The Royal Australasian College of Physicians
An introduction to issues with ionising Radiation
2022

This session will cover:

A Brief History Of Ionising Radiation.

Radiation Properties and Shielding.

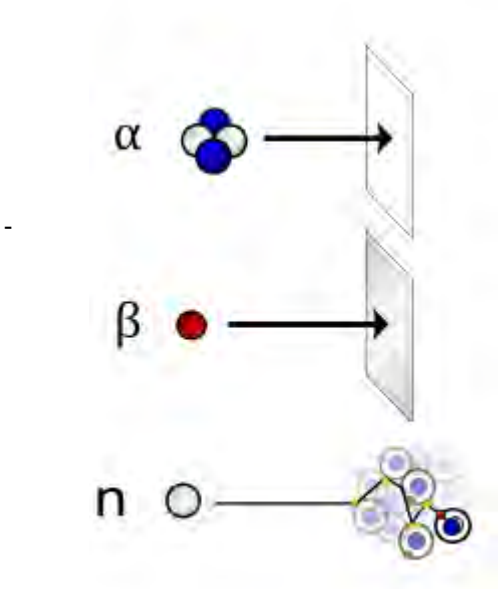
Scientific Units Used.

Hazards caused by Ionising Radiation.

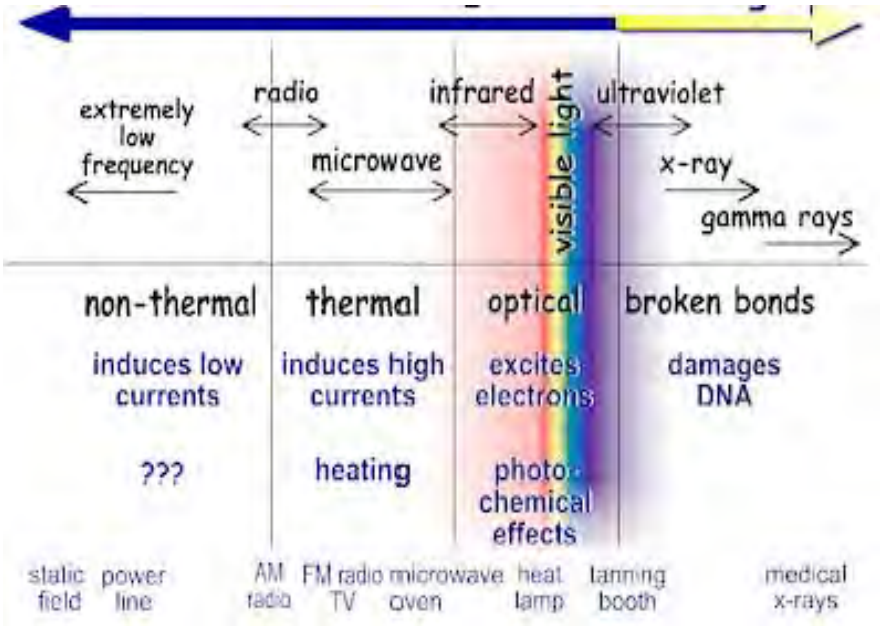
Defining Ionising Radiation

- Ionising radiation consists of highly energetic particles or electromagnetic waves that can detach electrons from atoms or molecules, thus ionising them.

https://www.who.int/Ionising_radiation/about/what_is_ir/en/

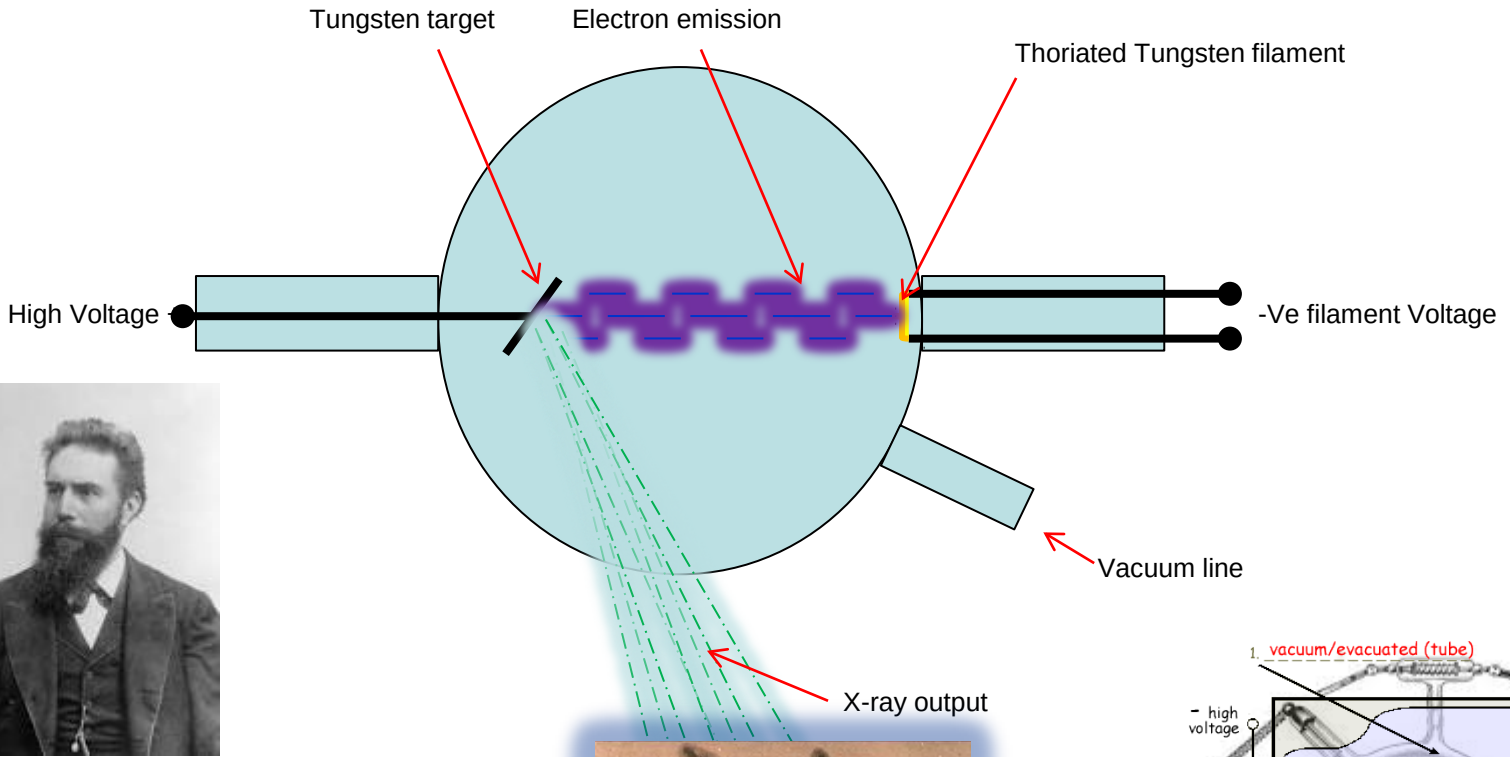


https://en.wikipedia.org/wiki/Ionising_radiation

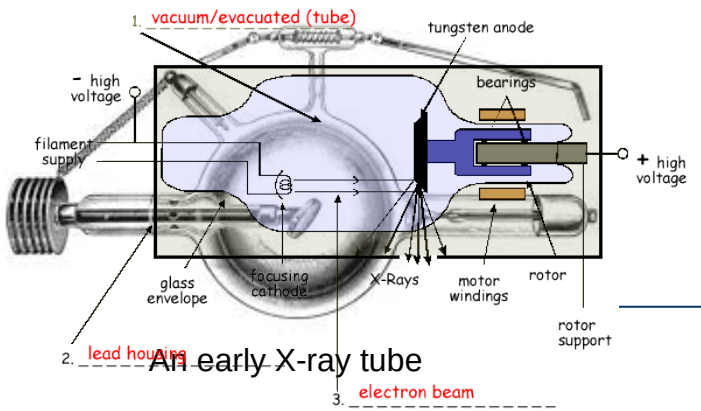


United States Environmental Protection Agency (2011)

How X-rays are generated

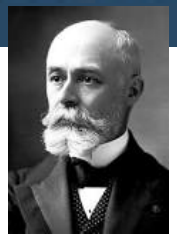


Wilhelm Röntgen 1895
Invented the X-ray machine and demonstrated the phenomenon Bremsstrahlung,



An early X-ray tube

Ionising Radiation – the real discoveries



1896 Becquerel discovered radioactive - negative, positive, and neutral aspects

x-rays & γ

Neutron $_{0}^{1}n$

Electron β^-

Alpha $_{2}^{4}\alpha^{++}$

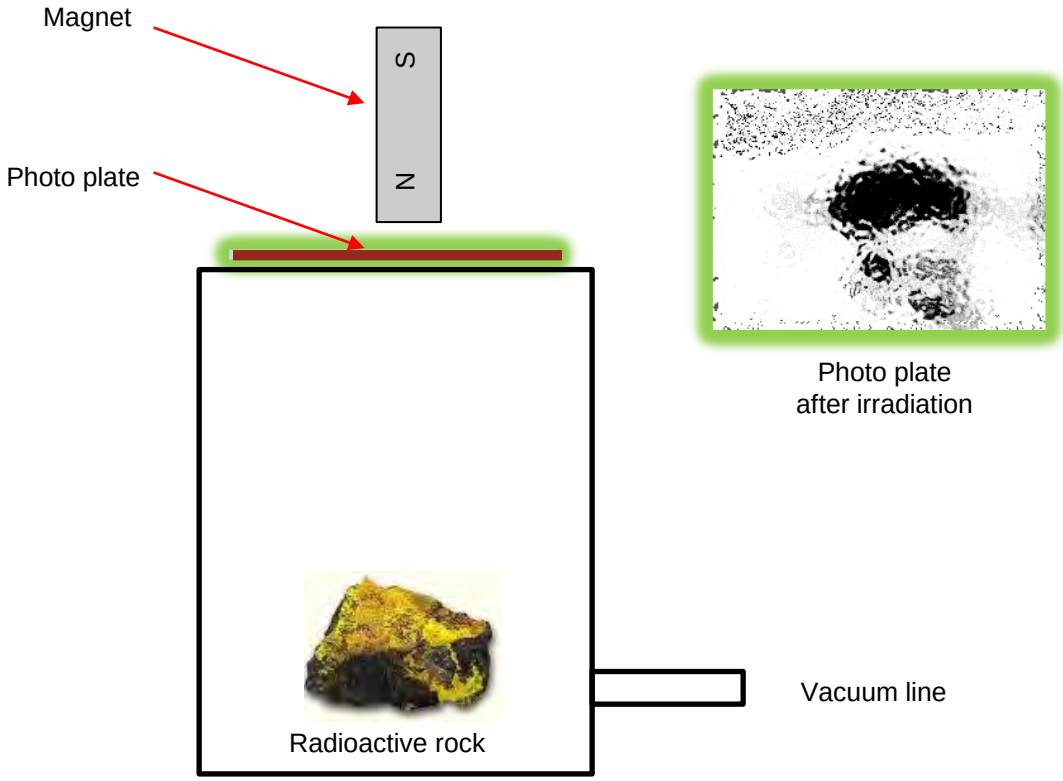
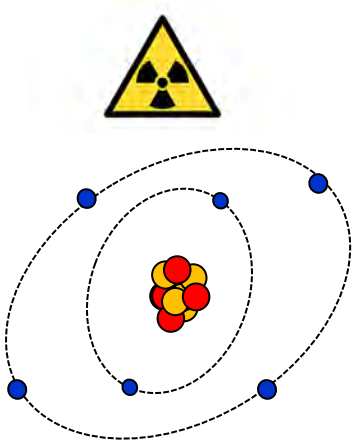
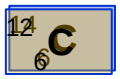


Photo plate
after irradiation

An atom (normally) consists of:

- A positive charged nucleus, surrounded by shell/s of negatively charged elections.
- A stable atom (carbon 12) has 12 nucleons, six positive charge (protons) plus six neutral elements (neutrons) balanced by six negative charges (electrons) in the orbit round the nucleolus



Total number of nuclides → 

← The element

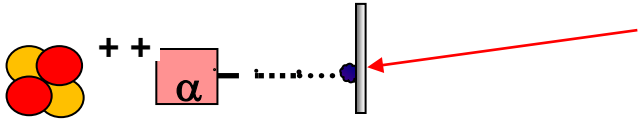
Number of protons →

On the other hand if carbon takes on two neutrons, it becomes a radioactive isotope of carbon

- Is unstable and releases energy by emitting beta β^-
- Has in half-life 5730 years and
- Varies in mass - having 2 more neutrons than the base element
- Has the same chemical properties as the base element.
- Has the same number of protons as the base element.

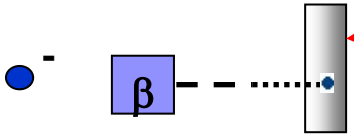
Proton $_1^1p^+$ **Neutron** $_0^1n$ **Electron** β^-

Radiation Properties - Shielding



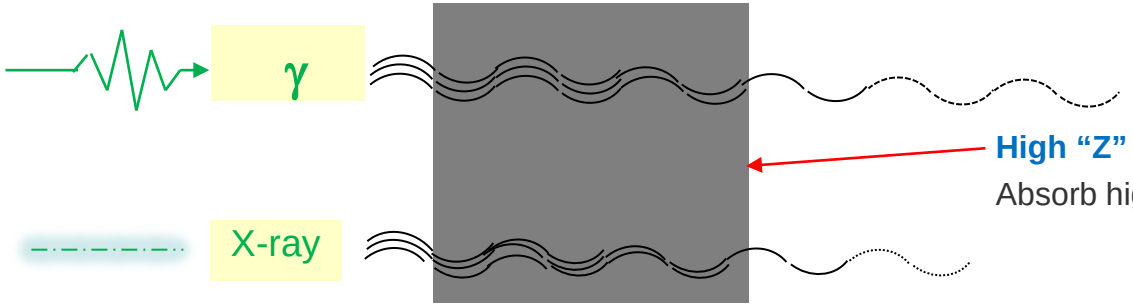
Not normally required

α is readily absorbed by air



Low "Z" material to absorb high energy β

8 mm Perspex. Paper or air to absorb low energy



High "Z" material

Absorb high energy **x-rays** and γ

Lead & concrete shielding

steel mix to absorb neutrons plus 2.2 MeV γ

High hydrogen content shielding

Helps thermalizes or slow down and absorb **N**

Materials like – borax, wax, water to moderate neutrons to thermal energies

Measuring Energy

The unit of energy is the joule however Ionising radiation energy uses the **electron volt** (**eV**).

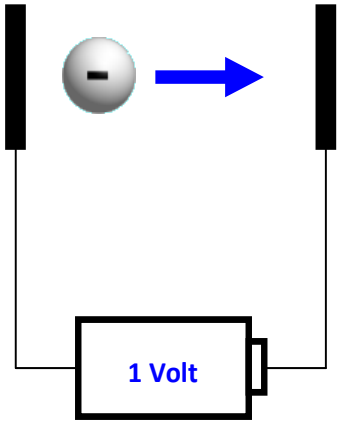
An electron volt is the kinetic energy gained by an electron passing through a potential difference of one volt.

It takes **1.602 x10^{19} eV = a joule** (**J**) (electron volts to equal a joule).

- Electron volts are normally expressed in **keV** (10^3) or **MeV** (10^6)

Radiation energies production:

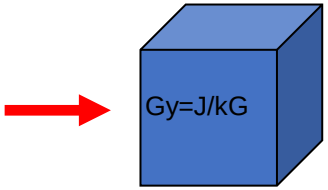
Radio nuclides sources energy's' range from **20 keV to ~ 5 MeV**
X-ray machine normally **~ 80kVp ~20mA ~ 0.1Sec**
CT –machine **~ 140kVp ~ 20mA ~ 15 Sec**
portable XRFs **20 keV to 50 keV ~ 60 Sec**
DXA **~ 40KeV to 140KeV**



Physical to Total Effective dose

Absorbed Dose: **Gray** (**Gy**)

- A Joule of Ionising energy deposited into 1kg of matter
- Energy = **J/kg**



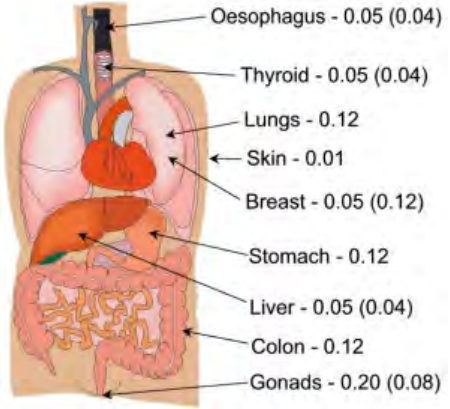
Equivalent Dose: **Sievert** (**Sv**)

- The absorbed dose weighted for the harmful effects of different forms of radiation on the body humans
- radiation weighting factor = ^{W}R

- **x-rays, gamma & beta = 1**
- **Neutrons = 5 to 20 and**
- **alpha = 20**

Effective dose: **Sievert** (**Sv**)

- It is the tissue-weighted sum of the equivalent doses in all specified tissues and organs
- Tissue weighting factor = ^{W}T



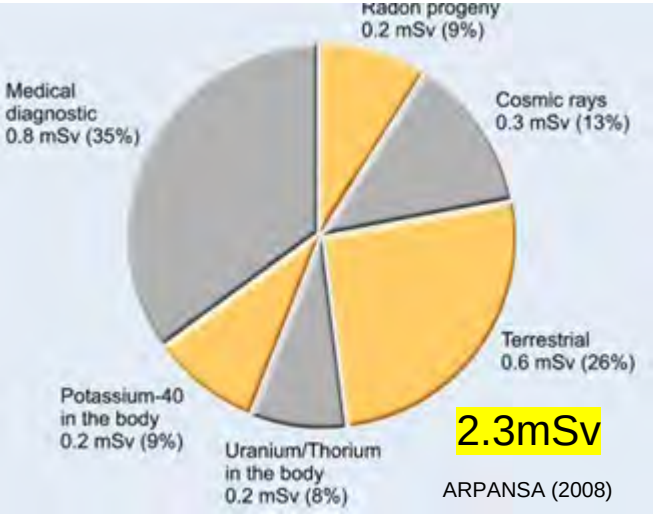
1991 (and 2007 in brackets) weighting factors for individual organs [ICRP].

Total Effective dose: **Sievert** (**Sv**)

- **$E = \sum_{T}(^{W}T \times {}^{W}R)$**

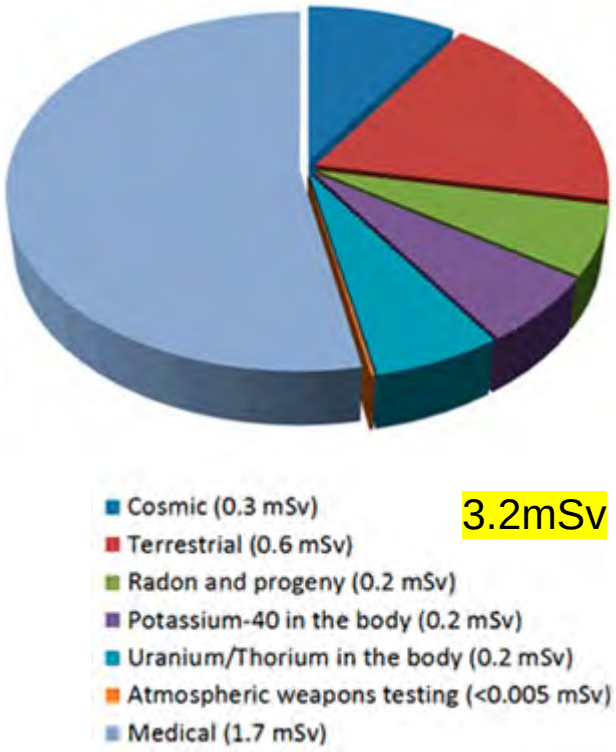
Radiation Background

Radiation is continuously present in the environment.



2.3mSv

ARPANSA (2008)



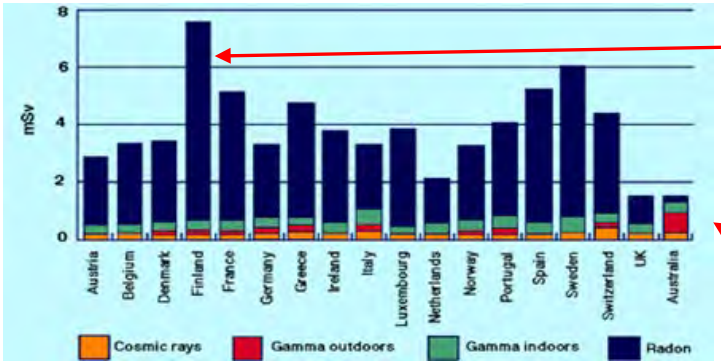
3.2mSv

ARPANSA (2017)

Background Radiation & Dose Limits

Application	Occupational exposure	Public Dose Limit
Effective dose	20 mSv per year, averaged over a period of 5 consecutive calendar years	1 mSv in a year
Lens of the eye	150 mSv	15 mSv
Skin	500 mSv	50 mSv
Hands and feet	500 mSv	

Occupational exposure = 2000 hr/yr Public exposure = continuous



The thing to note is radon levels Rn^{222} can be an issue, look at Finland (7.5mSv) the Russians would never invade!

1.5mSv

Radioactive Half-Life & Decay

The process where an isotope with an unstable nucleus undergoes spontaneous transformation resulting in new elements and/or isotopes with emissions of ionising radiation.

A. Litvinenko

Yasser Arafat

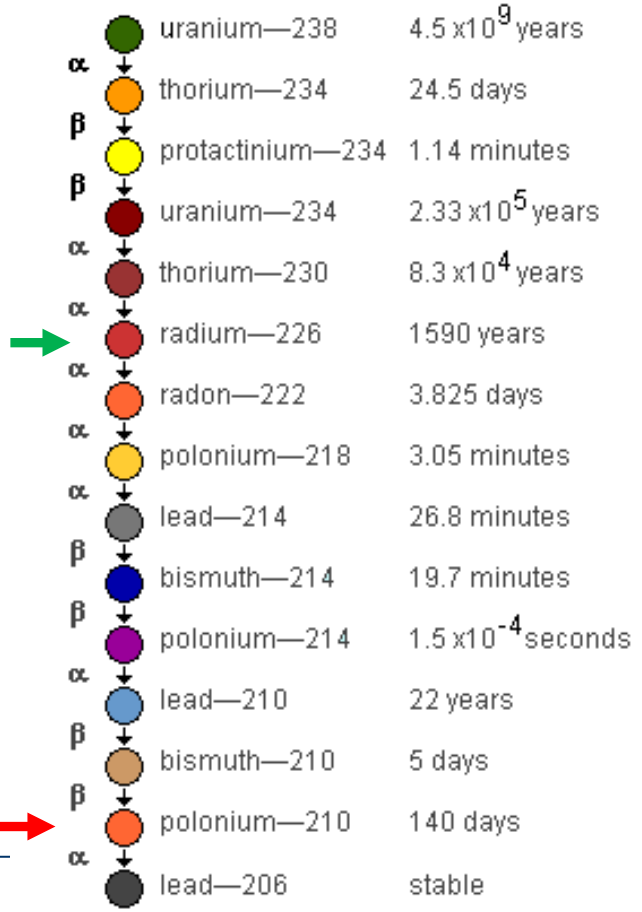
Marie Curie

She also discovered an element
Hint she named it after her homeland.

Po^{210} ~ 0.1-0.3 GBq ~ 1 mg absorbed to blood will be fatal within 1 month
https://pubmed.ncbi.nlm.nih.gov/17341802/.

In 1903 Marie Curie won the Nobel prize for physics, who did she share it with?

Radioactive Decay of ^{238}U

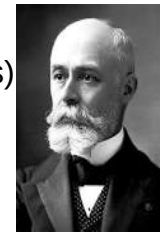


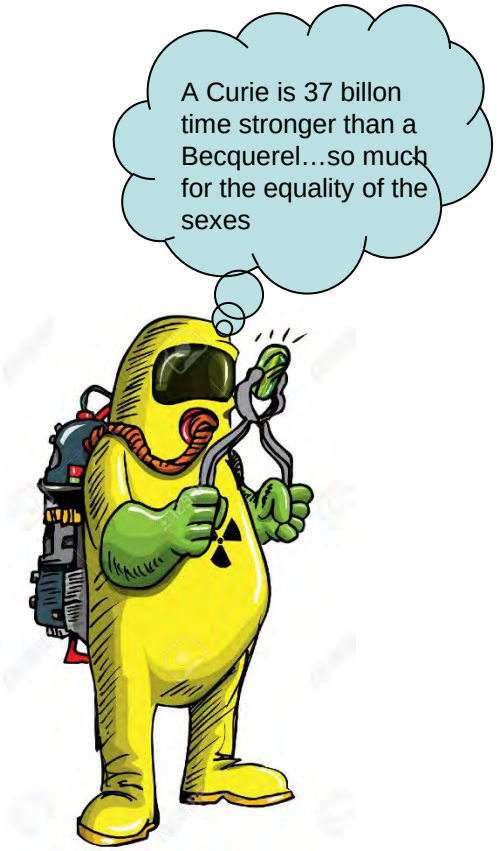
Radioactive Materials – Activity

The activity of a sample is, the average number of disintegrations per second (DPS) its unit is the **Becquerel** (**Bq**) or **Curie** (**Ci**)

A Curie is defined as :
1 gram of natural radium
37×10^9 disintegration per second = 1**Ci**

A Becquerel is defined as:
One disintegration per second (**1 Bq** = 1 dps)
60 counts per minute (60 Bq = 60 cpm)

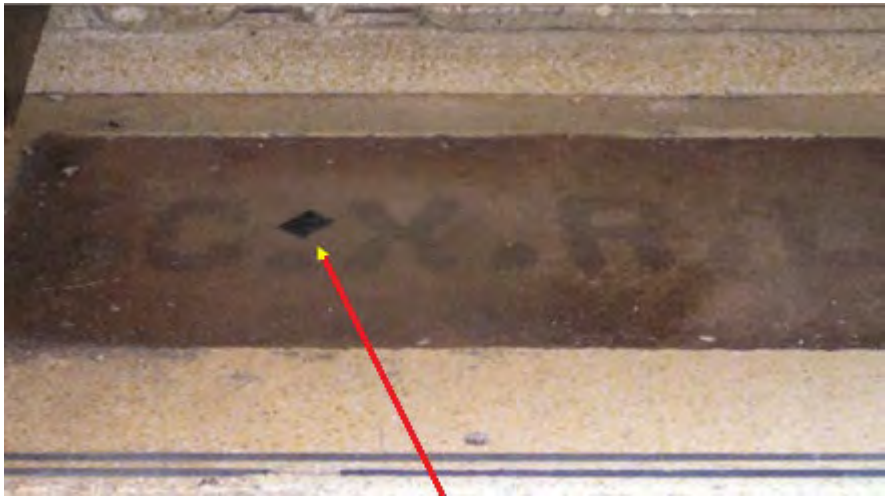




Radium – 226

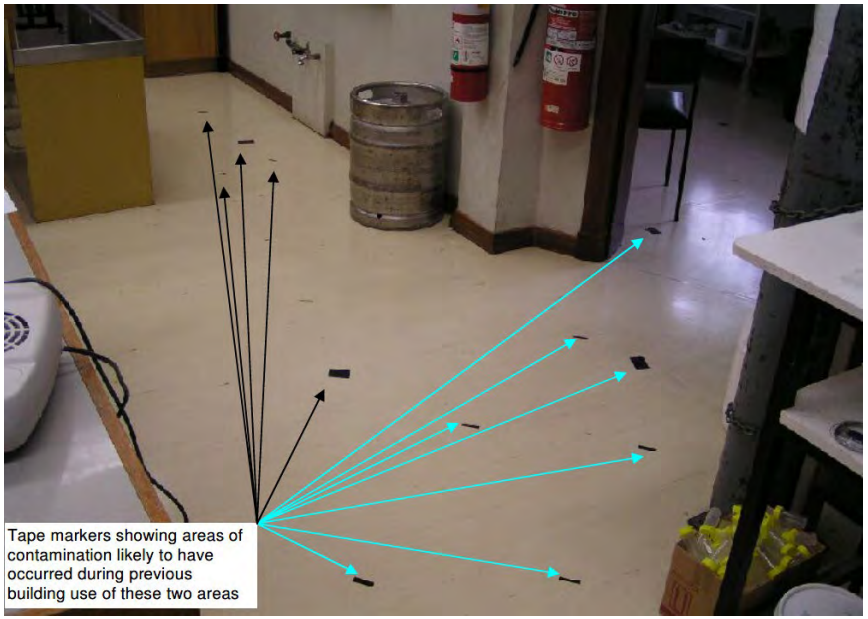
Commonwealth X-ray and Radium Laboratory (CXRL) in 1935

“old Radiation” Building 2016



C.X.R.L welcoming mat (2010)

The problem with RA-226 is the decay chain



Ra-226 was detected in a number of areas, but the real problem was the radium decay chain.

Ra-226 decays to Rn-222, a noble gas that emits high energy alpha particles, very hard to detect

Eventually it decays Po-210, extremally hard to detect!

ARPANSA Dosimetry Monitors
AFOEM Annual Training Meeting

OSL (Optically Stimulated Luminescence)

The OSL monitor measures potential occupational doses from gamma radiation and X-rays.

Polyallyl Diglycol Carbonate (PADC) plastic to measure potential occupational doses from fast neutrons, beta rays and gamma rays.

	OSL	PADC
Directly Measures	skin dose - Hp(0.07) whole body dose - Hp(10)	whole body dose - Hp(10)
Minimum Detectable Dose (MDD)	50 µSv	100 µSv
Minimum Reportable Dose (MRD)*	100 µSv	200 µSv
Uncertainty at the MRD**	30%	50%

- **Why use Real time beta/gamma monitor**
- **Are monitors for all isotopes?**

Thermo EPD® Mk2

- MRD is based on the Limit of Quantification as defined by "Determination and Interpretation of Characteristic Limits for Radioactivity Measurements" (IAEA/AQ/48)

** Uncertainty at the MRD is based on the 95% confidence limit

“old Radiation” the Building that kept on giving 2018

The take home message

Effective Control of an any hazard depends on your:

- **Knowledge**
- **Skill and Experience**
- **Married to your Work Practices**

Thank you listening, I will now hand over to my colleague will elaborate n the other issues associated with the building!