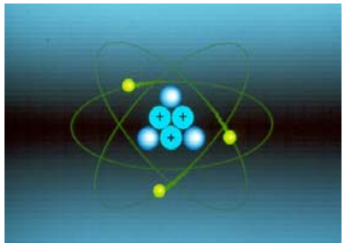
International Atomic Energy Agency and
World Health Organization

BASICS OF RADIATION AND RADIATION PROTECTION

Radiation is a fact of life: all around us, all the time. We live in a naturally radioactive world. But how much do physicians, nurses and medical technicians who may have to respond in a radiation emergency know about what radiation is, what it does and how to protect against it? This leaflet is directed at medical personnel and outlines basic concepts of radiation and radiation protection.

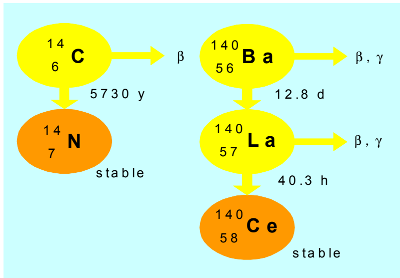
Atoms and Elements

All matter consists of atoms. Nearly all of an atom's mass is concentrated in the nucleus, which consists of positively charged protons and electrically neutral neutrons. Negatively charged particles called electrons orbit the nucleus. Atoms have equal numbers of protons and electrons and are electrically neutral. The total number of protons and neutrons is called the mass number. Since the number of protons is unique to each element, the element together with the mass number specify each nuclide. The nuclides of an element — atoms with the same number of protons but different numbers of neutrons — form what are called isotopes of that element. There may be several isotopes of an element. Hydrogen, for instance, has three isotopes: hydrogen-1 (common hydrogen), hydrogen-2 (deuterium) and hydrogen-3 (tritium).



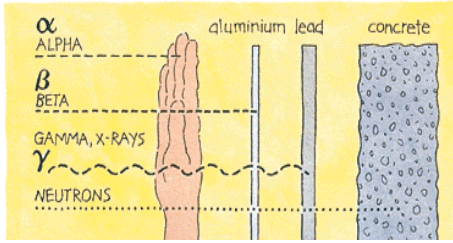
Radioactivity and Radiation

Although many nuclides are stable, most are not. Stability is determined mainly by the balance between the number of neutrons and the number of protons a nucleus contains. An unstable nucleus has excess energy and will spontaneously disintegrate at random by emitting radiation. Different nuclei release their energy in different ways, in the form of electromagnetic waves — gamma or X rays — and/or streams of particles, i.e. beta or alpha particles. This spontaneous disintegration of nuclei is called radio-activity and the excess energy emitted is a form of ionizing radiation. The process of disintegration is termed radioactive decay and the unstable nuclide which disintegrates and emits radiation is called a radionuclide. All radionuclides are uniquely identified by the type of radiation they emit, the energy of the radiation, and the half-life. The activity — used as a measure of the amount of a radionuclide present — is expressed in a unit called the becquerel (Bq): one becquerel is one disintegration per second. The half-life is the time required for the activity of a radionuclide to decrease to half of its value by decay. Half-lives for radionuclides range from tiny fractions of a second to millions of years.



Types of Radiation

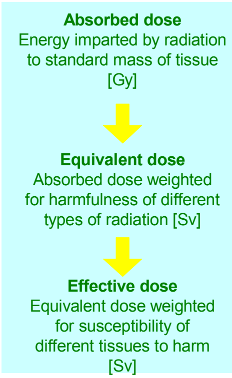
Alpha radiation consists of positively charged particles comprising two protons and two neutrons, which are emitted by radionuclides of heavy elements such as uranium, radium, radon and plutonium. Alpha radiation travels only a few centimetres in air and is blocked by a sheet of paper. Alpha radiation is not able to penetrate skin. If an alpha emitting substance is taken into the body, it will release all its energy to the surrounding cells. Alpha-emitters can be harmful to humans if the materials are inhaled, swallowed or absorbed through open wounds. *Beta radiation* consists of electrons, which are much smaller than alpha particles and are able to penetrate deeper. It can be stopped by a sheet of metal or glass or by ordinary clothing. Beta radiation can penetrate human skin to the 'germinal layer', where new skin cells are produced. If beta emitters remain on the skin for a long period of time, they may cause skin injuries. *Gamma radiation* is electromagnetic wave energy. Its range in air is long and its penetrating power substantial. Dense materials such as lead and concrete are good barriers against gamma rays. *X ray radiation* is similar to gamma radiation but is usually produced artificially by bombarding a metal target with electrons in a vacuum (in an X ray tube). Dense materials such as lead stop X rays. *Neutron radiation* consists of neutrons and is not in itself ionizing radiation. However, if a neutron hits a nucleus, it may activate it or cause the emission of a



gamma ray or charged particle, indirectly giving rise to ionizing radiation. Neutrons are more penetrating than gamma rays and can be stopped only by a thick barrier of, for example, concrete, water or paraffin.

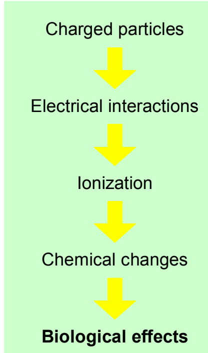
Radiation Dose

Radiation damage to tissue depends on the absorption of energy from the radiation or on the dose of radiation received, called the absorbed dose. Absorbed dose is expressed in a unit called the gray (Gy). The damage producing potential of a given absorbed dose depends on the type of radiation. An absorbed dose from alpha particles, for example, is more harmful than the same dose from beta radiation. To put all ionizing radiation on common ground with regard to potential for causing harm, a radiation weighted dose called the equivalent dose is introduced. The unit is the sievert (Sv). The equivalent dose is equal to the absorbed dose multiplied by a radiation weighting factor. For gamma rays, X rays and beta particles, the factor is set to 1. For alpha particles the factor is 20. In addition, the risk of harm is not the same for the various tissues in the body. For example, it is lower for the bone surfaces than for the tissue of the breast. This can be taken into account by taking the equivalent dose in each of the major organs and tissues of the body and weighting it by a factor related to the risk of harm for that organ or tissue, called the tissue weighting factor. The sum of the weighted equivalent doses is called the effective dose. The effective dose gives a broad indication of the detriment to health.



Radiation and Living Tissue

When radiation passes through matter it deposits some of its energy in the absorbing material by ionization or excitation of the atoms. It is ionization of atoms in tissue, accompanied by chemical changes, that causes the harmful biological effects of radiation. For instance, when ionizing radiation passes through cellular tissue, it produces charged water molecules. These break up into free radicals, which are highly reactive chemically and can alter important molecules such as deoxyribonucleic acid (DNA) in cells. Radiation can also ionize DNA molecules directly. These effects of ionization can lead to biological effects, including cell death and abnormal cell development.



Radiation Effects

There are two main types of radiation health effects. Deterministic effects occur only if the dose or dose rate (i.e. the dose per unit time) is greater than some threshold value. The effects occur early and are more severe for higher doses and dose rates. Examples are acute radiation syndrome, skin burn and sterility. If the dose is low or delivered over a longer period of time, there is a greater opportunity for the body’s damaged cells to repair themselves; however, harmful effects may still occur. Effects of this type, called stochastic, are not certain to occur, but their likelihood increases for higher doses, whereas the timing and severity of an effect do not depend on the dose. Examples are cancers of various types.

Radiation Exposure and Radiation Protection

Exposure of a person may be external or internal and may be incurred by various exposure pathways. *External exposure* may be due to direct irradiation from a sealed source or due to contamination, i.e. airborne radionuclides or radionuclides deposited onto the ground or onto clothing and skin. *Internal exposure* may result from the inhalation of radioactive material in air, the ingestion of contaminated food or water, or contamination of an open wound. Effective protection from external exposure is provided by: 1) limiting the time spent near the source of radiation; 2) moving away from the source of radiation; and 3) shielding from the source, the effect of which depends on the type of radiation emitted and the nature of the shielding material used. In contaminated areas, protective clothing helps to prevent external body contamination and appropriate respiratory protection helps to prevent internal contamination. Eating, drinking and smoking should be forbidden in contaminated areas.

In a Radiation Emergency

Any physician may have to take care of victims of radiation exposure. A patient who has been exposed only to an external source of radiation and is not contaminated poses no radiation hazard to others and no precautions are needed. If the patient is contaminated internally, precautions are needed when dealing with excreta, but he/she does not represent a direct hazard to others unless the intake was extremely large and involved gamma emitters. If the patient is externally contaminated, proper procedures (e.g. wearing vinyl gloves and mask, covering the patient with a blanket or sheet, washing hands and keeping them away from the mouth) help to prevent the spread of contamination and inadvertent ingestion by physicians, nurses or others.