01 Atomic Structure

Set B **Answer key**

A Multiple choice

3 MARKS

1 **B** 1 and 2 only [1]

Check each element's Group and recall its valence configuration.

1 Ga, Group 13: $ns^2\ np^1$. Full s subshell, partly filled p subshell just above it.
2 Se, Group 16: $ns^2\ np^4$. Fulfils both conditions.
3 Cs, Group 1: ns^1. Its s subshell is not fully occupied, so it fails the first condition.

2 **C** The 3d subshell has five orbitals of the same energy in an isolated atom. [1]

A 1s and 2s orbitals have different energies as well as different sizes.
B The five 3d orbitals do not all have the same shape ($3d_{z^2}$ differs from the other four).
D n = 2 has two subshells and four orbitals (2s, $2p_x$, $2p_y$, $2p_z$).

3 **C** ^{40}Ca [1]

Find the proton number from the Data Booklet, then neutrons = nucleon number – proton number.

	^{2}He	^{8}Be	^{40}Ca	^{210}Pb
protons	2	4	20	82
neutrons	0	4	20	128

Only ^{40}Ca has both numbers in the list.

B Structured questions

31 MARKS

4 **(a)**

Protons and deuterons are deflected towards the negative plate, but hydrogen atoms are not deflected. This is because protons and deuterons are positively charged, whereas hydrogen atoms are electrically neutral. [1]

The mass of a proton is half the mass of a deuteron (1 neutron and 1 proton), so the angle of deflection of protons is double that of deuterons. [1]

(b)

+1310 kJ mol^{-1} (the same value as the first ionisation energy of hydrogen) [1]

The electron to be removed from a deuterium atom and a hydrogen atom experiences the same nuclear charge and no shielding effect. They are at the same distance from the nucleus. Thus, the attraction of the positive nucleus for the (1s) electron to be removed is the same.

or Hydrogen and deuterium have the same electronic configuration. Although deuterium has an additional neutron, it has no charge, so it does not affect the attraction of the nucleus for the electron to be removed. [1]

5 **(a)**

$^4He^{2+}$: $\frac{\text{charge}}{\text{mass}} = \frac{2+}{4} = \frac{1+}{2}$, half that of a proton

Angle = ½ × (+15°) = **+7.50°** [1]

(b)

$\frac{q}{12} \times (+15°) = +5°$

q = **4+** [1]

(c)

The mass of A is the mass of its protons and neutrons (electrons are very light), so number of neutrons = 12 − 6 = **6** [1]

A has a charge of 4+, so number of electrons = 6 − 4 = **2** [1]

6 **(a)**

There is a large difference between the 5th and 6th ionisation energies: the 6th electron is removed from an inner electronic shell. A has 5 valence electrons, so it is in Group 15. [1]

Element A is **arsenic**. [1]

(b)

The element to the right is selenium. Its first ionisation energy involves removing one of a pair of 4p electrons, which experiences inter-electronic repulsion. [1]

Less energy is needed to remove this electron from Se than the unpaired 4p electron from As, so the first ionisation energy of Se is lower. [1]

7 **(a)**

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$ [1]

(b)

$Al^{2+}(g) \rightarrow Al^{3+}(g) + e^-$ (state symbols needed) [1]

(c)

Al^{2+} has a greater nuclear charge than Na (more protons). The shielding effect is the same for Al^{2+} and Na, as they have the same electronic configuration and both lose the single 3s electron. [1]

Hence, Al^{2+} has a greater effective nuclear charge: its 3s electron experiences a greater electrostatic attraction to the positive nucleus, and more energy is required to remove it, leading to a greater third ionisation energy than the first ionisation energy of sodium. [1]

8 **(a)**

Cu^+: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}$ [1]

Zn^+: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^1$ [1]

(b)

The second ionisation energy of Cu involves removing a 3d electron [½]. The second ionisation energy of Zn involves removing a 4s electron [½].

The 3d subshell is closer to the nucleus than the 4s subshell [½], so the electron removed from Cu experiences greater electrostatic attraction towards the nucleus [½]. More energy is required to remove it, so the second ionisation energy of Cu is greater.

9 **(a)**

First ionisation energy is the energy required to remove one mole of electrons from one mole of gaseous atoms to form one mole of singly positively charged gaseous ions. **[1]**

(b)

The first ionisation energy of Kr is higher than that of Br. **[1]**

Kr has a larger nuclear charge, and its electrons are added to the same quantum shell, so the shielding effect is relatively constant. Kr has a greater effective nuclear charge: the attraction between the nucleus and the outermost electron is stronger, so more energy is required to remove it. **[1]**

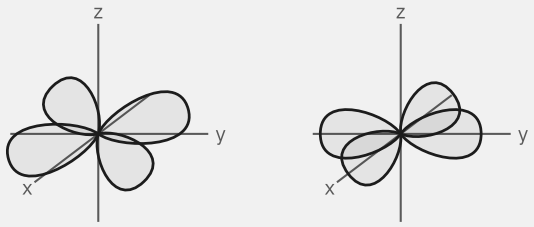
10

There is a large increase from the 5th to the 6th ionisation energies, so the 6th electron is removed from an inner principal quantum shell, which is nearer to the nucleus. **[1]**

A has 5 valence electrons, so it is in Group 15 and is phosphorus. **[1]**

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[1]



d_{xy} $d_{x^2-y^2}$

12 **(a)**

Amount of O = $\frac{1.994 - 1.00}{16}$ = 0.062125 mol **[1]**

Each SO_2 contains one S atom and two O atoms, so amount of S = $\frac{0.062125}{2}$ = 0.0310625 mol. Let the mass of ^{32}S be x g.

$\frac{x}{32} + \frac{1.00 - x}{34} = 0.0310625$ **[1]**

x = 0.898

Percentage by mass of ^{32}S = $\frac{0.898}{1.00} \times 100\%$ = **89.8%** **[1]**

(b)

Deep mantle degassing, since the sample is enriched in ^{32}S. **[1]**

(c)

$$A_r = \frac{95.02(31.972) + 0.75(32.971) + 4.21(33.968) + 0.02(35.967)}{100}$$

= **32.06** (2 d.p.) **[1]**