

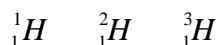
Nuclear Chemistry

Nuclide Symbols

Most elements in the periodic table have more than one form. These forms are known as **isotopes** or **nuclides**. Each nuclide has a unique symbol that shows us which particular isotope it is. The symbols have the following form:



Where Z is the atomic number (number of protons), A is the mass number (number of protons and neutrons) and E is the one or two letter symbol for the element. The three isotopes of Hydrogen can be represented as:



The latter two are also known as Deuterium (D) and Tritium (T).

Type of radiation

There are three kinds of radiation. The first is α (alpha) radiation. It is comprised of helium-4 nuclei. It is the weakest type of radiation and can be stopped by paper or clothing. The second is β (beta) radiation and consists of fast moving electrons. It requires a few inches of wood or Lucite to block it. The third type of radiation is the most energetic and is called γ (gamma) radiation. This is composed of high-energy photons (particles of light) and requires several inches of lead or concrete to block it.

In addition to the types of radiation we see here there are a few other types of particles that are encountered in nuclear chemistry.

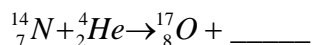
Type of particle	Symbol
Positron	β^+ or ${}^0_1 e$ or ${}^0_1 \beta$
Neutrino	ν
Proton	p or ${}^1_1 p$
Neutron	n or ${}^1_0 n$

All of these can appear in a nuclear reaction.

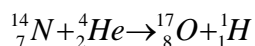
Other ways of protecting yourself from nuclear radiation are by distance and time. Limiting the amount of time you are around the radiation limits your exposure. Also the intensity of the radiation drops off with the square of the distance. This means that if you are twice as far from the radiation, your exposure will be $\frac{1}{4}$ th of what it would be closer to the source.

Balancing nuclear reactions

If you can add and subtract, you can balance a nuclear reaction. The main thing is that the numbers on top on both sides must add up to the same number. Also, the numbers on the bottom on both sides must add up to the same number. Keeping this in mind we can then balance nuclear reactions such as



The top numbers on the left add up to 18. This means that the top number on the last term on the right must be 1 (18-17). The bottom numbers on the left add up to 9 so the bottom number on the last term on the right must also be 1 (9-8). That means that the last term must be a proton, or a hydrogen nucleus.



Radiation Measurement

Radiation is most often measured with a Geiger counter. This is a device that has a gas filled tube with electrodes in it. When radiation passes through the tube it ionizes the gas and allows current to flow. This is registered as a click or a count on the device. The isotopes' activity is measured in a unit called the Curie (Ci). One Ci is 3.7×10^{10} disintegrations per second. A newer unit is also used called the Becquerel (Bq) which is 1 disintegration per second.

Radioactivity can also be measured based on the biological effect it has. The amount of radiation that a sample of tissue will absorb is the rad (radiation absorbed dose). It is being replaced by a newer unit called the Gray (Gy) which is 100 rads.

Another unit applies only to us. It is the rem (radiation equivalent in humans). It measures the biological effect of radiation on humans. To determine the dose in rem we multiply the absorbed dose in rad by a factor. For beta and gamma radiation the factor is 1. For alpha particles the factor is 20 and for high energy electrons or protons the factor is 10. The high factor for alpha particles is due to the fact that if an alpha source is ingested it can cause more damage than if it is not. Remember, our skin blocks alpha radiation. A newer unit for this is the sievert (Sv) which is 100 rem.

We are all constantly exposed to some radiation. This natural radiation amounts to about 0.17 rem per year. Living near a nuclear power plant will increase this slightly. Living at a higher altitude will also increase this. When we are exposed to larger amounts of radiation we start encountering health problems. 100 rem will temporarily decrease the number of white blood cells. More than 100 rem will cause the symptoms of radiation poisoning: nausea, vomiting, fatigue and a decrease in white blood cells. More than 300 rem will cause diarrhea, hair loss and infection. More than 500 rem results in death in 50% of the people exposed. More than 600 rem is fatal to all humans.

Decay Kinetics

Nuclear decay always follows first order kinetics. As a result the half-life of any nuclear decay is a constant. This means that if we know the half-life of a particular isotope, we can calculate how long it has been decaying. This has useful applications in the dating of fossils and rocks. It is the primary means by which we know how long humans have been on this continent and how old the Earth is.

When we start with a particular sample of a radioactive isotope and we wait one half-life, we will have $\frac{1}{2}$ of the original sample left. After another half-life we will have $\frac{1}{4}$ of the original sample left ($\frac{1}{2} \times \frac{1}{2}$). And so on...

The half-life of carbon-14 is 5750 years. The half-life of Uranium-238 is 4.5 billion years. The half-life of Technetium-99m is 6 hours. Half-lives are determined by looking at the activity of a sample of the radioisotope.

Medical Applications

Radioactive isotopes can be administered to the body and then detected. This can give us information about the health of certain organs. Certain isotopes tend to collect in particular organs.

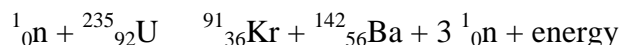
We can also do a Positron Emission Tomography (PET) scan. Radioactive carbon-11 is introduced into the body. This emits a positron which collides with an electron in an atom and produces gamma rays which are then detected.

Other imaging methods include CT (Computerized Tomography), which uses x-rays, and MRI (Magnetic Resonance Imaging), which uses radio waves and magnets.

Fission and Fusion

Fission is the breaking apart of a nucleus to produce lighter nuclei. Fusion is the combination of lighter elements to produce a heavier one.

An example of fission is:



An example of fusion is:



All nuclear reactors use fission reactions to produce electricity. An ongoing area of research is the production of electrical energy using fusion reactions. Fusion reactors would be capable of producing electricity without also creating the radioactive waste associated with fission reactors.