## Group displacement law.

**Soddy, Fajans and Russell (1911-1913)** observed that when an  $\alpha$ -particle is lost, a new element with atomic number less by 2 and mass number less by 4 is formed. Similarly, when  $\beta$ -particle is lost, new element with atomic number greater by 1 is obtained. The element emitting then  $\alpha$  or  $\beta$ -particle is called **parent** element and the new element formed is called **daughter** element. The above results have been summarized as **Group displacement laws** as follows:

(1) When an $\alpha$ -particle is emitted, the new element formed is displaced two positions to the **left** in the periodic table than that of the parent element (because the atomic number decreases by 2).



For example, when

$$_{92}U^{238} \longrightarrow _{90}Th^{234} + _{2}He^{4}$$

(2) When a  $\beta$ -particle is emitted, the new element formed is displaced one position to the **right** in the periodic table than that of the parent element (because atomic number increased by 1).



For example,

## $_{90} Th^{234} \longrightarrow _{91} Pa^{234} + _{-1}e^{0}; _{6} C^{14} \longrightarrow _{7} N^{14} + _{-1}e^{0}$

Hence, group displacement law should be applied with great care especially in the case of elements of lanthanide series (57 to 71), actinide series (89 to 103), VIII group (26 to 28; 44 to 46; 76 to 78), IA and IIA groups. It is always beneficial to keep in mind the setup and skeleton of the extended form of periodic table.

| ΙΑ | IIA | IIIB | IVB | VB | VIB | VII    | VIII |   | IB | IIB | IIIA | IVA | VA | VIA | VII | Zero           |    |
|----|-----|------|-----|----|-----|--------|------|---|----|-----|------|-----|----|-----|-----|----------------|----|
| 1  | 2   | 3    | 4   | 5  | 6   | в<br>7 | 8    | 9 | 10 | 11  | 12   | 13  | 14 | 15  | 16  | <b>A</b><br>17 | 18 |

|            | IA      | IIA | IIIB             | IVB | Zero    |
|------------|---------|-----|------------------|-----|---------|
|            | 1       |     |                  |     | 18      |
|            | At. No. |     |                  |     | At. No. |
| 1st period | 1       | _   | _                | _   | 2       |
| 2nd period | 3       | _   | _                | _   | 10      |
| 3rd period | 11      | _   | _                | _   | 18      |
| 4th period | 19      | _   | _                | _   | 36      |
| 5th period | 37      | _   | _                | -   | 54      |
| 6th period | 55      | 56  | 57*–71           | 72  | 86      |
| 7th period | 87      | 88  | 89 <b>!</b> –103 | 104 |         |

\*Lanthanides, ! Actinides

## **Important tips**

 $\sim \alpha$ -Decay produces isodiapher i.e., the parent and daughter nuclide formed by  $\alpha$ -decay have same isotopic number, i.e., difference between the number of neutrons and protons is same. For example,

|                 | $_{88}Ra^{226}$ | $\longrightarrow _{86} Rn^{222}$ |
|-----------------|-----------------|----------------------------------|
| No. of neutrons | 138             | 136                              |
| No. of protons  | 88              | 86                               |
| Difference      | 50              | 50                               |

Thus note that an  $\alpha$ -decay leads to

- (i) **Decrease** in atomic weight, mass number and number of nucleons by **four units**.
- (ii) Decrease in number of protons, neutrons, nuclear charge and atomic number by two units.
- (iii) Increase in n/p ratio.

 $_{19}K^{40} \longrightarrow _{20}Ca^{40} + _{-1}e^{0}$ 

Thus note that a  $\beta$ -decay leads to

- (i) No change in atomic weights, mass number and number of nucleons.
- (ii) **Decrease** in number of neutrons by **one unit**.
- (iii) Increase in nuclear charge, number of protons and atomic number by one unit.
- (iv) **Decrease** in n/p ratio.

It is important to note that although  $\beta$ -particle (electron) is not present in the nucleus, even then it is emitted from the nucleus since a neutron at first breaks down to a proton and electron.

$$_0n^1 \longrightarrow _1p^1 + _{-1}e^0$$

The proton is retained by the nucleus while the electron is emitted as a  $\beta$ -particle.

Emission of 1 α-particle and 2 β-particles in succession produces an isotope of the parent element. For example,

 $_{92}U^{235} \xrightarrow{-\alpha} _{90}Th^{231} \xrightarrow{-\beta} _{91}Pa^{231} \xrightarrow{-\beta} _{92}U^{231}$ 

- This law helps to fix the position of the radioelements in the periodic table.
- To determine the number of α- and β- particles emitted during the nuclear transformation. It can be done in following manner:

$$a^{a}_{c} X \rightarrow a^{b}_{d} Y + x \frac{4}{2} He + y - 1e^{0},$$

$$a = b + 4x \text{ or } \boxed{x = \frac{a - b}{4}} \qquad \dots \dots (i)$$

$$c = d + 2x - y \qquad \dots \dots (ii)$$

where x = no. of  $\alpha$ -emitted, y = no. of  $\beta$ -emitted

substituting the value of x from eq. (i) in eq. (ii) we get  $c = d + \left(\frac{a-b}{4}\right)2 - y$ ;  $y = d + \left[\frac{a-b}{2}\right] - c$