Physics with Synno – Radiation-Health – Lesson 2

NM.4 Radiation Dose

The effects of radiation on the human body depends on the amount of radiation that the body is exposed to and the type of radiation.
The energy absorbed is a way of measuring the effect of the radiation. This is known as absorbed dose. Absorbed dose is the amount of energy absorbed per kilogram of body tissue. It is measured in a quantity called the gray (Gy).
A dose of one gray means that 1 kilogram of tissue absorbs 1 joule of energy. 1Gy = 1 J/Kg.

$$absorbed\ dose = \frac{energy\ absorbed}{mass}$$

For example, if a 25 kg child absorbed 150 J of radiation energy, then the absorbed dose would be $\frac{150}{25}$ = 6 Gy.

To take into account the amount of damage caused by the various forms of radiation, the dose equivalent measure was developed. The units for dose equivalent are Sieverts (Sv).

$$dose\ equivalent = absorbed\ dose \times quality\ factor$$

The quality factor is determined by the type of radiation that delivered the energy.

Type of radiation	Approximate quality factor
X-rays	1
γ rays	1
β particles	1
Slow neutrons	3
Fast neutrons	10
α particles	20

Note: Quality Factor is also called Relative Biological Effectiveness. (RBE)
One Sievert of radiation causes the same amount of biological damage, no matter what type of radiation to which you may be exposed.

Example :

1. A 60 kg person absorbs 0.054 J of energy due to ionising radiation. Calculate the absorbed dose.

$$absorbed\ dose = \frac{energy\ absorbed}{mass}$$

$$absorbed\ dose = \frac{0.054}{60}$$

$$absorbed\ dose = 9 \times 10^{-4}\ Gy$$

2. What would be the dose equivalent if the energy was delivered by γ rays?

$$dose\ equivalent = absorbed\ dose\ \times quality\ factor$$
$$dose\ equivalent = 9 \times 10^{-4}\ \times 1$$
$$dose\ equivalent = 9 \times 10^{-4}\ Sv$$
$$dose\ equivalent = 0.9\ mSv$$

3. What would be the dose equivalent if the energy was delivered by α particles?

$$dose\ equivalent = absorbed\ dose\ \times quality\ factor$$
$$dose\ equivalent = 9 \times 10^{-4}\ \times 20$$
$$dose\ equivalent = 2 \times 10^{-2}\ Sv$$
$$dose\ equivalent = 20\ mSv$$

4. Which would cause more biological damage to the person?
   The α particles would cause about 20 times more damage

NM.4.1.1 Background Radiation

We are exposed to radiation which occurs naturally in our environment. Cosmic rays and rocks are the main contributors.

NM.4.2 Effects of Radiation

When radiation passes through a body cell, it may ionise one of the molecules in the cell forming an ion. Ions are reactive and can sometimes attack the DNA in the cell. This can cause the cell to either die or divide and reproduce at an abnormally rapid rate. When the latter occurs, a cancerous tumour may form.

The effects of a dose of ionising radiation can be divided into two groups: the **somatic** (short-term) effects and the long-term **genetic** effects.

NM.4.2.1 Somatic Effects

These effects appear when body cells are damaged. High doses can lead to immediate effects, while smaller doses may lead to symptoms developing years later.

The table below shows the effects of radiation on humans.

Level of Radiation Exposure	Effects
Low	White blood cell level drops Death unlikely Radiation sickness, i.e. nausea, vomiting and diarrhoea Skin rashes Hair loss Bone marrow damage
Medium	50% likelihood of death within 2 months Severe radiation sickness High probability of leukaemia and tumours
High	Almost certain death within 1 or 2 weeks Acute radiation sickness—convulsions, lethargy
Extreme	Death within 48 hours due to damage to the vascular system which results in an accumulation of fluid to the brain.

NM.4.2.3 Genetic Effects

Ionizing radiation can damage the cells of the reproductive organs. If the damage to these cells occurs in the DNA this damage can be passed on to children and grandchildren. The changed or defective cells are known as mutations.

A developing foetus is also very sensitive to radiation and so pregnant women should avoid having X-rays. For this reason foetal images are now gathered using ultrasound techniques.

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