1. What is the electron configuration for an Mg^{2+} ion?

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

Your answer ☐

[1]

2(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 $^{153}Eu^{3+}$ 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.

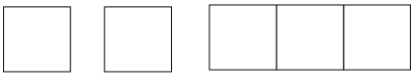
	number of electrons
the 1s sub-shell	
a 3p orbital	
the 3rd shell	

[3]

3. Ammonia is a gas with covalently-bonded molecules consisting of nitrogen and hydrogen atoms.

Show the electron configuration of a nitrogen atom using '*electron-in-box*' diagrams.

Label each sub-shell.



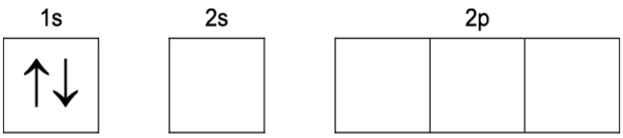
1s ....

[2]

4. This question is about electron structure and ions.

Electrons occupy orbitals within an atom. The diagram below shows an incomplete 'electrons in boxes' representation for the filling of orbitals in an oxygen atom.

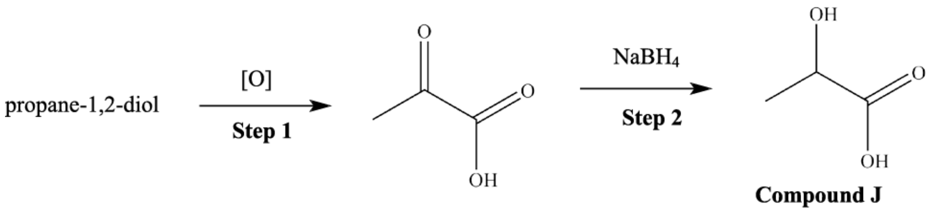
Complete the diagram.



[1]

5. α-Hydroxy acids (AHAs) are naturally occurring acids often used as cosmetics.

A student synthesises a sample of the AHA **J** using the following reaction scheme, starting from propane-1, 2-diol.



Compound J

i. In the space below:
   - state a suitable oxidising agent for **Step 1**
   - write an equation for **Step 1**
   - outline the mechanism for **Step 2**, showing curly arrows and relevant dipoles.

[5]

ii. The reagent used in **Step 2** of the synthesis in (**i**) was $NaBH_4$. $NaBH_4$ contains the ions Na^+ and $[BH_4]^-$.

Draw a '*dot-and-cross*' diagram of $NaBH_4$ and give the **full** electron configuration of Na^+.

Show outer shells of electrons only.

full electronic configuration of Na^+: ....

[2]

6. This question looks at properties of iron compounds and iron ions in different oxidation states.

Fe^{2+} and Fe^{3+} are the most common ions of iron.

i. Write the electron configuration, in terms of sub-shells, for the Fe^{2+} ion.

-- **[1]**

ii. How many orbitals contain an unpaired electron in an ion of Fe^{2+}?

-- **[1]**

7. 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.

$1s^2$ -- **[1]**

8.

i. Complete the electron configuration of a bromide **ion**.

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

9. 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]**

10. Complete the electron configuration of a manganese atom.

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

11. 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]**

12. 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]

---

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

Complete the electron configuration of a zinc atom.

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

14. How many orbitals are occupied in a silicon atom?

A 5
B 7
C 8
D 9

Your answer

[1]

15. 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 $1s^2 2s^2 2p^6 3s2$

Your answer

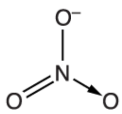
[1]

16. Nickel(II) nitrate, $Ni(NO_3)_2$, can be prepared by reacting nickel(II) oxide with dilute nitric acid.

i. Write the equation for this reaction.

[1]

ii. $Ni(NO_3)_2$ 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*' diagramfor the NO_3^- ion, showing outer shell electrons only.
Use a different symbol for the extra electron.

[2]

17. 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]

18. The accurate relative isotopic masses and relative abundances of the isotopes in a sample of bromine are shown below.

Isotope	Relative isotopic mass	Relative abundance (%)
^{79}Br	78.9183361	50.69
^{81}Br	80.9162896	49.31

i. What is the relative atomic mass of bromine in this sample?

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

relative atomic mass = ... **[2]**

ii. Write the electron configuration, in terms of all sub-shells, for an atom of bromine.

.... **[1]**

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

A C
B C*l*
C Ca
D Ga

Your answer [ ] **[1]**

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

i. Complete the electron configuration of a nitride ion.

$1s^2$ **[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]

---

21. 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]

22. B and **C** are ionic compounds of two different Group 1 elements.
The molar masses of **B** and **C** are both approximately 140 g mol^{-1}.

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 HNO_3(aq) followed by $BaCl_2$(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]

23. Two changes are described below.

For each change,

- write an equation, including state symbols,
- state and explain how the entropy changes.

i. The reaction of aqueous barium nitrate with aqueous sodium sulfate.

Full equation with state symbols

Explanation of entropy change

[2]

ii. The change that accompanies the standard enthalpy change of atomisation of iodine.

Equation with state symbols

Explanation of entropy change

[2]

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

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

$1s^2$ **[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]**

25. This question refers to the elements in the first three periods (H → Ar) of the Periodic Table.

Select an element from the first three periods that fits each of the following descriptions.

i. The element that forms a 1− ion with the same electron configuration as helium.

[1]

ii. The element with the highest first ionisation energy.

[1]

iii. The element in Period 3 which has the successive ionisation energies shown below.

Ionisation number	1st	2nd	3rd	4th
Ionisation energy/kJ mol^{-1}	738	1451	7733	10541

[1]

iv. The element which forms a compound with fluorine that has octahedral molecules.

[1]

v. An element which reacts with water to form an acidic solution.

[1]

vi. The element **X**, which forms a compound with hydrogen, **X**H_3, with a molar mass of 34.0 g mol^{-1}.

[1]

vii. An element which forms a compound with hydrogen in which the element has an oxidation number of −4.

[1]

viii. The element which has a density of 1.33×10^{-3} g cm^{-3} at room temperature and pressure.

[1]

26. The electron configuration of element **X** is: $1s^22s^22p^63s^23p^4$

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

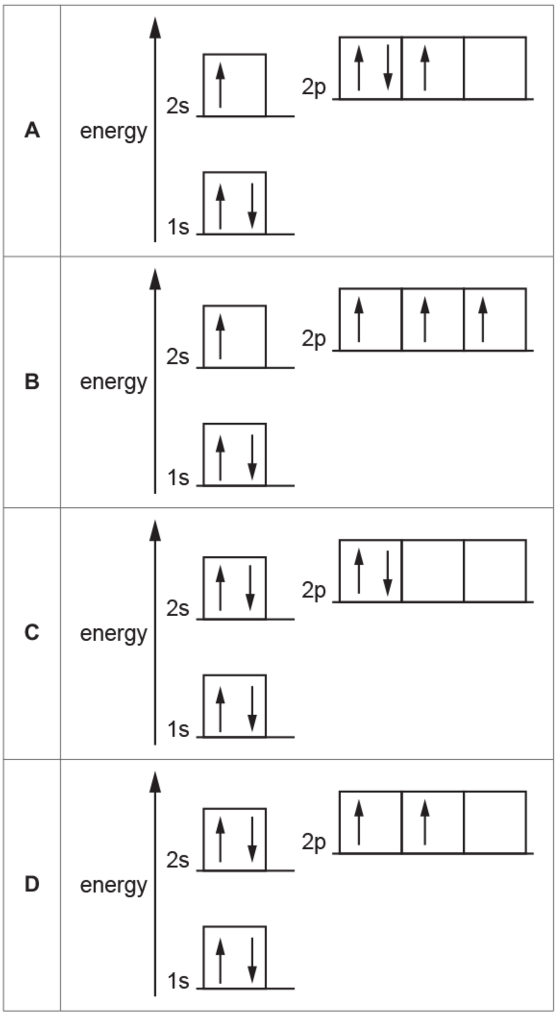
A Na**X**
B NaX_2
C Na_2**X**
D Na_2X_3

Your answer

[1]

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

Which diagram shows the correct arrangement of electrons in an atom of carbon?

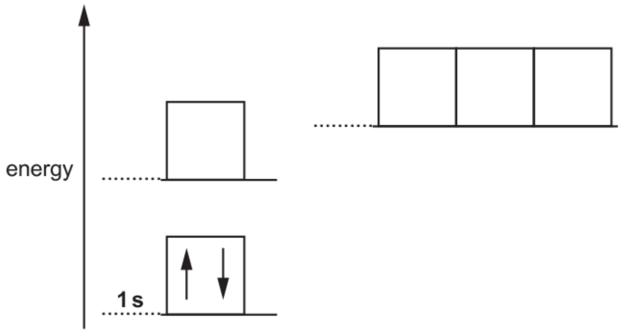


Your answer [ ] **[1]**

28. 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]

29. Which p-block element contains atoms with one unpaired electron?

A Al
B Si
C P
D S

Your answer

[1]

30. This question is about atoms, isotopes and mass spectrometry.

Complete the table to show the number of electrons that can fill the first four shells.

Shell	1st shell	2nd shell	3rd shell	4th shell
Number of electrons				

[1]

31. This question is about compounds of bromine.

Bromine reacts with phosphorus, P_4, to form phosphorus tribromide, PBr_3.

i. Complete the electron configuration of a bromine atom.

$1s^2$ -- **[1]**

ii. Write the equation for the reaction of phosphorus with bromine.

-- **[1]**

32. Which statement about elements in the d block of Period 4 of the periodic table is correct?

A Cr atoms have the electron configuration: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^1$.
B Cu^+ ions contain an incomplete 3d sub-shell.
C Fe^{2+} ions contain 3 unpaired electrons.
D Sc forms ions with different oxidation states.

Your answer ☐ **[1]**

33. Which statement(s) for Group 2 elements is/are correct?

1 The 2nd ionisation energy of magnesium is greater than the 2nd ionisation energy of calcium.
2 A strontium ion, Sr^{2+}, contains a total of 6 electrons in s orbitals.
3 The equation for the reaction of barium with water is:
$2Ba + 2H_2O \rightarrow 2BaOH + H_2$.

A 1, 2 and 3
B Only 1 and 2
C Only 2 and 3
D Only 1

Your answer ☐ **[1]**

34. Which element has atoms with the largest number of unpaired p-electrons?

A aluminium
B oxygen
C chlorine
D phosphorus

Your answer ☐ **[1]**

35. This question is about atomic structure.

Complete the table to show the maximum number of electrons that can occupy each shell and sub-shell. Some boxes may need to be left blank.

Shell	**Total number of electrons**	**Sub-shell**		
		s	**p**	**d**
1st				
2nd				
3rd				

[2]

36. Nickel and gallium are in period 4 of the periodic table.

i. Which block in the periodic table does nickel belong to?

[1]

ii. Complete the electron configuration of gallium.

$1s^2$

[1]

37. This question is about magnesium and magnesium halides.

The 12 successive ionisation energies of magnesium are shown in **Table 16.1**.

Ionisation number	**Ionisation energy / kJ mol^{-1}**
1	738
2	1451
3	7733
4	10541
5	13629
6	17995
7	21704
8	25657
9	31644

10	35463
11	169996
12	189371

Table 16.1

i. Write an equation to represent the **fourth** ionisation energy of magnesium.

Include state symbols.

[1]

ii. Explain how the successive ionisation energies provide evidence that magnesium is in Group 2 of the periodic table.

[1]

iii. Electrons occupy orbitals.

In **Table 16.2** below, add a tick (✓) below the ionisation numbers that are responsible for removing an electron from a full orbital in a magnesium atom.

Ionisation number	1	2	3	4	5	6	7	8	9	10	11	12

Table 16.2 **[1]**

38. What is the number of paired orbitals in a sulfur atom?

A 4
B 6
C 7
D 8

Your answer **[1]**

39. This question is about atomic structure and formulae.

Complete the table for an atom and an ion of **two** different elements.

Element	Mass number	Protons	Neutrons	Electron configuration	Charge
....	....	28	34	....	0
....	33	....	....	$1s^2 2s^2 2p^6 3s^2 3p^6$	3-

[2]

40. This question is about titanium (atomic number 22) and its compounds.

Titanium exists as a mixture of five isotopes.

A chemist analyses a sample of titanium using mass spectrometry.

The results are shown in the table below.

Isotope	Abundance (%)
^{46}Ti	8.30
^{47}Ti	7.40
^{48}Ti	73.70
^{49}Ti	5.40
^{50}Ti	5.20

i. Calculate the relative atomic mass of titanium in the sample.

Give your answer to **2** decimal places.

relative atomic mass = ... **[2]**

ii. Complete the electron configuration of a titanium atom.

$1s^2$ --

iii. Complete the table to show the number of protons, neutrons and electrons in a $^{48}Ti^{2+}$ ion.

	Protons	**Neutrons**	**Electrons**
$^{48}Ti^{2+}$ ion			

[1]

41. How many p-orbitals are occupied by electrons in a sulfur atom?

A 2
B 4
C 6
D 10

Your answer ☐ **[1]**

42. This question is about the d-block elements in Period 4 of the periodic table (Sc to Zn).

Explain, with examples from Period 4, what is meant by the terms **d-block element** and **transition element**.

Explain why some d-block elements are **not** transition elements.

Use electron configurations to support your explanations.

.... **[6]**

43. This question is about the first 36 elements in the periodic table:

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr

From these 36 elements **only**, write the symbol for the element(s) that fit each description.

The **two** elements with atoms containing five unpaired d electrons.

.... **[2]**

44(a). Hydrogen and oxygen have different electronegativities.

What is meant by the term **electronegativity**?

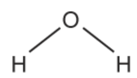
[2]

(b). H_2O is a polar molecule that has hydrogen bonding.

i. Complete the diagram below to show hydrogen bonding between the H_2O molecule shown and another H_2O molecule.

Include relevant dipoles and lone pairs.

Label the hydrogen bond.



[2]

ii. Explain why molecules of H_2O are polar.

[1]

iii. One unusual property of H_2O is that ice floats on water.

Explain why ice has a lower density than water.

[1]

(c). Solid ammonia, NH_3, contains hydrogen bonds.

i. Suggest why solid ammonia has a lower melting point than ice.

[2]

ii. When ammonia dissolves in water, ammonium ions, NH_4^+, are formed.

Draw a 'dot-and-cross' diagram to show the bonding in an NH_4^+ ion.

Show outer electrons only.

[2]

iii. Outline how you would test for the presence of NH_4^+ ions in a solution.

Your answer should include observations.

[2]

45. This question is about periodicity and the reaction of some Group 2 metals.

Periodicity is the repeating trend in properties of elements across different periods in the periodic table.

i. Complete the table below with the electron configurations and blocks.

	Group 2	**Group 17 (7)**
Period 2	Be $1s^2$	F $1s^2$ ....
Period 3	Mg $1s^2$	C*l* $1s^2$ ....
Block	....	....

[3]

ii. Use your answers to **(i)** to explain why electron configuration is an example of a periodic trend.

[2]

iii. Mg forms 2+ ions but C*l* usually forms 1− ions in their reactions. Explain why.

[2]

iv. Magnesium reacts with oxygen in the air.

Write the equation for this reaction.

[1]

46. Oxygen has the electron configuration $1s^2 2s^2 2p^4$.

How are the electrons in an atom of oxygen arranged in the p-orbitals?

A	↑↑	↑↑	
B	↑↓	↑↓	
C	↑↑	↑	↑
D	↑↓	↑	↑

Your answer ☐ **[1]**

47. Chlorine has the electron configuration $[Ne]3s^2 3p^5$.

Which statement(s) about chlorine is/are correct when it reacts in redox reactions?

1 It can gain one electron to form 1− ions.
2 It can lose its $3s^2$ electrons to form 2+ ions.
3 It can lose its $3p^5$ electrons to form 5+ ions.

A 1, 2 and 3
B Only 1 and 2
C Only 2 and 3
D Only 1

Your answer ☐ **[1]**

48. This question is about transition elements.

Iron is in the d block of the periodic table and contains s, p and d orbitals.

- Draw diagrams to show the shapes of an s orbital and a p orbital.
- Complete the electron configurations of an iron atom and an iron(II) ion.

Shapes

s orbital	**p orbital**

Electron configurations

Iron atom: $1s^2$ ....

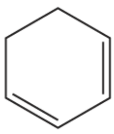
Iron(II) ion $1s^2$ .... **[2]**

49. Which diagram shows a p-orbital?

A	
B	
C	
D	

Your answer ☐ **[1]**

50. The structure of a hydrocarbon is shown below.



Which terms describe this hydrocarbon?

A Alicyclic and saturated
B Aliphatic and alicyclic
C Aliphatic and aromatic
D Aromatic and unsaturated

Your answer ☐ **[1]**

51. Hydrogen reacts much more readily with alkenes than with alkanes.

Why is this?

A Alkenes are polar molecules whereas alkanes are not.

B All atoms in an alkane have a full outer shell of electrons.

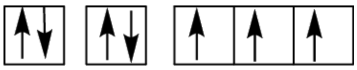
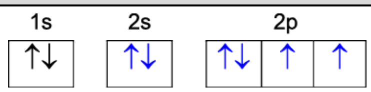
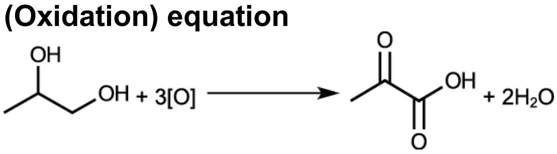
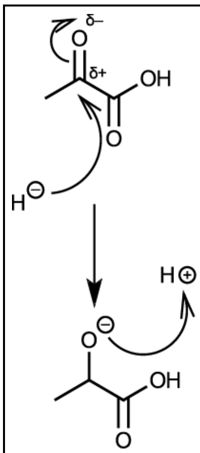
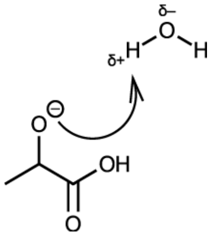
C The bond enthalpy of C–C σ bonds is **higher** than that of **π** bonds.

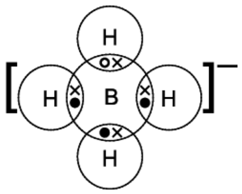
D The bond enthalpy of C–C σ bonds is **lower** than that of **π** bonds.

Your answer ☐ **[1]**

END OF QUESTION PAPER

Mark scheme

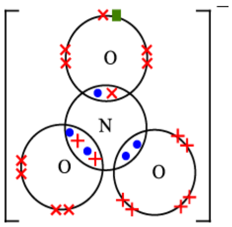
Question			Answer/Indicative content	Marks	Guidance
1			B	1	
			Total	**1**	
2	a		63 p 90 n 60 e	1	
	b		2 (1) 2 (1) 18 (1)	3	
			Total	**4**	
3			 (1) 2s 2p (1)	2	**allow** half headed arrows
			Total	**2**	
4				1	**ALLOW** unpaired electrons in last two boxes pointing down.
			Total	**1**	
5		i	Oxidising agent = acidified (potassium / sodium) dichromate(VI) **(Oxidation) equation**  **(Reduction) mechanism**  curly arrow from H^- to $C^{\delta+}$ dipole **AND** curly arrow from C=O bond to O intermediate **AND** curly arrow to H^+	5	**ALLOW** $Cr_2O_7^{2-}$ **OR** $K_2Cr_2O_7$ **OR** $Na_2Cr_2O_7$ for dichromate **ALLOW** H^+ **OR** (conc.) sulfuric acid for "acidified" **ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous **ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous  **ALLOW** for second stage **IF** H_2O is used it **MUST** show the curly arrow from the intermediate to

					$H^{\delta+}$ in H_2O **AND** from the O—H bond to the O **IGNORE** product **IGNORE** stereochemistry of intermediate
		ii	Na^+  $1s^2\ 2s^2\ 2p^6$	2	**IGNORE** inner electron shells for both ions Three different symbols required to identify electrons from different elements **DO NOT ALLOW** [Ne] **OR** [He] $2s^2\ 2p^6$
			Total	**7**	
6		i	$1s^22s^22p^63s^23p^63d^6$	1	
		ii	4	1	
			Total	**2**	
7			$1s^22s^22p^63s^23p^63d^{10}4s^24p^5$	1	**allow** …$4s^23d^{10}$…
			Total	**1**	
8		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**	
9		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.
		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**	
10			$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^2$ ✓	1	**ALLOW** $4s^2\ 3d^5$ **IGNORE** $1s^2$ seen twice **Examiner's Comments** Answers proved that candidates were familiar with electron configurations.

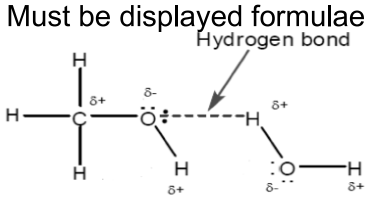
			Total	**1**	
11		i	$1s^22s^22p^63s^2$ ✓	1	**ALLOW** upper case S and P, and subscripts, e.g. ......$2S_23P_6$ **Examiner's Comments** This part was generally answered well showing a good understanding of electron configuration. Candidates frequently used subscripts rather than superscripts for denoting 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 3_s^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**	
12		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**	
13			$1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^6$ $3d^{10}$ $4s^2$ ✓	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**	
14			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**	

15			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**	
16		i	$NiO + 2HNO_3 \rightarrow Ni(NO_3)_2 + H_2O$ ✓	1	**ALLOW** multiples **IGNORE** state symbols (even if wrong) **Examiner's Comments** 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.
		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** ***Bonding around central N atom*** ✓ ○ 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	2	**NOT REQUIRED** • Charge ('−') • Brackets • Circles **IGNORE** inner shells **ALLOW** rotated diagram **ALLOW** diagram with missing N or O symbols. *Shown as diagram on QP anyway* In **N=O bond**, **ALLOW** sequence × × • • In **N−O bond**, **ALLOW** 'extra' electron with different symbol for O electron

			• N→O bond with 2 N electrons • N–O bond with 1 N electron **AND** 1 O electron ***Non-bonded (nb) electrons around 3 O atoms*** ✓ • 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		**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**	
17		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 + $2Br^-$ ⟶ $2Cl^-$ + Br_2 ✓ Chlorine/Cl/Cl_2 is more reactive/stronger oxidising agent **OR** reactivity decreases down group ✓	2	**ALLOW** multiples, e.g. ½Cl_2 + Br^- ⟶ Cl^-+½ Br_2 **IGNORE** state symbols **ALLOW** bromine is less reactive **IGNORE** explanation in terms of

					electronegativity **Examiner's Comments** 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**	
18		i	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer =** 79.904 award 2 marks .... $\frac{(78.9183361 \times 50.69) + (80.9162896 \times 49.31)}{100}$ **OR** 79.90352697 ✓ = 79.904 (to 3 DP) ✓	2	**ALLOW** value > 3 DP for 1st mark
		ii	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^5$ ✓	1	**ALLOW** 4s before 3d, i.e. $1s^2 2s^2 2p^6 3s^2 3p^6 \mathbf{4s^2 3d^{10}} 4p^5$ **ALLOW** upper case D, etc and subscripts, e.g. ......$4S_2 3D_{10}$ **DO NOT ALLOW** [Ar] as shorthand for $1s^2 2s^2 2p^6 3s^2 3p^6$ Look carefully at $1s^2 2s^2 2p^6 3s^2 3p^6$ – there may be a mistake
			Total	**3**	
19			A	**1**	**Examiner's Comments** This question discriminated well with less than half the candidates obtaining the correct answer. Answer option D was a common distractor.
			Total	**1**	

20		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	*Products of reaction* **A** = Barium hydroxide / $Ba(OH)_2$ ✓ **B** = Ammonia / NH_3 ✓ *Formula for barium nitride* Ba_3N_2 ✓ *Balanced equation **AND** state symbols* $Ba_3N_2(s) + 6H_2O(l) \rightarrow 3Ba(OH)_2(aq) + 2NH_3(g)$ ✓ 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**	
21			Displayed formulae of CH_3OH and H_2O **AND** C–O **AND** O–H polar bonds shown on CH_3OH molecule with δ+ and δ- **AND** Both O–H polar bonds shown on H_2O molecule with δ+ and δ- ✓ **Two** lone pairs shown on both oxygen atoms **AND** Hydrogen bond / H-bond labelled and in	**2**	Must be displayed formulae  **IGNORE** δ+ shown on other H atoms **ALLOW** hydrogen bond between the H on methanol (OH) and the oxygen

			the correct position between the H on water and the oxygen lone pair on methanol ✓		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**	
22			**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**	**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:

			B: K_2CO_3 ✓ **C:** Na_2SO_4 ✓		• Correct names: **B** potassium carbonate **AND C** sodium sulfate • Incorrect formulae i.e. **B** KCO_3 **AND C** $NaSO_4$ *Communicates the same as names* **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 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**	
23		i	*Equation* $Ba(NO_3)_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2NaNO_3(aq)$ ✓ *Entropy change **and** explanation* entropy decreases **OR** entropy change negative **AND** ($BaSO_4$) solid / ppt has less disorder / more order / fewer ways of arranging energy / less freedom / less random particles / dispersal of energy ✓	2	**ALLOW** multiples M2 is dependent on $BaSO_4(s)$ (even if formula is incorrect – eg $Ba(SO_4)_2(s)$) seen as a product in the attempted equation as long as reactants are not solid. $BaSO_4$ solid / ppt may be assumed from $BaSO_4(s)$ seen in the attempted equation. **Examiner's Comments** Candidates who correctly identified barium sulfate as a solid product tended to realise that entropy had decreased, although a significant number failed to state that this decrease in entropy was as a result of less disorder being created.
		ii	*Equation* $\frac{1}{2} I_2(s) \rightarrow I(g)$ ✓ *state symbols required* *Entropy change **and** explanation* entropy increases **OR** entropy change positive **AND** gas has more disorder / less order / more ways of arranging energy / more freedom / more random particles / more dispersal of energy ✓	2	**DO NOT ALLOW** $I_2(s) \rightarrow 2I(g)$ **DEPENDENT** on $\frac{1}{2}I_2(s) \rightarrow I(g)$ **OR** $I_2(s) \rightarrow 2I(g)$ **Examiner's Comments** Most candidates failed to produce a correct equation for the standard enthalpy change of atomisation of iodine. Of those who were able to produce the correct equation, a significant number failed to state that the increase in entropy was as a result of increased disorder being created.
			Total	**4**	
24		i	$(1s^2)\ 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^4$ ✓	1	**ALLOW** subscripts

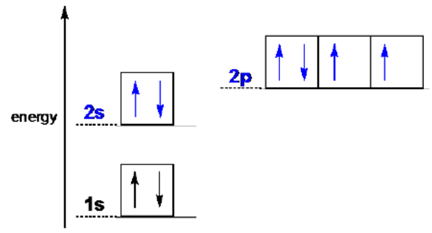
			Look carefully at $(1s^2)\ 2s^22p^63s^23p^6$ – there may be a mistake		**ALLOW** in any order i.e. $3d^{10}$ after $4s^2$ or after $4p^4$ **ALLOW** upper case D, etc and subscripts, e.g. ……$3S_23P^6$ **DO NOT ALLOW** [Ar] as shorthand for $1s^22s^22p^63s^23p^6$ **<u>Examiner's Comments</u>** Most candidates 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**	
25		i	Hydrogen/H ✓	1	**ALLOW** H_2 **<u>Examiner's Comments</u>** Most candidates were credited this straightforward mark and identified that hydrogen would gain an electron to form a 1− ion. Some candidates opted for lithium, able to form an ion with the same electron configuration as helium, but with a 1+ rather than a 1− charge. Candidates are recommended to

					look closely at the requirements of the question set.
		ii	Helium/He ✓	1	**Examiner's Comments** This part required candidates to recall their knowledge of trends in first ionisation energy. Candidates found this part harder than 1(a)(i) with only the higher ability candidates choosing the correct response of 'helium'. Many candidates instead chose another noble gas, with neon and argon commonly seen. Other common incorrect responses were hydrogen and fluorine.
		iii	Magnesium/Mg ✓	1	**Examiner's Comments** Most candidates did correctly select magnesium, but many other elements were seen, especially aluminium, silicon, beryllium and calcium. To identify the element's group, candidates needed to analyse the data to find the large increase in ionisation energy corresponding to a change in shell. From the responses, some candidates did not make use of 'Period 3' in the stem.
		iv	Sulfur/S ✓	1	**ALLOW** sulphur; S_8 **Examiner's Comments** Most candidates selected sulfur as the correct response, recalling their knowledge of molecular shapes encountered early in the course. There was no real pattern for incorrect responses, suggesting that they were guesses.
		v	Chlorine/C*l* **OR** fluorine/F ✓	1	**ALLOW** Cl_2 OR F_2 **Examiner's Comments** Most candidates chose the correct response of chlorine, although

					hydrogen was a common incorrect response, presumably by linking to the acidic properties of H^+ ions. Other candidates focused on 'reacts with water' and chose sodium (which does form a solution with water, but on that is alkaline rather than acidic).
		vi	Phosphorus/P ✓	1	**ALLOW** P_4 **<u>Examiner's Comments</u>** Almost all candidates correctly responded with phosphorus and this was the easiest part of 1(a).
		vii	Carbon/C ✓	1	**ALLOW** silicon/Si **<u>Examiner's Comments</u>** Most candidates correctly selected carbon. From their A Level studies, candidates would expect hydrogen to have an oxidation number of +1 and to form compounds with carbon (CH_4) and silicon (SiH_4) in which the element has an oxidation number of −4. Although hydrogen is actually slightly less electronegative than carbon, hydrogen is slightly more electronegative than silicon. Therefore, in the case of SiH_4, silicon has an oxidation number of +4. A response of silicon still indicates a correct understanding of oxidation number rules and was also credited
		viii	Oxygen/O ✓	1	**ALLOW** O_2 **<u>Examiner's Comments</u>** This proved to be the hardest part of 1(a) with only the higher ability candidates selecting oxygen. Sulfur proved to be the key distractor, having the same molar mass as O_2. Most candidates did not consider that the element was gaseous and could not be sulfur.
			Total	**8**	
26			**C**	**1**	**<u>Examiner's Comments</u>**

<table>
<tr><td></td><td></td><td></td><td></td><td></td><td>Nearly all candidates responded with the correct response of C.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>1</td><td></td></tr>
<tr><td>27</td><td></td><td></td><td>D</td><td>1
(AO 1.1)</td><td></td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>1</td><td></td></tr>
<tr><td>28</td><td></td><td></td><td>Sub-shells labels
2s (single box) AND 2p (3 boxes) ✓

Electrons as arrows
unpaired electrons in 3 boxes: ↿⇂ ↿ ↿
AND
Paired electrons in single box: ↿⇂ ✓</td><td>2
(AO1.1)

(AO1.2)</td><td>

ALLOW single headed arrows, e.g. 1

<u>Examiner’s Comments</u>

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.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>2</td><td></td></tr>
<tr><td>29</td><td></td><td></td><td>A</td><td>1
(AO2.1)</td><td><u>Examiner’s Comments</u>

Most candidates chose the correct response of A: Al. The best approach seen on many scripts was to write out the electron configuration beside the options and to count off the paired electrons.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>1</td><td></td></tr>
<tr><td>30</td><td></td><td></td><td><table><tr><td>Shell</td><td>1st shell</td><td>2nd shell</td><td>3rd shell</td><td>4th shell</td></tr><tr><td>Electrons</td><td>2</td><td>8</td><td>18</td><td>32</td></tr></table>
Requires all 4 numbers to be correct ✓</td><td>1
(AO1.1)</td><td><u>Examiner’s Comments</u>

Most candidates could recall the number of electrons in the first four shells as being 2, 8, 18 and 32. However, many made errors for the third and fourth shell. Common incorrect responses included 2,8,18,18 and 2,8,8,8, perhaps linking back to GCSE coverage.</td></tr>
</table>

					2,6,10,14 was also seen, confusing shells with subshells.
			Total	**1**	
31		i	$(1s^2)2s^22p^63s^23p^63d^{10}4s^24p^5$ ✓ Look carefully at $1s^22s^22p^63s^23p^6$ – there may be a mistake	1 (AO1.2)	**ALLOW** 3d after $4s^2$, e.g. $1s^22s^22p^63s^23p^64s^23d^{10}4p^5$ **ALLOW** upper case D, etc and subscripts, e.g. ……$4S_23D_1$ **DO NOT ALLOW** [Ar] as shorthand for $1s^22s^22p^63s^23p^6$ **IGNORE** $1s_2$ repeated **Examiner's Comments** Candidates answered this part well, showing good knowledge and understanding of electron configuration. When incorrect, it was usually errors with the number of electrons in the 3d and 4p subshells.
		ii	$P_4 + 6Br_2 \rightarrow 4PBr_3$ ✓	2 (AO2.4)	**ALLOW** multiples **Examiner's Comments** Most candidates were able to construct a correct balanced equation for this unfamiliar equation. The commonest error was use of Br instead of Br_2 in the equation.
			Total	**2**	
32			**A**	1 (AO 1.1)	
			Total	**1**	
33			**D**	1 (AO 1.2)	**ALLOW** 1 in the answer box
			Total	**1**	
34			**D**	1 AO1.2	
			Total	**1**	
35			**Shell** | **Total number of electrons** | **Sub-shell**: **s** | **p** | **d**	2 AO1.1×2	**ALLOW** $(1)s^2$ $(2)s^2$ $(2)p^6$ $(3)s^2$ $(3)p^6$ $(3)d^{10}$ **DO NOT ALLOW** extra numbers

<table>
<tr><td></td><td></td><td></td><td><table><tr><td>1st</td><td>2</td><td>2</td><td></td><td></td></tr><tr><td>2nd</td><td>8</td><td>2</td><td>6</td><td></td></tr><tr><td>3rd</td><td>18</td><td>2</td><td>6</td><td>10</td></tr></table>
1st 2 rows correct → 1 mark ✓

3rd row correct → 1 mark ✓</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>2</td><td></td></tr>
<tr><td>36</td><td></td><td>i</td><td>d-block ✓</td><td>1
(AO1.1)</td><td></td></tr>
<tr><td></td><td></td><td>ii</td><td>$1s^22s^22p^63s^23p^63d^{10}4s^24p^1$ ✓

Look carefully at $1s^22s^22p^63s^23p^6$– there may be a mistake</td><td>1
(AO1.2)</td><td>ALLOW 4s AND/OR $4p^1$ before 3d, e.g. $1s^22s^22p^63s^23p^64s^23d^{10}4p^1$

ALLOW $1s^2$ after answer prompt (ie $1s^2$ twice)ALLOW upper case D, etc and subscripts,
e.g. ……$4S_23D_8$

DO NOT ALLOW [Ar] as shorthand for
$1s^22s^22p^63s^23p^6$</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>2</td><td></td></tr>
<tr><td>37</td><td></td><td>i</td><td>$Mg^{3+}(g) \rightarrow Mg^{4+}(g) + e^-$ ✓</td><td>1
(AO1.2)</td><td>State symbols required (ignore states on electrons)
ALLOW $Mg^{3+}(g) – e^- \rightarrow Mg^{4+}(g)$
ALLOW Mg^{+3} (g)
ALLOW e for e^-</td></tr>
<tr><td></td><td></td><td>ii</td><td>Big jump/larger difference between 2 and 3 ✓</td><td>1
(AO1.2)</td><td>IGNORE big jump between 10 and 11
DO NOT ALLOW other combinations.</td></tr>
<tr><td></td><td></td><td>iii</td><td>1st AND 3rd AND 4th AND 5th AND 9th AND 11th ✓
i.e.
<table><tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td></tr><tr><td>✓</td><td></td><td>✓</td><td>✓</td><td>✓</td><td></td><td></td><td></td><td>✓</td><td></td><td>✓</td><td></td></tr></table></td><td>1
(AO2.1)</td><td></td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>3</td><td></td></tr>
<tr><td>38</td><td></td><td></td><td>C</td><td>1(AO2.1)</td><td>ALLOW 7

<u>Examiner's Comments</u></td></tr>
</table>

<table>
<tr><td></td><td></td><td></td><td></td><td></td><td>This question was answered reasonably well. From the annotations on scripts many candidates wrote out the electron configuration of a sulfur atom. The successful candidates used electrons in a box notation so that they could visually see, and count, the paired orbitals. This is an excellent strategy to use in any similar questions.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>1</td><td></td></tr>
<tr><td>39</td><td></td><td></td><td><table><tr><th>Element</th><th>Mass number</th><th>Protons</th><th>Neutrons</th><th>Electrons</th><th>Charge</th><th></th></tr><tr><td>Ni</td><td>62</td><td>28</td><td>34</td><td>$1s^22s^22p^63s^23p^63d^84s^2$</td><td>0</td><td>✓</td></tr><tr><td>P</td><td>33</td><td>15</td><td>18</td><td>$1s^22s^22p^63s^23p^6$</td><td>3–</td><td>✓</td></tr></table>Mark by row</td><td>2 (AO1.2 ×2)</td><td>Easiest to check element first
ALLOW P^{3-} ALLOW names for elements
IGNORE charges with element in 1st column, even if wrong.
For electron configuration, ALLOW $4s^2$ before $3d^8$ i.e. $1s^22s^22p^63s^23p^64s^23d^8$
ALLOW upper case D, etc and subscripts, e.g. ......$4S_23D_1$
ALLOW [Ar)$3d^84s^2$

<u>Examiner's Comments</u>

This question produced many mixed responses. Most candidates correctly identified nickel. However, its electron configuration was frequently shown as $3d^{10}$ instead of $3d^8$ and some less successful responses gave nickel's relative atomic mass of 58.7 from the periodic table, instead of the mass number of the isotope provided. Many candidates selected the incorrect element for phosphorus, with argon being a key distractor from the extra 3 electrons in the $P^{3–}$ ion. The numbers of protons and neutrons were largely correct, although the wrong way round for many less successful responses.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>2</td><td></td></tr>
<tr><td>40</td><td></td><td>i</td><td>FIRST CHECK ANSWER ON ANSWER LINE
If answer = 47.92 (to 2 DP) seen award 2 marks</td><td>2
(AO 2.2)
(AO 1.1)</td><td>ALLOW one mark for ECF from seen incorrect sum provided final answer between 46 and 50 and to 2 DP</td></tr>
</table>

<table>
<tr><td></td><td></td><td></td><td>(46 x 8.3) + (47 x 7.4) + (48 x 73.7) + (49 x 5.4) + (50 x 5.2)
OR
381.8 + 347.8 + 3537.6 + 246.6 + 260
OR
4791.8 ✓

4791.8/100
= 47.92 ✓ 2DP required</td><td></td><td><u>Examiner's Comments</u>

Most candidates scored both marks. Some lost marks for minor slips such as not giving their final answer to 2 decimal places or making calculator errors. A few didn't know how to attempt the calculation or calculated the average mass.</td></tr>
<tr><td></td><td></td><td>ii</td><td>$(1s^2)2s^22p^63s^23p^63d^24s^2$ ✓

Look carefully at $(1s^2)$ $2s^22p^63s^23p^6$ – there may be a mistake</td><td>1
(AO1.1)</td><td>ALLOW subscripts

ALLOW 4s before 3d i.e. $(1s^2)2s^22p^63s^23p^64s^23d^2$

ALLOW upper case D, etc and subscripts, e.g. ……$3S_23P^6$

DO NOT ALLOW [Ar] as shorthand for $1s^22s^22p^63s^23p^6$

<u>Examiner's Comments</u>

Again, most scored this mark. Common errors included using the mass number for number of electrons, no 4s but $3d^4$ instead, 4d rather than 3d, $4p^2$ instead of $3d^2$ or filling up d orbital $3d^{10}$.</td></tr>
<tr><td></td><td></td><td>iii</td><td><table><tr><td></td><td>Protons</td><td>Neutrons</td><td>Electrons</td></tr><tr><td>$^{48}Ti^{2+}$</td><td>22</td><td>26</td><td>20</td></tr></table> ✓

ALL 3 numbers required for the mark</td><td>1
(AO2.1)</td><td><u>Examiner's Comments</u>

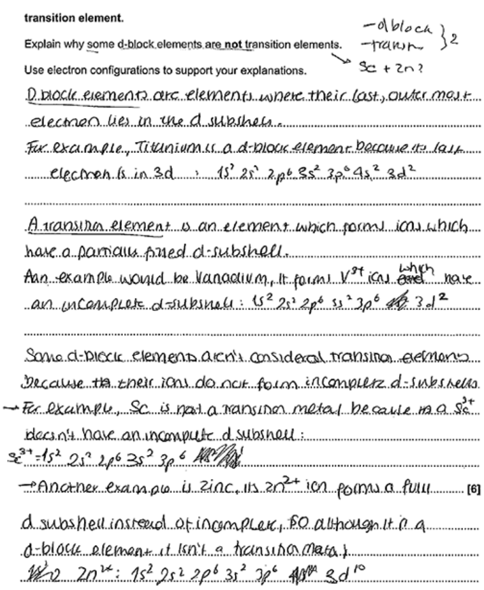
Most candidates gained this mark. Common errors included giving 24 or 22 for number of electrons, or 48 or 24 for neutrons. A few used the relative atomic mass of 47.9 from the periodic table so gave 24.7 for number of neutrons.

Assessment for learning

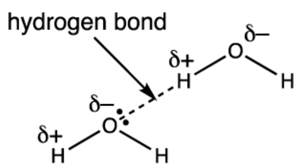
Fractional numbers of subatomic particles are not possible. Candidates should be aware that the relative atomic mass is the weighted</td></tr>
</table>

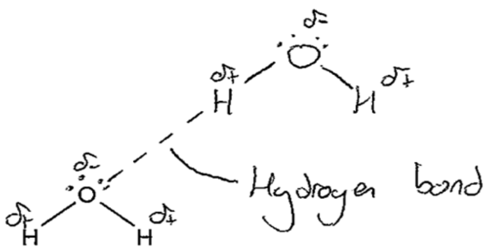
					average of the masses of all of an element's isotopes, and the mass number of an isotope must be used to determine the number of protons and neutrons in the nucleus.
			Total	**4**	
41			**C**	1 (AO 1.1)	**ALLOW 6** **<u>Examiner's Comments</u>** Candidates found this question more difficult than Questions 1–3. The question discriminated well. Most candidates showed the electron configuration in their working. A and D were the main distractors. Rather than the number of p-**orbitals** occupied, option A (2) is the number of p sub-shells (2p and 3p) and D (10) is the total number of p electrons (6 + 4). The errors may be the result of candidates not understanding the meaning of orbital and sub-shell or perhaps not reading the question closely enough. Underlining 'p-orbitals' may have helped candidates.
			Total	**1**	
42			**Level 3 (5–6 marks)** Explains the terms 'd-block element' **AND** 'transition element' **AND** Explains why not all d-block are transition elements **AND** At least **THREE correct** electron configurations (need to be one electron configuration of d block atom, transition element ion and zinc (or scandium) ion *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)**	6 (AO 1.1 × 4)	**Indicative scientific points may include:** **<u>Terms</u>** **d-block element:** element with highest energy/ valence electron in d-orbital/sub-shell **OR** d subshell is being filled **DO NOT ALLOW** d block for d-subshells **Transition element**: element forming one or more ions (allow atom and ion - IUPAC definition) with incomplete/partially filled d-subshell/d-orbitals **DO NOT ALLOW** d shell

			Explains both the terms ‘d-block element’ and ‘transition element’ **AND** Explains why not all d-block are transition elements **OR** Explains both the terms ‘d-block element’ and ‘transition element’ **AND** Links terms to at least **TWO correct** electron configurations **OR** Explains the terms ‘d-block element’ **OR** ‘transition element’ **AND** Explains why not all d-block are transition elements **AND** Links terms to at least **ONE correct** electron configuration *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** Explains the term ‘d-block element’ **OR** ‘transition element’ **AND** Attempts to link terms with **ONE correct** electron configuration **OR** Explains the term ‘d-block element’ **AND** ‘transition element’ **OR** Explains the term ‘d-block element’ **OR** ‘transition element’ **AND** Explains why not all d-block are transition elements **OR** **Any TWO** out of **THREE correct** electron configurations (one element and one ion that is a transition element and one ion that is not a transition element)		**d-block element:** **ALLOW** examples with an ion with an incomplete d-subshell, e.g. Fe^{2+} - $[Ar]4s^0 3d^6$ **ALLOW** examples with highest energy electrons in a d-subshell, e.g. Fe - $[Ar]4s^2 3d^6$ **Not all d-block are transition elements:** Sc and Zn form ions with complete or empty d-shells **ORA** For Sc^{3+}, ALLOW Sc^{+3} OR Sc forms a 3+ ion For Zn^{2+}, ALLOW Zn^{+2} OR Zn forms a 2+ ion Sc^{3+} $1s^2 2s^2 2p^6 3s^2 3p^6$ Sc^{3+} **AND** d subshell empty / d orbital(s) empty Zn^{2+} $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$ Zn^{2+} **AND** d subshell full / ALL d orbitals full **ALLOW** minor slips on **inner shell** electron configurations --- **NOTE**: A clear and logically structured response would link definitions to electron configurations to support the explanations. If stated, for the level, there should be clear indication that the d subshell is full/empty or partially full **Examiner’s Comments** Only the higher-attaining candidates scored full marks. Very few candidates were able to define d-block element correctly without the minor slip of saying outermost electron instead of highest energy or

			There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant. ***0 mark*** *No response or no response worthy of credit*		valence electron. Many candidates often did not mention ions for the transition metal definition. Many did not include any of the electron arrangements for d-block elements and transition elements. The majority of candidates who were able to recognise zinc and scandium as d-block elements, but not transition elements, gave their electronic configurations correctly. Common errors included the presence of the 4s electrons in the electron configurations of the ions and incorrect electron configurations of copper and chromium atoms. A few candidates thought chromium and copper were not transition elements due to the $4s^1$ electron configuration. Exemplar 3  **transition element.** Explain why some d-block elements are **not** transition elements. Use electron configurations to support your explanations. D block elements are elements where their last, outer most electron lies in the d subshell. For example, Titanium is a d-block element because its last electron is in 3d : $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^2$ A transition element is an element which forms ions which have a partially filled d-subshell. An example would be Vanadium, it forms V^{3+} ions which have an incomplete d-subshell : $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2$ Some d-block elements aren't considered transition elements because their ions do not form incomplete d-subshells. For example, Sc is not a transition metal because its Sc^{3+} doesn't have an incomplete d subshell : $Sc^{3+} = 1s^2 2s^2 2p^6 3s^2 3p^6$ Another example is zinc, its Zn^{2+} ion forms a full **[6]** d subshell instead of incomplete, so although it is a d-block element it isn't a transition metal. Zn^{2+}: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$ This candidate has mentioned outer electrons rather than highest energy but was this is a minor slip and they were still given a Level 3 response as everything else is correct. A holistic approach for LoRs is used and not a point-based marking system.
			Total	**6**	

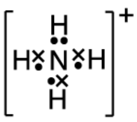
43			Cr ✓ Mn ✓	2 (AO 1.2)	**IGNORE** ions **<u>Examiner's Comments</u>** Most candidates chose at least one of the two elements Cr and Mn, with Mn being the most common. Incorrect elements were usually other d block elements.
			Total	**2**	
44	a		The ability/tendency of an atom to attract electrons ✓ in a covalent bond ✓	2	**ALLOW** 'attraction of an atom for electrons' **ALLOW** 'pull' for 'attract' **DO NOT ALLOW** 'element' for 'atom' **DO NOT ALLOW** ability to attract **an** electron (i.e. reference to a single electron) **ALLOW** 'shared pair' or 'bond(ing) pair' for 'covalent bond' 2nd mark is independent of first mark **<u>Examiner's Comments</u>** Many managed to score at least one mark here but most struggled to give a comprehensive definition. A mark was often lost mark for omission of 'atom', i.e. not saying what was attracting electrons, or for saying 'element' instead. The ability to attract **an electron** was not accepted as this is describing electron affinity rather than electronegativity. Many described the formation of dipoles or partial charges across the bond due to the difference in electronegativity but didn't demonstrate a clear understanding of what electronegativity is. Lower-scoring candidates often referred to the formation of ions and/or loss of electrons. **Assessment for learning**

					Learning key words and terminology is an important part of understanding Chemistry. Encourage students to make their own flash cards for each topic – this can be done on card or electronically using websites such as Quizlet. Display key words and definitions in classrooms. Although the current specifications place less emphasis on rote recall of definitions, students should still practice writing definitions for common terms with appropriate key words.
	b	i	*Dipole* At least one $H^{\delta+}$ **AND** one $O^{\delta-}$ shown correctly on each water molecule (see diagram) ✓ *Hydrogen bonding* H bond between H in one H_2O molecule and lone pair of O in an adjacent H_2O molecule ✓ 	2	**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 2 lone pairs on O atom **<u>Examiner's Comments</u>** Around half of candidates scored both marks with a well-drawn diagram (such as that shown in the exemplar below). Practising drawing hydrogen bonds between different molecules is a really good way of exploring students' understanding of what they are. The most common errors were missing the lone pair or showing a hydrogen bond that didn't originate from those drawn.

					Lower-scoring candidates often didn't draw a second water molecule, labelling the covalent bond between O and H as a hydrogen bond. Quite a few diagrams were seen with δ+ and δ− only on one molecule or with δ+ on one structure and δ− on the other. It was essential here to show that the O-H bond in both molecules is polar. Diagrams were often unclear so sometimes difficult to interpret. Exemplar 1 Exemplar 1  This is an example of a good diagram for hydrogen bonding.
		ii	Dipoles do not cancel out **OR** Has an **overall** dipole✓	1	**ALLOW** (Water is) unsymmetrical/ non-symmetrical/ asymmetrical **IGNORE** polar bonds do not cancel **IGNORE** charges uneven/ do not cancel **<u>Examiner's Comments</u>** Some appropriate answers were seen, mostly discussing the asymmetrical shape of water. More than half didn't score the mark. However, many were able to describe O-H being a polar bond due to the difference in electronegativity but didn't realise that this doesn't always mean that the molecule itself is polar. The relationship between the words electronegative, dipole and polar need more attention and how this all relates to the shapes of molecules. Some candidates said *symmetrical* when they meant *asymmetrical*.

		iii	(In ice) molecules are held apart by H bonds **OR** (Ice) has an open lattice due to H bonds✓	1	**Response must refer to H bonds/bonding** **ALLOW** spread/spaced out/apart instead of 'held apart' **IGNORE** length of hydrogen bonds **DO NOT ALLOW** 'atoms' instead of 'molecules' **ALLOW** H bonding (in ice) creates gaps in the lattice/ structure/between molecules… But **DO NOT ALLOW** if gaps contain 'air' **<u>Examiner's Comments</u>** Some good answers were seen referring to hydrogen bonds holding/keeping water molecules further apart or creating an open lattice. However, a number did not score for not mentioning hydrogen bonds or for referring to alternative intermolecular forces. For example, 'In solid state, the London forces are weaker' and 'Ice has less induced dipole-dipole forces'. Some also indicated that 'air' was in the structure and this wasn't accepted as air molecules are too large to fit in the gaps between water molecules in the ice crystal structure. Responses often demonstrated some significant misconceptions in candidate understanding. Many felt that the length of the hydrogen bond changed, for example 'when ice freezes hydrogen bonds expand' 'Atoms are further apart so longer hydrogen bonds'. Some suggested that the strength of the hydrogen bond changed (for example, 'ice has weaker H-bonds than water'). Some recognised that ice has a crystalline structure but didn't explain how this is different from other solid structures, which would be denser than their liquid counterparts. Lower-scoring candidates struggled to understand density (for example,

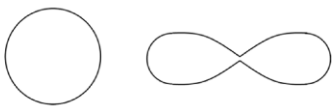
					'ice is more compact' or 'molecules closer together in ice'). Terminology was also a problem with candidates often referring to 'ice' or 'particles' rather than 'molecules'.
	c	i	(Ammonia has) weaker hydrogen bonds (than ice/water) ✓ N has **one** lone pair **AND** O has **two** **OR** N less electronegative than O ✓	2	**ORA** but assume 'it' refers to ammonia Answer must be comparative between hydrogen bonding in ammonia and ice **ALLOW** Ammonia has less hydrogen bonds **ALLOW** response in terms of energy required to break hydrogen bonds e.g. less energy needed to break hydrogen bonds (in ammonia) **DO NOT ALLOW** reference to breaking N-H and O-H bonds i.e. covalent bonds **IGNORE** reference to other intermolecular forces e.g. London forces, dipole-dipole interactions. **ALLOW** ammonia has **one** lone pair **AND** water/ice has **two** **<u>Examiner's Comments</u>** Despite being told in the question that ammonia contains hydrogen bonds, many gave responses in terms of ammonia having either London forces and permanent dipole-dipole forces which are weaker than hydrogen bonds. For example, 'ammonia consists of permanent dipole-dipole interactions which are weaker than hydrogen bonding in ice' and 'NH_3 has 17 electrons and H_2O has 18 electrons. Due to NH_3 having fewer electrons, there are fewer London forces'. Lower-scoring candidates often confused hydrogen bonds and covalent bonds, consistent with what was seen in 1(b)(i). For example, 'O-H bond is stronger than N-H bond' and 'more energy needed to break O-H bonds rather than N-H bonds'. Some of these candidates did score

					a mark for recognising that N is less electronegative than O. For others they understood that ammonia has weaker hydrogen bonds but then struggled to give a reason either in terms of lone pairs or electronegativity.
		ii	 **Bonded pairs** Electron pairs in 3 x N-H covalent bonds shown correctly using dots and crosses ✓ **Dative bond** shown with two crosses or two dots ✓	2	**ALLOW** shell circles **IGNORE** inner shell in N **Charge and brackets not required** **DO NOT ALLOW** additional electrons on either N or H for dative bond mark **<u>Examiner's Comments</u>** Less than half of the candidates scored both marks. Most candidates drew 4 x N-H shared covalent bonds and therefore lost the dative bond mark. Some added an additional electron to either N or H. Some drew an additional shaped electron (e.g. using a triangle) on one of the bonding pairs, obviously not realising that both electrons in dative bond originate from N, so have the same symbol. Many diagrams were unclear making it hard distinguish between dots and crosses especially if adding circles for electron shells. A few lower-attaining candidates attempted to draw an ionic dot-cross diagrams.
		iii	**Reagent and conditions** (Heat with) hydroxide ✓ **Observation *(Independent mark)*** pH/litmus/indicator paper turns blue/purple ✓	2	**ALLOW** NaOH/KOH/$Ca(OH)_2$/OH^- **DO NOT ALLOW** Ammonium hydroxide OR ammonia **<u>Examiner's Comments</u>** Higher-attaining candidates often gave a very detailed responses with all stages, including warming the NaOH, use of damp litmus paper and some included an ionic equation.

					Quite a few lost a mark as they missed the addition of hydroxide, just warmed, but they still gained mark for testing with indicator paper. Some thought that the indicator paper would turn red or be bleached and a few gave incorrect ion test e.g. add silver nitrate, add acid. Over a third of candidates did not score on this question, with a significant proportion not even attempting it.
			Total	**12**	
45		i	Be: $1s^2 2s^2$ F: $1s^2 2s^2 2p^5$ ✓ Mg: $1s^2 2s^2 2p^6 3s^2$ C*l*: $1s^2 2s^2 2p^6 3s^2 3p^5$ ✓ Block: s p ✓	3	**1 mark** per correct row **ALLOW** upper case letter S and P, and subscripts, e.g. $2S_2 2P_5$ **IGNORE** superscripts/numbers given on block (e.g. s^2 and p^5) if the letter is clear **<u>Examiner's Comments</u>** A very well answered question with most candidates very confident in giving the correct electron configurations and blocks. Errors were rare but included: $2p^5$ or $3p^6$ ending for Cl; using mass number for number of electrons; and assigning group 17 as d block and giving orbital box diagrams rather than block.
45		ii	Across period 2, the (2)s subshell fills first, followed by the (2)p ✓ **same pattern or trend** of filling (the subshells) repeated in other periods ✓	2	**ALLOW** Elements in the same group have same number of electrons in their outer shells or subshell e.g. s^2 in group 2/ s^2p^5 in group 17(7) **ALLOW** Elements in the same period have the same number of energy levels/shells **ALLOW** for both marks for indication that the pattern repeats across each period e.g Across each period, elements repeat the pattern of electrons filling the s-subshell then p-subshell ✓ ✓

					Examiner's Comments Many found this question challenging despite doing well in Question 2(a)(i). The question states 'use your answers from (a)(i)' but not many candidates wrote about the electron configurations they had given. Many gave very simplistic responses in terms of the number of electrons increasing but made no reference to how those electrons are arranged (e.g. 'number of electrons increases across a period as the electron configuration gets higher' or 'atomic number increases'). Some candidates struggled with terminology, often referring to 'block' or 'orbital' instead of subshell (e.g. 'outer electrons are in same block', 'going across a period the number of orbitals increases', 'elements in same group have their highest energy electron in same block' or 'orbital'). Candidates need clarity on the terminology used for electron configurations and periodic table i.e. blocks, shells, sub-shells and orbitals. It was rare for candidates to score both marks as this was a question that they were unfamiliar with. However, some did gain a mark for linking the number of outer shell electrons to the group number or stating that elements in the same period have the same number of shells. It was not enough to refer to the highest energy electron being in the s-subshell or p-subshell as this is the link to the block, but all groups in same block will be the same. Some described the trend in other physical or chemical properties. Some examples included: 'Elements have same chemical and physical

					properties due to similar electronic configuration'; 'as you go across period, number of electrons increase and their boiling and melting points increase'; and 'electrons are more easily lost in a paired orbital, due to greater repulsion and so have lower ionisation energies'. **OCR support** We have produced a transition guide on the topic of atomic structure. It covers content from KS4 and how this is developed at KS5 with a wide range of suggested resources to support teaching. At KS4, candidates are expected to be able to explain how the position of an element in the Periodic Table is related to the arrangement of electrons in its atoms, with development at KS5 to arrangement in to s, p and d orbitals. https:/ocr.org.uk/Images/170375-atomic-structure-ks4-ks5.pdf
		iii	Mg loses (2) electrons **AND** Cl gains an electron ✓ To gain a full/complete shell **OR** Noble gas configuration **OR** Stable/full octet✓	2	**ALLOW** Mg is oxidised **AND** Cl is reduced **Examiner's Comments** Generally, this question was well answered with a clear understanding of how and why ions are formed. However, approximately a quarter of students only gained 1 mark as they either didn't explain electrons being lost by Mg and gained by Cl or gave no justification. A common slip was stating Cl has one electron in its outer shell. Some described bonding between Mg and Cl, which wasn't what the question asked, but this didn't prevent them from scoring both marks.

		iv	$2Mg + O_2 \rightarrow 2MgO$ ✓	1	**ALLOW** multiples e.g. $Mg + \frac{1}{2}O_2 \rightarrow MgO$ **IGNORE** state symbols even if wrong **<u>Examiner's Comments</u>** Many candidates correctly gave the balanced equation here. However, some didn't balance but had the correct formula. A few gave Mg_2 as a reactant or MgO_2 as a product. Some had O_2 on both sides of the equation.
			Total	**8**	
46			**D**	1	**<u>Examiner's Comments</u>** The correct answer was D. Wrong answers were very rarely seen as candidates had secure knowledge of filling orbitals individually before pairing.
			Total	**1**	
47			**D**	1	**<u>Examiner's Comments</u>** The correct answer was D. Most candidates were able to select this response, but the common error was the selection of A. It is important that candidates can distinguish the difference between oxidation states and charge on the ions. Oxidation state is the measure of the number of electrons that an atom uses to bond with atoms of another element.
			Total	**1**	
48			s orbital p orbital  ✓Fe = $(1s^2)2s^22p^63s^23p^64s^23d^6$ **AND** $Fe^{2+} = (1s^2)2s^22p^63s^23p^63d^6$ ✓	2	**IGNORE** shading **IGNORE** axes directions x, y, z **DO NOT ALLOW** multiple p orbitals For electron configuration,

					ALLOW $4s^2$ after $3d^6$ i.e. $1s^22s^22p^63s^23p^63d^64s^2$ **ALLOW** upper case D, etc and subscripts, e.g. ……$4S_23D_1$ **ALLOW** $4s^0$ **IGNORE** [Ar]$3d^6$ $4s^2$ **Examiner's Comments** Many candidates were successful in drawing the orbital shapes. Occasionally candidates linked the question to the formation of a π bond or drew two arrows in a box to represent the electrons. Many candidates did not realise that when transition metal ions are formed, the first electrons removed from atoms are the 4s electrons and so wrote $2s^2$ $2p^6$ $3s^2$ $3p^6$ $3d^4$ $4s^2$.
			Total	**2**	
49			**C**	1	**Examiner's Comments** Most candidates recognised C as a diagram for a p orbital.
			Total	**1**	
50			**B**	1	**Examiner's Comments** This question assessed understanding of important terms used in organic chemistry, with some candidates correctly choosing B as the correct option. The question discriminated well with less successful responses choosing D, presumably thinking that the two double bonds in a cyclic structure makes the compound aromatic.

					Misconception A cyclic organic molecule containing single and/or double bonds is aliphatic. The molecule is described as aromatic if it contains a benzene ring.
			Total	**1**	
51			**C**	1	**<u>Examiner's Comments</u>** Approximately two thirds of candidates gave the correct answer C. The most common incorrect response seen was D, confusing the strength of the σ and π bonds, possibly as a C=C bond is stronger than C-C. Some gave D assuming alkenes are polar due to their reactivity and showing a misunderstanding of the term 'polar'.
			Total	**1**	