# Radiation and the cookie test*

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When I think of scientific scare words, the first one that always comes to mind is radiation. Although, when radiation and the radioactive processes that generate it were first discovered, there was actually a lot of public excitement about it, and many radioactive products were sold to give people the vital health force of radiation! But the development of nuclear weapons and greater understanding of the dangers of radiation, plus the lengthy Cold War and accidents at nuclear power facilities, have led many people to fear radiation without necessarily even understanding what it is or how it interacts with matter. But the best way to deal with a hazard is to know how it works!

There are lots of physical phenomena classified as radiation; the term itself just implies some form of energy which is radiating out from a source. Energy is carried by waves moving through a medium, and the waves can be subdivided into quanta or packets of energy, which is to say particles.

Visible light is one of the more familiar forms of electromagnetic radiation. Photons carry electromagnetic energy through space, and since our eyes are equipped to detect that energy at certain frequencies, we perceive it as light. Electromagnetic radiation can occur at many frequencies that the eye cannot detect, but visible light is actually fairly low-energy, and is called ǹon-ionizing' radiation because it's incapable of separating atoms into ions (positively charged nuclei and negatively charged electrons). Ultraviolet light can cause some damage to tissue, as a sunburn, but this damage comes from the heating of the tissue that occurs rather than ionization. UV light can also damage DNA, which affects the ability of any cell to reproduce itself without errors. UV light damages DNA both directly, by breaking bonds, and indirectly, by generating free radicals that chemically alter the DNA. But it takes a lot of UV exposure for the organism possessing the DNA to notice any effect.

Ionizing radiation, however, is much better at removing electrons from atoms, and can damage DNA at a much lower dose than UV light. How

*text taken from `https://letstalkaboutscience.wordpress.com/2013/03/15/radiation-and-the-cookie-test/`, posted on March 15, 2013 by Jessamyn Fairfield.

harmful any specific dose of ionizing radiation will be to an organism depends on the energy and amount of the radiation, as well as the sensitivity of the tissue exposed. And there are certain forms of matter, types of nuclei, which are r̀adioactive': this means that they emit ionizing radiation, usually during a decay from one configuration of nuclei to another.

So what kinds of radiation can ionize atoms? Well, although low-energy light is non-ionizing, very high-energy light with wavelengths below 200 nm is considered ionizing. This includes X-rays, which are widely used for medical imaging, and gamma rays, which are produced by reactions that occur in atomic nuclei. Gamma rays can penetrate very deeply into most materials and require a lot of shielding to stop.

Energetic charged particles interacting with an atom can also cause ionization, by attracting or exciting electrons from the electron cloud. This can be done by high-energy electrons, which are emitted during b̀eta decay' when a neutron decays into a proton. And other atomic decays can emit energetic alpha particles, which consist of two protons and two neutrons (the same as the nucleus of helium). While both alpha and beta particles are ionizing, both are easily absorbed by a small amount of shielding. However, if you think about the relatively high mass of protons and neutrons in the alpha particle compared to the very low mass electron in the beta particle, you'll realize that the alpha particle has much more energy and destructive capability than the beta particle. So alpha radiation is very harmful if a radiation source is placed close to tissue.

Neutrons on their own can also ionize atoms, by causing reactions in the nuclei. High-energy neutrons can travel through very thick shielding, because they have no charge and don't feel electromagnetic forces from the charges in matter. However, they combine easily with hydrogen to create heavy forms of it (isotopes), so any hydrogen-rich material makes a reasonably good neutron shield. This is why large amounts of water are used for shielding in nuclear reactors, because of the large amount of neutron radiation emitted. As shown in the image below, while neutrons ($\nu$) are absorbed by nuclei, gamma rays ($\gamma$) can only be stopped in dense materials, beta particles ($\beta$) can be stopped by an aluminum plate, and alpha particles ($\alpha$) can be stopped by a sheet of paper.

**The cookie test**

Imagine that you have four cookies. One is an alpha emitter, one is a beta emitter, one is a gamma emitter, and one is a neutron emitter. You can throw one cookie away, but you have to put one in your pocket, hold one in your hand, and eat one. How do you pick which cookies to do what with?