Tutorial –Physical Periodicity of Elements

Periodic Trend -Atomic and Ioni Radii

1 Oxygen reacts with platinum(VI) fluoride, PtF_6, as follows.

$$O_2 + PtF_6 \longrightarrow O_2^+PtF_6^-$$

It was suggested that xenon should react similarly and in this way, the first noble gas compound was produced.

$$Xe + PtF_6 \longrightarrow Xe^+PtF_6^-$$

What is the most likely reason for the suggestion being made?

A O and Xe have similar atomic radii

B O and Xe have similar electron affinities.

C O_2 and Xe have similar electronic configurations.

D O_2 and Xe have similar first ionisation energies.

N2003/I/3

Ans: D

Explanation: In both equations, O_2 and Xe loses 1 electron to give O_2^+ and Xe^+ respectively. Hence option D is the best explanation for their similar reactivity.

2 The elements radon (Rn), francium (Fr) and radium (Ra) have consecutive proton numbers in the Periodic Table.

What is the order of their first ionisation energies?

Least endothermic ⟶ Most endothermic

	Least endothermic		Most endothermic
A	Fr	Rn	Ra
B	Fr	Ra	Rn
C	Ra	Rn	Fr
D	Ra	Fr	Rn

N99/III/4; N2002/I/3

Ans: B
Explanation:
Ionisation energy generally increases across a period and decreases down the group.

The most loosely held electron for Rn is in a inner principal quantum shell (n=6) as compared to Fr and Ra (n=7). Hence the largest amount of energy is required to remove the most loosely held electron of Rn.

Nuclear charge of Ra is higher than Fr while both atoms have relatively constant shielding effect. Nuclear attraction is stronger for the most loosely held electron of Ra, hence 1st I.E. of Ra > Fr.

3 Gaseous particle **X** has a proton number n and a charge of +1.

Gaseous particle **Y** has a proton number of (n+1) and is isoelectronic (has the same number of electrons as) with **X**.

Which statements correctly describe **X** and **Y**?

1 **X** has a larger radius than **Y**.

2 **X** requires more energy than **Y** when a further electron is removed from each particle.

Explanation:
Problem Solving approach: Suggest two hypothetical example to represent **X** and **Y**.
X = Na^+ and Y = Mg^{2+}

Statement 1: True
Across isoelectronic series, ionic radius decreases. Hence **X** is larger than **Y**.
[Data Booklet shows ionic radius of Na^+ (0.095 nm) > Mg^{2+}(0.065 nm)]

Statement 2: False
More energy is required to remove electrons from Y (ie. Mg^{2+}) than X (ie. Na^+) due to the greater nuclear attraction for the most loosely held electron in the higher charged species.

$Na^+(g) \longrightarrow Na^{2+}(g) + e^-$ 2nd I.E. of Na = 4560 kJ mol^{-1}

$Mg^{2+}(g) \longrightarrow Mg^{3+}(g) + e^-$ 3rd I.E. of Mg = 7740 kJ mol^{-1}

Periodic Trend – Ionisation Energy

4 Table 1 provides data on elements in Period 2 of the Periodic Table.

	Li	Be	B	C	N
No. of protons	3	4	5	6	7
Electronic configuration	$1s^2\ 2s^1$	$1s^2\ 2s^2$	$1s^2\ 2s^2\ 2p^1$	$1s^2\ 2s^2\ 2p^2$	$1s^2\ 2s^2\ 2p^3$
1st ionization energy/ $kJ\ mol^{-1}$	520	900	801	1086	1402

Table 2 shows the first 6 successive ionisation energies of an element **X**, which is in Period 3 of the Periodic Table.

	1st	2nd	3rd	4th	5th	6th
Ionisation energy / $kJ\ mol^{-1}$	578	1817	2745	11578	14831	18378

(a) **(i)** Fill in the electronic configuration of each element in Table 1.

(ii) Using Table 1, describe and explain the trend in first ionisation energies shown by the Period 2 elements, Li–N.

Across the period:

- **Nuclear charge increases**.
- **Shielding effect** remains **relatively constant**
- **Nuclear attraction for the valence electrons increases**
- **More energy** is required to remove the most loosely held electron and hence 1st IE increases generally across the period 2 elements.

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A dip in 1st IE from Be to B.

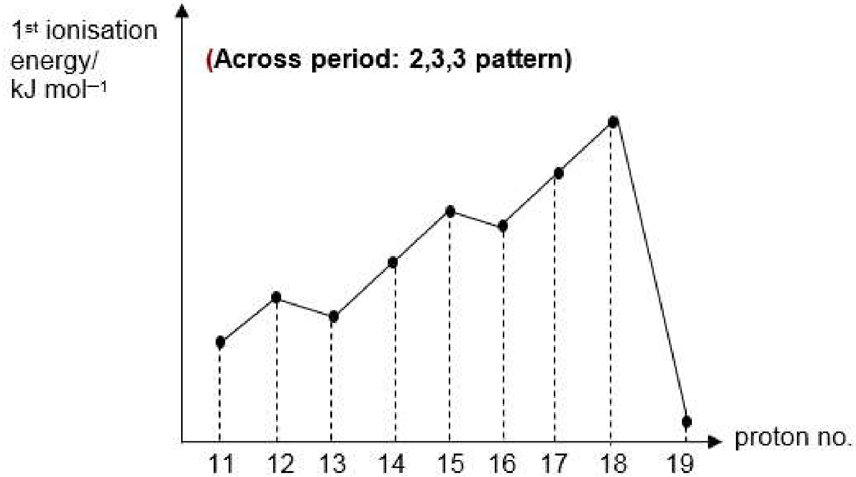
- The most loosely held electron is in the **higher energy 2p subshell** in B while that of Be is in the 2**s subshell**.
- **Less energy** is required to remove the **most loosely held 2p** electron, resulting in lower 1st IE.

(b) Using Table 2, identify element **X**. Explain how you decided on your answer.

- There is a large increase in IE from the 3rd to the 4th IE of X, suggesting that the 4th electron must be from the inner electronic shell.
- There are 3 valence electrons, hence element X must be in group 13.

Since it is also in period 3, element X is A*l*.

5 **(a)** Sketch a graph of the first IEs of the elements sodium to potassium against proton number.



(b) Using the graph, explain the difference in the first IEs of the following pairs of elements.

(i) Na and K

Na: $1s^2\ 2s^2\ 2p^6\ \mathbf{3s^1}$ K: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ \mathbf{4s^1}$

- The **most loosely held** electron in K is **further away from the nucleus** than that of Na due to K having **1 more filled principal quantum shell.**
- K has a **greater shielding effect**.
- These factors **outweigh the higher nuclear charge in K.**
- The nuclear attraction for the most loosely held electron is weaker in K, thus 1st I.E **is lower for K.**

(ii) Mg and A*l*

Mg: $1s^2\ 2s^2\ 2p^6\ \mathbf{3s^2}$ A*l*: $1s^2\ 2s^2\ 2p^6\ 3s^2\ \mathbf{3p^1}$

- The most loosely held electron is in the **higher energy 3p subshell** while that of Mg is in the **3s subshell**. **Less energy** is required to remove the **most loosely held 3p** electron, resulting in lower 1st IE for A*l*.

(iii) Si and P

Si: $1s^2\ 2s^2\ 2p^6\ 3s^2\ \mathbf{3p^2}$ P: $1s^2\ 2s^2\ 2p^6\ 3s^2\ \mathbf{3p^3}$

- Valence electron is removed from the **same 3p** subshell for both Si and P.
- **Nuclear charge** for P **larger** than Si.
- **Shielding effect** for both P and Si are **relatively constant**,
- **Nuclear attraction** for the valence electron in P is **larger** than Si.
- **More** energy is required to remove the most loosely held electron in P and 1st IE higher.

(iv) P and S

P: $1s^2\ 2s^2\ 2p^6\ 3s^2\ \mathbf{3p^3}$ $\boxed{\uparrow}\boxed{\uparrow}\boxed{\uparrow}$ S: $1s^2\ 2s^2\ 2p^6\ 3s^2\ \mathbf{3p^4}$ $\boxed{\uparrow\downarrow}\boxed{\uparrow}\boxed{\uparrow}$

3p 3p

- The most loosely held electron in S is in a **doubly filled 3p orbital** while that of P is in a singly filled 3p orbital.
- This most loosely held electron in S experiences **interelectronic repulsion with its paired 3p electron**.
- **Less energy** is required to remove this electron in S, resulting in lower 1st IE.