EXUBRION THERAPEUTICS

Authorized User/Radiation Safety Officer Training for Synovetin OA®

Module 4: Detection and Measurement

Chad A. Smith, PhD, CHP
F.X. Massé Associates, Inc.
www.fxmasse.com
info@fxmasse.com
978-283-4888

Introduction

- This module focuses on the measurement and detection of ionizing radiation.
- The instruments covered will be the most commonly used in veterinary nuclear medicine.
- After completing this module, the reader will be able to measure radiation and quantify radioactivity using several different methods.
- Assigned reading:
  - Ludlum 9DP Specifications Sheet
  - Ludlum 44-3 Specifications Sheet
  - Ludlum 44-88 Specifications Sheet
  - Ludlum 44-9 Specifications Sheet
  - Ludlum 44-38 Specifications Sheet
  - Ludlum 26-1 DOSE Specifications Sheet
  - AAPM Report No. 181: Dose Calibrators
  - ANSI Standard for Dose Calibrators

Outline

- Units of Measure for Ionizing Radiation
- Measurement Instruments: Gas-Filled Chambers
  - Ionization Chamber
  - Well Counter and Dose Calibrator
- Measurement Instruments: Scintillation Detectors
  - Ludlum 44-3
- Measurement Instruments: GM Counters
  - Ludlum 44-88
  - Ludlum 44-9
  - Ludlum 44-38
  - Ludlum 26-1 DOSE
- Quiz

Units of Measurement

Radioactivity Quantity Units	
Becquerel (Bq)	Curies (Ci)
SI unit	Customary unit
Decays per second (dps)	3.7 x 10^{10} Bq

Units Describing Radiation Field		
Roentgen (R)	Radiation Absorbed Dose (rad)	Roentgen Equivalent Man (rem)
Photon ionization in air (exposure)	Amount of energy deposited in unit mass of medium	Biological effect of energy deposited by radiation in system
2.58E-4 C/kg	SI unit: Gray (Gy) = 100 rad Gray = J/kg	SI Unit: Sievert (Sv) = 100 rem Sv = Rad*QF

Where:

C = Coloumbs
J = Joules
QF = Quality Factor

Mathematical Notations: Prefixes		
giga	G	10^9
Mega	M	10^6
kilo	k	10^3
milli	m	10^{-3}
micro	µ	10^{-6}
nano	n	10^{-9}

How To Use Various Units of Measurement

Units Describing Radiation Field		
Exposure	Contamination	Occupational Dose
Roentgen (R)	dpm/mCi/Bq	Roentgen Equivalent Man (rem)

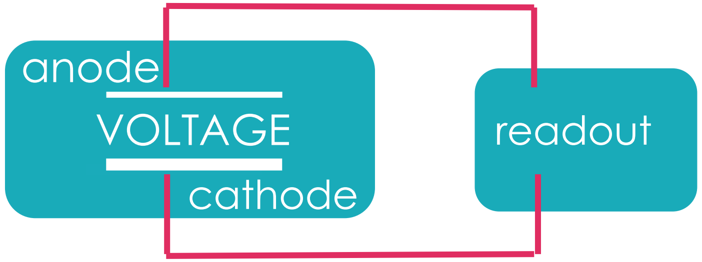
- Use Roentgen (R) when describing an exposure in air or mR/h for exposure rate in air.
  - "Exposure" measures how much radiation is present in air.
  - Measured with an ion chamber or a GM ratemeter.
  - Used for daily surveys or release measurements.
- Use dpm when describing how much radioactivity or contamination is present.
  - Dpm is "disintegrations per minute." 1 mCi = 2.22E6 dpm; 1 Bq = 1/60 dpm
  - Use a GM ratemeter to quantify contamination on a wipe sample (See Module 7 for more details).
  - Dpm = cpm/eff; where cpm is the counts per minute on the GM ratemeter and eff is the efficiency for the isotope in question.
- Use rem or Sievert (Sv) when describing the "occupational dose," or biological effect to the human body as a system.
  - These units are used to communicate risk in terms of cancer induction probability.
  - Note, the US still recognizes the rem (1 Sv = 100 rem).
  - This is the unit you will see on your dosimetry or occupational badge report.

*These units are not interchangeable.

Gas-Filled Chambers

The general principle of a gas-filled chamber or radiation detector:

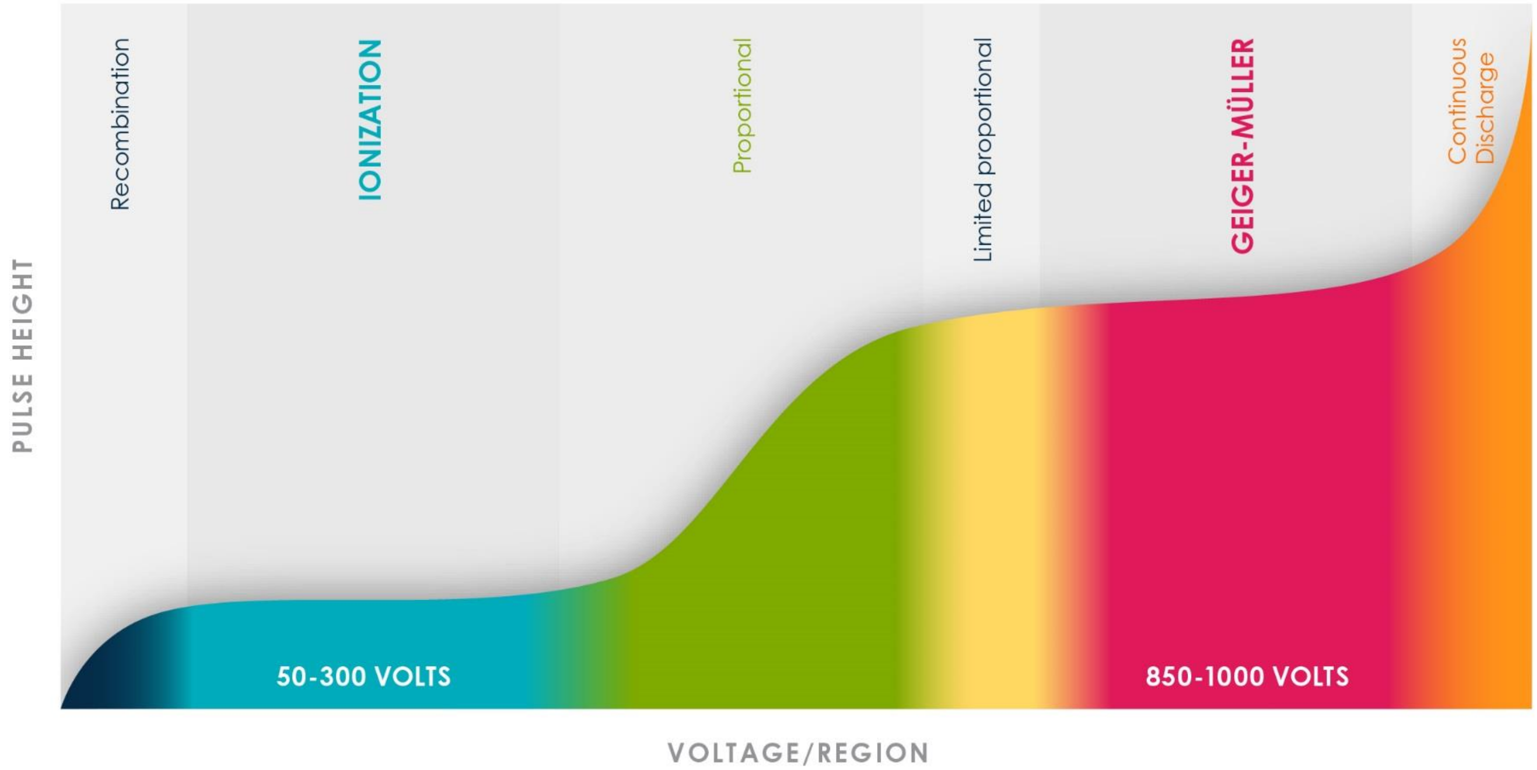
- A voltage is applied between an anode and cathode with gas in between.
  - The anode is a positively charged element and the cathode is a negatively charged element which creates a potential between the two elements.
- The ionizing radiation interacts with the gas, creating electrons which are then attracted by the positive side of the applied voltage.
- The charge is then collected and counted.



Gas-Filled Chambers *(continued)*

There are six regions as a function of voltage for gas-filled chambers. The two flat regions are of interest: the **ionization chamber region** and the **Geiger-Müller (GM) region**.

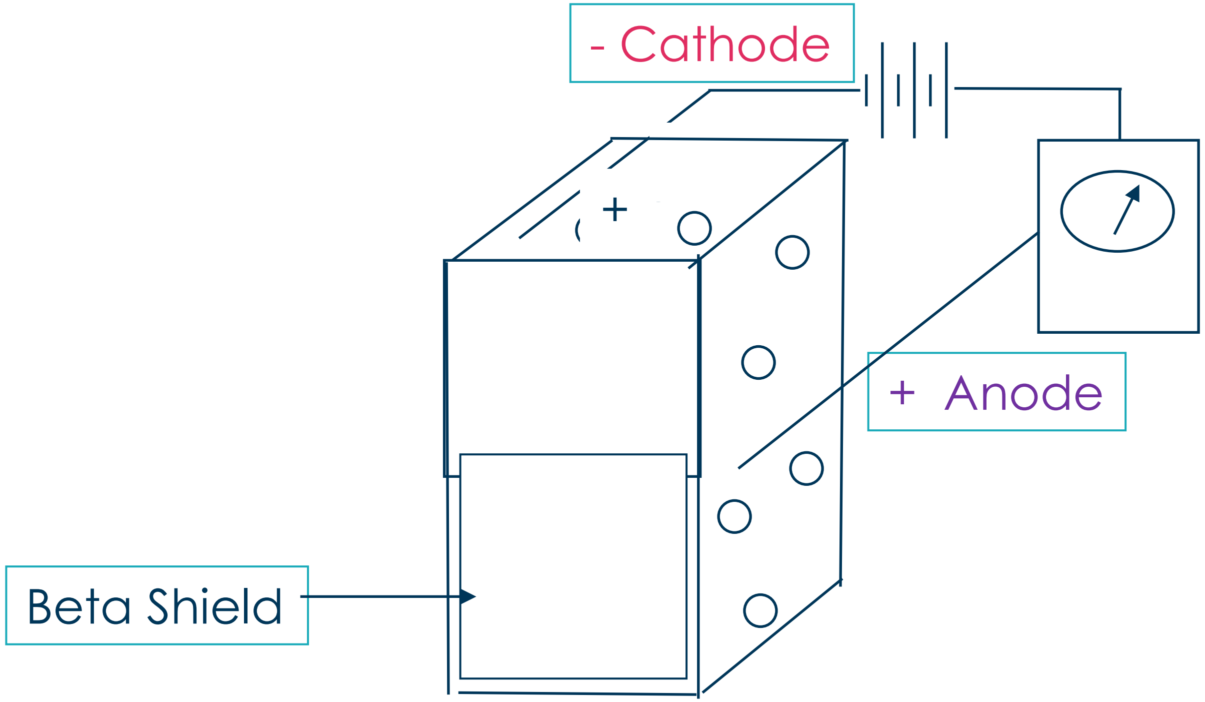
THE SIX-REGION CURVE FOR GAS-FILLED DECTORS



Ionization Chambers

The simple diagram below shows an ion chamber measuring ionization events in Coulombs (C)/kg per unit time.

- Coulombs/kg per unit time can be converted to Roentgen or milliroentgen per unit time, or mR/h for true exposure rate.



Ionization Chambers *(continued)*

Fluke P451: Pressurized ion chamber
very sensitive
reads μR/h to R/h
μR to R

Typical natural background reading:
15 to 20 μR/h

Ludlum 9DP: Pressurized ion chamber
very sensitive
reads μR/h to R/h
μR to R

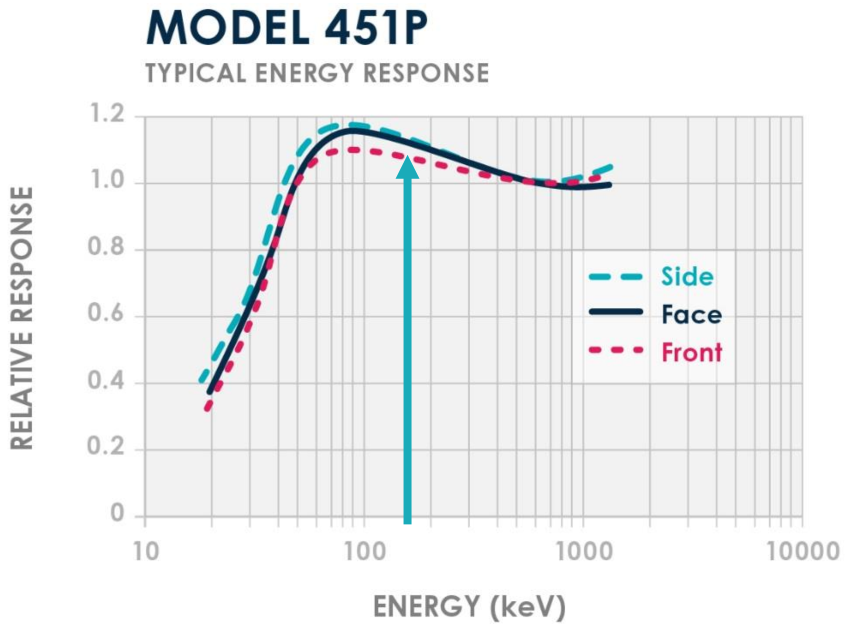
Typical natural background reading:
15 to 20 μR/h

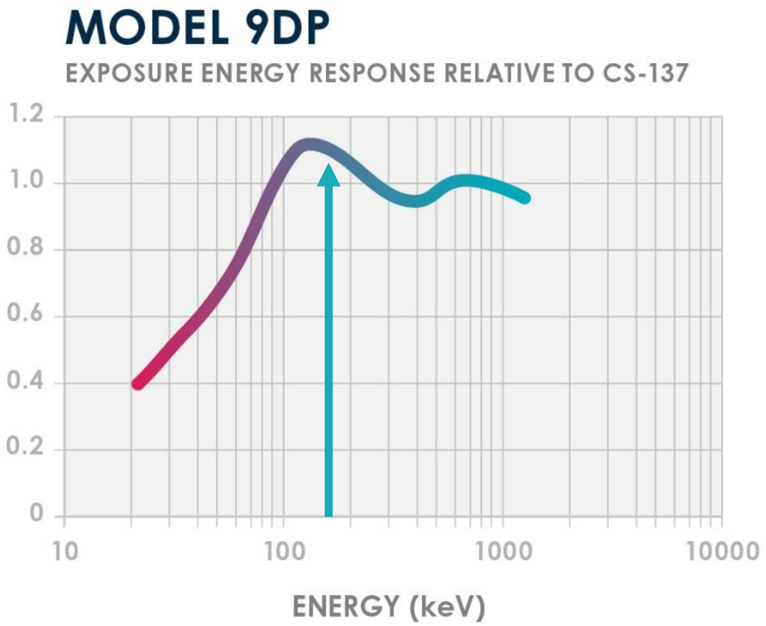
- The ionization chamber measures radiation in terms of exposure rate in mR/h.
- These measurements can be used for release criteria after treatment with Synovetin OA® (discussed in a later module).

EXUBRION
THERAPEUTICS

Ionization Chambers *(continued)*

- The graphs below represent the energy response curves for the Victoreen Model 451P and the **Ludlum 9DP** ionization chambers. The x-axis is energy in keV, and the y-axis is relative response as a percentage.
- For the case of ^{117m}Sn (Synovetin OA®) with a 159 keV photon emission, the relative response is high for both models. The blue arrows correspond to ^{117m}Sn primary photon energy.





Ionization Chamber Use

- To properly use an ion chamber:
  1. Turn the unit on.
  2. Wait approximately 30 seconds for the unit to stabilize.
  3. Capture the background rate (usually 20 microroentgen/hour, or 20 uR/h).
  4. Make your measurements from a known distance from the source of radiation (gross rate).
  5. Capture the net rate:
     - Net Rate = gross rate – background rate
- Ion chambers are required to be calibrated annually.

Exposure rate

Power button

Dose Calibrators

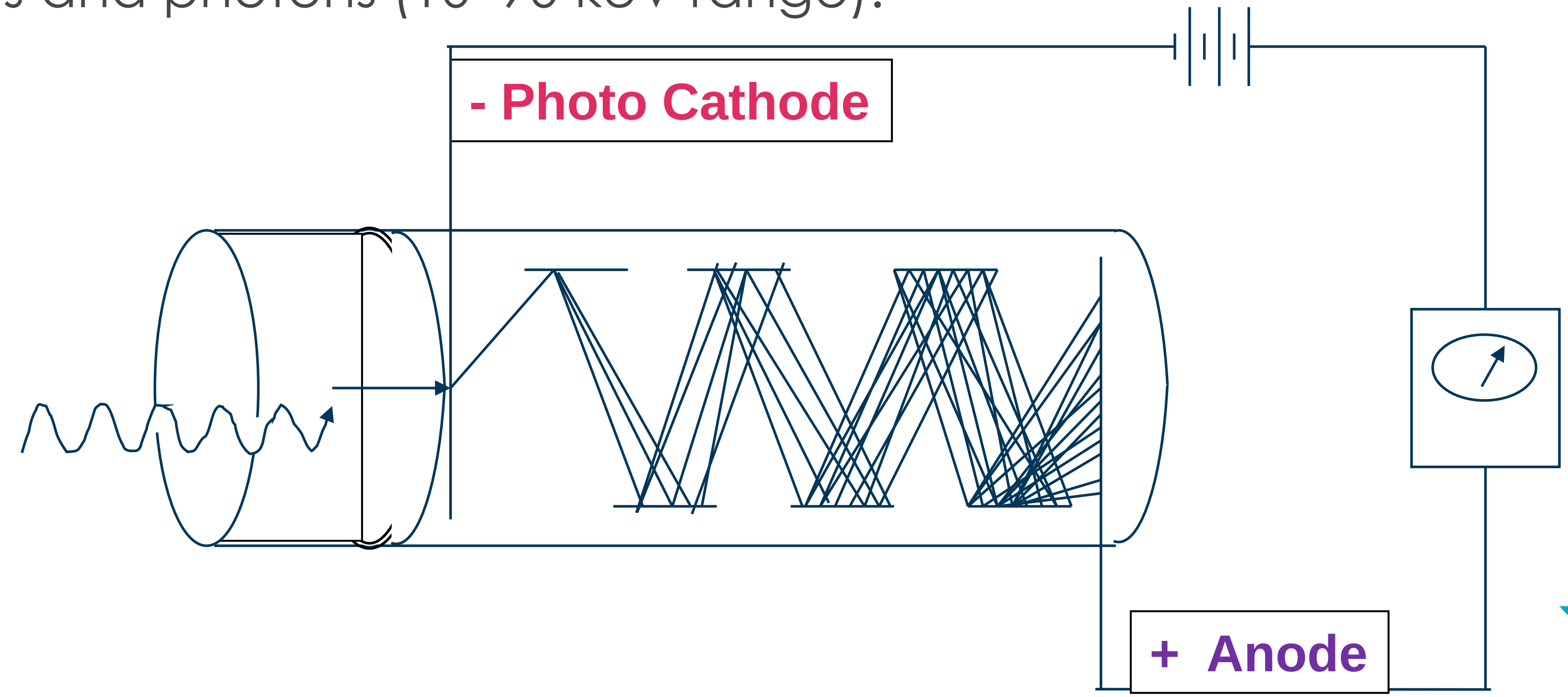
- The dose calibrator is the tool used to validate the activity present in a radiopharmaceutical or radiotherapeutic container.
- Dose calibrators are capable of quantifying radioactivity for radioisotopes used in nuclear medicine. Channel settings are prescribed by the manufacturer to match the emissions of the isotope to be quantified.
- The unit itself is a gas-filled well. The radioactive sample is lowered into the well, then counted on the appropriate setting/channel.
- The operator presses the proper isotope button or channel setting to quantify their sample.
- Each manufacturer is different. Refer to the user manual or contact the manufacturer to determine the proper channel for the isotopes used.

Dose Calibrator Quality Control

- Dose calibrators are not a requirement for veterinary practices using unit doses for therapy or diagnosis.
- However, should a practice decide to use a dose calibrator, quality control should follow the most recent ANSI standard N42.13:
  - Daily Background Checks
    - This test is done to capture net activity and subtract out natural background.
  - Daily Constancy Checks
    - This test is done with ^{57}Co and ^{137}Cs standard sources to verify that response is accurate over time.
  - Quarterly Linearity
    - This test is done to ensure the dose calibrator response is linear over all ranges used by the facility.
  - Annual Accuracy
    - Typically completed by a physicist, this test makes sure the each clinically used channel is accurate.
  - Initial Geometry
    - The geometry test is completed for all shapes and sizes of vials or capsules used at the facility to ensure the dose calibrator is responding appropriately for all clinically used geometries.

Scintillation Detectors

- The scintillation detector is a unique case for ionizing radiation detection that turns the ionizing radiation into visible light to enable counting of the interactions.
- A photon enters the scintillation crystal, visible light is created, then photomultipliers are used to increase the output signal.
- These instruments have outstanding response times and are very sensitive to low-level x-rays and photons (10–90 keV range).



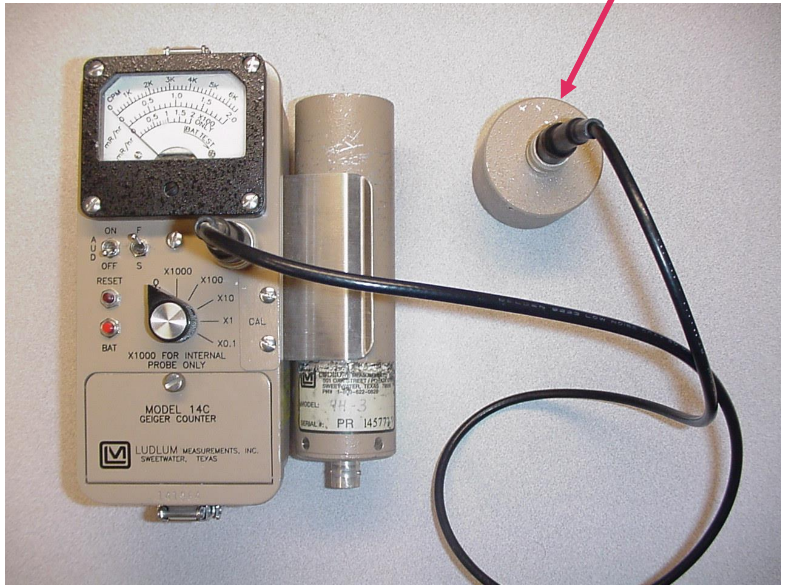
Scintillation Detectors *(continued)*

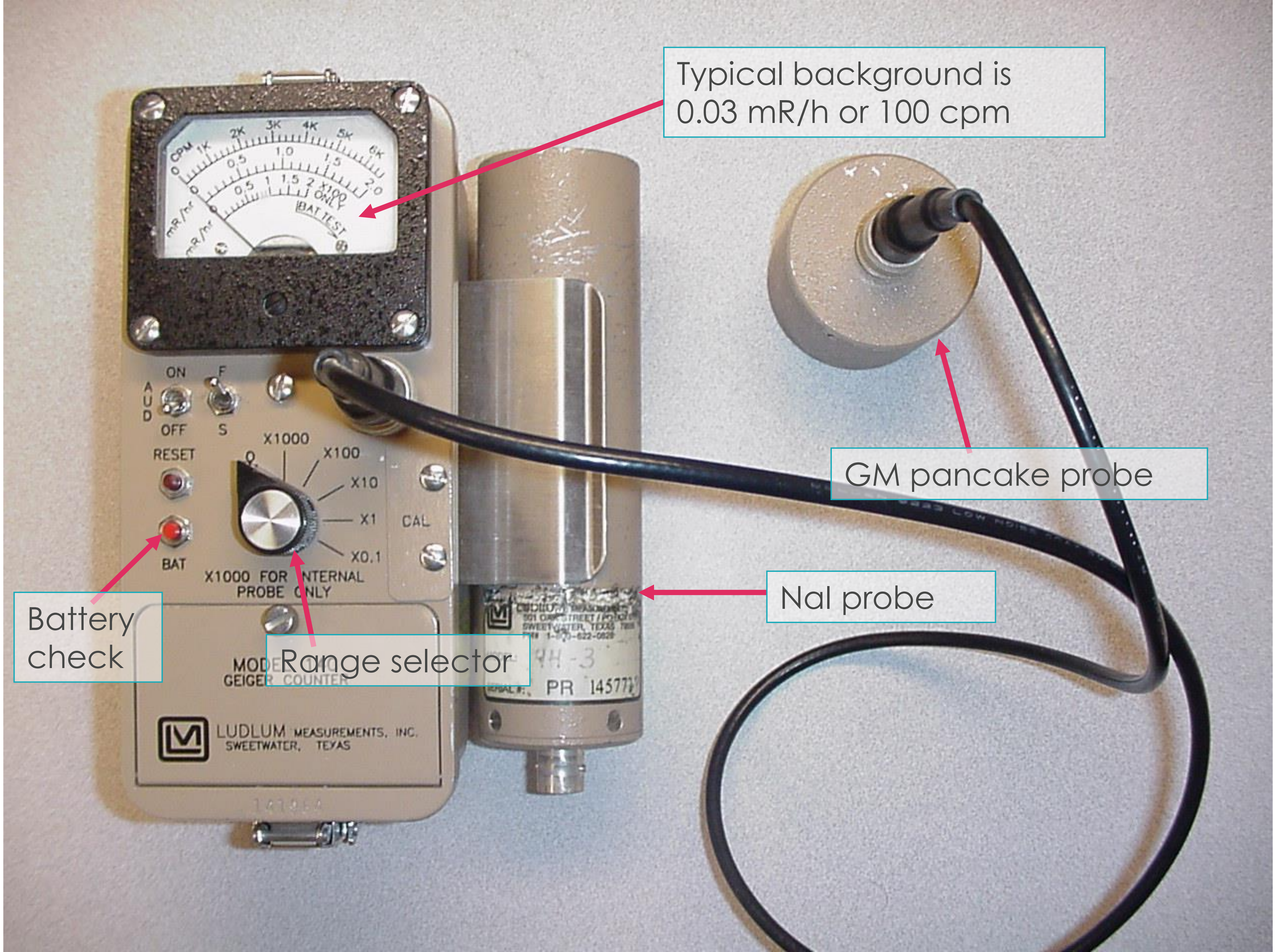
- The scintillation detector is typically used for gross leakage, or gross contamination detection. It is an excellent inspection tool to verify that contamination has not left the nuclear medicine department.
- Scintillation detectors have poor or no detection capability for electrons or beta particles, but they are excellent for low-energy gamma rays and x-rays.
- The **Ludlum 44-3** is the most common handheld scintillation detector used in human and veterinary nuclear medicine. It is used for thyroid bioassays for operators after unsealed use of ^{131}I.

Exubrion THERAPEUTICS

Geiger-Müller (GM) Counters

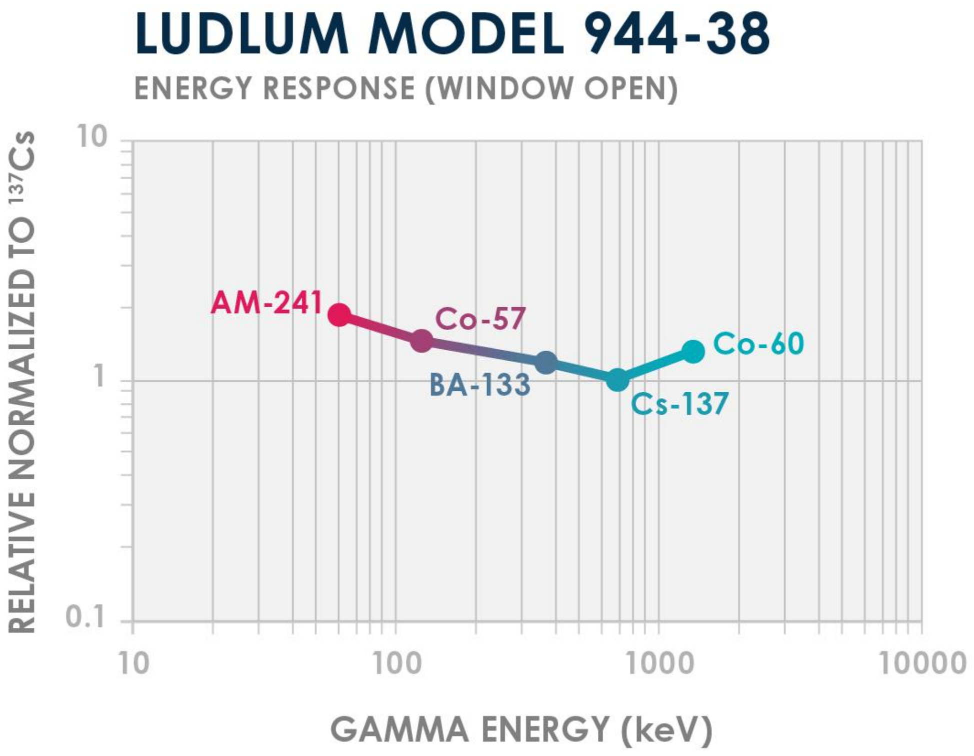
- The GM ratemeter or counter is the quintessential device used to detect radiation. It is rugged and versatile, and it is capable of detecting very energetic alpha particles, beta particles (electrons), and photons.
- A photon enters a small gas-filled chamber, charged particles are created, then the charged particles are attracted to an anode, where a charge and therefore a signal is created. A thin mylar window covers the probe, which can come in the form of a handheld pancake (**Ludlum 44-9**) or a cylindrical probe (**Ludlum 44-88**). Both units are the same size and geometry.




Typical background is
0.03 mR/h or 100 cpm
GM pancake probe
NaI probe
Battery
check
Range selector
ON
OFF
RESET
BAT
X1000
X100
X10
X1
X0.1
CAL
X1000 FOR INTERNAL
PROBE ONLY
LUDLUM MEASUREMENTS, INC.
SWEETWATER, TEXAS

Geiger-Müller (GM) Energy-Compensated Counter

Another GM probe is the **Ludlum 44-38** energy-compensated probe. It has a similar energy response to that of the ion chamber and is therefore desirable for regulatory exposure rate measurements. It is also an ideal tool to use when receiving radioactive packages.



Geiger-Müller (GM) Counter: Ludlum 26-1 DOSE

The **Ludlum 26-1 DOSE** is the preferred instrument for routine use with Synovetin OA®.

- Digital device that comes with a dose flattening filter that can be used for release measurements.
- Can also be used for contamination assessment with the flattening filter removed.

EXUBRION THERAPEUTICS

Instrument Usage

1. Check battery condition: needle should go to BAT TEST line on meter.
2. Turn range switch to the lowest scale, then turn on audio function.
3. Conduct "check source" test (typically affixed to meter).
4. Note meter "background" reading in a location away from radiation source or radioactivity.
5. Place probe (window face down) about ½ inch from surface being surveyed. Never let probe touch survey surface.
6. Survey work area by slowly moving probe over surfaces, listen to audible "clicks" from survey meter speaker.
7. Take into account efficiency to determine actual amount of radioactive material.

Disintegrations/min = (Counts/min – background)/efficiency → $$dpm = \frac{(cpm - bkg)}{efficiency}$$

EXUBRION THERAPEUTICS

Summary of Module 4: Radiation Detection and Measurement

- There are many different instruments used to measure and quantify radiation and radioactive material.
- "Exposure" describes how much radiation is present in air. It can be measured with an ion chamber or GM ratemeter.
- "Disintegrations per minute" (dpm) describes how much radioactivity is present in the form of contamination. It can be measured with a calibrated GM ratemeter, dose calibrator, or a scintillation detector.
- Dose calibrators are not a regulatory requirement for veterinary use of radioactive materials. If a dose calibrator is not used, unit doses are required for administration of radioactive materials.
- The GM ratemeter is the most versatile instrument for measuring both radiation and radioactivity. The Ludlum 26-1 DOSE is the preferred instrument for use in conjunction with Synovetin OA®.

Supplemental Reading Material

Assigned reading material for Module 4:

1. Ludlum 9DP Specifications Sheet
2. Ludlum 44-3 Specifications Sheet
3. Ludlum 44-88 Specifications Sheet
4. Ludlum 44-9 Specifications Sheet
5. Ludlum 44-38 Specifications Sheet
6. Ludlum 26-1 DOSE Specifications Sheet
7. AAPM Report No. 181: Dose Calibrators
8. ANSI Standard for Dose Calibrators: https://webstore.ansi.org/Standards/IEEE/ANSIN42132004

Upon successful completion of the Module 4 quiz, you may continue to Module 5.

EXUBRION THERAPEUTICS