Units Of Radioactivity

UNITS OF RADIOACTIVITY AND UNITS OF RADIATION ABSORBED DOSE

After completing this tutorial, attendees will be able to

- Understand the measurement of units of radioactivity.
- Give the definition of activity and identify the number of disintegrations/sec in a Ci and a mCi
- List all units from Ci to pCi
- State the relationship between disintegrations/sec and Bq
- Differentiate between a count and a disintegration
- State the definition of and formula for Detection Efficiency
- Define Specific Activity
- Define Rad, Rem, Quality Factor, Gray and Sievert
- Perform basic calculations of activity and radiation dose

This tutorial will define how radioactivity is measured and give different formulas for measuring units of radiation.

UNITS OF RADIOACTIVITY

Definition: A Curie is the unit of absolute activity and is abbreviated Ci. It is expressed in terms of disintegrations per second (dps). A Curie is represented by a sample with a decay rate of 3.7 X 10^{10} dps or 2.22 X 10^{12} dpm.

Unit	# of Curie	# of DPS	# of DPM
Megacurie (MCi)	10^6 Ci	3.7 x 10^{16}dps	2.22 x 10^{18} dpm
Kilocurie (kCi)	10^3 Ci	3.7 x 10^{13}dps	2.22 x 10^{15} dpm
Curie (Ci)	1 Ci	3.7 x 10^{10}dps	2.22 x 10^{12} dpm
Millicurie (mCi)	**10^{-3} Ci**	**3.7 x 10^7 dps**	**2.22 x 10^9 dpm**
Microcurie (µCi)	10^{-6} Ci	3.7 x 10^4 dps	2.22 x 10^6 dpm
Nanocurie (nCi)	10^{-9} Ci	3.7 x 10^1 dps	2.22 x 10^3 dpm
Picocurie (pCi)	10^{-12} Ci	3.7 x 10^{-2} dps	2.22 dpm
Femtocurie (MCi)	10^{-15} Ci	3.7 x 10^{-5} dps	2.22 x 10^{-3} dpm

The bolded line represents the most commonly used Ci-related terms**Definition**: In the SI System, the Basic Unit of Absolute Activity is a Bq (Becquerel). It is Equivalent to 1 disintegration per second (dps))

Unit	# of Becquerel	# of DPS
Becquerel (Bq)	1 Bq	1 dps
Kilobecquerel (KBq)	10^3 Bq	10^3 dps
Megabecquerel (MBq)	10^6 Bq	10^6 dps
Gigabecquerel (GBq)	10^9 Bq	10^9 dps
Terabecquerel (TBq)	10^{12} Bq	10^{12} dps

Useful Equivalents

- 37 MBq = 1 mCi
- 1 MBq = 0.027 mCi = 27 µCi

Tracer level work

Most tracer level work performed in Nuclear Medicine is on the µCi to mCi range. Less than 1 µCi is required for a measurement in a well counter. Imaging procedures require many µCi and often mCi

Potential source of confusion

One disintegration, representing the disintegration of a nucleus, is an absolute event that took place. Unfortunately, our detectors are never 100% efficient and in fact their efficiency generally falls in the range of 40 – 60%. In addition, counting geometry is never ideal. Depending upon detector efficiency and counting geometry, we may or may not be able to detect an individual event. 1 count will therefore not represent 1 disintegration.

Detector Efficiency

Detector efficiency indicates what fraction of total disintegrations is recognized by the detector. If we count a standard whose activity is precisely known, then mathematically,

$$\text{Detector Efficiency} = \frac{\text{count rate x } 100\%}{\text{disintegration rate}}$$

For example, a 1.0 mCi standard of Co-57 has a count rate of 2.4×10^7 c/s. What is the detector efficiency?

$$\text{Detector Efficiency} = \frac{2.4 \times 10^7 \text{ c/s.}}{3.7 \times 10^7 \text{ d/s.}} \times 100\% = 64.86\ \%$$

Mathematical Problem Solving

Let's assume that the detector efficiency of a particular detector is 47%. In problem solving, one may use either

$$\frac{\text{100 disintegrations}}{\text{47 counts}} \quad \text{or} \quad \frac{\text{47 counts}}{\text{100 disintegrations}}$$

Specific Activity

- Specific activity is defined as the activity per unit mass (e.g., mCi/g or KCi/mmol).
- It is unrelated to concentration in solution, which is activity per unit volume (e.g., mCi/ml). Specific Activity must contain a term related to mCi or disintegrations and a term related to mass such as a gram or mole term.

QUESTION: which one of the following is NOT an example of specific activity?

- mCi/mg
- kCi/µmole
- cpm/mmole
- dps/g

ANSWER: cpm/mmole.

Since specific activity is defined as activity/unit mass, the numerator must be directly relatable to disintegrations. Counts cannot be related to disintegrations unless the detector efficiency is known.

UNITS OF RADIATION ABSORBED DOSE

Rad (**R**adiation **A**bsorbed **D**ose):

Takes into account the fact that different absorbers that receive an identical exposure will absorb different amounts of energy. A Rad therefore represents the amount of energy from ionizing radiation that is transferred to a mass of material, typically patients undergoing diagnostic or therapeutic studies.

Rem (**R**oentgen **E**quivalent **M**an):

Is a unit that correlates the dose of any radiation to the biological effect of that dose. To relate the absorbed dose of specific types of radiation to their biological effect, a "quality factor" must be multiplied by the dose in rad, which then shows the dose in rems. Thus, rem = rad x Q. For gamma rays, X rays, and beta particles, 1 rad of exposure results in 1 rem of dose. X rays and gamma rays have a Q about 1, so the absorbed dose in rads is the same number in rems. Neutrons have a Q of about 5 and alpha particles have a Q of about 20. An absorbed dose of 1 rad of these particles is equivalent to 5 rem and 20 rem, respectively.

International Commission on Radiation Units and Measurements (ICRU)

According to the ICRU,

Gray (Gy): defined as 100 Rads

Sievert (Sv): defined as 100 Rem

1 mGy = 100 mRads

1 mSv = 100 mRem

1 µGy = 100 µRads

1 µSv = 100 µRem

Mathematical Problem Solving

1. The testicular dose from a 3 mCi dose of Tl-201 chloride is 9.0 Rems. To how many mSv is this dose equivalent?

$$9.0\ \text{Rem} \times \frac{\text{Sv}}{100\ \text{Rem}} \times \frac{1{,}000\ \text{mSv}}{\text{Sv}} = \mathbf{90\ mSv}$$

2. The Maximum Permissible Whole Body Dose (MPD) for Radiation workers is 50 mSv. To how many mRem is that dose equivalent?

$$50\ \text{mSv} \times \frac{100\ \text{mRem}}{\text{mSv}} = \mathbf{5{,}000\ mRem}$$

3. A package insert lists a liver dose from a Tc-99m radiopharmaceutical as 0.25 Rad/mCi. What would the dose rate be in mGy/mCi?

$$\frac{0.25\ \text{Rad}}{\text{mCi}} \times \frac{1\ \text{Gy}}{100\ \text{Rad}} \times \frac{1{,}000\ \text{mGy}}{\text{Gy}} = \mathbf{2.5\ mGy}$$

4. A package insert lists a liver dose from a Tc-99m radiopharmaceutical as 0.25 mSv/GBq. What would the dose rate be in mRem/mCi?

$$\frac{0.25\ \text{mSv}}{\text{GBq}} \times \frac{100\ \text{mRem}}{\text{mSv}} \times \frac{1\ \text{GBq}}{1{,}000\ \text{MBq}} \times \frac{37\ \text{MBq}}{\text{mCi}} = \mathbf{\frac{0.925\ mRem}{mCi}}$$

5. A vial of Y-90 Microspheres contains 3.0 GBq. 30% of the microspheres will be implanted into the left lobe of the patient's liver, conferring a dose to the left lobe of 6,000 Rems.. What is the radiation absorbed dose to the left lobe in terms of mSv/mCi?

Dose administered was 0.3 x 3 GBq = 0.9 GBq therefore,

$$\frac{6{,}000\ \text{Rems}}{0.9\ \text{GBq}} \times \frac{1\ \text{Sv}}{100\ \text{Rems}} \times \frac{1{,}000\ \text{mSv}}{\text{Sv}} \times \frac{\text{GBq}}{1{,}000\ \text{MBq}} \times \frac{37\ \text{MBq}}{\text{mCi}} = \mathbf{\frac{2466.7\ mSv}{mCi}}$$

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