Radiation Safety

with Unsealed and Sealed Radioactive Materials

MC01 / MC02

Health, Safety & Environment Office

Hong Kong University of Science and Technology

What is Radiation?

Radiation is a kind of ENERGY.

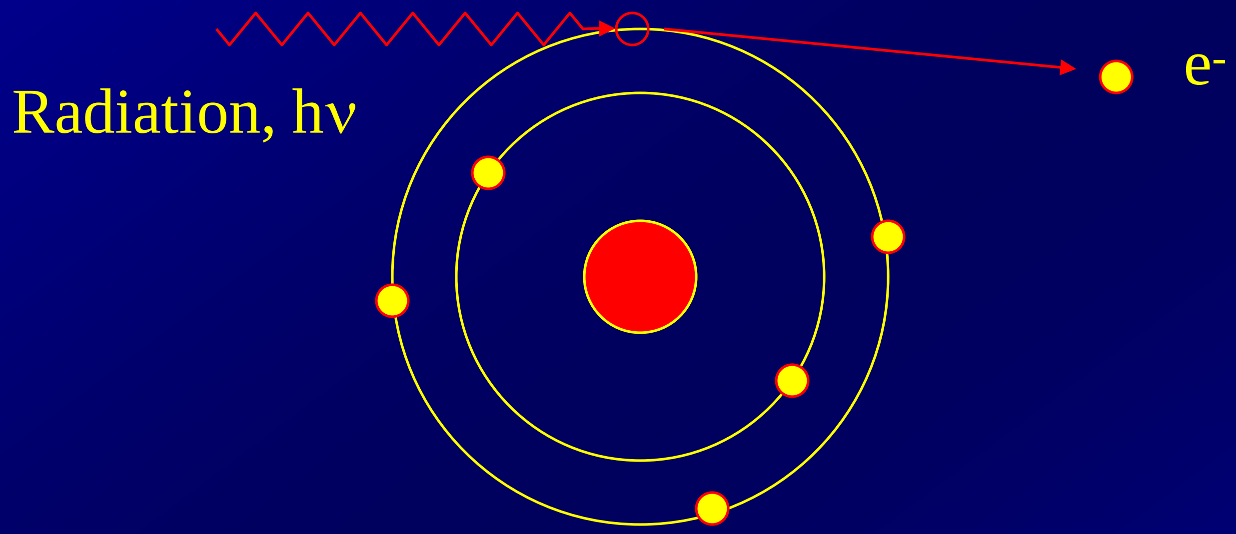
It can be broadly classified into

- Ionizing Radiation (電離輻射)
- Non-ionizing radiation (非電離輻射)

Ionizing Radiation

- Ionizing radiation is a kind of energy that have sufficient energy to overcome the binding energy between electron and an atom to cause ionization.

Ionization



- Ionization is the removal of an electron from an atom or an ion, resulting in an ion pair.
- Ionization is the primary cause of radiation-induced biological damage.

Radiation Sign

Non-Ionizing Radiation

- Radiation that does not have sufficient energy to ionize an atom.

e.g. Radar wave, microwave and UV lights.

Non-Ionizing Radiation Sign

Radionuclide

- A radionuclide is an unstable isotope of an element that decays or disintegrates spontaneously, emitting ionizing radiation.
- The number of radioactive atoms, in a radioactive material will decrease with the passage of time.

Radioactivity

- The quantity for an amount of radioactive atoms decay in a given energy state at a given time.

Conventional unit: **curie (Ci)**

1 Ci = 3.7 x 10^{10} disintegrations/sec

SI unit: **becquerel (Bq)**

1 Bq = 1 disintegration/sec

1 Bq = 27 pCi

Radioactivity

- One curie is an extremely large amount of radioactivity!
- Typically, at HKUST, μCi amounts are handled in experiments.

$$1\ \mu Ci = 10^{-6}\ Ci$$

$$= 3.7 \times 10^{4}\ Bq$$

Radioactive (Physical) Half-life

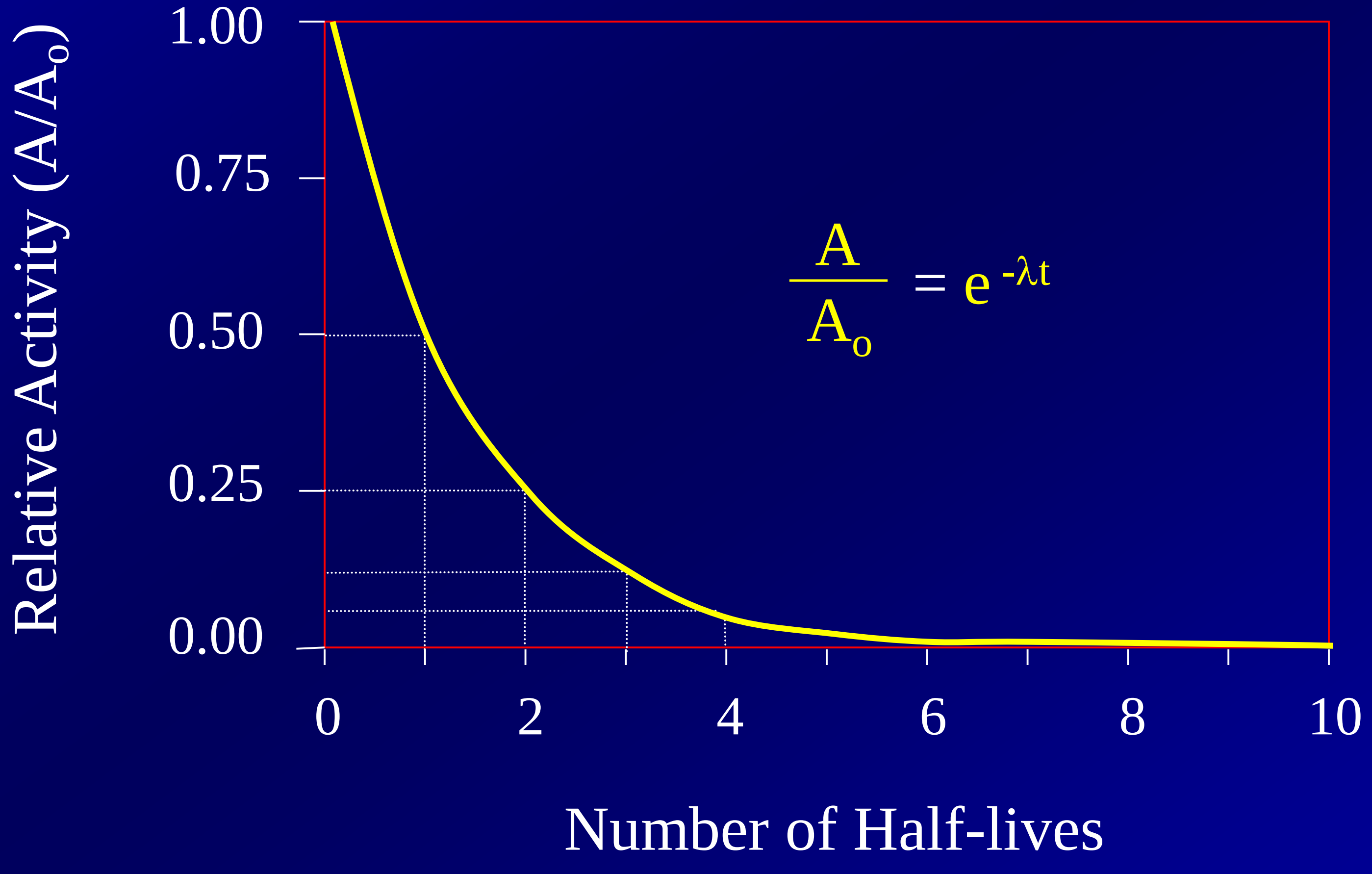
- Radioactivity as a function of time:

$$A = A_o \, e^{-\lambda t}$$

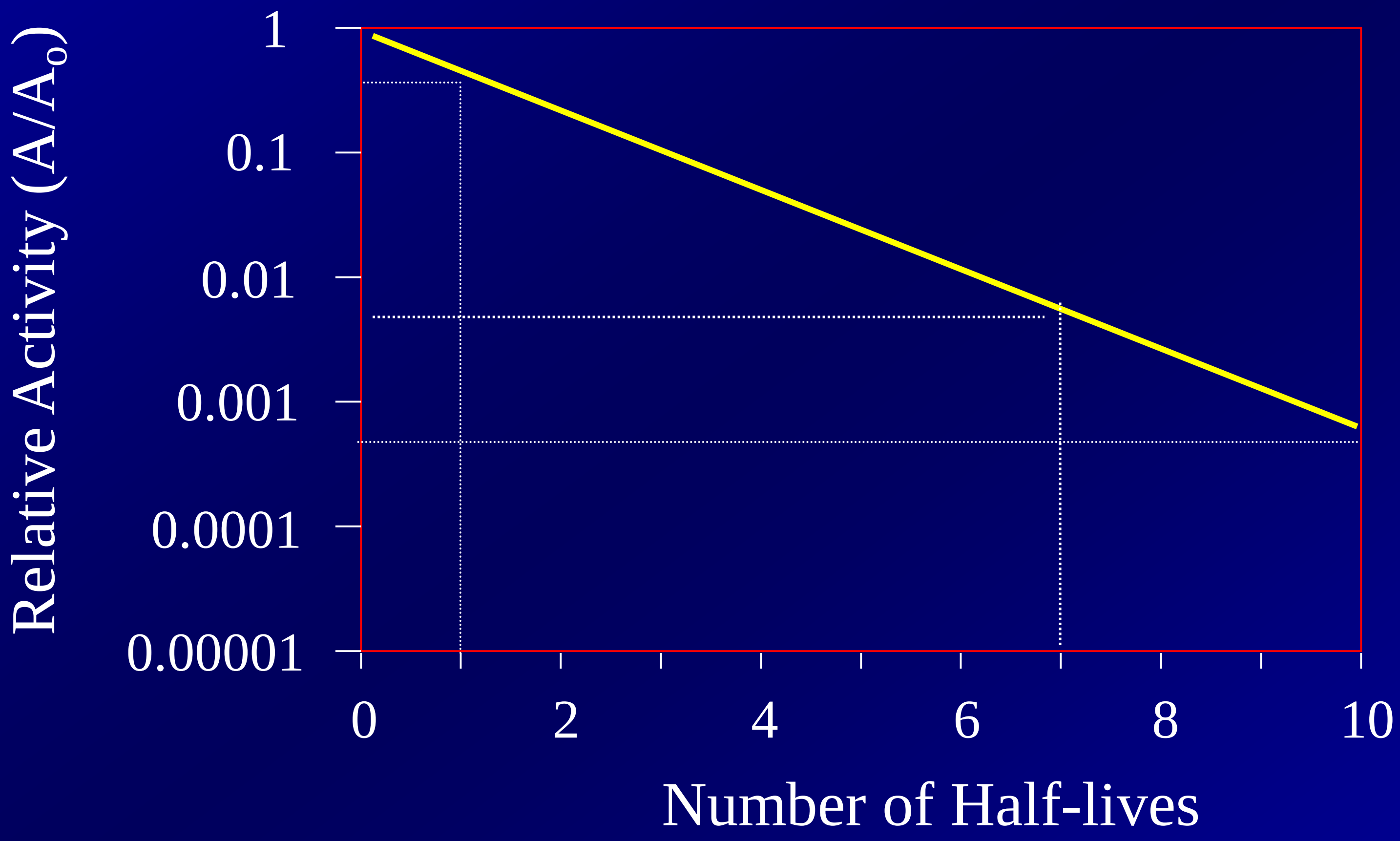
where A is activity, A_o is the original activity, λ is decay constant, t is time taken.

- The time in which half the radioactive atoms disintegrated is the physical half-life, $T_{½}$: When $t = T_{½}$, then $A = 1/2 \, A_o$.

Radioactive Decay Curve



Radioactive Decay Curve



Rule of thumb: less than 1% of original radioactivity remains after 7 half-lives

Common Types of Ionizing Radiation

Common types of ionizing radiation at the HKUST(GZ):

- Alpha particles
- Beta particles, electrons
- Gamma/X-ray

Alpha Particles

- Alpha particles are helium nuclide (Z=2, A=4) with a heavy mass, and they carry a positive charge (+2).
- Because of their heavy mass and positive charge, their ranges are short: 1 to 2 inches in air, 40 to 70 μm in tissue (cannot penetrate the dead layer of skin).
- They can be stopped by even a piece of paper.
- They are in general not an external hazard.
- When intake into the body, they can be a serious hazard because all energies are deposited locally.

Beta Particles

- Beta particles are electrons emitted from the nucleus, so they carry a negative charge (-1).
- Beta particles are emitted with an energy spectrum (from keV to MeV), with the average energy equals to about 1/3 of the maximum energy.
- Common ones are ^{3}H, ^{14}C, ^{32}P, ^{35}S, ...

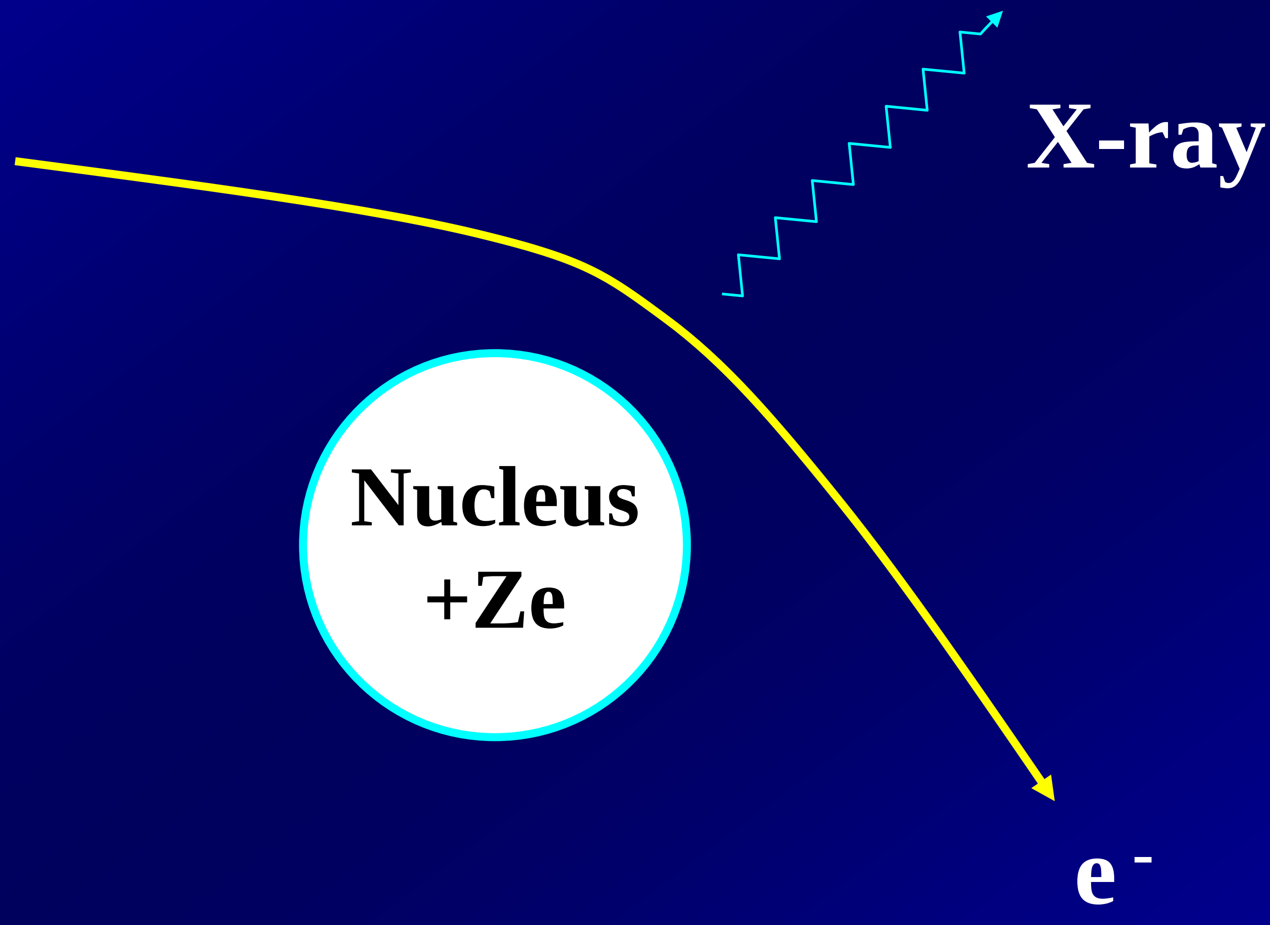
Beta Particles

- They have longer ranges than alpha particles: 10-20 feet in air, several mm in human tissue.
- They are an external hazard to the skin and the lens of the eye.
- Half inch of plastic or plexiglass will stop most beta particles.
- If intake occurs, they are also an internal hazard.

Bremstrahlung

- Bremstrahlung effect occurs when beta particles or electrons are slowed down or stopped by the absorbing medium, producing x-ray.
- Energy loss in bremstrahlung, or the energy of the x-ray produced, is proportional to the product of the beta energy (E) and the atomic number (Z) of the absorbing medium.
- Therefore, for high-energy betas or electrons, do not use high Z materials for shielding!

Bremstrahlung



Gamma and X Ray

- Gamma ray is emitted from the nucleus, while X ray is from the electron shells of the atom.
- Both gamma and x ray are electromagnetic radiation and have no charge.
- They loss energy in matters by photoelectric effect, Compton scattering and pair production.
- These interactions increase with the atomic number (Z) of the absorbing media. Therefore, high Z materials should be used for shielding.

Gamma and X Ray

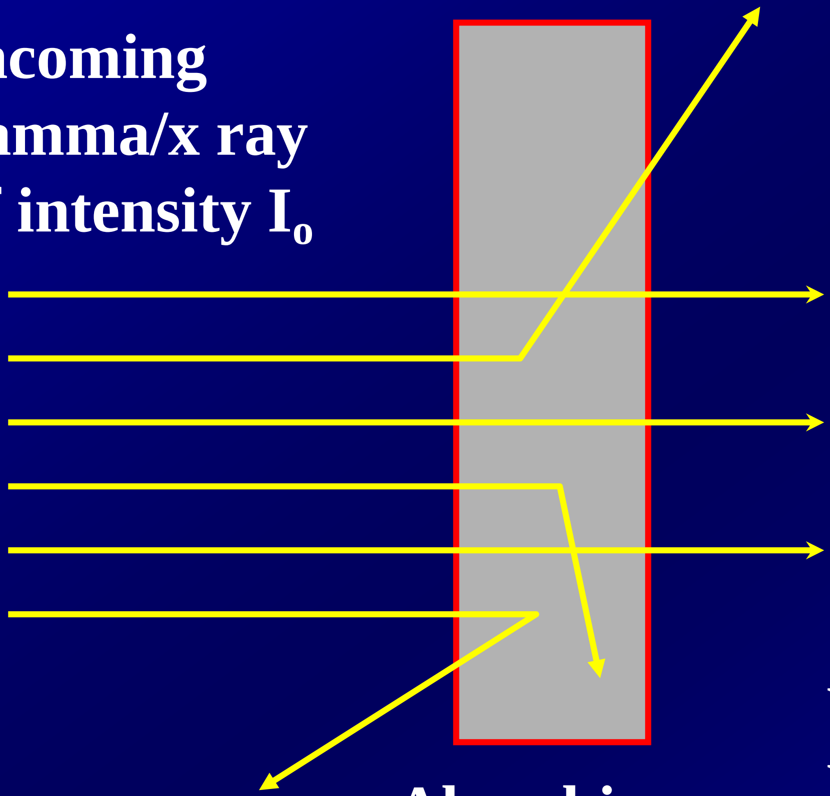
- Their range in air is long: several hundred feet.
- A significant fraction can pass through the human body.
- They are both external and internal hazards.

Shielding of Gamma and X Ray

- They should be shielded by heavy material such as lead.
- Shielding effectiveness increases with the thickness.
- Half-Value Layer (HVL) is the thickness of any given absorber that will reduce the intensity of beam of radiation to one-half its initial intensity.
- Seven HVLs will reduce the intensity to less than 1%.

Attenuation of Gamma/X Ray

Incoming gamma/x ray of intensity I_o

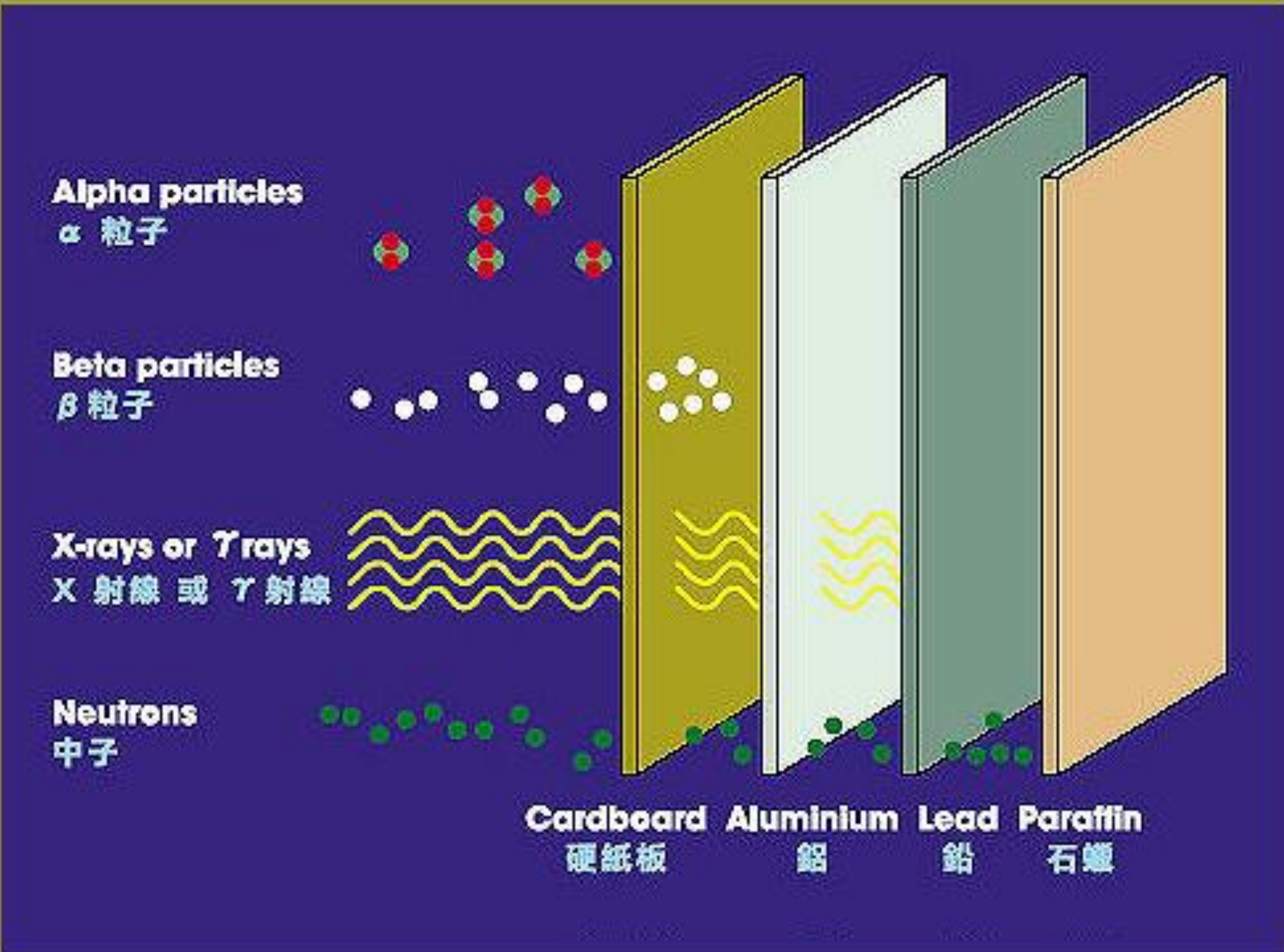


Outgoing gamma/x ray of intensity I

$$\frac{I}{I_o} = \exp\left[-\frac{L \times \ln 2}{HVL}\right]$$

Absorbing medium of thickness L

when $L = HVL$, $I = I_o/2$;
when $L = 7\ HVL$, $I < 0.01\ I_o$


Alpha particles
α 粒子
Beta particles
β 粒子
X-rays or γ rays
X 射線 或 γ 射線
Neutrons
中子
Cardboard
硬紙板
Aluminium
鋁
Lead
鉛
Paraffin
石蠟

Radiation Hazard

External Hazard:

Neutrons > Gamma/X > Beta > Alpha

Internal Hazard:

Alpha > Beta > Gamma/X

(intakes of neutron sources are rare.)

Measurements of Radiation Exposure

- Absorbed Dose, D
- Equivalent Dose, H
- Effective Dose, E

Absorbed Dose, D

- The absorbed dose is a measure of energy deposition per unit mass of tissue by ANY type of radiation.
- It does not take into account that different types of radiation have different potential effects on the human body.
- Conventional unit is “rad”
- SI unit is “gray (Gy)”
- 1 Gy = 100 rad = 1 joule/kg

Equivalent Dose, H_T

- Equivalent dose, H_T, takes into account the different potential biological effects to a body tissue T due to different type of radiation R, even at the same absorbed dose.
- It is equal to absorbed dose ($D_{T,R}$) multiply by radiation weighting factor (W_R).

$$H_{T,R} = D_{T,R} \cdot W_R$$

Conventional unit is "rem"

SI unit is "Sievert (Sv)"

1 Sv = 100 rem

1 mSv = 100 mrem = 0.1 rem

Radiation Weighting Factor, W_R

Radiation	W_R
Gamma/X-ray	1
Beta Particles, Electrons	1
Neutrons (all energies)	5-20
Alpha particles	20

Effective Dose, E

- Effective dose takes into account of the different biological sensitivities of each organ/tissues to radiation.
- Effective Dose, E, of whole body is the summation of tissue equivalent doses, H_T, multiplied by Tissue Weighting Factor, W_T

$$E = \sum_T H_T \cdot W_T$$

Tissue Weighting Factor, W_T

Tissue/Organ	W_T
Gonads	0.08
RBM, Colon, Breast, Lungs, Stomach (each 0.12)	0.60
Bladder, , Liver, Thyroid, Esophagus (each 0.04)	0.16
Skin, Bone Surface (each 0.01)	0.02
Remainder	0.14
Whole body	1.00

Exposure to X-ray- Roentgen, R

- The amount of ionization caused in air by x-ray or gamma radiation.

$$1\ R = 2.58 \times 10^{-4}\ C/kg$$

$$1R \sim 0.95\ rad$$

Biological Effects

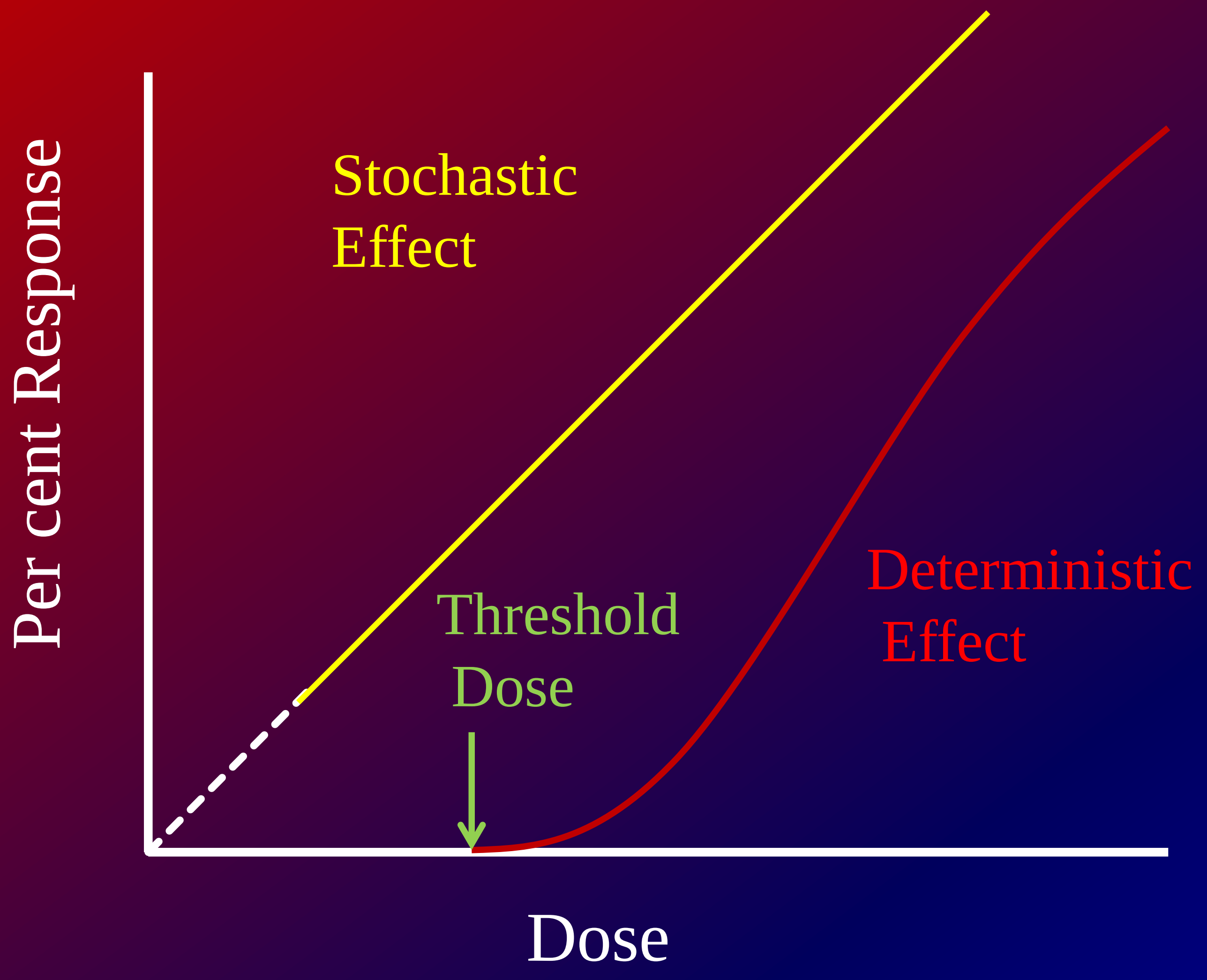
- Deterministic Effects:
  - Generally a threshold level of dose exists.
  - Once the threshold is exceeded, an individual shows the effect.

  Example: Lens receive > 5 Sv can cause cataract.

- Stochastic Effects:
  - Generally assumed to be without a threshold level of dose.
  - Generally assumed that the higher the dose, the higher risks of biological effect.

  Example: Cancer induction

Deterministic vs Stochastic Effect



Radiation Effects on Cells

- Each organ of the human body is made up of specialized cells. Ionizing radiation can potentially affect the normal functioning of these cells.
- Somatic effects: effects on the body of the individual receiving radiation, e.g., mutation of cells leading to cancer.
- Genetic effects: effects on chromosomes of reproductive cells, may be inherited.

Dose Limit for the Whole Body

- The whole body extends from the top of the head down to just below the knee.
- The regulatory limit for the effective dose for occupational radiation exposure is 20 mSv per year (annual average effective dose for 5 consecutive years) .

Dose Limits

Dose limits for the members of the public are one-tenth of the occupational dose limits:

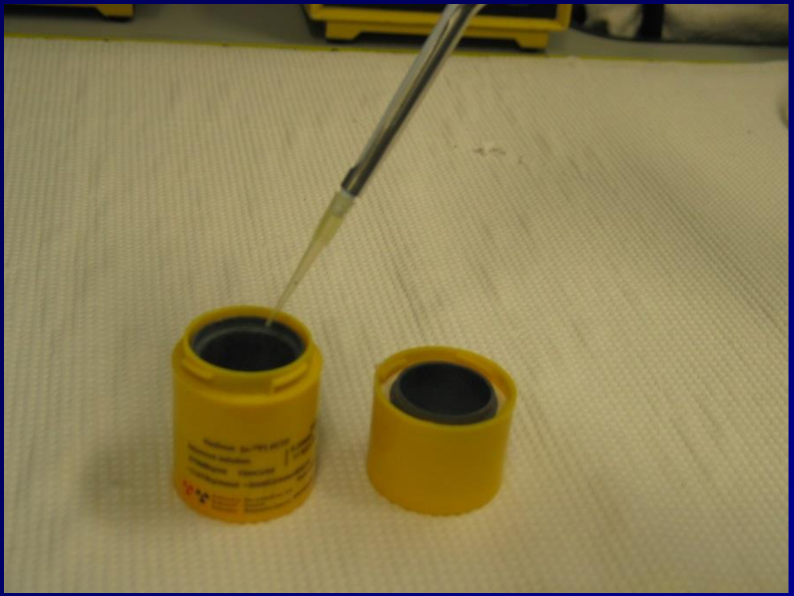
Region	Occupational	Public
Whole Body	20 mSv	1 mSv
Extremities	500 mSv	50 mSv
Skin	500 mSv	50 mSv
Lens of Eye	150 mSv	15 mSv
Pregnant Worker (& Embryo/fetus)	0.5 mSv per month	

Factors Affecting Biological Damage

- Total Dose
- Dose Rate
- Types of Radiation
- Area of the Body Irradiated
- Cell Sensitivity
- Individual Sensitivity

Unsealed Sources

- An unsealed source is a radioactive material which is not contained in a sealed capsule or container, and the radioactive material can be drawn out for further use.
- An unsealed source presents both external and internal exposure hazards.



Commonly-Used Beta Emitters at HKUST(GZ)

Radionuclide	Half-life	Emax (MeV)
^{3}H	12.3 y	0.018
^{14}C	5730 y	0.154
^{32}P	14.3 d	1.71
^{35}S	88 d	0.167
^{45}Ca	165 d	0.254

Commonly-Used Gamma Emitters in Labs

Radionuclide	Half life	E (MeV)
^{51}Cr	27.7 d	0.320 (9.9%)
^{59}Fe	44.6 d	1.292 (43.2%)
^{65}Zn	244 d	1.116 (50.7%)
^{75}Se	120 d	0.264 (59.5%)
^{109}Cd	463 d	0.088 (3.7%)
^{110m}Ag	250 d	0.658 (94.4%)

- All decays here are electron-capture type and emit x-ray and electrons (some also emit betas).
- Lead shielding is always needed.

A Sealed Source

- A sealed source is a radioactive material that is:
  - permanently sealed in a capsule, or
  - closely bounded in a solid form.
- The capsule or material of a sealed source shall be strong enough to maintain leaktightness under the condition of use for which the source was designed.

General Hazard of Sealed Sources

- Sealed sources are primarily an external hazard.
- They present a potential hazard only when an individual is exposed to the source.

Irradiating Apparatus

- Broadly classified into two types

  - Gamma-cell Irradiators

  - X-ray Systems

Gamma-cell Irradiators

- Designed to provide a large uniform gamma field for irradiation of samples.
- Common radioisotopes used are Co-60 or Cs-137.
- The containment vessel is heavily shielded with lead.
- After shielding, the regulatory dose rate is limited to 25µSv/h or less one foot from the system.

Types of X-ray Systems

- Closed beam system
  - X-ray diffractometers in Physics
- Open beam system
  - X-ray systems in Dental Clinic

Closed Beam Systems

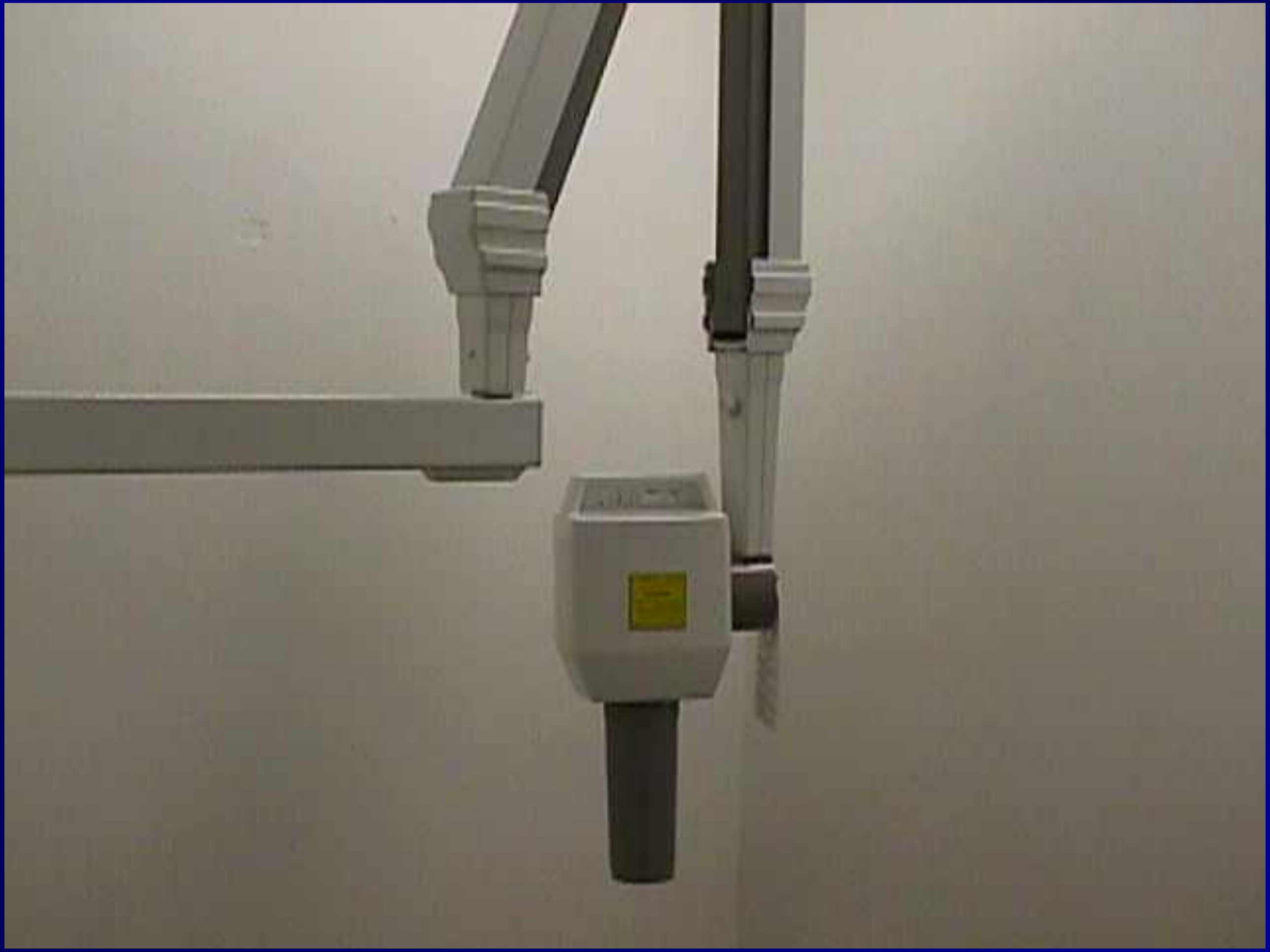
- In a closed beam system, both the primary and diffracted beams are completely enclosed and cannot irradiate any part of the body during normal operation.
- A fail-safe light must be installed near the X-ray tube housing to indicate when the X-ray is powered on.
- Radiation leakage measured at 0.1 m from any outer surface must not exceed 0.1 mR/h (1 μSv/h) during normal operation.

Closed beam system

Open Beam Systems

- Basically, primary beam and scattered beams are not enclosed and within the room. Room or facility is used as x-ray enclosure.
- It is usually for medical applications such as dental x-ray.
- The operator must work behind the radiation shield or outside the room.
- Radiation leakage measured outside the defined supervision area of the system must not exceed 2.5 mR/h (or 25 μSv/h).

Open beam system



Applications of Sealed Sources

- Sealed sources are widely used in industrial sectors and research institutions.
- Examples in use at HKUST:
  - Gas Chromatography (^{63}Ni)
  - Density Gauge ($^{241}Am/^{137}Cs$)
  - Calibration Sources
  - Internal Standards

The ALARA Approach

ALARA: As Low As Reasonably Achievable

- This concept includes reducing both external and internal exposure to the lowest.
- ALARA is everybody's responsibility.
- ALARA implies applying different control measures to limit occupational and general public exposure.

Source Reduction

- Exposure is directly proportional to source strength.
- By reducing the activity of the source, the exposure rate is reduced.
- If more than one source are present, and only one is needed, remove the unneeded sources.

Protection Against Exposure

Four basic principles used to protect against external radiation:

- decrease the time of exposure;
- increase the distance from the radiation source;
- increase shielding between the source and worker;
- try reducing the source activity.

Time

- Pre-plan and discuss the task thoroughly prior to enter the radiation work area.
- Perform as much non-radiation work as possible outside the designated areas of radiation work.
- Have all necessary tools before entering the area.
- Work efficiently.

Distance

- For a point source, radiation exposure is reduced by the inverse square of the distance from the source:

$$\text{Dose (or Dose Rate)} \propto \frac{1}{\text{Distance}^2}$$

- Stay as far away as possible from the source without hindering work.
- Use remote handling device when appropriate.

Shielding

- Use proper and sufficient shielding
- Work with workstation or bench top shielding screen

External Exposure Assessment

- For workplace

  - survey meters should be used to check that the dose rate at work area is minimal.
- For radiation worker

  - all radiation workers are required to wear a TLD badge to monitor the whole body exposure.

Dosimeters

- TLD for whole body dose badge

- Finger ring dosimeter

Proper Use of Personnel Dosimeters

- Dosimeters should not be shared with others.
- Wear dosimeters at all times in controlled areas.
- Dosimeters must be worn on the chest between the waist and the neck.
- All dosimeters should be stored in radiation-free area when not in use.
- Finger rings should be worn on the finger of hand most likely to receive the greatest exposure.

EXPOSURE SURVEY

Exposure Survey (Irradiating Apparatus

- The purpose is to ensure that the levels of radiation in the working area do not change and are at a minimal level, and that there is no breakdown in safety controls.
- Laboratories using sealed sources and x-ray systems should be checked periodically for radiation levels and records should be kept.
- Exposure to personnel should also be monitored.

Exposure Survey

- For external exposure:
  - survey meters should be used to check that the dose rate at work area is minimal;
  - all radiation workers are required to wear a TLD badge to monitor the whole body exposure; and
  - ring dosimeter should be used if suspected hand exposure is much higher than the whole-body exposure.

X-ray Survey Meter

Contamination Survey for Unsealed Source

- The purpose is to ensure that the levels of radiation and/or contamination in the working area do not change and are at a minimal level, and that there is no breakdown in safety controls.
- Contamination can be fixed or removable.
- Contamination survey can be done by either direct or indirect monitoring.

Direct Monitoring for Contamination

- Direct monitoring by using survey meter is for external radiation from gamma and strong betas and for fixed contamination.

  - Direct monitoring MUST be done before and after work.

Radiation Survey Meter

- Most common type of survey meter is Geiger-Muller (GM) counter.
- It is best for x-ray/gamma ray or strong beta.
- The count rate will respond linearly with the intensity of the radiation field.
- Primary used to detect the presence of radioactive material.
- CANNOT detect weak beta nuclide such as H-3.

Indirect Monitoring for Contamination (Swipe Test)

- Indirect monitoring, or the swipe test, should be used for removable contamination and for low energy betas.
- A piece of clean filter paper is swiped over the suspected surface for about 100 cm^2.
- The filter paper is counted for radioactivity using a liquid scintillation counter.
- Two action levels after the swipe test result:

  \- ADAL: 200 dpm/100 cm^2 , clean up is required

  \- DAL: 1000 dpm/100 cm^2 , clean up and after clean up swipe test is required until the level is below 200 dpm/100 cm^2 .

CONTROL MEASURES FOR UNSEALED SOURCES

Entry pathway

Four possible pathways into the body:

- Inhalation
- Ingestion
- Absorption through intact skin
- Puncture (injection or wound)

Internal Radiation Exposure

- Internal radiation exposure results when the body is contaminated internally with a radionuclide.
- When radioactive materials enter the body, they metabolized and distributed to the tissues according to the chemical properties of the element or compounds in which they are contained.

Target Organ

- H-3 ---- Whole body
- C-14 ---- Body fat
- P-32 ---- Bone
- S-35 ---- Whole body and testis
- Cr-51 ---- Lower large intestine and lung
- Fe-59 ---- Lower large intestine
- I-125 ---- Thyroid gland

Contamination Control

- Good housekeeping is always the first necessary step to contamination control.
- Protective clothing

  - lab coat, disposable gloves
- Workplace

  - absorbent paper, monitor before and after, …
- Labeling

  - tools, containers, …

Internal Exposure Evaluation

- There are several exposure evaluation:
  - indirect: bioassay such as urinalysis,
  - direct: whole body counting and thyroid counting.
- Consult HSE for the appropriate assessment.

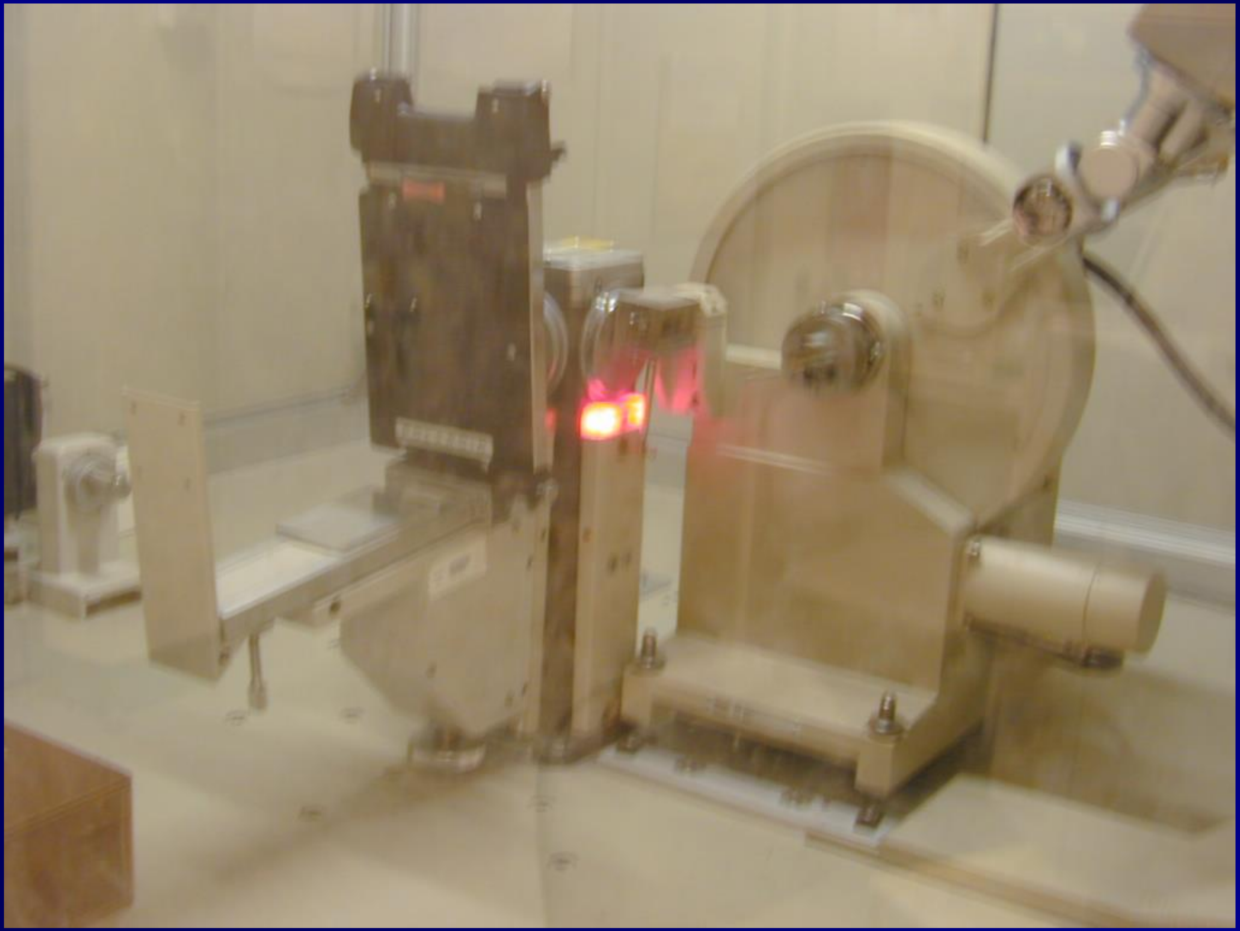
CONTROL MEASURES FOR SEALED SOURCE

Common Features of x-ray system

- X-ray “ON” indicator.
- Shielding for tube housing leakage and scattered radiation.
- Beam stop.
- Interlock indicator.
- Shutter indicator.

X-ray “ON” Indicator

Shutter Indicator



Basic Safety Requirements

- Shielding/Barriers
- Interlocks
- Warning signs
- Key control
- X-ray system survey
- Personnel monitoring
- Entry warning light

Shielding/Barriers

- X-ray units shall be designed with shielding so that regulatory dose limits are not exceeded.
- Dose equivalent rates around analytical X-ray units with shielding should not exceed 2.5 μSv/h.
- All ports of an analytical X-ray unit shall be covered with a radiation shield when not in use.

Interlocks

- X-ray safety interlocks is always fail-safe design.
- Enclosures for X-ray unit should be interlocked to prevent access or entry to x-ray beam while the high-voltage system is charged.
- This system should be designed so that the high voltage system is grounded automatically if an interlock is opened.

Interlocks

- For open beam systems, the entry-door may interlock with the x-ray system.
- If the system does not install with safety interlock , it should have emergency shutdown switches.
- These switiches should be labeled clearly and easy of access.

Interlock, Shutter Indicator

Warning Signs

- A ‘**CAUTION**’ sign shall be posted at the room entrances where x-ray units are operated and at the x-ray unit enclosure.
- An approved operating procedure shall be posted on or next to all x-ray units to indicate the maximum unshielded dose rate and the maximum operating parameters.

Warning Sign

Key Control

- X-ray units with key-controlled console should have the key removed and secured when the unit is left unattended.

Key Control

X-ray System Survey

- The appropriate X-ray survey instruments should be available to survey the X-ray for leakage at least quarterly.
- Interlocks shall be checked at least once every 6 months to ensure proper function.
- Interlocks that malfunctioned shall be repaired and re-tested before the unit can be operated again.

Access Control and Entry Warning

- Access should be controlled.
- Warning signs for radiation area should be posted on the door.
- A red warning light should be installed at the entrance of the facility and some have linked to the high-voltage power supply.
- When X-ray is 'ON', the entrance light must be 'ON' simultaneously to alert other personnel.


CAUTION
X-RAY
RADIATION
7 12 2000


CAUTION
FILM BADGE
REQUIRED
IN THIS AREA


2150
8999
CAUTION
CAUTION
X-RAY
RADIATION

Radiation Safety Program at HKUST(GZ)

- To keep radiation exposures to staff, students, the public and the environment ALARA.
- To ensure all radiation-related activities (teaching and research) performed at HKUST(GZ) comply with all legal requirements.

Legal Requirements of Radiation Use

- 《中华人民共和国放射性污染防治法》（2003年版）
- 《中华人民共和国职业病危害防治法》（2018年修订版）
- 《放射性同位素与射线装置安全和防护管理办法》（2011年版）
- 《电磁辐射环境保护管理办法》（1997年版）
- 《放射性同位素与射线装置安全和防护条例》（2019年修订版）
- 《电离辐射防护与辐射源安全基本标准》（GB 18871-2002）
- 《微剂量X射线安全检查设备 第1部分：通用技术要求》（GB 15208.1-2018）
- 《高校实验室安全工作参考手册》（2020年版）

All radiation work on the campus HKUST(GZ) must comply with these regulations!

Elements of Radiation Safety Program

- Review/approve Radiation Use Authorization (RUA) applications for adequacy of safety procedures and control measures.
- Perform user registrations and safety training.
- Keep track of purchasing, receiving, transfer, storage, use and disposal of radioactive materials.
- Ensure the effectiveness of safety procedures and control measures by :
  - measurement of personnel exposure, and
  - survey of work environment.
- Provide medical surveillance.

Radiation Use Authorization (RUA)

- For any work with radioactive materials on campus, a RUA must be obtained prior to the actual operation.
- RUA application form is available from HSE.
- RUA must be reviewed, signed and endorsed by the Department Head and submitted to HSE for approval.

Approval of RUAs

The following are also required as criteria for approval of RUA:

- training of personnel;
- radiation monitoring of personnel & workplaces;
- administrative, engineering & contamination controls;
- records and documentation.

Radiation Use Authorization (RUA)

- RUAs are valid for a maximum of 1 year.
- If approved, the RUA should be posted on the front door of the laboratory to show the relevant information on the use of radiation in this particular laboratory.
- RUAs **could be terminated** for serious violation of radiation safety procedures.

Revisions and Amendments of RUAs

The RUA should be amended if there is/are:

- changes in personnel,
- use of radionuclides or compounds not listed,
- change of use location,
- increase in the use and possession limits, and
- uses of processes or procedures not previously authorized.

Proposed changes should not be implemented until the amended RUA is approved.

Registration of Users

A staff or student is authorized to handle radioactive materials if he/she:

- is registered with HSE and listed on a RUA;
- has attended the radiation safety training courses;
- participates in the radiation dosimetry program;
- has signed a statement in the form that he/she agrees to observe safety procedures on handling of radioactive materials.

Receiving of Radioactive Materials

- Newly arrived packages should be checked for possible contamination during transit.
- Start a Stock Record Form for each purchase order of radioactive materials received.
- After filled in the Part I of the Stock Record Form, must be notified to HSE by fax.
- Log all uses of this stock until its final disposal, then note the final disposal date and send a copy of this Stock Form to HSE.

Inventory of Radioactive Materials

- Each user is responsible for keeping individual records to account for the purchase, arrival, transfer, utilization and disposal of the material.
- A centralized inventory of radioactive materials will be maintained by HSE.

Storage of Radioactive Materials

- Radioactive materials must be stored in lockable metal cabinets or refrigerators at designated locations in the laboratory.
- Storage locations must be logged into the Stock Form.
- Access to storage locations should be controlled.
- Appropriate shielding must be provided to reduce the radiation exposure.
- Protection against the release or spill should be used.
- Storage locations must be posted with warning signs labeled with "Caution: Radioactive Materials."

Transfer of Radioactive Materials

- No radioactive material is allowed to leave HKUST(GZ) campus without the written consent of HSE.
- Contact HSE for information on the packaging, labeling and necessary paperwork for transporting radioactive materials.

Workplace control measure

- Access Control.
- Designated work areas - covered with absorbent paper and change regularly.
- Posting – post warning sign on work benches, storage cabinets, refrigerators and incubators.
- Labeling – label all items, tools and equipment that could potentially be contaminated.

Radioactive Waste Management

- It is an important part of the radiation safety program!
- All waste contaminated with radioactive materials must be disposed of as radioactive waste.
- DO NOT discard any radioactive liquid down the drain!
- HSE will provide appropriate waste containers.
- Users should segregate radioactive waste according to radionuclide and physical form.
- Three main kinds of waste: dry solid waste, aqueous liquid waste, liquid scintillation vials waste.

Radioactive Waste Management

- Users should accurately fill out a Radioactive Waste Label (provided by HSE) and tag it to the container.
- Use different color labels for different radioisotopes
- Request for radioactive waste collection can be through HSE system.
- Place the rad waste containers in a designated location in the laboratory, with proper shielding.
- HSE will pick up radioactive waste from each laboratory on a regular basis for waste processing.

Radioactive Waste Label

RADIOACTIVE MATERIAL

Tag No. ______________

P-32

Act ____________ Date______

Waste Generator

Department___________________

Signature___________ Date _____

Collection

Department___________________

Signature___________ Date _____

Disposal

Destination___________________

Activity____________ Date _____

Signature___________ Date _____


tation B
P-32 solid
wastes
Please change a new container
when liquid waste reach this line
P-32 liquid
waste only


Micro Centaur
USA SCIENTIFIC PLASTICS

Emergency: Spill of Radioactive Liquid

When a spill of radioactive liquid occurs,

DO NOT PANIC!

- Notify all personnel in the room and ask them to leave the spill area immedicately.
- Call general emergency number (88330110).
- Notify the supervisor.
- DO NOT activate Emergency Ventilation system unless radioactive gas is involved.

Emergency Procedures for Spills (cont.)

- If safe to do so, confine spill with:
  - absorbent paper on most spills,
  - sodium thiosulphate for radioiodine liquid.
- Leave contaminated clothing or articles and close the door.
- Post warning sign at the door to prevent entry.
- Wait for the emergency response team to arrive.
- Report essential facts: radionuclide and activity spilled, any injury,...

Personnel Decontamination

- Internal contamination: report to HSE.
- External contamination:
  - remove all contaminated clothing, place in a plastic bag and seal it.
  - check skin for contamination with a portable survey meter or a test swipe, depending on the radionuclide.
  - for ^{32}P, clean skin with household vinegar.
  - for free iodine, use a paste of sodium iodide on the contaminated area and then wash the area with a detergent. Report to HSE for intake evaluation.

Area Decontamination

- Wear gloves and protective clothing.
- Start at periphery and work toward the center.
- Use soap, water and appropriate carrier chemicals.
- Do not use scrub brushes.
- Survey continuously.
- Do not resume work until the survey confirms that no contamination is above background.

After an Accident

- Report accidents/incidents involving radioactive materials to HSE.
- Fill out an Accident/Incident Report.
- Accident/Incident Report forms are available from HSE.
- Bioassay is provided for any person who is injury in accident.

Radiation Safety

Radiation Safety

DEPENDS ON YOU!