Nuclear Transmutation

Nuclear transmutation is artificial method of transforming one element/isotope into another element/isotope, without which the field of radiochemistry is limited to only natural radioactivity. Stable atoms can be transformed into radioactive atoms by bombardment with high speed particles. In the early experimental studies, high-speed alpha particles from ^{214}Bi (known as radium C) were used.

In 1919, Lord Rutherford and his collaborators in the Cavendish Laboratory at Cambridge carried out the first nuclear reaction between alpha particles and nitrogen that is given by

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

In this reaction, a nitrogen nucleus reacted with a high speed helium nucleus to form two new nuclei a ^{17}O and a proton. This reaction demonstrated the possibility of converting one element into another – a long cherished dream of alchemists. The natural radioactive decay and nuclear transmutation both produce new atoms but with one difference; the latter involves bombarding the nuclei in question with a high-speed particle.

The above reaction can be abbreviated as $^{14}_{7}N(\alpha, p)^{17}_{8}O$. The reacting nucleus is written first and then the parenthesis followed by the resulting nucleus. The parenthesis contains the reacting particle and the ejecting particle, with the reacting particle first written followed by the comma and then the ejecting particle.

Example

Write balanced nuclear reactions for

(a) $^{106}_{46}Pd(\alpha, p)^{109}_{47}Ag$
(b) $^{56}_{26}Fe(d, \alpha)^{54}_{25}Mn$

Answer

(a) The abbreviation tells us that when a palladium-106 is bombarded with an alpha particle, it produces a silver-109 nucleus with ejection of a proton. Therefore, the nuclear equation for this reaction is

$$^{106}_{46}Pd + {}^{4}_{2}He \longrightarrow {}^{109}_{47}Ag + {}^{1}_{1}p$$

Check: the sum of atomic numbers and mass numbers are the same on both sides of the equation, as they should be.

(b) In this example, the bombarding particle is d (deuterium, $^{2}_{1}H$), which is an isotope of hydrogen with charge 1 and mass 2. The ejecting particle is alpha ($^{4}_{2}\alpha$) with charge 2 and mass 4. Hence, the balanced equation for this nuclear reaction is

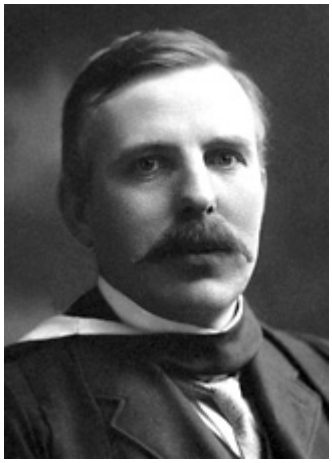
$$^{56}_{26}Fe + {}^{2}_{1}H \longrightarrow {}^{54}_{25}Mn + {}^{4}_{2}\alpha$$

Check: the sum of atomic numbers and mass numbers are the same on both sides of the equation, as they should be.

There is, however, one requirement in this technique. The bombarding particle must possess high kinetic energy (high velocity), otherwise it will not split the target nucleus. The particles are accelerated in a device known as **particle accelerator**. There are two kinds of particle accelerators; (a) cyclotron, and (b) linear accelerator. You may refer to any general chemistry textbook for further information on particle accelerators.

The Nobel Prize in Chemistry 1908

"for his investigations into the disintegration of the elements, and the chemistry of radioactive substances"



Ernest Rutherford

Taken from http://nobelprize.org/nobel_prizes/chemistry/laureates/1908/.