Radioactivity

- certain elements spontaneously release energy and particles of matter

- the number of neutrons vary in isotopes of the same element making little difference chemically but the nuclear properties of the isotopes may vary a great deal

- atoms with too many neutrons are unstable which may decay (a natural process called radioactivity wherein the energy and particles emitted are nuclear radiation)

Health issues

1) this ionizing radiation can produce charged ions in materials that it strikes; can produce changes in living tissues (a potential health hazard)
2) extreme case = fatal, lower levels may cause changes in enough cells to induce sickness, cause a slightly increased incidence of cancer, or have developmental effects on unborn children
3) Radiation injuries: hair loss and skin lesions, localized injuries similar to burns (normally to hands)
4) Radiation sickness: nausea, vomiting, diarrhea, malaise, hemorrhage and lowering of the body's resistance against disease and infection, if serious enough = death
5) Man-made radiation sources: diagnostic X-rays, radiotherapy x-rays, television tubes, luminous watch dials, radioactive waste products

Units of measure:

- roentgen (R) = a measurement of radiation in air/space only
- REM = measures radiation absorbed by a man or mammal, which produces a physiological effect equivalent to that produced by the absorption of one roentgen of radiation.
- mrem = millirem (1/1000 of a rem)
- > 100 000 mrem = statistical identifiable effects 10 000 - 100 000 mrem = grey area < 10 000 mrem = no statistically identifiable effect

Natural Radioactivity

a) release of alpha, beta, and gamma radiation along with spontaneous fission (breaking up of a nucleus into 2 large chunks with neutrons usually given off

b) **alpha particles** - charged particles similar to helium nuclei 1) can be stopped by a sheet of paper 2) problem is the possibility of alpha particles being inhaled or ingested with food or water 3) the protective layer of dead tissue found on skin is not present in lining of digestive, respiratory, and circulatory systems

alpha particles --> positively charged (+2) particle with a mass of 4 (times that of hydrogen atom), similar to the nuclei of helium ions

c) **beta particles**

beta particles --> negatively charged (-1) particle very similar to electron, travels somewhat faster

d) **gamma radiation** -X rays (from electron excitation) and gamma rays (from nuclear excitation) can only be stopped by several inches of lead or a foot of concrete

gamma radiation --> as radiation, has no charge or mass but is energy and travels at speed of light, travels as photons (X-rays that come from electron excitation or gamma rays from nuclear excitation)

Radioactivity in bombs and power plants:

a) if enough mass (called the **critical mass)** of the isotope of uranium-235 is simply placed together it will produce an uncontrolled chain reaction in less than a millionth of a second. ***A chain reaction*** is when one atom fissions and the products cause the fission of additional atoms. If the chain reaction is uncontrolled, it is called an atomic bomb
b) another danger from nuclear explosions are the neutrons - must dissipate energy as heat by using cadmium or boron absorbers (neutrons bounce off lead elastically with kinetic energy conserved)
c) in order to artificially induce fission and harness the process to generate electricity in a nuclear power plant slow neutrons are directed at the uranium nucleus to split it and control rods are used to absorb some of the resulting increase in neutrons (there is never enough uranium in a reactor to reach critical mass)

Decay schemes

alpha decay - radioactive nucleus that decays by giving off an alpha particle loses 2 protons and 2 neutrons. The atomic number is reduced by 2 and the atomic mass by 4.

radium-226 → alpha + _____________ + energy

beta decay - a radioactive nucleus that decays by giving off a beta particle loses an electron from the decay of a neutron into a proton, electron, anti-neutrino. The atomic number is thus increased by 1. The atomic mass stays the same.

thorium-234 → beta + _____________ + energy

electron capture - electron capture changes the nucleus by adding an electron from the innermost electron shell. This electron from the electron cloud combines with a proton to form a neutron. The atomic number is reduced by 1. The atomic mass stays the same.

potassium-40 + electron capture → ________________

Nuclear Reactions

The bombardment of an atomic nucleus with neutrons can result in nuclear fission. On common example of nuclear fission is seen when uranium-235 splits in barium-141 and krypton-92.

Uranium-235 can also split into other elements. Other unstable nuclei such as plutonium-239 can split in a variety of ways when struck by a neutron.

Like nuclear fission, nuclear fusion has more than one possibility. In nuclear fusion, two smaller nuclei fuse to form a larger nucleus. For example, in the sun three separate fusion reactions take place. As a result of these reactions smaller hydrogen nuclei are fused into large helium nuclei.

Complete the following fission reactions:

neutron + uranium-235 → barium-141 + krypton-92 + ________neutrons

neutron + uranium-235 → neodymium-152 + ___________ + 4 neutrons

neutron + plutonium-239 → __________ + zirconium-97 + 2 neutrons

Complete the following fusion reactions:

hydrogen-2 + hydrogen-2 → helium-3 + _________

helium-3 + helium-3 → _______ + 2 hydrogen-1

helium-3 + hydrogen-2 → helium-4 + ________

Complete the following decay reactions:

uranium-238 → 8 alpha + 6 beta + ________________

thorium-232 → 6 alpha + _________beta + lead-208

thorium-234 → _______ alpha + 4 beta + radon-218

plutonium-240 + electron capture → ________________

The following is an article on radioactivity in our lives: www.iem-inc.com/preverr.html

Is radioactivity unique?

The earth has always been radioactive. Everyone and everything that has ever lived has been radioactive. In fact, the natural radioactivity in the environment is just about the same today as it was at the beginning of the Neolithic Age, more than 10,000 years ago.

What is radiation?

Radiation is energy in the form of particles or rays given off by atoms as they go from an unstable to a stable state. Some radioactive atoms exist naturally; others are made artificially.

Is there radioactivity in our bodies?

Yes. During our lifetime, our bodies harbor more than 200 billion billion radioactive atoms. About half of the radioactivity in our bodies comes from Potassium-40, a naturally-occurring radioactive form of potassium. Potassium is a vital nutrient and is especially important for the brain and muscles. Most of the rest of our bodies' radioactivity is from Carbon-14 and tritium, a radioactive form of hydrogen.

These naturally-occurring radioactive substances expose our bodies to about 25 "millirem" per year, abbreviated as "mrem/yr".

Is there radioactivity in food and water?

Yes. Most radioactive substances enter our bodies as part of food, water or air. Our bodies use the radioactive as well as the nonradioactive forms of vital nutrients such as iodine and sodium. Radioactivity can be found at every step of the food chain. It is even in our drinking water. In a few areas of the United States, the naturally-occurring radioactivity in the drinking water can result in a dose of more than 1,000 millirem in one year.

Is there radiation in outer space?

Yes. Another type of natural radiation is cosmic radiation from the sun and outer space. Because the earth's atmosphere absorbs some of this radiation, locations at higher altitudes receive a greater exposure than those at lower altitudes. In Ohio, for example, the average resident receives a dose of about 40 millirem in one year from cosmic radiation. In Colorado, it is about 180 millirem in one year. Generally, for each 100-foot increase in altitude, there is an increased dose of one millirem per year.

Flying in an airplane increases our exposure to cosmic radiation. A coast-to-coast round trip gives us a dose of about four millirem.

The rocks and soils around us are radioactive.

In Ohio, radiation in soil and rocks contributes about 60 millirem in one year to our exposure. In Colorado, it is about 105 millirem per year. In Kerala, India, this radioactivity from soil and rocks can be 3,000 millirem per year, and at a beach in Guarapari, Brazil, it is over 5 millirem in a single hour -- but only a few residents who use that beach receive doses in excess of 500 millirem per year.

Is there radioactivity in our homes?

As a matter of fact, there is. If you live in a wood house, the natural radioactivity in the building materials gives you a dose of 30 to 50 millirem per year. In a brick house, it is 50 to 100 millirem per year. And, if your home is so tightly sealed that there is little ventilation, natural radioactive gases (radon) can be trapped for a longer period of time and thus increase your dose.

Is is true that we can't escape from radioactivity?

Yes, its quite true. Each person with whom we spend eight hours a day gives us a dose of about 0.1 millirem in a year.

Using a gas stove can increase the dose by about two millirem per year because of radioactive materials in the natural gas.

A person who smokes two packs of cigarettes a day receives a radiation dose of about 1,300 millrem per year. This is because polonium (a radioactive element) is part of the smoke and when inhaled, it gets trapped in the lungs.

So, **its everywhere, right?** Radiation really is everywhere. We are exposed to a constant stream of radiation from the sun and outer space. Radioactivity is in the ground, the air, the buildings we live in, the food we eat, the water we drink, and the products we use. The average person in the United States receives a dose of about 360 millirem per year from these natural sources of radioactivity as well as from typical medical radiation exposures.

To put these radiation doses into perspective, although theoretically the risk increases with increased exposure to radioactivity, no effects have ever been observed at levels below 5,000 millirem delivered over a one year period. In fact, effects seen when humans are exposed to 100,000 millirem over a short time period are temporary and reversible. It takes a short-term dose of more than 500,000 millirem to cause a fatality.

Is it true that we can't live without it?

Yes, our bodies are radioactive. Its a simple fact of nature. But there is no cause for alarm. These very small but detectable levels of radioactivity are natural . . . as natural as life itself

Added Notes:

Unstable nuclei are called radioisotopes. Radioisotopes may occur naturally or be produced artificially. Some natural radioisotopes are produced by cosmic ray bombardment of atmospheric atoms (carbon-14 and hydrogen-3 (tritium) are formed from nitrogen-14).

Alpha particle emission occurs only in elements of high atomic weight (example: radium-226 to radon 222). Radioisotopes with excess neutrons may decay into a more stable form by the conversion of a neutron into a proton with the concurrent emission of a negative beta particle (example: cobalt-60 to nickel-60). Radioisotopes with excess protons may become more energetically stable by positive beta particle (positron) emission. A nuclear proton is converted into a neutron with the emission of the positron (example: oxygen-15 to nitrogen-15). Gamma radiation, the emission of energetic photons, occurs most often with beta emission, however, some nuclides decay by gamma ray emission alone. (example: iodine-131). One unique decay mode is that of radium-223 which expels a carbon isotope nucleus (carbon-14) and becomes lead-206.

Geiger counter: Gas ionization techniques use the principle of ion pairs formed in a gas-filled ion chamber. the negatively charged ions move to the anode while the positively charged ions move to the cathode. This creates a pulse, which is amplified and recorded.

excellent source of information on the people involved in the development of radioactivity may be found at www.accessexcellence.org/AE/AEC/CC/historical_background.html

Carbon-14 Radioactive Dating

stable nitrogen in atmosphere + cosmic ray particle → electron capture takes place

reaction #1: nitrogen-14 + electron capture --> carbon-14

carbon in atmosphere forms CO_2 13 % is carbon-14 87% is carbon-12

all living things take in CO_2 till death → upon death carbon-14 starts to decay (beta decay) at regular rate to stable nitrogen-14

reaction #2: carbon-14 --> beta particle + nitrogen-14

Half-life:
$t_{1/2}$ = average length of time needed for 1/2 the mass of radioactive sample to decay into a different substance

1 half-life for carbon-14 is 5730 years.

carbon-14 dating technique is useful for organic materials up to 50 000 years old (about 10 half-lives)

technique has been checked by tree rings (chronodendrology) and super novas

technical name for process is neutron induced decay

calculations:

$$\text{amount radioactive remaining} = \frac{\text{original amount}}{2^n} \qquad n = \text{number of half-lives}$$

Problems:

Given 2.40 grams of a radioactive substance, calculate the amount of original radioactive sample remaining and the amount of material decay after 6 half-lives.

Given 400. grams of a radioactive substance, calculate the number of half-lives that would have to pass for only approximately 10 grams to remain radioactive.