

Please write clearly in block capitals.

Centre number

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Candidate number

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Surname StemUp Model Solution

Forename(s) _____

Candidate signature _____

I declare this is my own work.

INTERNATIONAL AS CHEMISTRY (9620)

Unit 1: Inorganic 1 and Physical 1

Time allowed: 1 hour 30 minutes

Materials

For this paper you must have:

- the Periodic Table/Data Sheet, provided as an insert
- a ruler with millimetre measurements
- a scientific calculator, which you are expected to use where appropriate.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do **not** write outside the box around each page or on blank pages.
- All working must be shown.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information

- The marks for questions are shown in brackets.
- The maximum mark for this paper is 70.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
TOTAL	



J U N 2 2 C H O 1 0 1

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

0 1

This question is about calcium.

0 1 . 1

State why calcium is an s block element.

[1 mark]

Its outer (highest energy) electrons are in the 4s sub-shell (4s orbital).

0 1 . 2

State why ^{40}Ca and ^{44}Ca have the same atomic radius.

[1 mark]

They have the same number of protons and the same number of electrons (same electron configuration).

0 1 . 3

How many neutrons are there in an atom of ^{44}Ca ?

[1 mark]

Tick (✓) **one** box.

20

☐

24

☒

44

☐

0 1 . 4

A sample of calcium is ionised by electron impact in a time of flight (TOF) mass spectrometer.

Write an equation, including state symbols, for the ionisation of calcium by electron impact.

[1 mark]

$\text{Ca(g)} + \text{e}^- \rightarrow \text{Ca}^+(\text{g}) + 2\text{e}^-$



0 1 . 5

Table 1 shows information about the three isotopes in a sample of calcium.

Table 1

Mass number	40	42	44
Relative abundance	48.0	1.5	2.0

Calculate the relative atomic mass of calcium in this sample.
Give your answer to 1 decimal place.

[2 marks]

$$A_r = [(48.0 \times 40) + (1.5 \times 42) + (2.0 \times 44)] \div (48.0 + 1.5 + 2.0)$$

$$A_r = (1920 + 63 + 88) \div 51.5$$

$$A_r = 2071 \div 51.5 = 40.21$$

$$A_r = 40.2 \text{ (1 d.p.)}$$

Relative atomic mass 40.2

Question 1 continues on the next page

Turn over ►



0 1 . 6

A $^{44}\text{Ca}^+$ ion travels, at speed $v \text{ m s}^{-1}$, along a 1.25 m flight tube in a TOF mass spectrometer.

The time of flight of the $^{44}\text{Ca}^+$ ion is $8.98 \times 10^{-7} \text{ s}$

The speed of the $^{44}\text{Ca}^+$ ion is shown by the equation

$$v = \sqrt{\frac{2KE}{m}}$$

KE = kinetic energy (J)

m = mass (kg)

Calculate the kinetic energy, in J, of the $^{44}\text{Ca}^+$ ion.
Give your answer to 3 significant figures.

The Avogadro constant, $L = 6.02 \times 10^{23} \text{ mol}^{-1}$

[4 marks]

$$\text{mass of one ion} = 44 \div (6.02 \times 10^{23}) = 7.309 \times 10^{-23} \text{ g}$$

$$m = 7.309 \times 10^{-23} \div 1000 = 7.309 \times 10^{-26} \text{ kg}$$

$$v = d \div t = 1.25 \div (8.98 \times 10^{-7}) = 1.392 \times 10^6 \text{ m s}^{-1}$$

$$v = \sqrt{(2KE \div m)} \quad \text{so} \quad KE = \frac{1}{2}mv^2$$

$$KE = \frac{1}{2} \times 7.309 \times 10^{-26} \times (1.392 \times 10^6)^2$$

$$KE = 7.08 \times 10^{-14} \text{ J} \quad (3 \text{ s.f.})$$

Kinetic energy 7.08×10^{-14} J

10



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ANSWER IN THE SPACES PROVIDED**

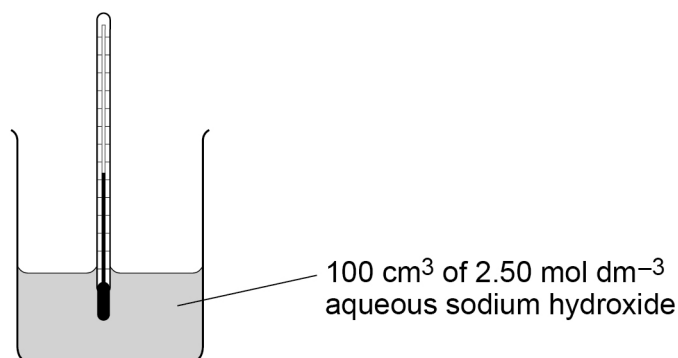
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0 5

0 2

An experiment is done to find the enthalpy change when aqueous sodium hydroxide is neutralised by hydrochloric acid.

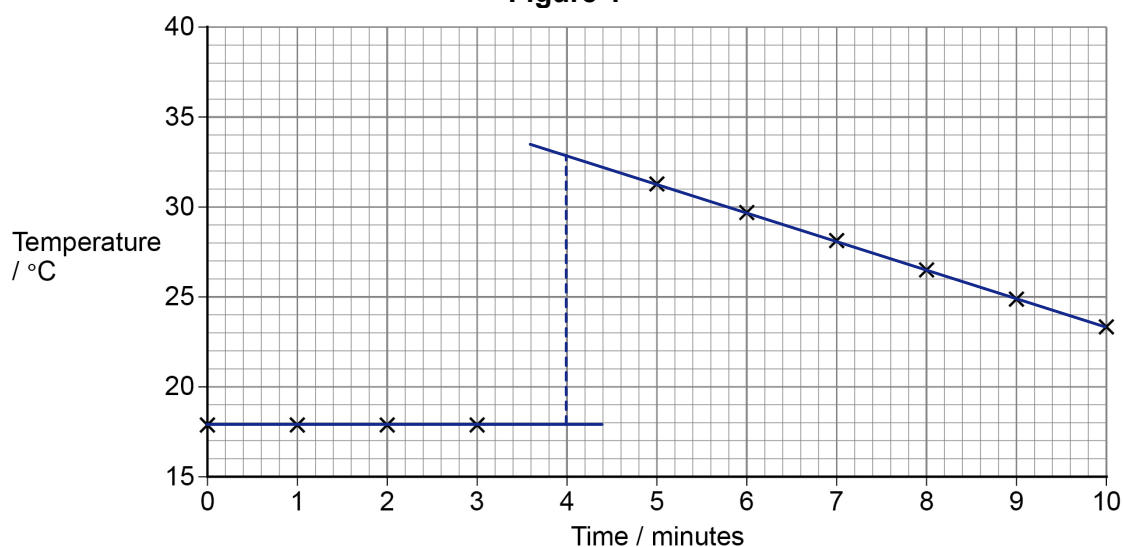


Method

- The temperature of the aqueous sodium hydroxide is measured every minute for 3 minutes.
- At the fourth minute 100 cm³ of 2.50 mol dm⁻³ hydrochloric acid are added, the solution is stirred, but no temperature measurement is made.
- The temperature is measured at the fifth minute and every minute for 5 more minutes.

Figure 1 shows the results.

Figure 1



0 2. 1

Use **Figure 1** to calculate the temperature rise during the reaction.

Show your working.

[2 marks]

Extrapolate both lines to 4 minutes:

temperature before = 17.9 °C, temperature after = 32.9 °C

temperature rise = 32.9 - 17.9 = 15.0 °C

Temperature rise 15.0 °C



0 2 . 2

Use your answer to Question **02.1** to calculate the heat energy, in kJ, released in this reaction.

The specific heat capacity of the final solution is $4.18 \text{ J K}^{-1} \text{ g}^{-1}$

(If you were unable to answer Question **02.1** you should use the value 19.3°C
This is **not** the correct answer.)

[2 marks]

$$\text{mass of solution} = 100 + 100 = 200 \text{ cm}^3 = 200 \text{ g}$$

$$q = mc\Delta T = 200 \times 4.18 \times 15.0 = 12\,540 \text{ J}$$

$$q = 12\,540 \div 1000 = 12.5 \text{ kJ}$$

Heat energy 12.5 kJ

0 2 . 3

Use your answer to Question **02.2** to calculate the enthalpy change, in kJ mol^{-1} , for the reaction between sodium hydroxide and hydrochloric acid.

(If you were unable to answer Question **02.2** you should use the value 10.4 kJ
This is **not** the correct answer.)

[2 marks]

$$n(\text{HCl}) = (100 \div 1000) \times 2.50 = 0.250 \text{ mol} = n(\text{NaOH}) = n(\text{H}_2\text{O})$$

$$\Delta H = -12.54 \div 0.250 = -50.2 \text{ kJ mol}^{-1}$$

(negative because the reaction is exothermic)

Enthalpy change -50.2 kJ mol^{-1}

0 2 . 4

The method used in Question **02.1** to calculate the temperature change allows for heat loss to the surroundings.

Suggest **one** reason for the difference between the experimental value and a data book value.

[1 mark]

Some of the heat energy is absorbed by the beaker and the
thermometer (not by the solution).

Turn over ►



0 3

This question is about redox reactions.

0 3 . 1

Identify the element that is oxidised in the reaction



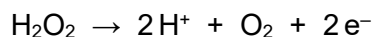
Explain your answer using oxidation states.

[2 marks]Element nitrogen (N)

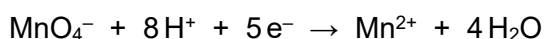
Explanation The oxidation state of N increases from +4 in NO₂ to +5 in NO₃⁻, so nitrogen loses electrons and is oxidised.

0 3 . 2

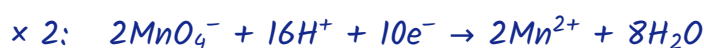
The half-equation for the oxidation of hydrogen peroxide is



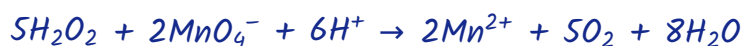
The half-equation for the reduction of manganate(VII) ions in acidic conditions is



Write the overall equation for the oxidation of hydrogen peroxide by manganate(VII) ions in acidic conditions.

[2 marks]

add and cancel the 10H⁺ and the 10e⁻:



0 3 . 3

In acidic conditions, Cr^{3+} ions can be oxidised to $\text{Cr}_2\text{O}_7^{2-}$ ions by MnO_2 .
The MnO_2 is reduced to Mn^{2+} ions.

Write a half-equation for the oxidation process.

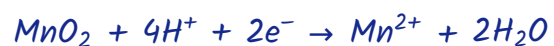
Write a half-equation for the reduction process.

[2 marks]

Oxidation half-equation



Reduction half-equation



6

Turn over for the next question

Turn over ►



0 4

This question is about the elements in Group 7 and their compounds.

0 4 . 1

Explain why chlorine has a lower boiling point than bromine.

[2 marks]

Chlorine molecules are smaller than bromine molecules and have fewer electrons, so the van der Waals forces between Cl_2 molecules are weaker and less energy is needed to overcome them.

0 4 . 2

Explain why bromine is a more powerful oxidising agent than iodine.

[2 marks]

*A bromine atom is smaller than an iodine atom: its outer shell is closer to the nucleus and less shielded.
So an electron being gained is more strongly attracted to the nucleus.*

0 4 . 3

When chlorine reacts with aqueous sodium iodide a redox reaction occurs.

State what is observed.

Write an ionic equation for the reaction.

State the role of chlorine in the reaction.

[3 marks]

Observation *The solution turns brown (a black precipitate may form).*

Ionic equation *$\text{Cl}_2 + 2\text{I}^- \rightarrow 2\text{Cl}^- + \text{I}_2$*

Role *oxidising agent (electron acceptor)*



0 4 . 4

A student tests an aqueous solution, **X**, to see if it contains chloride ions.

Method

Step 1 Add dilute nitric acid to **X**

Step 2 Add aqueous silver nitrate to the result of Step 1

Step 3 Add dilute aqueous ammonia to the result of Step 2

State why dilute nitric acid is added in Step 1

State the observation in Step 2 and the observation in Step 3 that would show that **X** contains chloride ions.

[3 marks]

Why nitric acid is added To remove carbonate ions (and other ions that would also give a precipitate with silver nitrate).

Observation in step 2 white precipitate forms

Observation in step 3 the precipitate dissolves to give a colourless solution

0 4 . 5

Hydrogen fluoride is a polar molecule.

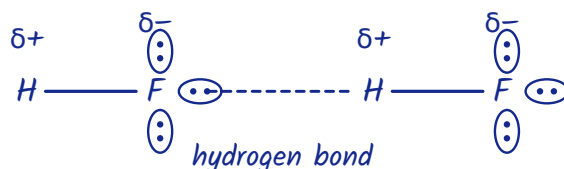
Draw a diagram to show how two molecules of hydrogen fluoride are attracted to each other.

Include all partial charges and all lone pairs of electrons.

State the strongest type of intermolecular force between molecules of hydrogen fluoride.

[4 marks]

Diagram



Strongest intermolecular force hydrogen bonding

14

Turn over ►



0 5

This question is about compounds of boron.

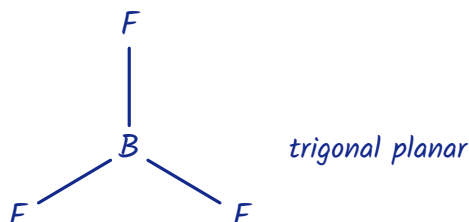
0 5 . 1

Draw the shape of the BF_3 molecule.

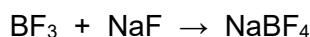
State its bond angle.

Shape

[2 marks]

Bond angle 120°

Boron trifluoride reacts with sodium fluoride as shown.

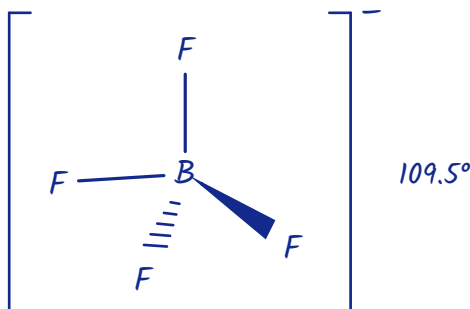
 NaBF_4 contains the BF_4^- ion.

0 5 . 2

Draw the shape of the BF_4^- ion.Name the shape of the BF_4^- ion.

Shape

[2 marks]

Name of shape tetrahedral

0 5 . 3

Explain why NaBF_4 has a high melting point.

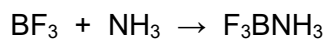
[2 marks]

NaBF_4 is ionic: it has a giant lattice of oppositely charged Na^+ and BF_4^- ions.

There are strong electrostatic attractions between the ions, so a lot of energy is needed to overcome them.



Boron trifluoride reacts with ammonia.



0 5 . 4

State how the B–N bond is formed.

Name this type of bond formation.

[2 marks]

How bond is formed The lone pair of electrons on the nitrogen of NH_3 is donated to the boron atom of BF_3 .

Type of bond formation coordinate (dative covalent) bond formation

8

Turn over for the next question

Turn over ►



0 6

This question is about Group 2 elements and their compounds.

0 6 . 1

State the element that has the lowest melting point in Group 2 from calcium to barium.

[1 mark]

barium

0 6 . 2

Explain why the first ionisation energies in Group 2 decrease from magnesium to barium.

[2 marks]

Down the group the atomic radius increases: the outer electron is in a higher energy level, further from the nucleus.

There is more shielding by inner electrons, so the attraction to the nucleus is weaker and less energy is needed.

0 6 . 3

State **two** observations that would be made when magnesium reacts with steam.

Write an equation, including state symbols, for the reaction.

[3 marks]

Observation 1 *a bright white light (white flame)*

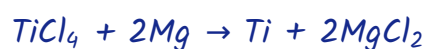
Observation 2 *a white solid (white powder) is formed*

Equation

**0 6 . 4**

Titanium can be extracted from titanium(IV) chloride by reaction with magnesium.

Write an equation for this reaction.

[1 mark]

0 6 . 5

Give **one** use of magnesium hydroxide in medicine.

[1 mark]

As an antacid, to neutralise excess stomach acid (to treat indigestion).

0 6 . 6

Barium ions are toxic but barium sulfate can be swallowed safely in medicines as a 'barium meal'.

State why barium sulfate can be swallowed safely.

[1 mark]

Barium sulfate is insoluble in water, so no toxic Ba^{2+} ions get into the blood.

9

Turn over for the next question

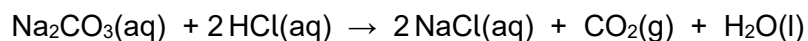
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07

This question is about sodium carbonate.

Sodium carbonate reacts with hydrochloric acid as shown.



07

1

A hydrate of sodium carbonate has the formula $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$, where x is a whole number.

A 2.88 g sample of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$ is dissolved in deionised water to make 250 cm^3 of solution.

In a titration, 16.55 cm^3 of 0.15 mol dm^{-3} hydrochloric acid reacts completely with 25.0 cm^3 of this solution.

Calculate the value of x in $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$

[6 marks]

$$n(\text{HCl}) = (16.55 \div 1000) \times 0.15 = 2.48 \times 10^{-3} \text{ mol}$$

$$n(\text{Na}_2\text{CO}_3) \text{ in } 25.0 \text{ cm}^3 = 2.48 \times 10^{-3} \div 2 = 1.24 \times 10^{-3} \text{ mol}$$

$$n(\text{Na}_2\text{CO}_3) \text{ in } 250 \text{ cm}^3 = 1.24 \times 10^{-3} \times 10 = 1.24 \times 10^{-2} \text{ mol}$$

$$M_r(\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}) = 2.88 \div (1.24 \times 10^{-2}) = 232.3$$

$$M_r(\text{Na}_2\text{CO}_3) = (2 \times 23.0) + 12.0 + (3 \times 16.0) = 106.0$$

$$\text{mass of water in } M_r = 232.3 - 106.0 = 126.3$$

$$x = 126.3 \div 18.0 = 7.01$$

$$x = 7 \quad (\text{Na}_2\text{CO}_3 \cdot 7\text{H}_2\text{O})$$

x 7



07.2

The reaction is repeated using a different sample of sodium carbonate.

The carbon dioxide collected occupies a volume of 598 cm³ at 300 K and 100 000 Pa

Calculate the mass of carbon dioxide collected.

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

[4 marks]

$$V = 598 \text{ cm}^3 = 598 \times 10^{-6} \text{ m}^3$$

$$pV = nRT \quad \text{so} \quad n = pV \div RT$$

$$n = (100\,000 \times 598 \times 10^{-6}) \div (8.31 \times 300)$$

$$n = 59.8 \div 2493 = 0.02399 \text{ mol}$$

$$M_r(\text{CO}_2) = 12.0 + (2 \times 16.0) = 44.0$$

$$\text{mass} = 0.02399 \times 44.0 = 1.06 \text{ g}$$

Mass 1.06 g

07.3

State what a student would observe in a beaker after a reaction between sodium carbonate and an excess of hydrochloric acid.

[1 mark]

A colourless solution (all the solid has dissolved and the fizzing stops).

11

Turn over ►



0 8

When water is added to anhydrous cobalt chloride, the blue solid turns pink as shown.

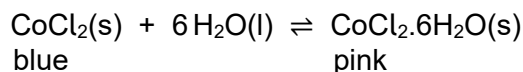


Table 2 shows some enthalpy data for this reaction.

Table 2

Substance	CoCl ₂ (s)	H ₂ O(l)	CoCl ₂ ·6H ₂ O(s)
Standard enthalpy of formation $\Delta_f H^\circ / \text{kJ mol}^{-1}$	−326	−286	−2130

0 8 . 1

Use the equation and the data in **Table 2** to calculate the enthalpy change, in kJ mol^{-1} , for the reaction.

[2 marks]

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

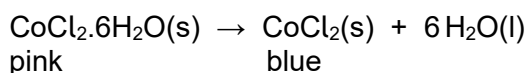
$$\Delta H = -2130 - [-326 + (6 \times -286)]$$

$$\Delta H = -2130 - (-2042) = -88$$

Enthalpy change −88 kJ mol^{-1}

0 8 . 2

Use your answer to Question **08.1** to deduce the enthalpy change for the following reaction.



(If you were unable to answer Question **08.1**, you should use the value -200 kJ mol^{-1} . This is **not** the correct answer.)

[1 mark]

Enthalpy change +88 kJ mol^{-1}



0 8 . 3

A student heats a sample of solid $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$ to obtain some completely dry CoCl_2

Suggest how the student could find out if the sample is completely dry.

[2 marks]

Weigh the sample, heat it again, cool it and reweigh it.

*Repeat until the mass no longer changes (heat to constant mass): then
all the water has been removed.*

5

END OF QUESTIONS



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2 4



2 2 6 X C H 0 1