

Radioactivity Units

Introduction

This is a short activity to explain the differences between the units commonly used for measuring radioactivity, becquerels, grays and sieverts.

The activity

Students should answer the questions, either individually or in pairs.

References

Living with radiation booklet from NRPB.

Suggested answers

Note: Although these question involve calculations as the best way to explain the differences in the units these calculations would not be examined.

1.

Radioactive material	Disintegrations (and time measured for)	Activity (Bq)
1 kg coffee	30 000 in $\frac{1}{2}$ minute	1 000
1 kg granite	1 000 in 1s	1 000
1 household smoke detector (with Americium)	60 000 in 2s	30 000
1 kg Uranium	50 million in 2s	25 million

2. Some university students carry out an experiment to investigate how radiation affects seed germination. They irradiate the seeds using a gamma-ray emitting source. The total number of seeds used have a mass of 0.1kg. How much energy is transferred to the seeds by the gamma rays for the following radiation doses?

a. 0.004Gy (background radiation)
0.0004J

b. 0.2Gy
0.02J

c. 2000Gy (about $\frac{2}{25}$ th of dose used by hospitals to sterilise equipment).
200J

3. How much energy would be absorbed if a human being, mass 70kg, accidentally received a dose of 0.2Gy

14J

Science Explanations

Db Radioactive atoms decay, emitting radiation. The number of emissions per second is called the activity of the source (in becquerel).

Dc Radioactive materials emit three types of radiation.

Alpha emissions (alpha particles) are easily absorbed e.g. by a thin layer of paper, or a few centimetres of air.

Beta emissions (beta particles) pass fairly easily through many substances but can be absorbed by a thin sheet of any metal.

Gamma emissions (gamma radiation) are very penetrating and can only be significantly reduced in strength by a thick sheet of a dense metal such as lead or by concrete several metres thick.

Dg All three types of emission can cause damage to the molecules in living cells, either killing the cells or causing mutations in the genes. Alpha does most damage (per centimetre of their path), followed by beta, then gamma. The radiation dose equivalent (in sievert) which a person receives is a measure of the amount of damage caused by the radiation within their body.

4. A person receives a dose of 0.8 mGy from β radiation
What is the equivalent dose?
weighting factor for β radiation is 1
equivalent dose is 0.8 mSv
5. One person receives 2mSV of alpha radiation to the lungs, another receives 2mSv of beta radiation to the lungs. Compare the risk of cancer to each of them.
The same risk because the effective dose corrects for the different effects of different types of radiation
6. Person A receives 0.2 mGy from α radiation.
Person B receives from 2.0 mGy γ radiation.
Who is at greater risk of cancer? Explain your answer.
Person B because α radiation causes more damage.
Effective doses are: A - $0.2 \times 20 = 4\text{mSv}$ B - $2.0 \times 1 = 2\text{mSv}$
7. Use the idea of effective dose to explain why some cancers are more common than others in those exposed to high radiation doses.
The lungs are more sensitive to radiation damage than the skin. They will receive a higher effective dose. Some tissues, depending on composition (e.g. amount of water,) absorb radiation energy differently and tissues which are growing/cells which are rapidly dividing are more likely to be damaged by radiation.

Radioactivity Units

Radioactivity of 1 becquerel (Bq) is equal to the disintegration of one radioactive atom per second.

A **radiation dose** of 1 gray (Gy) is equivalent to 1 Joule of energy transferred to 1 kg of body tissue.

$$(1 \text{ Gy} = 1 \text{ J kg}^{-1})$$

The **effective radiation dose** is used to estimate the risk resulting from an exposure to ionising radiation. It is measured in sieverts (Sv), or millisieverts (mSv).

*Imagine standing under a shower: the **radioactivity** is the amount of water falling from the shower, the **radiation dose** is how much water hits you, and the **effective radiation dose** is how wet you actually get.*

The Activity

Using the information given in the box answer the following questions.

Radioactivity

1. Complete the gaps in the table for the following radioactive sources:

Radioactive material	Disintegrations (and time measured for)	Time over which disintegrations measured	Activity (Bq)
1 kg coffee	30 000	0.5 min.	
1 kg granite		1 s	1000
1 household smoke detector (with Americium)	60 000	2 s	
1 kg Uranium		2 s	25 million

Data adapted from <http://www.world-nuclear.org/education/ral.htm>

Absorbed radiation dose

2. Some university students carry out an experiment to investigate how radiation affects seed germination. They irradiate the seeds using a gamma-ray emitting source. The total number of seeds used have a mass of 0.1kg. How much energy is transferred to the seeds by the gamma rays for the following radiation doses?
- 0.004Gy (background radiation)
 - 0.2Gy
 - 2000Gy (about 2/25th of dose used by hospitals to sterilise equipment).
3. How much energy would be absorbed if a human being, mass 70kg, accidentally received a dose of 0.2Gy

Effective dose

Radiation increases the risk of cancer. However the risk depends not only on the energy but also on what kind of radiation is absorbed. An alpha, α , particle will do 20 times more damage to the body than an absorbed dose of β or γ radiation of the same energy.

The radiation weighting factor is 1 for β or γ and 20 for α radiation.

The equivalent dose corrects for this difference. The same equivalent dose will do the same harm whether it is α , β or γ .

Equivalent dose = absorbed dose x radiation weighting factor

For example: a person receives a dose of 0.8 mGy from α radiation

What is the equivalent dose?

$$0.8 \times 20 = 16 \text{ mSv}$$

In addition different parts of the body have different sensitivities to radiation. For example the reproductive organs, bone marrow and lungs are particularly sensitive whilst bone surface and skin are much less sensitive. The effective dose takes this into account using a tissue factor. However the tissue factor is one for radiation affecting the whole body, so that the **effective dose** is the same as the equivalent dose for most applications.

4. A person receives a dose of 0.8 mGy from β radiation
What is the effective dose?
5. One person receives 2mSV of alpha radiation to the lungs, another receives 2mSv of beta radiation to the lungs. Compare the risk of lung cancer to each of them.
6. Person A receives 0.2 mGy from α radiation.
Person B receives from 2.0 mGy γ radiation.
Who is at greater risk of cancer? Explain your answer.
7. Use the idea of effective dose to explain why a person exposed to a high dose of irradiation is more likely to get lung cancer than skin cancer.

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