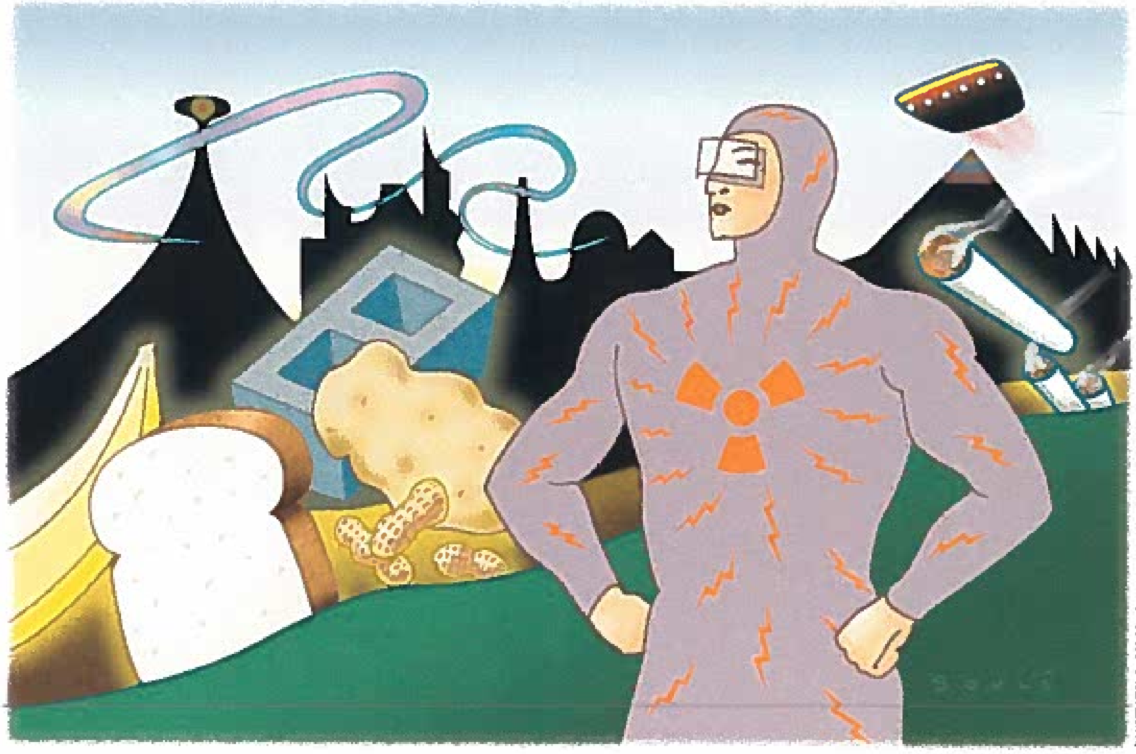


ILLUSTRATION BY BOB SOULE

RADIOACTIVITY
It's a Natural

By Brian Rohrig

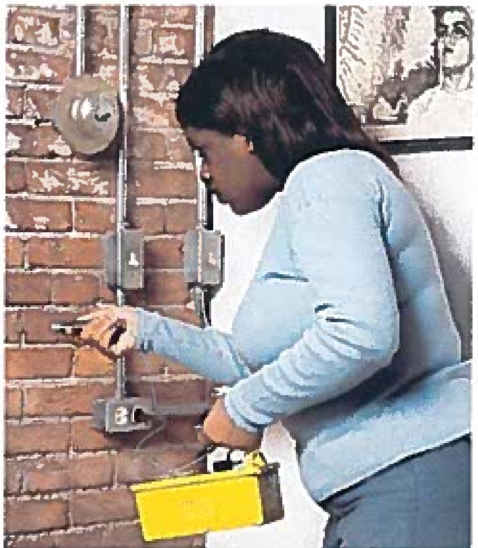
The Amazing Spider-Man got his extraordinary powers from the bite of a radioactive spider; the Incredible Hulk, from an overdose of gamma radiation, whereas Godzilla became "gorilla extraordinaire" after his exposure to radioactive fallout! No wonder we regard radiation with a mixture of awe and fear. But is this attitude justified by the facts?

Let's begin by sorting out the differences between radiation and radioactivity. Radiation is a general term for any type of energy that emanates or radiates outward in all directions. The most familiar form of radiation is the electromagnetic energy that is given off by subatomic particles. The full range of this energy, called the *electromagnetic spectrum* (see "As a Matter of Fact" in this issue of *ChemMatters*), encompasses radio waves, microwaves, infrared rays, visible light, ultraviolet rays, X-rays, and gamma rays. Obviously, not all types of radiation are harmful. Both visible light and infrared light are necessary for life on this earth.

Radioactivity, on the other hand, occurs with the breakdown or decay of certain unstable atomic nuclei. This *nuclear* radiation is dangerous because it has a lot of energy—on the order of millions of electron volts per emitted particle. Because chemical bonds take about 3–4 electron volts to break, this energy is enough to break apart ordinarily stable molecules into smaller, highly reactive fragments—most of which are ions. Thus, nuclear radiation gets the name *ionizing radiation*. These unstable fragments react with other nearby molecules causing further chemical reactions.

It is this ionizing potential of radioactive substances that gives us one means for measuring their activity. A Geiger counter, named after its inventor German physicist Hans Geiger, registers the formation of gaseous ions within the instrument. When formed, the ions conduct electrical current, thus completing a circuit. The result is a series of audible clicks that vary in frequency according to the rate and amount of radioactive decay occurring in the vicinity of the instrument.

Nuclei undergoing radioactive decay release alpha particles, beta particles, and gamma rays. Alpha particles—helium-4 nuclei—are the most massive of the three and have the greatest potential for causing short-range damage. But shielding against alpha emissions is easy. A piece of paper stops an alpha particle dead in its tracks. Beta particles, high-speed electrons, have less impact on living tissue, but have a much greater penetrating ability than alpha particles. To stop a beta particle, a sheet of alu-



PHOTOGRAPHS BY MIKE CIESIELSKI AND FROM ACS STOCK FILE

One source of home radiation is radon—an odorless colorless gas that can build up to dangerous levels in basements.

minum foil or a pane of glass suffices. Finally, gamma rays, without either mass or charge, represent the release of energy from a decaying nucleus. Protecting matter from the penetration of gamma rays requires thick lead shielding (see Figure 1). The release of particles and energy together make up *nuclear radiation.*

Actually, the particles themselves are not dangerous. We fill balloons with helium, electrons are all around us, and gamma rays are not particles at all. What makes radioactivity dangerous is the energy associated with the emissions—enough to ionize molecules in living cells. Some of these ionizations cause immediate destruction of living tissue; others may alter the structure of replicating molecules with future consequences for the organism.

When Henri Becquerel, a French physicist, discovered radioactivity in 1896, he was unaware of its potential for harm. Unfortunately, the rays given off by uranium, while Becquerel was exposing photographic plates, were also penetrating his body. Marie Curie, the first female winner of the Nobel Prize for her discovery of radium and polonium, died from anemia in 1934, after a lifetime of exposure to radioactive substances. Historians estimate that as many as 300 early radiation workers died from causes related to nuclear radiation.

Outside the research community, the world welcomed the newly discovered radioactive substances as entertaining novelties. In the early 20th century, many people were convinced that contact with these mysterious invisible rays offered health benefits, and they enthusiastically bathed in waters containing radioactive salts. Because radium glowed in the dark, it was especially prized. There were claims that radium could cure blindness, skin cancer, and stomach ulcers. Radium mixed with phosphors made the paint for glow-in-the-dark clock and watch dials that were welcomed as practical devices. (See "The Radium Girls—Dialing Up Trouble" in the October 1998 *ChemMatters.*) And high society enjoyed radium-spiked cocktails, while spinning radium-coated roulette wheels, making eerie light patterns in dimly lit casinos.

No single event demonstrated the awesome power contained within the atom more dramatically than the dropping of atomic bombs on the Japanese cities of Hiroshima and Nagasaki in the closing days of World War II. In the wake of this enormous destruction, public attitude toward radioactivity shifted to one of horror, as well as endless fascination. Today, while respected for its potential as an energy source and for its role in a variety of peace-time technologies, radioactivity is widely regarded as something to be avoided—certainly, as something to be kept out of our homes.

Radioactivity at home

You may be surprised to learn that you do not need to visit a nuclear power plant or a hospital X-ray laboratory to find sources of radioactivity. They are all around us. In fact, it is likely that you'll find a few at home. Your front porch may incorporate cinder blocks or granite blocks. Both contain uranium. Walk through the front door, look up, and you'll see a smoke detector that owes its effectiveness to the constant source of alpha particle emissions from Americium-241. As long as the gases remain ionized within the shielded container, electricity

A smoke detector owes its effectiveness to the constant emissions from Americium-241.

Smokers significantly increase their exposure to radioactivity. A person who smokes two packs of cigarettes per day inhales radioactive polonium-210 with a resulting increase in annual exposure to radioactivity 20 times greater than that experienced by a nonsmoker.

that after death, this radioactive carbon continues to decay at a constant rate, scientists can use C-14 as a means of estimating the age of the remains. (See "Carbon-14 Dating" in the February 1989 issue of *ChemMatters*.)

Fortunately, with the exceptions of radon and tobacco smoke, the radioactive substances that surround us pose little or no threat to our health. In fact, the benefits of many of these radioactive substances to our lives far outweigh their risks. In case you want to check your annual exposure, you can estimate your personal radiation dose by using the chart on the right provided by the American Nuclear Society.

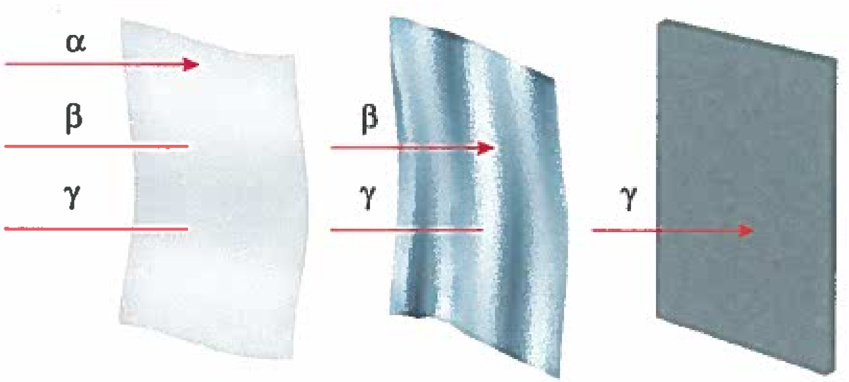


Figure 1. Alpha, beta, and gamma emissions require different kinds of shielding to protect one against exposure.

flows, and all is calm. When smoke enters the chamber, it neutralizes the charges on these ions. In the absence of these conducting ions, the circuit breaks and the alarm goes off (see illustration on previous page.)

Indicator lights on your appliances may use Krypton-85; electric blankets, promethium-147; and fluorescent lights, thorium-229. Even the food we eat is radioactive. Potassium, a mineral essential for good nutrition, is found in many foods. The more potassium-rich the food source, the more potassium-40—a radioactive isotope that makes up about 0.01% of the natural supply of this mineral—is present. Thus, brazil nuts, peanuts, bananas, potatoes, and flour, all rich in potassium, are radiation sources.

Smokers significantly increase their exposures to radioactivity. A person who smokes two packs of cigarettes per day inhales radioactive polonium-210, and as a result, increases his or her annual exposure to radioactivity 20 times greater than that experienced by a nonsmoker.

Even in the back yard, cosmic rays—radiation from outer space—are constantly bombarding the earth's surface. Cosmic rays are composed of either alpha particles or high-energy protons. Most are deflected by the earth's magnetic field, yet many do manage to reach the earth's surface, where they easily penetrate living tissue. Your exposure to these rays increases with altitude and proximity to the earth's magnetic poles.

Probably the most pernicious of all home radiation sources is *radon*. Radon is an odorless, colorless gas that can build up to dangerous levels in the basements of homes. This radioactive gas is a natural by-product of nuclear decay that occurs in certain uranium-containing rocks beneath the earth's surface. Radon gas can seep into your basement through tiny cracks in the walls and floors. Because it is relatively heavy (atomic mass = 222), it tends not to travel upward in the home, but rather to remain in the basement. An inexpensive radon detector that will give you an accurate reading of how much radon is in your home can be purchased at any hardware store.

Believe it or not, even our bodies are radioactive (see Figure 2). Every living thing contains Carbon-14, a radioactive isotope of carbon that comes from inhaling carbon dioxide from the atmosphere and from ingesting foods containing this substance. Given the facts that an organism contains a predictable level of C-14 at the time of death, and

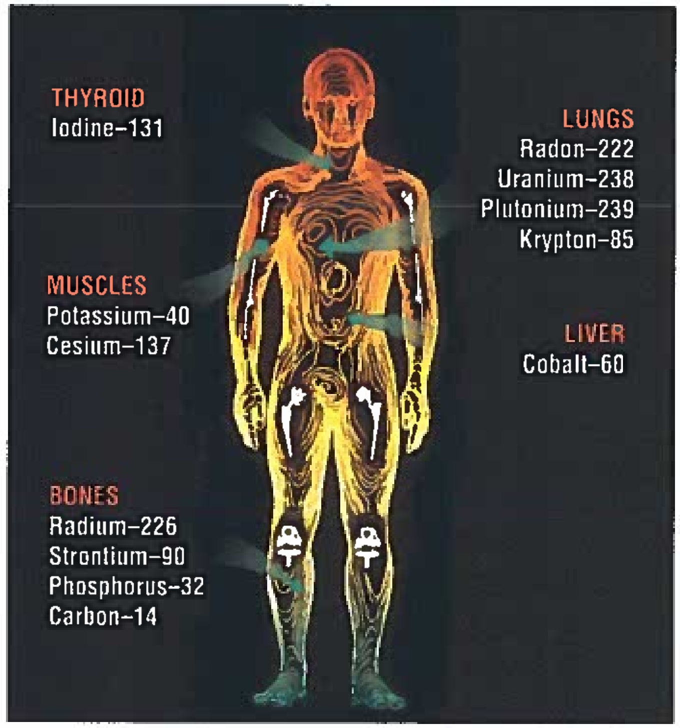


Figure 2. All living things contain some radioactive isotopes, including these found in humans.

Brian Rohrig is a chemistry teacher at Aurora High School in Aurora, OH. His most recent article, "Mt. Everest—Climbing in Thin Air" appeared in the December 1999 issue of *ChemMatters*.

REFERENCES

Badash, L. *Radioactivity in America: Growth and Decay of a Science*; Johns Hopkins University Press: Baltimore, 1979.

Bettis, C.; Throckmorton, C. What Teachers Should Know About Radon. *The Physics Teacher* **1991,** *29* (6) pp 338–343.

Couch, J. G. and Vaughn, K. L. Radioactive Consumer Products in the Classroom. *The Physics Teacher* **1995,** *33* (1) pp 18–22.

Draganic, I. G.; Draganic, Z. D.; Adloff, J. *Radiation and Radioactivity on Earth and Beyond;* CRC Press: Boca Raton, FL, 1990.

Estimate Your Personal Radiation Dose

Radiation is measured in terms of millirems (mrems). The average annual dose per person from all sources is about 360 mrems per year, but it is not uncommon for any of us to receive far more than that in a given year (largely due to medical procedures we may have had done). International standards allow up to 5000 mrems per year exposure for those who work with and around radioactive material.

Factors	Common sources of radiation	Your annual dose (mrems)
Where you live	**Cosmic radiation** (from outer space) Exposure depends on your elevation. Amounts are in millirems per year. At sea level ....26 mrem; 0–1000 ft ....28; 1000–2000 ....31; 2000–3000 .... 35; 3000–4000 ....41; 4000–5000 ft ....47 mrem; 5000–6000 ....52; 6000–7000 ....66; 7000–8000 ....79; 8000–9000 96	_____ mrem
	Terrestrial (from the ground) If you live in a state that borders the Gulf or Atlantic coasts, add 16 mrem. If you live in the Colorado Plateau (around Denver), add 63 mrem. If you live anywhere else in the continental United States, add 30 mrem.	_____ mrem
	House construction If you live in a stone, adobe, brick or concrete building, add 7 mrem.	_____ mrem
	Power plants If you live within 50 miles of a nuclear power plant, add 0.009 mrem. If you live within 50 miles of a coal-fired power plant, add 0.03 mrem.	_____ mrem
Food, Water, Air	**Internal radiation** (based on average values) From food (Carbon-14 and Potassium-40) and from water (radon dissolved in water)	40 mrem
	From air (radon)	200 mrem
How you live	Weapons test fallout (less than 1) — 1 mrem	1 mrem
	Travel by jet plane — 0.5 mrem per hour in the air	_____ mrem
	If you have porcelain crowns or false teeth — 0.07 mrem	_____ mrem
	If you wear a luminous wristwatch — 0.06 mrem	_____ mrem
	If you go through security inspection at airport (each time) — 0.002 mrem	_____ mrem
	If you watch TV — 1 mrem	_____ mrem
	If you use a video display (computer screen) — 1 mrem	_____ mrem
	If you have a smoke detector — 0.008 mrem	_____ mrem
	If you use a gas camping lantern — 0.2 mrem	_____ mrem
	If you wear a plutonium-powered pacemaker — 100 mrem	_____ mrem
Medical Tests	**Medical diagnostic tests** *Number of millirems per procedure* X-Rays: Extremity (arm, hand, foot, or leg) ......1 Dental ......1 Chest ......6 Pelvis/hip ......65 Skull/neck ......20 Barium enema ......405 Upper GI ......245 CAT Scan (head and body) ....110 Nuclear Medicine (e.g., thyroid scan) 14	_____ mrem
	Your Estimated Annual Radiation Dose	_____ mrem