RADIOACTIVITY REVIEW

2.27 Introduction

Before we can understand *radioactivity*, we must first learn something about ourselves and the world around us. All matter, even our own bodies, is composed of *atoms*. There are more than you can possibly imagine. The ink dot at the end of this sentence, for instance, has more than a thousand billion atoms.

2.28 The Atom Defined

What are atoms?

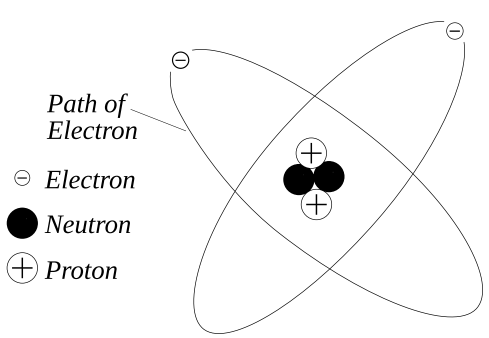
The atom is the smallest part of an element that has all the chemical properties of that element. The properties of the oxygen and carbon atoms, for example, determine the fact that when wood or coal burns in air, the principal end product is a combination of one carbon atom with two oxygen atoms called carbon dioxide. Similarly, when two hydrogen atoms combine with one oxygen atom, the result is ordinary water.

2.29 A Microscopic Universe

What are the parts of atoms?

The inside of the atom, however, is mostly empty space, a microscopic "universe" occupied by a relatively small number of negative *electrons* revolving around a central mass called the *nucleus*, millions of times smaller than the atom but accounting for nearly all its weight. The nucleus may be considered to be made up of particles called *protons,* with a positive electrical charge, and particles called *neutrons,* which are neutral and have no electrical charge. Protons and neutrons are thousands of times more massive than electrons, which explains why the nucleus accounts for nearly all the weight of the atom.

The Helium Atom



2.30 The Chemistry of an Element

What is an atomic number?

What is atomic weight?

The number of protons in the nucleus determines what the element is and, therefore, the chemistry of the element. The hydrogen nucleus is a single proton, the carbon nucleus has six protons, and oxygen has eight protons, etc. The *atomic number* of an atom is equal to the number of protons in the nucleus. Its *atomic weight* is the sum of the proton and neutrons in the nucleus. For instance, carbon has 6 protons and 6 neutrons. Its atomic weight is 12 (6 + 6 =12).

2.31 Isotopes

What is an isotope? A radioisotope?

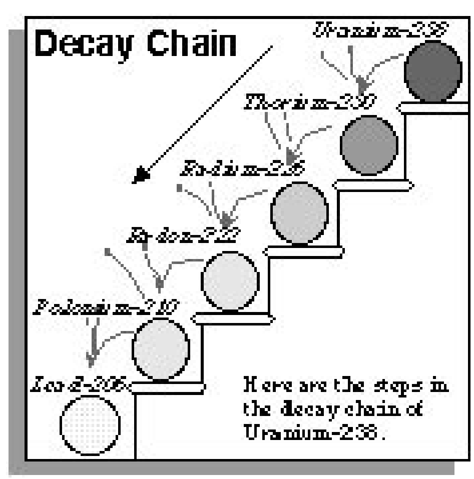
It is possible for atoms having the same chemistry or atomic number (the number of protons) to have different atomic weights because of differing numbers of neutrons. Atoms of the same chemical element having different atomic weights are called *isotopes* of that element. If the isotope is radioactive, it is sometimes referred to as a *radioisotope*.

In the case of atoms that are radioactive, the nucleus spontaneously emits energetic particles or electromagnetic rays that escape the bounds of the atom. This process is *radioactive decay*. Because the emitted particles and rays come from the nucleus, they are referred to as “nuclear” radiations.

2.32 Transformation of Atoms

What are alpha and beta particles?

The nuclei of some radioactive atoms, generally the heavier or larger atoms, expel a part of themselves as a particle composed of two neutrons and two protons (actually a helium nucleus) called an *alpha particle*. By expelling an alpha particle, the nucleus is changed to the nucleus of an element with an atomic number lower by 2 and an atomic weight lower by 4.



In other radioactive nuclei, one of the neutrons emits a negative electron called a *beta particle*. This increases the number of protons in the nucleus by one and converts the atom to another element with an atomic number higher by one.

For example, when the uranium-238 nucleus emits an alpha particle, it becomes the nucleus of a thorium-234 atom. In other words, the uranium atom becomes a thorium atom. It is the same nucleus but the chemistry has changed. When the strontium-90 nucleus emits a beta particle, it becomes the nucleus of yttritium-90. Again, it is the same nucleus, but the chemistry has changed.

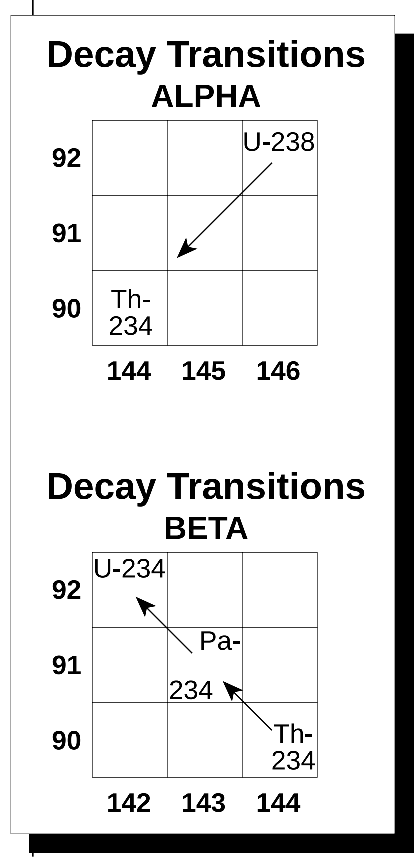
2.33 Radioactive Decay Series

What are the three naturally occurring radioactive decay series?

There are three naturally occurring radioactive decay series: the uranium-238 (U-238), the uranium-235 (U-235), and the thorium-232 (Th-232) series. The very long-lived uranium and thorium isotopes were present in the Earth from the beginning, and the many radioactive atoms resulting from their decay are called their “daughter products.”

It is important to understand these naturally occurring decay series and their daughter products and to understand that radioactivity is a fact of life on Earth and not necessarily the product of a nuclear age. It is also important, therefore, to distinguish between the naturally occurring radioactive daughter products like radium-226, radon-222, and polonium-210 and those radioactive “fission products” produced by the fissioning of uranium in a nuclear reactor. The fission products, such as iodine-131, cesium-137, strontium-90, etc., result from the splitting of uranium atoms in a nuclear reaction and are not the products of the radioactive decay of uranium.

Alpha and beta decay: The boxes at right illustrate what happens during decay.



2.34 Alpha Decay

During alpha decay, a uranium-238 nucleus (consisting of 92 protons and 146 neutrons) emits an alpha particle consisting of 2 protons and 2 neutrons. As a result, the nucleus now contains 90 protons and 144 neutrons. This means it is now the nucleus of a thorium atom. This thorium isotope has an atomic weight of 234 (90 + 144 = 234) so it is thorium-234.

2.35 Beta Decay

During beta decay, a neutron in a thorium-234 nucleus (that consists of 90 protons and 144 neutrons) becomes a proton. As a result, the nucleus now consists of 91 protons and 143 neutrons. This means it is an atom of protactinium. This protactinium isotope has an atomic weight of 234 (91 + 143 = 234) so it is protactinium-234.

2.36 Changing Chemistry

What are gamma rays?

Some radioactive materials emit what are called *gamma rays*. Gamma rays are electromagnetic rays that are similar to X-rays but are more energetic. Gamma rays are emitted when a nucleus changes from a higher to a lower energy state, and often accompanies alpha or beta decay. For example, cesium-137, a beta emitter, and radium-236, an alpha emitter, also emit very strong gamma rays.

2.37 Detecting Radioactive Decay

In their study of radioactive materials, scientists use a variety of extremely sensitive instruments. For example, a geiger counter uses high voltages to detect small amounts of radiation, even down to a single ionizing particle. Geiger counters are used to measure radioactivity in natural sources such as rocks and soils, as well as in man-made sources, including spent nuclear fuel.

This and other instruments are helpful in cleaning up research and work facilities where radioactive materials have been present. People at these work locations often wear badges that contain a small bit of photographic film. These film badges record the amount of ionizing radiation to which a worker has

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