \text{ so } V = nRT / p ; T = 333.15 \text{ K}, p = 1.00 \times 10^5 \text{ Pa}$$

$$V = (6.305 \times 10^{-4} \times 8.31 \times 333.15) / 1.00 \times 10^5 = 1.746 \times 10^{-5} \text{ m}^3$$

$$V = 1.746 \times 10^{-5} \times 10^6 = 17.46 \text{ cm}^3$$

Total volume of gas = 17.5 cm^3

0 7 . **2** The mass of MgO obtained in this experiment is slightly less than that expected from the mass of $\text{Mg}(\text{NO}_3)_2$ used.

Suggest **one** practical reason for this.

[1 mark]

Some of the solid was lost, e.g. blown out of the crucible with the

escaping gases (or spilt when weighing the product).

Section B

Answer **all** questions in this section.

Only **one** answer per question is allowed.

For each answer completely fill in the circle alongside the appropriate answer.

CORRECT METHOD



WRONG METHODS



If you want to change your answer you must cross out your original answer as shown.

If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown.

0 8

Which of these atoms has the largest atomic radius?

[1 mark]

A Ar ☐

B Cl ☐

C Mg ☐

D Na ☒

0 9

Which of these species is the best reducing agent?

[1 mark]

A Cl_2 ☐

B Cl^- ☐

C I_2 ☐

D I^- ☒

1 0

Which of these pieces of apparatus has the lowest percentage error in the measurement shown?

[1 mark]

- A** Volume of 25 cm³ measured with a burette with an error of ± 0.1 cm³. ☒
- B** Volume of 25 cm³ measured with a measuring cylinder with an error of ± 0.5 cm³. ☐
- C** Mass of 0.150 g measured with a balance with an error of ± 0.001 g. ☐
- D** Temperature change of 23.2 °C measured with a thermometer with an error of ± 0.1 °C. ☐

1 1

A student is provided with a 5.00 cm³ sample of 1.00×10^{-2} mol dm⁻³ hydrochloric acid. The student is asked to devise a method to prepare a hydrochloric acid solution with a concentration of 5.00×10^{-4} mol dm⁻³ by diluting the sample with water.

Which of these is the correct volume of water that should be added?

[1 mark]

- A** 45.0 cm³ ☐
- B** 95.0 cm³ ☒
- C** 100 cm³ ☐
- D** 995 cm³ ☐

1 2

Which of these species has a trigonal planar structure?

[1 mark]

- A** PH₃ ☐
- B** BCl₃ ☒
- C** H₃O⁺ ☐
- D** CH₃⁻ ☐

1 3

Use your understanding of intermolecular forces to predict which of these compounds has the highest boiling point.

[1 mark]

- | | | |
|----------|-----|----------------------------------|
| A | HF | ☒ |
| B | HCl | ☐ |
| C | HBr | ☐ |
| D | HI | ☐ |

1 4

Which type of bond is formed between N and B when a molecule of NH_3 reacts with a molecule of BF_3 ?

[1 mark]

- | | | |
|----------|----------------|----------------------------------|
| A | Ionic. | ☐ |
| B | Covalent. | ☐ |
| C | Co-ordinate. | ☒ |
| D | Van der Waals. | ☐ |

1 5

Which of these atoms has the highest electronegativity?

[1 mark]

- | | | |
|----------|----|----------------------------------|
| A | Na | ☐ |
| B | Mg | ☐ |
| C | Cl | ☒ |
| D | Ar | ☐ |

1 6

Which of these atoms has the smallest number of neutrons?

[1 mark]

- | | | |
|----------|---------------|----------------------------------|
| A | ^3H | ☐ |
| B | ^4He | ☐ |
| C | ^5He | ☐ |
| D | ^4Li | ☒ |

1 7

Which of these substances does **not** show hydrogen bonding?

[1 mark]

- A HF ☐
- B NH₃ ☐
- C CH₃COOH ☐
- D CHF₃ ☒

1 8

What is the formula of calcium nitrate(V)?

[1 mark]

- A CaNO₃ ☐
- B Ca(NO₃)₂ ☒
- C Ca₂NO₂ ☐
- D Ca(NO₂)₂ ☐

1 9

Which of these elements has the highest second ionisation energy?

[1 mark]

- A Na ☒
- B Mg ☐
- C Ne ☐
- D Ar ☐

2	0
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Which of the following shows chlorine in its correct oxidation states in the compounds shown?

[1 mark]

	HCl	KClO ₃	HClO	
A	-1	+3	+1	☐
B	+1	-5	-1	☐
C	-1	+5	+1	☒
D	+1	+5	-1	☐

2	1
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Which substance is **not** produced in a redox reaction when solid sodium iodide reacts with concentrated sulfuric acid?

[1 mark]

- | | | |
|---|------------------|----------------------------------|
| A | H ₂ S | ☐ |
| B | HI | ☒ |
| C | SO ₂ | ☐ |
| D | I ₂ | ☐ |

2	2
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Which of the following contains the most chloride ions?

[1 mark]

- | | | |
|---|--|----------------------------------|
| A | 10 cm ³ of 3.30 × 10 ⁻² mol dm ⁻³ aluminium chloride solution | ☐ |
| B | 20 cm ³ of 5.00 × 10 ⁻² mol dm ⁻³ calcium chloride solution | ☒ |
| C | 30 cm ³ of 3.30 × 10 ⁻² mol dm ⁻³ hydrochloric acid | ☐ |
| D | 40 cm ³ of 2.50 × 10 ⁻² mol dm ⁻³ sodium chloride solution | ☐ |

END OF QUESTIONS

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