Topical Past Paper Questions Worksheets

AS & A Level Chemistry (9701) Paper 2

Exam Series: Feb/Mar 2017 – Oct/Nov 2023

Format Type B:
Each question is followed by its answer scheme

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Introduction

Each Topical Past Paper Questions Workbook contains a comprehensive collection of hundreds of questions and corresponding answer schemes, presented in worksheet format. The questions are carefully arranged according to their respective chapters and topics, which align with the latest IGCSE or AS/A Level subject content. Here are the key features of these resources:

1. The workbook covers a wide range of topics, which are organized according to the latest syllabus content for Cambridge IGCSE or AS/A Level exams.
2. Each topic includes numerous questions, allowing students to practice and reinforce their understanding of key concepts and skills.
3. The questions are accompanied by detailed answer schemes, which provide clear explanations and guidance for students to improve their performance.
4. The workbook's format is user-friendly, with worksheets that are easy to read and navigate.
5. This workbook is an ideal resource for students who want to familiarize themselves with the types of questions that may appear in their exams and to develop their problem-solving and analytical skills.

Overall, Topical Past Paper Questions Workbooks are a valuable tool for students preparing for IGCSE or AS/A Level exams, providing them with the opportunity to practice and refine their knowledge and skills in a structured and comprehensive manner. To provide a clearer description of this book's specifications, here are some key details:

- Title: Cambridge AS & A Level Chemistry (9701) Paper 2 Topical Past Paper Questions
- Subtitle: Exam Practice Worksheets With Answer Scheme
- Examination board: Cambridge Assessment International Education (CAIE)
- Subject code: 9701
- Years covered: Feb/Mar 2017 – Oct/Nov 2023
- Paper: 2
- Number of pages: 641
- Number of questions: 183

Contents

Chapter 1

Atomic structure

1. 9701_m22_qp_22 Q: 1

Fig. 1.1 shows how **first** ionisation energies vary across Period 2.

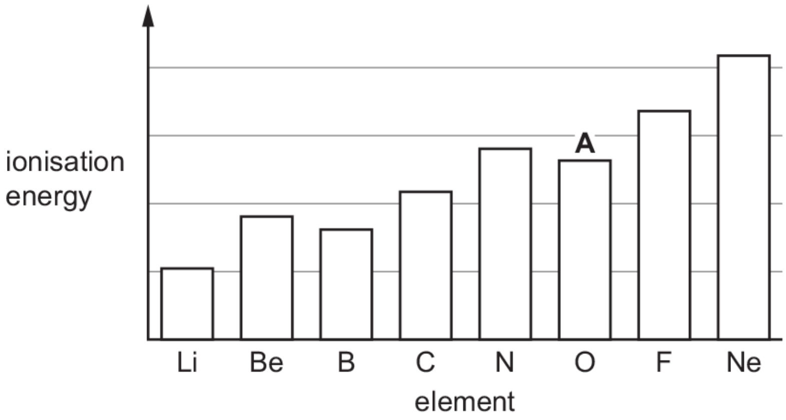


Fig. 1.1

(a) Construct an equation to represent the **first** ionisation energy of oxygen.
Include state symbols.

.... [1]

(b) (i) State and explain the general trend in first ionisation energies across Period 2.

....

....

....

....

.... [3]

(ii) Explain why ionisation energy **A** in Fig. 1.1 does **not** follow the general trend in first ionisation energies across Period 2.

....

....

....

.... [2]

(c) Element **E** is in Period 3 of the Periodic Table.
The first eight ionisation energy values of **E** are shown in Table 1.1.

Table 1.1

ionisation	1st	2nd	3rd	4th	5th	6th	7th	8th
ionisation energy / $kJ\,mol^{-1}$	577	1820	2740	11 600	14 800	18 400	23 400	27 500

Deduce the full electronic configuration of **E**.
Explain your answer.

full electronic configuration of **E** = ...

explanation ....

....

.... [3]

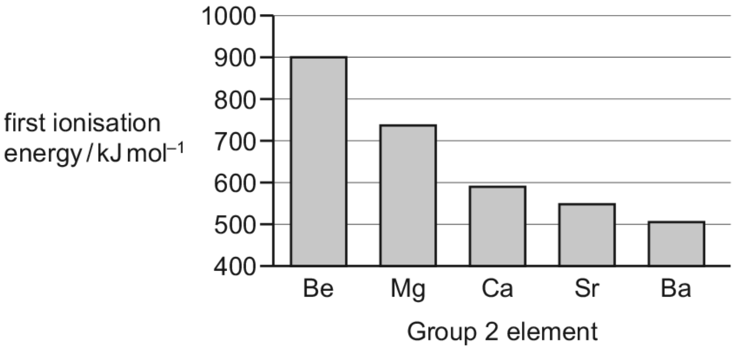
[Total: 9]

Answer:

Question	Answer	Marks
(a)	$O(g) \rightarrow O^{+}(g) + e^{-}$	**1**
(b)(i)	increase across period **AND** increased nuclear attraction **for** (valence / outer) **electrons** [1] increase in (positive) nuclear charge / number of protons (in the nucleus) [1] similar shielding (of outer electrons) [1]	**3**
(b)(ii)	spin-pair repulsion (of electrons) in (2)p orbital [1] outweighs increased nuclear charge [1]	**2**
(c)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$ [1] greatest jump between 3rd and 4th ionisations [1] indicates three electrons in outer shell [1]	**3**

2. 9701_w20_qp_21 Q: 1

The graph shows the first ionisation energies of some of the elements in Group 2.



(a) Write an equation for the first ionisation energy of Mg.

Include state symbols.

.... [1]

(b) Explain the observed trend in first ionisation energies down Group 2.

....

....

....

....

....

.... [3]

(c) The second ionisation energy of Be is 1757 kJ mol^{-1}.

Explain why the second ionisation energy of Be is higher than the first ionisation energy of Be.

....

....

....

....

.... [2]

[Total: 6]

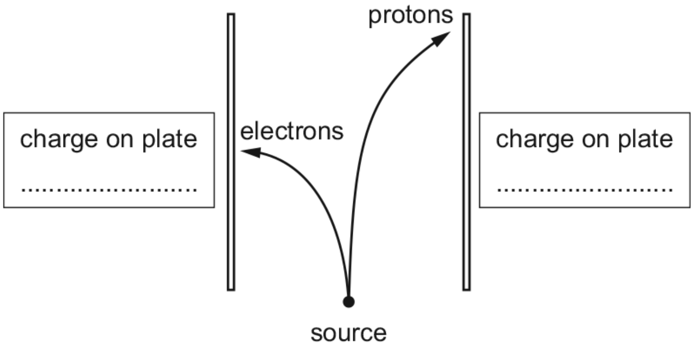
Answer:

(a)	$Mg(g) \rightarrow Mg^{+}(g) + e^{(-)}$	**1**
(b)	**M1:** distance between nucleus and **outer e⁻** increases **OR outer electron** removed from higher energy shell	**3**
	M2: increased **shielding**	
	M3: decreased **nuclear** attraction	
(c)	**M1**: **greater nuclear attraction**	**2**
	M2: (2nd / 2s) electron being removed from **smaller** (ion)	

3. 9701_w20_qp_22 Q: 1

Atoms contain the subatomic particles electrons, protons and neutrons. Protons and electrons were discovered by observations of their behaviours in electric fields.

(a) The diagram shows the behaviour of separate beams of electrons and protons in an electric field.



(i) Complete the diagram with the relative charge of each of the electrically charged plates. [1]

(ii) On the diagram, draw a line to show how a separate beam of neutrons from the same source behaves in the same electric field. [1]

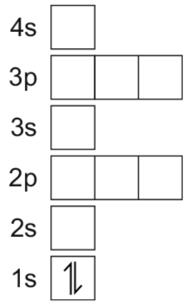
(b) Electrons in atoms up to $_{36}Kr$ are distributed in s, p and d orbitals.

(i) State the number of occupied orbitals in an isolated atom of $_{36}Kr$.

type of orbital	s	p	d
number of orbitals			

[3]

(ii) Complete the diagram to show the number and relative energies of the electrons in an isolated atom of $_{14}Si$.



[2]

(iii) The diagram shows a type of orbital.

State the total number of electrons that exist in all orbitals of this type in an atom of $_{9}F$.

.... [1]

(iv) The first ionisation energies of elements in the first row of the d block ($_{21}Sc$ to $_{29}Cu$) are very similar. For all these elements, it is a 4s electron that is lost during the first ionisation.

Suggest why the first ionisation energies of these elements are very similar.

....

....

....

.... [3]

(c) *Hydron* is a general term used to represent the ions $^{1}_{1}H^{+}$, $^{2}_{1}H^{+}$ and $^{3}_{1}H^{+}$.

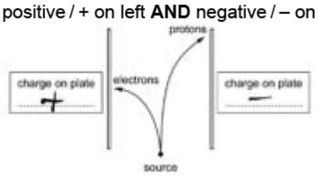
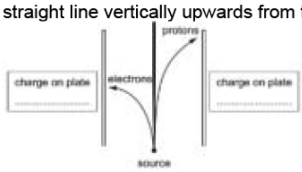
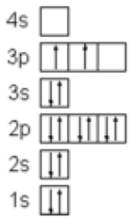
State, in terms of subatomic particles in the nucleus, what is the same about each of these ions and what is different.

same ....

different ....
[1]

[Total: 12]

Answer:

<table>
<tr><td>(a)(i)</td><td>positive / + on left AND negative / – on right

</td><td>1</td></tr>
<tr><td>(a)(ii)</td><td>straight line vertically upwards from the source

</td><td>1</td></tr>
<tr><td>(b)(i)</td><td><table><tr><td>type of orbital</td><td>s</td><td>p</td><td>d</td></tr><tr><td>number of orbitals</td><td>4</td><td>9</td><td>5</td></tr></table></td><td>3</td></tr>
<tr><td>(b)(ii)</td><td>
</td><td>2</td></tr>
<tr><td>(b)(iii)</td><td>5</td><td>1</td></tr>
<tr><td>(b)(iv)</td><td>Award one mark for each correct bullet point – max 3 marks
• nuclear charge increases
• extra electron(s) in inner shell / n=3 /d-subshell / d- orbital
• increased shielding (of 4s electrons by electrons in n=3 / 3rd shell / 3d)
• (overall) similar nuclear attraction (for outer electron)</td><td>3</td></tr>
<tr><td>(c)</td><td>answer in terms of subatomic particles in the nucleus
same (number of) protons
AND
different (number of) neutrons</td><td>1</td></tr>
</table>

Chapter 2

Atoms, molecules and stoichiometry

4. 9701_w22_qp_21 Q: 1

Atoms with nuclei containing an odd number of protons tend to have fewer isotopes than those with an even number of protons.

(a) Gallium has two stable isotopes, ^{69}Ga and ^{71}Ga.

(i) Complete Table 1.1 to show the numbers of protons, neutrons and electrons in the two stable isotopes of gallium.

Table 1.1

isotope	number of protons	number of neutrons	number of electrons
^{69}Ga			
^{71}Ga			

[2]

(ii) Define relative atomic mass.

....

....

.... [2]

(iii) The relative atomic mass of gallium, A_r, is 69.723.
The relative isotopic masses of ^{69}Ga and ^{71}Ga are:

^{69}Ga, 68.926; ^{71}Ga, 70.925.

Use this information to calculate the percentage abundance of ^{69}Ga in elemental gallium.
Show your working.
Assume that the element contains only the ^{69}Ga and ^{71}Ga isotopes.
Give your answer to **four** significant figures.

percentage abundance of ^{69}Ga = ... %
[2]

(b) Potassium also has two stable isotopes. Both isotopes have the same chemical properties.

(i) Explain why both isotopes of potassium have the same chemical properties.

....

.... [1]

(ii) State the full electronic configuration of an atom of potassium.

.... [1]

(iii) The first, second and third ionisation energies of potassium are 418, 3070 and 4600 kJ mol^{-1}, respectively.

Use this information to explain why potassium is in Group 1.

....

....

....

.... [2]

[Total: 10]

Answer:

Question	Answer	Marks
(a)(i)	columns 1 & 3 identical *isotope* | *No of p's* | *No of n's* | *No of e's* ^{69}*Ga* | *31* | *38* | *31* ^{71}*Ga* | *31* | *40* | *31*	1
	• √ √	1
(a)(ii)	**M1** (weighted) average / mean mass of the isotopes / average mass of the atom(s) (of an element)	1
	M2 compared to (the mass of) the unified atomic mass unit	1
(a)(iii)	69.723 = 68.926x + 70.925(1– x) ∴ x = 0.6013 / 69.723 = $\frac{68.926x + 70.925(100 - x)}{100}$	1
	60.13%	1
(b)(i)	they have the same electron arrangement / electronic configuration	1
(b)(ii)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$	1
(b)(iii)	**M1** big increase in IE between first and second **M2** second **(**and third**)** electron(s) is removed from inner shell **OR** second **(**and third**)** electron(s) is removed from a shell closer to the nucleus **OR** second **(**and third**)** electron(s) has a stronger nuclear attraction **ora**	2

5. 9701_s17_qp_22 Q: 1

The composition of atoms and ions can be determined from knowledge of atomic number, nucleon number and charge.

(a) Complete the table.

atomic number	nucleon number	number of electrons	number of protons	number of neutrons	symbol
3		2			$^{6}_{3}Li^{+}$
		23	26	32	

[2]

(b) Boron occurs naturally as a mixture of two stable isotopes, ^{10}B and ^{11}B. The relative isotopic masses and percentage abundances are shown.

isotope	relative isotopic mass	abundance / %
^{10}B	10.0129	19.78
^{11}B	to be calculated	80.22

(i) Define the term *relative isotopic mass*.

....

.... [2]

(ii) Calculate the relative isotopic mass of ^{11}B.

Give your answer to **six** significant figures. Show your working.

[2]

[Total: 6]

Answer:

<table>
<tr><td>(a)</td><td>
<table>
<tr><th>atomic number</th><th>nucleon number</th><th>number of electrons</th><th>number of protons</th><th>number of neutrons</th><th>symbol</th><th></th></tr>
<tr><td></td><td>6</td><td></td><td>3</td><td>3</td><td></td><td>1</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td>$^{58}_{26}Fe^{3+}$</td><td>1</td></tr>
</table>
</td><td>2</td></tr>
<tr><td>(b)(i)</td><td>EITHER
mass of an atom / isotope
relative / compared to 1/12 (the mass) of (an atom of) C-12 OR
on a scale in which a C-12 (atom / isotope) has (a mass of exactly) 12 (units)

OR
mass of one mol (of atoms) of an isotope
relative / compared to 1/12 (the mass) of 1 mol of C-12 OR
on a scale in which one mol C-12 (atom / isotope) has a mass of (exactly) 12 g</td><td>2
1
1</td></tr>
<tr><td>(b)(ii)</td><td>$\frac{(10.0129 \times 19.78) + (80.22x)}{100} = 10.8$</td><td>1</td></tr>
<tr><td></td><td>x = 10.9941</td><td>1</td></tr>
<tr><td></td><td>Total:</td><td>6</td></tr>
</table>

Chapter 3

Chemical bonding

6. 9701_m23_qp_22 Q: 1

The Pauling electronegativity values of elements can be used to predict the chemical properties of compounds.

Use the information in Table 1.1 to answer the following questions.

Table 1.1

element	H	Li	C	O	S
Pauling electronegativity value	2.1	1.0	2.5	3.5	2.6
first ionisation energy / $kJ\,mol^{-1}$	1310	519	1090	1310	1000
second ionisation energy / $kJ\,mol^{-1}$	—	7300	2350	3390	2260

(a) **(i)** Define electronegativity.

....

.... [1]

(ii) O and S are in Group 16.

Explain the difference in the Pauling electronegativity values of O and S.

....

....

.... [2]

(b) **(i)** LiH is an ionic compound.

Draw a dot-and-cross diagram of LiH.

Include **all** electrons.

[2]

(ii) Suggest the shape of a molecule of H_2S.

.... [1]

(c) **(i)** Write an equation that represents the first ionisation energy of H.

.... [1]

(ii) Explain why there is no information given in Table 1.1 for the second ionisation energy of H.

.... [1]

(iii) Give the full electronic configuration of $S^{2+}(g)$.

.... [1]

(d) CO_2 and SO_2 are acidic gases.

(i) Write an equation for the reaction of SO_2 with H_2O.

.... [1]

(ii) Write an equation for the reaction of SO_2 with NaOH.

.... [1]

(iii) Construct an equation for the reaction of CO_2 with $Mg(OH)_2$.

.... [1]

(e) **(i)** Complete Table 1.2 by placing a tick (✓) to show which of the compounds have molecules with an overall dipole moment.

Table 1.2

compound	O=C=O	O=S=O	S=C=S	S=C=O
overall dipole moment				

[2]

(ii) At 150 °C and 103 kPa, all of the compounds listed in Table 1.2 are gases.

Under these conditions, 0.284 g of one of the compounds occupies a volume of 127 cm^3.

Use this information to calculate the M_r of the compound. Hence, identify the compound from those given in Table 1.2.

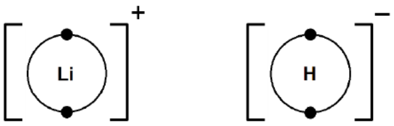
Show your working.

M_r = ... identity of compound = ...

[3]

[Total: 17]

Answer:

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>(a)(i)</td><td>power of an atom to attract electrons to itself</td><td>1</td></tr>
<tr><td>(a)(ii)</td><td>• O lower nuclear charge / lower proton number
• O has (one) fewer shell than S / less shielding
• greater attraction (for nucleus) in O</td><td>2</td></tr>
<tr><td>(b)(i)</td><td></td><td>2</td></tr>
<tr><td>(b)(ii)</td><td>non-linear</td><td>1</td></tr>
<tr><td>(c)(i)</td><td>$H(g) \rightarrow H^+(g) + e^-$</td><td>1</td></tr>
<tr><td>(c)(ii)</td><td>H (cannot undergo second ionisation because it only) has one electron / H^+ has no electron</td><td>1</td></tr>
<tr><td>(c)(iii)</td><td>$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$</td><td>1</td></tr>
<tr><td>(d)(i)</td><td>$SO_2 + H_2O \rightarrow H_2SO_3$</td><td>1</td></tr>
<tr><td>(d)(ii)</td><td>$SO_2 + 2NaOH \rightarrow Na_2SO_3 + H_2O$</td><td>1</td></tr>
<tr><td>(d)(iii)</td><td>$CO_2 + Mg(OH)_2 \rightarrow MgCO_3 + H_2O$</td><td>1</td></tr>
<tr><td>(e)(i)</td><td><table><tr><td>compound</td><td>O=C=O</td><td>O=S=O</td><td>S=C=S</td><td>S=C=O</td></tr><tr><td>overall dipole moment</td><td></td><td>✓</td><td></td><td>✓</td></tr></table></td><td>2</td></tr>
</table>

Question	Answer		Marks
(e)(ii)	*conversion of units*	103000 Pa $127 \times 10^{-6}\ m^3$ 423 K	1
	Use of $pV = (m / M_r)RT$	$M_r = \dfrac{0.284 \times 8.31 \times 423}{103000 \times 127 \times 10^{-6}}$	1
		$M_r = 76.3$ **AND** compound = CS_2	1

7. 9701_s23_qp_22 Q: 1

The melting points of some solids are shown in Table 1.1.

Table 1.1

solid	melting point / K
magnesium	923
phosphorus	317
sodium chloride	1074
sulfur	392

(a) **(i)** State the type of bonding present in magnesium and in sodium chloride.

bonding in magnesium ....

bonding in sodium chloride ....
[1]

(ii) Explain the difference in the melting points of magnesium and sodium chloride.

....

.... [1]

(iii) Explain the difference in the melting points of phosphorus and sulfur in terms of structure and bonding.

....

....

.... [2]

(b) **(i)** Define electronegativity.

....

.... [1]

(ii) Explain why electronegativity increases across a period.

....

....

.... [2]

(iii) Name the strongest intermolecular force that exists between $NH_3(l)$ molecules.

.... [1]

(iv) Draw a diagram to show the formation of the strongest intermolecular force between **two** molecules of $NH_3(l)$.

Include any relevant lone pairs of electrons and dipoles.

[2]

(v) The melting points of ice and ammonia are shown in Table 1.2.

Table 1.2

solid	melting point / K
ice	273
ammonia	195

Suggest **two** reasons for the difference in the melting points of ice and ammonia.

....

....

.... [2]

[Total: 12]

Answer:

Question	Answer	Marks
(a)(i)	bonding in magnesium – metallic **AND** bonding in sodium chloride – ionic	**1**
(a)(ii)	bonds in Na*Cl* are stronger than bonds in Mg	**1**
(a)(iii)	**M1** S_8 / molecules of sulfur have more electrons (than P_4 / molecules of phosphorus) **M2** S has stronger instantaneous dipole–induced dipole forces (than phosphorus / P)	**2**
(b)(i)	power of an atom to attract electrons to itself	**1**
(b)(ii)	(across a period) • increase in nuclear charge • similar shielding • (so) increase in nuclear attraction for bonding / outer / valence electrons **OR** bonding / outer / valence electron(s) are more strongly attracted to nucleus Two correct for one mark, three correct for two marks	**2**
(b)(iii)	hydrogen bond	**1**
(b)(iv)	**M1** link shown as a dashed line between the lone pair of electrons from N of one NH_3 to one H on other NH_3 **M2** minimum 3 correct partial charges (on adjacent atoms) over two NH_3 molecules **EITHER** $^{\delta-}$N—$^{\delta+}$H - - - $^{\delta-}$N **OR** $^{\delta+}$H - - -$^{\delta-}$N—$^{\delta+}$H	**2**
(b)(v)	**M1** O is more electronegative than N **M2** two H-bonds per water molecule : 1 per ammonia molecule.	**2**

Chapter 4

States of matter

8. 9701_s22_qp_23 Q: 1

(a) Define first ionisation energy.

....

....

.... [2]

(b) Successive ionisation energies for element **A** are shown in Table 1.1.

Table 1.1

ionisation	1st	2nd	3rd	4th	5th	6th	7th	8th
ionisation energy / $kJ\,mol^{-1}$	1310	3390	5320	7450	11 000	13 300	71 000	84 100

Use Table 1.1 to deduce the group of the Periodic Table that **A** belongs to. Explain your answer.

Group ....

....
[1]

(c) Across Period 3 there is a general trend for first ionisation energies to increase due to the increase in attraction between the nucleus and the outer electron.

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

....

....

.... [2]

(d) In an Al^{2+} ion the nuclear attraction for the outer electron is stronger than in an atom of Na.

Compare the electronic structures of Al^{2+} and an atom of Na and explain why the third ionisation energy of aluminium is greater than the first ionisation energy of sodium.

....

....

....

.... [2]

(e) An isotope of copper has a relative isotopic mass of 65.

Complete Table 1.2 for an atom of copper-65.

Table 1.2

	atomic number	nucleon number	number of neutrons	electronic arrangement
copper-65				

[3]

(f) **(i)** The element copper has a relative atomic mass of 63.5.

Calculate how many atoms are present in 1.05 g of copper.

atoms of copper present = ... [1]

(ii) Copper has a melting point of 1085 °C and a high electrical conductivity.

Explain these properties of copper by referring to its structure and bonding.

....

....

.... [2]

[Total: 13]

Answer:

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>(a)</td><td>• energy required
• when one electron is removed
• from each atom in one mole of
• gaseous atoms
two or three points for one mark, four points for two marks</td><td>2</td></tr>
<tr><td>(b)</td><td>Group VI / 16 AND large increase (in IE) after 6th</td><td>1</td></tr>
<tr><td>(c)</td><td>M1 reference to spin pair repulsion in (3)p orbital (in S)
OR due to repulsion of two electrons in a (3)p orbital (in S)

M2 outweighs increased nuclear charge (in S)</td><td>2</td></tr>
<tr><td>(d)</td><td>M1 similarity in electronic structure / shielding of Al^{2+} and Na
both remove electron from (3)s^1 / single electron in (3)s (sub-level / orbital)
OR Al^{2+} and Na have same electronic configuration
OR shielding (of outer electron) is the same

M2 greater nuclear charge / number of protons
$Al^{(2+)}$ has greater nuclear charge
OR 13p compared to 11p</td><td>2</td></tr>
<tr><td>(e)</td><td><table><tr><th></th><th>atomic no.</th><th>nucleon no.</th><th>no.of neutrons</th><th>electronic arrangement</th></tr><tr><td>copper –65</td><td>29</td><td>65</td><td>65 – 29 = 36</td><td>$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}4s^1$</td></tr></table>
M1 29 AND 65

M2 nucleon no – atomic no
ALLOW ecf from M1

M3 electronic arrangement</td><td>3</td></tr>
</table>

Question	Answer	Marks
(f)(i)	M_r = 63.5 (1.05 / 63.5) × 6.022 × 10^{23} = 9.95**8** × 10^{21} **OR** 9.96 × 10^{21}	1
(f)(ii)	**M1** *comment explaining high melting point of Cu* many strong metallic bonds **OR** many strong (electrostatic) attractions between cations and delocalised electrons **OR** strong bonds in giant metallic structure. **M2** *comment explaining electrical conductivity of Cu* delocalised electrons are free are to move through the structure (owtte)	2

9. 9701_s21_qp_22 Q: 2

The strength of interaction between particles determines whether the substance is a solid, liquid or gas at room temperature.

(a) Lithium sulfide, Li_2S, is a crystalline solid with a melting point of 938 °C. It conducts electricity when it is molten.

(i) Give the formulae of the particles present in solid lithium sulfide.

.... [1]

(ii) Explain, in terms of the structure of the crystalline solid, why lithium sulfide has a high melting point.

....

.... [2]

(b) Carbon monoxide, CO, is a gas at room temperature and pressure. It contains a coordinate bond.

(i) Explain what is meant by *coordinate bond*.

....

.... [1]

(ii) Draw a 'dot-and-cross' diagram to show the arrangement of outer electrons in CO.

Show the electrons belonging to the C atom as ×.

Show the electrons belonging to the O atom as ●.

[2]

Nitrogen, N_2, is also a gas at room temperature and pressure. Neither CO nor N_2 is an ideal gas.

(i) State two assumptions that are made about the behaviour of particles in an ideal gas.

1 ....

....

2 ....

....
[2]

(ii) Explain why N_2 does not behave as an ideal gas at very high pressures.

....

....

....

.... [2]

(iii) Complete the table by naming **all** the types of intermolecular forces (van der Waals') in separate samples of N_2(g) and CO(g).

	N_2(g)	CO(g)
number of electrons per molecule	14	14
presence of a dipole moment	✗	✓
boiling point / °C	–195.8	–191.5
intermolecular forces (van der Waals')		

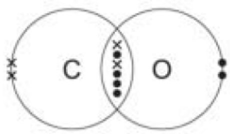
[2]

(iv) Suggest why the bond in a molecule of CO contains a dipole moment.

.... [1]

[Total: 13]

Answer:

Question	Answer	Marks
(a)(i)	Li^+ AND S^{2-}	1
(a)(ii)	**M1** giant	1
	M2 (many) strong force(s) of attraction between oppositely charged ions OR (many) strong ionic bond(s)	1
(b)(i)	(covalent) bond with both electrons are provided from the same / one species OR shared pair (of electrons) are provided from the same species / one atom *owtte*	1
(b)(ii)	3 bonding pairs between C and O, 4 •'s AND 2×'s 1 lone pair on C, ××, AND 1 lone pair on O, ••. 	2

Question	Answer	Mark
(c)(i)	*Any two assumptions about the behaviour of particles in an ideal gas from* • (particles / molecules have mass but) negligible size / volume (compared to total volume of gas / container) • no / negligible forces / interactions (between particles / molecules) • collisions are elastic	2
(c)(ii)	**M1** IMF become larger / more significant	1
	M2 volume of <u>molecules / particles</u> becomes significant / no longer negligible	1
(c)(iii)	N_2(g): instantaneous dipole–induced dipole ✓ CO(g): instantaneous dipole–induced dipole (and) permanent dipole–permanent dipole ✓	2
(c)(iv)	O is more electronegative than C	1

10. 9701_s20_qp_23 Q: 2

(a) Explain what is meant by the term *relative isotopic mass*.

....

....

.... [2]

(b) A sample of copper contains two isotopes, ^{63}Cu and ^{65}Cu. The relative atomic mass of the copper in this sample is 63.55.

Calculate the percentage abundance of each of these isotopes. Show your working.

percentage abundance of ^{63}Cu = ... %

percentage abundance of ^{65}Cu = ... %
[2]

(c) **(i)** Name the type of bonding within a sample of solid copper.

.... [1]

(ii) Draw a labelled diagram to show the bonding within a sample of solid copper.

[2]

(iii) State the electronic configuration of a copper atom.

$1s^2$ .... [1]

(d) A student is provided with a sample of hydrated copper(II) sulfate, $CuSO_4{\bullet}xH_2O$, and is asked to determine the value of x.
The student dissolves a sample of the hydrated copper(II) sulfate in water and adds it to an excess of aqueous potassium iodide to make a total volume of 250.0 cm³ of solution.

$$2CuSO_4 + 4KI \rightarrow 2CuI + I_2 + K_2SO_4$$

The amount of iodine produced during this reaction is found by titrating a sample of this solution with sodium thiosulfate solution.

25.0 cm³ of the iodine-containing solution requires 20.0 cm³ of 0.10 mol dm^{-3} sodium thiosulfate solution.

$$I_2 + 2S_2O_3^{2-} \rightarrow S_4O_6^{2-} + 2I^-$$

(i) Calculate the amount, in mol, of copper(II) sulfate present in the original sample of hydrated copper(II) sulfate.

Show your working.

amount of copper(II) sulfate = ... mol [2]

(ii) A total of 7.98 g of $CuSO_4$ is present in 10.68 g of $CuSO_4{\bullet}xH_2O$.

Complete each row of the table to calculate the value of x, where x is an integer.

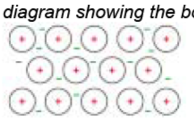
[M_r: $CuSO_4$,159.6]

amount of $CuSO_4$ in 10.68 g of $CuSO_4{\bullet}xH_2O$	.... mol
amount of H_2O in 10.68 g of $CuSO_4{\bullet}xH_2O$	.... mol
value of x	x = ...

[3]

[Total: 13]

Answer:

(a)	**EITHER** **M1** mass of an atom / isotope **M2** relative / compared to 1/12 (the mass) of (an atom of) C-12 OR on a scale in which a C-12 (atom / isotope) has (a mass of exactly) 12 (units) **OR** **M1** mass of one mol (of atoms) of an isotope **M2** relative / compared to 1/12 (the mass) of 1 mol of C-12 OR in which one mol C-12 (atom / isotope) has a mass of (exactly) 12 g	**2**
(b)	% abundance of ^{63}Cu = 72.5% % abundance of ^{65}Cu = 27.5% **M1** *correct algebraic expression AND correct calculation of x for one isotope* % ab of ^{63}Cu = x (x/100 × 63) + ((1- x)/100 × 65) = 63.55 so x =72.5 OR % ab of ^{65}Cu = x (1- x)/100 × 63) + x/100 × 65) = 63.55 so x = *27.5* **M2** *calculation of abundance of other isotope by 100- x*	**2**
(c)(i)	metallic	**1**
(c)(ii)	*diagram showing the bonding in a sample of copper*  **M1** diagram shows regular arrangement of spheres labelled as positively charged ions / +2 or +1 / cations **M2** diagram shows surrounded by electrons and clearly labelled as 'delocalised electrons'	**3**
(c)(iii)	($1s^2$) $2s^2$ $2p^6$ $3s^2$ $3p^6$ $3d^{10}$ $4s^1$ **OR** ($1s^2$) $2s^2$ $2p^6$ $3s^2$ $3p^6$ $4s^1$ $3d^{10}$	**1**
(d)(i)	**M1** *calculate the number mol $S_2O_3^{2-}$ added* 20/1000 x 0.10 = $2x10^{-3}$ = 0.002 (mol $S_2O_3^{2-}$) **M2** *calculate number mol $CuSO_4$ in 250cm^3* (1mol $S_2O_3^{2-}$: 1 mol $CuSO_4$) = 0.002 mol $CuSO_4$ in 25cm^3 so 0.02 mol $CuSO_4$ in 250cm^3	**2**
(d)(ii)	**M1** amount of $CuSO_4$ in 10.68 g of $CuSO_4{\cdot}xH_2O$ — 7.98 / (159.6) = <u>0.05</u> (mol) **M2** amount of H_2O in 10.68 g of $CuSO_4{\cdot}xH_2O$ — (10.68 – 7.98) / 18 = 2.7 / 18 =) <u>0.15</u> (mol) **M3** value of **x** — (mol H_2O ÷ mol $CuSO_4$ =) 3	**3**

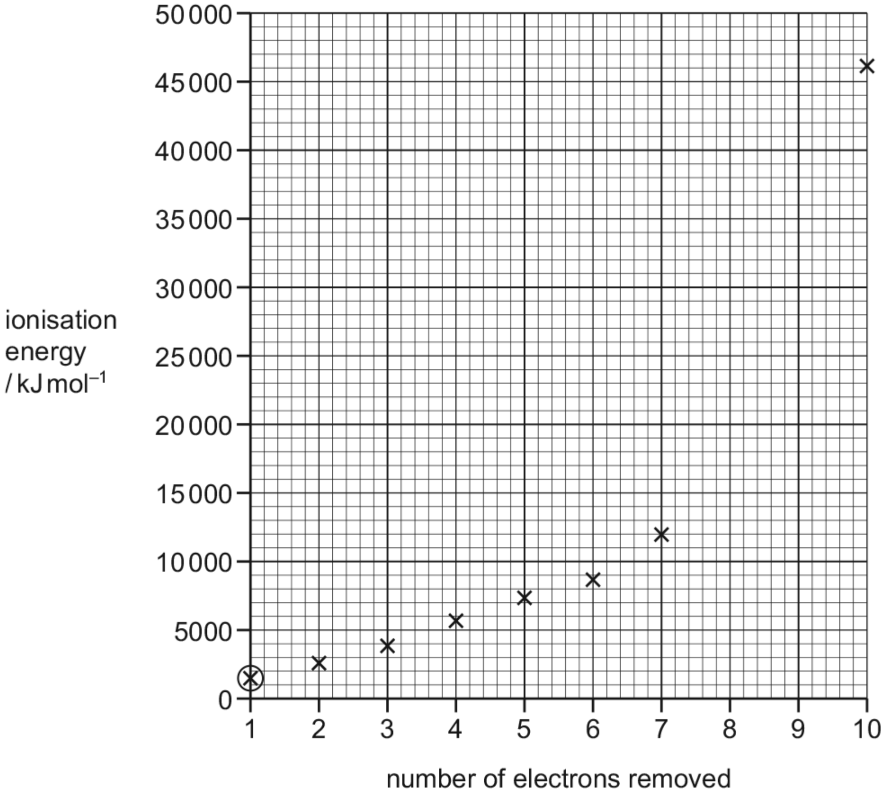
11. 9701_s19_qp_21 Q: 3

(a) Construct an equation for the **second** ionisation energy of argon.

.... [1]

(b) The graph shows successive ionisation energies for the element argon.

Complete the graph with predictions for the eighth and ninth ionisation energies of argon. Use a cross (×) for each data point. [2]



(c) The energy value required to remove the first electron from an atom of argon is circled on the graph.

Sketch the shape of the orbital that contains this electron.

[1]

(d) Chlorine exists as a diatomic gas, Cl_2(g). A sample of Cl_2(g) was made during a chemical reaction. When measured at 404 kPa and 25 °C the sample occupied a volume of 20.0 cm^3.

(i) Calculate the mass, in grams, of Cl_2(g) formed.

For this calculation, assume that chlorine behaves as an ideal gas under these conditions.

mass of Cl_2(g) = ... g [3]

(ii) Calculate the number of chlorine atoms in this sample of Cl_2(g). You may find it helpful to use your answer to **(d)(i)**.

If you are unable to calculate an answer to **(d)(i)**, use 0.36 g of Cl_2. This is **not** the correct answer.

number of chlorine atoms = ... [2]

(iii) Cl_2(g) does **not** behave as an ideal gas under these conditions.

Explain why Cl_2(g) behaves even **less** ideally at:

- very high pressures

....

....

....

- very low temperatures.

....

....

....

[2]

[Total: 11]

Answer:

(a)	$Ar^{+}(g) \rightarrow Ar^{2+}(g) + e^{(-)}$ **OR** $Ar^{+}(g) - e^{(-)} \rightarrow Ar^{2+}(g)$	1
(b)	at $x = 8$, within range 13000–20000	1
	at $x = 9$, within range 35000–45000	1
(c)	 **OR** 	1
(d)(i)	**M1** *correct conversions of data to SI/consistent units* $p = 404\,000$; $V = 20 \times 10^{-6}$; $T = 298$	1
	M2 *calculation of n (= pV/RT) from* ***M1*** *values* $n = \dfrac{404000 \times 20 \times 10^{-6}}{8.31 \times 298} = 3.263 \times 10^{-3}$ mol of Cl_2	1
	M3 *finding the mass of* Cl_2 $= 3.263 \times 10^{-3} \times 71.0 = 0.23$ (g)	1
(d)(ii)	**Method 1** **M1** $= 3.263 \times 10^{-3} \times 2$ **Method 2** **M1** $= \dfrac{0.23}{71.0} \times 2$ **OR** 6.53×10^{-3}	1
	Method 1: **M2** $= 6.02 \times 10^{23} \times$ **M1** $= 3.93 \times 10^{21}$ atoms of Cl Method 2: **M2** $= 6.02 \times 10^{23} \times$ **M1** $= 3.90 \times 10^{21}$ atoms of Cl	1
(d)(iii)	**M1** size / volume of **molecule / particle** becomes significant / non-negligible **OR** IMFs become significant / non-negligible	1
	M2 IMFs becomes significant / non-negligible / collisions are not elastic	1

12. 9701_w17_qp_22 Q: 1

The elements sodium to sulfur react with chlorine. The melting points of some of the chlorides formed are shown.

chloride	$NaCl$	$MgCl_2$	$AlCl_3$	$SiCl_4$	PCl_3	SCl_2
melting point / K	1074	987	463	203	161	195

(a) Predict the shapes of $AlCl_3$ and PCl_3.

Draw diagrams to show the shapes, name the shapes and state the bond angles.

$AlCl_3$	PCl_3
shape	shape ....
angle	angle ....

[4]

(b) **(i)** Explain, in terms of structure and bonding, why the melting point of $SiCl_4$ is much lower than that of $NaCl$.

....

....

....

....

.... [3]

(ii) Explain why the melting point of $SiCl_4$ is higher than that of PCl_3.

....

....

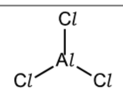
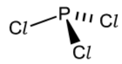
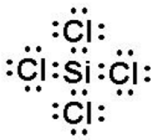
.... [2]

(iii) Draw the 'dot-and-cross' diagram of a molecule of $SiCl_4$.
Show outer electrons only.

[1]

[Total: 10]

Answer:

(a)	 trigonal planar 120°  (trigonal) pyramid(al) 100–107° 3 marking points for each box: diagram, name and shape. for each box: all three correct = 2 marks two correct = 1 mark	**4**
(b)(i)	$SiCl_4$ simple / molecular **AND** Van der Waals' / id-id forces / London / dispersion forces / IMFs	**1**
	NaC*l* ionic **OR** giant	**1**
	bonding (in NaC*l*) strong<u>er</u> (than forces in $SiCl_4$) owtte	**1**
(b)(ii)	$SiCl_4$ has more electrons ORA	**1**
	stronger Van der Waals' / id-id forces / London / dispersion forces / IMFs	**1**
(b)(iii)		**1**

Chapter 5

Chemical energetics

13. 9701_s17_qp_21 Q: 2

Structure and bonding can be used to explain many of the properties of substances.

(a) Copper, ice, silicon(IV) oxide, iodine and sodium chloride are all crystalline solids.

Complete the table with:

- the name of a type of bonding found in each crystalline solid,
- the type of lattice structure for each crystalline solid.

crystalline solid	type of bonding	type of lattice structure
copper		
ice		
silicon(IV) oxide		
iodine		
sodium chloride		

[5]

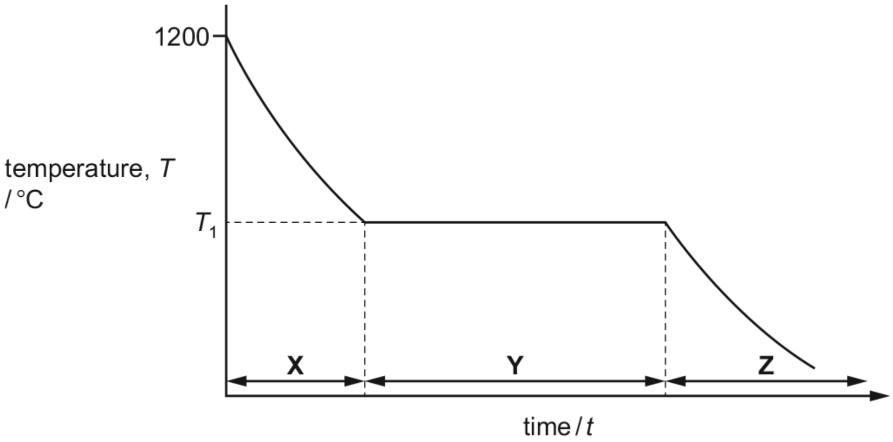
(b) **(i)** Name the strongest type of intermolecular force in ice.

.... [1]

(ii) Draw a fully labelled diagram of two water molecules in ice, showing the force in **(i)** and how it forms.

[3]

(c) The graph represents how the temperature of a sample of copper (melting point 1085 °C) changes as it is gradually cooled from 1200 °C.



(i) Identify the state(s) of matter present during each stage of the process shown in the graph.

X ....

Y ....

Z ....

[2]

(ii) State what is happening to the energy and movement of the particles in the copper during stage **X**.

....

....

.... [2]

(iii) Explain why the temperature stays constant at T_1 during stage **Y**.

....

....

....

.... [2]

[Total: 15]

Answer:

(a)	substance / type of bonding / type of lattice structure	
	copper: metallic; giant/metallic	1
	ice: covalent OR hydrogen(-bonding) / H(–bonding); hydrogen-bonded / simple / molecular	1
	silicon(IV) oxide: covalent; giant (molecular) / macromolecular	1
	iodine: covalent; simple / molecular	1
	sodium chloride: ionic; giant / ionic	1
(b)(i)	hydrogen bonding	1
(b)(ii)	H-bond between O and H of different molecules	1
	minimum **three** partial charges (in a row) over **two** H_2O molecules, i.e.: either $^{\delta-}O—H^{\delta+}$ - - - - $^{\delta-}O$ or $H^{\delta+}$ - - - - $^{\delta-}O—H^{\delta+}$	1
	lone pair of electrons on O of H-bond, in line with H-bond	1
(c)(i)	X = liquid AND Z = solid	1
	Y = liquid and solid OR 'liquid / solid' OR 'liquid OR solid'	1
(c)(ii)	(kinetic) energy reducing	1
	motion slowing *owtte*	1
(c)(iii)	energy given out / released forming bonds / forming bonds exothermic	1
	compensates for / counteracts heat loss / cooling *owtte*	1
	Total:	**15**