

OCR A-LEVEL CHEMISTRY A • H432

CHEMISTRY



EXAM QUESTION PACK

2.2 ELECTRONS, BONDING AND STRUCTURE

SCORE

/242

PERCENTAGE

%

STEMUP

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1(a) Antimony, Sb, has atomic number 51.

Antimony exists as a mixture of isotopes.

(i) What is meant by the term *isotopes*?

----- [1]

(ii) Different isotopes of antimony have the same chemical properties.

Explain why.

----- [1]

(iii) Complete the table below to show the atomic structure of ^{121}Sb .

Protons	Neutrons	Electrons

[1]

(b) The relative atomic mass of antimony is 121.8.

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

----- [3]

(ii) A sample of antimony, $A_r = 121.8$, was analysed and was found to consist of 60% ^{121}Sb and one other isotope.

Determine the mass number of the other isotope in the sample of antimony.

mass number of the other antimony isotope = ----- [1]

2 This question is about the elements with atomic numbers between 58 and 70.

Cerium, atomic number 58, is a metal.

Complete the table to show the relative charge of each particle and the number of each particle found in a $^{140}\text{Ce}^{2+}$ ion.

Particle	Relative charge of each particle	Number of each particle present in a $^{140}\text{Ce}^{2+}$ ion
proton		
neutron		
electron		

[2]

3 Bromine has two isotopes, Br-79 and Br-81. The relative atomic mass of bromine is 79.9.

Calculate the percentage of Br-79 atoms in a sample of bromine.

Answer = _____ % [2]

4 How many electrons are in a

- A 10
- B 12
- C 14
- D 22

Your answer

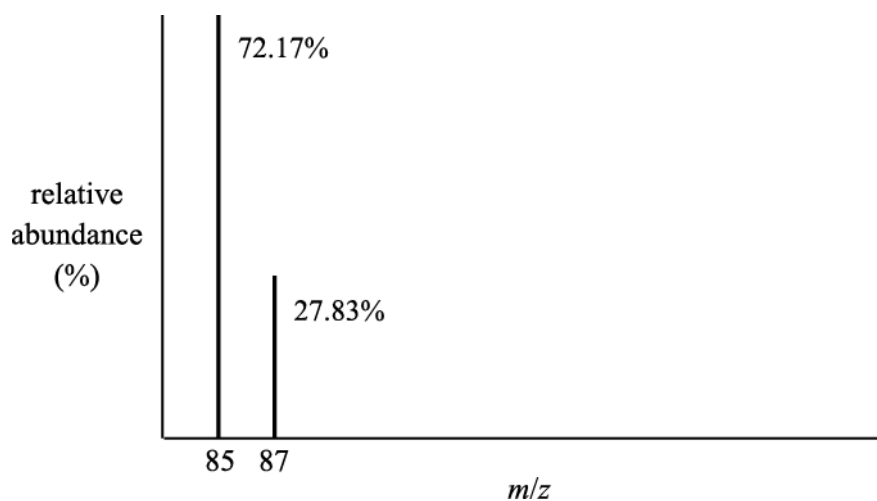
[1]

- 5 Bromine and mercury are the only two naturally occurring elements that are liquids at room temperature and pressure. Some physical properties of these two elements are given below.

	Appearance at room temperature	Melting point / °C	Boiling point / °C	Electrical conductivity of the liquid
Bromine	dark orange liquid	−7.2	58.8	very low
Mercury	shiny silver liquid	−38.8	356.7	good

Element X melts at temperatures reached on very hot summer days.

A sample of element X was analysed by mass spectrometry. The mass spectrum is shown below.



- (i) Calculate the relative atomic mass of element X.

Give your answer to **two** decimal places.

relative atomic mass = _____ [2]

- (ii) Suggest the identity of element X.

_____ [1]

6 Information about two isotopes of an element is given in the table.

Isotope	Mass number	% Abundance
A	144	24
B	145	9

Which statement is correct?

- A The relative atomic mass of the element is 47.61.
- B Isotope **B** has more protons than isotope **A**.
- C Isotope **B** has fewer neutrons than isotope **A**.
- D The relative isotopic mass of isotope **B** is 145.

Your answer

[1]

7(a) Europium, atomic number 63, has two isotopes, ^{151}Eu and ^{153}Eu .

Complete the table to show the number of protons, neutrons and electrons in the $^{153}\text{Eu}^{3+}$ ion of europium.

	protons	neutrons	electrons
$^{153}\text{Eu}^{3+}$			

[1]

(b) Atoms of europium have electrons in orbitals within the first five shells. The first three shells of europium are full.

Complete the table to show the number of electrons in the following regions of a europium atom.

	number of electrons
the 1s sub-shell	
a 3p orbital	
the 3 rd shell	

[3]

8 Aluminium forms a sulfide, Al_2S_3 .

Al_2S_3 reacts with water to form aluminium hydroxide and hydrogen sulfide, H_2S .

Write an equation for the reaction of Al_2S_3 with water.

[1]

9 Nitrogen is the most common gas in the atmosphere.

Atoms of nitrogen consist of protons, neutrons and electrons.

Complete the table below.

Particle	Relative mass	Relative charge	Position within the atom
Proton			
Neutron			
Electron			shell

[2]

10 A sample of zinc was found to contain four isotopes with the abundances shown in the table.

Isotope	Abundance (%)
^{64}Zn	49.0
^{66}Zn	27.9
^{67}Zn	4.3
^{68}Zn	18.8

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

----- [3]

(ii) Calculate the relative atomic mass of zinc in this sample.

Give your answer to **two** decimal places.

relative atomic mass of zinc = ----- [2]

11 Which row shows the atomic structure of $^{37}\text{Cl}^-$?

	protons	neutrons	electrons
A	17	18	20
B	17	20	18
C	18	19	17
D	20	17	21

Your answer

[1]

12 What is the oxidation number of nitrogen in $\text{Mg}(\text{NO}_3)_2$?

- A -3
- B +2
- C +5
- D +6

Your answer

[1]

13(a) A twenty pence coin contains copper and nickel.

Copper and nickel each exist as a mixture of isotopes.

State the similarities and differences between the atomic structure of isotopes of the **same** element.

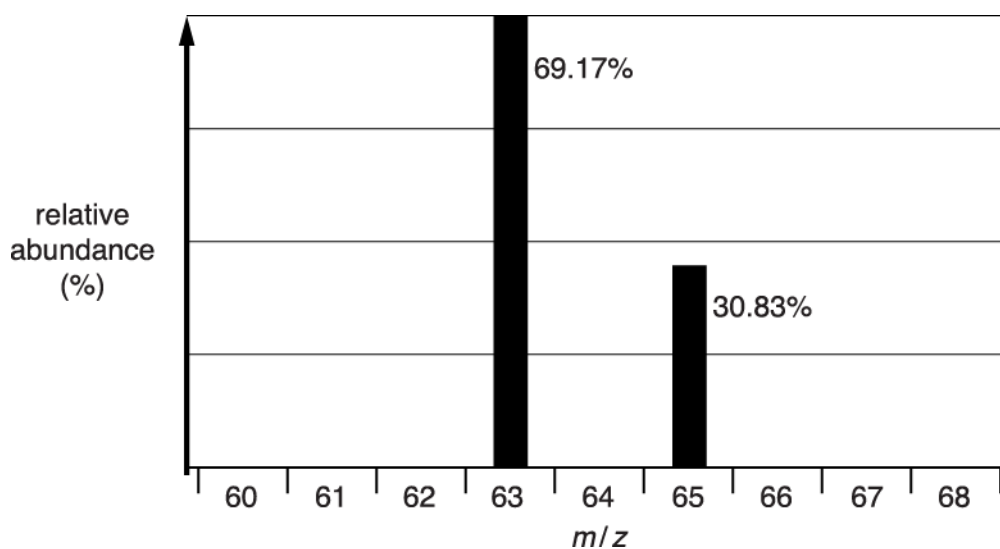
Similarities

.....

Differences

[2]

- (b) The copper used to make a batch of coins is analysed by mass spectrometry. The mass spectrum is shown below.



- (i) Calculate the relative atomic mass of the copper used to make the coins.

Give your answer to **two** decimal places.

relative atomic mass = _____ [2]

(ii) One coin has a mass of 5.00 g and contains 84.0% of copper, by mass.

Calculate the number of copper atoms in one coin.

Give your answer in standard form and to **three** significant figures.

number of copper atoms = _____ [2]

14 Which ion has a different number of electrons from the other three ions?

A Ga^{3+}

B Cl^-

C S^{2-}

D Ca^{2+}

Your answer

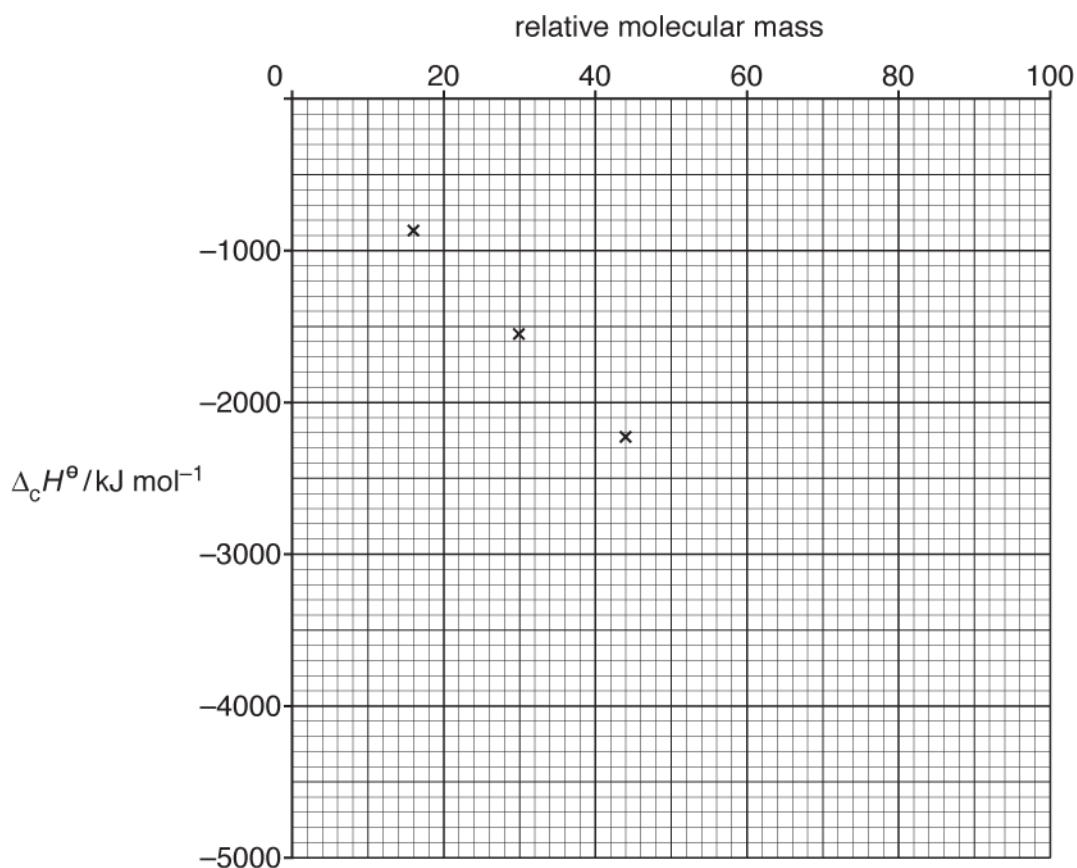
[1]

- 15 Data book values for the standard enthalpy changes of combustion, $\Delta_c H^\theta$, of the first four alkanes are shown in the table.

Alkane	methane	ethane	propane	butane
$\Delta_c H^\theta / \text{kJ mol}^{-1}$	-890	-1560	-2219	-2877

- (i) The values for the first three alkanes are plotted on the graph below.

Plot the value for butane on the graph.



[1]

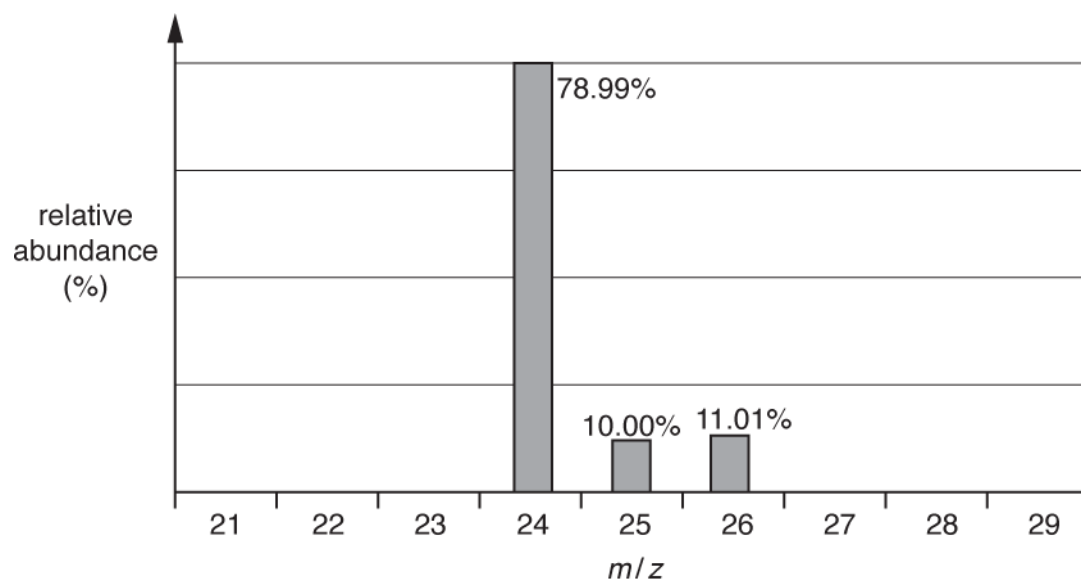
- (ii) Use the graph to estimate the energy released during complete combustion of 1.80 g of pentane.

Show relevant working below and on the graph.

energy released = _____ kJ [3]

16 This question is about elements from the s-block and p-block of the periodic table.

A sample of magnesium is analysed by mass spectrometry. The mass spectrum is shown below.



(i) The species causing the peaks in the mass spectrum are 1+ ions of magnesium.

Complete the table to show the number of protons, neutrons and electrons in each 1+ ion of magnesium.

m/z	protons	neutrons	electrons
24			
25			
26			

[2]

(ii) Calculate the relative atomic mass of the magnesium in the sample.

Give your answer to **two** decimal places.

relative atomic mass = _____ [2]

17 This question is about elements from the p-block of the periodic table.

Silicon exists as a mixture of three isotopes, ^{28}Si , ^{29}Si and ^{30}Si .

(i) Complete the table to show the atomic structure of ^{30}Si .

	Protons	Neutrons	Electrons
^{30}Si			

[1]

(ii) A sample of silicon is analysed by mass spectrometry.

The mass spectrum shows peaks with the relative abundances below.

- ^{28}Si 92.23%
- ^{29}Si 4.68%
- ^{30}Si 3.06%

Calculate the relative atomic mass of silicon in the sample.

Give your answer to **two** decimal places.

relative atomic mass = ... [2]

18(a) This question is about atomic structure and the compounds of calcium, nitrogen and oxygen.

Most elements contain different isotopes.

State **two** differences between isotopes of the same element.

[1]

(b) Complete the table for an atom and an ion of two different elements.

Element	Mass number	Protons	Neutrons	Electrons	Charge
.....		26	28		0
.....	80			36	2-

[2]

19 This question is about the properties and reactions of the Group 2 element strontium.

The relative atomic mass of strontium can be determined using a mass spectrometer.

(i) Explain what is meant by the term **relative atomic mass** of an element.

----- [2]

(ii) A sample of strontium has a relative atomic mass of 87.73.

The sample consists of:

- 82.9% Sr-88
- 6.9% Sr-87
- one other isotope.

Determine the other isotope of strontium in the sample.

isotope of strontium = ... [2]

END OF QUESTION PAPER

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
1	a	i	Atom(s) of an element AND with different numbers of neutrons (and with different masses) ✓	1	ALLOW for 'atoms of an element': Atoms of the same element OR Atoms with the same number of protons OR Atoms with the same atomic number IGNORE different relative atomic masses IGNORE different mass number IGNORE same number of electrons DO NOT ALLOW different number of electrons DO NOT ALLOW 'atoms of elements' for 'atoms of an element' DO NOT ALLOW 'an element with different numbers of neutrons' (ie atom(s) is essential) Examiner's Comments This question was well answered. The one common error made was to omit any reference to 'atoms' and so answers in terms of the same element having different number of neutrons received no credit. Candidates should be advised to avoid unnecessary references to isotopes having the same number of electrons.
		ii	same number of electrons in outer shell OR same electron configuration OR electron structure ✓	1	IGNORE same number of protons IGNORE same number of electrons IGNORE they are the same element Examiner's Comments The key reason why isotopes show similar chemical properties (ie because they have an identical numbers of electrons in the outer shell) was not always understood. Weaker candidates struggled and gave answers referring to the number of protons remaining the same. Even slightly improved answers referring to the total number of electrons remaining the same did not deliver the required level of detail.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	51p 70n 51e ✓	1	Examiner's Comments This straightforward question saw virtually every candidate secure this mark.
	b	i	The (weighted) mean mass of an atom (of an element) ✓ OR The (weighted) average mass of an atom (of an element) ✓ compared with 1 / 12th (the mass) ✓ of (one atom of) carbon-12 ✓	3	ALLOW average atomic mass DO NOT ALLOW mean mass of an element ALLOW mean mass of isotopes OR average mass of isotopes DO NOT ALLOW the singular 'isotope' For second AND third marking points ALLOW compared with (the mass of) carbon-12 which is 12 For three marks; ALLOW mass of one mole of atoms compared to 1 / 12th (mass of) one mole OR 12g of carbon OR ALLOW <u>mass of one mole of atoms</u> 1/12th mass of one mole OR 12g of carbon-12 Examiner's Comments This familiar recall question was well answered by all candidates. In the past there have been problems with weaker candidates omitting reference to average or mean mass, or muddling comparisons by referring to a single atom of the element and then a mole of carbon-12. On this occasion, however, such errors were rare and the answers seen were extremely strong.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance												
		ii	123 ✓	1	ALLOW ¹²³Sb OR Sb-123 OR antimony-123 ALLOW 123.0 IGNORE working Examiner's Comments This question analysed the methodology of determining relative atomic mass in a more unusual way compared to the normal calculation from data about the constituent isotopes. As a result those candidates who had simply committed a method to memory without real understanding of what they were doing found themselves somewhat exposed here and consequently this question proved to be challenging for many. Stronger candidates scored well, however.												
			Total	7													
2			<table><tr><th>Particle</th><th>Relative charge</th><th>Number of particles present in a ¹⁴⁰Ce²⁺ ion.</th></tr><tr><td>Protons</td><td>+1</td><td>58</td></tr><tr><td>Neutrons</td><td>Nil (or 0)</td><td>82</td></tr><tr><td>Electrons</td><td>−1</td><td>56</td></tr></table> One mark per column ✓ ✓	Particle	Relative charge	Number of particles present in a ¹⁴⁰ Ce ²⁺ ion.	Protons	+1	58	Neutrons	Nil (or 0)	82	Electrons	−1	56	2	DO NOT ALLOW '+' or '-' without '1' DO NOT ALLOW 1 without charge ALLOW 1+ AND 1− IGNORE '−' (ie a dash) for relative charge of a neutron Examiner's Comments Virtually every candidate made a good start to the paper by securing at least one mark of the two available. Less able candidates gave the mass of the sub-atomic particles rather than their charge and a few gave 140 as the number of neutrons but such errors were a minority.
Particle	Relative charge	Number of particles present in a ¹⁴⁰ Ce ²⁺ ion.															
Protons	+1	58															
Neutrons	Nil (or 0)	82															
Electrons	−1	56															
			Total	2													

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
3			55% ✓	1	Examiner's Comments Although some very good algebraic attempts were seen in this variant of an A_r calculation, it was clear from the working shown that even when the right answer was given, some candidates had not got to this answer in a systematic way but often in a very muddled and confused manner.
			Total	1	
4			A	1	
			Total	1	
5		i	$\frac{(85.00 \times 72.17) + (87.00 \times 27.83)}{2} \quad (1)$ $= 85.56 \text{ (to 2 d.p.)} \quad (1)$	2	
		ii	Rubidium OR Rb	1	
			Total	3	
6			D	1	
			Total	1	
7	a		63 p 90 n 60 e	1	
	b		2 (1) 2 (1) 18 (1)	3	
			Total	4	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance																
8			$\text{Al}_2\text{S}_3 + 6\text{H}_2\text{O} \rightarrow 2\text{Al}(\text{OH})_3 + 3\text{H}_2\text{S} \checkmark$	1	IGNORE state symbols ALLOW correct multiples Examiner's Comments This question discriminated well between the most able, who found no difficulty writing and balancing the equation and the least able who frequently were not able to give the correct formula of the product, aluminium hydroxide. Those who managed to obtain the correct symbols often failed to provide the correct balancing number before the water.																
			Total	1																	
9			<table><tr><td>particle</td><td>relative mass</td><td>relative charge</td><td>position within the atom</td></tr><tr><td>proton</td><td>1</td><td>+ 1</td><td>nucleus</td></tr><tr><td>neutron</td><td>1</td><td>nil/0</td><td>nucleus</td></tr><tr><td>electron</td><td>1/2000</td><td>-1</td><td>shell</td></tr></table> Relative mass column ✓; Relative charge AND position columns ✓	particle	relative mass	relative charge	position within the atom	proton	1	+ 1	nucleus	neutron	1	nil/0	nucleus	electron	1/2000	-1	shell	2	For relative masses ALLOW 1/1800 to 1/2000 for electron value (0.0005–0.00056) ALLOW 'negligible' for electron value IGNORE '+' in front of correct values DO NOT ALLOW '-' in front of 1/2000 DO NOT ALLOW 'nil' OR 'zero' for mass of electron For relative charges ALLOW 1+ and 'neutral' and 1– IGNORE '-' (ie a dash) for neutron DO NOT ALLOW '+' or '-' without '1' DO NOT ALLOW '1' without charge For position within the atom IGNORE 'middle OR 'centre' for 'nucleus' Examiner's Comments This was well-answered but it was evident that this basic material, usually covered very early in the syllabus had been forgotten by a few.
particle	relative mass	relative charge	position within the atom																		
proton	1	+ 1	nucleus																		
neutron	1	nil/0	nucleus																		
electron	1/2000	-1	shell																		
			Total	2																	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
10		i	M1 The (weighted) mean mass of an atom (of an element) ✓ M2 Compared with 1/12th (the mass) ✓ M3 Of (one atom of) carbon-12 ✓	3	ALLOW 'average' for 'mean' ALLOW 'mean mass of isotopes' but DO NOT ALLOW 'mean mass of isotope' (singular) DO NOT ALLOW 'mean mass of an element' For M2 and M3 ALLOW compared with the mass of carbon-12 which is 12 ALLOW for three marks Mass of one mole of atoms Compared to 1/12th (mass of) one mole OR 12 g of carbon-12 ALLOW for three marks <u>Mass of one mole of atoms</u> 1/12th (mass of) one mole OR 12 g of carbon-12 Examiner's Comments This commonly asked for definition was well answered by all.
		ii	First check the answer line. If answer = 65.44 award 2 marks. $\frac{(64 \times 49.0) + (66 \times 27.9) + (67 \times 4.3) + (68 \times 18.8)}{100}$ OR 31.36(0) + 18.414 + 2.881 + 12.784 OR 65.439 ✓ = 65.44 ✓	2	ALLOW one mark for ECF from transcription error in the first sum provided the final answer is to two decimal places and is between 64 and 68 and is a correct calculation of the transcription Examiner's Comments The vast majority were able to calculate the relative atomic mass of zinc to two decimal places.
			Total	5	
11			B	1	Examiner's Comments Generally scored well.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
12			C	1	ALLOW +5 OR 5+ in box <u>Examiner's Comments</u> Generally scored well.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
13	a		Similarities: (Same) number of protons AND electrons ✓ Differences: (Different) number of neutrons ✓	2	ALLOW same electron configuration ALLOW 'amount' for 'number' IGNORE different masses/mass numbers (Question asks for atomic structures) <u>Examiner's Comments</u> Most candidates identified that different isotopes had the same number of protons but then omitted electrons. The different number of neutrons was usually seen although sometimes atomic mass was shown instead.
	b	i	FIRST CHECK ANSWER ON THE ANSWER LINE If answer = 63.62 award 2 marks $\frac{(63 \times 69.17) + (65 \times 30.83)}{100}$ OR 63.6166 OR 63.617 ✓ = 63.62 (to 2 DP) ✓ IGNORE any units with A_r	2	ALLOW ECF for a correct calculation to 2 DP if: %s have been used with wrong isotopes i.e. $\frac{(63 \times 30.83) + (65 \times 69.17)}{100} \rightarrow 64.38$ OR - decimal places for ONE % have been transposed, i.e. 69.71 → 63.96; 30.38 → 63.32 <u>Examiner's Comments</u> This part was mostly correct. Low-scoring candidates sometimes produced errors in averaging or rounding. Most final answers were given to the required two decimal places. Answer = 63.62

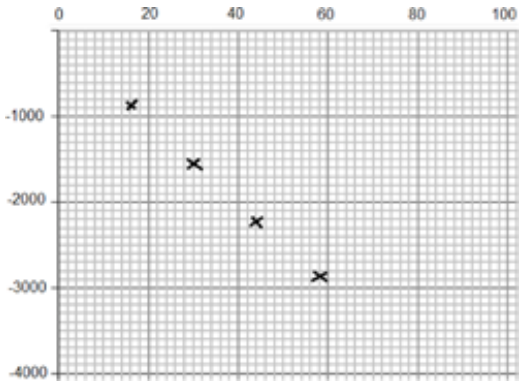
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance								
		ii	FIRST CHECK ANSWER ON THE ANSWER LINE If answer = 3.97×10^{22} (from 63.62) award 2 marks If answer = 3.98×10^{22} (from 63.5) award 2 marks Using 63.62: correct A_r of Cu from 21(b)(i) See bottom of answer zone $n(\text{Cu}) = \frac{5.00 \times 0.840}{63.62} = \frac{4.2}{63.62} = 0.066(0) \text{ (mol)} \checkmark$ Cu atoms = $0.0660 \times 6.02 \times 10^{23} = 3.97 \times 10^{22} \checkmark$ Must be calculated in standard form AND to 3 SF OR _____ Using 63.5: A_r of Cu from periodic table $n(\text{Cu}) = \frac{5.00 \times 0.840}{63.5} = \frac{4.2}{63.5} = 0.0661 \text{ (mol)} \checkmark$ Cu atoms = $0.0661 \times 6.02 \times 10^{23} = 3.98 \times 10^{22} \checkmark$ Must be calculated in standard form AND to 3 SF	2	If there is an alternative answer, check to see if there is any ECF credit possible SEE answer from 21b(i) at bottom of answer zone ALLOW correct answer from 3 SF up to calculator value of 0.06601697579 ALLOW incorrect $n(\text{Cu}) \times 6.02 \times 10^{23}$ correctly calculated to 3 SF AND in standard form For ECF, A_r must have been used for $n(\text{Cu})$ ALLOW correct answer from 3 SF up to calculator value of 0.06614173228 ALLOW incorrect $n(\text{Cu}) \times 6.02 \times 10^{23}$ correctly calculated to 3 SF AND in standard form For ECF, A_r must have been used for $n(\text{Cu})$ Common errors Using 63.62: <table><tr><td>3.984×10^{22}</td><td>1 mark (SF)</td></tr><tr><td>4.73×10^{22}</td><td>1 mark (ECF: omitting 0.840)</td></tr></table> Using 63.5: <table><tr><td>3.982×10^{22}</td><td>1 mark (SF)</td></tr><tr><td>4.74×10^{22}</td><td>1 mark (ECF: omitting 0.840)</td></tr></table> Examiner's Comments This part was generally well answered with most candidates processing the data	3.984×10^{22}	1 mark (SF)	4.73×10^{22}	1 mark (ECF: omitting 0.840)	3.982×10^{22}	1 mark (SF)	4.74×10^{22}	1 mark (ECF: omitting 0.840)
3.984×10^{22}	1 mark (SF)												
4.73×10^{22}	1 mark (ECF: omitting 0.840)												
3.982×10^{22}	1 mark (SF)												
4.74×10^{22}	1 mark (ECF: omitting 0.840)												

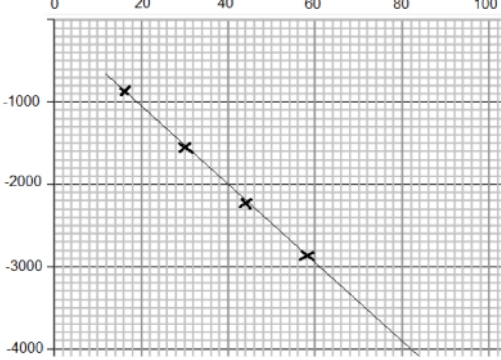
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					correctly. Candidates sometimes failed to consider 84% or rounded incorrectly in places. Answer = 3.97×10^{22} atoms
			Total	6	
14			A	1	Examiner's Comments The majority of candidates provided the correct answer with only the very weakest candidates not achieving the mark.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
15		i	Value for butane plotted accurately on the graph ✓	3	relative molecular mass = 58 $\Delta_c H^\ominus = -2877 \text{ kJ mol}^{-1}$  Check accuracy: • There must be a visible point • Vertically: touching the 58 line • Horizontally: between 2800 and 2900 Examiner's Comments Most, but not all, candidates were able to plot the value for butane accurately on the graph.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	FIRST, CHECK THE ANSWER ON ANSWER LINE IF energy released = 87.5 (minimum) to 90 (maximum) AND line is extrapolated to 72 (molar mass) award 3 marks IF energy released <87.5 OR > 90.0 check the estimated value of $\Delta_c H^\ominus$ from the graph <i>Estimation of $\Delta_c H^\ominus$</i> extrapolated (straight) line of best fit (see graph) AND correctly estimated value $\Delta_c H^\ominus$ from graph ✓ <i>Calculation of energy released</i> $n(\text{C}_5\text{H}_{12}) = 0.0250 \text{ mol}$ ✓ <i>energy released</i> $= 0.0250 \times \text{correctly estimated value of } \Delta_c H^\ominus$ ✓	3	relative molecular mass = 72 $\Delta_c H^\ominus = -3509 \text{ KJ mol}^{-1}$  Expected value within range: (-)3500 to (-)3600 (kJ mol^{-1}) moles = $1.80/72.0$ IGNORE sign ALLOW ECF from incorrectly calculated moles of pentane OR incorrectly estimated $\Delta_c H^\ominus$ Examiner's Comment: A good proportion of candidates scored full marks for their estimate but some did not extrapolate the line on the graph and many did not calculate the amount of pentane. This restricted their answer to an estimate of the energy released by one mole of pentane and this could only score one mark.
			Total	4	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance																
16		i	<table><tr><th>m/z</th><th>protons</th><th>neutrons</th><th>electrons</th></tr><tr><td>24</td><td>12</td><td>12</td><td>11</td></tr><tr><td>25</td><td>12</td><td>13</td><td>11</td></tr><tr><td>26</td><td>12</td><td>14</td><td>11</td></tr></table> Mark vertically: protons AND neutrons ✓ electrons ✓	m/z	protons	neutrons	electrons	24	12	12	11	25	12	13	11	26	12	14	11	2	Examiner's Comments This straightforward question was generally well answered. Some candidates completed the table for atoms rather than 1+ ions, with 12, rather than 11 electrons.
m/z	protons	neutrons	electrons																		
24	12	12	11																		
25	12	13	11																		
26	12	14	11																		
		ii	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 24.32 award 2 marks $\frac{(24 \times 78.99) + (25 \times 10.00) + (26 \times 11.01)}{100}$ OR 24.320 OR 24.3202 ✓ = 24.32 (to 2 DP) ✓	2	ALLOW ECF for a correct calculation to 2 DP if: • %s have been used with wrong isotopes ONCE OR • decimal places for ONE % have been transposed Examiner's Comments This stock calculation proved to be one of the easiest questions on the paper. When an error was seen, it was inevitably for not showing the answer to two decimal places.																
			Total	4																	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance										
17		i	<table><tr><td></td><td>Protons</td><td>Neutrons</td><td>Electrons</td><td></td></tr><tr><td>²⁹Si</td><td>14</td><td>16</td><td>14</td><td>✓</td></tr></table>		Protons	Neutrons	Electrons		²⁹ Si	14	16	14	✓	1	<u>Examiner's Comments</u> This question was an easy starter to the paper with most candidates producing the correct answer.
	Protons	Neutrons	Electrons												
²⁹ Si	14	16	14	✓											
		ii	FIRST CHECK ANSWER ON THE ANSWER LINE IF answer = 28.11 (to 2 DP) award 2 marks $\frac{(28 \times 92.23) + (29 \times 4.68) + (30 \times 3.09)}{100}$ OR 28.1086 OR 28.109 ✓ = 28.11 (to 2 DP) ✓	2	For 1 mark: ALLOW ECF → to 2 DP if: • %s used with wrong isotopes ONCE OR • transposed decimal places for ONE % <u>Examiner's Comments</u> Almost all candidates followed a well-learned procedure to complete the calculation. Despite being in the rubric to the question, some candidates did not give an answer to two decimal places. Others made a rounding error in reducing 28.1086 to two decimal places, with 28.10 and 28.12 being common errors.										
			Total	3											

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
18	a		TWO correct responses from ✓ • Different numbers of neutrons • Different (atomic) masses/mass numbers • Different physical properties <i>Physical required</i>	1 (AO1.1)	IGNORE heavier/lighter DO NOT ALLOW different relative atomic masses BUT ALLOW different relative isotopic masses DO NOT ALLOW different chemical properties OR different properties IGNORE different abundancies <u>Examiner's Comments</u> Candidates needed to state two differences for 1 mark. Most candidates selected 'different numbers of neutrons' but this was often followed up by different 'relative atomic mass', the weighted mean of different isotopes, rather than 'different mass' for a single isotope. This suggested that many candidates may not have understood the meaning of 'relative' in 'relative atomic mass'. Misconception When discussing the mass of individual isotopes, 'mass' or 'mass number' should be used. The relative atomic mass is the weighted average mass of all of the isotopes of an element, and is consequently the incorrect term to use in this context.

Mark Scheme

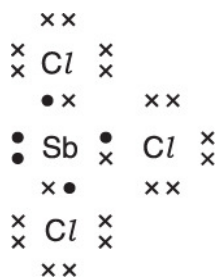
Question			Answer/Indicative content	Marks	Guidance																		
	b		<table border="1"> <thead> <tr> <th>Ele- ment</th><th>Mass number</th><th>Pro- tons</th><th>Neu- trons</th><th>Elec- trons</th><th>Charge</th></tr> </thead> <tbody> <tr> <td>Fe</td><td>54</td><td>26</td><td>28</td><td>26</td><td>0</td></tr> <tr> <td>Se</td><td>80</td><td>34</td><td>46</td><td>36</td><td>-2</td></tr> </tbody> </table> ✓ ✓ Mark by row	Ele- ment	Mass number	Pro- tons	Neu- trons	Elec- trons	Charge	Fe	54	26	28	26	0	Se	80	34	46	36	-2	2 AO1.2×2	THREE responses for each mark <i>Easiest to check element first</i> ALLOW Se²⁻ ALLOW names for elements <u>Examiner's Comments</u> Candidates answered this question reasonably well but many selected incorrect elements despite having identified the correct mass number and numbers of protons, neutrons and electrons. A common error was a mass number of 55.8 for Fe, clearly a confusion between the mass number of an isotope and relative atomic mass (see also comments for 21(a)). Mn was also a common error for the first element, presumably by matching the mass number of 54 with the relative atomic mass of Mn (54.9).
Ele- ment	Mass number	Pro- tons	Neu- trons	Elec- trons	Charge																		
Fe	54	26	28	26	0																		
Se	80	34	46	36	-2																		
			Total	3																			

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
19		i	(Weighted) mean/average mass of an atom ✓ compared with 1/12th mass of carbon-12 OR compared with mass of carbon-12 which is 12 ✓	2(AO1.1x2)	DO NOT ALLOW mean mass of an element <i>i.e.</i> 'atom' essential Both marks available based on mole: ALLOW mass of 1 mole of atoms ✓ compared to 1/12th 1 mole/12 g of carbon-12 ✓ ALLOW mass of one mole of atoms ✓ 1/12th mass of one mole/12 g of carbon-12 ✓ <u>Examiner's Comments</u> Most candidates were given at least one mark but lost the second mark due to omitting the word "atom", or "mean" or "one-twelfth"
		ii	Use of isotope data Use of 87×6.9 AND 88×82.9 AND 10.2 anywhere ✓ Calculation of isotopic mass $\frac{(100 \times 87.73) - (87 \times 6.9) - (88 \times 82.9)}{10.2} = 86 \text{ OR } 86.03 \checkmark$	2(AO1.2x2)	ALLOW $877.5 = 10.2A$ ALLOW $87.73 = \frac{(A \times 10.2) + 600.3 + 7295.2}{100}$ ALLOW $\frac{8773 - 600.3 - 7295.2}{10.2} = 86.03$ ALLOW $\frac{87.73 - 78.955}{0.102} \text{ OR } \frac{8.775}{0.102} = 86 \text{ OR } 86.03$ DO NOT ALLOW Sr-86 with no working/justification ALLOW any unambiguous representation <u>Examiner's Comments</u> Algebra was used very well here and allowed most candidates to obtain at least one mark, with the majority obtaining 2 marks
			Total	4	

- 1 Antimony chloride, SbCl_3 , exists as simple covalent molecules.

A 'dot-and-cross' diagram of SbCl_3 is shown below.



- (i) Predict the shape of a molecule of SbCl_3 .

Explain your answer.

name of shape: _____

explanation: _____

_____ [3]

- (ii) SbCl_3 molecules are polar.

Explain why.

_____ [2]

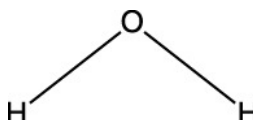
2(a) Oxides can have different types of bonding.

H₂O has hydrogen bonding.

- (i) Complete the diagram below to show hydrogen bonding between the H₂O molecule shown and **one** other H₂O molecule.

Include relevant dipoles and lone pairs.

Label the hydrogen bond.



[2]

- (ii) State and explain **two** anomalous properties of ice caused by hydrogen bonding.

1

2

[4]

(b) Draw a 'dot-and-cross' diagram to show the bonding in CO₂.

Show outer electrons only.

[1]

(c) Describe and explain the electrical conductivity of sodium oxide, Na₂O, and sodium in their solid and molten states.



In your answer you should use appropriate technical terms, spelled correctly.

[5]

- 3 A chemist carries out reactions of barium and barium nitride, Ba_3N_2 .

Reaction 1 Barium is reacted with water.

Reaction 2 Barium nitride is reacted with water, forming an alkaline solution and an alkaline gas.

Reaction 3 Barium is reacted with an excess of oxygen at 500°C , forming barium peroxide, BaO_2 .

- (i) Write equations for **Reaction 1** and **Reaction 2**.

Ignore state symbols.

Reaction 1: _____

Reaction 2: _____

[3]

- (ii) Predict the structure and bonding of Ba_3N_2 .

_____ [1]

- (iii) BaO_2 formed in **Reaction 3** contains barium and peroxide ions.

The peroxide ion has the structure $[\text{O}-\text{O}]^{2-}$.

Suggest a '*dot-and-cross*' diagram for BaO_2 .

Show outer shell electrons only.

[1]

4(a) Solid aluminium fluoride has a giant ionic lattice structure.

- (i) Describe what is meant by the term *ionic lattice*, in terms of the type and arrangement of particles present.

[2]

- (ii) Draw a '*dot-and-cross*' diagram for aluminium fluoride.

Show outer electrons only.

[2]

- (b) Solid boron tribromide has a simple molecular lattice structure. The atoms are held together by covalent bonds.

- (i) What is meant by the term *covalent bond*?

[1]

- (ii) Draw a '*dot-and-cross*' diagram to show the bonding in a boron tribromide molecule.

Show outer electrons only.

[1]

5 Chlorine gas reacts with methane. One of the products is dichloromethane, CH_2Cl_2 .

- (i) Chlorine is more electronegative than carbon and hydrogen, which have approximately equal electronegativity values.

Explain what is meant by the term *electronegativity*.

----- [2]

- (ii) Draw a 3-D diagram of a molecule of CH_2Cl_2 .

Use partial charges to indicate polar bonds.

[2]

- (iii) Explain why a CH_2Cl_2 molecule is polar.

----- [1]

6

	Boiling point / °C
ammonia, NH ₃	– 33
fluorine, F ₂	– 188
bromine, Br ₂	59

Explain the different boiling points of NH_3 , F_2 and Br_2 .

Include the names of any relevant forces and particles.

In your answer you should use appropriate technical terms, spelled correctly.

[5]

7 Which molecule is non-polar?

- A SF_6
- B H_2S
- C PF_3
- D NH_3

Your answer

☐

[1]

8 Which substance contains hydrogen bonding in the liquid state?

- A $\text{CH}_3(\text{CH}_2)_4\text{CH}_3$
- B $\text{CH}_3(\text{CH}_2)_3\text{CHFCH}_3$
- C $\text{CH}_3(\text{CH}_2)_3\text{COCH}_3$
- D $\text{CH}_3(\text{CH}_2)_3\text{CH}(\text{OH})\text{CH}_3$

Your answer

☐

[1]

- 9(a) Bromine and mercury are the only two naturally occurring elements that are liquids at room temperature and pressure. Some physical properties of these two elements are given below.

	Appearance at room temperature	Melting point / °C	Boiling point / °C	Electrical conductivity of the liquid
Bromine	dark orange liquid	−7.2	58.8	very low
Mercury	shiny silver liquid	−38.8	356.7	good

Explain how the structure and bonding in bromine account for its relatively low melting point.

[3]

- (b) Mercury and bromine react together to form mercury(II) bromide, HgBr_2 .

Describe and explain how electrical conductivity occurs in mercury(II) bromide and mercury, in both solid and molten states.

[5]

10 Carbon monoxide contains a triple bond, and includes a dative covalent bond.

Construct a '*dot-and-cross*' diagram to show the outer electron pairs in a molecule of carbon monoxide.

11 Predict the shape and bond angle in a molecule that has 2 bonding pairs and 2 lone pairs around a central atom. [2]

- A linear, 180°
- B non-linear, 104.5°
- C tetrahedral, 109.5°
- D trigonal planar, 120°

Your answer

[1]

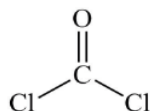
12 Which molecule is polar?

- A CH_4
- B C_2H_4
- C CH_3Cl
- D CCl_4

Your answer

[1]

- 13 The diagram shows the bonds present in a molecule of COCl_2 .



What is the shape of a molecule of COCl_2 ?

- A non-linear
- B pyramidal
- C tetrahedral
- D trigonal planar

Your answer

[1]

- 14 A chemist determines some properties of two substances, **C** and **D**.

The results are shown in the table.

	C	D
Melting point / °C	660	801
Electrical conductivity when solid	Yes	No
Electrical conductivity when molten	Yes	Yes
Solubility in water	No	Yes

Which row correctly identifies the bonding and structure in **C** and **D**?

	C	D
A	giant ionic	giant metallic
B	giant ionic	giant ionic
C	giant metallic	giant metallic
D	giant metallic	giant ionic

Your answer

[1]

- 15 Bromine is a reactive element. It combines with other non-metals to form covalent compounds. Phosphorus tribromide, PBr_3 , and iodine monobromide, IBr , are examples of covalent compounds used in organic synthesis.

PBr_3 can be prepared by heating bromine with phosphorus, P_4 .

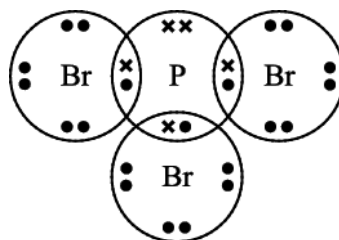
- (i) Write an equation for this reaction.

----- [1]

- (ii) How many molecules are present in 1.3535 g of PBr_3 ?

number of molecules = ----- [3]

- (iii) The 'dot-and-cross' diagram of a molecule of PBr_3 is given below.



Name the shape of this molecule and explain why the molecule has this shape.

name: -----

explanation: -----

[3]

16 Solid barium chloride has a high melting point. Barium chloride dissolves in water to form a solution that can be used to test for sulfate ions.

- (i) Draw a '*dot-and-cross*' diagram to show the bonding in solid barium chloride.
Show outer electrons only.

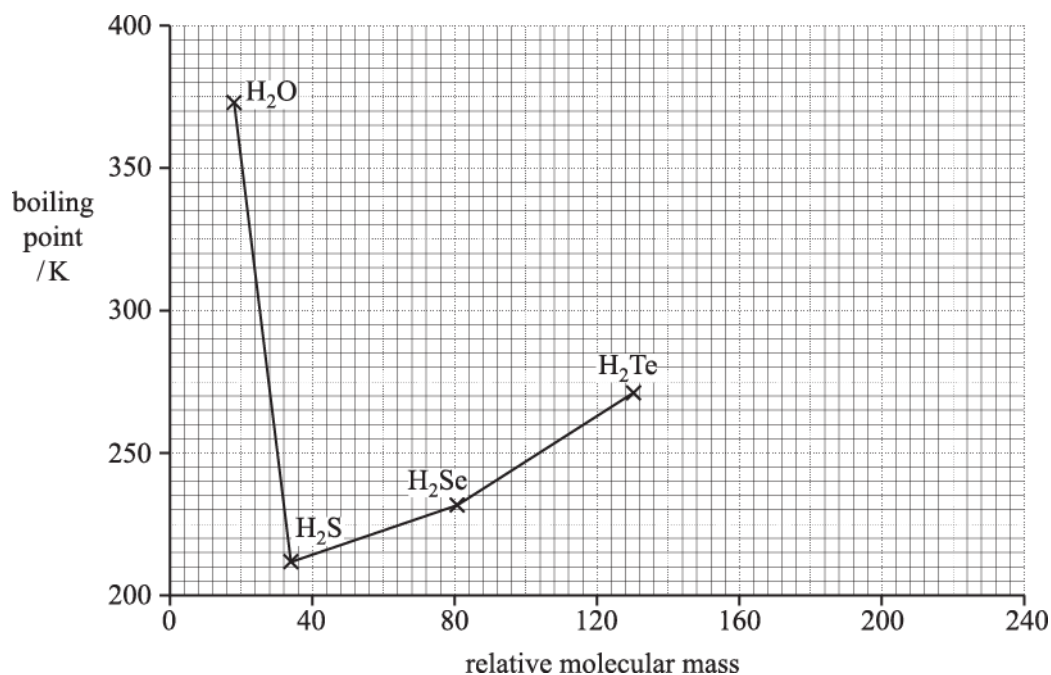
[2]

- (ii) A solution of barium chloride can be made in the laboratory using dilute hydrochloric acid.

Suggest a compound that can be reacted with hydrochloric acid to make barium chloride.

-----[1]

17(a) The graph below shows the variation in boiling points of the Group 16 hydrides.



- (i) The variation in boiling point can be explained by intermolecular bonding.
Explain why H₂S has a lower boiling point than H₂O and H₂Se.

[4]

- (ii) Polonium, Po, is at the bottom of Group 16. Its hydride has the formula H₂Po.
Estimate from the graph the boiling point of H₂Po.
The relative molecular mass of H₂Po is 211.

[1]

(b) The compounds SO₂ and MgO both contain oxygen.

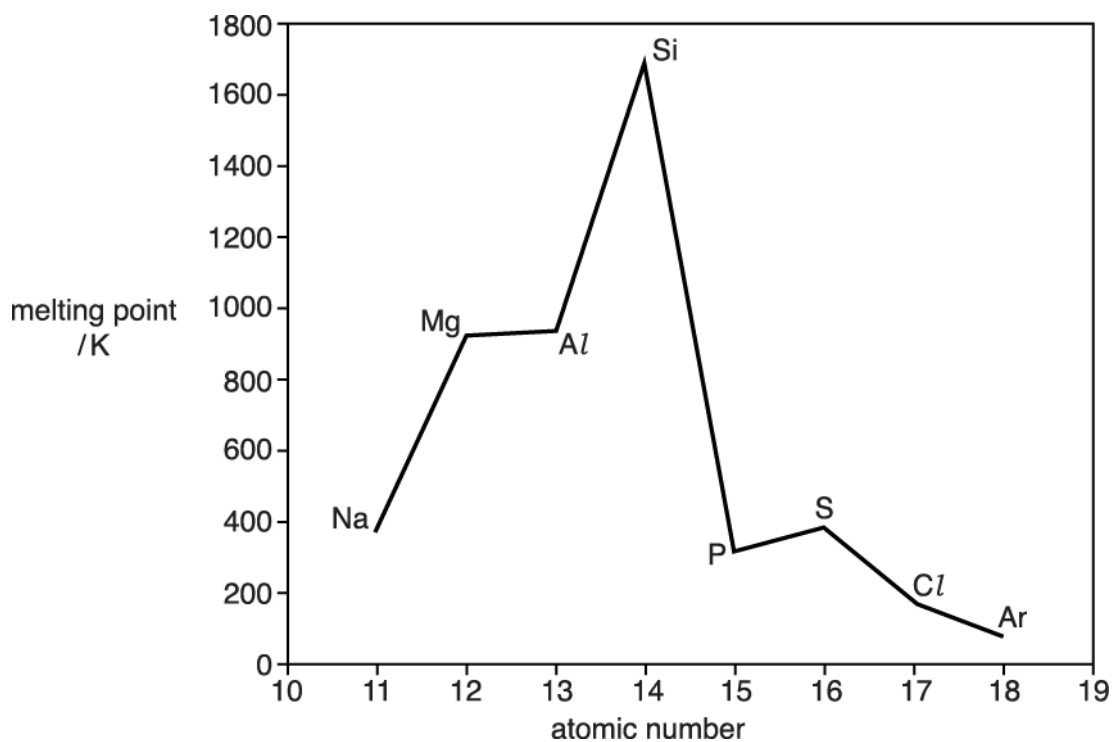
The table below shows the melting point of both compounds:

Compound	Melting point / K
SO ₂	200
MgO	3125

Predict the type of structure and bonding of SO₂ and MgO and explain the difference in their melting points.

[4]

18(a) The graph shows the melting points of the elements in Period 3 of the periodic table.



Phosphorus and chlorine have simple molecular structures.
More information about phosphorus and chlorine is given in the table below.

Element	Molecular formula
phosphorus	P ₄
chlorine	Cl ₂

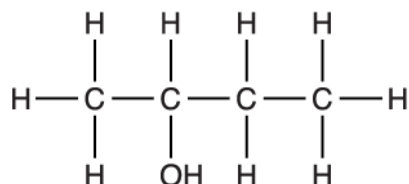
Explain the differences in the melting points of phosphorus and chlorine.

[3]

Include the names of the particles and describe the forces between the particles in the structures.

[4]

19 This question is about the properties and reactions of butan-2-ol.



Some properties of butan-2-ol are listed in the table.

Melting point	-115 °C
Boiling point	99.5 °C

The shape around the oxygen atom in butan-2-ol is non-linear.

Predict the C–O–H bond angle and explain this shape.

bond angle _____

explanation _____

[4]

20 Draw a '*dot-and-cross*' diagram to show the bonding in a nitrogen molecule.

Show **outer** electrons only.

[1]

21 This question is about halogens.

Solid chlorine and solid bromine have a similar structure.

Name this structure.

[1]

22(a) Fluorine forms several compounds with sulfur and with oxygen.

- (i) Give the **formula** and the **name** of the compound formed between fluorine and sulfur which has octahedral molecules.

Formula _____

Name _____

[1]

- (ii) Fluorine reacts with aqueous sodium hydroxide to form the oxide F_2O .

Two other products are also formed. One product is an ionic compound with a relative formula mass of 42.0.

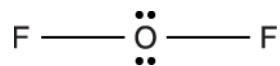
Construct a balanced equation for this reaction.

_____ [2]

(b)

- (i) Fluorine is the most electronegative element.

Indicate any dipoles on the molecule of F_2O below using partial charges.



[1]

- (ii) Suggest the **shape** of the F_2O molecule and the $\text{F}-\text{O}-\text{F}$ **bond angle**.

Shape

Bond angle

[1]

- (iii) What is the oxidation number of oxygen in F_2O ?

Include the sign in your answer.

.....[1]

- (i) Identify a compound of calcium that could be used to convert a soil pH from 5.8 to 7.5.

-----[1]

- (ii) Calcium phosphide, Ca_3P_2 , is an ionic compound used in rat poison.

Calcium phosphide can be prepared by reacting calcium metal with phosphorus, P_4 .

Write the equation for the reaction of calcium with phosphorus to form calcium phosphide.

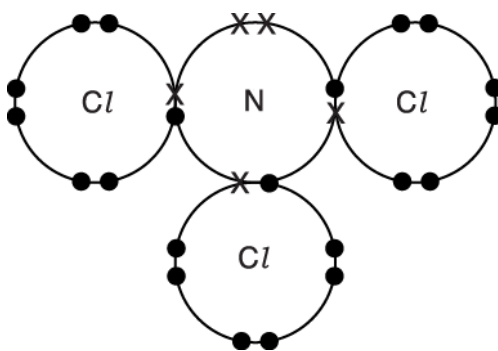
-----[1]

- (iii) Draw a '*dot-and-cross*' diagram to show the bonding in calcium phosphide, Ca_3P_2 .

Show **outer** electrons only.

[2]

24 A 'dot-and-cross' diagram for nitrogen trichloride, NCl_3 , is shown below.



Which row shows the correct shape and bond angle in a molecule of NCl_3 ?

	Name of shape	Bond angle
A	Pyramidal	104.5°
B	Pyramidal	107°
C	Tetrahedral	107°
D	Trigonal planar	120°

Your answer

[1]

25 Which compound has non-polar molecules?

- A *E*-1,2-dichlorobut-2-ene
- B *E*-2,3-dichlorobut-2-ene
- C *Z*-2,3-dichlorobut-2-ene
- D *Z*-1,4-dichlorobut-2-ene

Your answer

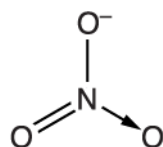
[1]

26 Nickel(II) nitrate, $\text{Ni}(\text{NO}_3)_2$, can be prepared by reacting nickel(II) oxide with dilute nitric acid.

(i) Write the equation for this reaction.

[1]

(ii) $\text{Ni}(\text{NO}_3)_2$ contains the NO_3^- ion. The nitrogen atom bonds to the oxygen atoms with a single covalent bond, a double covalent bond and a dative covalent bond, as shown below.



Draw the '*dot-and-cross*' diagram for the NO_3^- ion, showing outer shell electrons only.
Use a different symbol for the extra electron.

[2]

27(a) At room temperature and pressure, the first four members of the alkanes are all gases but the first four alcohols are all liquids.

Explain this difference in terms of intermolecular forces.

----- [2]

(b) The boiling points of 2-methylpropan-1-ol and butan-1-ol are shown below.

Alcohol	Boiling point / °C
2-methylpropan-1-ol	108
butan-1-ol	117

Explain why the boiling points are different.

----- [2]

28 Which compound has polar molecules?

- A OCl_2
- B BCl_3
- C CCl_4
- D SCl_6

Your answer

[1]

29 Which element has the highest melting point?

- A silicon
- B phosphorus
- C sulfur
- D chlorine

Your answer

[1]

30 What is the best explanation for the trend in boiling points down the halogens group?

- A The covalent bonds become stronger.
- B The hydrogen bonds become stronger.
- C The permanent dipole–dipole interactions become stronger.
- D The induced dipole–dipole interactions (London forces) increase.

Your answer

[1]

31(a) Barium combines with oxygen, chlorine and nitrogen to form ionic compounds.

Barium oxide, BaO, has a giant ionic lattice structure.

(i) State what is meant by the term *ionic bond*.

----- [1]

(ii) Draw a '*dot-and-cross*' diagram to show the bonding in barium oxide.

Show outer electrons only.

[2]

(iii) Calculate the number of barium ions in 1.50 g of barium oxide.

Give your answer in standard form and to **three** significant figures.

number of barium ions = ----- [2]

(b) Barium chloride, BaCl₂, is soluble in water.

- (i) Compare the electrical conductivities of solid and aqueous barium chloride.

Explain your answer in terms of the particles involved.

----- [2]

- (ii) Describe the use of aqueous barium chloride in qualitative analysis.

----- [2]

- (iii) Hydrated barium chloride can be crystallised from solution.

Hydrated barium chloride has the formula $\text{BaCl}_2 \cdot x\text{H}_2\text{O}$ and a molar mass of 244.3 g mol^{-1} .

Determine the value of x in the formula of $\text{BaCl}_2 \cdot x\text{H}_2\text{O}$.

Show your working.

$x =$ ----- [2]

32 The hydroxyl group, -OH , is responsible for many properties of alcohols.

Methanol, CH_3OH , is soluble in water because it has polar bonds.

Pauling electronegativity values for carbon, oxygen and hydrogen are shown below.

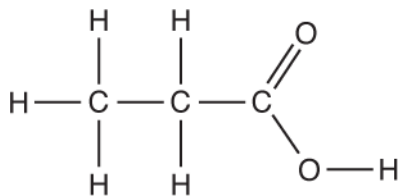
Element	Electronegativity
Carbon	2.5
Oxygen	3.5
Hydrogen	2.1

Use a labelled diagram to explain why methanol is soluble in water.

- Use displayed formulae showing one molecule of methanol and one molecule of water.
- Add partial charges δ^+ and δ^- to show the **two** most polar bonds in a methanol molecule and the polar bonds in a water molecule.
- Show all lone pairs.
- Label the most important intermolecular bond between the molecules.

[2]

33 The displayed formula for propanoic acid is shown below.



- (i) State the shape and bond angle around a carbon atom in the alkyl group of propanoic acid. Explain the shape.

Shape -----

Bond angle -----

Explanation -----

----- [2]

- (ii) Suggest a value for the C–O–H bond angle in propanoic acid.

----- [1]

34(a) Sodium sulfide, Na₂S, is an ionic compound of sodium, Na, and sulfur, S.

Draw a 'dot-and-cross' diagram to show the bonding in sodium sulfide.

Show outer electrons only.

[2]

(b) The table below compares the properties of sodium sulfide, sodium and sulfur.

Complete the table.

		Sodium sulfide	Sodium	Sulfur
Melting point / °C		1180	98	113
Type of structure (giant or simple)				
Electrical conductivity (good or poor)	solid			
	liquid			

[3]

35 'Enthalpy change of vaporisation' is the enthalpy change when one mole of a substance changes from a liquid to a gas at its boiling point.

(i) Write an equation, including state symbols, to represent the enthalpy change of vaporisation of bromine.

-----[1]

(ii) Suggest whether the enthalpy change of vaporisation of bromine is exothermic or endothermic.

Explain your answer.

-----[1]

36 Which element has induced dipole–dipole interactions (London forces) in its solid lattice?

A boron

B magnesium

C silicon

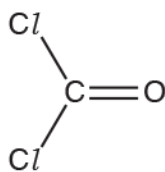
D sulfur

Your answer

[1]

37 Phosgene, COCl_2 , exists as simple molecules.

The displayed formula of a phosgene molecule is shown below.



(i) Draw a '*dot-and-cross*' diagram of a phosgene molecule.

Show outer electrons only.

[1]

(ii) Name the shape of a phosgene molecule and explain why it has this shape.

Name of shape

Explanation

.....

.....

..... [3]

38 Which molecule contains the largest bond angle?

A C_2H_4

B H_2O

C NH_3

D CH_4

Your answer

[1]

END OF QUESTION PAPER

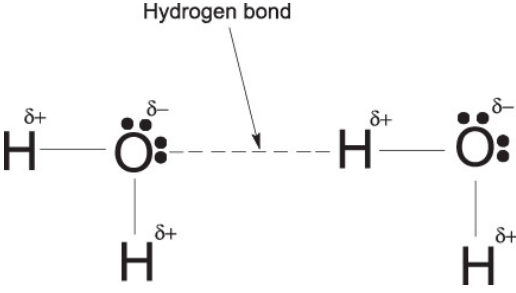
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
1		i	(Trigonal) Pyramidal ✓ (Sb has) three bonding pairs AND one lone pair of electrons ✓ Pairs of electrons repel ✓	3	ALLOW alternative phrases / words to repel eg 'push apart' ALLOW lone pairs repel more than bonding pairs ALLOW bonds for bonded pairs ALLOW lp and bp IGNORE electrons repel DO NOT ALLOW atoms repel Examiner's Comments This question was well answered. Many candidates approached this question in a systematic manner and consequently gained marks for stating the number of bonding and lone pairs around the nitrogen atom and used this to determine the molecular shape. Centres are advised to demonstrate this method of addressing this type of question.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	There is a difference in electronegativities (between Sb and Cl) OR (Sb-Cl) bonds are polar OR have a dipole OR Dipoles seen on the diagram ✓ The molecule is not symmetrical AND dipoles do not cancel ✓	2	ALLOW Because Cl is more electronegative (than Sb) OR Because Sb is more electronegative (than Cl) ALLOW description that electrons are drawn along a covalent bond IGNORE single δ^+ or single δ^- for dipole IGNORE diagram if M1 awarded in text ALLOW partial charges do not cancel IGNORE references to lone pair causing dipoles Examiner's Comments This question was relatively challenging with the need for the candidate first to refer to the polar nature of the Sb—Cl bond and then to note that the shape of the molecule prevents these individual dipoles from cancelling out. It was rare for candidates picked up both marks.
			Total	5	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
2	a	i	<i>The Dipole Mark</i> At least one $\text{H}^{\delta+}$ AND one $\text{O}^{\delta-}$ shown correctly on each water molecule (see diagram) ✓  <i>The Hydrogen bonding Mark</i> One Hydrogen bond between H in one water molecule and a lone pair of O in an adjacent water molecule ✓	2	DO NOT ALLOW $\text{H}^{\delta-}$ OR $\text{O}^{\delta+}$ IGNORE lone pairs for first marking point All Hydrogen bonds must hit a lone pair Hydrogen bond does NOT need to be labelled but it must be different from the covalent bond if it is not labelled ALLOW H-bond as label ALLOW only one lone pair on O atom ALLOW additional, correctly drawn Hydrogen bonded water molecules with correct dipoles DO NOT ALLOW more than two lone pairs on O atom Examiner's Comments Nearly all candidates answered this familiar question very well. Failure to show full dipoles on both molecules was the most common omission by some margin, whilst omitting to show a lone pair or not showing it involved in the hydrogen bond was seen comparatively more rarely.
		ii	<i>Property 1</i> Ice is less dense than water ✓ <i>Explanation 1</i> The molecules in ice are held apart by hydrogen bonds ✓ OR ice has an open lattice OR structure <i>Property 2</i>	4	ALLOW ice floats (on water) ALLOW ice contracts when it melts ALLOW ice (water) has a higher melting

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			Ice has a relatively high melting point ✓ <i>Explanation 2</i> Hydrogen bonds are relatively strong OR Hydrogen bonds are stronger (than other intermolecular attractions or forces) OR More energy is needed to overcome hydrogen bonding		point than expected OR predicted ALLOW other expressions which convey that the melting point is anomalously high e.g. 'Ice has an unusually high melting point' IGNORE boiling point IGNORE the following unqualified statements 'Ice has a higher melting point' or 'Ice has a high melting point' IGNORE references to surface tension as a property IGNORE explanations of surface tension ALLOW hydrogen bonds are the strongest intermolecular attraction or force DO NOT ALLOW 'hydrogen bonds are strong' but ALLOW this as part of a qualified statement (e.g. 'hydrogen bonds are strong compared with weak van der Waals forces') Examiner's Comments This question proved to be one of the more challenging ones on this paper. Of the possible properties of ice, the fact that ice is less dense than water was quoted often and was then supported by the correct explanation. It was when it came to discussing the anomalous melting point of water that candidates found it more difficult. Weaker candidates were content to give a very brief account, simply saying that ice's melting point was high (0°C is not a particularly high temperature) because hydrogen bonds are strong (a hydrogen bond is not a strong bond in comparison to a typical ionic bond). Such answers lacked the required comparison in terms of this property relative to other small molecules or of the strength of the hydrogen bonds in relation to other intermolecular forces.

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	b	 'dot-and-cross' of CO₂ ✓	1	Lone pairs on O must be seen Lone pairs may be seen as 4 individual electrons ALLOW correct use of three different symbols Examiner's Comments The 'dot-and-cross' diagram of the bonding in CO₂ was well known.
	c	<i>Conductivity of Na mark</i> M1: Sodium conducts in the solid and molten states ✓ <i>Reason for conductivity of Na mark</i> M2: Sodium has delocalised electrons (in both solid and liquid state) ✓ <i>Conductivity of Na₂O mark</i> M3: Na₂O conducts when molten and not when solid ✓ <i>Reason for conductivity of Na₂O marks</i> M4: Molten Na₂O has ions which are mobile ✓ M5: Solid Na₂O has ions which are fixed (in position) OR ions are held (in position) OR ions are not mobile AND in an (ionic) lattice OR structure ✓	5	Quality of written communication 'delocalis(z)ed' spelled correctly once and used in context for second marking point ALLOW 'carries charge' for conducts for M1 and M3 IGNORE 'charge carriers' for electrons OR ions for M2, M4 and M5 DO NOT ALLOW M2 if incorrect bonding is seen for Na DO NOT ALLOW ions move for solid Na for M2 IGNORE ions move for molten Na for M2 ALLOW solid Na₂O is a poor conductor for M3 IGNORE references to aqueous Na₂O for M3 IGNORE references to aqueous Na₂O for M4 IGNORE 'delocalised ions' OR 'free ions' for 'mobile ions' for M4 DO NOT ALLOW M4 AND M5 if incorrect bonding is seen in Na₂O DO NOT ALLOW any mention of electrons moving for M4 DO NOT ALLOW suggestion that it is only positive or only negative ions move for M4 IGNORE 'there are no delocalised electrons' for M5 ALLOW first and second statements of M5 to be unlinked in separate sentences

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					ALLOW 'ions fixed in position by ionic bonds' for M5 Examiner's Comments This extended writing question gave weaker candidates problems, often resulting from a weakness in the ability to arrange their answer in a cogent, non-repeating manner. The more able candidates were able to rattle off excellent answers but weaker candidates dropped marks by leaving out key points; in the worst cases failing to discuss the conductivity of sodium at all. Of the possible errors that candidates made, the most common remained the suggestion that conductivity in molten Na₂O relies on mobile electrons. Within the better answers it was common for candidates to say that the ions were unable to move in solid Na₂O, but not to give the required explanation of why they lacked mobility. Centres are recommended to advise candidates, particularly weaker ones, that the use of bullet points often helps as a form of response that allows candidates to check that all aspects of the answer have been addressed.
			Total	12	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
3		i	Reaction 1: $\text{Ba} + 2\text{H}_2\text{O} \rightarrow \text{Ba}(\text{OH})_2 + \text{H}_2$ ✓ Reaction 2: $\text{Ba}_3\text{N}_2 + 6\text{H}_2\text{O} \rightarrow 3\text{Ba}(\text{OH})_2 + 2\text{NH}_3$ Correct products ✓ Balancing ✓	3	Ignore state symbols Examiner's Comments Both equations were relatively challenging. Reaction 1 was a direct question about reactions of Group 2 elements. Reaction 2 demanded a higher level of application based upon information given. Many identified the alkaline gas as NH_3, but then incorrectly assumed that the alkaline solution was BaO instead of $\text{Ba}(\text{OH})_2$. Weaker candidates suggested equations with hypothetical species that could not have born any relation to formulae that they might have encountered before.
		ii	Giant ionic (lattice) ✓	1	ALLOW 'Giant lattice with ionic bonds' ALLOW 'Giant ionic bonds' DO NOT ALLOW 'atoms or molecules or dipoles' Examiner's Comments This question was relatively well answered, although some candidates did negate the mark by referring to molecules of Ba_3N_2 either directly or by indirect reference to intermolecular forces.
		iii		1	Ba must have a 2+ charge Ba can be with or without octet. IGNORE lack of charge on O_2^{2-} ion

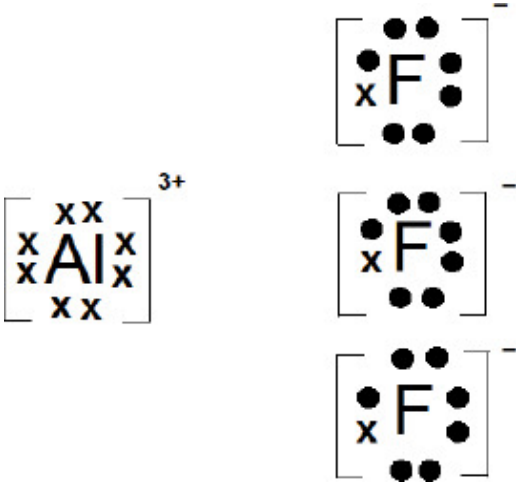
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
	$\left[\begin{array}{c} \text{x x} \\ \text{x Ba x} \\ \text{x x} \end{array} \right]^{2+}$ $\left[\begin{array}{cc} \bullet\bullet & \bullet\bullet \\ \text{x O} & \bullet\text{O x} \\ \bullet\bullet & \bullet\bullet \end{array} \right]^{2-}$ OR $\left[\begin{array}{c} \text{x x} \\ \text{x Ba x} \\ \text{x x} \end{array} \right]^{2+}$ $\left[\begin{array}{cc} \bullet\bullet & \circ\circ \\ \text{x O} & \circ\text{O x} \\ \bullet\bullet & \circ\circ \end{array} \right]^{2-}$ OR $\left[\begin{array}{c} \text{x x} \\ \text{x Ba x} \\ \text{x x} \end{array} \right]^{2+}$ $\left[\begin{array}{cc} \bullet\bullet & \circ\circ \\ \text{x O} & \circ\text{O} \\ \bullet\bullet & \circ\circ \end{array} \right]^{2-}$ OR $\left[\begin{array}{c} \text{x x} \\ \text{x Ba x} \\ \text{x x} \end{array} \right]^{2+}$ $\left[\begin{array}{cc} \bullet\bullet & \bullet\bullet \\ \text{x O} & \bullet\text{O} \\ \bullet\bullet & \bullet\bullet \end{array} \right]^{2-}$		O_2^{2-} ion to have 12 electrons belonging to O atoms + 2 other electrons of another symbol. The 2 other electrons must match Ba if Ba has an octet. If O electrons are shown as 6 of one symbol and 6 of another, each O must have six electrons of the same symbol ALLOW $\left[\begin{array}{c} \text{x x} \\ \text{x Ba x} \\ \text{x x} \end{array} \right]^{2+}$ $\left[\begin{array}{cc} \bullet\bullet & \bullet\bullet \\ \bullet\text{O} & \text{x O} \\ \bullet\bullet & \bullet\bullet \end{array} \right]^{2-}$ OR $\left[\begin{array}{c} \text{x x} \\ \text{x Ba x} \\ \text{x x} \end{array} \right]^{2+}$ $\left[\begin{array}{cc} \bullet\bullet & \bullet\bullet \\ \bullet\text{O} & \text{x O} \\ \bullet\bullet & \bullet\bullet \end{array} \right]^{2-}$ Examiner's Comments This question was designed to be difficult, but many candidates rose to the challenge. Weaker candidates simply drew a 'dot-and-cross' diagram for BaO_2 in which they treated each oxygen species as an oxide ion each having a single negative charge. Many stronger candidates did realise from the structure given in the question that there was only a single bond between the two oxygen atoms, as was clear from their suggested diagram. Only the stronger candidates managed to incorporate correctly the electrons from barium, to arrive at a correct version of the bonding of BaO_2.

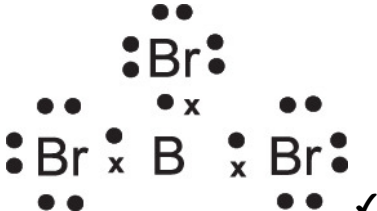
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			Total	5	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
4	a	i	Repeating pattern ✓ of oppositely charged ions ✓	2	ALLOW 'regular' OR 'alternating' OR 'uniform (arrangement)' for 'repeating pattern' ALLOW positive and negative ions OR aluminium ions and fluoride ions ALLOW oppositely charged ions from a labelled diagram Examiner's Comments Most candidates were quick to describe ionic bonding by making reference to ions of opposite charge and so were awarded the first mark. Very few went on to describe the repeating or regular nature of the lattice.
		ii	 Al with 8 (or no) outermost electrons AND 3 × fluoride (ions) with 'dot-and-cross' outermost octet ✓ Correct charges ✓	2	For first mark: If 8 electrons are shown in the cation then the 'extra' electron in the anion must match the symbol chosen for the electrons in the cation IGNORE inner shells IGNORE circles ALLOW one mark if both electron arrangements and charges are correct but only one F is drawn. ALLOW one mark if incorrect symbol is the only error, unless ECF from 2(a) in which both marks are available DO NOT ALLOW any marks for BF₃ ALLOW 3[F⁻] 3[F]⁻ [F⁻]₃ (brackets not required) DO NOT ALLOW [F₃]⁻ [F₃]³⁻ [3F]³⁻ [F₃]⁻ Examiner's Comments This question was answered by the majority of candidates. It is noteworthy, however, that some candidates gave unacceptable versions of the diagram when attempting to show the presence of three fluoride ions e.g. [F₃]⁻ suggests one anion. with a single negative charge, consisting of three F species.

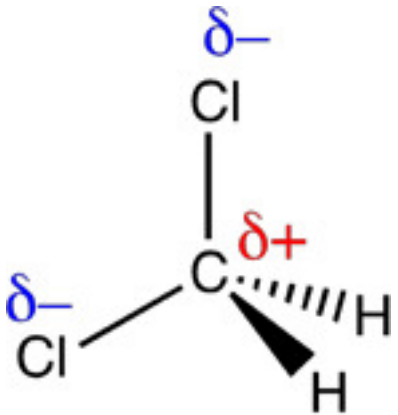
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b	i	A shared pair of electrons.	1	Examiner's Comments The quality of answers to this question were very high. Only the weakest of candidates failed to state that it is a pair (or two) of electrons which are shared.
		ii		1	Examiner's Comments As with the previous 'dot-and-cross' diagram this was well answered. Only a very few attempted to show the molecule's bonding as ionic. Some candidates did lose the mark by adding a lone pair to the boron atom.
	c		<i>Conductivity of Al mark</i> M1: Aluminium conducts in solid and molten states ✓ <i>Reason for conductivity of Al mark</i> M2: Aluminium has delocalised electrons ✓ <i>Conductivity and reason for molten AlF₃ mark</i> M3: Aluminium fluoride conducts when molten AND because it has mobile ions ✓	5	ALLOW 'carries charge' for conducts IGNORE 'charge carriers' for 'electrons' or 'ions' for M2, M3 and M4. <i>Quality of written communication:</i> 'delocalis(z)ed' spelled correctly and used in context for the second marking point. DO NOT ALLOW M2 if incorrect bonding is seen for Al DO NOT ALLOW 'ions move' for solid Al. IGNORE 'ions move' for molten Al. IGNORE references to 'aqueous' AlF₃ for M3 IGNORE 'delocalised ions' OR 'free ions' for mobile ions in M3 DO NOT ALLOW M3 if incorrect bonding is seen in AlF₃ DO NOT ALLOW any mention of electrons moving for M3 DO NOT ALLOW suggestion that it is only positive or only negative ions moving for M3 For conductivity parts of M3 + M4 ALLOW 'AlF₃ only conducts when molten' ALLOW Solid AlF₃ is a poor conductor for

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			<i>Conductivity and reason for solid AlF_3 mark</i> M4: Aluminium fluoride does not conduct when solid AND Solid aluminium fluoride has ions which are fixed (in position) OR ions are held (in position) OR ions are not mobile AND In an (ionic) lattice OR (ionic) structure OR by (ionic) bonds ✓ <i>Conductivity and reason for BBr_3 mark</i> M5 Boron tribromide does not conduct in solid and molten states AND Boron tribromide has no mobile electrons OR no (mobile) ions OR no mobile charge carriers OR no mobile charged particles ✓		M4 ALLOW second and third statements to be unlinked in separate sentences for M4 IGNORE 'there are no delocalised electrons' for M4 DO NOT ALLOW M4 if incorrect bonding is seen in AlF_3 Lattice OR structure OR ionic bonds can be seen anywhere in relation to AlF_3. ALLOW Solid BBr_3 is a poor conductor for M5 ALLOW electrons are fixed in position OR used in bonds IGNORE 'there are no delocalised electrons' OR 'there are no free electrons' for M5 DO NOT ALLOW M5 if incorrect bonding is seen in BBr_3 eg 'ions are fixed in position' ALLOW 'no (free) ions' Examiner's Comments Of the marks available for this question, most candidates picked up the first two by correctly discussing the conductivity of aluminium and using the word delocalised spelt correctly in the correct context. When it came to aluminium fluoride most candidates knew that it conducts when molten but not when solid. Candidates were able to ascribe the conduction to the presence of mobile ions but they did not go quite far enough in explaining why it cannot conduct as a solid, as they omitted that the ions were fixed within the lattice structure or by the presence of ionic bonds. The final part of the question, describing the conductivity of BBr_3, was the most challenging part and a significant number of candidates omitted to comment on the lack of mobility of any charged particles that they had suggested.
			Total	11	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance								
5		i	The ability of an atom to attract electrons ✓ (Electron pair) in a (covalent) bond ✓	2	ALLOW 'Measure' for ability ALLOW 'attraction' for 'ability to attract' ALLOW 'The ability of an atom to attract a shared pair of electrons' for two marks Examiner's Comments This definition enabled many candidates to pick up both marks. Where errors did arise they tended to be from not making clear that the attraction has to be for the electrons in the covalent bond or for there to be confusion between electronegativity and electron affinity.								
		ii	 Correct orientation of 3-D tetrahedral arrangement of bonds around C atom ✓ δ + on C atom AND δ- on both Cl atoms ✓	2	For a 3D structure, <table border="1"><tr><td>For bond in the plane of paper, a solid line is expected:</td><td></td></tr><tr><td>For bond out of plane of paper, a solid wedge is expected:</td><td></td></tr><tr><td>For bond into plane of paper, ALLOW:</td><td></td></tr><tr><td>ALLOW a hollow wedge for 'in bond' OR an 'out bond', provided it is different from the other in or out wedge e.g.:</td><td></td></tr></table> ALLOW any 3D representation with a minimum of one bond into the plane of paper AND minimum of one out of plane of paper ALLOW 2 lines in the plane + 2 different bonds for M1 IGNORE dipole charges on H Examiner's Comments It was surprising to see just how many different versions of 3-D shape were presented. The dipole mark was frequently lost usually due to omission of a partial charge on the central C atom.	For bond in the plane of paper, a solid line is expected:		For bond out of plane of paper, a solid wedge is expected:		For bond into plane of paper, ALLOW :		ALLOW a hollow wedge for 'in bond' OR an 'out bond', provided it is different from the other in or out wedge e.g.:	
For bond in the plane of paper, a solid line is expected:													
For bond out of plane of paper, a solid wedge is expected:													
For bond into plane of paper, ALLOW :													
ALLOW a hollow wedge for 'in bond' OR an 'out bond', provided it is different from the other in or out wedge e.g.:													

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Question			Answer/Indicative content	Marks	Guidance
		iii	The dipoles do not cancel out OR Because the molecule is non-symmetrical ✓	1	ALLOW partial charges do not cancel IGNORE charges do not cancel ALLOW (the more) electronegative atoms are on one side of the molecule Examiner's Comments Most candidates correctly focussed upon the fact that the molecule was not symmetrical.
			Total	5	

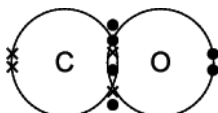
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
6	<i>M1 NH₃ forces mark</i> NH₃ has hydrogen bonding ✓ <i>M2 F₂ AND Br₂ forces mark</i> F₂ AND Br₂ have van der Waals' (forces) ✓ <i>M3 Type of particle mark</i> Forces OR attractions are between molecules OR are intermolecular for ammonia AND Forces OR attractions are between molecules OR are intermolecular for fluorine OR for bromine ✓ <i>M4 Br₂ / F₂ comparison mark</i> The van der Waals' forces in Br₂ are greater than in F₂ AND Because bromine has more electrons than fluorine ✓ <i>M5 Br₂ / NH₃ / F₂ comparison mark</i> The van der Waals' forces in Br₂ are greater than hydrogen bonding in NH₃ AND hydrogen bonding in NH₃ is stronger than van der Waals' forces in F₂ ✓	5	<i>Quality of written communication:</i> 'molecule(s)' or 'intermolecular' spelled correctly once and used in context for the third marking point. ALLOW H-bonding for hydrogen bonding IGNORE van der Waals' forces AND permanent dipoles in M1 IGNORE covalent bonds for M1 AND M2 ALLOW, for van der Waal's: vdWs OR induced dipole temporary OR instantaneous dipole (-dipole) forces ALLOW for forces: attractions OR interactions; DO NOT ALLOW M3, M4 or M5 if covalent OR ionic bonds are the forces between the particles in that mark M3 can be seen anywhere eg in M1 NH₃ has hydrogen bonding between molecules AND the intermolecular force in Br₂ is stronger than that of F₂ eg a generic statement such as 'boiling point of these substances is determined by strength of <i>intermolecular bonding</i>' eg 'All these <i>molecules</i> are <i>held</i> together by weak forces' If correct force is given in M2 ALLOW, for M4, 'intermolecular force in Br₂ is stronger than that in F₂' ALLOW more van der Waals' for greater van der Waals' ALLOW more shells of electrons IGNORE 'permanent dipoles' in NH₃ for M5 if quoted in addition to hydrogen bonding If correct force is given in M1 AND M2 ALLOW, for M5, 'intermolecular force in Br₂ is stronger than that in NH₃' AND 'intermolecular force in NH₃ is stronger than that in F₂' If incorrect intermolecular force is given in

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Question			Answer/Indicative content	Marks	Guidance
					M1 OR M2 ALLOW this as ECF for M5 but DO NOT ALLOW if the comparison is based only on van der Waals' forces Eg DO NOT ALLOW the van der Waals' forces in bromine are stronger than those in ammonia which in turn are stronger than those in fluorine Examiner's Comments This was a challenging question. Most candidates knew that ammonia has hydrogen bonding and many also knew that the intermolecular forces in F₂ and Br₂ were van der Waals. Hereafter, the marks proved more difficult to award. The next most common mark was for linking the strength of van der Waals' forces between F₂ and Br₂ to the number of electrons. The mark for establishing that the forces acted between molecules was often missed as the candidates simply did not really address this part of the question despite being told to include the particles involved in their answers. The final mark for comparing the strength of intermolecular forces between all three molecules was very rarely awarded. Weaker candidates relied upon the false mantra of 'van der Waals' forces are weaker than hydrogen bonding' which the data clearly disproved. Other candidates attempted to explain the relative strength of the intermolecular forces solely in terms of the strength of van der Waals' forces between all three types of molecule. Only the most able students were able to secure full marks on this question.
			Total	5	
7			A	1	
			Total	1	
8			D	1	
			Total	1	

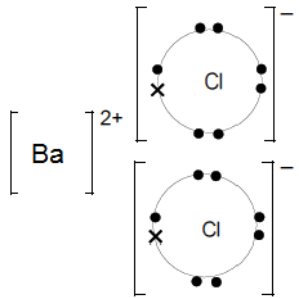
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
9	a		forces between (simple) molecules ... (1) ... (which are) induced dipole–dipole forces OR London forces ... (1) ... are weak, so (relatively easily) overcome by increased thermal motion / kinetic energy (1)	3	ignore any reference to covalent bonds allow van der Waals' forces
	b		HgBr ₂ conducts when molten but not when solid (1) ... because ions are mobile in molten HgBr ₂ (1) ... but are fixed in a lattice in solid HgBr ₂ (1) Mercury conducts in both the solid and molten states ... (1) ... because delocalised electrons move (in both solid and liquid state) (1)	5	Explanations must be included for 2nd and 3rd marks. ignore references to aqueous HgBr ₂ ignore 'delocalised ions' OR 'free ions' for 'mobile ions' do not allow any mention of electrons moving do not allow any mention of + ions moving
			Total	8	
10			 three shared electron pairs plus a lone pair on C and O (1) one of the shared pairs shown as dative – i.e. both with the same type of dot / cross as the other electrons around the O (1)	2	mark can be awarded if either lone pair is missing, but there must be three shared pairs
			Total	2	
11			B	1	
			Total	1	
12			C	1	
			Total	1	

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Question			Answer/Indicative content	Marks	Guidance
13			D	1	
			Total	1	
14			D	1	
			Total	1	
15		i	$P_4 + 6Br_2 \rightarrow 4PBr_3$	1	ignore state symbols
		ii	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 3.01×10^{21} award 3 marks $M_r(PBr_3) = 270.7 \text{ (g mol}^{-1}\text{)} \text{ (1)}$ $n(PBr_3) = 1.3535 / 270.7 = 5.000 \times 10^{-3} \text{ mol (1)}$ number of molecules = $5.000 \times 10^{-3} \times 6.02 \times 10^{23} = 3.01 \times 10^{21} \text{ molecules (1)}$	3	If there is an alternative answer, check to see if there is any ecf credit possible using working below. allow in working shown as $28.1 + 35.5 \times 4$ allow ecf from incorrect molar mass of PBr_3 allow 0.005(00) (mol) for two marks allow ecf for incorrect amount of PBr_3 allow calculator value or rounding to 3 significant figures or more but ignore 'trailing' zeroes, e.g. 0.200 allowed as 0.2 do not allow any marks for: $1.3535 \times 6.02 \times 10^{23} = 8.15 \times 10^{23}$
		iii	Pyramidal (1) (because there are) 3 bonded pairs and 1 lone pair (around the central phosphorus atom) (1) and electron pairs repel each other as far apart as possible so will take on a tetrahedral arrangement (giving a pyramidal shape overall) (1)	3	
			Total	7	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
16		i	 Barium ion with no (or eight) electrons AND two chloride ions with correct <i>dot-and-cross</i> octet (1) Correct charges (1)	2	For the first mark, if eight electrons are shown in the cation then the 'extra' electron in the anion must match the symbol chosen for electrons in the cation ignore inner shell electrons Circles not essential allow One mark if both electron arrangement and charges are correct but only one Cl is drawn allow 2[Cl]⁻ (Bracket not required)
		ii	Barium hydroxide OR barium oxide OR barium carbonate	1	allow Ba(OH) ₂ OR BaO OR BaCO ₃
			Total	3	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
17	a	i	Boiling point of H₂S lower than H₂O H₂O has hydrogen bonding (1) Hydrogen bonding is stronger OR more energy required to overcome hydrogen bonding (1) Boiling point of H₂S lower than H₂Se induced dipole–dipole interactions / London forces in H₂S are weaker (1) H₂S has fewer electrons OR less energy required to overcome induced dipole–dipole interactions (1)	4	ora throughout do not allow covalent bonds break allow instantaneous–induced dipole interactions allow dispersion forces allow van der Waals' / vdW ignore permanent dipole–dipole do not allow covalent bonds break
		ii	Any value between 285 and 335 (K) (1)	1	Graph must show an extrapolation line
	b		MgO: giant ionic (1) SO₂: simple molecular (1) ionic bonds (in MgO) are (much) stronger than intermolecular bonds (in SO₂) (1) ionic bonds (in MgO) need more energy to overcome / break (than intermolecular forces in SO₂) (1)	4	ora throughout For intermolecular bonds allow induced dipole–dipole interactions / London forces / permanent dipole–dipole interactions / van der Waals' forces do not allow hydrogen bonds ignore covalent bonds in SO₂ unless statement that they break: CON
			Total	9	

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Question			Answer/Indicative content	Marks	Guidance
18	a		Phosphorus has more electrons ✓	1	ALLOW ORA but comparison should be used for the all marks DO NOT ALLOW Phosphorus has more electrons in the outer shell or larger electron cloud. IGNORE Phosphorus molecules are bigger or have greater M_r. Examiner's Comments It as pleasing to see that the vast majority of candidates were able to use the terms London forces or induced dipole–dipole interactions rather than van der Waals as used in the legacy specification. Unfortunately, many candidates also chose to discuss how the strength of the covalent bonds increased melting points rather than just considering the intermolecular forces. Answers were either very good or very poor. Where a candidate only scored two marks it was mainly due to not discussing the influence the number of electrons has on the strength of the force.
			Stronger London forces OR Stronger induced dipole(-dipole) interactions ✓	1	ALLOW 'more' for 'stronger' ALLOW stronger van der Waals' / vdW forces
			More energy required to break the intermolecular forces / bonds OR London forces ✓	1	DO NOT ALLOW attraction between atoms- or that covalent bonds are broken
	b		Magnesium metallic (bonds) ✓	1	ALLOW the (electrostatic) attraction between cations / positive ions and delocalised electrons for both Mg marks ✓✓
			cations/positive ions/ Mg^{2+} AND delocalised electrons ✓	1	DO NOT ALLOW molecules for second mark IGNORE 'sea of electrons'
			Silicon covalent ✓	1	ALLOW the attraction between a shared pair of electrons and the nuclei of the (bonded) atoms for both marks ✓✓

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Question			Answer/Indicative content	Marks	Guidance
			between atoms ✓	1	DO NOT ALLOW any intermolecular forces in marking points 2 and 4 or silicon molecules Examiner's Comments The best answers linked the type of bonding with the correct particles in just a few statements to score all four marks. Those candidates who attempted to fill the answer space often contradicted correct answers by discussing the intermolecular forces between the particles. Some very able candidates did not include that the particles in silicon are atoms whereas others gave answers which suggested that silicon was made up of molecules.
			Total	7	
19			104.5° ✓ (oxygen atom) has two bond pairs and two lone pairs ✓ Bonded pairs / lone pairs / electron pairs repel ✓ Lone pairs repel more than bonding pairs ✓ NOTE: 'Lone pairs repel more than bonding pairs' would gain the last two marking points	1 1 1 1	ALLOW 104–105 ALLOW lp and bp ALLOW bonding regions for bond pairs IGNORE bonds repel / electrons repel DO NOT ALLOW atoms repel ALLOW alternative phrases / words to repel e.g. 'push apart' Examiner's Comments Although the weaker candidates appear to have little idea of the bond angles found in simple molecules many were able to pick up one or two marks for communicating that lone pairs repel more than bonding pairs. The more able candidates also described the number of lone pairs and bonding pairs and obtained the correct bond angle.
			Total	4	

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Question			Answer/Indicative content	Marks	Guidance
20				1	ALLOW <i>all</i> dots or <i>all</i> crosses. Examiner's Comments Nearly all were able to draw an accurate 'dot-and-cross' diagram of a nitrogen molecule.
			Total	1	
21			Simple molecular lattice ✓	1	ALLOW 'simple covalent' OR 'simple molecular' ie 'simple' must be seen. DO NOT ALLOW 'simple covalent <i>bonds</i>' Examiner's Comments Nearly all candidates understood that halogens consisted of simple molecular lattices.
			Total	1	

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Question			Answer/Indicative content	Marks	Guidance
22	a	i	SF_6 AND Sulfur(VI) fluoride OR Sulfur hexafluoride ✓	1	IGNORE sulfur fluoride Examiner's Comments Nearly all candidates knew the formula of the molecule in question but some of these were less secure when it came to the name. Sulfur(IV) fluoride being the most common error.
		ii	$2\text{F}_2 + 2\text{NaOH} \rightarrow \text{F}_2\text{O} + 2\text{NaF} + \text{H}_2\text{O}$ M1 F_2O AND NaF ✓ M2 Rest of equation (including balance) ✓	2	ALLOW multiples IGNORE state symbol ALLOW OF_2 for F_2O AND FNa for NaF ALLOW both marks for alternative equations which have both F_2O and NaF AND three products Eg $3\text{F}_2 + 2\text{NaOH} \rightarrow 2\text{F}_2\text{O} + 2\text{NaF} + \text{H}_2$ Eg $2\text{F}_2 + \text{NaOH} \rightarrow \text{F}_2\text{O} + \text{NaF} + \text{HF}$ Examiner's Comments Even weaker candidates coped well with the construction of this difficult equation. (Once again suggesting that having covered the A2 part of the specification, this had given candidates the experience that the normal AS candidate would not have met.)
	b	i	δ^- on each F AND δ^+ on O ✓	1	ALLOW δ^+ OR $\delta^+ \delta^+$ on O Examiner's Comments The application of dipoles to the molecule was done well.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Shape: non-linear AND Bond angle: 104.5° ✓	1	For shape ALLOW alternative words eg 'V-shaped' 'bent' 'angular'. In the absence of words allow a diagram with a non-linear shape F – O – F bond angle $> 90^\circ$. For bond angle ALLOW 106° bond angle $\geq 102^\circ$ (Actual = 102°) Examiner's Comments Only a few candidates failed to realise that two bonding pairs and two non-bonding pairs would lead to the molecule being bent-shaped with an expected bond angle of 104.5° .
		iii	+2 ✓	1	ALLOW 2+ Examiner's Comments The question told candidates that fluorine was the most electronegative element which should have led them to realising that oxygen's oxidation state had to be a positive number. Many chose to ignore this despite allocating the oxygen atom a partial positive charge in part (i).
			Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
23		i	Ca(OH) ₂ OR Calcium hydroxide OR CaO OR Calcium oxide ✓ □	1	ALLOW Calcium carbonate OR CaCO ₃ Examiner's Comments The unusual equation involving P4 molecules was answered well. Weaker candidates assumed that phosphorus was monatomic and consequentially lost credit.
		ii	6Ca + P ₄ □ 2Ca ₃ P ₂ ✓	1	ALLOW multiples IGNORE state symbols Examiner's Comments This potentially difficult dot-and-cross diagram of the ions present was done well by candidates.
		iii	$3x \left[\begin{array}{ccc} & xx & \\ x & Ca & x \\ x & & x \\ & xx & \end{array} \right]^{2+} \quad 2x \left[\begin{array}{ccc} \bullet & \bullet & \\ \bullet & P & x \\ x & & \bullet \\ \bullet & & x \end{array} \right]^{3-}$ Ca with 8 (or no) electrons AND phosphide ion with dot-and-cross outermost octet ✓ Three Ca ions AND two phosphide ions with correct charges ✓	2	For first mark: If 8 electrons are shown on the cation then the extra electron in the anion must match the symbol chosen for the electrons in the cation. IGNORE inner shells IGNORE circles ALLOW one mark if both electron arrangements and charges are correct but only one of each ion is drawn. ALLOW (brackets not required) 3[Ca²⁺] 3[Ca]²⁺ [Ca²⁺]₃ 2[P³⁻] 2[P]³⁻ [P³⁻]₂ DO NOT ALLOW [Ca₃]²⁺ [3Ca]²⁺ [Ca]³²⁺ [P₂]³⁻ [2P]³⁻ [P]₂
			Total	4	
24			B	1	Examiner's Comments Generally scored well.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
25			B	1	<u>Examiner's Comments</u> Candidates struggled with this very different polarity question. The majority of candidates are clearly used to applying symmetry to much simpler molecules.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
26		i	$\text{NiO} + 2\text{HNO}_3 \rightarrow \text{Ni}(\text{NO}_3)_2 + \text{H}_2\text{O} \checkmark$	1	ALLOW multiples IGNORE state symbols (even if wrong) <u>Examiner's Comments</u> This part was surprisingly poorly answered. Common errors included incorrect formulae for nickel(II) oxide and HNO_3, and H_2 shown as a product instead of H_2O.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
ii	Global rules - N and O electrons must be shown differently, e.g. • for N and × for O 'Extra' electron shown with different symbol MARKING <i>Bonding around central N atom ✓</i> 5 electrons for N shown as • OR × 3 electrons for O, different from N as • OR × - N=O bond with 2 N electrons AND 2 O electrons - N→O bond with 2 N electrons - N–O bond with 1 N electron AND 1 O electron <i>Non-bonded (nb) electrons around 3 O atoms ✓</i> - N=O oxygen has 4 nb 'O' electrons - N□O oxygen has 6 nb 'O' electrons - N–O[–] oxygen has 5 nb 'O' electrons AND 1 'extra' electron with different symbol	2	NOT REQUIRED - Charge ('–') - Brackets - Circles IGNORE inner shells ALLOW rotated diagram ALLOW diagram with missing N or O symbols. <i>Shown as diagram on QP anyway</i> In N=O bond, ALLOW sequence × × • • In N–O bond, ALLOW 'extra' electron with different symbol for O electron ALLOW non-bonding electrons unpaired If 'extra' electron has been used in N–O[–] bond, N–O[–] oxygen MUST have 6 nb 'O' electrons ALLOW 'extra' electron as • OR × if it has been labelled 'extra electron' or similar <u>Examiner's Comments</u> Most candidates attempted this novel '<i>dot-and-cross</i>' diagram. Many candidates correctly showed the bonding electrons around the central nitrogen atom. The remaining electrons around the oxygen atoms proved to be more difficult, with many omitting to show the 'extra electron'.
	Total	3	

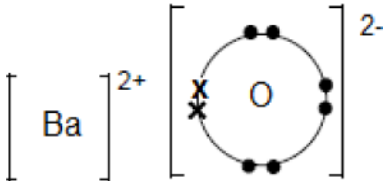
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
27	a		Alcohols have hydrogen bonds (and van der Waals' forces) ✓ Hydrogen bonds are stronger than van der Waals' forces (in alkanes) ✓	2	ANNOTATE ANSWER WITH TICKS AND CROSSES ALLOW reference to specific compounds e.g. comparing methane and methanol Second marking point requires BOTH types of intermolecular forces in response i.e comparison of hydrogen bonds AND van der Waals is essential DO NOT ALLOW the second mark for a comparison of van der Waals' and hydrogen bonds between alcohols and water ALLOW more energy required to break hydrogen bonds than van der Waals' forces ALLOW it is harder to overcome the hydrogen bonds than van der Waals' forces IGNORE more energy is needed to break bonds Examiner's Comments Many candidates attributed the difference in boiling point between alkanes and alcohols to the relative strength of hydrogen bonds compared with van der Waals' forces. Weaker responses simply identified alcohols as being able to form hydrogen bonds, but failed to compare these with van der Waals' forces.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b		2-methylpropan-1-ol has less surface (area of) contact OR fewer points of contact ✓ 2-methylpropan-1-ol has fewer / weaker van der Waals' forces OR less energy required to break van der Waals' forces in 2-methylpropan-1-ol ✓	2	ANNOTATE ANSWER WITH TICKS AND CROSSES Both answers need to be comparisons ALLOW ORA throughout Reference to just surface area / closeness of molecules is not sufficient IGNORE reference to H bonds IGNORE less energy is needed to break bonds Examiner's Comments Most candidates recognised that 2-methylpropan-1-ol is branched and communicated both marking points succinctly. Weaker responses identified that 2-methylpropan-1-ol would have weaker intermolecular forces, but failed to specify these as van der Waals' forces.
			Total	4	
28			A	1	Examiner's Comments Surprisingly, less than half of candidates obtained the correct answer. Many candidates incorrectly chose answer option B, BCl₃, despite it having no lone pair.
			Total	1	
29			A	1	Examiner's Comments Most candidates correctly identified Si as giant covalent. A common error was answer option D.
			Total	1	
30			D	1	Examiner's Comments This part was generally well answered. The common incorrect answer was answer option A.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
31	a	i	<u>Electrostatic attraction</u> between positive and negative ions ✓	1	ALLOW oppositely charged ions ALLOW cations and anions ALLOW '+' for positive and '-' for negative IGNORE references to metal and non-metal IGNORE references to transfer of electrons Examiner's Comments The specification describes ionic bonding as an electrostatic attraction and a small proportion of answers were missing this key phrase.
		ii	 Ba shown with either 0 or 8 electrons AND O shown with 8 electrons with 6 dots and 2 crosses (or vice versa) ✓ Correct charges on both ions ✓	2	For first mark, if eight electrons are shown around Ba, the 'extra' electrons around O must match the symbol chosen for the electrons for Ba. IGNORE inner shells Circles not required Brackets not required Examiner's Comments Covalent bonding diagrams were not common and this question was well answered by the vast majority of candidates.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	FIRST CHECK THE ANSWER ON THE ANSWER LINE IF answer = 5.89×10^{21} award 2 marks for calculation <i>Moles of barium oxide</i> $n(\text{BaO}) = 1.50/153.3$ OR 9.78×10^{-3} ✓ <i>Number of barium ions</i> $(9.78 \times 10^{-3} \times 6.02 \times 10^{23}) = 5.89 \times 10^{21}$ ✓ 3 SF AND standard form required	2	ALLOW 0.00978 up to calculator value 0.009784735 ALLOW ECF from incorrect moles of BaO Common incorrect answers are shown below IF 137.3 is used for the molar mass ALLOW 1 mark total for 6.58×10^{21} (0.010924981 mol) OR 6.56×10^{21} (0.0109 mol) IF 153 is used for the molar mass ALLOW 1 mark total for 5.90×10^{21} Examiner's Comments Use of the relative mass of barium to calculate moles of barium oxide was a common error but these candidates were usually able to pick up one mark for correctly multiplying their moles by the Avogadro constant. Some candidates correctly calculated moles but then divided by two thus losing the final mark.

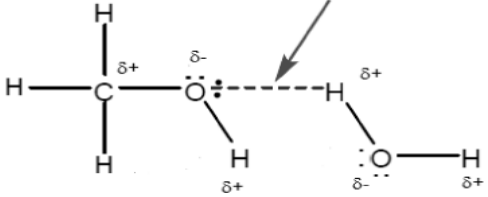
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b	i	Barium chloride does not conduct electricity when solid AND because it has ions which are fixed (in position / in lattice) ✓ Barium chloride conducts when in aqueous solution AND because it has mobile ions	2	IGNORE use of 'free' instead of 'mobile' ALLOW ions are not free to move ALLOW ions are held (in position / in lattice) ALLOW ions are not mobile IGNORE charge carriers DO NOT ALLOW electrons moving ALLOW one mark for comparison that does not identify (s) and (aq). Examiner's Comments Many precise answers gained full marks by describing the fixed position of ions in a lattice and the mobility of ions in aqueous solution. Delocalised or free electrons were occasionally mentioned. Vague answers often used the terms 'free' instead of mobile, 'charge carrier' instead of ion and 'carry a charge' instead of conduct electricity.
		ii	Test for sulfate / SO_4^{2-} ✓ <u>White</u> precipitate forms (when barium chloride solution is mixed with a solution containing sulfate ions) ✓	2	IGNORE hydrochloric acid ALLOW white solid IGNORE cloudy DO NOT ALLOW test result linked to incorrect anion Examiner's Comments There was some confusion with the displacement reactions of halogens, the test for halide ions and the use of silver nitrate but the majority of students could recall the use of aqueous barium chloride to test for sulfate ions. Occasionally candidates described the use of dilute hydrochloric acid to remove carbonate ions from solution before their creditworthy description of the sulfate test.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	FIRST CHECK THE ANSWER ON THE ANSWER LINE IF answer = 2 award 2 marks $M(\text{BaCl}_2) = ((137.3 + (35.5 \times 2))$ ✓ $= \underline{208.3} \text{ (g mol}^{-1}\text{)}$ $244.3 - 208.3 = 36$ AND $36/18 = 2$ ✓	2	ALLOW 208 (g mol⁻¹) ALLOW ECF for incorrectly calculated molar mass provided the final answer is rounded to nearest whole number Examiner's Comments Very well answered, the majority of candidates scored full marks for this simple calculation.
			Total	11	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
32	Displayed formulae of CH₃OH and H₂O AND C–O AND O–H polar bonds shown on CH₃OH molecule with δ+ and δ- AND Both O–H polar bonds shown on H₂O molecule with δ+ and δ- ✓ Two lone pairs shown on both oxygen atoms AND Hydrogen bond / H-bond labelled and in the correct position between the H on water and the oxygen lone pair on methanol ✓	2	Must be displayed formulae Hydrogen bond  IGNORE δ+ shown on other H atoms ALLOW hydrogen bond between the H on methanol (OH) and the oxygen lone pair on water Examiner's Comment: Candidates did not cope well with the requirement to produce a hydrogen bonding diagram that was expected to match the content of all four of the bullet points listed in the question. Perhaps candidates did not read the question carefully enough but some diagrams did not include displayed formulae, dipoles were often missing from the methanol molecule, lone pairs were absent from oxygen atoms and the hydrogen bond was marked in an incorrect position. This resulted in a low scoring question for a diagram that had produced much higher scores when asked on papers from the legacy specification.
	Total	2	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
33		i	Tetrahedral AND 109.5(°) ✓ four bonded pairs repel OR four bonds repel ✓	2	Mark each point independently ALLOW range 109 – 110° IGNORE surrounded by four atoms IGNORE four areas of electron charge repel IGNORE four electron pairs repel (<i>one could be lp</i>) DO NOT ALLOW atoms repel Examiner's Comments This question was poorly answered. Many candidates ignored the instruction to give the shape around the carbon atom in the alkyl group and instead focussed on the bond angle and shape around the carbonyl carbon. Even candidates who could identify the correct shape and bond angle did not explain that it is due to the repulsion between four bonding pairs.
		ii	104.5(°) ✓	1	ALLOW range 104 – 105° Examiner's Comments Generally well answered but many examples of incorrect bond angles including 107, 120 and 180 were seen here.
			Total	3	

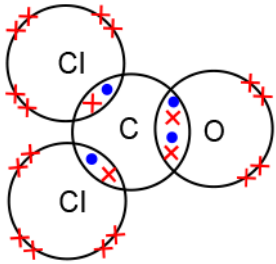
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance																				
34	a		Na Na x S x 2- Na shown with either 0 or 8 electrons AND S shown with 8 electrons with 6 dots and 2 crosses (or vice versa) ✓ Correct charges ✓	2	ALLOW 2[Na]⁺ ALLOW [Na]₂⁺ Brackets not required For first mark, if eight electrons are shown around Na, the 'extra' electrons around S must match the symbol chosen for the electrons for Na. IGNORE inner shells Circles not required <u>Examiner's Comments</u> The majority of candidates obtained full marks on this question. The most common errors were incorrect charges or covalent structures.																				
	b		<table><tr><td></td><td>Na₂S</td><td>Na</td><td>S</td></tr><tr><td>Melting point / °C</td><td>1180</td><td>98</td><td>113</td></tr><tr><td>Type of structure</td><td>giant</td><td>giant</td><td>simple</td></tr><tr><td>Conductivity of solid</td><td>poor</td><td>good</td><td>poor</td></tr><tr><td>Conductivity of liquid</td><td>good</td><td>good</td><td>poor</td></tr></table> ✓ ✓ ✓ One mark for each correct column		Na ₂ S	Na	S	Melting point / °C	1180	98	113	Type of structure	giant	giant	simple	Conductivity of solid	poor	good	poor	Conductivity of liquid	good	good	poor	3	Mark by COLUMN <u>Examiner's Comments</u> The majority of candidates obtained 2 or 3 marks on this question. Many candidates seemed unaware that sodium was a metal.
	Na ₂ S	Na	S																						
Melting point / °C	1180	98	113																						
Type of structure	giant	giant	simple																						
Conductivity of solid	poor	good	poor																						
Conductivity of liquid	good	good	poor																						
			Total	5																					

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
35		i	$\text{Br}_2(\text{l}) \rightarrow \text{Br}_2(\text{g})$ ✓	1	<u>Examiner's Comments</u> A good attempt by many candidates but some lost marks by having the wrong state of bromine, even though the question stated it was a liquid changing to a gas. Many added water or oxygen, some confused the equation with bond enthalpy and answers such as $\text{Br}_{2(\text{l})} \rightarrow 2\text{Br}_{(\text{g})}$ were commonly seen.
		ii	Endothermic AND Energy required to overcome induced dipole–dipole forces/London forces ✓	1	Mark independently of 3 (d) (i) ALLOW endo to break intermolecular forces/bonds ALLOW bonds between molecules DO NOT ALLOW van der Waals' forces <u>Examiner's Comments</u> The majority of candidates answered this question incorrectly. Only 10% of candidates mentioned intermolecular/London forces. Most stated 'exothermic' or described breaking covalent bonds.
			Total	2	
36			D	1	<u>Examiner's Comments</u> As is often the case, candidates find structure and bonding difficult. Many candidates selected silicon (C) instead of the correct response of sulfur (D).
			Total	1	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
37 i	 <i>CARE: Check that lone pairs on Cl and O are included</i> - Cl (×2) has 6 non-bonded electrons (3 LPs) - O has 4 non-bonded electrons (2 LPs)	1	NOTE: O and Cl electrons MUST be shown differently from C electrons (<i>e.g. expected answer</i>) IGNORE inner shells ALLOW diagram with missing C, O or Cl symbols. For C=O bond, ALLOW sequence × × • • ALLOW non-bonding electrons unpaired <u>Examiner's Comments</u> Most candidates attempted a dot-and-cross diagram of a COCl₂ molecule, with ionic representations being rare. Candidates should take care to include any lone pairs in their diagrams. Omission of the O and Cl lone pairs was the most common error.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Shape Trigonal planar ✓ Number of bonded regions (C has) 3 electron (dense) regions OR 3 bonding regions ✓ Electron pair repulsion (<i>Seen anywhere</i>) electron pairs/bonded pairs/bonded regions repel OR electron pairs move as far apart as possible OR bonds repel ✓	3	ALLOW bp for bonded pair ALLOW 3 bonded pairs (BOD) OR 3 sigma bonds OR 2 bonded pairs and 1 double bond OR 4 bonded pairs including a double bond IGNORE bonded atoms IGNORE just 3 bonds ALLOW alternative phrases/words for repel e.g. 'push apart' IGNORE electrons repel (<i>pairs needed</i>) DO NOT ALLOW atoms repel Examiner's Comments This question discriminated well. Most candidates recognised that a COCl_2 molecule has a trigonal planar shape. The best answers explained this shape in terms of the three electron regions around the central C atom and their repulsion.
			Total	4	
38			A	1 (AO1.1)	Examiner's Comments This part discriminated well, with most able candidates selecting the correct answer of A. A sizeable number selected B, accompanied by a diagram of an H_2O molecule with a 180° bond angle, presumably by ignoring the lone pairs. C_2H_4 was often shown with a bond angle of 109.5°, presumably as the $\text{C}=\text{C}$ bond had not been identified, giving a bond angle of 120°.
			Total	1	

1

- (i) Complete the electron configuration of a bromide ion.

1s² [1]

- (ii) A student adds a small volume of aqueous silver nitrate to an aqueous solution of bromide ions in a test-tube. The student then adds a similar volume of dilute aqueous ammonia to the same test-tube.

Describe what the student would see in the test-tube after the addition of aqueous ammonia.

..... [1]

- (iii) Write an ionic equation for any precipitation reaction which occurs in the student's tests.

Include state symbols.

..... [1]

- 2 Ytterbium, atomic number 70, is the first element in the Periodic Table to have the first four shells full.

- (i) State the number of electrons in the **fourth** shell of ytterbium.

..... [1]

- (ii) How many orbitals are there in the **third** shell of ytterbium?

..... [1]

- 3 Complete the electron configuration of a manganese atom.

1s² [1]

- 4 Bromine and mercury are the only two naturally occurring elements that are liquids at room temperature and pressure. Some physical properties of these two elements are given below.

	Appearance at room temperature	Melting point / °C	Boiling point / °C	Electrical conductivity of the liquid
Bromine	dark orange liquid	−7.2	58.8	very low
Mercury	shiny silver liquid	−38.8	356.7	good

Complete the full electron configuration of a bromine atom.

1s² _____ [1]

- 5 What is the electron configuration for an Mg²⁺ ion?

- A 1s²2s²
 B 1s²2s²2p⁶
 C 1s²2s²2p⁶3s²
 D 1s²2s²2p⁶3s²3p⁶3d⁴

Your answer

[1]

- 6(a) Europium, atomic number 63, has two isotopes, ¹⁵¹Eu and ¹⁵³Eu.

Complete the table to show the number of protons, neutrons and electrons in the ¹⁵³Eu³⁺ ion of europium.

	protons	neutrons	electrons
¹⁵³ Eu ³⁺			

[1]

(b) Atoms of europium have electrons in orbitals within the first five shells. The first three shells of europium are full.

Complete the table to show the number of electrons in the following regions of a europium atom.

	number of electrons
the 1s sub-shell	
a 3p orbital	
the 3 rd shell	

[3]

7 Group 2 elements are metals that react with oxygen and water.

Magnesium is oxidised when it burns in oxygen to form an ionic compound.

(i) Write the electron configuration, in terms of sub-shells, of a magnesium atom.

----- [1]

(ii) Explain what happens when magnesium is oxidised in terms of electron transfer.

----- [1]

8 The electrons in the second shell of a nitrogen atom are found in an s-orbital and three p-orbitals.

(i) State, in words, the 3D shape of an s-orbital and a p-orbital.

s-orbital -----

p-orbital -----

[1]

(ii) Describe the relative energies of the 2s orbital and **each** of the three 2p orbitals in a nitrogen atom.

----- [2]

9 This question is about the chemistry of the metals zinc, magnesium, aluminium and calcium.

Complete the electron configuration of a zinc atom.

1s² ----- [1]

10 How many orbitals are occupied in a silicon atom?

- A 5
- B 7
- C 8
- D 9

Your answer

[1]

11 Electron configurations for atoms of different elements are shown below.

Which electron configuration represents the element with the largest first ionisation energy?

- A $1s^2 2s^2$
- B $1s^2 2s^2 2p^4$
- C $1s^2 2s^2 2p^6$
- D $1s^2 2s^2 2p^6 3s^2$

Your answer

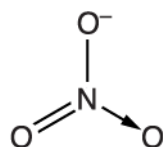
[1]

12 Nickel(II) nitrate, $\text{Ni}(\text{NO}_3)_2$, can be prepared by reacting nickel(II) oxide with dilute nitric acid.

(i) Write the equation for this reaction.

[1]

(ii) $\text{Ni}(\text{NO}_3)_2$ contains the NO_3^- ion. The nitrogen atom bonds to the oxygen atoms with a single covalent bond, a double covalent bond and a dative covalent bond, as shown below.



Draw the '*dot-and-cross*' diagram for the NO_3^- ion, showing outer shell electrons only.
Use a different symbol for the extra electron.

[2]

13 This question is about properties of the halogens and halide ions.

Bromine can be extracted by bubbling chlorine gas through concentrated solutions containing bromide ions.

(i) Write the electron configuration of a bromide ion, in terms of sub-shells.

-----[1]

(ii) Write an ionic equation for this reaction and state why this reaction takes place in terms of reactivity of the halogens.

-----[2]

14 Which element has atoms with the greatest number of singly occupied orbitals?

- A C
- B C/
- C Ca
- D Ga

Your answer

[1]

15 Barium nitride is formed when barium is heated with nitrogen.

(i) Complete the electron configuration of a nitride ion.

1s² -----[1]

(ii) Solid barium nitride is reacted with water, forming an alkaline solution **A** and an alkaline gas **B**.

Identify **A** and **B**.

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

A -----

B -----

-----[4]

16 The hydroxyl group, -OH , is responsible for many properties of alcohols.

Methanol, CH_3OH , is soluble in water because it has polar bonds.

Pauling electronegativity values for carbon, oxygen and hydrogen are shown below.

Element	Electronegativity
Carbon	2.5
Oxygen	3.5
Hydrogen	2.1

Use a labelled diagram to explain why methanol is soluble in water.

- Use displayed formulae showing one molecule of methanol and one molecule of water.
- Add partial charges δ^+ and δ^- to show the **two** most polar bonds in a methanol molecule and the polar bonds in a water molecule.
- Show all lone pairs.
- Label the most important intermolecular bond between the molecules.

[2]

- A student dissolves **B** and **C** in water in separate test tubes and analyses the solutions.

The observations are shown below.

Test	Observation	
	B(aq)	C(aq)
Addition of $\text{HNO}_3(\text{aq})$ followed by $\text{BaCl}_2(\text{aq})$	bubbles no change	no change white precipitate

Use this information and the observations to identify the formulae of B and C.

Explain your reasoning.

[5]

18 Selenium is in the same group of the periodic table as sulfur.

(i) Complete the full electron configuration of a selenium atom.

1s² [1]

(ii) Sodium selenide reacts with hydrochloric acid to form a toxic gas, **B**, with a relative molecular mass of 81.0.

Identify gas **B** and write an equation for this reaction.

Gas B

Equation [2]

19 The electron configuration of element **X** is: 1s²2s²2p⁶3s²3p⁴

What is the formula of a compound formed when sodium reacts with element **X**?

A NaX

B NaX₂

C Na₂X

D Na₂X₃

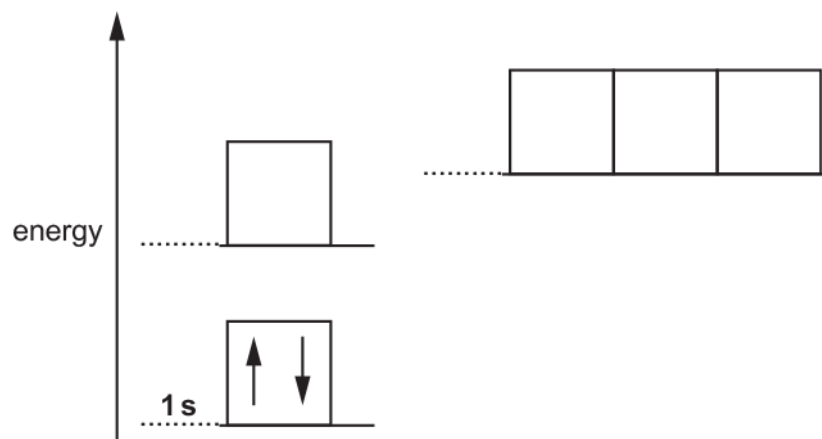
Your answer

[1]

20 Electrons occupy orbitals which are arranged in energy levels.

In the diagram below, each box represents an orbital and each electron is shown as an arrow.

Label the sub-shells and add arrows to show how electrons occupy orbitals in an atom of oxygen.



[2]

END OF QUESTION PAPER

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
1		i	$(1s^2) 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6$ ✓	1	ALLOW ... $4s^2 3d^{10} 4p^6$ ALLOW subscripts AND 3D IGNORE $1s^2$ seen twice Examiner's Comments Most candidates were awarded the mark available for the electron configuration of the bromide ion, but weaker responses included the electronic configuration of a bromine atom or of the ion, Br^+.
		ii	Cream AND precipitate ✓	1	ALLOW solid OR ppt for precipitate IGNORE 'does not dissolve' OR 'partially dissolves' Examiner's Comments Many candidates focused exclusively in their answers on the solubility of silver bromide in aqueous ammonia, writing as a result that the precipitate would remain, or that it would not dissolve and so not gaining the mark by omitting the colour of the precipitate.
		iii	$Ag^+(aq) + Br^-(aq) \rightarrow AgBr(s)$ ✓	1	Equation AND state symbols required Examiner's Comments The majority of candidates answered this question successfully with the only recurring error made being to omit some or all of the state symbols.
			Total	3	
2		i	32 ✓	1	Examiner's Comments Although there is a clear statement in the specification that candidates should know the number of electrons in the first four shells many were uncertain about how many electrons would be found in a complete fourth shell.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	9 ✓	1	Examiner's Comments This question proved to be slightly more demanding than (i). There were a range of answers suggested where it was not possible to see how the student had come to that conclusion but 3 was not an uncommon response presumably arising from a confusion between the number of orbitals and the number of sub-shells or different types of orbital.
			Total	2	
3			$1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^2$ ✓	1	ALLOW $4s^2 3d^5$ IGNORE $1s^2$ seen twice Examiner's Comments Answers proved that candidates were familiar with electron configurations.
			Total	1	
4			$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^5$	1	allow ... $4s^2 3d^{10}$...
			Total	1	
5			B	1	
			Total	1	
6	a		63 p 90 n 60 e	1	
	b		2 (1) 2 (1) 18 (1)	3	
			Total	4	

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7		i	$1s^2 2s^2 2p^6 3s^2$ ✓	1	ALLOW upper case S and P, and subscripts, e.g. 2S₂3P₆ Examiner's Comments This part was generally answered well showing a good understanding of electron configuration. Candidates frequently used subscripts rather than superscripts for denoting the number of electrons in a particular sub-shell and although this was still credited the correct use of notation should be emphasised in lessons.
		ii	(Mg) loses / transfers / donates two electrons ✓	1	ALLOW Mg loses the 3s electrons provided electronic configuration in (i) is $3s^2$ ALLOW $Mg \rightarrow Mg^{2+} + 2e^-$ IGNORE reference to oxidation numbers / states Examiner's Comments Most candidates understood that oxidation resulted in the loss of electrons although some answers considered changes in oxidation number. A significant number of candidates did not specify how many electrons were lost when magnesium was oxidised preventing the award of the mark.
			Total	2	

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8		i	s-orbital = spherical AND p-orbital = dumb-bell shape ✓	1	For s-orbital IGNORE 'circular' For p-orbital ALLOW other words indicating 3-D shape of p-orbital eg 'Peanut-shaped' OR hour glass etc ALLOW 'figure of eight' OR 'figure of 8 ' IGNORE diagrams Examiner's Comments Spherical was almost universally known as the shape of the s-orbital and this was mirrored in the responses for the shape of the p-orbital
		ii	p-orbitals have greater energy than s-orbitals ✓ (three) p-orbitals have equal energy ✓	2	ALLOW reverse argument ALLOW suitable energy diagram for either part Examiner's Comments This question asked about the simple concept of relative energies of the 2s orbital and the 2p orbitals. However, many candidates decided that the irrelevant details of the numbers of electrons should be given in their answer and further compounded their confusion by relating this fact to the relative energies of these orbitals. This said, the better candidates were able to give concise, accurate responses for two marks.
			Total	3	

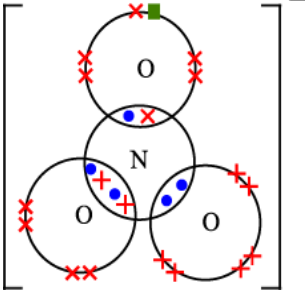
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Question			Answer/Indicative content	Marks	Guidance
9			$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2$ ✓	1	ALLOW $4s^2 3d^{10}$ Examiner's Comments The electron configuration of the d-block element zinc was extremely well known – once again suggesting that the knowledge gained from studying transition elements at A2 was of considerable benefit.
			Total	1	
10			C	1	ALLOW 8 in box Examiner's Comments Less able candidates did not consider that orbitals fill singularly and simply chose B as half of 14, the number of electrons in a silicon atom.
			Total	1	
11			C	1	Examiner's Comments Many candidates did not take into account the trend across periods, with A being a common incorrect answer.
			Total	1	

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Question			Answer/Indicative content	Marks	Guidance
12		i	$\text{NiO} + 2\text{HNO}_3 \rightarrow \text{Ni}(\text{NO}_3)_2 + \text{H}_2\text{O}$ ✓	1	ALLOW multiples IGNORE state symbols (even if wrong) <u>Examiner's Comments</u> This part was surprisingly poorly answered. Common errors included incorrect formulae for nickel(II) oxide and HNO_3, and H_2 shown as a product instead of H_2O.

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ii	 Global rules - N and O electrons must be shown differently, e.g. • for N and × for O 'Extra' electron shown with different symbol MARKING <i>Bonding around central N atom ✓</i> 5 electrons for N shown as • OR × 3 electrons for O, different from N as • OR × - N=O bond with 2 N electrons AND 2 O electrons - N→O bond with 2 N electrons - N-O bond with 1 N electron AND 1 O electron <i>Non-bonded (nb) electrons around 3 O atoms ✓</i> - N=O oxygen has 4 nb 'O' electrons - N□O oxygen has 6 nb 'O' electrons - N-O⁻ oxygen has 5 nb 'O' electrons AND 1 'extra' electron with different symbol	2	NOT REQUIRED - Charge ('-') - Brackets - Circles IGNORE inner shells ALLOW rotated diagram ALLOW diagram with missing N or O symbols. <i>Shown as diagram on QP anyway</i> In N=O bond, ALLOW sequence × × • • In N-O bond, ALLOW 'extra' electron with different symbol for O electron ALLOW non-bonding electrons unpaired If 'extra' electron has been used in N-O⁻ bond, N-O⁻ oxygen MUST have 6 nb 'O' electrons ALLOW 'extra' electron as • OR × if it has been labelled 'extra electron' or similar <u>Examiner's Comments</u> Most candidates attempted this novel 'dot-and-cross' diagram. Many candidates correctly showed the bonding electrons around the central nitrogen atom. The remaining electrons around the oxygen atoms proved to be more difficult, with many omitting to show the 'extra electron'.
Total		3	

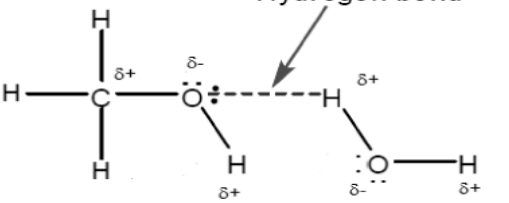
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Question			Answer/Indicative content	Marks	Guidance
13		i	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6$ ✓ Look carefully at $1s^2 2s^2 2p^6 3s^2 3p^6$ – there may be a mistake	1	ALLOW 3d after $4s^2$ or after $4p^6$, e.g. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6$ ALLOW upper case D, etc and subscripts, e.g. 4S ₂ 3D ₁ DO NOT ALLOW [Ar] as shorthand for $1s^2 2s^2 2p^6 3s^2 3p^6$ <u>Examiner's Comments</u> This part was generally answered well showing a good understanding of electron configuration. When incorrect, it was usually for giving the configuration of a bromine atom rather than a bromide ion, or the subtraction of an electron rather than addition giving $4p^4$.
		ii	$Cl^2 + 2Br^- \rightarrow 2Cl^- + Br_2$ ✓ Chlorine/Cl/Cl ₂ is more reactive/stronger oxidising agent OR reactivity decreases down group ✓	2	ALLOW multiples, e.g. $\frac{1}{2}Cl_2 + Br^- \rightarrow Cl^- + \frac{1}{2}Br_2$ IGNORE state symbols ALLOW bromine is less reactive IGNORE explanation in terms of electronegativity <u>Examiner's Comments</u> Most candidates identified that chlorine was the more reactive element, although a significant number responded in terms of electronegativity. More commonly, it was the equation that was incorrect, usually unbalanced or with bromine reacting instead of chlorine.
			Total	3	
14			A	1	<u>Examiner's Comments</u> This question discriminated well with less than half the candidates obtaining the correct answer. Answer option D was a common distractor.
			Total	1	

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15		i	$(1s^2) 2s^2 2p^6$ ✓	1	IGNORE $1s^2$ seen twice ALLOW upper case letters AND subscripts Examiner's Comments Many incorrect answers but I am happy to report that the use of incorrect notation, mentioned in last year's report, was not an issue in the 2017 paper.
		ii	<i>Products of reaction</i> A = Barium hydroxide / $Ba(OH)_2$ ✓ B = Ammonia / NH_3 ✓ <i>Formula for barium nitride</i> Ba_3N_2 ✓ <i>Balanced equation AND state symbols</i> $Ba_3N_2(s) + 6H_2O(l) \rightarrow 3Ba(OH)_2(aq) + 2NH_3(g)$ ✓ State symbols are required	4	ANNOTATE ANSWER WITH TICKS AND CROSSES ETC ALLOW one mark for correct products incorrectly labelled Formulae must be correct No ECF from any incorrect formula ALLOW multiples Correct equation with state symbols scores 4 marks Examiner's Comment: This question discriminated well and only the most able candidates were able to score full marks with a correctly balanced equation including state symbols. Weaker candidates were able to pick up some marks for identifying barium hydroxide or ammonia, although barium oxide and nitrogen were not uncommon. Some failed to score the more accessible marks because they used an incorrect formula instead of writing the name of the product.
			Total	5	

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16	Displayed formulae of CH₃OH and H₂O AND C–O AND O–H polar bonds shown on CH₃OH molecule with δ⁺ and δ⁻ AND Both O–H polar bonds shown on H₂O molecule with δ⁺ and δ⁻ ✓ Two lone pairs shown on both oxygen atoms AND Hydrogen bond / H-bond labelled and in the correct position between the H on water and the oxygen lone pair on methanol ✓	2	Must be displayed formulae Hydrogen bond  IGNORE δ⁺ shown on other H atoms ALLOW hydrogen bond between the H on methanol (OH) and the oxygen lone pair on water Examiner's Comment: Candidates did not cope well with the requirement to produce a hydrogen bonding diagram that was expected to match the content of all four of the bullet points listed in the question. Perhaps candidates did not read the question carefully enough but some diagrams did not include displayed formulae, dipoles were often missing from the methanol molecule, lone pairs were absent from oxygen atoms and the hydrogen bond was marked in an incorrect position. This resulted in a low scoring question for a diagram that had produced much higher scores when asked on papers from the legacy specification.
	Total	2	

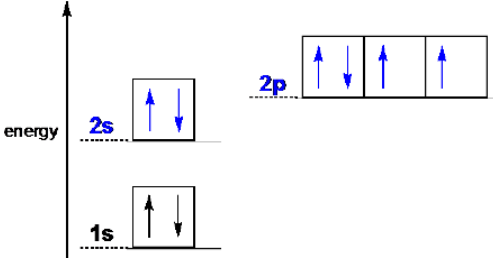
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Question			Answer/Indicative content	Marks	Guidance
17			Observations linked to anion identifications Bubbles/effervescence/fizzing/gas AND carbonate ✓ (white OR precipitate) AND sulfate ✓ Use of molar mass in reasoning Molar mass used ONCE with carbonate OR sulfate ✓ Identification B: K_2CO_3 ✓ C: Na_2SO_4 ✓	5	FULL ANNOTATIONS WITH TICKS, CROSSES, CON, etc MUST BE USED For bubbles, ALLOW carbon dioxide/CO_2 BUT DO NOT ALLOW hydrogen/H_2 For carbonate, ALLOW CO_3 For sulfate, ALLOW SO_4 e.g. Carbonate: $140 - (12 + 48)$; $140 - 60$ Sulfate: $140 - (32.1 + 64)$; $140 - 96.1$ $K_2CO_3 = 138.1$ $Na_2SO_4 = 142.1$ ALLOW ONE of the two identification marks for: • Correct names: B potassium carbonate AND C sodium sulfate • Incorrect formulae i.e. B KCO_3 AND C $NaSO_4$ <i>Communicates the same as names</i> Examiner's Comments This was a challenging question that discriminated extremely well. The more able candidates derived the anions from the two chemical tests and identified the cations using the molar masses of the salt and the anions. Weak candidates seemed to have little idea on how to approach such a question and they often achieved no credit. It was disappointing that many candidates were unable to identify a carbonate and sulfate from their chemical tests. Common errors included incorrectly identifying the gas with dilute acid as hydrogen, and identifying the white precipitate with barium ions as characteristic of a chloride. Candidates who used the provided molar mass of 140 usually went on to show that the cations contributed masses of approximately 80 for the carbonate and 44 for the sulfate. Candidates then needed to divide each value by 2 to obtain formulae

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					of K_2CO_3 and Na_2SO_4. Many did not divide by 2 and instead concluded that the compounds were $RbCO_3$, KSO_4 or $CaSO_4$. Strangely, some candidates thought they were identifying Group 1 metals and not salts.
			Total	5	
18		i	$(1s^2) 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^4$ ✓ Look carefully at $(1s^2) 2s^2 2p^6 3s^2 3p^6$ – there may be a mistake	1	ALLOW subscripts ALLOW in any order i.e. $3d^{10}$ after $4s^2$ or after $4p^4$ ALLOW upper case D, etc and subscripts, e.g. 3S₂3P⁶ DO NOT ALLOW [Ar] as shorthand for $1s^2 2s^2 2p^6 3s^2 3p^6$ <u>Examiner's Comments</u> Most candidates answered this correctly. The most common error seen was $4p^6$ instead of $4p^4$
		ii	Gas B H_2Se / Hydrogen selenide / Selenium hydride ✓ Equation $Na_2Se + 2HCl \rightarrow 2NaCl + H_2Se$ All formulae and balancing ✓	2	ALLOW SeH_2 ALLOW correct multiples IGNORE STATE SYMBOLS DO NOT ALLOW H_2S for gas B BUT ALLOW ECF from H_2S for equation: $Na_2S + 2HCl \rightarrow 2NaCl + H_2S$ <u>Examiner's Comments</u> The majority of candidates obtained 1 or 2 marks on this question. The most common errors seen were identifying the gas as H_2S or incorrect balancing.
			Total	3	

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Question			Answer/Indicative content	Marks	Guidance
19			C	1	Examiner's Comments Nearly all candidates responded with the correct response of C.
			Total	1	
20			Sub-shells labels 2s (single box) AND 2p (3 boxes) ✓ Electrons as arrows unpaired electrons in 3 boxes: ↑ ↓ ↑ ↑ AND Paired electrons in single box: ↑ ↓ ✓	2 (AO1.1) (AO1.2)	 ALLOW single headed arrows, e.g. 1 Examiner's Comments Most candidates added arrows correctly to the boxes but the sub-shell labels were sometimes omitted. Lower attaining candidates sometimes paired electrons, rather than showing them singly or showed six electrons in the 2p sub-shell. This suggested either a lack of understanding or failure to read the question.
			Total	2	