Q1.

There is a general trend in the values of the first ionisation energies of the elements Na to Ar. The first ionisation energies of the elements Al and S deviate from this trend.

(a) Write an equation, including state symbols, to represent the process for which the energy change is the first ionisation energy of Na.

_____

(2)

(b) State and explain the general trend in the values of the first ionisation energies of the elements Na to Ar.

Trend _____

Explanation _____

_____

_____

(3)

(c) State how, and explain why, the values of the first ionisation energies of the elements Al and S deviate from the general trend.

How the values deviate from the trend _____

Explanation for Al _____

_____

Explanation for S _____

_____

(5)

(Total 10 marks)

Q2.

Which one of the following explains why boron has a lower first ionisation energy than beryllium?

A A boron atom is smaller than a beryllium atom.

B In beryllium all the electrons are paired in full sub-shells.

C A beryllium atom has fewer protons than a boron atom.

D In boron the 2*p* electron occupies a higher energy level than a 2*s* electron.

(Total 1 mark)

Q3.

Which one of the following atoms has only two unpaired electrons in its ground (lowest energy) state?

A helium

B beryllium

C nitrogen

D oxygen

(Total 1 mark)

Q4.

An atom has all its electrons in their lowest energy levels.

Which atom contains only two unpaired electrons?

A Helium ⬭

B Beryllium ⬭

C Oxygen ⬭

D Iron ⬭

(Total 1 mark)

Q5.

The first six ionisation energies, in kJ mol^{-1}, of an element are:

1090, 2350, 4610, 6220, 37 800, 47 000

What is the element?

A Boron ⬭

B Carbon ⬭

C Nitrogen ⬭

D Oxygen ⬭

(Total 1 mark)

Q6.

In which pair is the first ionisation energy of atom **Y** greater than that of atom **X**?

	Electron configuration of atom **X**	Electron configuration of atom **Y**	
A	$1s^2 2s^2$	$1s^2 2s^2 2p^1$	⬭
B	$1s^2 2s^2 2p^3$	$1s^2 2s^2 2p^4$	⬭
C	$1s^2 2s^2 2p^5$	$1s^2 2s^2 2p^6$	⬭
D	$1s^2 2s^2 2p^6$	$1s^2 2s^2 2p^6 3s^1$	⬭

(Total 1 mark)

Q7.

Which atom in the ground state contains at least one unpaired p electron?

A Na ⬭

B Ne ⬭

C O ⬭

D Sc ⬭

(Total 1 mark)

Q8.

Which ionisation needs less energy than this process?

$$Mg(g) \rightarrow Mg^+(g) + e^-$$

A $Al(g) \rightarrow Al^+(g) + e^-$ ⬭

B $Ar(g) \rightarrow Ar^+(g) + e^-$ ⬭

C $Be(g) \rightarrow Be^+(g) + e^-$ ⬭

D $Mg^+(g) \rightarrow Mg^{2+}(g) + e^-$ ⬭

(Total 1 mark)

Q9.

What is the electron configuration of V^{2+} in the ground state?

A $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^3$ ⬭

B $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^1\ 4s^2$ ⬭

C $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^3\ 4s^2$ ⬭

D $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^2$ ⬭

(Total 1 mark)

Q10.

Which element has a first ionisation energy lower than that of sulfur?

A Chlorine ⬭

B Oxygen ⬭

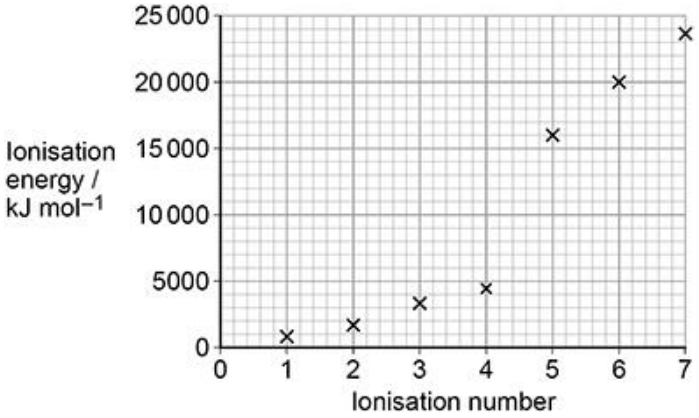
C Phosphorus ⬭

D Selenium ⬭

(Total 1 mark)

Q11.

The first seven successive ionisation energies for element Z are shown.



What is element Z?

A Carbon ⬭

B Nitrogen ⬭

C Silicon ⬭

D Phosphorus ⬭

(Total 1 mark)

Q12.

Which has the electron configuration of a noble gas?

A H^+ ⬭

B O^- ⬭

C Se^{2-} ⬭

D Zn^{2+} ⬭

(Total 1 mark)

Q13.

This question is about atomic structure.

(a) There is a general trend for an increase in ionisation energy across Period 3. Give **one** example of an element that deviates from this trend.

Explain why this deviation occurs.

Element _____

Explanation _____

_____

_____

_____

_____

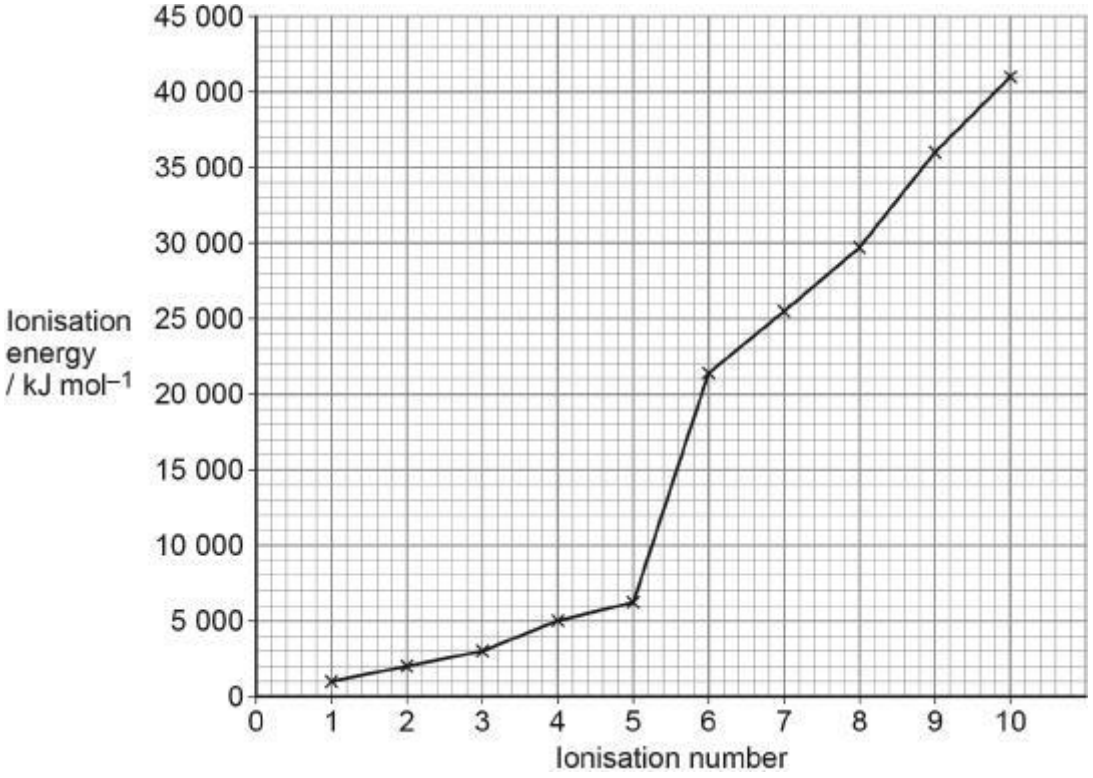
(3)

(b) Give an equation, including state symbols, to represent the process that occurs when the **third** ionisation energy of sodium is measured.

_____

(1)

(c) The graph shows the successive ionisation energies of a Period 3 element, **X**.



Identify element **X**.
Explain your choice.

Element _____

Explanation _____

_____

_____

_____

_____

_____

_____

_____

(3)

(Total 7 marks)

Q14.

Which is the electron configuration of an atom with **only two** unpaired electrons?

A $1s^2\ 2s^2\ 2p^3$ ⬭

B $1s^2\ 2s^2\ 2p^4$ ⬭

C $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$ ⬭

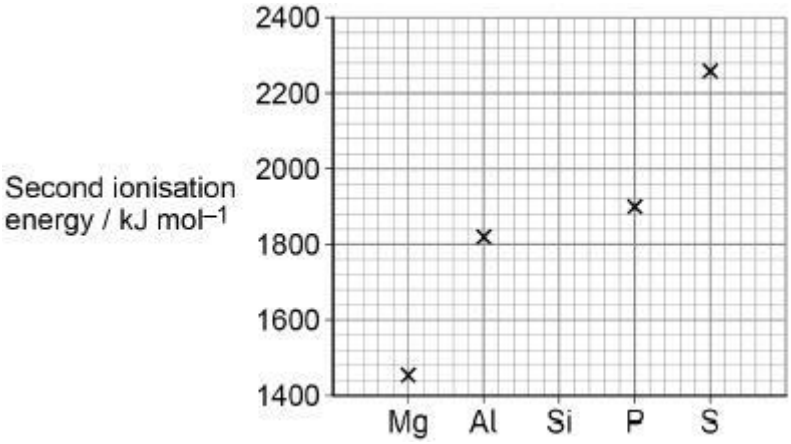
D $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1\ 3d^5$ ⬭

(Total 1 mark)

Q15.

This question is about Period 3 elements.

The graph shows the **second** ionisation energies of some elements in Period 3.



(a) Draw a cross (x) on the graph above to show the **second** ionisation energy of silicon.

(1)

(b) Identify the element in Period 3, from sodium to argon, that has the highest **second** ionisation energy.

Give an equation, including state symbols, to show the process that occurs when the **second** ionisation energy of this element is measured.

If you were unable to identify the element you may use the symbol **Q** in your equation.

Element _____

Equation

_____

(2)

(c) Explain why the atomic radius decreases across Period 3, from sodium to chlorine.

_____

_____

_____

_____

(2)

(d) Identify the element in Period 3, from sodium to chlorine, that has the highest electronegativity.

_____

(1)

(e) Phosphorus burns in air to form phosphorus(V) oxide.
Give an equation for this reaction.

_____

(1)

(Total 7 marks)

Q16.

Which shows the electron configuration of an atom of a transition metal?

A [Ar] $4s^2 3d^0$ ⬭

B [Ar] $4s^2 3d^8$ ⬭

C [Ar] $4s^2 3d^{10}$ ⬭

D [Ar] $4s^2 3d^{10} 4p^1$ ⬭

(Total 1 mark)

Q17.

This question is about chromium and its compounds.

(a) Complete the full electron configuration of a chromium atom.

$1s^2$ _____

(1)

(b) An atom has 2 more protons and 3 more neutrons than an atom of ^{52}Cr.

Deduce the symbol, including the mass number and the atomic number, for this atom.

_____

(1)

(c) A sample of chromium contains four isotopes and has a relative atomic mass of 52.09

The table shows the mass number and the percentage abundance of three of these isotopes.

Mass number	52	53	54
Abundance (%)	82.8	10.9	2.7

Determine the percentage abundance of the fourth isotope.
Show by calculation that the mass number of this isotope is 50

Percentage abundance _____

Calculation

(3)

(d) Deduce the oxidation state of chromium in the $Cr_2O_7^{2-}$ ion.

_____

(1)

(e) Iodide ions can be oxidised to iodine using $Cr_2O_7^{2-}$ ions.

Deduce a half-equation to show the oxidation of iodide ions to iodine.

State symbols are **not** required.

_____

(1)

(f) Deduce a half-equation for the conversion in acidic solution of $Cr_2O_7^{2-}$ ions to Cr^{3+} ions.

State symbols are **not** required.

_____

(1)

(g) Use your answers from questions (e) and (f) to deduce the overall redox equation for the reaction between iodide ions and acidified $Cr_2O_7^{2-}$ ions.

State symbols are **not** required.

_____

(1)

(Total 9 marks)

Q18.

The first ionisation energies of the elements in Period 2 change as the atomic number increases.

Explain the pattern in the first ionisation energies of the elements from lithium to neon.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(Total 6 marks)

Q19.

A student does an experiment to determine the percentage of copper in an alloy.

The student

- reacts 985 mg of the alloy with concentrated nitric acid to form a solution (all of the copper in the alloy reacts to form aqueous copper(II) ions)
- pours the solution into a volumetric flask and makes the volume up to 250 cm^3 with distilled water
- shakes the flask thoroughly
- transfers 25.0 cm^3 of the solution into a conical flask and adds an excess of potassium iodide
- uses exactly 9.00 cm^3 of 0.0800 mol dm^{-3} sodium thiosulfate ($Na_2S_2O_3$) solution to react with all the iodine produced.

The equations for the reactions are

$$2\ Cu^{2+} + 4\ I^- \rightarrow 2\ CuI + I_2$$

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

(a) Calculate the percentage of copper by mass in the alloy.

Give your answer to the appropriate number of significant figures.

% copper _____

(6)

(b) Suggest **two** ways that the student could reduce the percentage uncertainty in the measurement of the volume of sodium thiosulfate solution, using the same apparatus as this experiment.

1 _____

_____

2 _____

_____

3 _____

_____

(2)

(c) State the role of iodine in the reaction with sodium thiosulfate.

_____

(1)

(d) Give the full electron configuration of a copper(II) ion.

_____

(1)

(e) Copper(I) iodide is a white solid.

Explain why copper(I) iodide is white.

_____

_____

_____

_____

_____

_____

(2)

(f) Iodine vaporises easily.

Calculate the volume, in cm^3, that 5.00 g of iodine vapour occupies at 185 °C and 100 kPa

The gas constant R = 8.31 J K^{-1} mol^{-1}

Give your answer to 3 significant figures.

Volume _____ cm^3

(4)

(Total 16 marks)

Q20.

Which atom has the greatest first ionisation energy?

A H ⬭

B He ⬭

C Li ⬭

D Ne ⬭

(Total 1 mark)

Mark schemes

Q1.

(a) $Na(g) \rightarrow Na^+(g) + e^-$
OR $Na(g) + e^- \rightarrow Na^+(g) + 2e^-$

(-) on electron not essential
equation (1)
state symbols (1)
Ignore state symbols on electrons

2

(b) *Trend* : Increases **(1)**

Explanation : Increased nuclear charge or proton number **(1)**
Stronger attraction (between nucleus and (outer) e^-) **(1)**

Trend wrong
Allow M2 only if M3 correct (con)

3

(c) *How values deviate from trend*: (both values) too low **(1)**
Explanation for Al: e^- removed from (3) p **(1)**
e^- or orbital is higher in energy or better shielded than (3)**s**
or p electron is shielded by 3s electrons **(1)**

Allow e^- is further away

Mark independently

Explanation for S: e^- removed from (3)p electron pair **(1)**
repulsion between paired e^- (reduces energy required) **(1)**

Mark separately
If deviation wrong allow M2 and M4
If M3 and / or M5 right (con)
If used 'd' rather than 'p' orbital - lose M2 + M4 but may get M3, M5 (explanation marks)

5

[10]

Q2.

D

[1]

Q3.

D

[1]

Q4.

C

Oxygen

[1]

Q5.

B

Carbon

[1]

Q6.

C

C	$1s^2 2s^2 2p^5$	$1s^2 2s^2 2p^6$

[1]

Q7.

C

O

[1]

Q8.

A

$Al(g) \rightarrow Al^+(g) + e^-$

[1]

Q9.

A

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^3$

[1]

Q10.

D

Selenium

[1]

Q11.

C

Silicon

[1]

Q12.

C

Se^{2-}

[1]

Q13.

(a) Aluminium / Al

*Allow **M2/M3** if a Group 3 element is given*

1

(Outer) electron in (3)p orbital / sub-shell (level)

Not energy level

1

(3p) higher in energy / slightly more shielded (than 3s) / slightly further away (than 3s)

1

or

OR

Sulfur / S

*Allow **M2/M3** if a Group 6 element is given*

1

(Outer) electrons in (3)p orbital begin to pair

Do not allow just p^4 vs p^3

1

Repel

1

(b) $Na^{2+}(g) \rightarrow Na^{3+}(g) + e^-$

State symbols essential.

Allow
$Na^{2+}(g) + e^- \rightarrow Na^{3+}(g) + 2\ e^-$

1

(c) **M1** Phosphorus / P

Mark independently

M2 large jump in ionisation energy for the 6th ionisation energy

Large jump after the 5 e^- is removed / when the 6th e^- is removed

M3 This is when the electron is being removed from the 2nd (principle) energy level / from a lower energy level / from a lower shell / from 2p / from an energy level that is closer to the nucleus

3

[7]

Q14.

B

$1s^2 2s^2 2p^4$

[1]

Q15.

(a) Cross at 1580

Allow a cross drawn for Si that is between the values for Mg and Al

1

(b) **M1** Na

1

M2 $Na^+(g) \rightarrow Na^{2+}(g) + e^-$

M2 *Allow* $Q^+(g) \rightarrow Q^{2+}(g) + e^-$

State symbols essential

Allow correct equation consequential on their element

1

(c) The number of protons increases OR nuclear charge increases

1

Shielding is similar/same OR electrons are added to the same shell

Allow same number of shells

1

(d) Chlorine/Cl

1

(e) $4P + 5O_2 \rightarrow P_4O_{10}$ OR $P_4 + 5O_2 \rightarrow P_4O_{10}$

Allow multiples

Ignore state symbols

Do not allow equations with P_2O_5

1

[7]

Q16.

B

[1]

Q17.

(a) $(1s^2)\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^1$
Or
$(1s^2)\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1 3d^5$

Ignore commas

Do not penalise capitals and subscripts

1

(b) $^{57}_{26}Fe$

Allow mass number and atomic number on RHS of Fe

1

(c) % of 4th isotope = 3.6

1

M2:

$$\frac{(52 \times 82.8) + (53 \times 10.9) + (54 \times 2.7) + (3.6x)}{100} = 52.09$$

1

M3:
x = 49.97 OR
179.9 = 3.6 x and x = 50
(evidence of working)

1

Allow alternative methods
M2 *(52 × 82.8) + (53 × 10.9) + (54 × 2.7) + (50 × 3.6) =5209*
M3 *A_r = 5209/100 = 52.09*
Or
M2

$$\frac{(52 \times 82.8) + (53 \times 10.9) + (54 \times 2.7) + (50x)}{100} = 52.09$$

M3 *awarded for 50.. = 179.9 and then .. = 3.6*
(evidence of working)

(d) +6 / VI / six / 6+

1

(e) $2\ I^- \rightarrow I_2 + 2\ e^-$

Allow multiples / ignore ss

1

(f) $Cr_2O_7^{2-} + 14\ H^+ + 6\ e^- \rightarrow 2\ Cr^{3+} + 7\ H_2O$

Allow multiples / ignore ss

1

(g) $Cr_2O_7^{2-} + 14\ H^+ + 6\ I^- \rightarrow 2\ Cr^{3+} + 7\ H_2O + 3\ I_2$

Allow multiples / ignore ss
Allow $Cr_2O_7^{2-} + 14\ H^+ + 8\ I^- \rightarrow 2\ Cr^{2+} + 7\ H_2O + 4\ I_2$ as ecf to part (f)

1

[9]

Q18.

This question is marked using Levels of Response.	
Level 3: ALL Stages with matching justifications All stages are covered and the explanation of each stage is generally correct and virtually complete. Answer is well structured with no repetition or irrelevant points. Accurate and clear expression of ideas with no errors in use of technical terms.	5-6 marks
Level 2: TWO Stages with matching justifications OR THREE Stages with incomplete justifications. All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR two stages are covered	3-4 marks

and the explanations are generally correct and virtually complete. Answer shows some attempt at structure Ideas are expressed with reasonable clarity with, perhaps, some repetition or some irrelevant points. Some minor errors in use of technical terms.	
Level 1: ONE Stage with matching justification OR TWO Stages with incomplete justifications Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies, OR only one stage is covered but the explanation is generally correct and virtually complete. Answer includes isolated statements but these are not presented in a logical order or show confused reasoning. Answer may contain valid points which are not clearly linked to an argument structure. Errors in the use of technical terms.	1-2 marks
Insufficient correct chemistry to gain a mark.	0 marks

Indicative Chemistry Content

Stage 1: General Trend (Li → Ne)
1a. 1st IE increases
1b. More protons/increased nuclear charge
1c. Electrons in same energy level / shell
1d. No extra/similar shielding
1e. Stronger attraction between nucleus and outer e OR outer e closer to nucleus (ignore radius decreases)

Stage 2: Deviation Be → B
2a. B lower than Be
2b. Outer electron in (2)p
2c. higher in energy than (2)s

If Al vs Mg then do not award 2a or 2b

Stage 3: Deviation N → O
3a. O lower than N
3b. 2 electrons in (2)p need to pair
3c. pairing causes repulsion (do not award if it is clear reference to repulsion is in s orbital)

If S vs P then do not award 3a or 3b

[6]

Q19.

(a) **M1** Amount of $S_2O_3^{2-} = \frac{9.00 \times 0.0800}{1000} = 7.20 \times 10^{-4}$ mol

1

(From equations mol $S_2O_3^{2-}$ = mol Cu^{2+})
M2 Amount of Cu^{2+} in 25 cm^3 = 7.20×10^{-4} mol

M2 *= answer to* ***M1*** *(1:1 ratio)*

1

M3 Amount of Cu^{2+} in 250 cm^3 = 7.20 v 10^{-4} **× 10** = 7.20 × 10^{-3} mol

M3 = ***M2*** × *10*

1

M4 Mass of copper = 7.20 × 10^{-3} mol **× 63.5** = 0.457 g

M4 = ***M3*** × *63.5*

1

M5 mass = 0.985 g

M5 *converting 985 mg to g*

1

M6 $\%\ Cu = 0.457 \times \frac{100}{0.985} = 46.4\ \%$

M6 *is for the answer to* ***3 sf***

Allow $\%\ Cu = 457 \times \frac{100}{985} = 46.4\ \%$ *for* ***M5*** *and* ***M6***

*Allow (****M4*** *×1000)/985 v 100 for* ***M5*** *and* ***M6***

1

(b) Use more of the alloy

1

Use a lower concentration of the thiosulfate solution/lower mass of $Na_2S_2O_3$ to make solution

1

(c) Oxidizing agent

Allow electron acceptor

1

(d) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^9$

Do not allow [Ar]3d ^{9}

1

(e) Full (3)d (sub)shell or (3)d^{10}

1

No (d-d) transitions possible/ cannot absorb visible/white light

M2 *is dependent on* ***M1***

Ignore reflects visible/white light

1

(f) **M1**: n = (5.00/253.8) = 0.0197 mol

Allow 254

If 126.9 or 127 used lose ***M1*** *only*

1

M2: T = 458 K and P = 100 000 Pa

1

M3 $V = \frac{nRT}{P}$ or $\frac{0.0197 \times 8.31 \times 458}{100\ 000}$ or $7.50 \times 10^{-4}\ (m^3)$

M3 *If rearrangement incorrect can only score* ***M1*** *and* ***M2***

1

M4: V = 750 (cm^3)

M4*: Allow* ***M3*** × 10^6

M4*: Allow 749*

1

[16]

Q20.

B

[1]