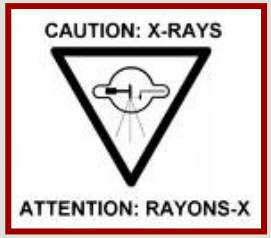
# Analytical X-Ray Device Safety




***Updated: October 17, 2013***

***This online training is intended for users of X-ray devices equipped with an interlock system***

***X-Ray Compliance Specialist***
**(613) 562-5800 x2000** ***xray.safety@uottawa.ca***

# Important Factors

- X-ray devices must be registered with the Ministry of Labour (MoL)
  - ORM completes and files registration for the devices
  - Fill out the internal X-Ray Permit Application

- X-ray devices must be internally permitted by the Office of Risk Management (ORM)
  - ensure potential exposure controls exist and have not been compromised

- If you will be using an open X-ray beam device, a more comprehensive training is mandatory
  - Please contact ORM for assistance

# Training Objectives

- *Creating and maintaining a safe work environment*
- *Developing proper work procedures, habits and attitudes*

# Training Outline

- Legislation
- Sources and Use of X-rays
- Biological & Health Effects
- X-ray safety in the lab
  - Exposure
  - SOPs
  - Security
  - Emergencies
  - Summary
- References

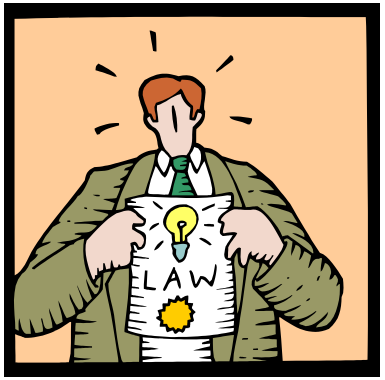
# Legislation
## Federal Guidelines

- Health Canada Safety Code 32: Safety Requirements & Guidance for Analytical X-ray Equipment
  - outlines responsibilities of owners of equipment, safety procedures, standards, surveillance and monitoring

- Radiation Emitting Devices Regulations (C.R.C., c. 1370)
  - regulates the interpretation, standards of design and construction and standards of functioning of radiation emitting devices

# Legislation
## Ontario Ministry of Labour

- Operates in accordance with *Ontario Occupational Health and Safety Act*
  - Non-medical uses
  - Sets standards
  - Establishes regulations for:
    - Possession
    - Safe use of X-ray equipment



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# Sources and Uses

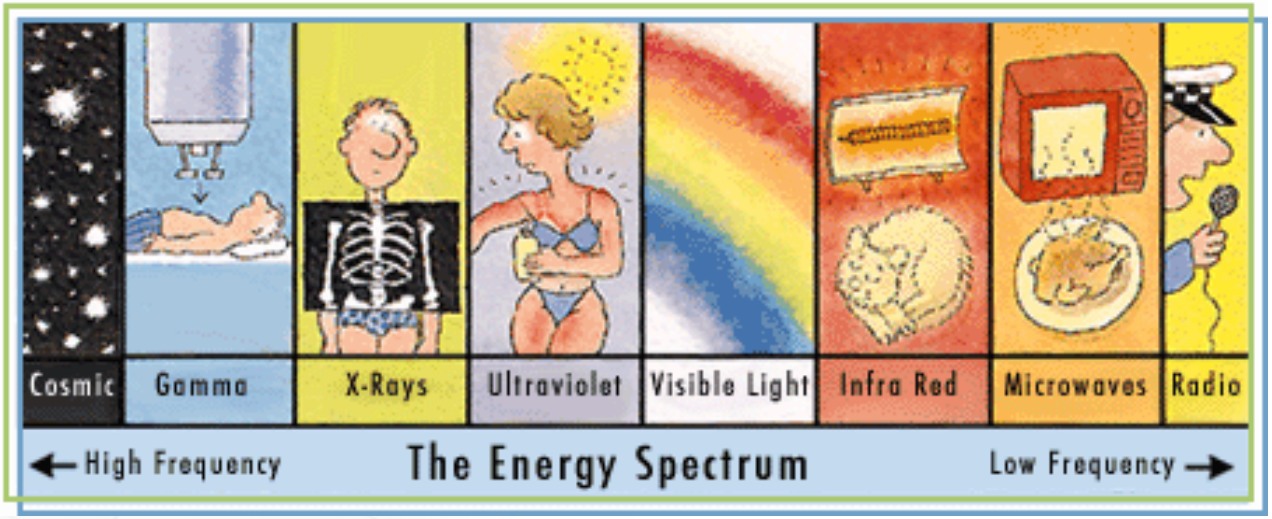
- How are X-rays produced
- Atomic properties and interaction with matter
- X-ray machine vs. X-ray source
- What you can find at uOttawa



***University of Ottawa***
***Office of Risk Management***
***X-Ray Compliance Specialist ext.2000***

# What are X-rays?

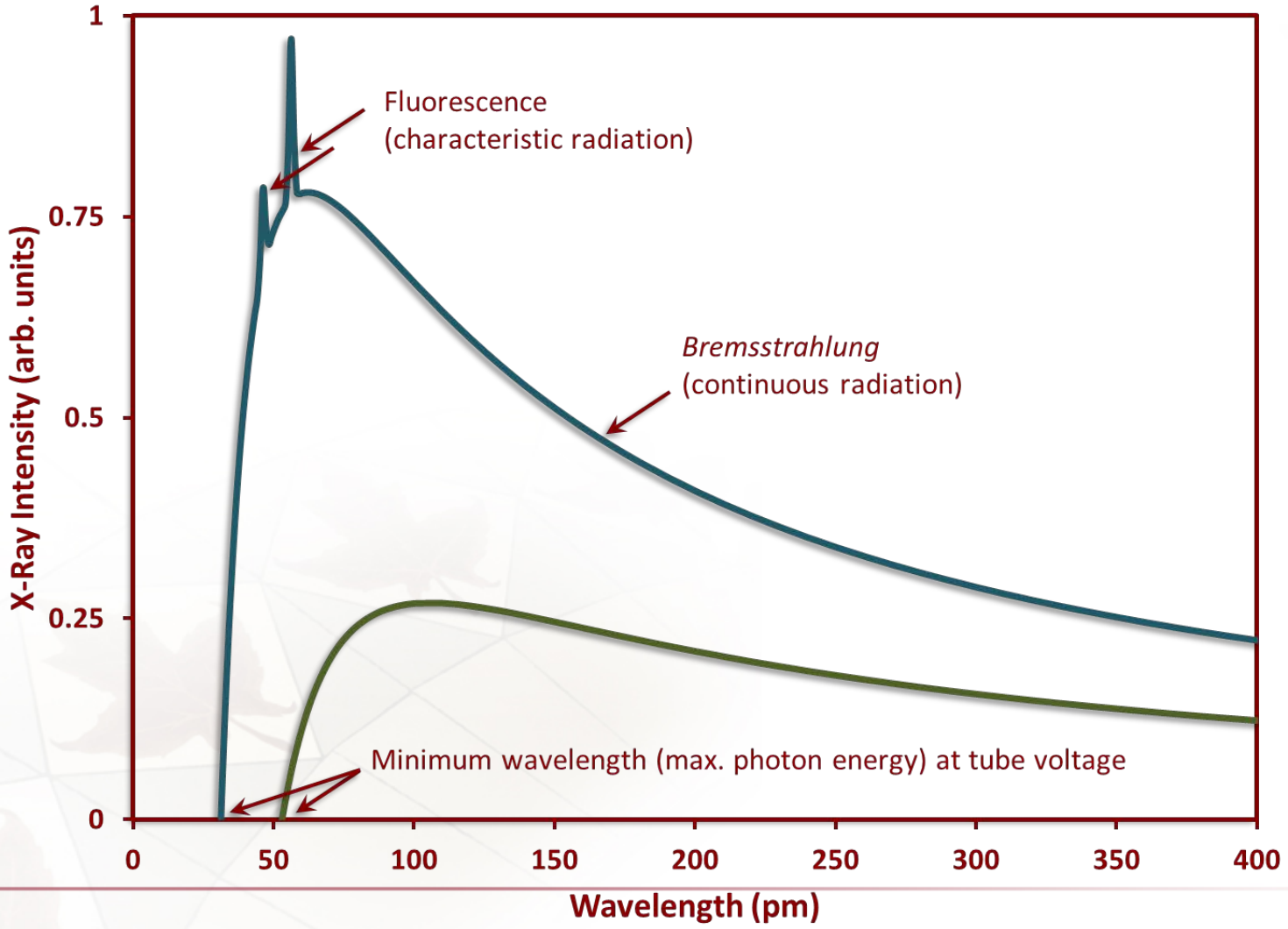
- Part of electromagnetic spectrum (photons)
  - energy range of 10 eV – 120 keV (0.01 nm – 130 nm)
- Ionizing radiation ***originating from the electron shell***
- May be produced by machines



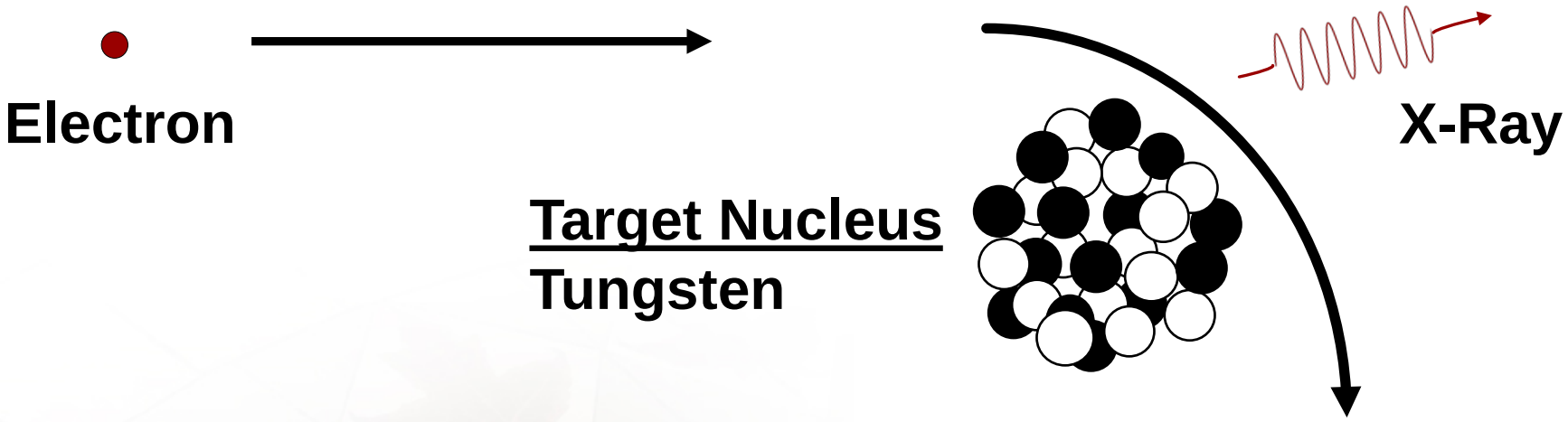
# How are X-rays Produced?

- Two ways of creating X-rays:
  - *Bremsstrahlung*:
    - ‘braking radiation’ (German)
    - Caused by acceleration/deceleration of a charged particle (usually electron)
    - Electron deflected by a nucleus (X-ray tubes)
    - Electron deflection by a magnet (cyclotron/synchrotron/wigglers)
  - Fluorescence:
    - Electronic transitions in an atom (ionization/relaxation)
    - Usually inner shell vacancies filled by outer shell electrons
    - Characteristic X-rays of materials

# How are X-rays Produced?



# X-ray Production: *Bremsstrahlung*

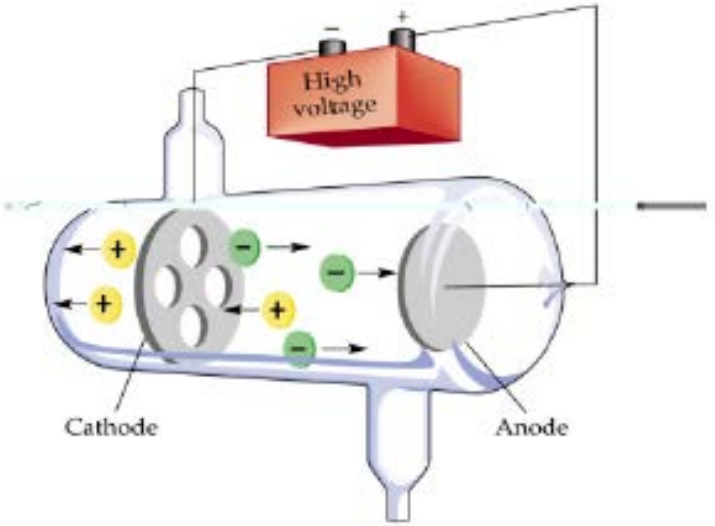



X-rays produced from acceleration of electrons which are deflected from their original paths by other charged particles such as the nucleus

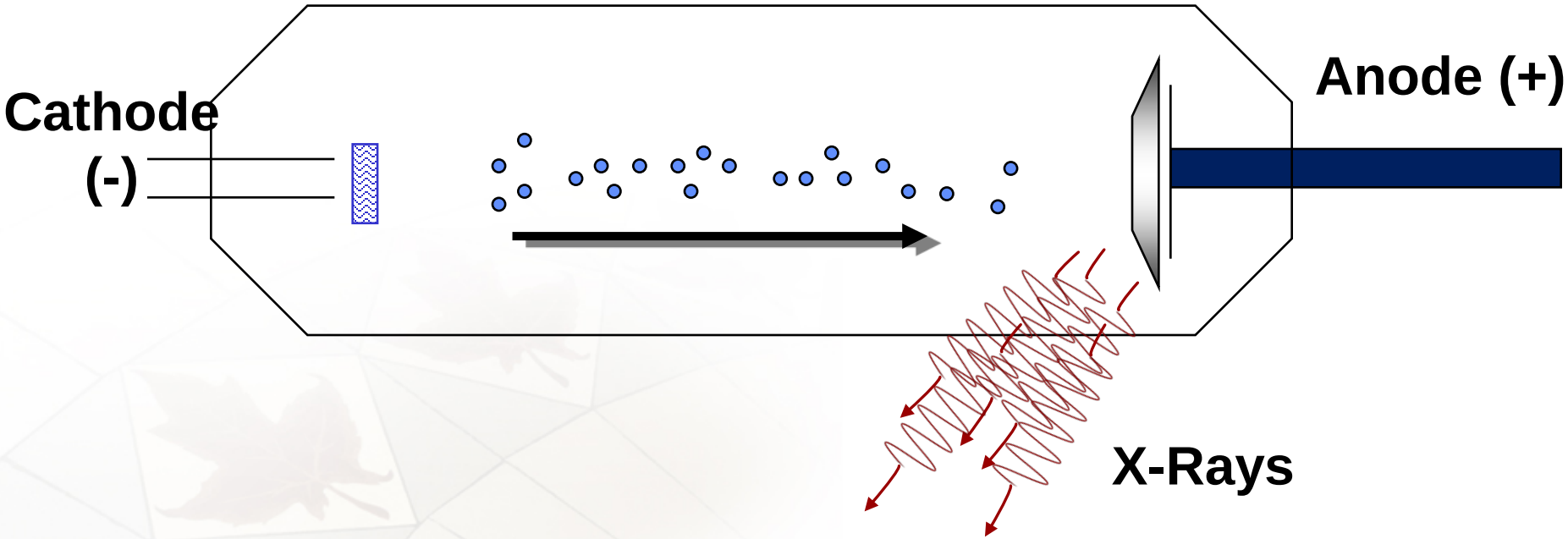
# X-ray Devices

- X-rays produced whenever a high voltage, a vacuum and a source of electrons present

- Most X-ray devices emit electrons from a cathode, accelerate them with a voltage and hit the anode (target) that emits X-ray



# X-ray Tube



# Sources and Uses

## X-ray machine

- electrically powered device with a PRIMARY purpose of producing X-rays
- analyzes structures or materials

## X-ray source

- any part of a device that emits X-rays, whether or not the device is an X-ray machine
  - e.g.: electron microscope

# Sources and Uses

*The University of Ottawa holds two types of X-ray instruments used for academic research*

## X-ray Diffractometer (XRD)

- commonly used in structural analysis
- powder and single-crystal versions available

## X-ray Fluorescence (XRF)

- observes fluorescent emissions of x-ray and UV as atoms hit by x-rays
- commonly used to study earth materials

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# Biological & Health Effects

## FACTORS DETERMINING BIOLOGICAL EFFECTS

- Dose and equivalent dose
- Total dose and dose rate
- Energy of radiation
- Amount of body exposed
- Cell and individual sensitivity

# Biological & Health Effects

## DOSE (D)

- Effects from radiation depend on amount of radiation received (absorbed) by the body

- Called Dose or Absorbed Dose (D)
  - ***quantity of energy deposited in a unit of mass of material***

- *Units of Measure:Gray (Gy) or rad*

***1 Gy = 100 rad***

# Biological & Health Effects

## EQUIVALENT DOSE (H)

- Biological effect caused by radiation being deposited in human body
  - Dependent on type of radiation and energy
- Quality factor (QF) relates absorbed dose to biological damage of the exposed tissue
  - Different types of radiation cause different degrees of damage.
- The higher the quality factor, the greater biological risk or effect than radiation
  - for the same absorbed dose

# Biological & Health Effects

## Total Dose

- Effects from acute doses (> 1 Sv = 100 rem) easily observed
- At 0.1 Sv, effects not reliably quantifiable due to no observable effects

# Biological & Health Effects

## DOSE RATE

- Dependent on amount of radiation over period of time (exposure)
- Acute (large) vs chronic (small)
- For the same radiation dose, acute dose is more damaging, since tissues does not have time for repairs

# Biological & Health Effects

## ENERGY OF RADIATION

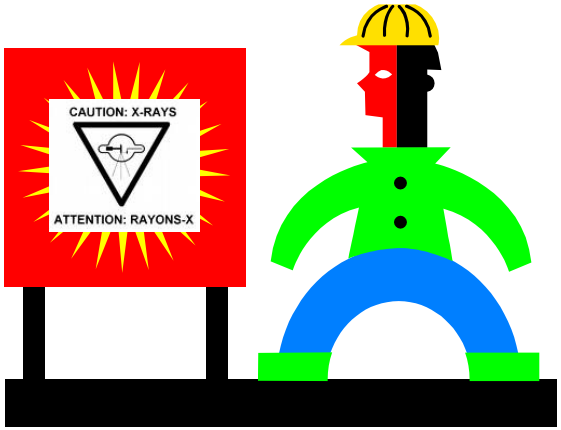
- X-rays span a large energy range
  - 10 to 100 keV
- Higher energy photons penetrate deeper into tissue
- Lower energy X-ray absorbed in first layers of skin (shallow dose)

# Biological & Health Effects

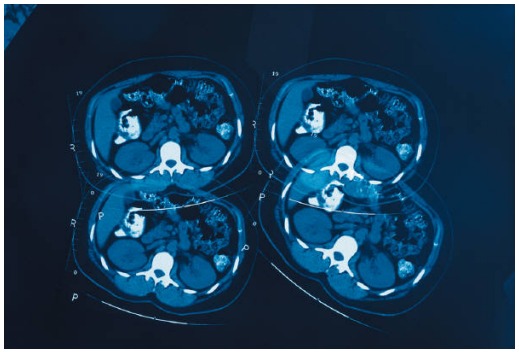
## AMOUNT OF BODY EXPOSED

- Harder and more damaging for body to recover from dose to large area of body than a small, localized area such as hand

- Might include sensitive organs



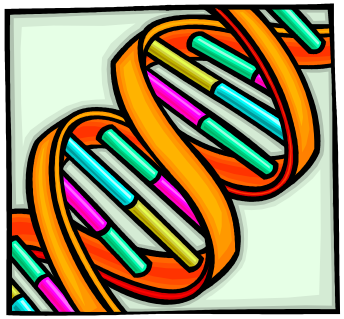
# Biological & Health Effects



## SENSITIVITY

- Individual sensitivity to absorbed radiation
- Type of cells:  some more radiosensitive such as those undergoing cell division

# Biological & Health Effects



## GENETIC EFFECTS

- Biological effect inherited by children resulting from a modification of genetic material in a parent
  - No genetic effects observed in humans only in animal studies

- No statistically significant genetic effects observed in children in Japanese atomic bomb survivors
  - any effects on offspring from nuclear bombing survivors in Japan in WW2 from women already pregnant)

# Biological & Health Effects

## SOMATIC EFFECTS

- Biological effect observed in our lifetime to exposed individual (not carried to offspring)

- Skin damage (“sunburn”) at doses 5 Sv (5000 mSv)
  - *MoL annual limit = 50 mSv*

- Eye damage (cataracts) can results at doses > 6 Sv (6000 mSv)
  - *MoL annual limit = 150 mSv*

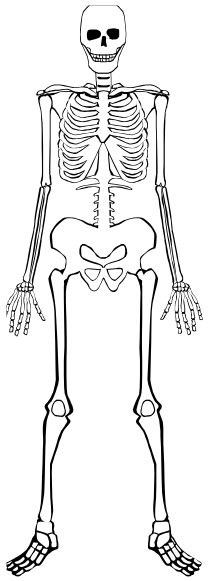
# Biological & Health Effects

## CANCER RISK

- Radiation exposure including exposure to X-rays does not cause any unique forms of cancer that are not normally observed in humans

# Biological & Health Effects

- Due to localized nature of X-ray beams
  - acute doses to whole body NOT USUAL
- Most health effects occur due to chronic exposure
  - hospital, dentist
- Most exposure to analytical X-rays results in exposure to skin and extremities



# Ministry of Labour

## DOSE LIMITS

**Worker Protection: Occupational Dose Limits**

(designated X-ray worker)

- 50 mSv annually whole body
- 50 mSv annually – to any organ, skin, or extremity
- 150 mSv annually – eye dose equivalent
- < 5 mSv during pregnancy

**General Public:**

- 5 mSv annually (whole body)

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# X-Ray Safety in the Lab

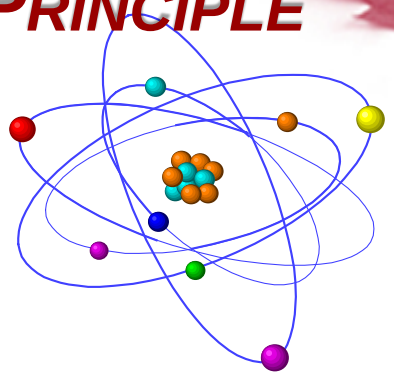
## THE ALARA PRINCIPLE

**ALARA = As Low As is Reasonably Achievable**

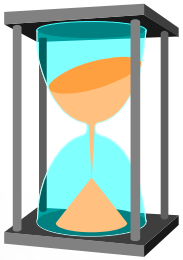
The ALARA Principle is a philosophy of radiation safety that every reasonable effort should be made to minimize dose. This guiding philosophy has actually been incorporated in regulations for all entities that possess radioactive material. The ALARA provision in regulations facilitates proactive measures for radiation protection and safety.

# X-Ray Safety in the Lab

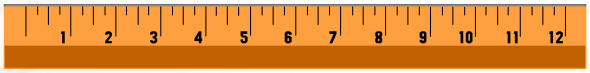
## THE ALARA PRINCIPLE



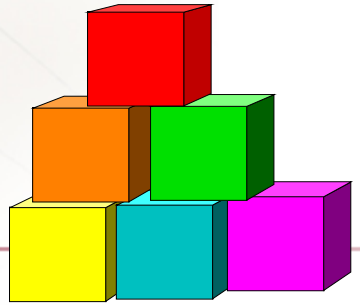
- AMOUNT & TYPE OF RADIATION EXPOSURE
- TIME



- DISTANCE



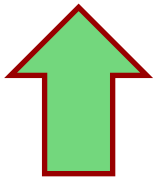

- SHIELDING



# X-Ray Safety in the Lab

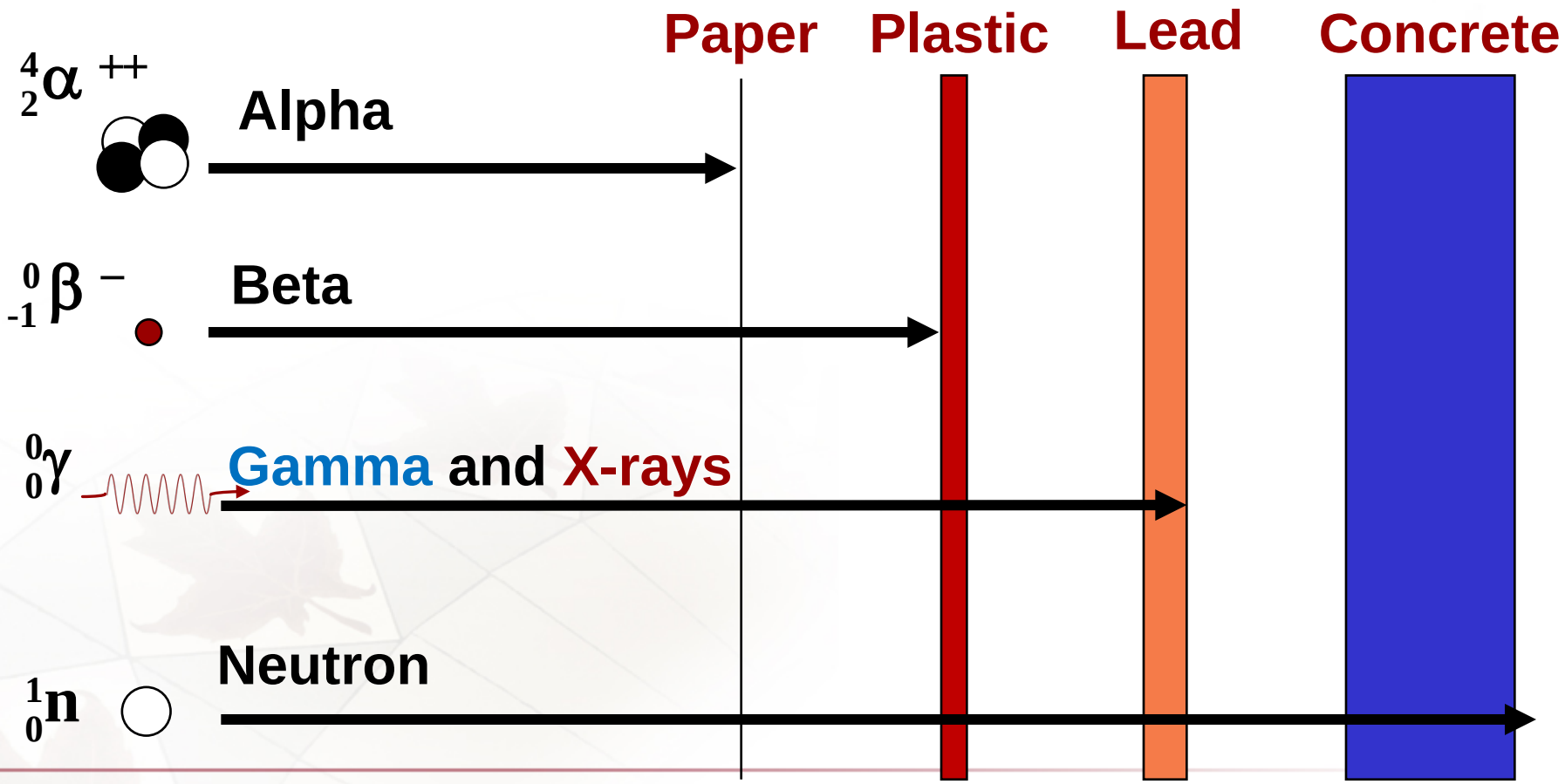
## MAINTAINING THE ALARA PRINCIPLE

Exposure to X-ray radiation is reduced if:

- TIME exposed to source is decreased 
- DISTANCE from source is increased 
- SHIELDING from source is increased 

# X-Ray Safety in the Lab

## COMPARISONS ON SHIELDING REQUIREMENTS







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***Office of Risk Management***
***X-Ray Compliance Specialist ext.2000***

# X-Ray Safety in the Lab

## RADIATION PROTECTION BASICS

- Be aware of potential X-ray hazards, exposure levels and safety controls
- Be aware of operating and emergency procedures
- Be aware of practice that does not follow ALARA principle
- Report incident or unsafe working conditions to your supervisor and ORM

# X-Ray Safety in the Lab

## AM I AT RISK OF A X-RAY EXPOSURE?

- Engineering controls on X-ray instruments at uOttawa prevent exposure using:
  - Enclosure (interlocked and shielded)
  - Lead shielded doors and walls
  - Beam shutters
  - Fail-safe warning lights
  - Remote or computer control
- ORM performs annual leak testing on each registered instrument

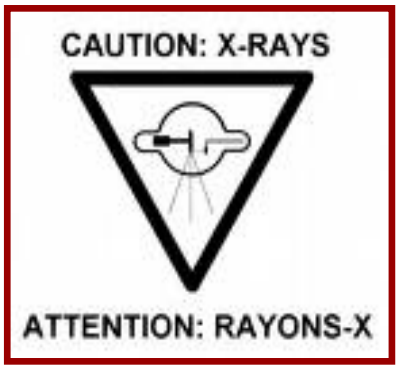
**No further exposure control is necessary for the user. HOWEVER …**

# X-Ray Safety in the Lab

## AM I AT RISK OF A X-RAY EXPOSURE?

**…should the engineering controls be overridden for additional work outside the standard procedures recommended by the manufacturer, such as:**

- Beam alignment
- Change of X-ray tube
- General maintenance

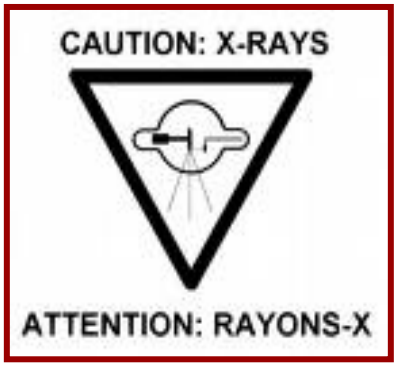



**YOU MUST CONTACT ORM FOR FURTHER ASSISTANCE. ADDITIONAL CONTROL MEASURES, SUCH AS A PERSONAL DOSIMETER, MAY BE REQUIRED.**

# X-Ray Safety in the Lab

## AM I AT RISK OF A X-RAY EXPOSURE?

- Ensure you have proper training
- Ensure the device is in its proper configuration
- Do not handle samples in an energized beam



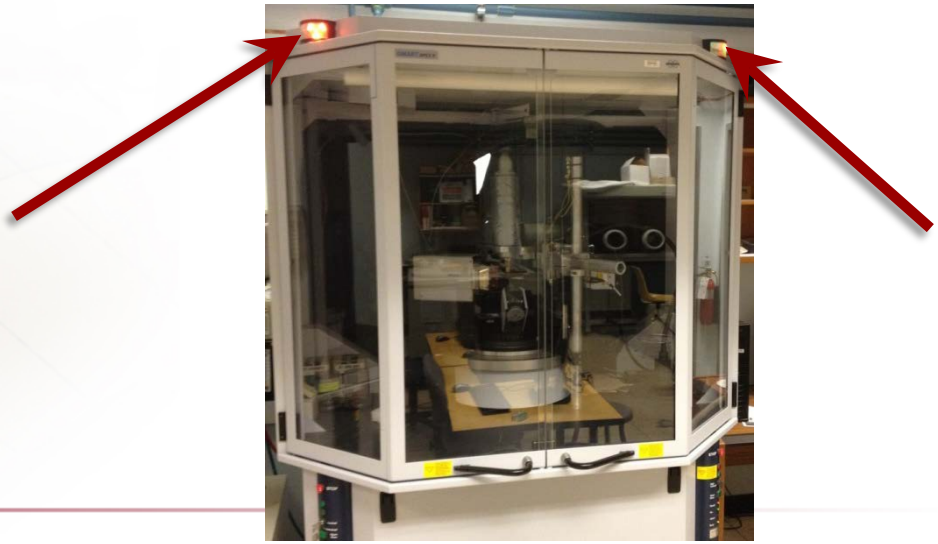
# X-Ray Safety in the Lab

## SIGNS AND LABELS

- X-ray warning signs or devices posted in visible location on equipment & door



- Lights on energized equipment



# X-Ray Safety in the Lab

## EXPOSURE CONTROL

### DOSIMETRY

- Devices monitor and record ionizing radiation doses
  - occupational exposure
- Must distinguish from background radiation

# X-Ray Safety in the Lab

## Thermoluminescence Detector (TLD) Badges

- Record cumulative whole body dose (mSv)
- Helps prevent over-exposure
- Worn at the chest or waist level
- Assigned to a specific individual
  - cannot be shared
- Worn only at work and not taken off campus

# X-Ray Safety in the Lab

## LEAK TESTS

- Annual leak test recommended or after equipment has been moved or modified
- Dose rate must not exceed 1 µGray/hr from any accessible external surface
- Contact X-ray compliance safety specialist to arrange test
- Ontario Health and Safety Act, 28.1.c:
  - you must report to your employer/supervisor the absence or defect in any equipment or protective device of which you are aware of and which may endanger yourself or others

# X-Ray Safety in the Lab

## SOPs

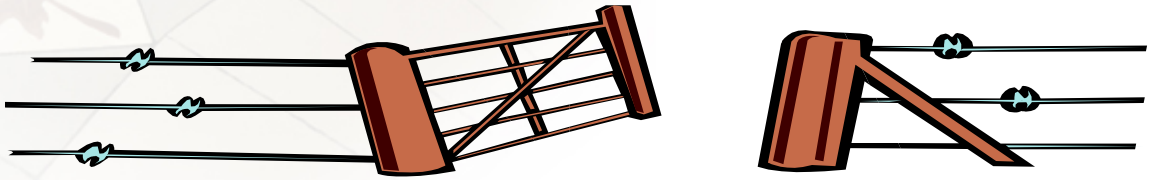
Standard operating procedures (SOPs) are required; developed by Supervisor for each X-ray device:

- used under guidance and supervision of Authorized User
- beam shall be directed toward an unoccupied area (eg. wall)
- limit dimensions of beam
- adequate shielding
- energized equipment never unattended in unlocked area
- no repairs or sample adjustment when equipment energized

# X-Ray Safety in the Lab

## SECURITY

- Only authorized users may have access to X-ray devices
- Energized equipment must be attended at all times
- Lock lab door when equipment not attended



# X-Ray Safety in the Lab

## NON-BEAM HAZARDS

Hazards not directly associated with X-ray beam:

- Electrical Hazards
  - X-ray generator has high DC power supply
  - Operates around 40-50 kV
  - May contain large capacitors that store sufficient charge to possibly kill a person even when turned off
  - Should only be handled by trained qualified personnel

# X-Ray Safety in the Lab

## NON-BEAM HAZARDS

Hazards not directly associated with X-ray beam:

- Cryogenics
  - Cooling systems with liquid nitrogen, helium, or hydrogen
  - Can cause frostbite upon contact with eye or skin
- Chemicals
  - Toxicity, corrosiveness, flammability may be an issue
  - Appropriate or additional safety precaution may be required when use with X-ray equipment

# Emergencies

- Report any incidents of excessive exposure or theft to X-ray compliance specialist at ext.2000
- After hours call Protection Services at 5499 or Emergency at 5411
- If safe to do, de-energized equipment by turning power supply
- Prevent further access by locking lab door

# Please Remember

- Register X-ray instrument with ORM and MOL
- Be a registered user with ORM
  - Complete online training and knowledge quiz
- Respect and follow the ALARA principle
- Be aware of: X-ray hazards, non-beam hazards, SOPs, emergency procedures and malpractices
- Be compliant: report incidents/accidents, unsafe working conditions, wear dosimeter if required

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- University of Ottawa X-ray Safety Program
  www.uottawa.ca/services/ehss/x-ray-safety-prgm.html
- Ryerson University X-ray Safety Training
  www.ryerson.ca/cehsm/training/index.html#xray
- Ontario Ministry of Labour; OHSA Act R.R.O. 1990, Reg 861
  http://www.e-laws.gov.on.ca/html/regs/english/elaws_regs_900861_e.htm
- Health Canada Safety Requirements and Guidance for Analytical X-ray Equipment (Safety Code 32)
  www.hc-sc.ca/hecs-secs/ccrpb/publication/94ejd186/print.htm
- National Atomic Museum (New Mexico)
  www.atomicmuseum.com
- Health Physics Historical Instrumentation Collection Museum
  www.orau.org/ptp/museumdirectory.htm