RADIATION USES AND EFFECTS

INTERACTION OF RADIATION WITH MATTER

When an α or β or γ particle enter a piece matter, energy is transferred to the matter through the collisions with the material in the matter.
These interactions lead to ejection of electrons from the atoms and produce ions in the material.

- α + matter .... produces a straight line leaving high density of ions along its path

- β + matter ....produces ionization density less than in the case of an α , it suffers frequent deflections and therefore proceeds along erratic path , these resulting ions can themselves produce further ionization.

- γ Interact by photoelectric effect in which γ is completely absorbed and the energetic electron is ejected from the atom or it can be deflected by and atomic electron transferring to the electron some of its energy.

Alpha particles and other nuclei

α and nucleus of a helium atom are the same, will produce exactly the same effects. Therefore exactly the same effects will be produced by a 5 MeV α particle from a radioactive substance as by helium nucleus that has acquired energy of 5MeVin some accelerator. Depending on the application, one source may be convenient than the other. Radioactive α sources emit particles at a rate that decreases slowly with time, require no maintenance and are portable.
A beam of helium nuclei from the accelerator can be made more intense than the radioactive source, particles will emerge all in the same direction and the beam can be turned of when it is no longer in use.

Accelerators can be used to produce other energetic particles e.g. protons, deuterium nuclei and carbon nuclei which are not emitted by radioactive decays.

Beta particle and the electrons

Negatively charged β particles emitted in radioactive decay are identical to ordinary atomic electrons. A device that produces electron beam can be substituted for a β source in radiation application.

Gamma rays and x rays

Gamma rays ~ high electromagnetic
~ Identical to the x-rays, light, photon, radio waves except for energy
∴ Classification of a quantum as X-ray or γ ray depends on its origin not its energy
E.g. origin from a nucleus → γ ray
Origin from an atomic electron shell → x ray

This x-ray and γ can be emitted from the same atom and the radiation would be exactly the same

Neutrons

Can be produced in nuclear reactions initiated by high-energy particles in accelerator beams e.g.

$^{7}Li + H \longrightarrow {}^{7}Be + n$

When a neutron strikes a piece of matter it does not produce ionization or interact with the atomic electrons instead with nuclei.
This reaction may result in transfer of energy from the neutron to the nucleus.
The capture of the neutron by the nucleus often results in the formation of a radioisotope.

Supplies of radioisotopes

~ Few from natural minerals
~ Produced in reactions

Chemical reactions induced by radiation

Ex.: CH_4 is irradiated with electrons that have energy of a few KeV Electrons produce ionization in the gas and we expect to find the molecular ions, CH_4^+ which are present in the sample during irradiation. A molecule is bound together by electrons and if a disruptive collision occurs, the molecule can easily be broken apart to produce fragments like Ch_3^+, CH_2^+, which are chemically active and can combine with methane molecules in reactions. By irradiating CH_4, with electrons, molecules are formed that have the structures more complex than the original gas molecule.

Polymerization by irradiation

~ Radiation curing of paint speeds up the processing time as well as better adhesion to underlying surface
~ Production of wood plastic composites by radiation methods
~ Electron irradiation is used to fix various chemicals onto cotton fibres

Sterilization of medical supplies.

~ Sterilization of medical sutures by radiation methods energy absorbed in the irradiation raises temperature of the no more than 10^0c while conventional thermal sterilization would require 15 minutes treatment at 120^0c

Food preservation

Radiation treatment prolongs shelf lives of many types of food but it affects the odor, texture and the color of the food.

Gauging and control

Radiation methods involving radio- isotopes are used for gauging the thickness or the density of items in the production line, e.g. control of

capsule filling by radiation gauging allows for exercise of precise quality control over every item on the production line.

Radiography

X ray technologies are often used to check whether there are any voids or fissures in the casting of valves to be used in a high pressure system. This case uses the same technique used by dentists in taking the X-ray of a tooth. Similar radiographic techniques employing radioisotopes are also used to inspect welded joints ship parts and jet engines

Activation analysis

Identifying the constituents of a sample....

~ Stable isotopes when bombarded with neutrons capture a neutron and are converted to radioactive isotopes that undergo β decay e.g.

$^{30}Si + n \longrightarrow {}^{31}Si$

$^{31}Si \xrightarrow{\beta \text{ decay}} {}^{31}P$

The β decay of ^{31}Si to ^{31}P produces a γ with an energy of 1,27 MeV. This energy and the half- life of 2.6h are unique decay of ^{31}Si

∴ If a sample of material with neutrons and find a radioactivity that produces 1.27MeV of ray and decreases intensity according to half life of 1.26h we conclude that the radioactivity id due to ^{31}Si and that ^{30}Si is present in the sample.

The advantages of activation analysis is that, the activation is not destructive, the sample needs to be changed by chemical reactions and the sensitivity for some elements is enormously greater than is possible with chemical analysis.

Biological effects of radiation.

High energy X-rays can penetrate our bodies and damage internal organs. The unit of absorbed dose (rad) refers to the energy absorbed per kg e.g. 100kg man who receives a whole body dose of 1 rad is much greater than if he receives 1 rad dose only on his arm

Radiation quality

An individual who receives a whole body dose of 1 rad due to high-speed α particles suffers more tissue damage than if he received the same dose of 200KeV X-rays.
α Particles have greater quality radiation than low energy X-rays
200KeV X-rays have a QF of 1 compared to QF of α particles with a QF of 20

References
Physics in the modern world (second edition): J.B. Marion
Physics (third edition): Cutnell / Johnson