Types of Particles

Three particle are of primary consideration in chemistry. There are other particles which are important to understand nuclear reactions. The following is a list of these particles with three of their important quantum numbers - atomic mass number, atomic number and charge - and their mass.

Particle	Symbol	Atomic Mass Number	Atomic Number	Charge	Atomic Mass in amu ($gmol^{-1}$)
electron	${}^{0}_{-1}e^{-}$	0	-1	-1	0.00054858
beta particle	${}^{0}_{-1}\beta^{-}$	0	-1	-1	0.00054858
proton	${}^{1}_{1}p$	1	1	+1	1.0073
neutron	${}^{1}_{0}n$	1	0	0	1.0087
positron	${}^{0}_{+1}\beta^{+}$	0	+1	+1	0.00054858
gamma	γ	0	0	0	0
alpha	${}^{4}_{2}\alpha$	4	2	(+2)	4.0026

For particles and atoms the atomic number is written as a subscript before the letter symbol and the atomic mass number is written as a superscript before the letter symbol.

Nuclear Reactions

Writing nuclear reactions:

Nuclear reactions are written with the following symbolism. An arrow indicates that there is a change from one type of material to another. The material which one begins with is referred to as reactants and the material one ends with is referred to as products. I.E.:

$$\text{Reactants} \rightarrow \text{Products}$$

Example #1:

$$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n$$

This means that hydrogen of atomic mass number 2 reacts with hydrogen of mass number 3 to form helium of mass number 4 and a neutron.

Notice that both the atomic mass number and the atomic number are conserved. The sums of the atomic number are 2 on both sides of the equation, and the sums of the atomic mass number are 5 on both sides of the equation. Conservation of atomic mass number and atomic number must be true for all nuclear reaction.

For example, for the reaction:

$$^{235}_{92}U \rightarrow ^{4}_{2}\alpha + ?$$

The missing quantity in this reaction must be $^{231}_{90}Th$ in order for the atomic mass number to add up to 235 and for the atomic number to add up to 92 on the product side of the reaction.

Example #2:

$$^{6}_{3}Li + ^{1}_{0}n \rightarrow ^{4}_{2}\alpha + ^{3}_{1}H$$

This means that lithium of atomic mass number 6 reacts with a neutron to form an alpha particle and hydrogen of atomic mass number 3.

There is another method of writing nuclear reactions, especially when one of the reactants and one of the products is a simple particle. This can be symbolized as:

$$Reactant_1(Reactant_2, Product_2)Product_1$$

As an example, the alternative way of writing this last reaction is: $^{6}_{3}Li\ (^{1}_{0}n\ ,\ ^{4}_{2}\alpha)\ ^{3}_{1}H$ This method is shorter and easier to type and is often seen in physics articles.

Energy from nuclear reactions

Many nuclear reactions release energy. This released energy can be calculated from the masses of the reactants and products of the reaction. For example in the reaction:

$$^{2}_{1}D + ^{2}_{1}D \rightarrow ^{4}_{2}\alpha \quad (D \equiv H \text{ for the mass 2 isotope})$$

the mass of the reactants is 2 x 2.0140 amu = 4.0280 amu. The mass of the product, the alpha particle is 4.00260 amu. There is thus a mass difference between the reactants and products of 0.0240 amu which is lost, i. e. converted to energy. The equation which yields the energy, ΔE, for this lost mass, m, is:

$\Delta E = mc^2$ where c is the speed of light = 3.00×10^8 m/s

Using all SI units, where amu is converted to kg/mol, an energy of 2.29×10^{12} J/mol is obtained.

The above reaction is a proposed method of obtaining commercial energy and is referred to as the DD burner, after the fuel used. Another possible series of reactions considered are those listed on the previous page, that is:

$^{2}_{1}D + ^{3}_{1}T \rightarrow ^{4}_{2}He + ^{1}_{0}n$ (T ≡ H for the mass 3 isotope)

and

$^{6}_{3}Li + ^{1}_{0}n \rightarrow ^{4}_{2}\alpha + ^{3}_{1}T$

The change in mass for the first reaction is 0.0187 amu of an energy of 1.69×10^{12} J/mol. The second reaction in this series is for the purpose of producing $^{3}_{1}T$ from $^{6}_{3}Li$ which is available from natural sources.

Nuclear Decay and the Band of Stability:

There are three common modes of nuclear decay reactions. A nuclear decay reaction is the reaction which an unstable nucleus spontaneously undergoes to change to another nucleus. The three decay reactions are illustrated by the following:

Alpha decay:

$^{238}_{92}U \rightarrow ^{234}_{90}Th + ^{4}_{2}\alpha$

Beta decay:

$^{20}_{9}F \rightarrow ^{20}_{10}Ne + ^{0}_{-1}\beta^-$

Positron decay and K-capture:

$^{18}_{9}F \rightarrow ^{18}_{8}O + ^{0}_{+1}\beta^+$ and
$^{18}_{9}F + ^{0}_{-1}e^- \rightarrow ^{18}_{8}O$ which occur together.

A stable isotope does not undergo radioactive decay. The atomic weights of the Periodic Chart are average numbers for the stable isotopes for each of the elements. These numbers therefore represent the (approximately) average stable number for the atomic mass number. This is refer to as the band of stability. Those atoms which have an atomic mass number higher than the band of stability will decay to increase the atomic number to compensate. This decay is by beta emission. Those atoms which have an atomic mass number lower than the band of stability will decay to decrease the atomic number to compensate. This decay is by positron emission or electron capture (K-capture). The third mode of decay is for those atoms which are on the band of stability, but have an atomic number greater that 82. These atoms decay by alpha emission. The following table summarizes these considerations.

Condition with respect to the band of stability	Type of radioactive decay
Above the band	beta, ${}^{0}_{-1}\beta^{-}$, emission
Below the band	positron, ${}^{0}_{+1}\beta^{+}$, emission and ${}^{0}_{-1}e^{-}$ K-capture
On the band above AN = 82	Alpha, ${}^{4}_{2}\alpha$, emission