Nuclear Reactions

As discussed in Introduction, the nuclear reactions are significantly different from ordinary chemical reactions. Therefore, the nuclear reactions are the reactions involving nucleus. Radioactivity is the nuclear phenomenon and hence, the nuclear reactions express the phenomenon of radioactivity, whether it is natural or artificial.

Chemical equations are used to indicate the chemical reactions. Similarly, nuclear equations are used to indicate nuclear reactions. In essence, nuclear equations are the simple recipes to carry out nuclear reactions or shorthand notations to exhibit the nuclear reactions. Like chemical equations, you also need to learn how to balance nuclear equations, which is of much simpler task than chemical equations. In doing so, you utilize symbols for elementary particles as well as nuclides (isotopic symbols). Symbols for some elementary particles with their charges and masses are given below:

Proton	${}_{1}^{1}p \text{ or } {}_{1}^{1}H$	charge = 1, mass = 1
Neutron	${}_{0}^{1}n$	charge = 0, mass = 1
Electron or beta particle	${}_{-1}^{0}e \text{ or } {}_{-1}^{0}\beta$	charge = -1, mass = 0
Positron	${}_{+1}^{0}e \text{ or } {}_{+1}^{0}\beta$	charge = +1, mass = 0 (positron is the anti-particle to electron).
Alpha particle Or α particle	${}_{2}^{4}He \text{ or } {}_{2}^{4}\alpha$	charge = 2, mass = 4
Gamma energy (rays)	γ	charge =0, mass=0

The left side subscript is the atomic number (charge) and the left side supersubscript is the mass number (mass).

Balancing Nuclear Reactions

Balancing any nuclear reaction is not that hard. There are two simple rules that you keep in mind.

- The atomic number (total number of protons) of products must be equal to that of reactants. This is a lower left side number.

- The mass number (sum of protons and neutrons) of products must be equal to that of reactants. This is an upper left side number.

Nuclear reaction usually involves one or more nuclides and one or more particles. If atomic numbers and mass numbers of all the species except one are known, the unknown is identified using the above rules.

Examples

Balance the following nuclear equations and identify X.

(a) $^{212}_{84}Po \longrightarrow ^{208}_{82}Pb + X$

(b) $^{137}_{55}Cs \longrightarrow X + ^{0}_{-1}e$

(c) $^{26}_{12}Mg + ^{1}_{1}p \longrightarrow ^{4}_{2}\alpha + X$

(d) $^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{94}_{36}Kr + ^{139}_{56}Ba + 3X$

(e) $^{14}_{7}N + X \longrightarrow ^{17}_{8}O + ^{1}_{1}p$

Answer

(a) Here, the polonium-212 emits some particle and transforms into lead-208. The sum of atomic numbers of products (82 +x) must be equal to the sum of the atomic numbers of reactants, i.e., 84. Therefore, X must have atomic number of 2:

$$82+x = 84$$

Therefore $\quad x = 84-82 = 2$

Similarly, sum of total mass numbers of products (208 + x) must be equal to the sum of mass numbers of reactants, i.e., 212. Thus, the mass number of X must be 4:

$$208+ x = 212$$

Therefore $\quad x = 212 – 208 = 4$

The X has now atomic number of 2 and mass number of 4 ($^{4}_{2}X$), which is alpha-particle. The balanced equation is

$$^{212}_{84}Po \longrightarrow ^{208}_{82}Pb + ^{4}_{2}He$$

(b) Here, cesium-137 emits one electron and converts into some nuclide X. Applying the same rule, we can identify the atomic number as 56 and mass number as 137. Since the atomic with 56 is barium (Ba), we can write the balance equation as

$$^{137}_{55}Cs \longrightarrow ^{137}_{56}Ba + ^{0}_{-1}e$$

(c) The total atomic number on reactant side is 13 (=12+1) and total mass number is 27 (26+1). Then X should have the atomic number of 11 and mass number of 23, i.e. ${}^{23}_{11}X$. The element with this atomic number is Na. Thus the balance equation is

$${}^{26}_{12}Mg + {}^{1}_{1}p \longrightarrow {}^{4}_{2}\alpha + {}^{23}_{11}Na$$

(d) The sum of atomic numbers of reactants is 92 (= 92+0) and sum of mass numbers is 236 (= 235+1). The sum of atomic numbers of Kr and Ba is 92, and hence the atomic number of X should be 0. The sum of mass numbers of Kr and Ba is 233, and therefore the mass number of X should be 1 as there are 3 Xs. The particle with 0 atomic number and 1 mass number is neutron. Therefore, the balanced equation is

$${}^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{94}_{36}Kr + {}^{139}_{56}Ba + 3\,{}^{1}_{0}n$$

(e) In this example, the unknown is on the reactant side, which should have the atomic number of 2 and mass number of 4, which is alpha particle. The balanced equation takes the following form.

$${}^{14}_{7}N + {}^{4}_{2}He \longrightarrow {}^{17}_{8}O + {}^{1}_{1}p$$