02 Atomic Structure

Set B **Answer key**

A Competition questions

23 MARKS

1

C Y and Z have the same number of electrons. [1]

Y and Z each have 18 protons, so each atom has 18 electrons.

X and Y have different proton numbers, so they are different elements. X has 20 neutrons and Y has 19. Z has 38 − 18 = 20 neutrons, the same as X.

2

C Y^{3+} [1]

Protons = nucleons − neutrons. The electrons are the protons minus the charge. W^-: 19 protons, 20 electrons. X^{2+}: 17 protons, 15 electrons. Y^{3+}: 17 protons, 14 electrons. Z^{3-}: 15 protons, 18 electrons.

Y^{3+} has 14 electrons < 16 neutrons < 17 protons. W^- has more electrons than neutrons. X^{2+} has equal neutrons and protons. Z^{3-} has more electrons than neutrons.

3

B They have 10 neutrons in their nuclei. [1]

^{18}O has 18 − 8 = 10 neutrons and ^{19}F has 19 − 9 = 10 neutrons.

Both ions have 10 electrons, equal to the neutrons, not more. Their outer configuration is $2s^2\ 2p^6$. The nucleon numbers are 18 and 19.

4

B 3 protons, 3 neutrons, 5 electrons [1]

A proton has charge/mass = +1 and gives +15°. So Y has charge/mass = −5 ÷ 15 = −1/3.

Option B has charge 3 − 5 = −2 and mass 3 + 3 = 6, so charge/mass = −1/3. Option A is neutral. Option C has charge +3 and mass 9, giving +1/3, the wrong direction. Option D has +1/9.

5

D −4° [1]

Angle = k × charge ÷ mass. For Ca^{2+}: +4 = k × (+2) ÷ 40, so k = 80.

For F^-: angle = 80 × (−1) ÷ 19 = −4.2, which is about −4°. The negative sign means it bends the opposite way.

6

B $^9Be^{2+}$ [1]

The deflection is proportional to charge ÷ mass, ignoring the sign. Li^+: 1/7 = 0.143. Be^{2+}: 2/9 = 0.222. O^{2-}: 2/16 = 0.125. N^{3-}: 3/14 = 0.214.

Be^{2+} has the largest ratio.

7 **D** 42, 43, 44 [1]

Argon-41 has 18 protons, 18 electrons and 41 − 18 = 23 neutrons.

X^+, Y^{2+} and Z^{3+} each have 18 electrons, so X, Y and Z have 19, 20 and 21 protons. With 23 neutrons each, the mass numbers are 42, 43 and 44.

8 **D** 31 [1]

The angle is proportional to charge ÷ mass. For O^{2-}: 10.0 = k × 2 ÷ 16, so k = 80.

For Z^-: 2.58 = 80 × 1 ÷ mass, so mass = 80 ÷ 2.58 = 31.

9 **B** row B [1]

For $^9Be^{2+}$, charge ÷ mass = 2 ÷ 9. Half of this is 1 ÷ 9, or 2 ÷ 18.

Each particle has 10 electrons. B has 8 protons, so its charge is −2, and its mass is 8 + 10 = 18: charge ÷ mass = 2 ÷ 18 in size. A gives 4 ÷ 14, C 2 ÷ 20 and D 5 ÷ 35.

10 **C** ^{210}Pb atom has 3 neutrons more than ^{207}Pb atom. [1]

Isotopes have the same number of protons and differ only in neutrons, so the difference in nucleon number, 210 − 207 = 3, is 3 neutrons.

210 and 207 are nucleon numbers, not neutron numbers, and lead has 82 protons, not 125.

11 **B** The occupied orbital of lowest energy is spherical. [1]

Carbon is $1s^2\ 2s^2\ 2p^2$. The lowest energy orbital is 1s, which is a sphere.

The orbital of highest energy is 2p, a dumb-bell. There are 2 electrons in p orbitals and 4 in s orbitals. There are three energy levels, 1s, 2s and 2p.

12 **B** 8 [1]

Cu is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^1$. Only the d orbitals can have four lobes.

Four of the five 3d orbitals have four lobes. The fifth, d_{z^2}, has two lobes and a ring. The four orbitals hold 4 × 2 = 8 electrons.

13 **C** 4 [1]

Of the five 3d orbitals, d_{xy}, d_{xz}, d_{yz} and $d_{x^2-y^2}$ each have four lobes.

d_{z^2} has two lobes along the z axis with a ring round the middle.

14 **A** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^3$ [1]

24 protons is chromium. The atom is [Ar] $3d^5\ 4s^1$. X^{3+} has lost 3 electrons: the 4s electron first, then two 3d electrons.

This leaves 21 electrons, [Ar] $3d^3$. Electrons leave 4s before 3d.

15 **A** Cr [1]

Cr is [Ar] $3d^5\ 4s^1$, with 6 unpaired electrons.

Cu^{2+} is $3d^9$, with 1. Mn^{2+} is $3d^5$, with 5. Te^{2-} has the configuration of xenon, with none.

16 **D** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$ [1]

PH_3 has 15 + 3 = 18 electrons, so G^{2+} has 18 electrons and the atom G has 20. G is calcium.

The 4s subshell fills before 3d, so the last two electrons go into 4s. Option B is the configuration of the ion G^{2+}, and option C puts the electrons in 3d instead of 4s.

17 **B** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$ [1]

This is aluminium. Losing its three outer electrons, $3s^2\ 3p^1$, gives Al^{3+} with the stable configuration of neon.

Option A is nitrogen, which gains electrons rather than losing three. Option C is argon, which does not form ions. Option D has 21 electrons but is not a ground state, because 4s fills before 3d: scandium is $3d^1\ 4s^2$.

18 **A** The outermost orbital of the atoms of both elements has the same shape. [1]

Calcium is [Ar] $4s^2$ and copper is [Ar] $3d^{10}\ 4s^1$. In both atoms the outermost orbital is a 4s orbital, which is spherical.

Copper also has d orbitals, so it has three orbital shapes. Calcium has two outer electrons and copper has one. Ca^{2+} is [Ar] but Cu^{2+} is [Ar] $3d^9$.

19 **B** 2 [1]

Following the filling order, element 118 completes 7p and elements 119 and 120 fill 8s. The diagonal rule then reaches 5g before 6f, 7d and 8p.

So elements 121 and 122 put their electrons into 5g, and element 122 is expected to have 2 electrons there.

20 **B** Group 15 [1]

Z gains 3 electrons to fill its valence shell with 8, so its atom has 8 − 3 = 5 valence electrons: Group 15.

A Group 15 element with nucleon number 31 is phosphorus, proton number 15, in Period 3.

21 **B** 15 [1]

The big jump is after the 4th electron, so G^+ has 4 valence electrons.

G^+ has lost one electron already, so the atom G has 5 valence electrons and is in Group 15.

22

A P [1]

The big jump is between the 5th and 6th ionisation energies. The element has 5 valence electrons, so it is in Group 15.

In Period 3, Group 15 is phosphorus. S has 6 valence electrons, Cl has 7 and Ar has 8.

23

C The nuclear charge in argon is greater than that in sulfur. [1]

Both outer electrons are in the third shell, so the shielding is about the same. Argon has 18 protons and sulfur has 16, so argon's outer electron is held more strongly.

Electronegativity and a complete octet do not explain an ionisation energy. The electron removed from sulfur is a paired 3p electron, so D is also wrong.