Revision Topic 2:
Atomic Structure

1 The artificially produced isotope of cobalt, $^{60}_{27}Co$, is used as a source of x-rays in medical radiotherapy.

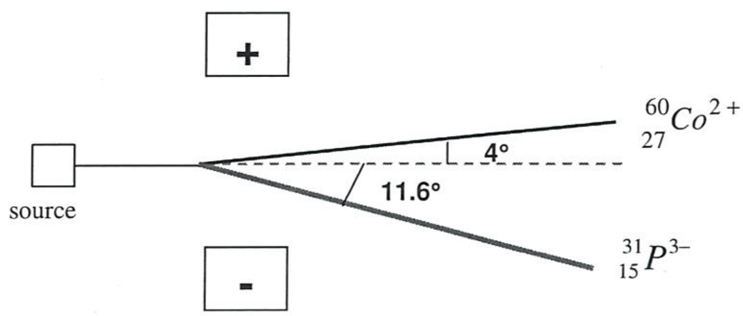
(a) Define the term *isotope*. [1]

Isotopes are **atoms of the same element** which contain **the same number of protons** but **different number of neutrons**. **[1]**

(b) Write the full electronic configuration of cobalt ion, $^{60}_{27}Co^{2+}$. [1]

$^{60}_{27}Co^{2+}$: **$1s^2 2s^2 2p^6 3s^2 3p^6 3d^7$** **[1]**

(c) In an experiment, a sample of cobalt was vaporised, ionised and passed through an electric field. Analysis of the deflection occurring at the electric region revealed the following data for a sample of $^{60}_{27}Co^{2+}$ charged ions. It was observed that a beam of $^{60}_{27}Co^{2+}$ gives an angle of deflection of 4º.



[½] for correct deflection upon entering field for Co^{2+}
[½] for correct deflection upon entering field for P^3
[½] for angle of P^{3-} being slightly greater than that of Co^{2+}

(i) Sketch on the above diagram to show how the beam of $^{60}_{27}Co^{2+}$ is deflected. State its angle of deflection clearly on the diagram.

(ii) Predict with reasoning and sketch on the above diagram the angle of deflection for a sample of $^{31}_{15}P^{3-}$. *(Ans :11.6°)*

[3]

$^{31}_{15}P^{3-}$ is **negatively charged**. Hence, the beam of $^{31}_{15}P^{3-}$ will be deflected towards the **positive potential**. **[½]**

The angle of deflection $\propto \frac{q}{m}$ ratio.

$$\left.\begin{array}{l}\frac{q}{m} \text{ of } ^{60}_{27}Co^{2+} = \frac{2}{60} \\ \\ \frac{q}{m} \text{ of } ^{31}_{15}P^{3-} = \frac{3}{31}\end{array}\right\} \textbf{[½]}$$

Since the beam of $^{60}_{27}Co^{2+}$ has an angle of deflection of 4°, hence the angle of deflection for $^{31}_{15}P^{3-} = (4 \div \frac{2}{60}) \times \frac{3}{31}$ = **11.6° [½]* 1 dp**

2 The Group II metals have generally higher melting points than Group I metals.

One factor that contributes towards the higher melting points of Group II metals is due to the smaller inter-atomic distances between adjacent metallic ions in the metallic lattice structure.

(a) Explain, in terms of ionization energy, why there is smaller inter-atomic distance in the metallic lattice structure of Group II elements such as magnesium as compared with that of Group I element such as sodium.
[2]

Comparing Sodium, Na and Magnesium, Mg:

Na: $1s^22s^22p^63s^1$ Mg: $1s^22s^22p^63s^2$

The nuclear charge of Mg > nuclear charge of Na

The electrons of Mg are added to the same outer shell, 3s.

The increase in nuclear charge outweighs the negligible increase in shielding effect. [1/2]

Hence the **effective nuclear charge of the Mg > Na. . [1/2]**

There is a **stronger electrostatic force of attraction between the nucleus** and **valence electrons in Mg. . [1/2]**

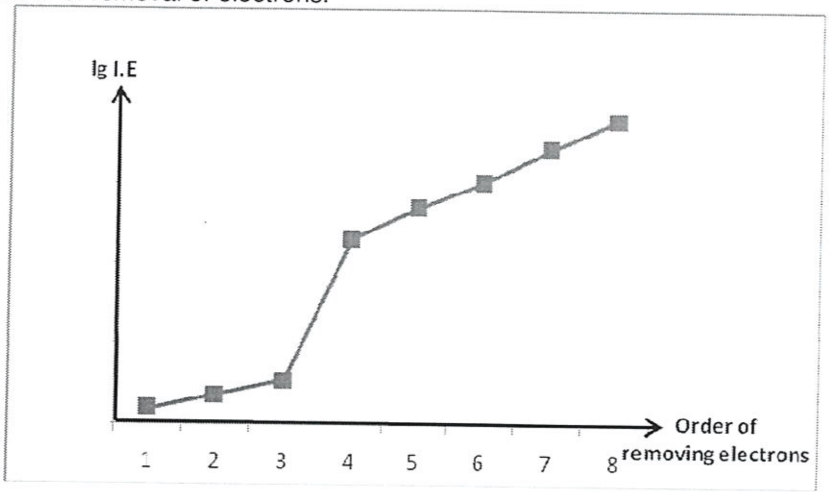
Valence electrons of Mg are closer to the nucleus[1/2], hence **atomic radius of Mg < Na.**

Therefore, the inter-atomic distance in the metallic lattice structure of Group II elements such as Mg is smaller than that in Group I elements such as Na.

(b) Rubidium is a Group I metal. Write the electronic configuration of rubidium.
[1]

$_{37}Rb$: $1s^22s^22p^63s^23p^64s^23d^{10}4p^65s^1$ **[Total : 3 marks]**

3 The graph below shows the first eight successive ionisation energies of **X** against the order of removal of electrons.



(a) From the graph, deduce which group of the periodic table does element **X** belongs to. **[2]**

Removing the 4th valence electron **requires a vast amount of energy**./ There is a **large jump** from the **3rd to 4th IE. [½]**

The **4th electron** is removed from an **inner shell [½]**
/ There are **3 valence electrons. [½]**

Therefore, element **X** is from **group III**. **[½]**

(b) Given that element **X** is from period 3, identify element **X**. **[1]**

X is **aluminium**. **[½]**

(c) Explain whether **X** or the element below **X** in the same group will have higher first ionization energy. **[2]**

Electrons are added to the **next valence shell**. **[½]**
The **distance** between the nucleus and the valence electrons **increases**. **[½]**
Decrease in electrostatic forces of attraction between the nucleus and valence electrons. **[½]**
Less energy needed to remove the valence electron, thus 1st I.E. decreases. **[½]**
Element X will have a higher first ionization energy.

[Total : 5 marks]

4 The table below shows the first ionization energies and the second ionization energies of the elements from nitrogen to calcium.

Element	First ionisation energy / kJ mol^{-1}	Second ionisation energy / kJ mol^{-1}
N	1400	2860
O	1310	3390
F	1680	3370
Ne	2080	3950
Na	494	4560
Mg	736	1450
Al	577	1820
Si	786	1580
P	1060	1900
S	1000	2260
Cl	1260	2300
Ar	1520	2660
K	418	3070
Ca	590	1150

(a) Write one equation, with state symbols, which represents the first and second ionisation energies of calcium.

[1]

Ca (g) → Ca^{2+}(g) + $2e^-$ [1] No state symbols [0]

(b) Explain why there is a sudden decrease in the first ionisation energy after neon by writing appropriate electronic configurations.

[2]

Ne: $1s^2 2s^2 2p^6$
Na: $1s^2 2s^2 2p^6 3s^1$ } **[½]**

- From Ne to Na, **significant increase in shielding effect outweighs** the **increase in nuclear charge. [1/2]**
- **Effective nuclear charge of Na < Ne**[1/2]
- **Less energy** is required to remove the **valence electrons from Na compared to Ne. [1/2]**

(c) Explain why the second ionisation energy of silicon is lower than aluminium.

[2]

Si^+ : $1s^2 2s^2 2p^6 3s^2 3p^1$
Al^+ : $1s^2 2s^2 2p^6 3s^2$

The second ionisation energy corresponds to removal of 3p electron for Si^+ and 3s electron for Al^+. **Greater amount of energy** is required to **remove the 3s electron in Al^+ which is closer to the nucleus compared to the 3p electron in Si^+ [1]** as it **experiences greater electrostatic attraction to the nucleus[1]**

(d) Explain why the second ionisation energy of sulphur and chlorine . **[2]**

S^+ : $1s^2 2s^2 2p^6 3s^2 3p^3$
Cl^+ : $1s^2 2s^2 2p^6 3s^2 3p^4$

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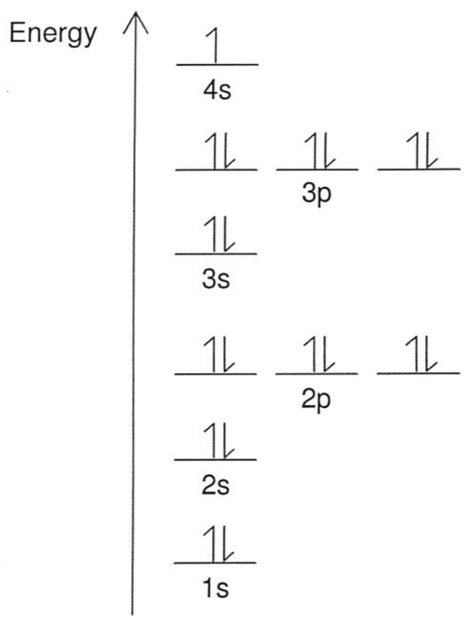
- **Inter-electron repulsion is predominant in the doubly filled 3p orbital of Cl^+** / **between paired electrons in the 3p orbital of Cl^+.[1]**
- **Hence less energy is required to remove the valence electron from Cl^+.[1]**

(e) Draw the energy level diagram for Ca^+. **[1]**



[1 or 0]

[Total : 8 marks]