

CHAPTER 4 UNITS OF RADIATION MEASUREMENT

Introduction

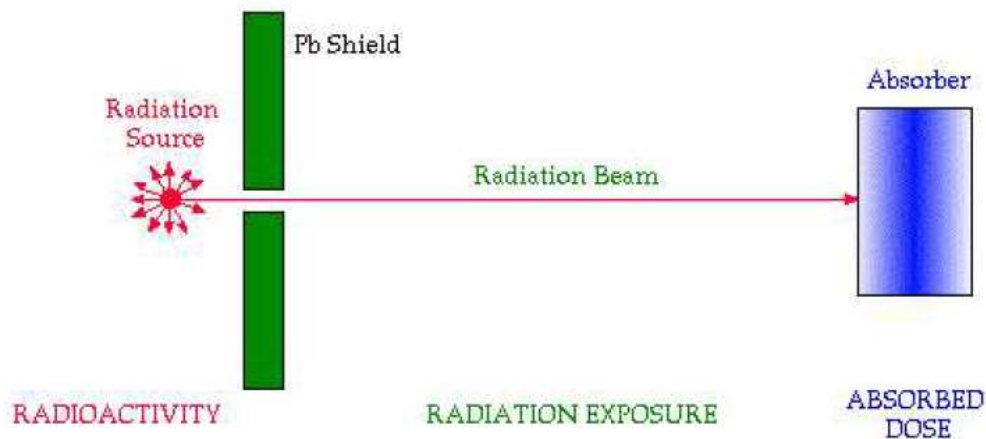
After that rather long and detailed chapter we have just finished we will now proceed at a more leisurely pace for a short treatment of some of the more common units of measurement used in this field.

Before we do so however it is useful to consider the typical radiation environment.

By doing so we will gain an appreciation of the various quantities that can be measured before considering the units which are used to express such measurements. So, we will first of all consider a typical radiation situation and then go on to consider the various units of measurement.

A Typical Radiation Situation

A typical radiation set-up is shown in the figure below. Firstly, there is a source of radiation, secondly a radiation beam and thirdly some material which absorbs the radiation. So the quantities which can be measured are associated with the source, the radiation beam and the absorber.



This type of environment could be one where the radiation from the source is used to irradiate a patient (that is the absorber) for diagnostic purposes where we would place a device behind the patient for producing an image or for therapeutic purposes where the radiation is intended to cause damage to a specific region of a patient. It is also a situation where we as an absorber may be working with a source of radiation.

The Radiation Source

When the radiation source is a radioactive one the quantity that is typically measured is the radioactivity of the source. We saw in the previous chapter that the units used to express radioactivity are the **becquerel** (SI unit) and the curie (traditional unit).

The Radiation Beam

The characteristic of a radiation beam that is typically measured is called the **Radiation Exposure**.

This quantity expresses how much ionisation the beam causes in the air through which it travels.

We will see in the following chapter that one of the *major* things that happens when radiation encounters matter is that ions are formed - air being the form of matter it encounters in this case. So the radiation exposure produced by a radiation beam is expressed in terms of the amount of ionisation which occurs in air.

A straight-forward way of measuring such ionisation is to determine the amount of electric charge which is produced. You will remember from your high school physics that the SI unit of electric charge is the **coulomb**.

The SI unit of radiation exposure is the **coulomb per kilogram** - and is given the symbol $C\ kg^{-1}$. It is defined as the quantity of X- or gamma-rays such that the associated electrons emitted per kilogram of air at standard temperature and pressure (STP) produce ions carrying 1 coulomb of electric charge.

The traditional unit of radiation exposure is the roentgen, named in honour of Wilhelm Roentgen (who discovered X-rays) and is given the symbol R. The roentgen is defined as the quantity of X- or gamma-rays such that the associated electrons emitted per kilogram of air at STP produce ions carrying 2.58×10^{-4} coulombs of electric charge.

So 1 R is a small exposure relative to $1\ C\ kg^{-1}$ - in fact it is 3,876 times smaller.

Note that this unit is confined to radiation beams consisting of X-rays or gamma-rays.

Often it is not simply the exposure that is of interest but the exposure rate, that is the exposure per unit time. The units which tend to be used in this case are the $C\ kg^{-1}\ s^{-1}$ and the $R\ hr^{-1}$.

The Absorber

Energy is deposited in the absorber when radiation interacts with it. It is usually quite a small amount of energy but energy nonetheless. The quantity that is measured is called the Absorbed Dose and it is of relevance to all types of radiation be they X- or gamma-rays, alpha- or beta-particles.

The SI unit of absorbed dose is called the gray, named after a famous radiobiologist, LH Gray, and is given the symbol Gy. The gray is defined as the absorption of 1 joule of radiation energy per kilogram of material. So when 1 joule of radiation energy is absorbed by a kilogram of the absorber material we say that the absorbed dose is 1 Gy.

The traditional unit of absorbed dose is called the rad, which supposedly stands for Radiation Absorbed Dose. It is defined as the absorption of 10^{-2} joules of radiation energy per kilogram of material.

As you can figure out 1 Gy is equal to 100 rad.

There are other quantities derived from the gray and the rad which express the biological effects of such absorbed radiation energy when the absorber is living matter - human tissue for example. These quantities include the **Equivalent Dose** and the **Effective Dose**.

Let us pause here for a bit to ponder on the use of the term *dose*. It usually has a medical connotation in that we can say that someone had a dose of the 'flu, or that the doctor prescribed a certain dose of a drug. What has it to do with the deposition of energy by a beam of radiation in an absorber? It could have something to do with the initial applications of radiation in the early part of the 20th century when it was used to treat numerous diseases. As a result, we can speculate that the term has stayed in the vernacular of the field. It would be much easier to use a term like absorbed radiation energy since we are talking about the deposition of energy in an absorber. But this might make the subject just a little too simple!

Specific Gamma Ray Constant

A final quantity is worth mentioning with regard to radiation units. This is the Specific Gamma- Ray Constant for a radioisotope. This quantity is an amalgam of the quantities we have already covered and expresses the exposure rate produced by the gamma-rays emitted from a radioisotope.

It is quite a useful quantity from a practical viewpoint when we are dealing with a radioactive source which emits gamma-rays. Supposing you are using a gamma-emitting radioactive source (for example ^{99m}Tc or ^{137}Cs) and you will be standing at a certain distance from this source while you are working. You most likely will be interested in the exposure rate produced by the source from a radiation safety point of view. This is where the Specific Gamma-Ray Constant comes in.

It is defined as the exposure rate per unit activity at a certain distance from a source. The SI unit is therefore the

$$C \text{ kg}^{-1} \text{ s}^{-1} \text{ Bq}^{-1} \text{ at } 1 \text{ m},$$

and the traditional unit is the

$$R \text{ hr}^{-1} \text{ mCi}^{-1} \text{ at } 1 \text{ cm}.$$

These units of measurement are quite cumbersome and a bit of a mouthful. It might have been better if they were named after some famous scientist so that we could call the SI unit 1 smith and the traditional unit 1 jones for example. But again things are not that simple!

The Inverse Square Law

Before we finish this chapter we are going to consider what happens as we move our absorber away from the radiation source. In other words, we are going to think about the influence of distance on the intensity of the radiation beam. You will find that a useful result emerges from this that has a very important impact on radiation safety.

The radiation produced in a radioactive source is emitted in all directions. We can consider that spheres of equal radiation intensity exist around the source with the number of photons/particles spreading out as we move away from the source.

Consider an area on the surface of one of these spheres and assume that there are a certain number of photons/particles passing through it. If we now consider a sphere at a greater distance from the source the same number of photons/particles will now be spread out over a bigger area. Following this line of thought it is easy to appreciate that the radiation intensity will decrease with the square of the distance from the source.

This effect is known as the **Inverse Square Law**. As a result if we double the distance from a source, we reduce the intensity by a factor of two squared, that is 4. If we treble the distance the intensity is reduced by a factor of 9, that is three squared, and so on.

This is a very useful piece of information if you are working with a source of radiation and are interested in minimising the dose of radiation you will receive.