Radiation Safety in the Workplace

Radiation Safety Institute of Canada
Institut de radioprotection du Canada

Good Science in Plain Language®

v1.0

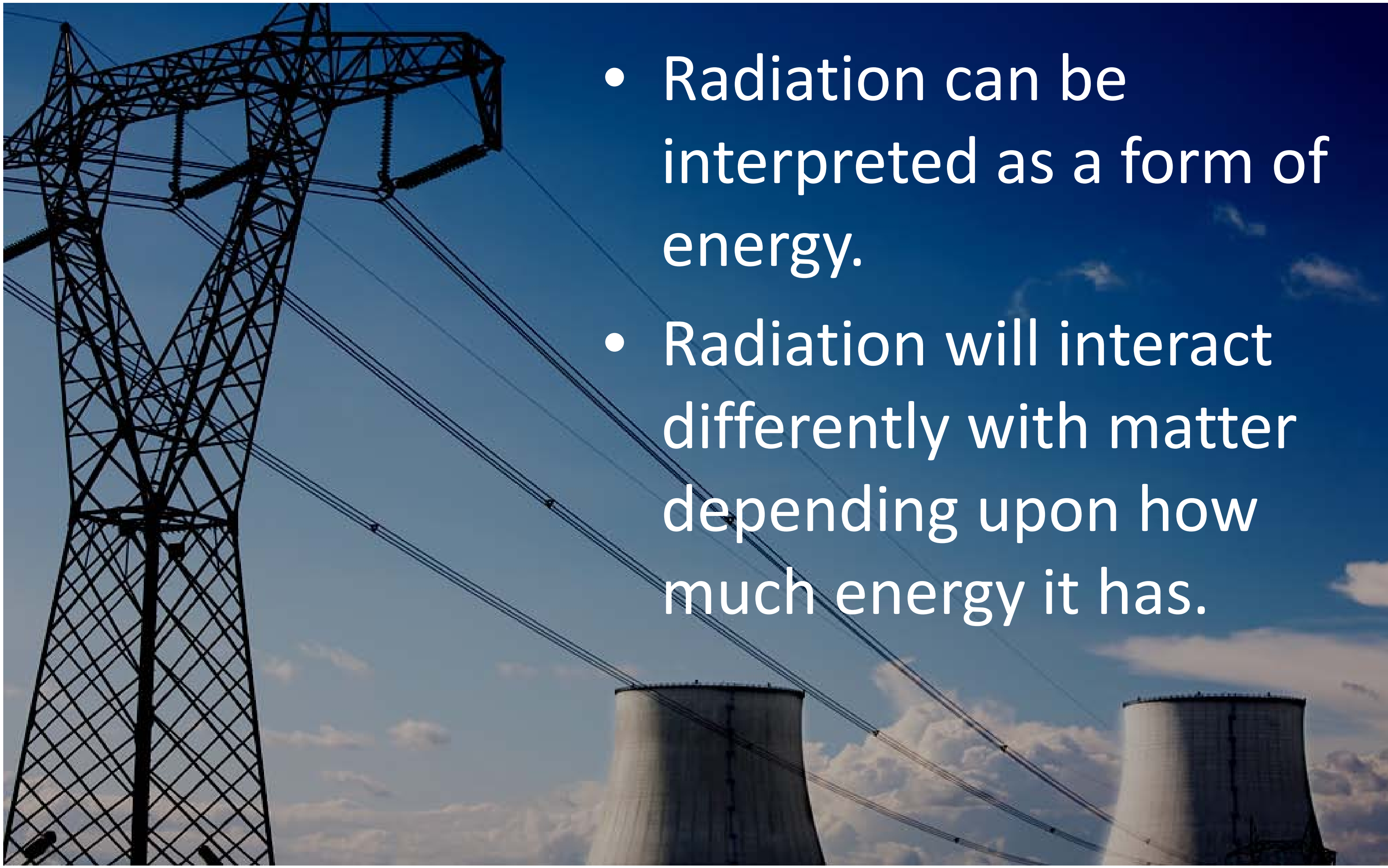
Outline

- What is radiation?
- Different types of radiation
- Activity and Half-life
- Units of radiation dose
- Health effects of exposure to radiation
- Dose limits
- Common radiation exposures
- Regulatory bodies in Canada

Use of Radiation in Canada

- 150,000 Canadians are monitored annually for workplace exposure to radiation
- 50% are associated to healthcare
- 19% are part of the nuclear power industry
- The remaining 31% are from
  - Industry (construction, manufacturing, transport, etc)
  - Education and Research Facilities
- But what IS radiation?

Radiation and Energy

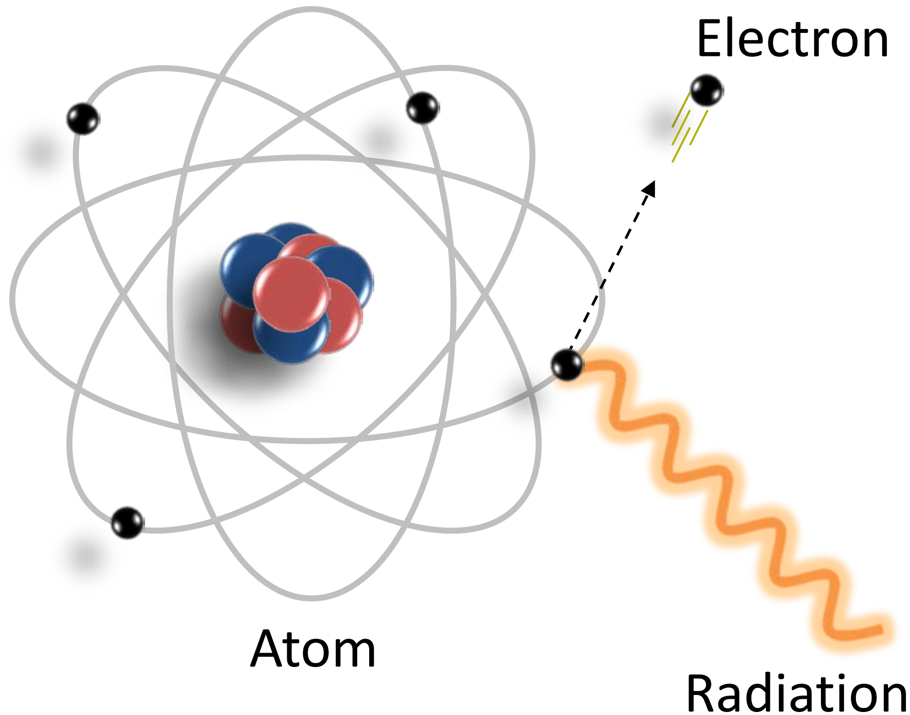


- Radiation can be interpreted as a form of energy.
- Radiation will interact differently with matter depending upon how much energy it has.

Ionizing Radiation

When radiation strikes matter, it interacts with the atoms of the matter.

Radiation with enough energy can knock **electrons** out of orbit from the atoms it strikes.



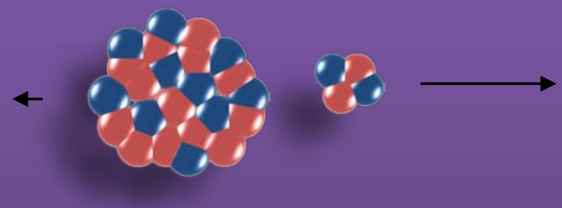
Non-Ionizing (Low Energy) Radiation

Radiation that does not have enough energy to break bonds in matter.

Sources of Ionizing Radiation

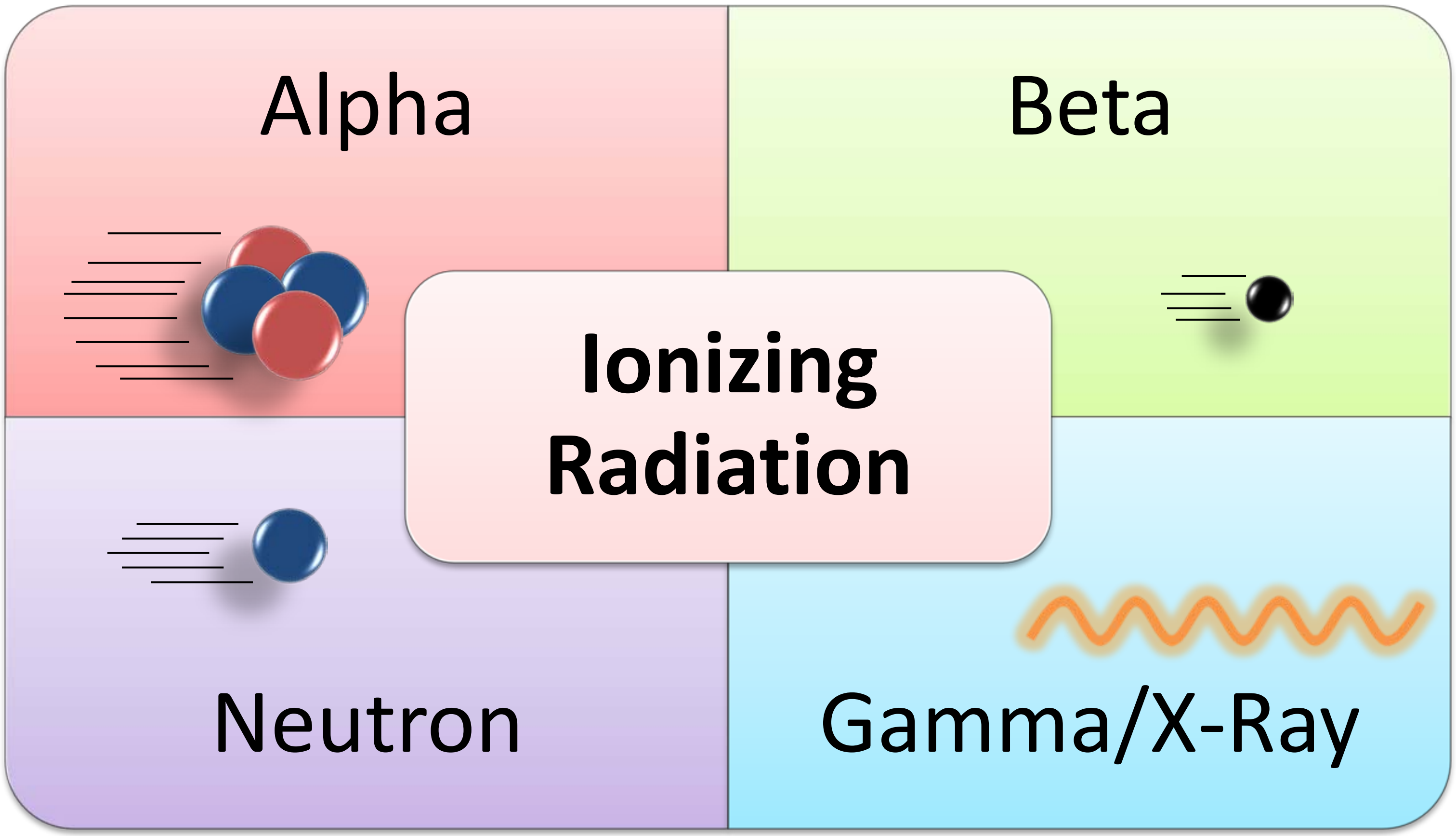
Where does ionizing radiation come from?

Radioactive atoms



Man-made devices

Types of Ionizing Radiation



Alpha Radiation

- Alpha radiation is highly ionizing.
  - It can easily strip electrons from atoms.

- Alpha radiation does not travel far in matter:

Approximately **7 cm of air**

Stopped by a **piece of paper**

Can't penetrate the **dead outer layer of skin**

Alpha Radiation

- Only atoms heavier than lead may decay emitting alpha radiation

Uses:

- Smoke Detectors
- Static Eliminators
- Cancer Treatment

- Commonly found (though well shielded from) in nuclear power plants.

Beta Radiation

- Beta radiation is less ionizing than alpha radiation.

- It can travel farther in matter than alpha:

Approximately **200 cm of air**

Stopped by glass, plastic, or aluminium

Can penetrate skin and tissue, to about 0.2 cm

Beta Radiation

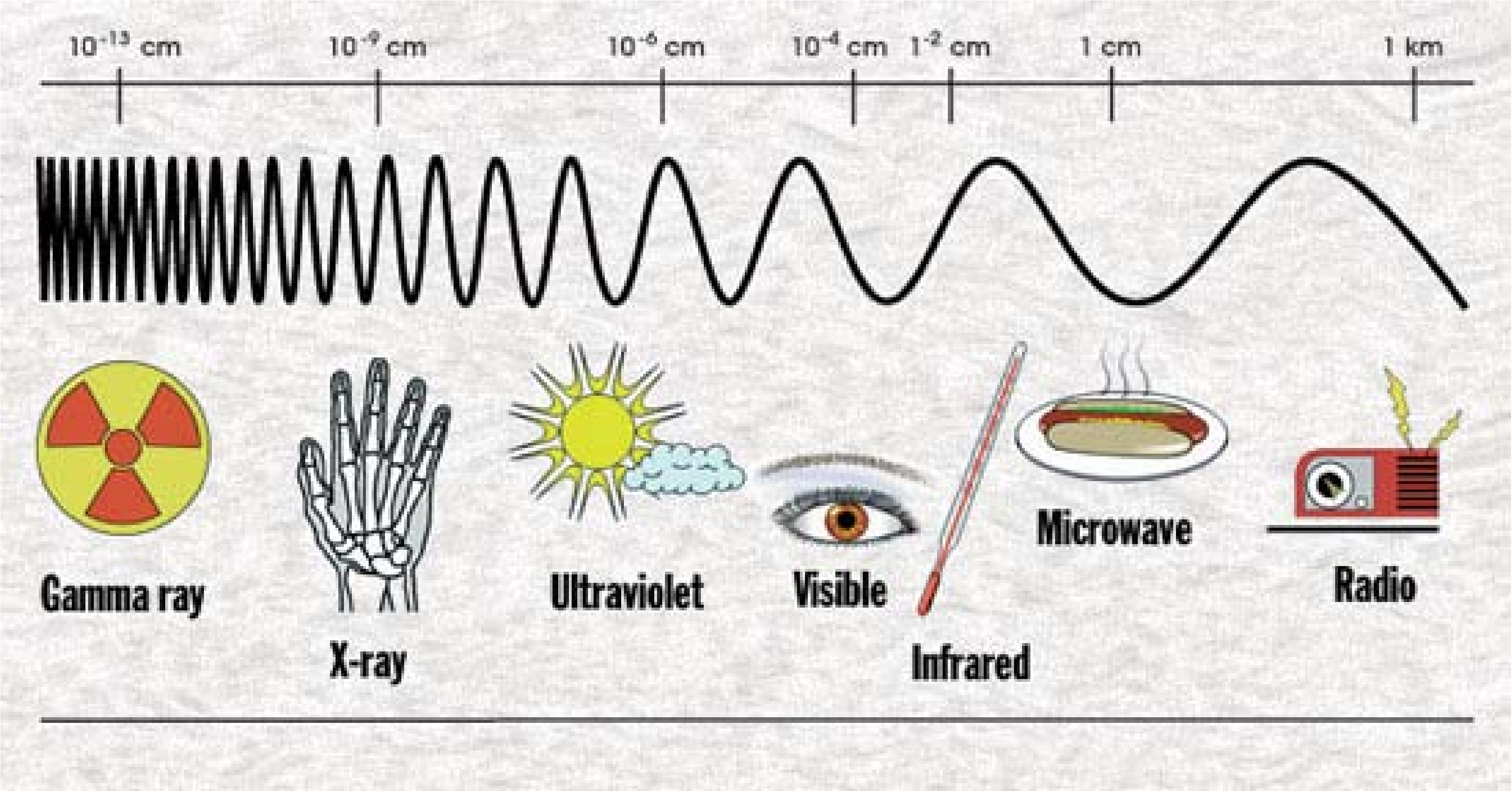
- There are both negatively charged and positively charged beta particles, called electrons and positrons, respectively

Uses:

- Tracing
- Carbon dating
- Positron Emission Tomography (PET scans)
- Cancer Treatment (brachytherapy)

Gamma/X-Ray Radiation

Gamma rays and x-rays are electromagnetic radiation just like **visible light**.



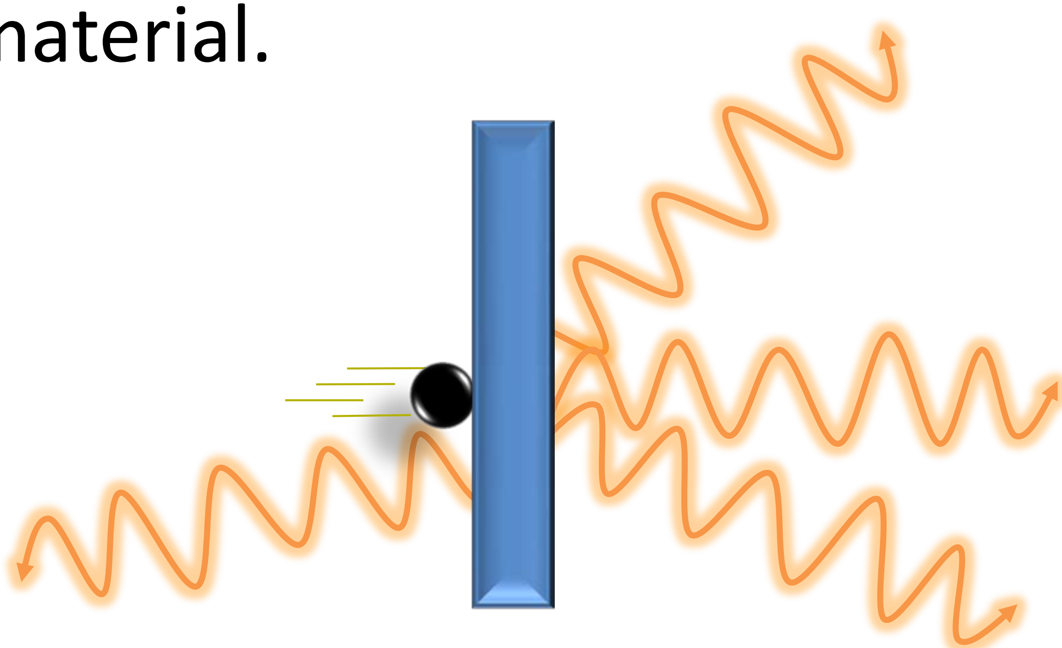
Gamma/X-Ray Emission

- Gamma rays are emitted from the nuclei of radioactive atoms.
  - The emission of a gamma ray is **always** preceded by either a beta or an alpha decay.

- X-rays are created by forcing electrons to hit a target.

How Are X-rays Produced?

- Get a fast moving (energetic) electrons to hit a target material.



- They will slow down, releasing energy and creating x-rays.

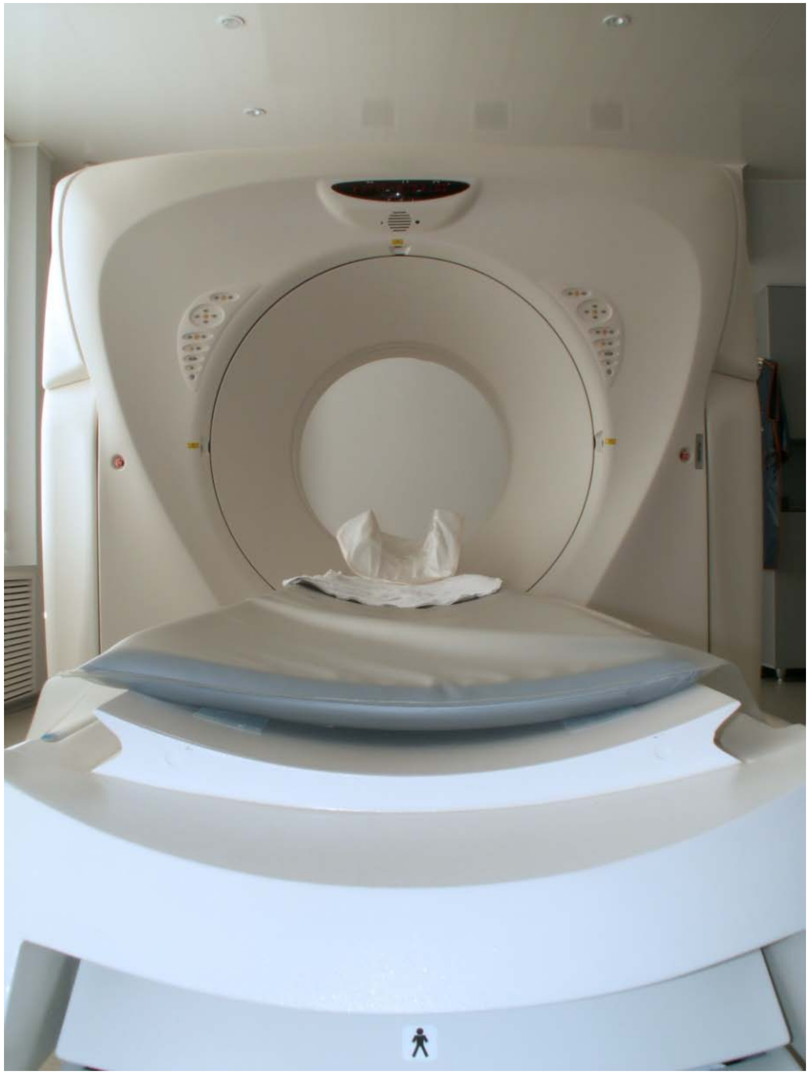
Gamma Rays and X-Rays

- Gamma rays and x-rays are **ionizing** radiation.
- They do not have a range.
  - They can theoretically travel forever.
- As they pass through matter, their ***intensity*** is reduced.

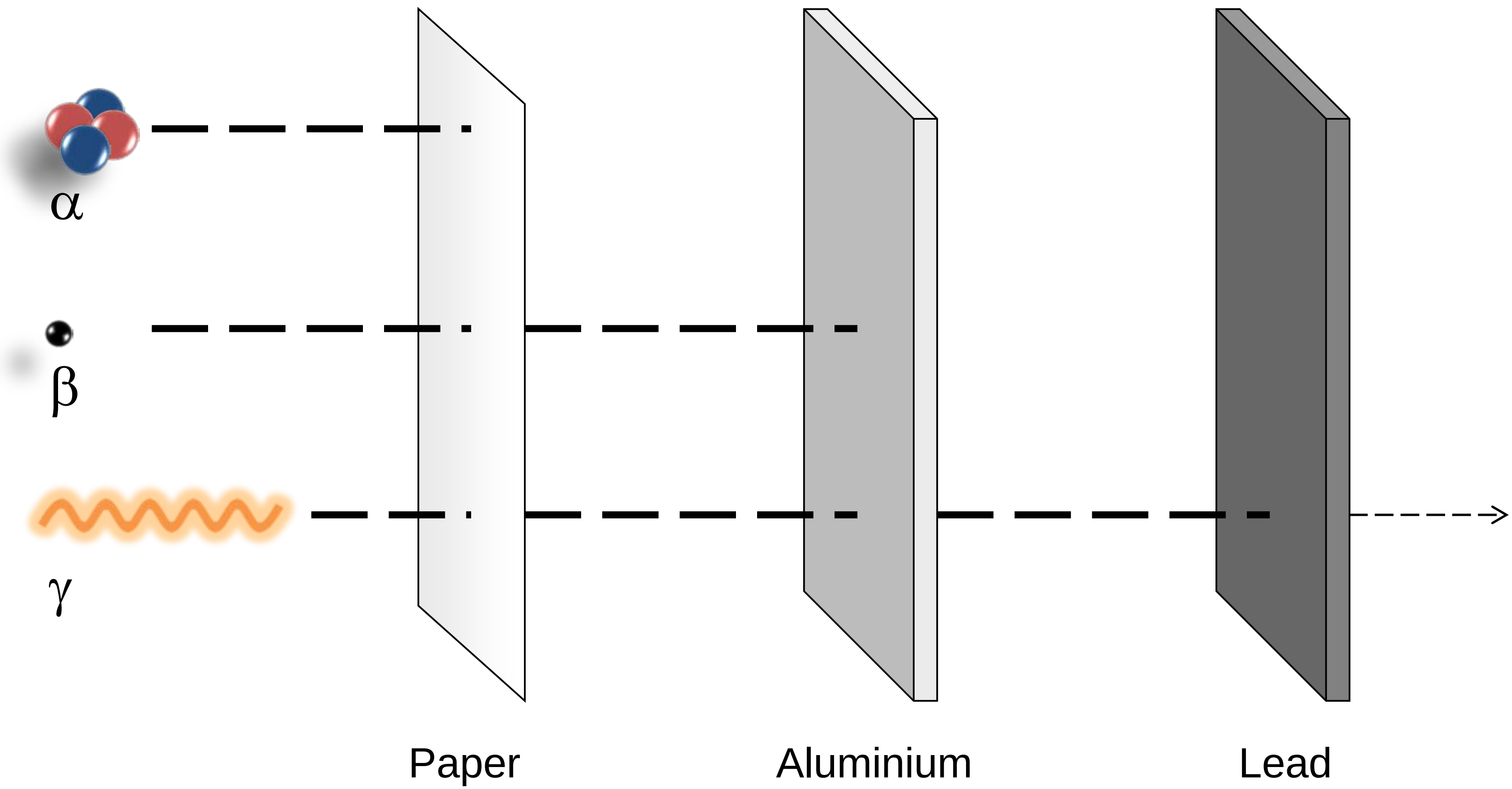
Gamma Ray/X-ray radiation

Uses:

- Diagnostic Imaging
- Radiotherapy
- Baggage Inspection and Security
- Measuring Densities and Thicknesses
- Inspecting Welds

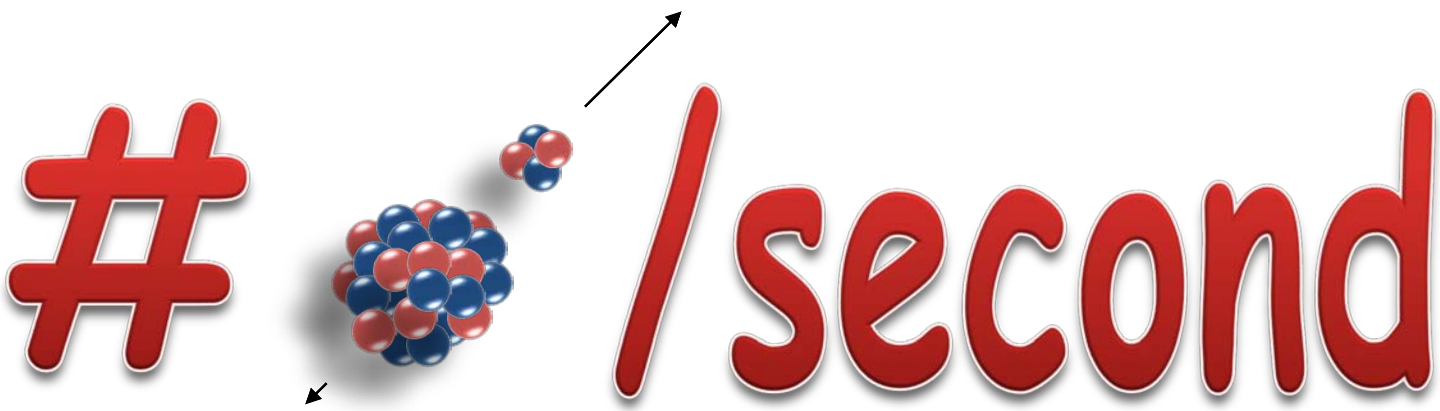


Radiation Penetrating Power

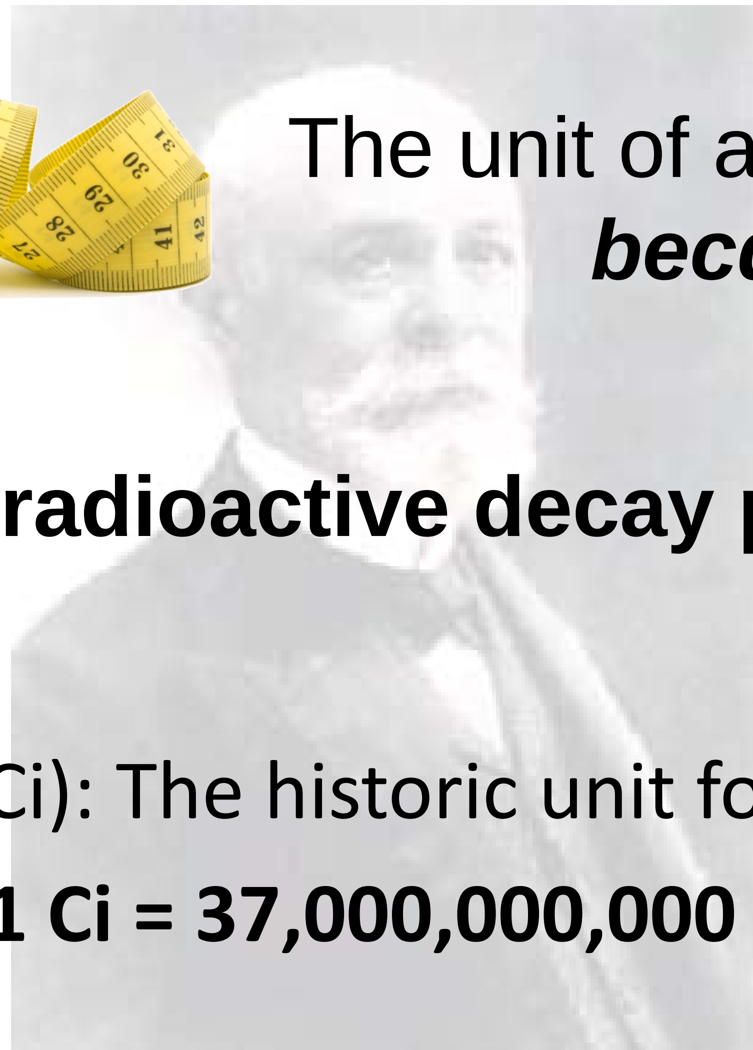


Activity

- ***Activity***: The rate of radioactive decay.
  - The number of radionuclide decays per unit of time.



Activity



The unit of activity is the ***becquerel*** (Bq).

1 Bq = 1 radioactive decay per second

Curie (Ci): The historic unit for activity.

1 Ci = 37,000,000,000 Bq

Activity

To give you an idea...

Use	Type of Radiation	Typical Activity
Smoke Detector	Alpha	37,000 Bq
PET scans (FDG)	Beta	300,000 Bq
Nuclear Gauges	Gamma, neutron	500,000,000 Bq
Brachytherapy (Iodine seeds in prostate)	Beta	1,000,000,000 Bq

Half-Life

- ***Half-life***: The time required for a radioactive sample to lose 50% of its activity by radioactive decay.

- Each radioactive atom has its own unique half-life, regardless of the quantity or form.
  - Solid, liquid, gas
  - Element or compound

Half-life

To give you an idea...

Radioisotope	Half-life
Uranium-238	4.5×10^{9} years
Tritium	12.32 years
Phosphorus-32	14.29 days
Iodine-131	8.02 days
Radon-222	3.8 days
F-18 (FDG for PET)	110 minutes
Tc-99m	6 hours
Polonium-212	3.04×10^{-7} seconds

Radiation Dose

- The effects of radiation depend on the amount of ***energy*** the radiation transfers to your body.
  - Energy is transferred when the radiation knocks electrons out of orbit

- This transfer of energy results in a radiation ***dose.***

Radiation Dose

- Absorbed dose is a measure of the amount of energy radiation deposits in the body, per unit mass.
- The unit of absorbed dose, is called ***gray*** (Gy).
- 1 Gy is a very large dose.
  - mGy or µGy are used more often

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Equivalent Dose

- The *equivalent dose* is the *absorbed dose* multiplied by a radiation weighting factor

- The radiation weighting factor accounts for the different biological damage produced by different types of radiation

- Unit of equivalent dose:
  – *millisieverts (mSv)*

Equivalent Dose

- 1 unit of *absorbed dose* from **gamma**, **x-ray** and **beta** radiation produce approximately the **same** amount of damage in tissue

- 1 unit of *absorbed dose* from internal **alpha** radiation causes approximately **20 times** more damage to tissue than 1 unit of absorbed dose from gamma, x-ray or beta radiation

1 mGy of alpha = 20 mGy gamma = 20 mGy beta

- The concept of **equivalent dose** takes this into account

1 mSv of alpha = 1 mSv gamma = 1 mSv beta

Effective Dose

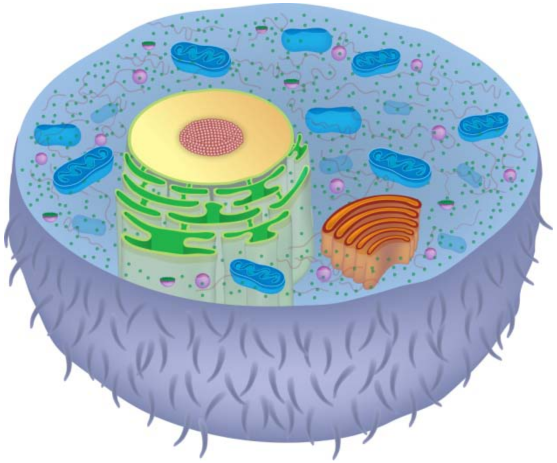
- The ***effective dose*** is the *equivalent dose* multiplied by a tissue weighting factor, to assess dose on the scale of the whole body

- The tissue weighting factor helps to account for the varying sensitivities to radiation exposure of the different tissues and organs

- The unit of effective dose is also the ***millisievert*** (mSv)

Interaction with the Body

- When radiation strikes living tissue, there are a number of possible outcomes:



  - No damage at all
  - Damage to cells that is repaired
  - Damage to cells that leads to cell death
    - Causes ***deterministic effects*** when exposed to large amounts of radiation in a short period of time
  - Damage to cell chromosomes that is incorrectly repaired ("mutated")
    - Probability increases with increased exposure to radiation
    - Main concern: mutation leading to cancer

Effect of Radiation on People

Cell mutations caused by radiation could lead to:

- Hereditary (genetic) effects

- Somatic effects

Hereditary Effects

- Hereditary or genetic effects are potential health effects future generations might experience as a result of our exposure to radiation.

Hereditary Effects

- Radiation alters the DNA molecule in the egg cells of a female or in the sperm cells of a male.
  - This may cause abnormalities in descendants, such as leukemia and developmental delays.
- Hereditary effects have been demonstrated on laboratory animals.
- Hereditary effects have not been proven on human beings yet.

Somatic Effects

- Somatic effects are experienced by the people exposed to radiation.
- A radiation dose has a certain probability of causing a mutation in a cell, which might:
  - Cause cells to divide in an uncontrolled manner.
- Uncontrolled cell division could lead to ***cancer***, which could be fatal.

Cancer

- Radiation exposure increases the ***likelihood*** of developing cancer.

- The greater the exposures the greater is the likelihood.

- But we cannot be certain that an effect will or will not occur.

Cancer

- We know that smoking causes lung cancer.
  - But, Joe smoked sixty a day and lived to be 95!
- Some people develop lung cancer in their life anyway.
  - Only some of these people are smokers.
- Smoking increases the likelihood of developing lung cancer.
  - This is a stochastic effect.

Cancer Risk from Radiation

- The risk of developing a fatal cancer as a result of exposure to radiation is approximately 4% per 1000 mSv.
  - Consider a person who worked for 50 years and received 20 mSv per year.
  - This person's total lifetime radiation dose is 1000 mSv.
  - This person will have an extra 4% chance of developing a fatal cancer.

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Effective Dose Limits

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Person	Period	Effective Dose (mSv)
Nuclear Energy Worker (NEW)	1-yr dosimetry period	50
	5-yr dosimetry period	100
Pregnant NEW	Balance of the pregnancy	4
A person who is not a nuclear energy worker	1 calendar year	1

Radiation Protection Regulations, Section 13(1)

Chronic Exposure

- Exposure to low doses of radiation over months or years
  - Deterministic effects
    - Cataracts
  - Probabilistic effects
    - Cancer

Acute Exposure

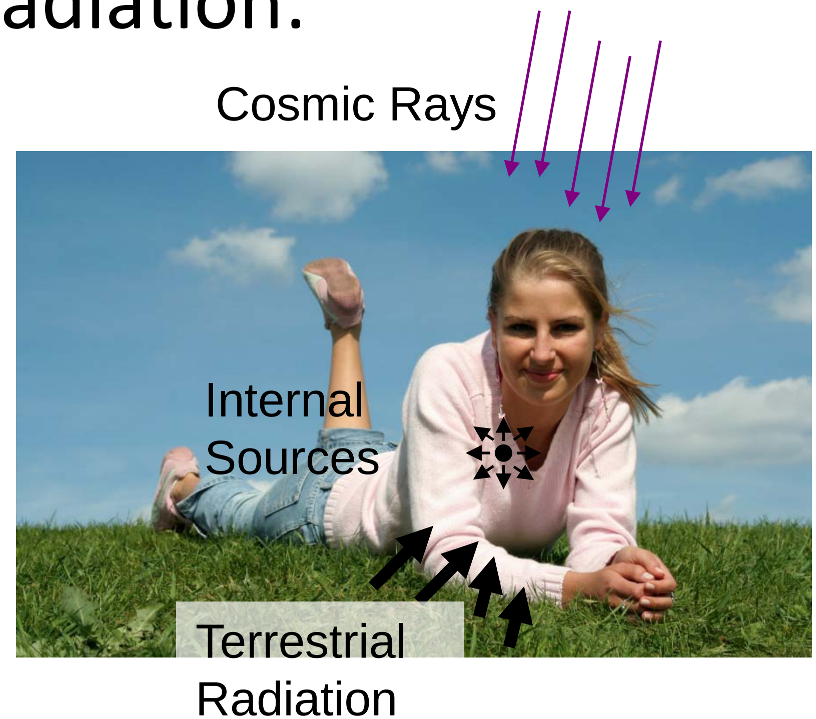
- Exposure to a high dose delivered within seconds, minutes or days
- Possible ***deterministic effects***
  - Blood changes
  - Nausea
  - Diarrhea
  - Hair-loss
  - Malaise
  - Death

Acute Exposure

Acute Dose (mGy)	Effect
< 250	No detectable effects
> 3,000	Chance of death 50% and above
> 6,000	Death an almost certainty, time between exposure and death depends on amount of dose

Radiation Exposure

- We are all exposed to radiation:
  - Cosmic radiation
    - sun, space
  - Terrestrial radiation
    - soil, rocks
  - Internally
    - Food, air (radon gas)
  - Medical treatment



- On average, we receive about 2 – 4 mSv per year from background radiation

Radiation Protection Principles

- External radiation exposure can be decreased by:
  - Time
  - Distance
  - Shielding

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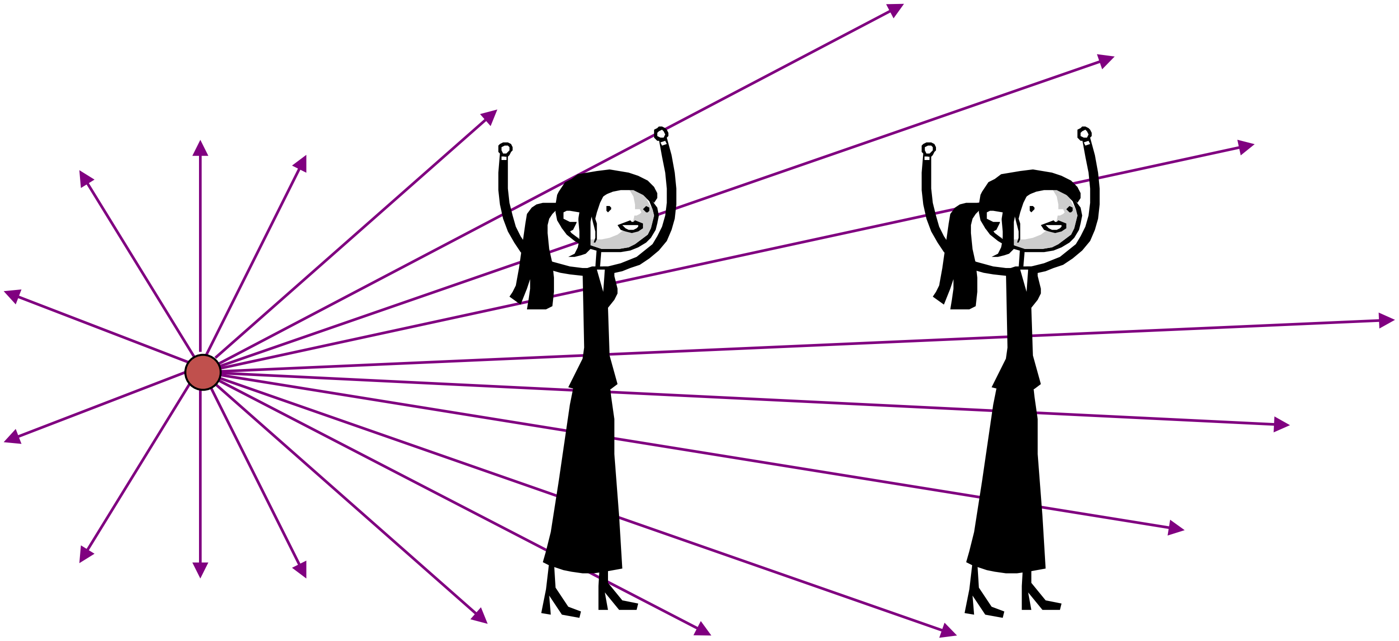
Time

Radiation exposure can be reduced by simply limiting the time a person spends near the source, or the time the X-ray unit is on.

Distance

- The worker farther from the radiation source/X-ray unit will receive less radiation exposure than the worker closer to it



Shielding

- Shielding is the main source of protection from exposure to radiation sources.

- For example:
  - Lead
  - Steel
  - Glass
  - Paper

Lead bricks
Image courtesy of Radiation Protection Products, Inc.

Radiation Protection

- Good work habits are very important to minimize the intake of radiation
  - Hygiene
    - Wash hands regularly
    - Do not eat or drink in work areas
    - Do not smoke in work areas

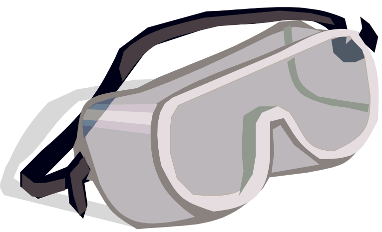
Radiation Protection

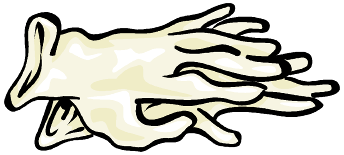
– Work practices

- Follow work instructions
- Follow radiation safety procedures

– Use appropriate equipment

- Gloves, goggles, protective clothing, etc.
- Wear dosimeter
- Wear respirators





Credit: Global Dosimetry Solultions

Safe Work Habits

- Use the minimum quantity of radioactivity required.
- Promptly return unused radioisotopes to storage areas.
- Clearly identify work surfaces and objects used for handling radioactive material.
  - Ideally, maintain room(s) which are used solely for radioactive work.
- Use disposable absorbent liners on trays and surfaces.

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Regulations

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Radioactive Materials

- Nuclear Safety and Control Act
- Independent Regulator:
  Canadian Nuclear Safety Commission (CNSC)
- Regulations, licences and orders are legally binding documents

X-rays

- Above 10 MeV: same as radioactive materials
- Below 10 MeV: provincially regulated

CNSC Regulations

- General Nuclear Safety and Control
- Radiation Protection
- Nuclear Substances and Radiation Devices
- Packaging and Transport of Nuclear Substances
- Nuclear Security
- Class I Facilities
- Class II Facilities
- Uranium Mines and Mills
- Nuclear Non-Proliferation Import and Export Control

Provincial X-ray Acts and Regulations

Province	Ministries & Departments	Acts and Regulations
Alberta	Ministry of Employment, Immigration and Industry	Radiation Protection Act and the associated Regulation Radiation Health Administration Regulation
British Columbia	Workers' Compensation Board WorkSafe BC	Occupational Health and Safety Regulation, Part 7, Division 3
Manitoba	Manitoba Labour and Immigration Manitoba Health CancerCare Manitoba	Workplace Health and Safety Regulation, Part 18 X-Ray Regulation

Provincial X-ray Acts and Regulations

Province	Ministries & Departments	Acts and Regulations
New Brunswick	Department of Health	Radiological Health Protection Act X-Ray Equipment Regulation General Regulation
Newfoundland & Labrador	Department of Government Services	Radiation Health and Safety Act Radiation Health and Safety Regulations
Northwest Territories and Nunavut	Workers' Safety and Compensation Commission	Safety Act General Safety Regulations

Provincial X-ray Acts and Regulations

Province	Ministries & Departments	Acts and Regulations
Nova Scotia	Department of Labour and Workforce Development	Occupational Health and Safety Act Occupational Health Regulations Specific x-ray regulation was repealed in 2005
Ontario	Ministry of Labour Ministry of Health and Long-Term Care	Occupational Health and Safety Act, Regulation 861 Healing Arts Radiation Protection Act (HARP) and Regulation 543
Prince Edward Island	Department of Health	Public Health Act Radiation Safety Regulations

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Provincial X-ray Acts and Regulations

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Province	Ministries & Departments	Acts and Regulations
Quebec	Commission de la santé et de la sécurité au travail Laboratoire de Santé Publique du Québec Radioprotection Unit	Workplace Health and Safety Act Workplace Health and Safety Regulation
Saskatchewan	Ministry of Advanced Education, Employment and Labour	Radiation Health and Safety Act Radiation Health and Safety Regulations
Yukon	Workers' Compensation Health and Safety Board	Occupational Health and Safety Act Radiation Protection Regulations

Resources

Web Sites

- Canadasafeimaging.ca
- www.radiationsafety.ca
- imagewisely.org
- imagegently.org
- radiologyinfo.org
- radiationanswers.org
- rpop.iaea/safrad/

Organizations

- Canada Safe Imaging
- Radiation Safety Institute of Canada
- ICRP
- NCRP
- IAEA

Radiation Safety Institute of Canada

- The Radiation Safety Institute of Canada is an independent, not-for-profit organization specializing in radiation safety.

- For further information on all types of radiation contact us at:

1-800-263-5803

info@radiationsafety.ca

www.radiationsafety.ca

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Thank you for listening!

Curtis Caldwell, Ph.D.

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