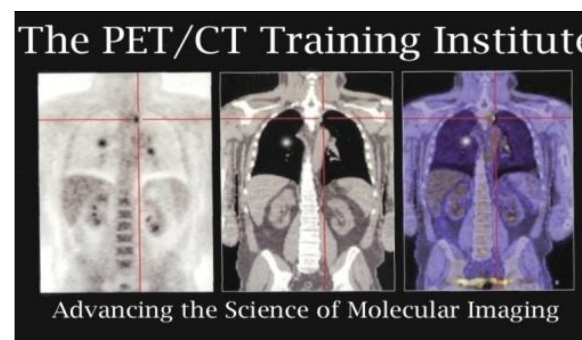
Nuclear Decay Mathematics

- **Tim Marshel R.T. (R)(N)(CT)(MR)(NCT)(PET)(CNMT)**



SNMTS Approved
45-Hour PET Registry Review Course

Nuclear Decay Mathematics

- SNM Voice Reference Number: 028601,   1.0 CEH's

- Participants must answer at least an 80% of the post-test questions correctly in order to receive CE credit.

Program Objectives:

- Upon completion of this section, the student should be able solve simple mathematical problems using the Texas Instruments TI 30 X IIS calculator.
- Perform simple radioactive decay equations using the decay equation, decay chart method, and universal decay table method
- Choose the correct pre-calibration factor from a chart
- Determine specific concentration and activity of a sample
- Review dose volume calculations
- Calculate effective half-life
- Determine radiation dose versus time
- Compute radiation dose versus distance
- Calculate radiation intensity with shielding
- Convert units of activity, exposure, and absorption

Principles of Radioactive Decay

- Radionuclide's are always constantly decaying at a specific rate.
- The activity is constantly decreasing.
- The amount of decrease per time is dependent upon the physical half-life of the radionuclide.
- If you can identify the radionuclide's physical half-life, then you should be able to calculate the activity for any time in the future or past.

Post Calibration (Decay) Defined:

- Each radionuclide decays at its own unique time.
- Post Calibration is the equation that we use to calculate the breakdown of these radioactive particles.
- What we use is called half-life, which is defined as the time required for radioactive nuclides to decrease to half of its initial value.

Why is the radionuclide decaying?

- What goes on in the unstable atomic nuclei is emitting subatomic particles, called **radiation.**
- Decay is just the process of the “parent” nucleus producing a “daughter” nucleus.
- Or to make it easier, these unstable nuclei’s are trying to become stable nuclei’s.

Three methods for calculating for Radioactive Decay

- **Method I:** Decay Equation: $\underline{At = Ao\ e^{-.693\ (t/t/2)}}$

  Where: At= Activity at a specified time
  Ao= Original Activity
  e = Euler's number (2.718) constant
  t = Elapsed time
  t/2= Half-life

- **Method II:** Decay Chart: At = Ao (DF)

  Where: At= Activity at a specified time
  Ao= Original Activity
  DF= Decay Factor (Found in Book)

- **Method III:** Universal Decay Table Half-Life: t/T

Question #1 Method I: Decay Equation

- A vial of generator elute contains 432 mCi immediately following elution. How many mCi will remain 8 hours later? The half life for Tc^{99m} is 6.01 hours. Try to solve it using the Decay Equation.

Formula: $At = Ao\ e^{-.693\ (t/t/2)}$ = $At = 432\ e^{-.693\ (8/6)}$

- At= Unknown
- Ao= 432 mCi
- e= -.693
- t= 8 hours
- t/2= 6 hours

Using your Calculator: Decay Equation: TI 30XIIS

A vial of generator elute contains 432 mCi immediately following elution. How many mCi will remain 8 hours later? The half life for Tc^{99m} is 6.01 hours.

Calculator

432

2nd

LN

(-)

.693

X

8

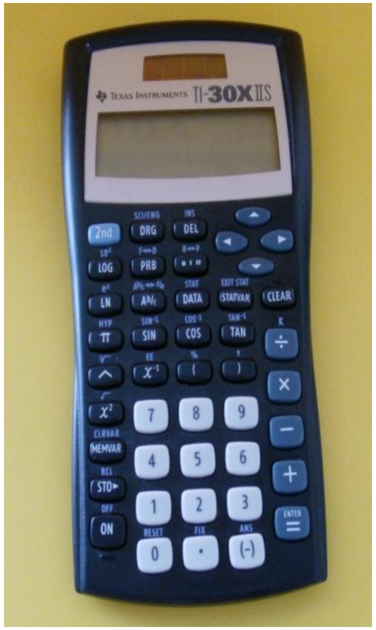
6.01

)

=

171.73 mCi Remain after 8 hours of decay.

TI 30XIIS Calculator: Features



)

/

X

2nd

LN

TI 30XIIS Calculator: Features

2nd

LN

ON

/

)

X

=

-

Question #2

- 10mCi F-18 (FDG) calibrate for 0700; Patient shows up at 0815. How much will remain? Try solving this with the Decay Equation.

- Ao= 10 mCi
- At= Unknown
- e= -.693
- t= 75 minutes
- t/2= 110 minutes

Calculator Method: Decay Equation TI 30XIIS

- 10mCi F-18 (FDG) calibrate for 0700; Patient shows up at 0815. How much will remain?
- Calculator
- 10
- 2nd
- LN
- (-)
- 0.693
- X
- 75
- ÷
- 110
-)
- =
- 6.234mCi Remain in syringe at 8:15 am for patients use.

Question #3 Method I: Decay Equation

40mCi Rb89 calibrated for 0715. How much will remain at 0740?

(Rubidium 89 half-life is 75 seconds)

At = Unknown
Ao = 40 mCi
e = -.693
t= 25 minutes or 1500 seconds
t/2= 75 seconds

Calculator Method: Decay Equation TI 30XIIS

40mCi Rb89 calibrated for 0715. How much will remain at 0740?

<u>Calculator</u>

40
2nd
Ln
(-)
.693
X
1500

75
)
=

0.00003 mCi Rb 89 remain after 25 minutes of decay.

Principles: Method II: Decay Charts

- **Most Convenient method**
- **Allows quicker problem solving and fewer errors**
- **Most commonly used in the nuclear medicine department**

How to calculate activity using a decay factor (DF).

- **Calculate the time elapsed since the time at which the activity was known, Ao or original activity.**
- **Refer to the appropriate decay table and select the correct decay factor.**
- **Apply the data to the equation.**

- **Formula: $A_t = A_o \times DF$**

Technetium 99m Half-life Chart

Technetium ^{99m}Tc

Half Life 6.02 Hours

Pre Calibration Decay Factor	Hours	Post-Calibration Decay Factor
1.122	1	0.891
1.259	2	0.794
1.413	3	0.708
1.585	4	0.631
1.778	5	0.562
	6	0.501
	7	0.447
	8	0.398
	9	0.355
	10	0.316
	11	0.282
	12	0.251
	18	0.126
	24	0.063

Thallium 201 Half-Life Chart

Thallium ^{201}Tl

Half Life 73.1 Hours

Pre Calibration Decay Factor	Hours	Post-Calibration Decay Factor
1.048	5	0.954
1.099	10	0.910
1.152	15	0.868
1.207	20	0.828
1.266	25	0.790
1.327	30	0.753
1.391	35	0.719
1.458	40	0.686
1.529	45	0.654
1.602	50	0.624
1.680	55	0.595
1.761	60	0.568
1.846	65	0.542
1.935	70	0.517
2.028	75	0.493

Iodine 131 Half-Life

Iodine ^{131}I

Half-Life 8.04 Days

Pre Calibration Decay Factor	Days	Post-Calibration Decay Factor
1.090	1	0.918
1.188	2	0.842
1.294	3	0.773
1.411	4	0.709
1.537	5	0.651
	6	0.597
	7	0.548
	8	0.503
	9	0.461
	10	0.423
	11	0.388
	12	0.356
	13	0.327
	14	0.300
	15	0.275

Question # 1

A vial of Tc99m Sodium pertechnetate contains 572 mCi at 8:00am. What is its activity at 12:30 pm?

Formula: At= Ao (DF)

Calculate the elapsed time: 8am-1230pm is 4.5hrs
Look up the decay factor from book: = 0.595
Calculate the activity at the specified time:

572 mCi x 0.595 = 340 mCi

Note: The decay chart were formulated using the $e^{-.693 \times 4.5/6.01\ \text{hrs}} = e^{-.694 \times .7488} = e^{-.5189} = 0.595$

Question #2

A vial of Thallium 201 contains 6.6 mCi at 8am on Monday. How many mCi remain at 2pm on Tuesday?

<u>Formula: Ao x DF</u>

Ao = 6.6 mCi
DF: .754 (Found in Appendix of Book)

Solution: 6.6 mCi x .754 = 5 mCi

Question #3

A vial of Tc99m MAA contains 54.7 mCi at 730am. What is the activity at 10:15am?

<u>**Formula: Ao x DF**</u>

Ao = 54.7 mCi
DF: 0.728

54.7 mCi x 0.728= 39.8 mCi Tc99m MAA at 10:15am

Principles: Method III: Universal Decay Table

The universal decay table allows you to determine the decay factor for any radionuclide based on the half-life and elapsed time. The universal decay table will identify the fraction of activity remaining at t/T where: t= elapsed time and T = half-life.

How to find a decay factor using the universal decay table.

- Calculate t/T
- Use the answer, to three significant figures, to find the decay factor on the table
- Locate the first two figures along the left hand column
- Locate the third figure along the top of the columns.
- Read across from left and down from the top to find the decay factor

Universal Decay Table

Activity Remaining for $t/T_{1/2}$

	0.000	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
0.01	1.00000	0.99931	0.99861	0.99792	0.99723	0.99654	0.99585	0.99516	0.99447	0.99378
0.02	0.99309	0.99240	0.99172	0.99103	0.99034	0.98966	0.98897	0.98829	0.98760	0.98692
0.03	0.97942	0.97874	0.97806	0.97739	0.97671	0.97603	0.97536	0.97468	0.97400	0.97333
0.04	0.97265	0.97198	0.97131	0.97063	0.96996	0.96929	0.96862	0.96795	0.96728	0.96661
0.05	0.96594	0.96527	0.96460	0.96393	0.96326	0.96259	0.96193	0.96126	0.96059	0.95993
0.06	0.95926	0.95860	0.95794	0.95727	0.95661	0.95595	0.95528	0.95462	0.95396	0.95330
0.07	0.95264	0.95198	0.95132	0.95066	0.95000	0.94934	0.94868	0.94803	0.94737	0.94671
0.08	0.94606	0.94540	0.94475	0.94409	0.94344	0.94278	0.94213	0.94148	0.94083	0.94017
0.09	0.93952	0.93887	0.93822	0.93757	0.9692	0.93627	0.93562	0.93498	0.93433	0.93368
0.10	0.93303	0.93239	0.93174	0.93109	0.93045	0.92980	0.92916	0.92852	0.92787	0.92723
0.11	0.92659	0.92595	0.92530	0.92466	0.92402	0.92338	0.92274	0.92210	0.92146	0.92083
0.12	0.92019	0.91955	0.91891	0.91828	0.91764	0.91700	0.91637	0.91573	0.91510	0.91447
0.13	0.91383	0.91320	0.91257	0.91193	0.91130	0.91067	0.91004	0.90941	0.90878	0.90815
0.14	0.90752	0.90689	0.90626	0.90563	0.90501	0.90438	0.90375	0.90313	0.90250	0.90188
0.15	0.90125	0.90063	0.90000	0.89938	0.89876	0.89813	0.89751	0.89689	0.89627	0.89565
0.16	0.89503	0.89440	0.89379	0.89317	0.89255	0.89193	0.89131	0.89069	0.89008	0.88946
0.17	0.88884	0.88823	0.88761	0.88700	0.88638	0.88577	0.88515	0.88454	0.88393	0.88332
0.18	0.88270	0.88209	0.88148	0.88087	0.88026	0.87965	0.87904	0.87843	0.87782	0.87721
0.19	0.87661	0.87600	0.87539	0.87478	0.87418	0.87357	0.87297	0.87236	0.87176	0.87115
0.20	0.87055	0.86995	0.86934	0.86874	0.86814	0.86754	0.86694	0.86634	0.86574	0.86514
0.21	0.86454	0.86394	0.86334	0.86274	0.86214	0.86155	0.86095	0.86035	0.85976	0.84916
0.22	0.85857	0.85797	0.85738	0.85678	0.85619	0.85559	0.88500	0.85441	0.85382	0.85323
0.23	0.85263	0.85204	0.85145	0.85086	0.85027	0.84968	0.84910	0.84851	0.84792	0.84733
0.24	0.84675	0.84616	0.84557	0.84499	0.84440	0.84382	0.84323	0.84265	0.84206	0.84148
0.25	0.84090	0.84031	0.83973	0.83915	0.83857	0.83799	0.83741	0.83683	0.83625	0.83567

Question #1

Activity Remaining for $t/T_{1/2}$

	0.000	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
0.01	1.00000	0.99931	0.99861	0.99792	0.99723	0.99654	0.99585	0.99516	0.99447	0.99378
0.02	0.99309	0.99240	0.99172	0.99103	0.99034	0.98966	0.98897	0.98829	0.98760	0.98692
0.03	0.97942	0.97874	0.97806	0.97739	0.97671	0.97603	0.97536	0.97468	0.97400	0.97333
0.04	0.97265	0.97198	0.97131	0.97063	0.96996	0.96929	0.96862	0.96795	0.96728	0.96661
0.05	0.96594	0.96527	0.96460	0.96393	0.96326	0.96259	0.96193	0.96126	0.96059	0.95993
0.06	0.95926	0.95860	0.95794	0.95727	0.95661	0.95595	0.95528	0.95462	0.95396	0.95330
0.07	0.95264	0.95198	0.95132	0.95066	0.95000	0.94934	0.94868	0.94803	0.94737	0.94671
0.08	0.94606	0.94540	0.94475	0.94409	0.94344	0.94278	0.94213	0.94148	0.94083	0.94017
0.09	0.93952	0.93887	0.93822	0.93757	0.9692	0.93627	0.93562	0.93498	0.93433	0.93368
0.10	0.93303	0.93239	0.93174	0.93109	0.93045	0.92980	0.92916	0.92852	0.92787	0.92723
0.11	0.92659	0.92595	0.92530	0.92466	0.92402	0.92338	0.92274	0.92210	0.92146	0.92083
0.12	0.92019	0.91955	0.91891	0.91828	0.91764	0.91700	0.91637	0.91573	0.91510	0.91447
0.13	0.91383	0.91320	0.91257	0.91193	0.91130	0.91067	0.91004	0.90941	0.90878	0.90815
0.14	0.90752	0.90689	0.90626	0.90563	0.90501	0.90438	0.90375	0.90313	0.90250	0.90188
0.15	0.90125	0.90063	0.90000	0.89938	0.89876	0.89813	0.89751	0.89689	0.89627	0.89565
0.16	0.89503	0.89440	0.89379	0.89317	0.89255	0.89193	0.89131	0.89069	0.89008	0.88946
0.17	0.88884	0.88823	0.88761	0.88700	0.88638	0.88577	0.88515	0.88454	0.88393	0.88332
0.18	0.88270	0.88209	0.88148	0.88087	0.88026	0.87965	0.87904	0.87843	0.87782	0.87721
0.19	0.87661	0.87600	0.87539	0.87478	0.87418	0.87357	0.87297	0.87236	0.87176	0.87115
0.20	0.87055	0.86995	0.86934	0.86874	0.86814	0.86754	0.86694	0.86634	0.86574	0.86514
0.21	0.86454	0.86394	0.86334	0.86274	0.86214	0.86155	0.86095	0.86035	0.85976	0.84916
0.22	0.85857	0.85797	0.85738	0.85678	0.85619	0.85559	0.88500	0.85441	0.85382	0.85323
0.23	0.85263	0.85204	0.85145	0.85086	0.85027	0.84968	0.84910	0.84851	0.84792	0.84733
0.24	0.84675	0.84616	0.84557	0.84499	0.84440	0.84382	0.84323	0.84265	0.84206	0.84148
0.25	0.84090	0.84031	0.83973	0.83915	0.83857	0.83799	0.83741	0.83683	0.83625	0.83567

What is the 3 hour decay factor for Mo-99 which has a half-life of 66.6 hours? **Formula: t/T (t=time elapsed T= half-life)**

Universal Decay Tables

SOLUTION:

Locate the 0.04 on the left side of the table and .005 on the top. Read from the left and down to find the decay factor of 0.96929. Can be rounded to .969 without compromising the degree of accuracy needed in most situations.

Question #2

What is the 68 hour decay factor for Mo-99? Half-life of Mo-99 is 66.6 hours.

Calculate t/T: 68/66.6 hours = 1.021

The decay factor for t/T when greater than 1 , use .500 because of one half life has expired, and the remaining .021 is .98555 on the table.

Multiply the two decay factors to obtain the decay factor for 68 hours:

(.500)(.98555)= .493

Always check your results: $e^{-.693 \times t/T}$

$e^{-.693 \times 68/66.6}$

$e^{-.7076}$

$= .493$

Question #3

What is the 14.5 hour decay factor for I-123 which has a half-life of 13.2 hours?

First, calculate the t/T value: 14.5 hrs/13.2 hrs= 1.098

Remember, when the half-life exceeds 1, use .500, and then use the remaining numbers , therefore, .098= .93433

Now, multiply the two decay factors to obtain the decay factor for 14 hours.

(.500)(.93433) = DF= .467

Remember to always double check your work.

Conclusion: Decay Equations

- **Post-calibration must be calculated correctly in order for the patient to receive the correct dosage.**
  - Failure to properly calculate the dosage can lead to too much or not enough radiation for accurate counting statistics.
  - Too much radiation can lead to high levels of radiation exposures.
  - Can lead to a reportable misadministration event.

Pre-Calibration Mathematics

Tim Marshel R.T
(R)(N)(CT)(MR)(NCT)(PET)(CNMT)

The PET/CT Training Institute
Advancing the Science of Molecular Imaging

Principles of Pre-Calibration

When preparing unit doses and bulk kits, the NMT must determine the amount of activity to be used based on the activity needed at a future time. The time at which the dose is intended for use is referred to as the calibration time. The activity placed in the vial or syringe at preparation time (time 0) will be larger than the actual activity needed at calibration time (time t) in order to account for decay. Pre-calibration factors allow you to determine the activity needed at time 0.

How to calculate activity using a Pre-calibration factor (PCF)or Decay Factor (DF)

- **Calculate the elapsed time between preparation (Ao) and calibration (At)**
- **Refer to the appropriate decay table and select the PCF**
- **Apply the equation**
- **Pre-calibration can be calculated with a PCF or DF.**

Formula :Ao= At x PCF

Formula: Ao= At/DF

Where: At= Activity at time t (calibration time)

Ao= Activity at time o (preparation time)

Technetium 99m Half-life Chart

Technetium ^{99m}Tc

Half Life 6.02 Hours

PCF

DF

Pre Calibration Decay Factor	Hours	Post-Calibration Decay Factor
1.122	1	0.891
1.259	2	0.794
1.413	3	0.708
1.585	4	0.631
1.778	5	0.562
	6	0.501
	7	0.447
	8	0.398
	9	0.355
	10	0.316
	11	0.282
	12	0.251
	18	0.126
	24	0.063

Decay Chart

Note about Pre-calibration

Pre-calibration factors will always be greater than 1, because the activity at preparation time must always be greater than the activity to be used sometime later in the future. A larger value can only be produced by multiplying the original activity by a number greater than 1.

Post calibration or decay factors will always be less than 1, because radioactivity decreases with time. A smaller value can only be produced by multiplying the original activity by a number less than 1.

Question #1 Pre-calibration Method (PCF)

A 22 mCi Tc99m MDP unit dose is needed at 10am. The dose is being prepared at 6am. How many mCi must be placed in the syringe?

PCF Method: Calculate the elapsed time between preparation and calibration time: 4 hours

Select the PCF from the table which is 1.587

<u>Formula: Ao=At x PCF</u>

Calculated Activity to be drawn:

22 mCi x 1.587 = 35 mCi must be withdrawn at 6am for a 10am 22 mCi Tc99m MDP injection.

Question #2 Post Calibration Method (DF)

A 22 mCi Tc99m MDP unit dose is needed at 10am. The dose is being prepared at 6am. How many mCi must be place in the syringe?

Calculate the elapsed time between preparation and calibration time: =4 hours.

Select the decay factor from the Tc99m Table: = .631

<u>Formula: Ao= At/DF</u>

Calculate the activity to be drawn: 22mCi/.631= 35 mCi

The results are identical regardless of which of the two methods is used.

Technetium 99m Half-life Chart

Technetium ^{99m}Tc

Half Life 6.02 Hours

PCF

DF

Pre Calibration Decay Factor	Hours	Post-Calibration Decay Factor
1.122	1	0.891
1.259	2	0.794
1.413	3	0.708
1.585	4	0.631
1.778	5	0.562
	6	0.501
	7	0.447
	8	0.398
	9	0.355
	10	0.316
	11	0.282
	12	0.251
	18	0.126
	24	0.063

Decay Chart

Questions #3

- **Tc99m sodium pertechnetate dose that is to be drawn up at 8:00 A.M. must be calibrated to contain 10 mCi at 11:00 A.M. How many mCi must be placed in the syringe?**

- **Formula: Ao= At x PCF**

- **Unknown Ao= 10 mCi x 1.413**

14 mCi needed at 8am for a 10am 10 mCi dose.

Conclusion: Pre-calibration

- Pre-calibration can be determined by using a Pre-calibration factor (PCF) or a Decay factor (DF)
- It is important to have a good understanding of how much available activity you have on hand at all time, in the event of an add-on emergency patient.
- Always be sure you have enough radiopharmaceuticals to make it through the day and perhaps the night as well.

Specific Activity & Specific Concentration Mathematics

Tim Marshel R.T
(R)(N)(CT)(MR)(NCT)(PET)(CNMT)

The PET/CT Training Institute
Advancing the Science of Molecular Imaging

Principles of Specific Activity and Specific Concentrations

- The specific concentration of a radiopharmaceutical is the activity per unit volume or unit mass. Because most radiopharmaceuticals are in liquid form, one can usually assume units of volume will be used. Activity is expressed as mCi, uCi, or Ci (or MBq, kBq, or GBq), depending convenience or convention.
- You must know the specific concentration in order to calculate the volume of radiopharmaceutical that must be administered in order to provide the patient with the correct dose, or to determine the volume needed to reconstitute a radiopharmaceutical kit to a given activity.

How to calculate Specific Activity

- **Definition:**

$$\text{Specific Activity (SA)} = \frac{\text{Activity}}{\text{Mass}}$$

- **Mass may designate the mass of the radionuclide or labeled compound.**

Specific Activity

- An equation such as this can be solved for several types of useful information:

$$\text{mass} = \frac{\text{activity}}{\text{SA}}$$

or

$$\text{activity} = \text{mass} \times \text{SA}$$

Units of Specific Activity

- mCi/gm, μCi/mg, kBq/mcg, etc.
- Any convenient units of activity/mass.

Sample problem

- A 120 mCi sample of I^{123} is chemically bound to 50 mg of NaI. What is the specific activity of the sample?

$$\text{Specific Activity (SA)} = \frac{\text{Activity}}{\text{Mass}}$$

$$SA = \frac{120\ \text{mCi}}{50\ \text{mg}}$$

$$SA = 2.4\ \text{mCi/mg of}\ I^{123}$$

Sample Problem 2

- Using the previous sample, where SA was found to be 2.4 mCi/mg, how much I123 would be contained in a 90 mCi sample?

$$\text{mass} = \frac{\text{activity}}{\text{SA}}$$

$$\text{mass} = \frac{90\ \text{mCi}}{2.4\ \text{mCi/mg}}$$

mass = 37.5 mg of I-123

Specific Concentration

- **Definition:**

$$\text{Concentration} = \frac{\text{activity}}{\text{volume}}$$

- **Units: mCi/cc, μCi/ml, kBq/cc, etc.**

Specific Concentration

- This equation may also be solved for either volume or activity to yield:

$$\text{activity} = \text{volume} \times \text{concentration}$$

or

$$\text{volume} = \frac{\text{activity}}{\text{concentration}}$$

Sample Problem

- A liquid radioactive sample of Th-201 has a concentration of 10 mCi/cc. What volume must be drawn up to have an activity of 25 mCi?

$$\text{volume} = \frac{\text{activity}}{\text{concentration}}$$

$$\text{volume} = \frac{25\ \text{mCi}}{10\ \text{mCi/cc}}$$

$$\text{volume} = 2.5\text{cc}$$

Sample Problem 2

- A F-18 sample has a concentration of 3.5 mCi /cc. What activity is contained in a volume of 4.25 cc?

activity = volume x concentration

activity = 4.25 cc x 3.5 mCi/cc

activity = 14.875 mCi

Specific Activity

- **Definition:**

$$\text{Specific Activity (SA)} = \frac{\text{Activity}}{\text{Mass}}$$

- **Mass may designate the mass of the radionuclide or labeled compound.**

Specific Activity

- An equation such as this can be solved for several types of useful information:

$$\text{mass} = \frac{\text{activity}}{\text{SA}}$$

or

$$\text{activity} = \text{mass} \times \text{SA}$$

Units of Specific Activity

- mCi/gm, μCi/mg, kBq/mcg, etc.
- Any convenient units of activity/mass.

Sample problem

- A 120 mCi sample of I^{123} is chemically bound to 50 mg of NaI. What is the specific activity of the sample?

$$\text{Specific Activity (SA)} = \frac{\text{Activity}}{\text{Mass}}$$

$$SA = \frac{120\ \text{mCi}}{50\ \text{mg}}$$

$$SA = 2.4\ \text{mCi/mg of}\ I^{123}$$

Sample Problem 2

- Using the previous sample, where SA was found to be 2.4 mCi/mg, how much NaI would be contained in a 90 mCi sample?

$$\text{mass} = \frac{\text{activity}}{\text{SA}}$$

$$\text{mass} = \frac{90\ \text{mCi}}{2.4\ \text{mCi/mg}}$$

$$\text{mass} = 37.5\ \text{mg of NaI}$$

Specific Concentration

- **Definition:**

$$\text{Concentration} = \frac{\text{activity}}{\text{volume}}$$

- **Units: mCi/cc, μCi/ml, kBq/cc, etc.**

Specific Concentration

- This equation may also be solved for either volume or activity to yield:

$$\text{activity} = \text{volume} \times \text{concentration}$$

or

$$\text{volume} = \frac{\text{activity}}{\text{concentration}}$$

Sample Problem

- A liquid radioactive sample of Ga67 has a concentration of 10 mCi/cc. What volume must be drawn up to have an activity of 25 mCi?

$$\text{volume} = \frac{\text{activity}}{\text{concentration}}$$

$$\text{volume} = \frac{25\ \text{mCi}}{10\ \text{mCi/cc}}$$

$$\text{volume} = 2.5\text{cc}$$

Sample Problem 2

- A Xe-133 sample has a concentration of 3.5 mCi /cc. What activity is contained in a volume of 4.25 cc?

activity = volume x concentration

activity = 4.25 cc x 3.5 mCi/cc

activity = 14.875 mCi

Conclusion

If a decay factor must be applied to the activity, it can be applied either before or after the specific concentration is calculated. The answer will be the same regardless of the sequence used.

Dose Volume Determination Mathematics

Tim Marshel R.T.
(R)(N)(CT)(MR)(NCT)(PET(CNMT)

The PET/CT Training Institute
Advancing the Science of Molecular Imaging

Objectives

- Define the principles.
- Discuss how to calculate dose volumes.
- Provide examples of how to calculate dose volumes with at calculator.

Principles

- **In order to calculate the volume of solution needed to provide the desired quantity of radioactivity, the specific concentration of the solution must be known.**

- **The desired dose and specific concentration must be in the same units of activity. If a mCi dose is needed the specific concentration must be in mCi/ml. If a uCi dose is to be used instead, the concentration must be converted to uCi/ml.**

How to calculate Dose Volumes

Formula:

$$\textbf{Required Volume} = \frac{\textbf{Activity desired}}{\textbf{Specific Concentration}}$$

or

$$\textbf{ml} = \frac{\textbf{mCi}}{\textbf{mCi/ml}}$$

The dose or activity required represents what you want.

The specific concentration represents what you have.

An easy way to remember the equation is:

$$\textbf{Volume needed} = \frac{\textbf{what you want}}{\textbf{what you have}}$$

Question #1

- A vial of Tc99m Sodium Pertechnetate contains 375 mCi in 8.2 ml. If a 20 mCi dose is needed, how many ml must be withdrawn from the vial?

Calculate the concentration:

$$\frac{375 \text{ mCi}}{8.2 \text{ ml}} = 45 \text{ mCi/ml}$$

Calculate the required volume:

$$\frac{20 \text{ mCi}}{45 \text{ mCi/ml}} = .4 \text{ ml}$$

Note

- The answer above equation is .43 ml. The number is rounded to .4 ml, however, because the syringes used to prepare doses and inject patients cannot measure to the hundredth place. As a standard practice, syringe volumes should be rounded to the tenths place.

Question #2

- An 18 mCi dose of Tc99m MDP is needed. The kit contains 78.3 mCi in 2.8 ml. What volume must be withdrawn to obtain the desired dose?

- Calculate the concentration: $\frac{78.3 \text{ mCi}}{2.8 \text{ ml}} = 28$ mCi/ml

Calculate the required volume: $\frac{18 \text{ mCi}}{28 \text{ mCi/ml}} = .6$ ml

Note

- If a decay factor is needed, it can be applied to the original activity before the specific concentration is calculated. An alternative method is to calculate the specific concentration, then apply the decay factor. The answer will be the same regardless of the method used.

Question #3

- A vial of Tc99m Sodium Pertechnetate contains 325.8 mCi in 5.3 ml at 3:30pm. At 4:45 pm, a 20 mCi dose is needed. What volume must be withdrawn?
- Calculate the current activity using the decay table: The decay factor for Tc99m for 1 hour 15 minutes is .865.
- 325.8 x .865 = 281.8 mCi

Question #3 Continued

- Calculate the specific concentration: $\frac{281.8 \text{ mCi}}{5.3 \text{ ml}}$

  $= 53 \text{ mCi/ml}$

  Calculate the required volume: $\frac{20 \text{ mCi}}{53 \text{ mCi/ml}}$

  $= .4 \text{ ml}$

  Or another way…..

Question #3 continued

- Calculate the concentration, then multiply by the decay factor:

$$\frac{325.8\text{ mCi}}{5.3\text{ ml}} \times .865 = 53\text{ mCi/ml}$$

Calculate the required volume:

$$\frac{20\text{ mCi}}{53\text{ mCi/ml}} = .4\text{ ml}$$

Effective Half-Life Mathematics

Tim Marshel R.T.
(R)(N)(CT)(MR)(NCT)(PET)(CNMT)

The PET/CT Training Institute
Advancing the Science of Molecular Imaging

Objectives

- Discuss the principles
- Review the methods for calculating effective half-life.
- Provide examples to calculate.

Principles

- The effective half-life (T_e) is used to estimate the patient's radiation dose after administration of a radiopharmaceutical. The effective half-life takes into account both the physical and biological half-life's.
- The physical half-life is fixed. It will be the same regardless of where the radionuclide is, what it is attached to, or the environmental condition to which it is subjected. The biological half-life (T_b), however, will vary depending upon which pharmaceutical is used. The physical half-life of Tc99m is always 6.01 hours. However, the biological half-life of Tc99m labeled radiopharmaceutical will depend upon the pharmaceutical's behavior within the patient's body.

Principles

- The biological half-life varies from patient to patient, because it is affected by metabolism, pathological conditions, radiochemical impurities, age, function of the excretory system, ect. The biological half-life, therefore, is an estimate. Because the biological half-life is an estimate, the effective half-life is also an estimate.

Principles

- The Effective Half-Life combines the physical and the biological half-life's in a way that allows a reasonable estimation of the length of time a person is irradiated by a particular radiopharmaceutical.

How to calculate Effective Half-Life

- **Formula:**

$$\mathbf{T_e = \frac{T_p \times T_b}{T_p + T_b}}$$

Where: T_e= Effective Half-Life
T_p= Physical Half-Life
T_b= Biological Half-Life

Question #1

- If the physical half-life of a radiopharmacetical is 12 hours and the biological half-life of the radiopharmaceutical is 4 hours, what is the effective half-life?

- **Formula:** $$\frac{\mathbf{T_p \times T_b}}{\mathbf{T_p + T_b}} = \frac{12 \text{ hrs} \times 4 \text{ hr}}{12 \text{ hrs} + 4 \text{ hr}} = \frac{48 \text{ hrs}}{16 \text{ hrs}} = 3 \text{ hrs}$$

Question #2

- Calculate the effective half-life for radiopharmaceutical X.

T_p= 75 hrs
T_b= 98 hrs

Formula: $\dfrac{\mathbf{T_p \times T_b}}{\mathbf{T_p + T_b}}$ $\dfrac{75 \text{ hrs} \times 98 \text{ hrs}}{75 \text{ hrs} + 98 \text{ hrs}} = \dfrac{7350 \text{ hr}}{173 \text{ hr}}$

$= 42$ hrs

Question #3

- Calculate the effective half-life for Tc99m MAA using the following data.

T_p= 6 hrs

T_b= 11 hrs

Formula: $$\frac{\mathbf{T_p \times T_b}}{\mathbf{T_p + T_b}} \quad \frac{6\text{ hrs} \times 11\text{ hrs}}{6\text{ hrs} + 11\text{ hrs}} = \frac{66\text{ hrs}}{17\text{ hrs}}$$

$$= 3.88\text{ hrs}$$

Conclusion

- Observe what happens to the effective half-life when the $\mathbf{T_p}$ and $\mathbf{T_b}$ are drastically different from one another. When the biological half-life is very short as compared to the physical half-life, then $\mathbf{T_e=T_b}$.
- The reverse is also true. If the biological half-life is very long compared to the physical half-life, then $\mathbf{T_e= T_p}$. For example, Tc99m Microspheres are released from the liver cells only when they die. The biological half-life is, therefore, in terms of years, while the physical half-life is 6 hours. The effective half-life would, therefore, be 6 hours.

Radiation Dose versus Time Mathematics

Tim Marshel R.T.
(R)(N)(CT)(MR)(NCT)(PET)(CNMT)

The PET/CT Training Institute
Advancing the Science of Molecular Imaging

Objectives

- Discuss the principles of radiation dose versus time.
- Review how to calculate the total radiation dose based on time of exposure.
- Provide examples of math problems.

Principles

- There is a direct linear relationship between radiation dose and time. The radiation dose increases in a linear fashion as the time of exposure increases. The dose resulting from exposure is expressed as the total effective dose equivalent (TEDE) and is measured in rem, mrem, mSv, or uSv.

Principles

- When dealing with x-rays and gamma rays that have energies greater than 30 keV, R, rad, and rem are essentially equivalent for whole-body exposures. Therefore a survey meter reading of 60 mR/hr can be assumed to produce an exposure rate of 60 mrad/hr and an effective dose equivalent of 60 mrem/hr. You are usually concerned with measuring exposure (R) for the purpose of determining the radiation dose to workers or patients (effective dose-equivalent, rem, or Sv).

How to calculate the total radiation dose based on the time of exposure

- **Formula = (dose rate) x (time)**

- **The dose rate and the time must be expressed in the same units of time. Convert one to match the other if necessary.**

Example: 3 mrem/**hr** for 2 **hr**

75 R/**second** for **60 seconds**

Question #1

- If a technologist is exposed to a source with a dose rate of 8.0 mrem/hr for a period of 2 hours, what is the total radiation dose?

- **Formula: (Dose Rate) x (time)**

- 8 mrem/hr x 2 hours= 16 mrem

Question #2

- If the technologist is exposed to the source for 20 minutes, what is the total radiation dose?

- Convert 8 mrem/hr to 8 mrem/60 minutes.

$$\frac{8.0 \text{ mrem}}{60 \text{ minutes}} \times 20 \text{ minutes} = 2.67 \text{ mrem}$$

Question #3

- You are next to a source with a dose rate of 15 uSv/hr. What will be your total radiation dose if you are exposed for 4 hours?
- Formula: (Dose rate) x (Time)
- 15 uSv x 4 hr = 60 uSv

Conclusion

- NRC 10 CFR20 sets the total effective dose equivalent for occupationally exposed individuals and members of the general public. Occupationally exposed workers can receive up to 5 rem/year (.05 Sv). Members of the general public can receive up to .1 rem/year (1.0 mSv). The fetus of an occupationally exposed female is not to receive more than .5 rem (5 mSv) during gestation after written declaration of the pregnancy.

Conclusion

- Other radiation dose terms also used by the NRC include deep-dose-equivalent (DDE), shallow-dose-equivalent (SDE), committed dose-equivalent (CDE), eye-dose equivalent (EDE), and annual limit on intake (ALI).

Radiation Dose versus Distance Mathematics

Tim Marshel R.T.
(R)(N)(CT)(MR)(NCT)(PET)(CNMT)

The PET/CT Training Institute
Advancing the Science of Molecular Imaging

Objectives

- Discuss the principles of the Inverse Square Law
- Review how to calculate the radiation dose based on distance.
- Provide examples of equations for solving for Inverse Square Law.

Principles

- **There is an inverse geometric relationship between the radiation dose and the distance from a source of radiation. Radiation is emitted symmetrically from a source, with photons traveling in all directions. The path of the emissions diverge from one another to a greater degree the farther from the source you move.**
- **Close to the source, you interact with many emissions. As you move further from the source, the number of interactions drop off rapidly, by the square of the distance. This is referred to as the Inverse Square Law.**

How to calculate the radiation dose based on the distance (Inverse Square Law)

- **Formula:** $\frac{I_1}{I_2} = \frac{(D_2)^2}{(D_1)^2}$

or

$$(I_1)(D_1)^2 = (I_2)(D_2)^2 \text{ (most common)}$$

I_1= Intensity at original distance (D_1)
I_2= Intensity at new distance (D_2)
This is an inverse proportion.

Question #1

- **You are standing 1 foot from a radioactive patient and receiving a radiation exposure dose of 20 mrem/hr. If you move to a position 2 feet from the patient, what will be your rate of exposure?**
- **Formula: $(I_1)(D_1)^2 = (I_2)(D_2)^2$**

$I_1 =$ 20 mrem
$I_2 =$ (x) unknown
$(D_1)^2 =$ (1 ft.)^2
$(D_2)^2 =$ (2 ft.)^2

- $\dfrac{(20\ \text{mrem/hr})(1\ \text{ft})^2}{4\ \text{ft}} = \dfrac{20}{4\ \text{ft}} =$ 5.0 mrem/hr

Question #2

- **A radioactive source produces 150 mrem/hr at 1 meter. What is the exposure rate at 3 meters?**

- **Formula:** $(I_1)(D_1)^2 = (I_2)(D_2)^2$

$I_1 =$ 150 mrem/hr
$I_2 =$ (x)
$(D_1)^2 = (1)^2$
$(D2)^2 = (3)^2$

$(150\ \text{mrem/hr})(1\ \text{meter})^2 = (x)(3\ \text{meters})^2$

$$\frac{(150\text{mrem/hr})}{9\ \text{meters}} = 16.67\ \text{mrem/hr}$$

Question #3

- **A technologist is standing 6 inches from a radioactive patient which results in an exposure rate of 10 mrem/hr. To what distance must the technologist move to decrease the exposure to a background level of .05 mrem/hr?**

- **Formula: $(I_1)(D_1)^2 = (I_2)(D_2)^2$**
- **I_1 = 10 mrem/hr**

I_2 = .05 mrem/hr

$(D_1)^2$ = 6 inches

$(D_2)^2$ = (x) unknown

(10 mrem/hr)(6 inches)^2 = (.05 mrem/hr) $(x)^2$

$$(x)^2 = \frac{(10\ \text{mrem/hr})\ (36)}{.05} = \quad (x)^2 = \frac{360}{.05} \quad (x) = \sqrt{7200}$$

x= 85 inches or approx. 7 feet

Conclusion

- **By doubling the distance you have decreased the exposure rate to one quarter of the original dose rate.**
- **NRC 10CFR20 sets the total effective dose equivalent (TEDE) for workers over the age of 18 at 5 rem/year or 5000 mrem/year. For members of the general public, the TEDE is .1 rem/year or 100 mrem/year.**
- **NRC 10CFR20 and 10CFR35 require employees to participate in an ALARA program, which strives to minimize radiation exposure to a level As Low As Reasonably Achievable. The suggested level is 10% of the TEDE. Ideally then, an occupationally exposed worker would receive a whole-body dose of no more than .5 rem/year or 500 mrem/year.**

Conclusion

- **NRC 10CFR20 gives the limit for exposure to the extremities as 50 rem/year (.5 Sv).**
- **Members of the general public must not receive an exposure from external sources that exceed 2 mrem in an hour when in an unrestricted area.**
- **NRC 10CFR20 states that members of the general public must not receive an exposure from an external source that exceeds 2 mrem in any hour, therefore, visitors to patients who have received therapeutic doses of radionuclide's, must stay back to a line marked on the floor identifying the 2 mrem/hr limit.**

Radiation Dose versus Shielding Mathematics

Tim Marshel R.T.
(R)(N)(CT)(MR)(NCT)(PET)(CNMT)

The PET/CT Training Institute
Advancing the Science of Molecular Imaging

Objectives

- Discuss the principles of radiation dose versus shielding materials.
- Review how to solve mathematical problems using the half-value layer formula.
- Provide examples of problems.

Principles

- **Shielding decreases exposure rates according to the thickness and density of the shielding material used, and the type and energy of radiation involved.**
- **The denser the material, the higher the probability that a photon or particle will collide with an atom of the shielding material. By increasing the thickness of shielding, you increase the probability of an interaction because the photon must pass through more atoms before exiting the shield.**
- **A low energy radionuclide is more likely to lose all its energy to interactions within the shield than high energy radionuclide. Because of its mass, a beta particle is more likely to interact with shielding material than is a photon. The thickness and density of materials needed to shield betas of a given energy are significantly less than that needed for the same energy photons.**

Principles

- The effectiveness of a shielding material is measured in half-value layers (HVL). For example, the HVL of lead is .27 mm for the 140 keV photon of Tc99m and 3 mm for the 364 keV photon of I-131.
- Each HVL will decrease the exposure rate to one half its original intensity.

Principles

Number of HVLs	Percent of Original Exposure Rate	Fraction of Original Exposure Rate
1	50%	0.50
2	25%	0.25
3	12.5%	0.125
4	6.3%	0.063
5	3.1%	0.031
6	1.6%	0.016
7	0.8%	0.008
8	0.4%	0.004
9	0.2%	0.002
10	0.1%	0.001

How to calculate the change in exposure rate due to shielding

- **Formula: $I = I_o e^{-(.693)(x/HVL)}$**

I	=	Exposure rate (intensity) being calculated
I_o	=	Original exposure rate (intensity)
e	=	Euler's constant (2.718…)
-.693	=	Natural log of 2. Reducing the intensity by half.
x	=	Thickness of shielding material
HVL	=	Half value layer for given shielding material

Question #1

- The half value layer of lead for Ga67 is .1 cm. A vial of Ga67 is stored in a lead shield that is .7 cm thick. If the exposure rate for the unshielded vial is 730 mR/hr, what will it be when the vial is placed in the shield?
- **Formula:** $I=I_o e^{-(.693)(x/HVL)}$

I= (x) Unknown

I_o= 730 mR/hr

-.693

X = .7 cm

HVL = .1 cm

$I = 730\, e^{-(.693)\,(.7/.1)}$

$I = 730\, e^{-(.693)(7)}$

I = 730 (.0078)

I = 5.70 mR/hr

How to do on Calculator (TI30XIIS)

- 730
- 2nd
- LN
- (-)
- .693
- X
- 7
-)
- =
- 5.709

Question #2

- **The half-value layer of lead for Tc99m is .3mm. If a radiopharmaceutical dose is producing 11 R/hr, what will be the exposure rate if the dose is placed in a lead syringe shield that has a thickness of 2.5 mm?**
- **Formula: $I=I_o e^{-(.693)(x/HVL)}$**

I = Unknown
Io = 11 R/hr
-.693
X = 2.5mm
HVL = .3

$I= 11\ e^{-(.693)(2.5/.3)}$
$I= 11\ e^{-(.693)(8.33)}$
$I= 11\ e^{-5.772}$
$I= 11\ (.0031)$
$I= .034$ R/hr or 34 mR/hr

How to do on Calculator (TI30XIIS)

- 11
- 2nd
- LN
- (-)
- .693
- x
- 8.3
-)
- =
- .0349 R/hr or 34.9 mR/hr

Question #3

- A radioactive source produces an exposure rate of 15 mR/hr outside a 1 HVL shield. If an additional two half-value layers are added, what will the resultant exposure rate be?

- Original Intensity = 15 mR/hr
- Add 1 HVL = 7.5 mR/hr
- Add 1 HVL = 3.75 mR/hr

Conclusion

- NRC 10CFR35 requires all doses and vials containing radionuclide's to be shielded. This includes the time during which doses are being drawn up and injected.
- NRC 10CFR 20 requires unrestricted areas of public access to have exposure rates that do not exceed 2 mrem in any hour. The 2 mrem in an hour exposure rate from a photon producing source would be indicated by an ionization survey meter reading 2 mR/hr.

Units Conversion Mathematics

Tim Marshel R.T.
(R)(N)(CT)(MR)(NCT)(PET)(CNMT)

The PET/CT Training Institute
Advancing the Science of Molecular Imaging

Objectives

- Review how to convert between curie and Becquerel's
- Discuss how to convert between rads and grays
- Review how to convert between rems and sieverts
- Provide examples to calculate

Principles

- In 1975, the International Commission on Radiological Units (ICRU) adopted the International System (SI) as the standard for measurement of radioactivity.
- The becquerel (Bq) was the preferred unit of measurement for radioactivity over the old standard of curie (Ci).
- The becquerel is equivalent to 1 disintegration per second (dps).
- Although the Bq is the accepted unit, many texts and practioners continue to use the curie (Ci) out of habit, tradition, or preference.

Principles

- **The conventional curie units are usually converted to Becquerel's as follow:**

- **curie (Ci) to gigabecquerels (GBq)**
- **millicuries (mCi) to megabecquerels (MBq)**
- **microcuries (uCi) to kilobecquerels (kBq)**

- **1 Bq = 1 dps**

- **Because 1 Ci equals 3.7 x 10^{10} disintegration per second (dps), Becquerel, or 37 billion disintegration per second, you will always have a larger number in Bq than Ci when converting between the two commonly used units as listed above.**

HOW TO **CONVERT CURIES TO BECQUERELS; AND BECQUERELS TO CURIES**

- Multiply the number of curies by the equivalent number of becquerels.

1Ci = 37GBq

1mCi = 37MBq

1µCi = 37kBq

- Multiply the number of becquerels by the equivalent number of curies.

1Bq = 2.7 10^{-11}Ci

1GBq = 0.027Ci or 27mCi

1MBq = 0.027mCi or 27µCi

1kBq = 0.027µCi

USING CALCULATOR TO SOLVE A PROBLEM. CALCULATOR: (TI-30X IIS)

- **Problem I: Convert 25mCi to MBq.**

1- Plug in 25

2- Multiply ( ) by 37

(because 1mCi = 37MBq)

4- Enter (=)

5- 925

6- Answer: 925MBq

- **Problem II: Convert 75Ci to kBq.**

1. Plug in 75
2. Multiply ( ) by 37
    - because 1Ci = 37kBq)
3. Enter (=)
4. 2775
5. Then multiply 2775 1000,000 or 10^6
6. Enter (=)
7. $2.7E^9$
8. Answer: $2.7kBqE^9$

USING CALCULATOR TO SOLVE A PROBLEM. CALCULATOR: (TI-30X IIS)

- **<u>Problem I</u>: Convert 25mCi to MBq.**

1- Plug in 25

2- Multiply ( ) by 37

(because 1mCi = 37MBq)

4- Enter (=)

5- 925

6- Answer: 925MBq

- **Problem II: Convert 75Ci to kBq.**

1. Plug in 75
2. Multiply ( ) by 37
   - because 1Ci = 37kBq)
3. Enter (=)
4. 2775
5. Then multiply 2775 1000,000 or 10^6
6. Enter (=)
7. $2.7E^9$
8. Answer: $2.7kBqE^9$

Note

- When you convert from kBq to MBq divide ( ) by 1000, and kBq to GBq divide ( ) by 1000,000 or 10^6.
- When you convert from GBq to MBq multiply ( ) by 1000, and GBq to kBq multiply ( ) by 1000,000 or 10^6

How to convert curies to Becquerel's

- Multiply the number of curies by the equivalent number of Becquerel's.

- 1 Ci= 37 GBq
- 1 mCi= 37 MBq
- 1 uCi= 37 kBq

- Formula: GBq= (Ci)(37 GBq/Ci)
- Formula: MBq = (mCi)(37 MBq/mCi)
- Formula: kBq = (uCi)(37 kBq/uCi)

Question #1

- Convert 30 Ci to GBq.

- Formula: GBq = (Ci)(37 GBq/Ci)

  If 1 Curie = 37 GBq

  then

  GBq= (30 Ci)(37 GBq/Ci)

  = 1110 GBq

Question #2

- Convert 10 mCi to MBq.

- Formula: MBq = (mCi)(37 MBq/mCi)

  If 1 mCi = 37 MBq

  then

  MBq=(10 mCi)(37 MBq/mCi)

  =370 MBq

Question #3

- Convert 100 uCi to kBq.

- Formula: kBq= (uCi)(37 kBq/uCi)
- If 1 uCi = 37 kBq

then

(100 uCi)(37 kBq/uCi)

= 3700 kBq or 3.7×10^3 kBq

Principles

- The traditional unit for absorbed dose is the rad (radiation absorbed dose). The International System (SI) unit is the gray (Gy).

- These units are used to measure the amount of energy deposited in tissue by ionizing radiation.

How to convert rad to grays

- Multiply the number of rad by the equivalent number of Gy.

Formula: Gy= (rad)(.01 Gy/rad)

1 rad = .01 Gy

1 mrad= .01 mGy

or

1 Gy= 100 rad

1 mGy= 100 mrad

-

How to Convert rad to grays, and grays to rad:

- Multiply the number of rad by the equivalent number of Gy.
  1 rad= 0.01 Gy
  1 mrad= 0.01 mGy
- Multiply the number of Gy by the equivalent number of rad.
  1 Gy= 100 rad
  1 mGy= 100 rad
- Equations:
- Gy=rad X 0.001Gy
- Mrad=mGy X 100mrad/mGy

The properties of rad and grays:

- Converting rad to grays is the same method of converting curies to becquerels.

rad to gigagrays(Ggy)

millirad(mrad) to milligrays(mGy)

microrad(µrad) to micrograys (µGy)

Using Calculator to Solve an Equation.

- **rad to grays**
- Put the number of rad you wish to change and multiply (x) by 0.001
- **grays to rad**
- Put the number of Gy you wish to change and multiply (X) it by 100
- Remember that depending on property you must divide (/) or multiply(x) by 1000 or 1000000.

- **Problems**
- Convert 66 mrad to mGy and µGy:
  66rad X 0.01mGy/rad=.66mGy
  66rad X 0.01µGy/rad=.66mGyX1000µ Gy/mGy=660µGy

- Convert 3 µgy to µrad and mrad:
  3 µgy X 100µrad/ugy= 300µgy
  3 µgy X 100mrad/µgy= 300mgy/1000mrad/mgy= .3mrad

Note

- When going from mrad to urad multiply by 1000, when going from µrad to mrad divide by 1000. When going from rad to µrad multiply by 1000000, when going from µrad to rad devide by 1000000.

Question #1

- Convert 5 rad to grays.

Formula: Gy= (rad)(.01 Gy/rad)

rad= .01 Gy or 1 Gy=100 rad

then

=(5 rad)(.01 Gy/rad)

= .05 Gy

Note

- When converting between the traditional and the SI system, you are using a direct proportion.

$$\frac{.01\ \text{Gy}}{1\ \text{rad}} = \frac{(x)\ \text{Gy}}{5\ \text{rad}}$$

$$(x) = \frac{(.01\ \text{Gy})(5\ \text{rad})}{1\ \text{rad}}$$

$$(x) = .05\ \text{Gy}$$

Question #2

- Convert .2 mGy to mrad.

Formula: mGy= (mrad)(.01 mGy/mrad)

1 mrad= .01 mGy

1 mGy= 100 mrad

then

(.2 mGy)(100 mrad/mGy)

= 20 mrad

Question #3

Convert 66 mrad to mGy and uGy:

Formula: mGy= (mrad)(.01 mGy/mrad)

1 mrad= .01 mGy

1 mGy= 100 mrad

- mGy= (66 mrad)(.01 mGy/mrad)

  = .66 mGy

  = 666 uGy

To convert mGy to uGy, move the decimal point three places to the right.

How to convert rem to sievert

- The traditional unit for dose equivalent is the rem (roentgen equivalent man). The International System (SI) unit is the sievert (Sv).
- These units are used to measure the potential effects of an absorbed dose (rad) based on the type of radiation involved (quality factor).
- Multiply the number of rem by the equivalent number of Sv.

Formula: Sv=(rem)(.01 Sv/rem)

Formula: mSv=(100 mrem/mSv)

1 Sv= 100 rem

1 mSv= 100 mrem

CONVERTING BETWEEN REM AND SIEVERTS; AND SIEVERTS TO REM

- **How to convert rem to sieverts:**

- Multiply the number of rem by the equivalent number of Sv.

1rem= 0.01 Sv
1mrem= 0.01 mSv

- **How to convert sieverts to rem**

- Multiply the number of Sv by the equivalent number of rem.

1Sv=100 rem
1 mSv= 100 mrem

According to Patrica Wells

- **Examples & How to Use on Calculator**

- Convert 4 rem to sieverts

1. 4
2. X Multiplied by
3. 0.01- because 1 rem is equal to 0.01
4. =
5. 0.04
6. Don’t forget to add the dose or you’ll obtain the wrong answer.

- **Examples**

- Convert 5000mrem to mSv
- Convert 7.2 mSv to mrem and rem

Note

- Multiply the number of rem by the equivalent number of Sv.
- Multiply the number of Sv by the equivalent number of rem.

Note

- The relationship between rem and Sv is the same as that between rad and Gray.
- Because 1 rem equals 1/100th of a Sv, you will always have fewer Sv than rem when converting between equivalent tradition units and SI units.

Question #1

- **Convert 7 rem to sieverts.**

Formula: Sv=(rem)(.01 Sv/rem)

1 Sv= 100 rem

(7 rem)(.01 Sv/rem) = .07 Sv or 70 mSv

Question #2

Convert .2 rem to Sv and mSv.

Formula: Sv=(rem)(.01 Sv/rem)

1 Sv= 100 rem

(.2 rem)(.01 Sv/rem)= .002 Sv or .2 mSv

Note

- When converting between the traditional and the SI system, you are using direct proportions.

$$\frac{.01\ \text{Sv}}{1\ \text{rem}} \quad \frac{(x)\ \text{Sv}}{5\ \text{rem}} \qquad (x) = \frac{(.01\ \text{Sv})(5\ \text{rem})}{1\ \text{rem}}$$

$$(x) = .05\ \text{Sv}$$

Question #3

- Convert 36 mrem to mSv.

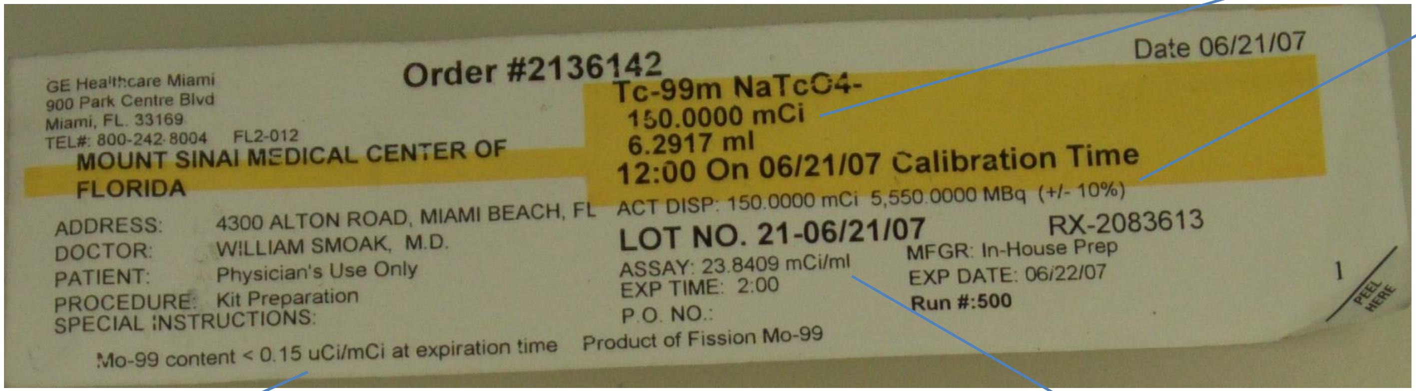
Formula: mSv=(100 mrem/mSv)

1 mSv= 100 mrem

(36 mrem)(.01 mSv/mrem) = .36 mSV

Conclusion

When converting units between traditional and the SI will be an important function for the NMT when handling incoming shipments.



Any Questions?

Send questions to: tkmarshel@thepetcttraininginstitute.com or attend a lecture series at http://na1.connect.acrobat.com/petctclassroom