Chap 31

31-4 Passage of Radiation Through Matter; Biological Damage

Radiation includes α, β, γ and X-ray, as well as protons, neutron and pions which is an elementary particle consists of quark and antiquark which is a kind of meson.

- Radiation produces ionization, so it can cause considerable damage to the materials, particularly to biological tissue.
- Charged particles, such as α, β rays and protons can cause ionization because of electric forces. They can atract or repel electrons strongly to remove them from atoms of the material through which the radiation pass

- Since α and β rays have energies of the order 1 MeV, so that a single α or β particle can cause thousands of ionizations.
- Neutral particles such as X-ray and γ-ray can cause ionization by knocking out electrons by means of photoelectric effect and Compton effect from the material they pass through
- Neutrons can produce ionization by collisions with the nuclei of the material they pass through
- Radiation passing through matter can do considerable damage

Biological Damage

The radiation damage produced in biological organisms is primarily due to the ionization produced in cells. These ions are highly chemically reactive that interfere with the normal operation of the cell.

- If the electrons knocked up by radiation are bonding electrons, the molecule may break apart or its structure may be altered so that it does not perform its normal function or may perform a harmful function. So if the radiation doses are high the cell die.

- Damage to DNA is more serious, since each alteration in the DNA can affect a gene and alter the molecule that gene codes for, so that needed proteins or other molecules may not be made at all, therefore the cell will die. On the other hand the cell may survive but be defective. It may go on dividing and produce many more defective cells, to detriment of the whole organism, so radiation can cause cancer

31-5 Measurement of Radiation – Dosimetry

Although ionization radiations are harmful to the human body, it can also be used to treat some certain diseases, particularly cancer.

It is therefore important to be able to quantify the amount of radiation (dose). This is the subject of dosimetry.

- The strength of the source of radiation can be specified by its source activity which is how many nuclear decay occur per second.

The traditional unit is the curie (Ci), defined as

$$1\ Ci = 3.7\times10^{10}\ \text{decays per second.}$$

The SI unit for source activity is the becquerel (Bq), defined as

$$1\ Bq = 1\ \text{decay/s}$$

- Because the activity decreases over time, it's important to take this decrease into account.

The magnitude of the source activity, $\frac{\Delta N}{\Delta t}$, is related to the number of radioactive nuclei present, N, and to the half-life, $T_{1/2}$, by

$$\frac{\Delta N}{\Delta t} = \lambda N = \frac{0.693}{T_{1/2}} N$$

Example 31-10 Radioactivity taken up by cells

In an experiment, 0.016 μCi of phosphorous $^{32}_{15}P$ is injected into a medium containing a cluture of bacteria. After one hour, the cells are washed and 70% efficient detector (Counts 70% of emitted β rays) records 720 Counts per minute from the Cells. What percentage of the original $^{32}_{15}P$ was taken up by the cells?

the half-life of $^{32}_{15}P$ is 14 days

Solution

The total number of decay per second originally is

$0.016\,\mu Ci = (0.016 \times 10^{-6}\ Ci)\left(3.7 \times 10^{10}\ \frac{\text{decays per second}}{1\,Ci}\right)$

$= 590.$

The number of decay per second counted by the counter is 70% that is $= 590 \times \frac{70}{100} = 413$ decays per second.

But the counter has counted 720/min

$\frac{720}{min} \cdot \frac{min}{60s} = 12$ decays/second.

then the percentage of decays counted to the total decays is $= \frac{12}{(413)} = 0.029 \times 100\%$

$= 2.9\%$ was incorporated into the cells

Another type of measurement is the exposure or absorbed dose which is the effect of radiation on the absorbing material.

- The earliest unit of dosage was roentgen (R)

$1R = 1.6 \times 10^{12}$ ion pairs per gram of dry air at a standard conditions also, the new definition

[1R is defined as the amount of X-ray or γ-ray that deposits 0.878×10^{-2} J/kg] Energy of air

The most applicable unit of dose is the rad

1 rad: is the amount of radiation which deposits energy per unit mass of 1×10^{-2} J/kg in any absorbing material

1 roentgen $\simeq$ 1 rad

The proper SI unit for absorbed dose is the gray

1 gray (Gy) = 1 J/kg = 100 rad

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- The absorbed dose depends not only on the energy per particle and on the strength of the source of radiation (number of particles per second), but also on the type of the absorbing material.

for example, Bone absorbs more X-ray or γ ray more than flesh. So the same radiation beam passing through a human body deposits a greater does (in rads or grays) in bone than in flesh.

- The gray and rad are not the most meaningful units for measuring the biological damage by radiation because equal doses of different types of radiation cause different amounts of damage. For example 1 rad of α radiation does 10 to 20 times the amount of damage as 1 rad of β or γ rays because heavy particles (α, proton, neutron) move much more slowly than β and γ rays of equal energ due to their greater mass. Hence ionizing Collisions occur more and this causes more damage.

- The relative biological effectiveness (RBE) of a given type of radiation is defined as the number of rads of X-ray or γ radiation that produces the same biological damage as 1 rad of the given radiation. For example, 1 rad of Slow neutrons does the same damage as 5 rads of X-rays. (Table 31.1 in the book).

- The effective dose Can be given as the product of the dose in rads and the RBE.

effective dose (in rem) = dose (in rad) × RBE (31-10a)

where the unit of effective dose (rem) (which stands for rad equivalent man).

31-10

- The SI unit for "effective dose" is the sievert (Sv)

effective dose (Sv) = dose (Gy) × RBE (31-10b)

so

1 Sv = 100 rem or 1 rem = 10 mSv.

- By these definitions, 1 rem (or 1 Sv) of any type of radiation does approximately the same amount of damage. For example 50 rem of fast neutrons does the same damage as 50 rem of γ rays. But note that 50 rem of fast neutrons is only 5 rads, whereas 50 rem of γ rays is 50 rads.

- The average dose received per person per year in the USA is about 360 mrem.

- There is no safe level or threshold of radiation exposure. The upper limit for people who work around radiation (hospitals, power plants and in research) about 50 mSv (5 rem) per one year.

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31-6 Radiation Therapy

The medical application of radiation to human beings involves two basic aspects

1) Radiation therapy . the treatment of disease (mainly Cancer)

2) The diagnosis of disease .

- Radiation can cause Cancer, but also can be used to treat it. To minimize the destruction of normal cells, A narrow beam of γ or x-rays is often used When a cancerous tumor is well localized. The beam is directed at the tumor; and the source (or body) is rotated so that the beam passes through various parts of the body to keep the dose low as possible, except at the tumor and it near surroundings

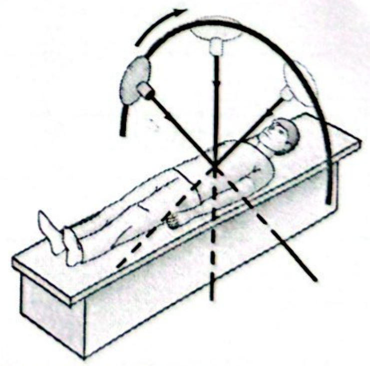


FIGURE 31–17 Radiation source rotates so that the beam always passes through the diseased tissue, but minimizes the dose in the rest of the body.

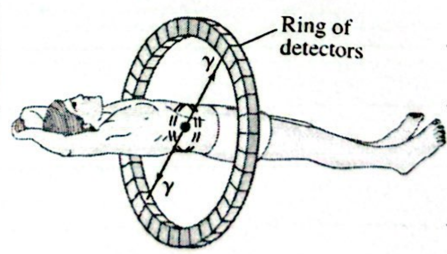
31-8 Emission Tomography: PET and SPECT

Tomography is a series of detailed pictures of areas inside the body. The pictures are created by a computer linked to an X-ray machine.

There are two techniques to get tomography images

1) Single photon emission computed tomography (SPECT) or simply (SPET) (single photon emission tomography).

2) positron emission tomography (PET)



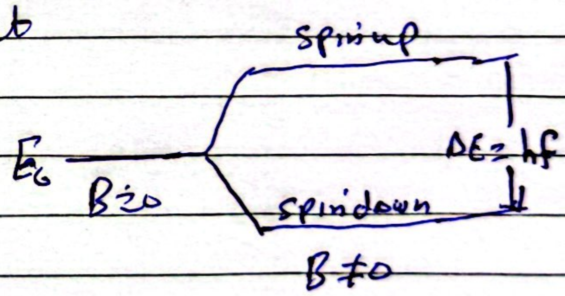
90%

FIGURE 31–21 Positron emission tomography (PET) system showing a ring of detectors to detect the two annihilation γ rays ($e^+ + e^- \rightarrow 2\gamma$) emitted at 180° to each other.

31-9 Nuclear Magnetic Resonance (NMR) and Magnetic Resonance Imaging (MRI)

In a standard nuclear magnetic resonance (NMR) setup, the sample to be examined is placed in a static magnetic field (few Tesla). A radio frequency (RF) pulse of electromagnetic radiation (photons) is applied to the sample. If RF is the same as the energy difference between the two energy levels so that

$$\Delta E = hf = (RF)h = kB_T$$



then the photons of the RF beam will be absorbed, exciting many nuclei from the lower state to the upper state

Magnetic Resonance Imaging (MRI)

(MRI) is anon-invasive imaging technique that produces three dimensional detailed anatomical images It is oftenused for disease detection, diagnosis and treatment monitoring

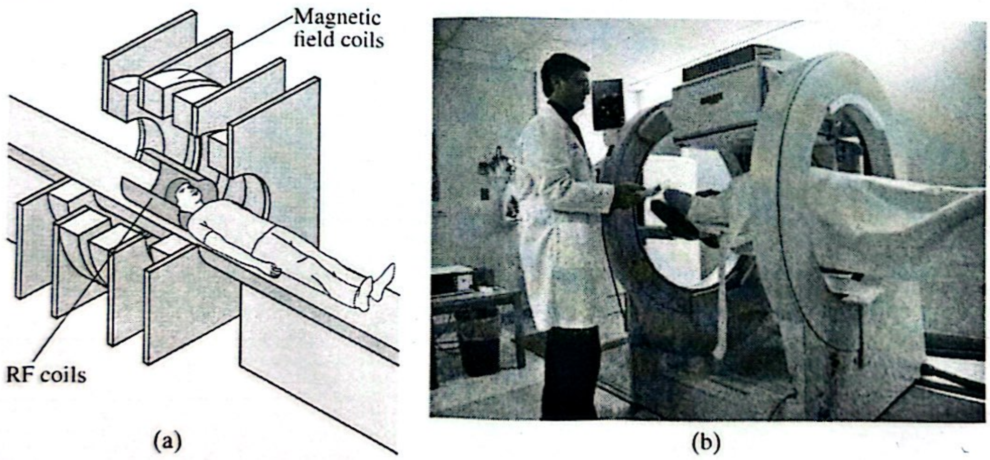


FIGURE 31–25 NMR imaging setup: (a) diagram; (b) photograph.