Appendix 1 Introduction to radiation

Most of the radioactive materials used in the laboratory are produced in a nuclear reactor. Elementary particles are usually injected into a stable nucleus changing it from a stable neutron/proton ratio to an unstable one. Sooner or later one or more radioactive decays occur enabling the nucleus to regain its stability. In the process the chemical nature of the element often changes.

Many materials in nature are radioactive. This naturally occurring radioactive material is present in rocks and soil, in building materials and in our own bodies. As a result of this and of natural background radiation we all receive a radiation dose of about 2.2 mSv (220 millirems) each year, which is about 11% of the maximum allowed for radiation workers.

It is known that more harm results from high doses when the dose is delivered in a short time, but at the low doses encountered in well controlled work with radioactive substances and radiation sources the effect of dose rate is less clear. The maximum permissible doses relate to those received over an extended period.

Two distinct types of radiation hazards can be identified when working with unsealed radioisotopes, these are external and internal hazards, the former is caused by the worker being exposed to ionising radiation through being in the close proximity of a source or by the contamination of skin and eye while the latter occurs through the ingestion of radioactive material.

The external radiation hazard is restricted to the more energetic radioactive emissions such as from ^{32}P or ^{125}I, the use of the personal dosimeter is to detect the level of external radiation that a person has been exposed to.

All radioisotopes can constitute an internal radiation hazard, even weak emitters such as ^{3}H can cause significant cellular damage when ingested by a person.

Alpha particles are particularly dangerous in cells because they are highly ionising and cause the formation of reactive chemicals within the cells that can damage DNA; this is one of the reasons that α-emitting radioisotopes are particularly toxic.

Personal dosimeters do not give an accurate estimate of the internal radiation hazard to which the worker has been exposed and instead it is necessary to use biological monitoring procedures by, for example measuring radioactivity in urine samples after the incident.

The radiations emitted in radioactive decay are of several different types. The most important are:

1.1 Alpha Decay (α)

In the case of some of the elements heavier than lead, some of the nuclei are unstable and they attain stability not by losing electrons but by ejecting from the nucleus a positively charged particle consisting of two protons and two neutrons, equivalent to the mass and composition of the nucleus of a helium atom, and these are termed α particles.

α particles are generally slow moving and highly ionising and can cause extensive damage inside cells. As a rule they are not very energetic and hence they are not a significant external hazard and cannot pass through the dead layer of skin, even thin card is able to absorb all **α** particle radiation.

1.2 Beta Decay (β)

Some nuclei contain too many neutrons. This situation is usually rectified by the conversion of a neutron to a proton. In the process an electron, now termed a β-particle, leaves the nucleus at almost the speed of light. Each β-particle may have any energy from zero to the maximum transition energy with an average energy of about one third of this value.

β-particles interact strongly with matter. By 'knocking' electrons from nearby atoms each leaves a relatively high density of ionised molecules along its track. The net effect of the resulting radiation damage depends on the nature of the absorbing material.

The range of **β**-radiation depends on the source and the absorbing medium. Tritium β -radiation has a range of about 0.007 mm in tissue and 7 mm in air, while ^{32}P **β**-radiation can penetrate 0.8 cm of tissue and 7 metres of air. For this reason **β** -radiation doses from external sources are seldom whole body doses. For ^{32}P radiation 1 cm of Perspex or 2 mm of aluminium is usually used as a shield.

Auger electrons produced in the decay of isotopes such as ^{125}I are the result of an energy transfer from an X-ray to an orbital electron in the daughter element. The spectra of Auger electrons are quantized but in all other respects they can be regarded as **β** -particles.

1.3 Gamma Rays (γ)

After a radioactive decay the nucleus may regain a stable configuration but still be left with excess energy. This is usually relieved almost instantly by the emission of a γ-ray. These γ-rays are high energy electromagnetic waves which have quantized energies and travel in straight lines.

γ-Rays interact only weakly with matter. When an interaction does occur energy is transferred to an electron. The path of a γ-ray is thus marked by occasional short ionisation paths caused by the electrons. However, the overall ionisation density is low.

Each γ-ray can suffer one of a number of fates, some are absorbed completely and some partly absorbed and scattered in a new direction.

High energy γ-rays have considerable penetrating power even in heavy materials such as lead. It is not always possible to obtain 100% shielding under laboratory conditions. γ-Rays from ^{125}I can travel an average of 3.3 cm through tissue before interaction. Those from ^{59}Fe or ^{86}Rb travel an average of 16 cm.

1.4 X-rays and Bremsstrahlung Radiation

If the orbital electrons of an atom are excited in radioactive decay or in an X-ray set, X-rays are emitted. These are identical to γ-rays, but usually of lower energy. Typical dose rates from X-ray generators can be very high indeed. Any high tension equipment can produce X-rays, for example low intensity X-rays are produced in electron microscopes.

Bremsstrahlung radiation is similar in nature to X-rays and is produced when α and β particles are stopped in an absorber such as glass. The intensity produced increases as the shielding material becomes more dense, but represents only a small fraction of the unshielded dose rate. The Bremsstrahlung dose is most easily reduced by approximately 2 mm of lead fixed to the outside of a Perspex shield.

1.5 Neutrons

This is a neutral elementary particle of mass number 1 present in all nuclei except hydrogen. As it is an uncharged particle it produces no primary ionisation as it passes through matter. It interacts with matter though mainly through collisions but some magnetic interactions may also occur. Special types of dosimeters and shielding are required for neutron sources. Neutron sources are rarely used within the University and so work with them will require special permission.