

Please write clearly in block capitals.

Centre number

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Candidate number

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Surname StemUp Model Solution

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Candidate signature _____

I declare this is my own work.

INTERNATIONAL AS CHEMISTRY (9620)

Unit 1: Inorganic 1 and Physical 1

Thursday 6 January 2022 07:00 GMT 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.
- 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).
- All working must be shown.
- 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	
TOTAL	



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

0 1

This question is about some elements in Period 3.

Table 1 shows data about some elements in Period 3.

Table 1

Element	First ionisation energy / kJ mol^{-1}	Atomic radius / nm
magnesium	736	—
aluminium	577	—
silicon	786	0.117
phosphorus	1060	0.110
sulfur	1000	0.104

0 1 . 1

Explain why the first ionisation energy of aluminium is less than the first ionisation energy of magnesium.

[2 marks]

*the outer electron of aluminium is in a 3p sub-shell (orbital), whereas
in magnesium it is in the 3s sub-shell
the 3p sub-shell is higher in energy than 3s (and more shielded), so
less energy is needed to remove the electron*

0 1 . 2

Explain why the first ionisation energy of sulfur is less than the first ionisation energy of phosphorus.

[2 marks]

*in sulfur the 4th electron in the 3p sub-shell goes into an orbital that
already has one electron, so the 3p electrons begin to pair
the paired electrons repel each other, so one is easier to remove*



0 1 . 3

Identify the element in Period 3 that has the highest **third** ionisation energy.

[1 mark]

magnesium (Mg)

0 1 . 4

Explain the decrease in atomic radius of the elements silicon, phosphorus and sulfur.

[2 marks]

the nuclear charge increases (more protons) from Si to Selectrons are added to the same shell, so the shielding is similar, andthe outer electrons are pulled closer to the nucleus7

Turn over for the next question

Turn over ►



0 2

This question is about fluorine and its compounds.

0 2 . 1

State the meaning of the term electronegativity.

[1 mark]

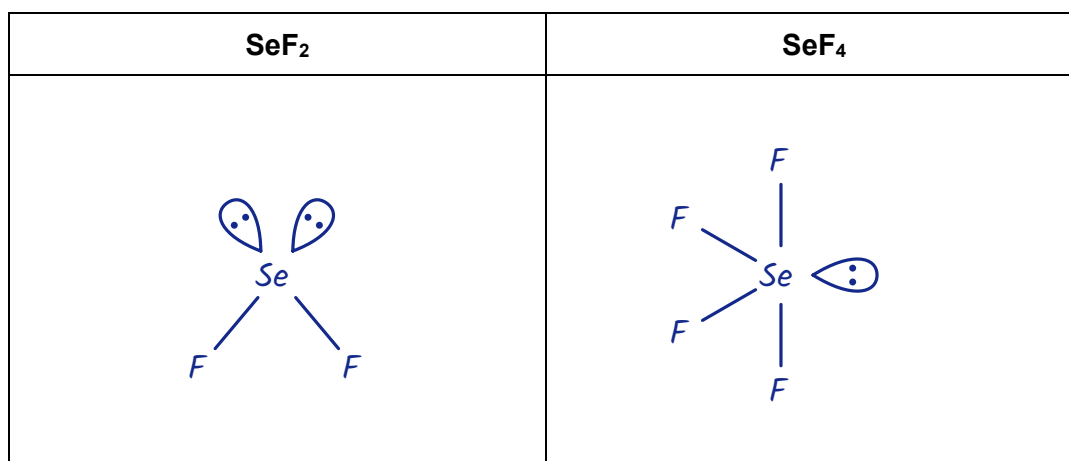
*the power of an atom to attract the pair of electrons (electron density)
in a covalent bond towards itself*

0 2 . 2

Draw the shape of a SeF_2 molecule and of a SeF_4 molecule.

Include any lone pairs of electrons that affect the shapes of the molecules.

[2 marks]



0 2 . 3

Van der Waals' forces exist between molecules of SeF_2

Explain how these forces arise.

[3 marks]

*electrons are constantly moving in a SeF_2 molecule, so at any instant
the electron distribution is uneven and a temporary dipole forms
this temporary dipole induces a dipole ($\delta+$ and $\delta-$) in a neighbouring
molecule
the $\delta+$ end of one molecule attracts the $\delta-$ end of the adjacent
molecule, so there are weak attractions between the molecules*



0 2 . 4

Explain how a lone pair of electrons in a molecule of NF_3 affects the bond angle in the molecule.

[2 marks]

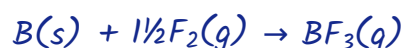
the lone pair on N repels more strongly than the bonding pairs (lone pair to bond pair repulsion is greater than bond pair to bond pair repulsion)
so the bonding pairs are pushed closer together and the F–N–F bond angle is reduced from 109.5° to about 107°

0 2 . 5

Boron reacts with fluorine to form the compound BF_3
 Boron is solid at 298 K

Write an equation, including state symbols, for the reaction that has an enthalpy change equal to the standard enthalpy of formation for $\text{BF}_3(\text{g})$

[1 mark]



0 2 . 6

BF_3 molecules are trigonal planar.

A molecule of BF_3 reacts with a fluoride ion to form a BF_4^- ion.

State the bond angle in the BF_3 molecule.

Describe how the bond between a BF_3 molecule and a fluoride ion is formed.

[2 marks]

Bond angle in BF_3 *120°*

How bond is formed *the F^- ion donates a lone pair (both electrons) to the boron atom in BF_3 , forming a co-ordinate (dative covalent) bond*

Question 2 continues on the next page

Turn over ►



0 2 . 7

The melting point of potassium fluoride (KF) is 1131 K but the melting point of iodine fluoride (IF) is 228 K

Explain, in terms of structure and bonding, why the melting point of KF is higher than the melting point of IF

[4 marks]

KF has a giant ionic lattice structure

there are strong electrostatic attractions between the oppositely charged

K^+ and F^- ions, which need a lot of energy to overcome

IF has a simple molecular structure (it consists of small molecules)

only weak intermolecular forces (van der Waals and dipole-dipole forces)

exist between IF molecules, which need little energy to overcome, so the

melting point of KF is much higher

15



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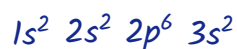
0 3

This question is about magnesium.

0 3 . 1

Give the full electron configuration of magnesium.

[1 mark]



0 3 . 2

Magnesium is used in the extraction of titanium metal from titanium(IV) chloride.

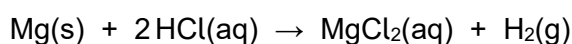
Write an equation for this reaction.

[1 mark]



0 3 . 3

A sample of magnesium reacts completely with an excess of hydrochloric acid to form hydrogen.

At 298 K and 101 kPa, the hydrogen formed has a volume of 149 cm³Calculate the mass, in g, of the sample of magnesium.
Give your answer to 3 significant figures.The gas constant, $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$

[4 marks]

$$V = 149 \text{ cm}^3 = 149 \times 10^{-6} \text{ m}^3 \quad p = 101\,000 \text{ Pa}$$

$$n = pV \div RT$$

$$n(H_2) = (101\,000 \times 149 \times 10^{-6}) \div (8.31 \times 298)$$

$$n(H_2) = 6.08 \times 10^{-3} \text{ mol} = n(Mg)$$

$$\text{mass Mg} = 6.08 \times 10^{-3} \times 24.3 = 0.1477 \text{ g}$$

$$= 0.148 \text{ g (3 s.f.)}$$

Mass 0.148 g

0 3 . 4

Calculate the minimum volume, in dm^3 , of $0.500 \text{ mol dm}^{-3}$ hydrochloric acid needed to react completely with all the sample of magnesium.

[2 marks]

$$n(\text{HCl}) = 2 \times 6.08 \times 10^{-3} = 0.01216 \text{ mol}$$

$$\text{volume} = n \div c = 0.01216 \div 0.500$$

$$\text{volume} = 0.0243 \text{ dm}^3$$

Volume 0.0243 dm^3

0 3 . 5

Magnesium reacts slowly with cold water to form magnesium hydroxide.

State **one** use of magnesium hydroxide.

[1 mark]

as an antacid, to neutralise excess stomach acid (indigestion)

0 3 . 6

Magnesium hydroxide decomposes on heating to form magnesium oxide.

Deduce an equation for the reaction.

[1 mark]



10

Turn over for the next question

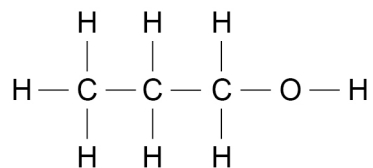
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0 4

This question is about energetics.

Propan-1-ol has the structure



Propan-1-ol burns according to the equation

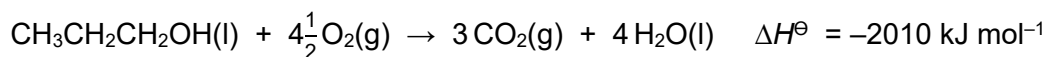


Table 2 shows some standard enthalpies of formation, $\Delta_f H^\ominus$

Table 2

	$\Delta_f H^\ominus / \text{kJ mol}^{-1}$
$\text{CO}_2\text{(g)}$	-394
$\text{H}_2\text{O(l)}$	-286

0 4 . 1

Use the data in **Table 2** to calculate a value, in kJ mol^{-1} , for the enthalpy of formation of $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH(l)}$

[2 marks]

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

$$-2010 = [(3 \times -394) + (4 \times -286)] - \Delta_f H$$

$$-2010 = -2326 - \Delta_f H$$

$$\Delta_f H = -2326 + 2010$$

$$\Delta_f H = -316 \text{ kJ mol}^{-1}$$

Enthalpy of formation -316 kJ mol^{-1}



0 4 . 2 Table 3 shows some bond enthalpy data.

Table 3

Bond	Bond enthalpy / kJ mol ⁻¹
C–C	348
C–H	412
C–O	360
O–H	463
O=O	496
C=O	805

Use the data in **Table 3** to calculate a value, in kJ mol⁻¹, for the enthalpy of combustion of CH₃CH₂CH₂OH(g)

[2 marks]

$$\text{bonds broken} = (7 \times 412) + (2 \times 348) + 360 + 463 + (4.5 \times 496)$$

$$= 6635 \text{ kJ mol}^{-1}$$

$$\text{bonds made} = (6 \times 805) + (8 \times 463) = 8534 \text{ kJ mol}^{-1}$$

$$\Delta H_c = 6635 - 8534$$

$$\Delta H_c = -1899 \text{ kJ mol}^{-1}$$

Enthalpy of combustion -1899 kJ mol⁻¹

0 4 . 3 Suggest **two** reasons why the value for enthalpy of combustion of propan-1-ol calculated in Question **04.2** is different from the value used in Question **04.1**.

[2 marks]

Reason 1 bond enthalpies are mean (average) values from a range of compounds

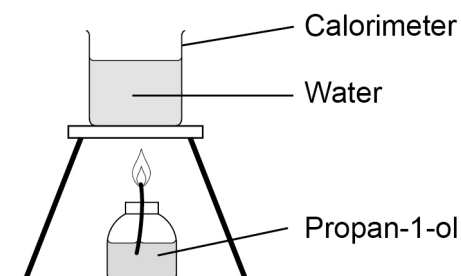
Reason 2 bond enthalpy calculations are for gases, but propan-1-ol is a liquid in 04.1

Turn over ►



0 4 . 4

A sample of propan-1-ol ($M_r = 60.0$) is burned to heat 250 g of water in a calorimeter.



The temperature of the water rises from 296 K to 319 K

Calculate the mass, in g, of propan-1-ol used in this experiment.

You may assume that all the heat energy from the flame is used to heat the water.

The specific heat capacity of water = $4.18 \text{ J K}^{-1} \text{ g}^{-1}$

$\Delta_c H^\ominus$ for propan-1-ol = $-2010 \text{ kJ mol}^{-1}$

[3 marks]

$$q = mc\Delta T = 250 \times 4.18 \times (319 - 296)$$

$$q = 24\,035 \text{ J} = 24.035 \text{ kJ}$$

$$n(\text{propan-1-ol}) = 24.035 \div 2010$$

$$n = 0.01196 \text{ mol}$$

$$\text{mass} = n \times M_r = 0.01196 \times 60.0$$

$$\text{mass} = 0.718 \text{ g}$$

mass 0.718 g

9



0 5

Bromine is an oxidising agent.

0 5 . 1

State, in terms of electrons, the meaning of oxidising agent.

[1 mark]

*an oxidising agent is an electron acceptor (it gains electrons)*In aqueous solution, bromine oxidises SO_2 to SO_4^{2-} ions.

0 5 . 2

Write a half-equation for the oxidation of aqueous SO_2 to SO_4^{2-} ions.

[1 mark]



0 5 . 3

Write an equation for the reaction of bromine with aqueous SO_2 Explain, using oxidation states, how bromine oxidises SO_2 to SO_4^{2-} ions.

[3 marks]

Equation

Explanation *the oxidation state of S increases from +4 in SO_2 to +6 in* *SO_4^{2-} , so S is oxidised**the oxidation state of Br decreases from 0 in Br_2 to -1 in Br^- , so**bromine is reduced (it gains the electrons lost by S)*

0 5 . 4

A few drops of aqueous bromine are added to a test tube that contains some sodium iodide solution.

State the colour change observed in the test tube.

Write an equation for this reaction.

[2 marks]

Colour change *colourless solution turns brown*

Equation



7

Turn over ►



0 6

This question is about argon.

0 6 . 1

Give the meaning of the term mass number.

[1 mark]

the total number of protons plus neutrons in the nucleus of an atom

0 6 . 2

The most abundant isotope of argon has mass number = 40

The most abundant isotope of potassium has mass number = 39

Justify why argon is placed before potassium in the Periodic Table.

Do **not** refer to the chemical properties of the elements in your answer.

[2 marks]

*the Periodic Table is arranged in order of atomic (proton) number, not mass number**argon has atomic number 18 but potassium has atomic number 19 (K has one more proton than Ar), so argon comes before potassium*

0 6 . 3

A sample of argon is analysed in a time of flight (TOF) mass spectrometer.

The first stage is ionisation of the argon atoms by electron impact.

Write an equation, including state symbols, for this ionisation.

[1 mark]



0 6 . 4

In the TOF mass spectrometer an $^{40}\text{Ar}^+$ ion takes 2.00×10^{-4} seconds to travel along a flight tube of length 1.25 m

The time of flight of an ion is shown by the equation

$$t = d \sqrt{\frac{m}{2 KE}}$$

m = mass / kg

d = length of flight tube / m

t = time of flight / s

KE = kinetic energy / J

Calculate the mass, in kg, of an $^{40}\text{Ar}^+$ ion.

Calculate the kinetic energy, in J, of the $^{40}\text{Ar}^+$ ion.
Give your answers to 3 significant figures.

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

[3 marks]

$$\text{mass of one ion} = 40 \div (1000 \times 6.02 \times 10^{23})$$

$$m = 6.645 \times 10^{-26} \text{ kg} = 6.64 \times 10^{-26} \text{ kg}$$

Mass of $^{40}\text{Ar}^+$ 6.64×10^{-26} kg

$$t = d\sqrt{m \div 2KE} \quad \text{so} \quad KE = d^2 m \div 2t^2$$

$$KE = (1.25)^2 \times 6.645 \times 10^{-26} \div (2 \times (2.00 \times 10^{-4})^2)$$

$$KE = 1.038 \times 10^{-25} \div (8.00 \times 10^{-8})$$

$$KE = 1.30 \times 10^{-18} \text{ J}$$

Kinetic energy 1.30×10^{-18} J

Turn over ►



0 6 . 5

A sample of argon that contains ^{38}Ar and ^{40}Ar is analysed using a TOF mass spectrometer.
The sample is ionised using electron impact.

Which statement is correct?

Tick (✓) **one** box.

[1 mark]

The kinetic energy of the $^{38}\text{Ar}^+$ ion is greater than the $^{40}\text{Ar}^+$ ion.

☐

The kinetic energy of the $^{38}\text{Ar}^+$ ion is the same as the $^{40}\text{Ar}^+$ ion.

☒

The kinetic energy of the $^{38}\text{Ar}^+$ ion is less than the $^{40}\text{Ar}^+$ ion.

☐

0 6 . 6

A different sample of argon has relative atomic mass = 39.964
This sample contains only two isotopes.
The abundance of the ^{40}Ar isotope in the sample is 99.090%

Calculate the mass number of the other isotope of argon in the sample.

[3 marks]

$$\text{abundance of other isotope} = 100 - 99.090 = 0.910\%$$

$$39.964 = [(40 \times 99.090) + (y \times 0.910)] \div 100$$

$$3996.4 = 3963.6 + 0.910y$$

$$0.910y = 32.8 \quad \text{so} \quad y = 36.04$$

$$\text{mass number} = 36$$

Mass number 36

11



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07

Test-tube reactions can be used to distinguish between pairs of colourless solutions.

07.1

Identify a reagent that can be used to distinguish between aqueous solutions of sodium sulfate and sodium nitrate.

Give the observation that would be made in each case.

[3 marks]

Reagent barium chloride solution, $\text{BaCl}_2(\text{aq})$

Observation with sodium sulfate white precipitate forms

Observation with sodium nitrate no visible change, solution stays colourless

07.2

Identify a reagent that can be used to distinguish between aqueous solutions of potassium carbonate and potassium hydroxide.

Give the observation that would be made in each case.

[3 marks]

Reagent dilute hydrochloric acid, $\text{HCl}(\text{aq})$

Observation with potassium carbonate fizzing (effervescence, CO_2 gas given off)

Observation with potassium hydroxide no visible change, colourless solution (it gets warm)

07.3

Describe a test-tube reaction to show that a solution of ammonium chloride contains ammonium ions.

[2 marks]

add sodium hydroxide solution to the ammonium chloride and warm gently

hold damp red litmus paper at the mouth of the test tube: ammonia gas is given off which turns the red litmus paper blue



0 7 . 4

Some acidified silver nitrate is added to separate aqueous solutions of two unknown potassium halides, **P** and **Q**.

A yellow precipitate is seen with **P**.

A colourless solution is seen with **Q**.

Give the formula of an acid that can be used to acidify the silver nitrate solution.

Give the formulas of the potassium halides **P** and **Q**.

[3 marks]

Formula of acid HNO_3

Formula of **P** KI

Formula of **Q** KF

11**END OF QUESTIONS**

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2 4



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