

Radiation Safety Short Course

Radiation Detectors & Survey Instrumentation

Environmental Health and Safety
Radiation Control and Radiological Services

Welcome to the University of Florida Radiation Safety Short Course presented by Environmental Health and Safety's Radiation Control office. This is Chapter 4 – Radiation Detectors and Survey Instrumentation.

Survey Meter Support Services

RC&RS provides:

- Pick-up and delivery of meters
- Required 9-month calibration
- Preventive maintenance and repairs
- Shipping for extensive repairs

RC&RS Contact:

John Parker
Nuclear Science Center
392-7359

Radiation Control provides support services for survey meters at campus locations. We provide pick-up and delivery, nine month calibrations, and preventive maintenance and repairs. For extensive problems we will need to ship the meters to the vendor for repairs. The contact person for all meter issues is John Parker, he can be reached at 392-7359.

Types of Surveys

- Direct measurements
 - Portable survey instruments
- Indirect measurements
 - Swipes and use of counters (Liquid Scintillation and Gamma)

There are two types of surveys. Direct and indirect. Direct measurements are taken with portable survey instruments and provide immediate information. Indirect measurements are taken by swiping the area and then counting the swipes in either a Liquid Scintillation Counter or Gamma Counter.

Use of Portable Survey Instruments

- ✓ Read the instrument's operating manual
- ✓ Check the batteries before each use



Before using a survey meter it is important to understand it. If there is a manual for the meter used in your lab please familiarize yourself with it. One of the most important things to do is to check the batteries before each use. If the batteries are not working properly you will not be able to tell if there is contamination present.

Use of Portable Survey Instruments

- Use a check source to determine operability of detector
- Determine efficiency of detector
- Determine the instruments response time
- Determine the operating background

If there is a check source for your survey meter then use it to determine the operability of the detector. Some meters have check sources located on the side. The efficiency will be noted on the side of the meter. Always ensure that the instrument response time is switched to Fast (this could be an F or a rabbit). It is also good to determine the background.



This is an example of a survey meter that has a check source on the side.

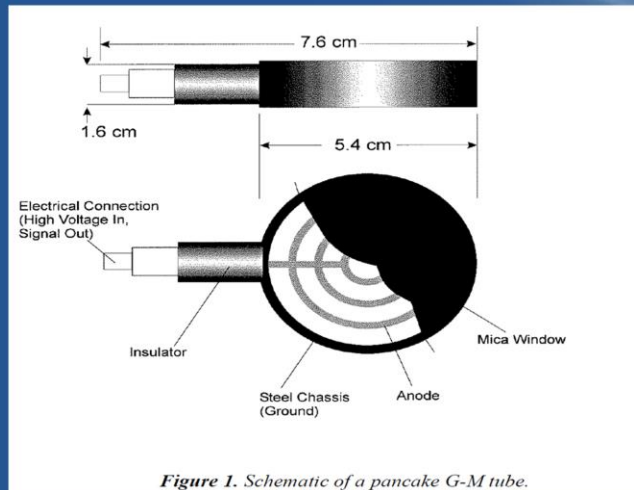
Geiger Mueller (GM) Detectors



- Used for radioactive contamination monitoring
- Detects high energy beta radiation
- GM measures each individual interaction inside the detector
- Do **NOT** identify the radioisotope or specific energy

Geiger Mueller (or GM) Detectors are used for direct radioactive contamination monitoring. These detectors are able to detect high energy beta radiation. They do this by measuring each individual interaction inside the detector. It is important to note that GM detectors do not identify the radioisotope or specific energy.

Pancake Probe on GM Detector



Most GM detectors are outfitted with a Pancake probe. There is a mica window covering the probe that is extremely delicate. If these windows are punctured the meter will not function properly.

Geiger Mueller Detectors



- GM Detectors – Do NOT identify the radioisotope or the specific energy!

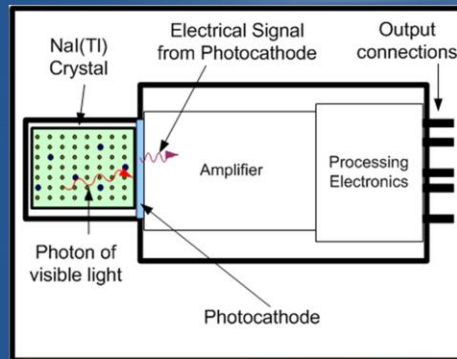
Let me stress, GM detectors do not identify the radioisotope or the specific energy!



Sodium iodide probes

Sodium Iodide (NaI) Probe

- Probe has a NaI crystal and a photomultiplier tube
- Detection is based on emission of photons



These probes have a sodium iodide crystal and a photomultiplier tube. Detection of the radiation is based on emission of photons.

Sodium Iodide (NaI) Probe

- Used for radioactive contamination monitoring
- Detects low energy gamma-rays
- Does NOT identify the radioisotope



Sodium iodide probes are used for direct radioactive contamination monitoring. They are used to detect low energy gamma-rays. These probes do not identify the radioisotope



This is an example of a Civil Defense kit that was provided to communities in the 60's.

Nal Probes



Nal probes do
NOT identify the
radioisotope or
the specific
energy!

Again, let me stress, sodium iodide probes do not identify the radioisotope or the specific energy!

Ionization Chambers



- Ion Chambers are filled with air
- Used for measuring radiation field intensity (exposure rate)
- Detect x-rays and gamma radiation
- Measure average current produced over many interactions
- Do NOT identify the radioisotope or specific energy

Ionization Chambers are used to detect x-rays and gamma radiation. The chambers are filled with air and measure average current produced over many interactions. They are used for measuring radiation field intensities (or exposure rates). They do not identify the radioisotope of the specific energy.

Ion Chamber

- a.k.a, Dose rate meter or micro-R meter



Ion chambers have several names, they are sometimes referred to as dose rate meters or micro-R meters.

Ion Chambers



- Ion Chambers do NOT identify the radioisotope or the specific energy.

Remember, ion chambers do not identify the radioisotope or the specific energy.

Ionization Chambers

A.K.A. – Dose Rate Meter

Roentgen (R): a unit of exposure to **x-rays** or **gamma rays**. One roentgen is the amount of gamma or x-rays needed to produce **ions** carrying 1 electrostatic unit (esu) of electrical charge in 1 cubic centimeter of dry air under standard conditions.

Ion chambers or Dose rate meters read in units of Roentgen. This is a unit of exposure to x-rays or gamma rays. One roentgen is the amount of gamma or x-rays needed to produce ions carrying 1 electrostatic unit of electrical charge in 1 cubic centimeter of dry air under standard conditions.

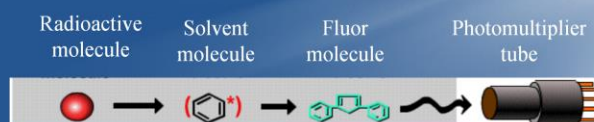
Liquid Scintillation Counter (LSC)

- Detection is based on emission of visible or near visible light (photon)
- Sample vial must contain scintillation cocktail
- Interaction between radiation and cocktail causes photons to be emitted
- Photomultiplier tubes are used to detect and amplify the photons

Indirect measurements can be done by using liquid scintillation counters or LSCs. Detection is based on emission of visible or near visible light. The sample vial must contain a scintillation cocktail. Interactions between the radiation and the cocktail cause photons to be emitted, the photomultiplier tube is used to detect and amplify the photons.

The Scintillation Process

- Beta particles are emitted, which cause solvent molecules to become excited.
- The energy of the solvent molecule is transferred to the fluor molecule, which in turn emits light.



Beta particles are emitted, which then cause the solvent molecules to become excited. The energy of the solvent molecule is transferred to the fluor molecule, which in turn emits light.

LSC

- It can identify the activity and energy of a beta emitter in a sample vial
- It is much more efficient than a portable survey meter



LSCs can identify the activity and energy of a beta emitter in a sample vial. It is much more efficient than a portable survey meter. It is also the only means for detecting tritium contamination. Tritium is a low energy beta emitter and cannot be seen with a GM detector.



This is an example of an older LSC.

Gamma Counters

- Detection is based on emission of visible or near visible light (photons).
- Uses solid scintillation (no scintillation cocktail required).
- Interaction between radiation and a solid scintillator causes photons to be emitted.
- Photomultiplier tubes detect and amplify photons.

Another indirect measurement device is a gamma counter or GC. Detection is also based on emission of visible or near visible light. They use solid scintillation, meaning no scintillation cocktail is required. Interaction occurs between the radiation and the solid scintillator causing photons to be emitted. The photomultiplier tubes detect and amplify the photons.

Gamma Counter

- Used to determine the activity of a gamma emitter in a sample vial.
 - Unlike the LSC, the scintillation crystal surrounds the sample.
 - The gamma rays interact with the crystal, are absorbed, and produce light.
- Gamma counters can identify activity and energy of gamma emitters.

Gamma counters are used to determine the activity of a gamma emitter in a sample vial. Unlike the LSC, the scintillation crystal surrounds the sample. The gamma rays interact with the crystal, are absorbed, and produce light. Gamma counters can identify activity and energy of gamma emitters.



Here is an example of a gamma counter.

Choosing the correct instrument



- Radiation Field / Dose Rate (mR/hr)
 - Ion chamber
- Activity / Contamination
 - Beta emitters
 - Low and Mid energy
 - LSC only
 - High energy
 - GM Detector
 - LSC (for documentation purposes)
 - Gamma emitters
 - Sodium Iodide
 - Gamma counter (for documentation purposes)

When choosing the correct instrument for your work consider the following: will you be working in a radiation field? If so, you want a dose rate meter or ion chamber. Are you working with low and mid-energy beta emitters, if so you will need access to a working LSC. Are you working with high energy beta emitters, if so you will need a GM detector and access to a working LSC. Will you be working with gamma emitters, if so you will need a sodium iodide probe and access to a working gamma counter.

			Primary uses of detectors				
			Fixed or removable beta contamination monitoring.	Dose rate assessment.	Fixed or removable gamma contamination monitoring.	Assessment of removable gamma contamination and sample counting.	Assessment of removable beta contamination and sample counting.
Detector Types			GM Tube	Ion Chamber	Nal Probe	Gamma Counter	Liquid Scintillation Counter
a)	³² P surface contamination (Beta emitter)						
b)	x-rays from a dental machine						
c)	a ¹²⁵ I labeled bacteria sample (EC-Gamma emitter)						
d)	a ³ H labeled water sample (Beta emitter)						

Sample problem for detectors: Let's say you are working with P-32 and you want to know if there is any surface contamination. Remember that P-32 is a beta emitter. Which detector and/or counter would you need? Remember GM detectors will tell you if there is something there and an LSC will provide you with documentation that there is contamination there or not.

Let's say you are working in an area with dental x-ray units and you want to know if there are scattered x-rays coming from the units. Which detector or counter would you use? Remember, you are looking at a field of radiation so you will need an ion chamber.

Let's say you are working with and Iodine-125 labeled bacteria sample and you want to ensure there is no contamination in your work area. What detectors or counters would you use? For direct measurement you would choose the sodium iodide probe and then document the results with either an LSC or a gamma counter.

You are working with a tritium labeled water sample in the lab. How would you determine if there is any contamination in you work area? The only way you will see it is by using a liquid scintillation counter.

Useful Formulas/Conversions

Hmm...a
conversion
might help
here!

- $1 \mu\text{Ci} = 2.22 \times 10^6 \text{ dpm}$
- $\text{net cpm} = \text{gross cpm} - \text{background}$
- $\text{efficiency} = (\text{net cpm}) / (\text{dpm})$
- $\text{dpm} = (\text{net cpm}) / (\text{efficiency})$
- $\text{cpm} = (\text{dpm}) \times (\text{efficiency})$

Some very useful formulas and conversion factors for solving problems in this section are as follows: 1 microcurie is equal to 2.22E6 dpm. Net counts per minute can be obtained by subtracting the background from the gross counts per minute.

Efficiency is obtained by dividing the net counts per minute by the disintegration per minute.

Disintegrations per minute are merely the net counts per minute divided by the efficiency

Counts per minute can be found by multiplying the disintegrations per minute by the efficiency.

Sample Problem 1

You have a swipe that was counted for 5 minutes that yields 5800 counts.

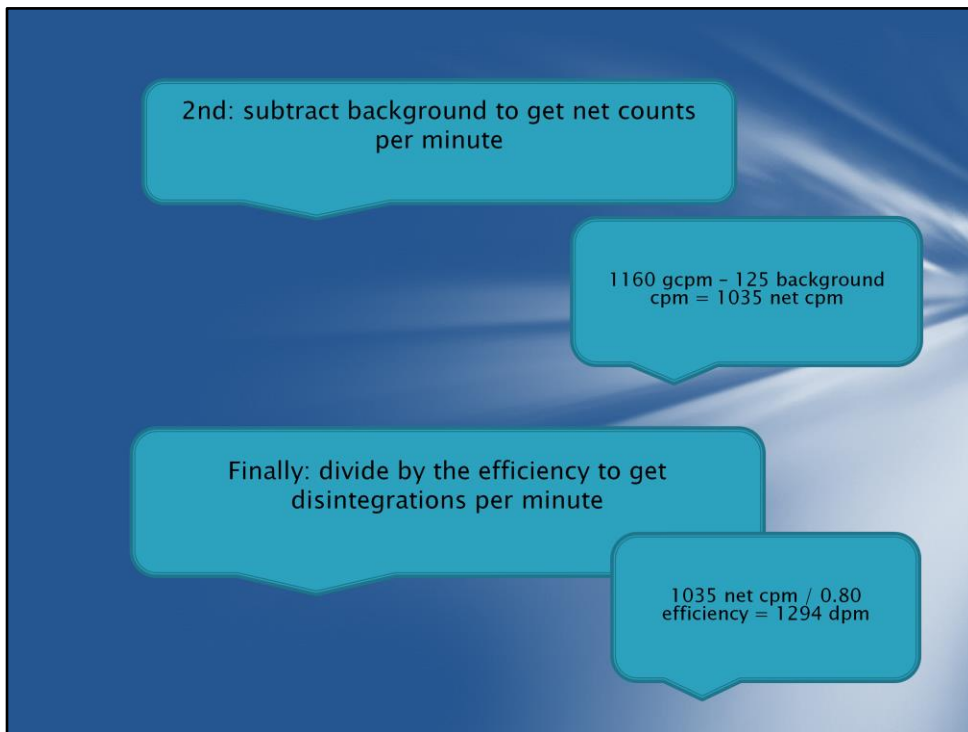
If the background is 125 cpm and the counter efficiency is 80%, calculate the dpm of the swipe.

1st: calculate the gross counts per minute

$$5800 \text{ counts} / 5 \text{ minutes} = 1160 \text{ gross cpm}$$

So let's try some sample problems. The first problem, you have a swipe that was counted for 5 minutes that yields 5800 counts. If the background is 125 counts per minute and the counter efficiency is 80%, calculate the disintegrations per minute of the swipe.

First you must calculate the gross counts per minute. 5800 counts divided by 5 minutes which equals 1160 gross counts per minute.



Then, subtract the background (125 cpm) to get net counts per minute. So 1160 gross cpm – 125 background cpm = 1035 net cpm.

Finally, divide the net counts per minute by the efficiency (80%) to obtain disintegrations per minute. (1035 net cpm/0.8 = 1294 dpm)

Sample Problem 2

You have a standard that has an activity of 105,000 dpm.

After 2 minutes of counting in a gamma counter you get 120,000 counts.

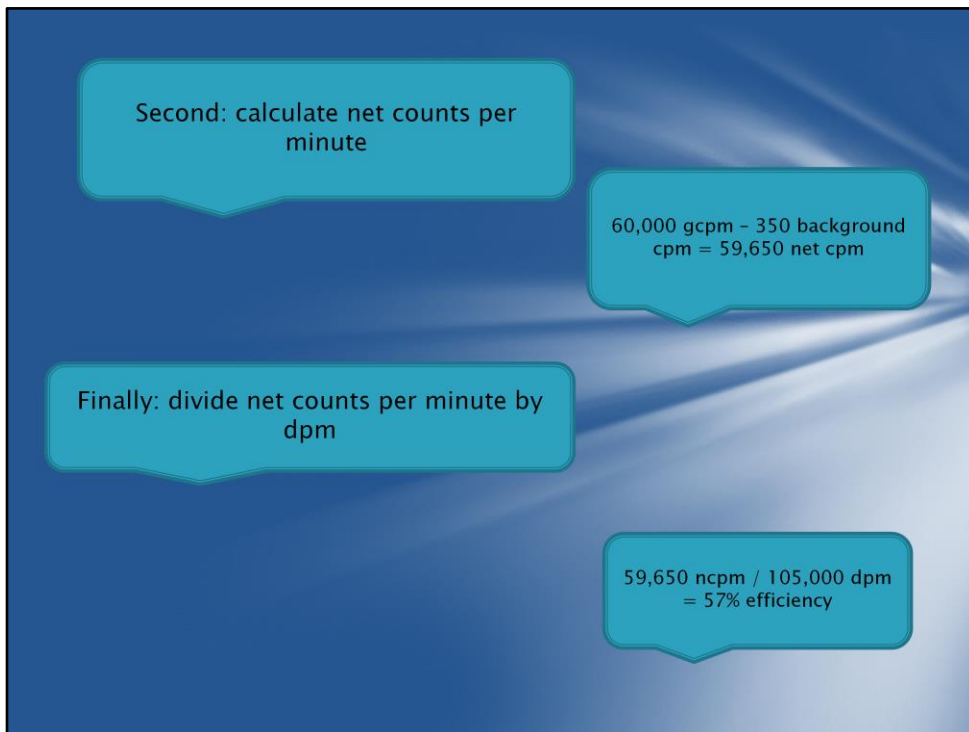
If the background is 350 cpm, what is the efficiency of the gamma counter?

First: calculate gross counts per minute

$$120,000 \text{ counts} / 2 \text{ minutes} = 60,000 \text{ gross cpm}$$

Sample problem 2. You have a standard that has an activity of 105,000 dpm. After 2 minutes of counting in a gamma counter you get 120,00 counts. If the background is 350 cpm, what is the efficiency of the gamma counter?

First you will need to calculate the gross counts per minute (120,000 counts divided by 2 minutes which gives us 60,000 gross cps).



Next, calculate the net counts per minute by subtracting the background (350 cps). So 60,000 gross cpm – 350 counts per minute gives us 59,650 net cpm. Finally, divide the net counts per minute by the disintegrations per minute. (59,650 net counts per minute divided by 105,000 disintegrations per minute gives up 57% efficiency

Sample Problem 3

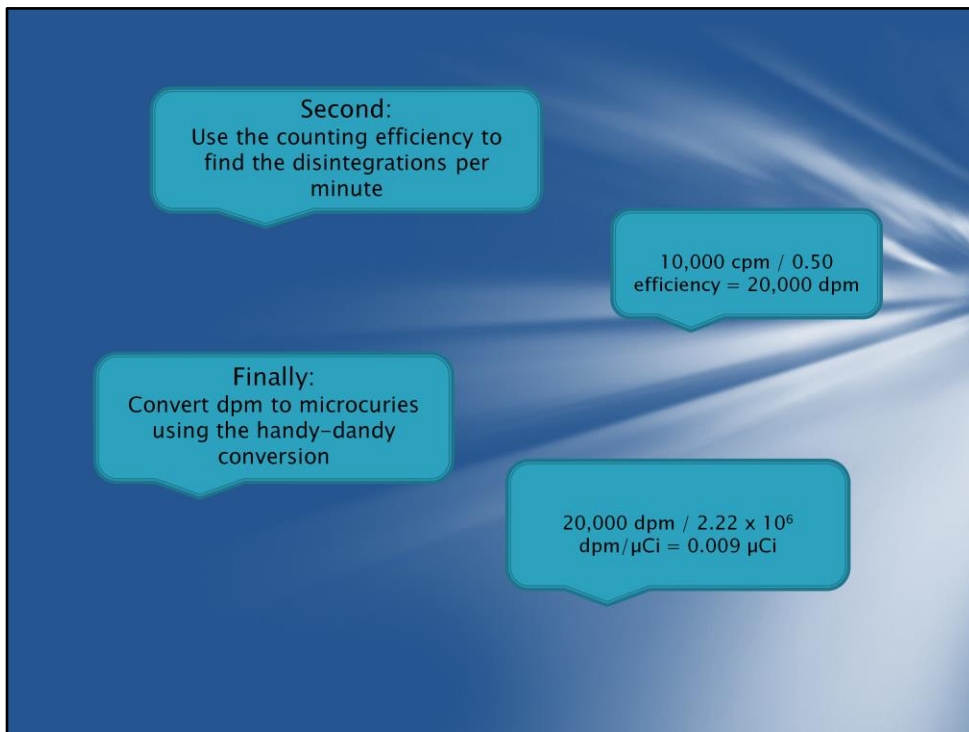
You are using P-32 as a tracer and determine that 20% of the labeled material incorporates with the metabolic product.

If you need a net count rate of 2,000 cpm in a standard, determine how many microcuries you must use given the fact that your LSC has an efficiency of 50% for P-32.

First: Determine the counts per minute you will need based on 20% incorporating into the product

$$2,000 \text{ cpm} / 0.20 = 10,000 \text{ cpm}$$

Sample problem 3. You are using P-32 as a tracer and determine that 20% of the labeled material incorporates with the metabolic product. If you need a net count rate of 2000 counts per minute in a standard, determine how many microcuries you must use given the fact that your LSC has an efficiency of 50% for P-32. First, you must determine the counts per minute that you will need based on 20% incorporating into the product. So divide 2000 counts per minute by 20% which gives you 10,000 counts per minute.



Then, use the counting efficiency to determine the disintegrations per minute. 10,000 cpm divided by 50% gives us 20,000 dpm. Finally, using the conversion factor provided earlier (1 microcurie equals 2.22E6 dpm) obtain the required value. 20,000 dpm divided by 2.22E6 dpm/microcurie equals 0.009 microcurie.