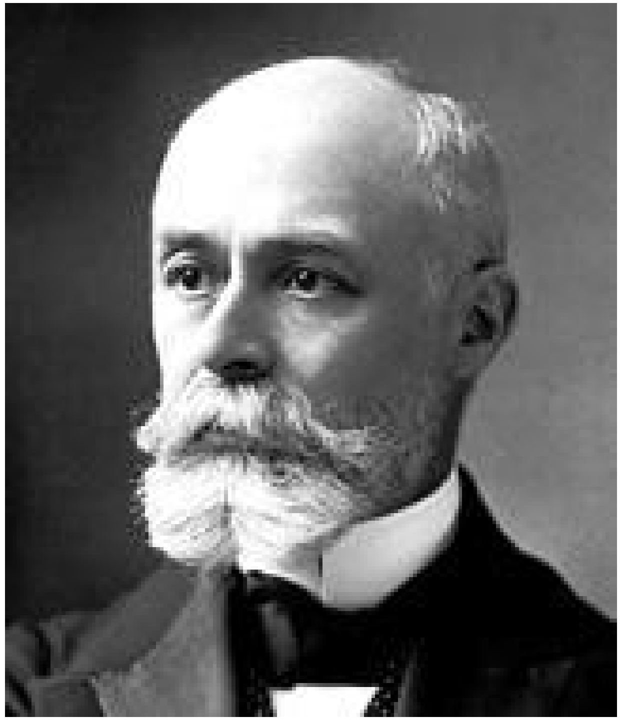
Units and Conversions



Units of Radioactivity

- Becquerel (Bq)

  1 Bq = 1 dps

- Curie (Ci)

  1 mCi = 37 MBq

SI Unit multipliers

Curie
Becquerel
REM
Sv
Gray
RAD

Factor	Name	Value
10^9	Giga (G)	1,000,000,000
10^6	Mega (M)	1,000,000
10^3	kilo (k)	1,000
UNIT		1
10^{-3}	milli (m)	0.001
10^{-6}	micro (u)	0.000001
10^{-9}	nano (n)	0.000000001

Convert 10 mCi to uCi.

$$10\ \text{mCi} \left(\frac{1{,}000\ \text{uCi}}{1\ \text{mCi}} \right) =$$

$$10\ \cancel{\text{mCi}} \left(\frac{1{,}000\ \text{uCi}}{1\ \cancel{\text{mCi}}} \right) = 10{,}000\ \text{uCi}$$

Factor	Name
10^9	Giga (G)
10^6	Mega (M)
10^3	kilo (k)
1	UNIT
10^{-3}	milli (m)
10^{-6}	micro (u)
10^{-9}	nano (n)

Convert 1.3 Ci to uCi

$$1.3\ \text{Ci}\left(\frac{1{,}000\ \text{mCi}}{1\ \text{Ci}}\right)\left(\frac{1{,}000\ \text{uCi}}{1\ \text{mCi}}\right) =$$

$$1.3\ \cancel{\text{Ci}}\left(\frac{1{,}000\ \cancel{\text{mCi}}}{1\ \cancel{\text{Ci}}}\right)\left(\frac{1{,}000\ \text{uCi}}{1\ \cancel{\text{mCi}}}\right) = 1{,}300{,}000\ \text{uCi}$$

Factor	Name
10^9	Giga (G)
10^6	Mega (M)
10^3	kilo (k)
1	UNIT
10^{-3}	milli (m)
10^{-6}	micro (u)
10^{-9}	nano (n)

Convert 500 MBq to GBq

$$500\ \text{MBq} \left(\frac{1\ \text{GBq}}{1{,}000\ \text{MBq}} \right) =$$

$$500\ \cancel{\text{MBq}} \left(\frac{1\ \text{GBq}}{1{,}000\ \cancel{\text{MBq}}} \right) = 0.5\ \text{GBq}$$

Factor	Name
10^9	Giga (G)
10^6	Mega (M)
10^3	kilo (k)
1	UNIT
10^{-3}	milli (m)
10^{-6}	micro (u)
10^{-9}	nano (n)

Convert 25 mCi to MBq

1 mCi = 37 MBq

$$25\ \text{mCi}\left(\frac{37\ \text{MBq}}{1\ \text{mCi}}\right) =$$

$$25\ \cancel{\text{mCi}}\left(\frac{37\ \text{MBq}}{1\ \cancel{\text{mCi}}}\right) = 925\ \text{MBq}$$

Convert 120 mCi to GBq

1 mCi = 37 MBq

$$120\ \text{mCi}\left(\frac{37\ \text{MBq}}{1\ \text{mCi}}\right)\left(\frac{1\ \text{GBq}}{1{,}000\ \text{MBq}}\right) =$$

$$120\ \cancel{\text{mCi}}\left(\frac{37\ \cancel{\text{MBq}}}{1\ \cancel{\text{mCi}}}\right)\left(\frac{1\ \text{GBq}}{1{,}000\ \cancel{\text{MBq}}}\right) = 4.44\ \text{GBq}$$

How many dps in 2 mCi?

1 mCi = 37 MBq

1 Bq = 1 dps

$$2\ \text{mCi}\left(\frac{37\ \text{MBq}}{1\ \text{mCi}}\right)\left(\frac{1{,}000\ \text{kBq}}{1\ \text{MBq}}\right)\left(\frac{1{,}000\ \text{Bq}}{1\ \text{kBq}}\right)\left(\frac{1\text{dps}}{\text{Bq}}\right) =$$

$$2\ \cancel{\text{mCi}}\left(\frac{37\ \cancel{\text{MBq}}}{1\ \cancel{\text{mCi}}}\right)\left(\frac{1{,}000\ \cancel{\text{kBq}}}{1\ \cancel{\text{MBq}}}\right)\left(\frac{1{,}000\ \cancel{\text{Bq}}}{1\ \cancel{\text{kBq}}}\right)\left(\frac{1\text{dps}}{\cancel{\text{Bq}}}\right) = 7.4 \times 10^{7}\ \text{dps}$$

A sample is counted 320,000 disintegrations per minute (dpm). How many uCi are in the sample?

$$320{,}000\ \text{dpm} \left(\frac{1\ \text{dps}}{60\ \text{dpm}}\right)\left(\frac{1\ \text{Bq}}{1\ \text{dps}}\right)\left(\frac{1\ \text{kBq}}{1{,}000\ \text{Bq}}\right)\left(\frac{1\ \text{MBq}}{1{,}000\ \text{kBq}}\right)\left(\frac{1\ \text{mCi}}{37\ \text{MBq}}\right)\left(\frac{1{,}000\ \text{uCi}}{1\ \text{mCi}}\right) =$$

$$320{,}000\ \cancel{\text{dpm}} \left(\frac{1\ \cancel{\text{dps}}}{60\ \cancel{\text{dpm}}}\right)\left(\frac{1\ \cancel{\text{Bq}}}{1\ \cancel{\text{dps}}}\right)\left(\frac{1\ \cancel{\text{kBq}}}{1{,}000\ \cancel{\text{Bq}}}\right)\left(\frac{1\ \cancel{\text{MBq}}}{1{,}000\ \cancel{\text{kBq}}}\right)\left(\frac{1\ \cancel{\text{mCi}}}{37\ \cancel{\text{MBq}}}\right)\left(\frac{1{,}000\ \text{uCi}}{1\ \cancel{\text{mCi}}}\right) = 0.14\ \text{uCi}$$

Exposure

$1\ R = 2.58 \times 10^{-4}\ C/kg$

- Roentgen or C/kg
- Coulomb is a unit of electrical charge

- Measurement of ionizations in air (gas)

- GM meter
- Exposure = R or mR
- Exposure rate = R/hr or mR/hr

Limitations of the Roentgen

Defined only for x-rays and gamma rays (no particles)

Only defined up to about 3 MeV

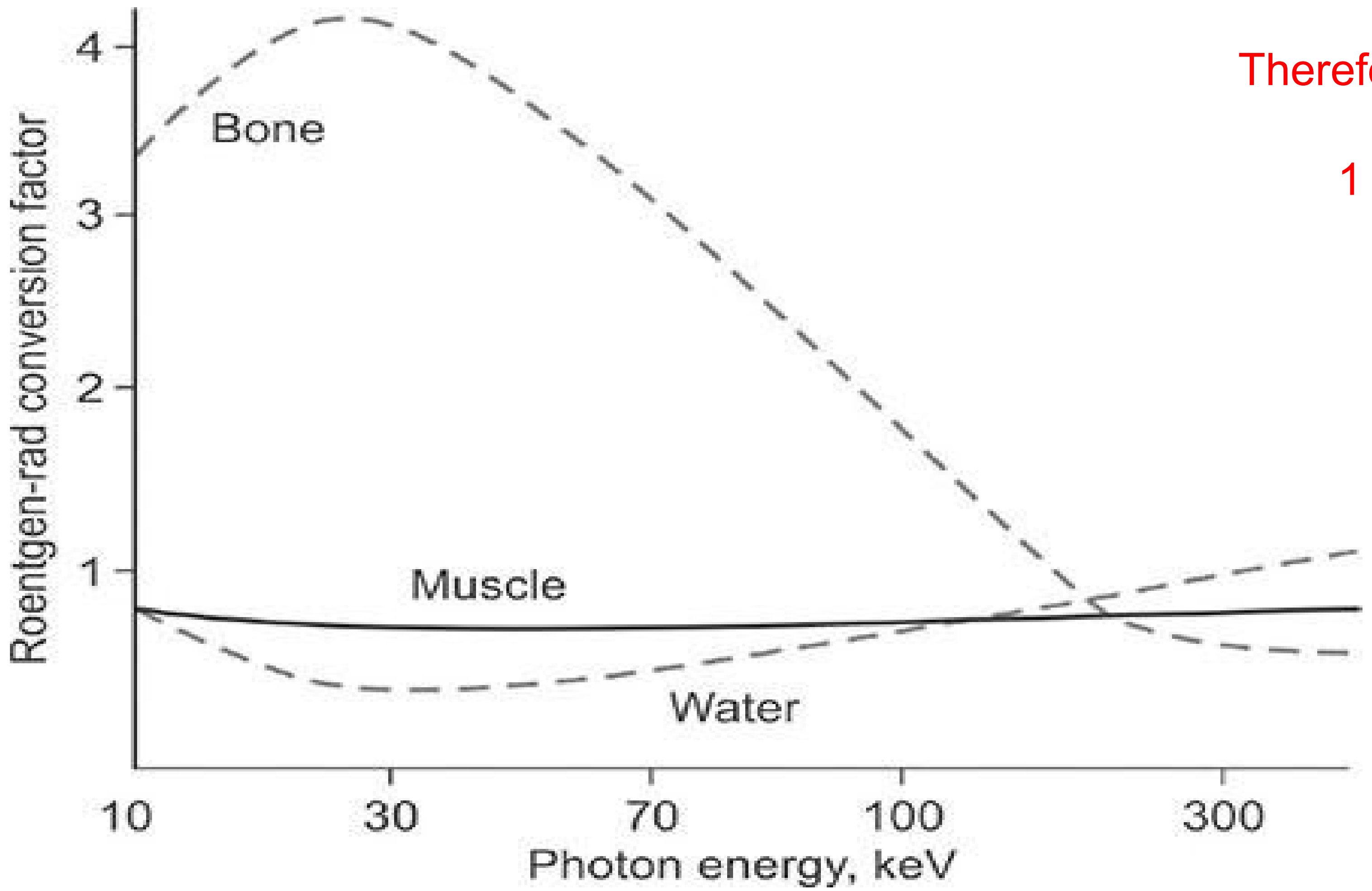
Defined only for air

Absorbed Dose

1 Gray = 100 RAD

- RAD or Gray (Gy)
- Describes the dose absorbed in the body (think therapeutic application of radiation)
- Energy absorbed per unit mass
- Applies to all radiations

Roentgen-to-rad conversion



1 R = 0.87 rad in air
1 R = 0.94 to 0.98 rad in soft tissue

Therefore, in soft tissue

1 R ~ 1 rad

Equivalent Dose

1 Sv = 100 REM

- REM or Sievert (Sv)
- Takes onto account the type of radiation
  - Alpha
  - Beta
  - Gamma

	*Radiation Weighting Factor W_R
X-rays, gamma rays, electrons and positrons	1
Neutrons	5-20
Protons	2
Alpha particles, fission fragments, heavy nuclei	20

**Older texts call this Quality Factor QF*

Example: A researcher accidentally ingests a mixture of chemicals from which the dose to
the liver is 50 mGy (5 rad) from alpha particles, 30mGy (3 rad) from beta particles and 20mGy (2 rad) from gamma rays. Radiation Quality/Weighting Factor for alpha = 20.

- What is the absorbed dose to the liver?

50 mGy + 30 mGy + 20 mGy = 100 mGy

5 RAD + 3 RAD + 2 RAD = 10 RAD

- What is the Equivalent Dose to the liver?

50 mGy (5 RAD) alpha * 20 = 1,000 mSV (100 REM)

30 mGy (3 RAD) beta * 1 = 30 mSv (3 REM)

20 mGy (2 RAD) gamma *1 = 20 mSv (2 REM)

TOTAL = 1,050 mSv (105 REM)

Exposure vs Absorbed Dose in Tissue

- 1 R = 0.87 rad in air
- 1 R = 0.94 to 0.98 rad in soft tissue
- 1 rad = 1 rem for gamma rays, x-rays, electrons and positrons
- Therefore, in soft tissue: 1R ~ 1 rad ~ 1 rem

Effective Dose

Gonads	0.20
Red bone marrow	0.12
Colon	0.12
Lung	0.12
Stomach	0.12
Bladder	0.05
Breast	0.05
Liver	0.05
Esophagus	0.05
Thyroid	0.05
Skin	0.01
Bone Surface	0.01
Remainder	0.05

Considers different tissue sensitivities

- Example: Assume 1.7 rads to lungs from gamma, x-rays or electrons

- Equivalent dose = 17 RADs * 1 = 1.7 REMS
- Effective dose = 1.7 REMS * 1.2 = 0.204 REM or 204 mREM (2.04 mSv)

The thyroid receives an absorbed dose of x-rays of 100 RAD. The weighting factor for the thyroid is 0.03. What is the effective dose?

Equivalent dose = absorbed dose times radiation weighting factor

Effective dose = equivalent dose times tissue weighting factor

100 X 1 (radiation weighting factor) X 0.03 (thyroid weighting factor) = 3 rem (0.03 Sv)

- Calculate the effective dose:
  2 RAD of alpha to the bone marrow (WF = 0.12)
  100 mRAD of gamma to the bone surface (WF = 0.01)

- 2 RAD alpha times QF of 20 = 40 REM
  - 40 REM times WF of 0.12 for bone marrow = 4.8 REM Effective dose (0.048 Sv)

- 100 mRAD of gamma times QF of 1 = 100 mREM
  - 100 mREM times WF of 0.01 for bone surface = 1 mREM (0.01 mSv)

- 4,800 mREM plus 1 mrem = 4,801 mREM
- 4801 mREM = 48.01 mSv

How is our exposure measured?

- Deep Dose Equivalent (DDE)—exposure of internal organs from external sources
- Committed Effective Dose Equivalent (CEDE)—exposure of internal organs from internal sources
- Total Effective Deep Dose Equivalent = DDE + CEDE
- Shallow Dose Equivalent (SDE) = skin or extremity dose (separate badge)
- Lens of Eye Dose Equivalent (LDE) = dose to eyes (separate badge)

Exposure Limits for Radiation Workers

- Whole Body = 5 REM
- Lens of the Eye = 15 REM
- Any organ = 50 REM
- Skin or extremity = 50 REM
- Public = 0.1 REM
- Embryo/Fetus (entire pregnancy) = 0.5 REM
- Minors = 0.5 REM
- Family member of therapy patient = 0.5

Make sure you can convert between REM and Sievert

Refer to Regulatory Guide 8.7 “Instructions for recording and reporting occupational radiation dose data”

Let’s do some more math!

$1 \text{ R} = 2.58 \text{ X } 10^{-4} \text{ C/kg}$

1 Gray = 100 RAD

1 Sv = 100 REM

Convert 3 Roentgen to C/kg

$$3\ R \left(\frac{2.58 \times 10^{-4}\ C/kg}{1\ R} \right) =$$

$$3\ \cancel{R} \left(\frac{2.58 \times 10^{-4}\ C/kg}{1\ \cancel{R}} \right) = 7.74 \times 10^{-4}\ C/kg$$

1 R = 2.58×10^{-4} C/kg

1 Gray = 100 RAD

1 Sv = 100 REM

Convert 50 mRAD to mGy anduGy

$$50\ \cancel{\text{mRAD}} \left(\frac{1\ \text{mGy}}{100\ \cancel{\text{mRAD}}} \right) = 0.5\ \text{mGy}$$

$$0.5\ \cancel{\text{mGy}} \left(\frac{1{,}000\ \text{uGy}}{1\ \cancel{\text{mGy}}} \right) = 500\ \text{uGy}$$

$1\ R = 2.58 \times 10^{-4}\ C/kg$

1 Gray = 100 RAD

1 Sv = 100 REM

Convert 0.8 mGy to mrad and rad

$$0.8\ \cancel{\text{mGy}} \left(\frac{100\ \text{mRAD}}{1\ \cancel{\text{mGy}}} \right) = 80\ \text{mRAD}$$

$$80\ \cancel{\text{mRAD}} \left(\frac{1\ \text{RAD}}{1{,}000\ \cancel{\text{mRAD}}} \right) = 0.08\ \text{RAD}$$

1 R = 2.58×10^{-4} C/kg

1 Gray = 100 RAD

1 Sv = 100 REM

Convert 8.5 mSv to mrem and rem

$$8.5 \text{ mSv} \left(\frac{100 \text{ mREM}}{1 \text{ mSv}} \right) = 850 \text{ mREM}$$

$$850 \text{ mREM} \left(\frac{1 \text{ REM}}{1{,}000 \text{ mREM}} \right) = 0.85 \text{ REM}$$

1 R = 2.58×10^{-4} C/kg

1 Gray = 100 RAD

1 Sv = 100 REM

Conversions you should know:

Factor	Name
10^9	Giga (G)
10^6	Mega (M)
10^3	kilo (k)
1	UNIT
10^{-3}	milli (m)
10^{-6}	micro (u)
10^{-9}	nano (n)

1 kg = 2.2 pounds

100 rem = 1 Sv

100 rad = 1 Gray

1 mCi = 37 MBq

1 Bq = 1 dps

1 dps = 60 dpm