Dosimetry

szerző: PGY

Acute radiation syndrome

Level, REM	Reported Effect
5000	Death within 3 days. All earlier effects. Third degree burns.
12000	Death within 36 hours. Severe bleeding and fluid loss.

Radiation Safety

- Radiation safety policies are established by a collaborative effort of appropriate government agencies and your local site.
- To insure that your are in compliance, you should consult your Radiation Safety Officer.
- The material in this section is only a general coverage and is not a substitute for formal radiation safety training.

Types of hazards

A function of the type, intensity and duration.

The exposed location is also significant.

External

Irradiation by being to close to a source.

Can be minimized by using standard chemical safety practices and good housekeeping.

Internal

Ingestion or inhalation. Again follow the same precautions as with a toxic chemical.

Radiation heath effects

Damage falls into two general classes.

Somatic damage

- chronic (cancer)
- acute (acute radiation syndrome)

Genetic damage

- alters genetic material
- may lead to mutation of offspring
- may cause cancer

Units of radiation

curie	The amount of radioactive materials that produces 3.7×10^{10} disintegrations/second.
roentgen	measures the ions that radiation produces - X-ray - gamma radiation
rad	radiation absorbed dosage, accounts for the type of radiation.
rem	rad equivalent for man used to describe biological damage.

Radiation absorbed dose - RAD

A measure of the energy absorbed by matter.

Defined as 10^{-5} J/g

Working unit in the SI system is the Gray (Gy) which is defined as 1 J / kg.

This is a physical unit and does not account for the type of radiation - only the energy.

It is the only “real” physical measurement.

Roentgen (R)

Accounts for the type of radiation.

Defined as the total electrical charge produced by a radiation / kg of air required to stop the radiation.

Measures the degree of ionization but it is still a purely physical unit.

Rad equivalent Man (REM)

No - not the rock group!

This unit attempts to account for the effects of radiation on man. It as accounts for the type of radiation.

The value is obtained by multiplying theRad value by the Relative Biological Effectiveness (RBE) for the specific type of radiation.

REM

REM = Rad x RBE

Type	RBE
X-rays, γ, β	1
α	10
p	10
fast n	10
thermal n	2.5
heavy nuclei	20

Sieverts

Sieverts (Sv)

- The newer SI unit of dose equilivent.
- Dose (Sv) = Dose (gray) * RBE
- 1 Sv = 100 rem

Dose rate

A function of

- source strength
- energy
- type of radiation
- distance from source
- exposure time
- shielding

All should be considered when considering using radioisotopes.

Radiation exposure and safety

Factors that influence degree of exposure

Magnitude of the half-life
Shorter half-life materials decay faster and can result in greater damage.

Shielding
Provides protection by blocking radiation.

Type of radiation
Some types are worse than others.

Area of exposure
Hand exposure not as bad as ovaries.

Shielding and types of radiation

Alpha particles

Blocked by 1 cm of air.

Beta particles

Requires 1 mm of aluminum to block.

Gamma rays

Most penetrating. Need concrete and lead to provide adequate protection.

X-rays

The same as gamma rays.

Other factors

Distance from radiation source

Intensity decreases with increased distance.

If exposure a 1 meter is 100 rem, it will be

50 rem at 2 meters.

25 rem at 4 meters.

Time of exposure

Effects are cumulative.

Maximum permissible exposure levels

These have been established by international agreement.

Occupational γ exposure

Whole body - 100 mREM / 40 hours

Long term - < 5 x (age - 18) REM

Occupational β exposure

5 x the MPL for g

For the general public

~ 1/10th of the occupational limits.

US limits

MPL levels in REM / quarter

Whole body	1.25
Hands, feet	18.75
Skin	7.5

5 REM maximum exposure for a year.

Once you reach the limit - you get sent home.

Estimated loss of life expentancy

Source of risk	Average life lost (days)
Smoking, 1pack/day	2370
Overweight by 20%	985
Accidents, all types	435
ROH consumption, U.S.	130
Drowning	41
1 rem/y dose for 30 years	30
Natural BG radiation	8
Medical X-rays	6

Dose and exposure calculations

- Exact calculations are beyond the scope of this course.
- We'll look at some relatively simple methods that are reasonably accurate.
- β and γ exposure are the most common so we'll just deal with calculations for those types.
- Remember -- these are only estimates!

Gamma Ray exposure

- The rate of exposure is directly related to the intensity and energy of the γ rays.
- It is inversely related to the distance from the source of radiation.

$$\text{Exposure rate (mR/h)} = 6\ AEn/d^2$$

Where

A = activity (mCi)

E = energy of γ ray (MeV)

n = number of γ rays emitted/decay

d = distance from source (ft)

Gamma Ray exposure

Example.

Determine the exposure rate that results from sitting 20 feet away from a 500 mCi ^{59}Fe source.

^{59}Fe emits two γ rays

1.10 MeV (56%)

1.29 MeV (44%)

The half life is 44.5 days so would not change significantly over a one hour period.

Gamma Ray exposure

^{59}Fe - 500 mCi, 10 ft distance.

1.10 MeV (56%)

Exposure rate $= (6)(1.10 MeV)(500 mCi)(.56)/10^2$

$= 18.5$ mR/h

1.29 MeV (44%)

Exposure rate $= (6)(1.29 MeV)(500 mCi)(.44)/10^2$

$= 17.0$ mR/h

Total rate $= 18.5$ mR/h $+ 17.0$ mR/h

$= 35.5$ mR/h

Beta particles

- β radiation is much less penetrating that γ.
- They will undergo significant attenuation with distance.
- For high energy β, an estimate of the upper limit of dose can be obtained from:

$$\text{Dose rate (mrad/h)} = 338\,000\ A/d^2$$

Where A = activity, mCi

d = distance, cm

Beta particles

Example.

Estimate the dose rate from a 10 mCi β source that is at a distance of 10 cm.

Dose rate (mrad/h)

$$= 338\,000\ (10\ \text{mCi})/(10\ \text{cm})^2$$

$$= 33.8\ \text{rad/h}$$

Monitoring radiation

Radiation exposure

- measure of “safe” exposure
- safety requirements

Measurement of exposure

- photographic imaging
- computer imaging
- Geiger counter
- film badges

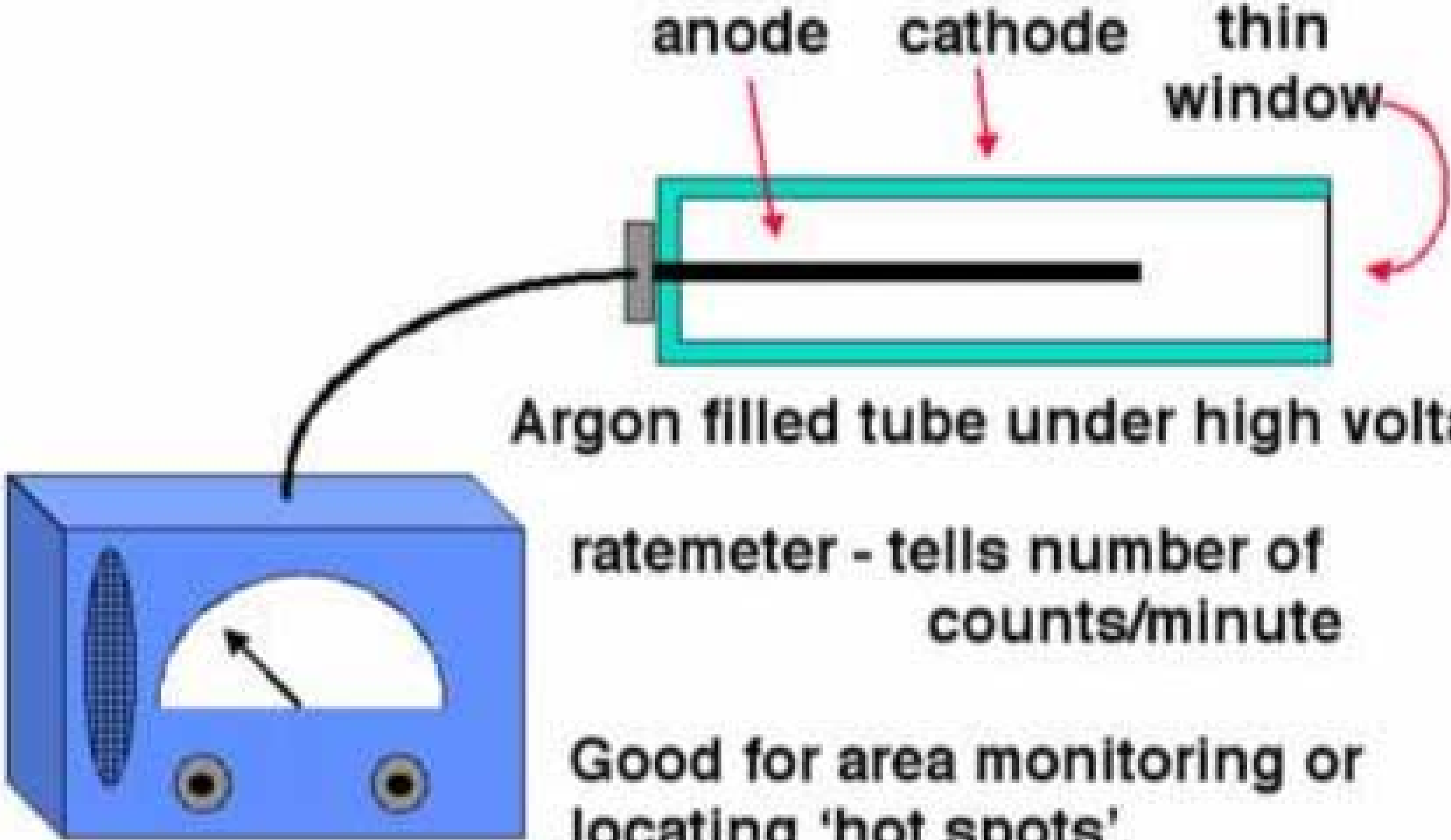
Monitoring radiation

Two types of approaches

- **Personal dosimetry**
  - Monitoring individual exposure of a person or a portion of a person.
- **Area monitoring**
  - Set monitors in representative areas
  - Survey areas with a movable system.

Most plans will use a combination of both.

Survey meter

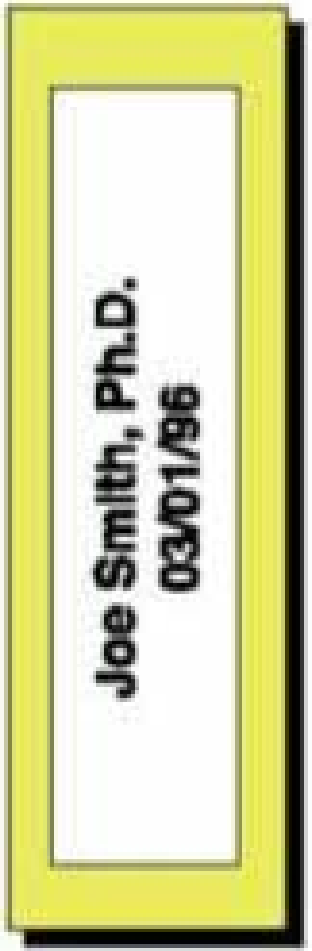


Argon filled tube under high voltage

ratemeter - tells number of counts/minute

Good for area monitoring or locating 'hot spots'.

Film badges



Each badge contains a piece of film that is sensitive to radiation exposure.

It comes in various types based on area you need to monitor.

Only good for X and γ radiation and is not specific.

Thermoluminescent dosimeters (TLD)

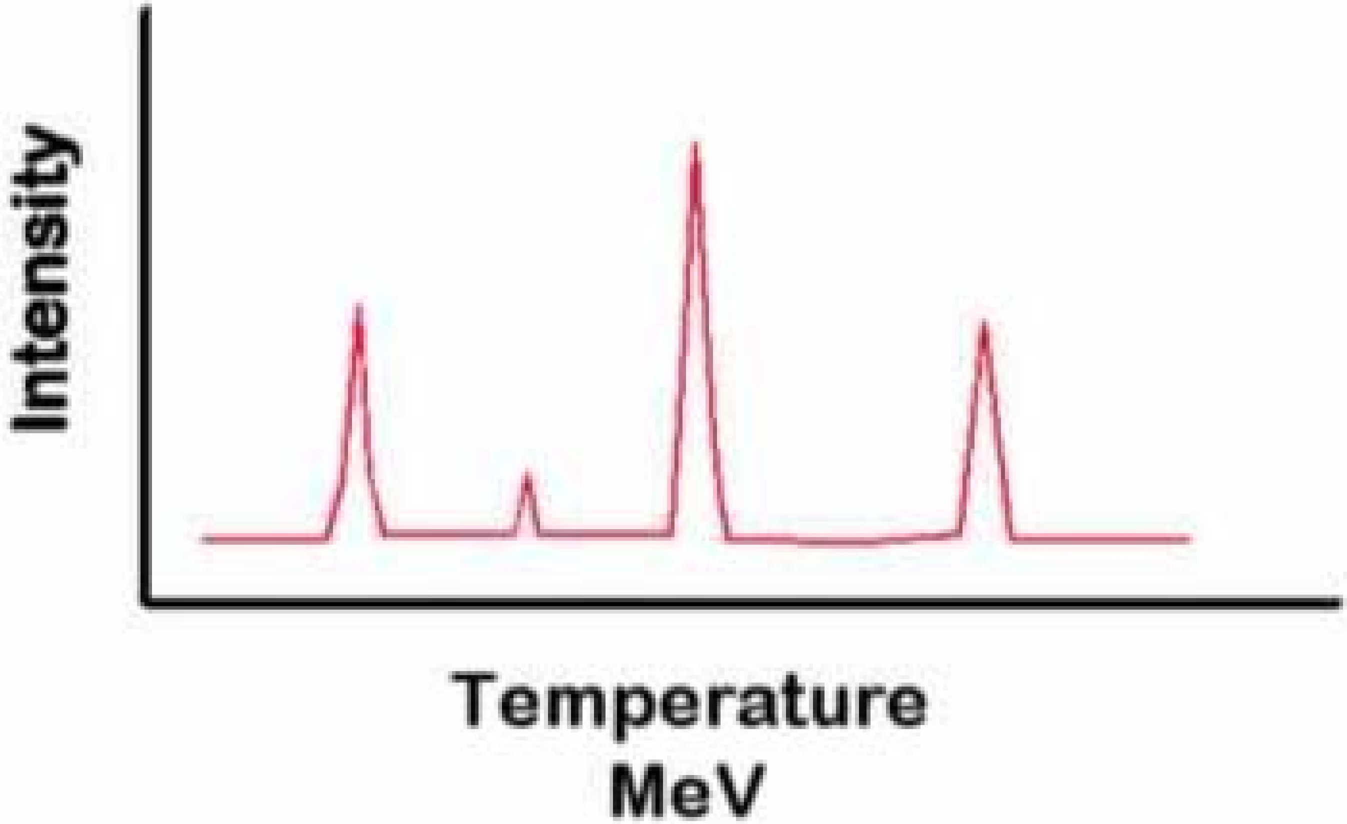
Many crystals will emit light when hit by ionizing radiation.

Some are able to store the energy in crystal "flaws." The energy can be released as light when the crystal is heated above a critical temperature.

Light intensity is proportional to dose.

Temperature when emission occurs is proportional to the energy of the radiation that produced it.

Thermoluminescent dosimeters (TLD)



Thermoluminescent dosimeters (TLD)

LiF, LiB_4O_7, CaF_2:Mn

10 keV - 10 MeV range

$CaSO_4$:Mn

> 100 keV range

Both will measure exposures in the 10mR - 10^5 R range with $\pm$ 10% error

They can be reused are are unaffected by environment, shock, pressure and temperatures up to 70^o C

Handling techniques

Typically follow the same precautions as you would for toxic chemicals.

Use gloves - change when contamination is even suspected.

For 'Hot' samples - use remote manipulation and shielding.

Decontamination

Remove contamination from equipment with a 2-5% Decon solution (a combination of complexing and wetting agents.)

Cover bench tops with disposable absorbent backed papers.

Floors should be highly polished

Stainless steel, lipped tops are best.

Walls should have a non-porous paper or coating on them.

Disposal

Follow federal, state, local and site guidelines. Document everything you do.

Commonly, small amounts (μCi level) can be flushed down the drain. This assumes that your site has a large fluid volume.

Short half-life materials - safely store and allow to decay - 7 half-lives.

Contaminated equipment, supplies and longer half life materials must be shipped to a radiation storage site using an approved shipper.

Acute radiation syndrome

LD_{50} for man is 400-500 rads.

Level, REM	Reported Effect
below 100	No definite sign of syndrome.
100-500	50% survival rate. Loss of hair. Altered blood chemistry.

Acute radiation syndrome

Level, REM	Reported Effect
500-700	All earlier effects plus Destruction of bone marrow. Loss of RBC, WBC & platelets. Death within 36 days.
900-2000	Vomiting, diarrhea, infections. Death within 10 days.