UQ X-ray Safety Training Module

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UQ X-ray Safety Training Module

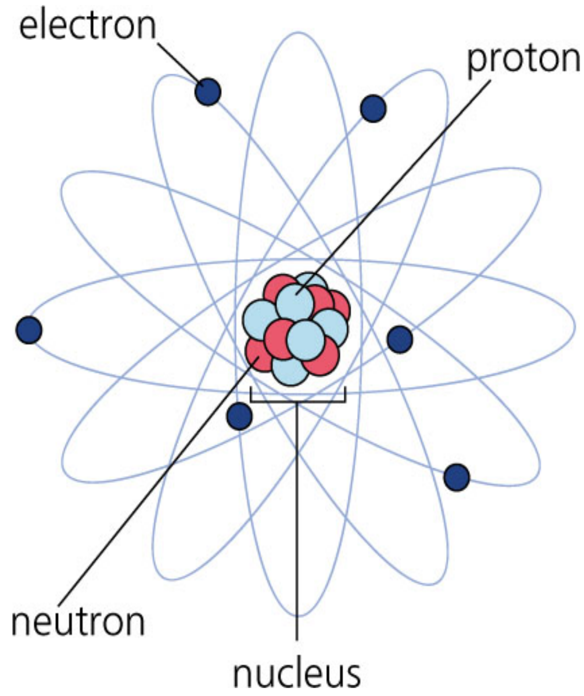
Course Overview:

- This training module has been developed for workers at the University of Queensland, and forms part of the OH&S training program at UQ.
- The broad aims of this training module are to ensure UQ workers are familiar with X-ray safety systems for x-ray diffraction (XRD) and x-ray fluorescence (XRF) devices.
- Throughout the training module, UQ workers will be introduced to:
  - Compliance with regulations
  - Responsibilities and duties
  - Radiation protection theory

Simple atomic model

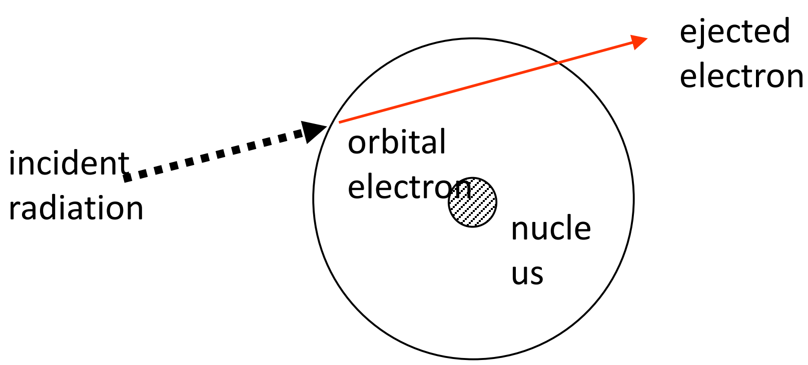
An atom is comprised of 3 elements:

- Nucleus of **protons** & **neutrons**
- Orbiting **electrons**



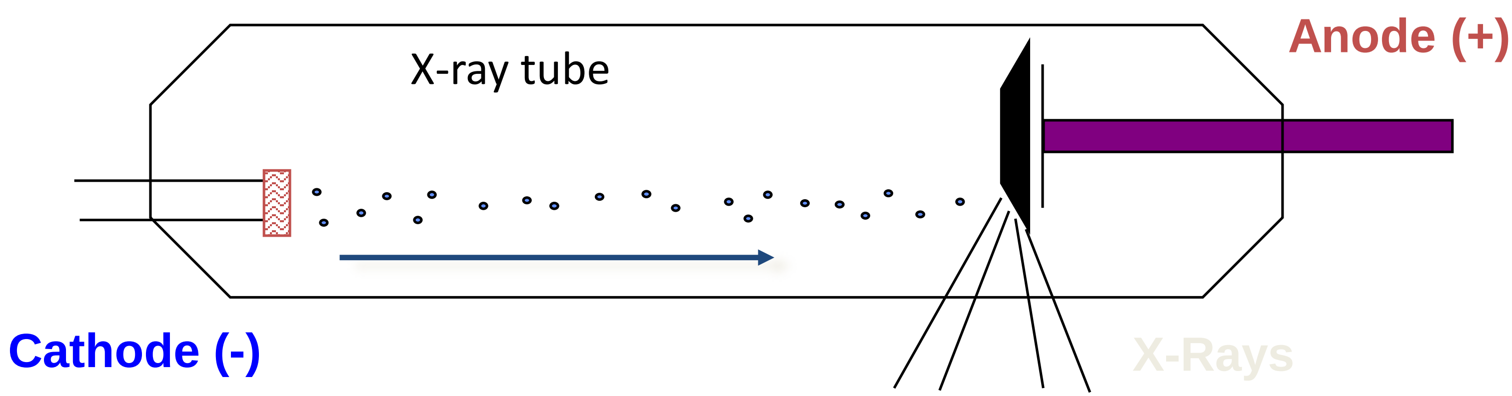
Nature of Ionising Radiation

- Ionising radiation is radiation capable of removing electrons from atoms, thus creating an ion pair, i.e. a positively charged atom and an ejected negatively charged electron
- ionising radiation include high energy electromagnetic radiations (X and gamma rays)
- Both cause damage at the atomic level



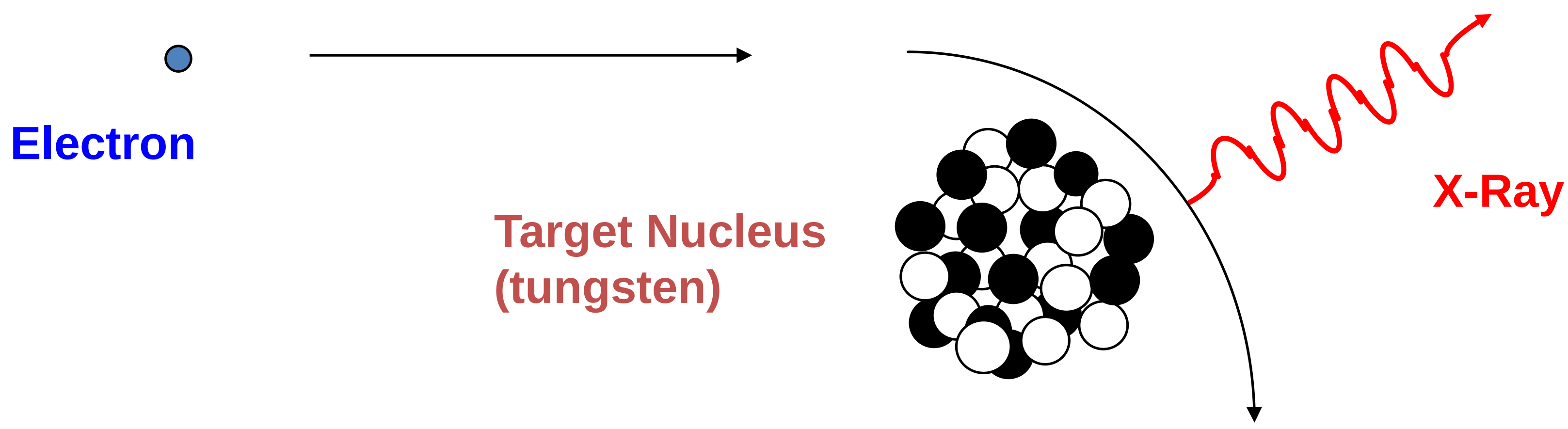
Generating x-rays

- 2 processes produce x-rays:
  - Bremsstrahlung: Deceleration of high speed electrons, this process is used in an x-ray tubes.
  - Fluorescence: Excitation of orbital electrons



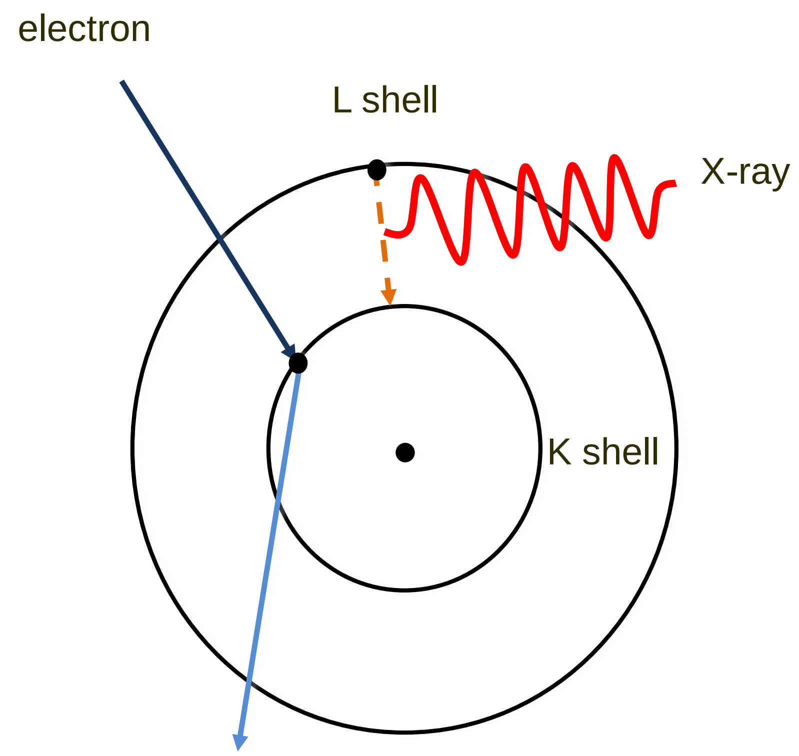
Bremsstrahlung:

- A high speed electron is decelerated by a large metal atom
- Due to conservation of energy the slowing electron releases energy in the form of an x-ray
- The electron may come from a strong Beta emitter or from electronic device, as seen in the x-ray tube



Generating x-rays

- Fluorescence:
  - Electrons orbit the nucleus in electron shells
  - The K-shell electron can be ejected by incident electron
  - Vacancy filled from a higher energy shell
  - X-ray emitted by the falling electron due to conservation of energy
  - “K fluorescent radiation”



X-ray hazards and health effects

The dose received is measured in 2 ways

Absorbed dose – energy absorbed per unit of mass: **grays** (joules per kg) **Gy**

Effective dose – absorbed dose corrected for differing biological effects of different kinds of radiation and varying organ and tissue responses: **sieverts Sv**

The sievert is the unit used in radiation protection legislation.

X-ray hazards and health effects

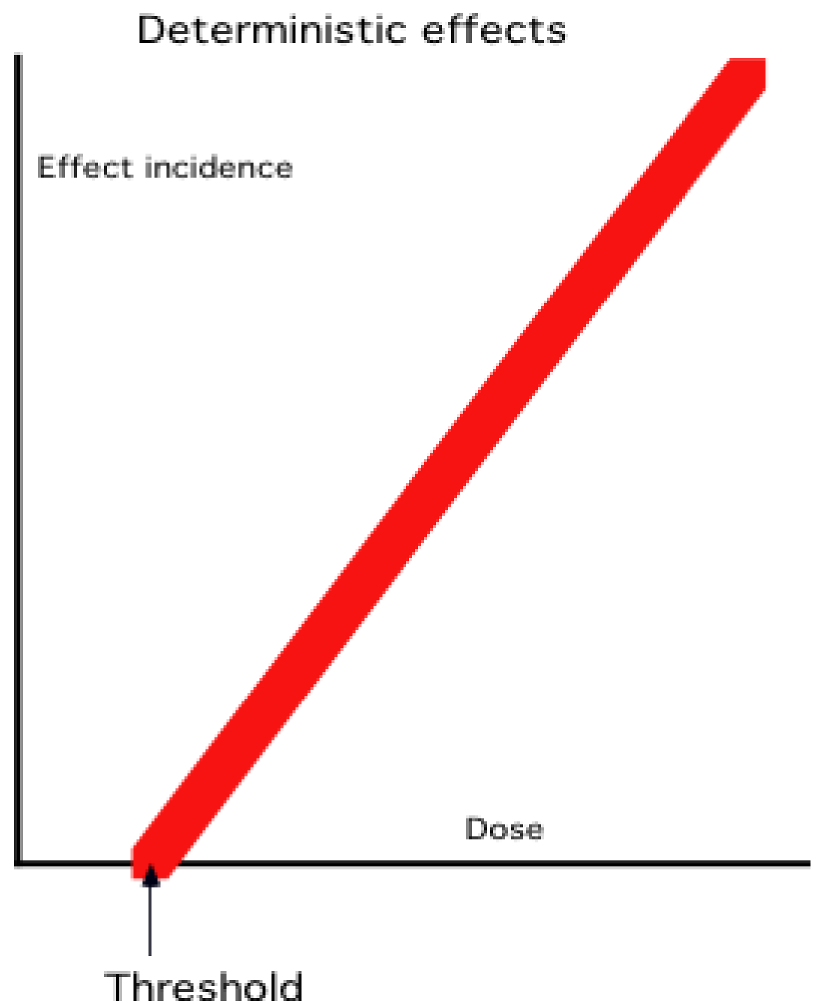
- Ionising radiation can damage biomolecules by ionisation of their component atoms, ionising radiation has an obvious potential to damage living systems.

- There are two types of effects: **stochastic** and **deterministic**.

Health Effects

Deterministic effects

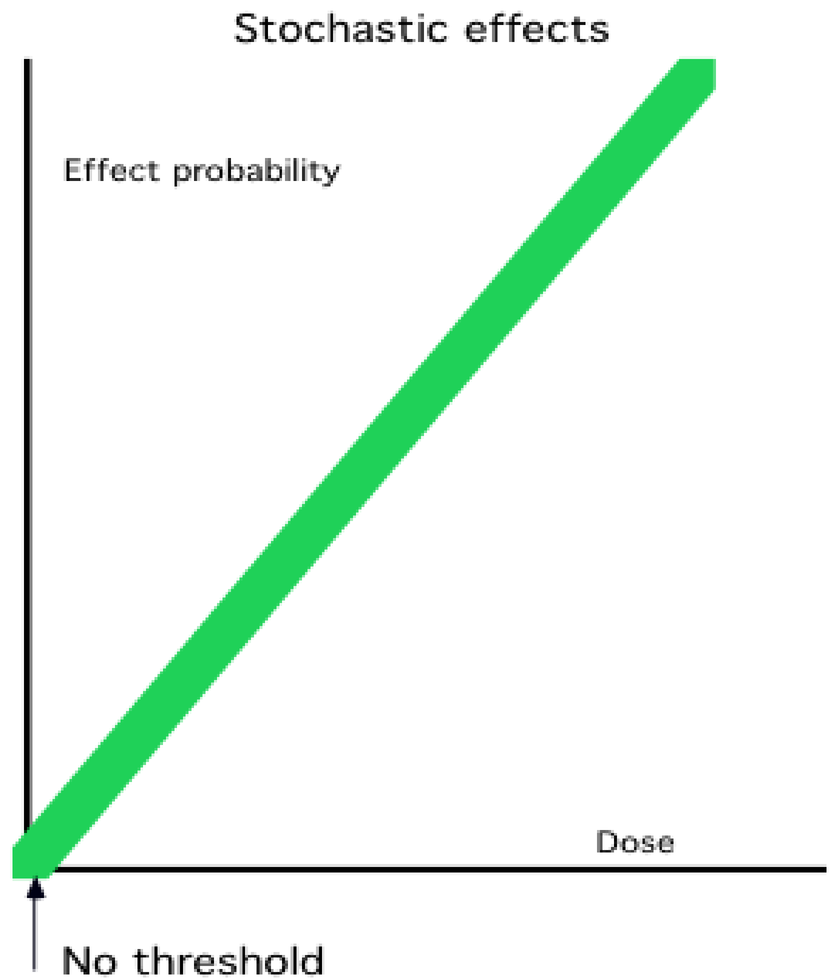
- Has a threshold
- Severity of the effect increases with dose
- Examples: skin burns, cataract in eyes
- Protective measures aim to completely prevent these effects
- The narrow beam used in XRD and XRF can cause damage before operator realizes



Health Effects

Stochastic effects

- Probability of the effect occurring increases with dose
- No threshold
- Limits to full body exposure aims to limit incidences
- Examples: induction of cancer
- Protective measures aim to minimise these effects
- The potential for the induction of stochastic effects from exposures received in analytical X-ray work is small

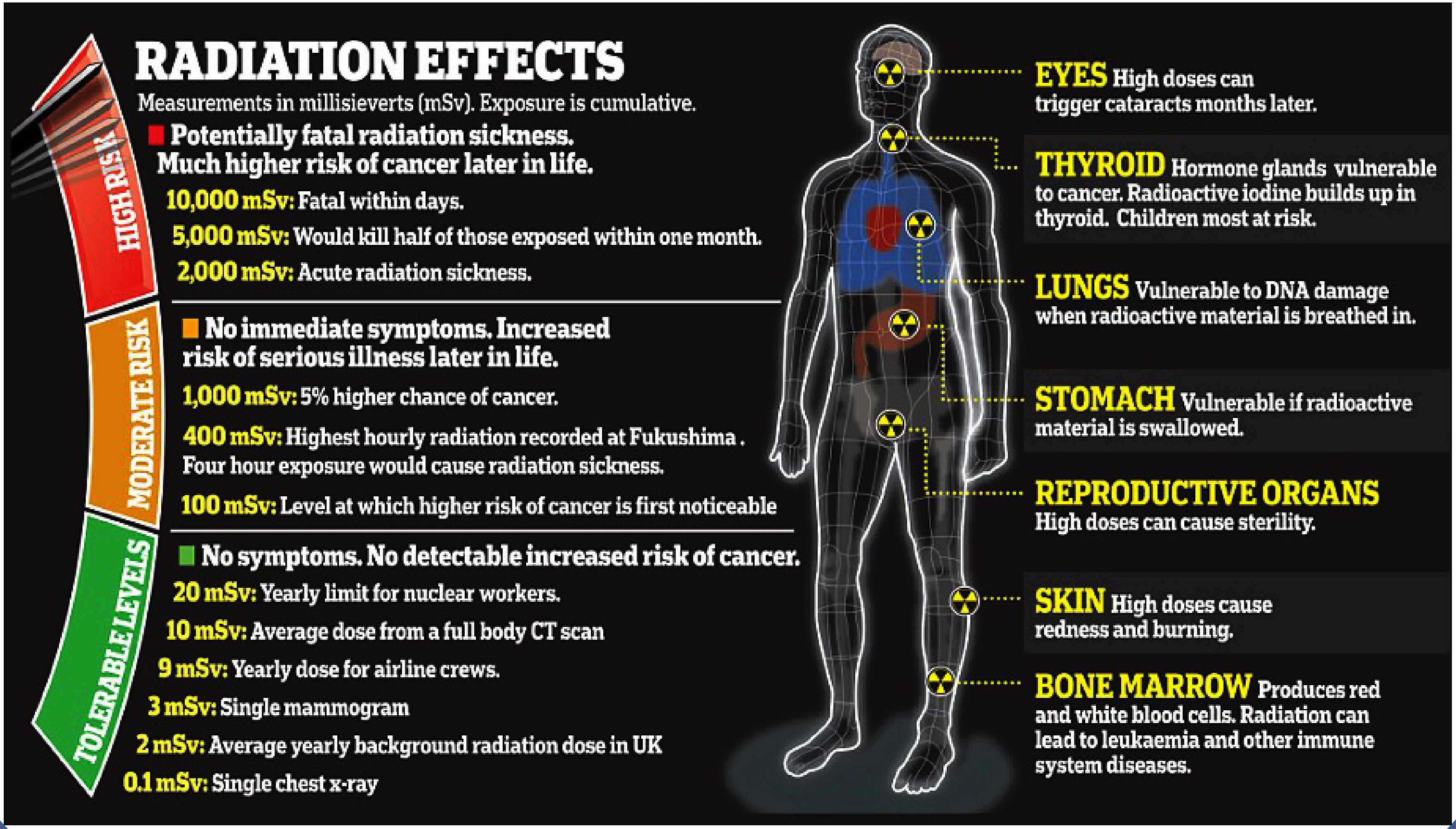


Stochastic effects

Occupational limits are set at 20mSv/year, which results in negligible increases to cancer risk

The table below show risk coefficients (% per Sv received)

Exposed population	Cancer risk	Heritable effects	Total risk
Whole population	5.5%	0.2%	5.7%
Adults	4.1%	0.1%	4.2%


RADIATION EFFECTS
Measurements in millisieverts (mSv). Exposure is cumulative.
HIGH RISK
Potentially fatal radiation sickness. Much higher risk of cancer later in life.
10,000 mSv: Fatal within days.
5,000 mSv: Would kill half of those exposed within one month.
2,000 mSv: Acute radiation sickness.
MODERATE RISK
No immediate symptoms. Increased risk of serious illness later in life.
1,000 mSv: 5% higher chance of cancer.
400 mSv: Highest hourly radiation recorded at Fukushima . Four hour exposure would cause radiation sickness.
100 mSv: Level at which higher risk of cancer is first noticeable
TOLERABLE LEVELS
No symptoms. No detectable increased risk of cancer.
20 mSv: Yearly limit for nuclear workers.
10 mSv: Average dose from a full body CT scan
9 mSv: Yearly dose for airline crews.
3 mSv: Single mammogram
2 mSv: Average yearly background radiation dose in UK
0.1 mSv: Single chest x-ray
EYES High doses can trigger cataracts months later.
THYROID Hormone glands vulnerable to cancer. Radioactive iodine builds up in thyroid. Children most at risk.
LUNGS Vulnerable to DNA damage when radioactive material is breathed in.
STOMACH Vulnerable if radioactive material is swallowed.
REPRODUCTIVE ORGANS High doses can cause sterility.
SKIN High doses cause redness and burning.
BONE MARROW Produces red and white blood cells. Radiation can lead to leukaemia and other immune system diseases.

The International Commission for Radiation Protection (ICRP) System of Radiation Protection

- **Justification of Practices**
  - No radiation practice to to be adopted unless it produces sufficient benefit to offset the radiation detriment
- **Optimisation of Protection**
  - Doses shall be kept as low as reasonably achievable, (ALARA) economic and social factors being taken into account.
- **Limitation of Doses**
  - The exposure of individuals is to be subject to dose limits aimed at ensuring that no person is exposed to unacceptable levels of risk.

Summary of ICRP dose limits:

- ICRP strongly emphasises the need to keep all exposures to radiation as low as reasonably achievable, ie the dose limits should not be taken as operational limits but rather as the upper bounds of acceptability.

Application	Occupational	Public
Effective dose	**20 mSv per year averaged over defined period of 5 years[2]**	**1 mSv in a year[3]**
Annual equivalent dose in: the lens of the eye	**150 mSv**	**15 mSv**
the skin[4]	**500 mSv**	**50 mSv**
the hands and feet	**500 mSv**	**-**

Analytical X-ray Hazards

- Samples can be analysed by X-ray diffraction (XRD) and X-ray fluorescence (XRF).
- Both techniques require samples to be exposed to very high intensity narrow beams of ionising radiation.
- Very high dose rates, up to100 Sv/second
- Injury level doses can be delivered without the user noticing (initially)
- High volume and industrial process control units can be automated and totally enclosed
- Safety in research applications requires combination of user training and engineering controls
- There is virtually no potential for whole body radiation exposure and the hazard is mainly confined to exposure of the skin of the hands.

Safety systems for X-ray analysis equipment

- Engineering design to minimise hazards
- Protective shields and electrical insulation
- Interlocked barriers
- Unambiguous indication of tube status (energised or not)
- "Beam on" indication where appropriate
- Standard operating procedures
- Safe working rules and emergency procedures
- Radiation Safety and Protection Plans

Analysis of Accidents - 3 common types of failure:

- Procedural failures
  - more frequent with earlier models of equipment which had little engineered safety features and depended more heavily on the skill and experience of the operator to avoid exposure
- Failure (or absence) of mechanical or electronic safety features
  - These types of accidents have occurred when an interlock that has been relied upon to de-energise the tube fails to do so and the worker is exposed, often without being aware of a problem until symptoms of X-ray burn become apparent
- Unauthorised modification or repair of equipment
  - such as the deliberate bypassing of interlocks, or make-shift experimental apparatus can lead to exposure accidents and should be forbidden

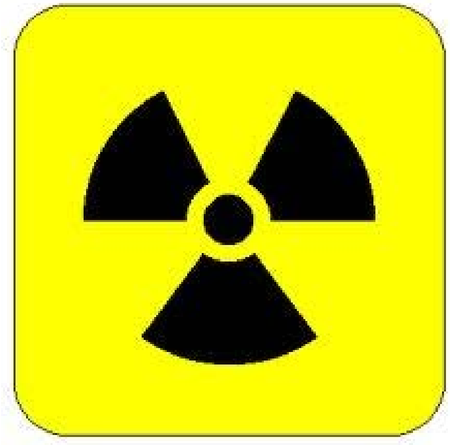
Use of Survey Meters

- X-ray equipment should be regularly monitored for leakage and the results recorded by the Radiation Safety Officer
- X-rays can be detected with either Geiger Muller tube monitors, scintillation detectors or ionisation chamber monitors.
- The ion chamber units are used to monitor x-ray equipment and ensure the shielding is still effective.

Personal Monitoring

- Personal monitors are used to record any doses received.
- Generally, extremity dosemeters are preferred as they can be used to estimate actual doses to the skin and exposure of the skin of the hands is a much more likely event than whole body exposure.
- Limitations of whole body monitors
  - Beam must pass through monitor
  - Often worn on belt that maybe shielded by objects
  - Used in plain field x-ray
- Extremity monitor – finger monitor
  - Most useful for analytical x-ray devices

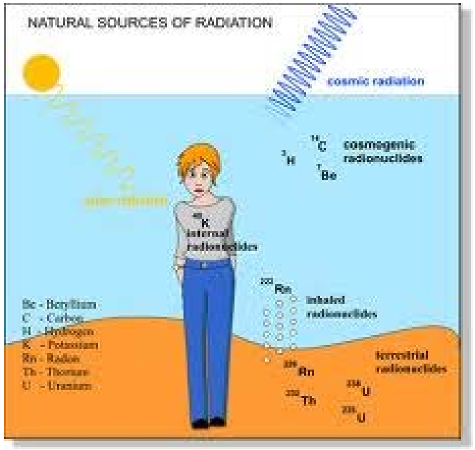
Legislation



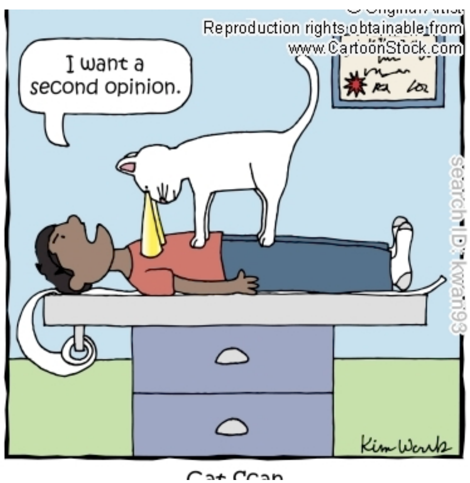
- The Queensland radiation control legislation consists of the principal act:
  - *The Radiation Safety Act 1999*
  - The *Radiation Safety Regulation 2010*
  - Under the Act, licences are required for the possession and use of X-ray equipment
  - A Radiation Safety and Protection Plan is required prior to purchasing equipment

Radiation Safety & Protection Plans (RSPP)

- Is a work procedure that has been assessed by the regulator (Queensland Health Radiation Unit)
- Each RSPP contains the following information:
  - Assessment of the radiation hazards
  - Required safety measures
  - Procedures for monitoring and review
  - Functions of the RSO
  - Training program
  - Requirements of specific regulations



Use licensee obligations



- Obey instructions and directions issued by the RSO concerning radiation hazards, safe working practices, and precautions to be taken to avoid excessive exposure

- Work in accordance with the approved Radiation Safety and Protection Plan (RSPP)

- Use equipment supplied for radiation protection

- Notify the RSO of any issues that might affect radiation safety

Radiation Safety Officer RSO

- The Regulation requires each possession licensee to appoint an RSO
- One RSO is appointed for each particular practice or operating site, although an appropriate deputy should be available to act as RSO in the absence of the principal RSO.
- RSO may also have the duty of assessing, on behalf of the possession licensee, whether new users have appropriate training or sufficient experience to apply for a use licence enabling unsupervised work with radiation sources

Radiation Safety Officer RSO continued …

- To identify ways of minimising the radiation doses received by persons
- To provide or arrange for radiation safety training
- To monitor compliance with the radiation Safety and Protection Plan RSPP
- To regularly review the RSPP to ensure its continued effectiveness
- To monitor compliance with the relevant radiation safety standard for the source or premises

Possession licensee

- A possession licensee for radiation apparatus has a general obligation to ensure that X-ray equipment is not used unless both the premises and the equipment comply with the radiation safety standards issued by the Health Department.
  - NM005:2010 *Standard for radiation apparatus used to carry out chemical analysis*
  - PR100:2010 *Standard for premises – ionising radiation source*

Possession licensee continued …

- The licensee has a responsibility to ensure that the provisions of both the *Act* and the *Regulation* are complied with

- While a licensee may delegate many duties to the Radiation Safety Officer (RSO) the ultimate responsibility for ensuring the security of the radiation sources in the charge of the possession licensee cannot be delegated

UQ policy

- The OH&D Division supplies SDS on radioactive elements and general safety guides.
- All research involving radiation must be approved by local RSO and the OH&S Division Radiation Protection Adviser.
- Radiation Project applications are found here http://www.uq.edu.au/ohs/radiation-project-approval-forms-guidance

Summary of gaining a Use Licence

- Complete this module
- Gain training from local RSO or supervisor on equipment
- Competency assessment from local RSO
- Request personal monitor
- Apply for licence from Queensland Health Radiation Unit

Assessment

- You have now completed the University of Queensland X-ray Safety Training module. Refresher training is provided by local RSO every year.
- If you would like to revise any of the topics covered before you begin the assessment, please use the quick find index to navigate to a particular topic.
- You will be asked a set of randomly selected questions. The pass mark is 80%. You may repeat the test as many times as you require. Each time you attempt the assessment, you will be presented with a different set of questions.

Assessment Location

Please return to the ‘UQ Workplace Inductions and OH&S Training’ course within eLearning@UQ (Blackboard) and select the ‘X-ray Safety Assessment’.

https://learn.uq.edu.au/