Safe Handling of Radiation

X-ray Generators

ISBN978-4-905025-03-0
大学等放射線施設協議会

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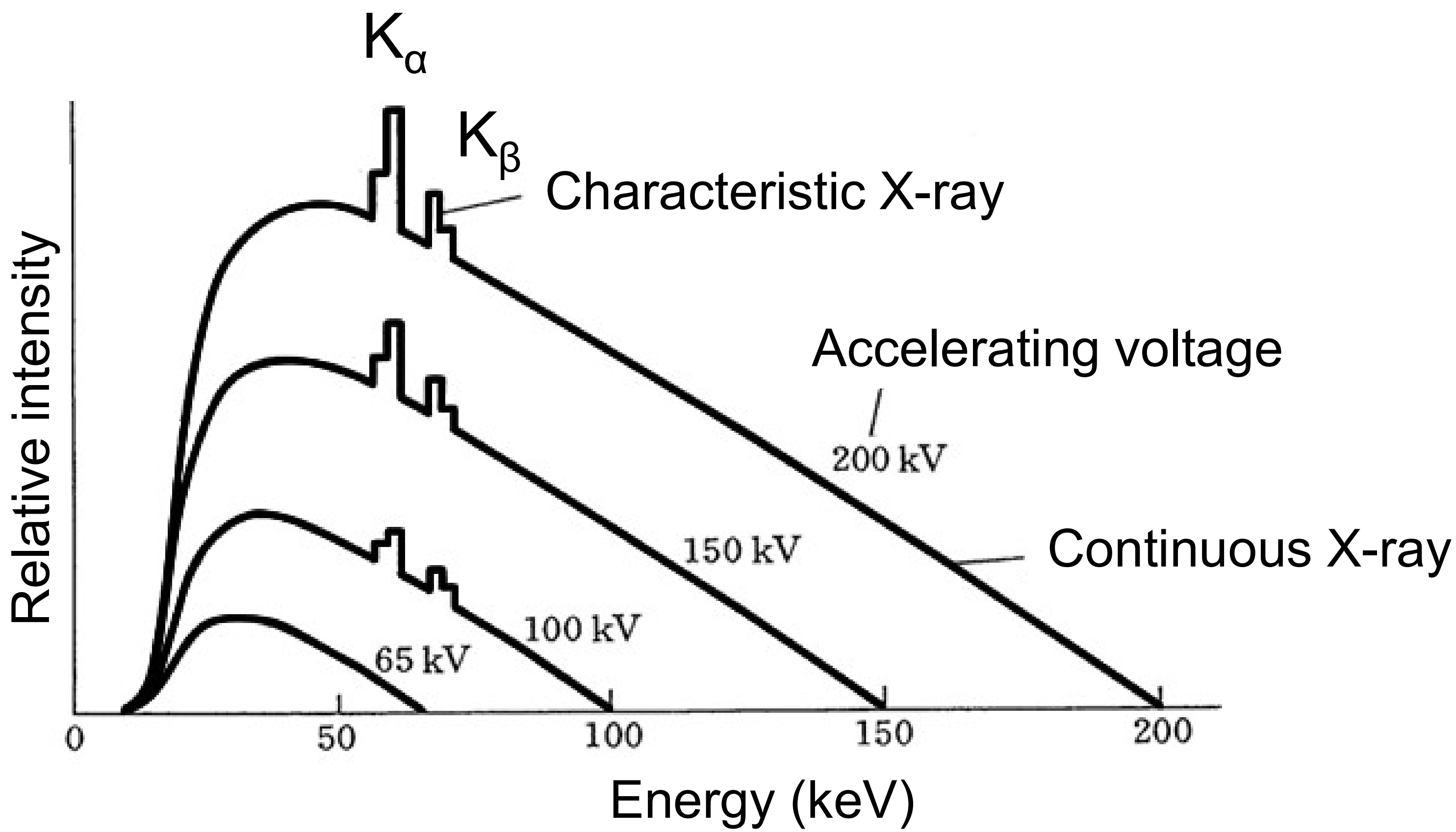
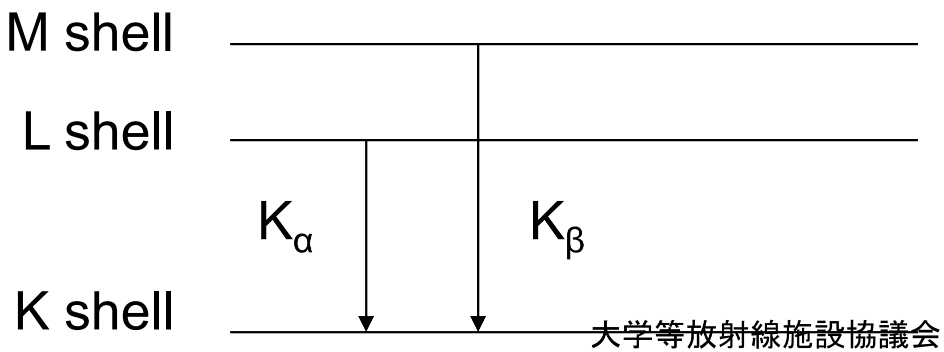
- Radiation Protection

1. Basic Physical Aspects of X-rays
1.1 Generation of X-rays

- Characteristic X-rays
  - de-excitation of atoms
  - inherent wave length ⇒ Elemental analysis

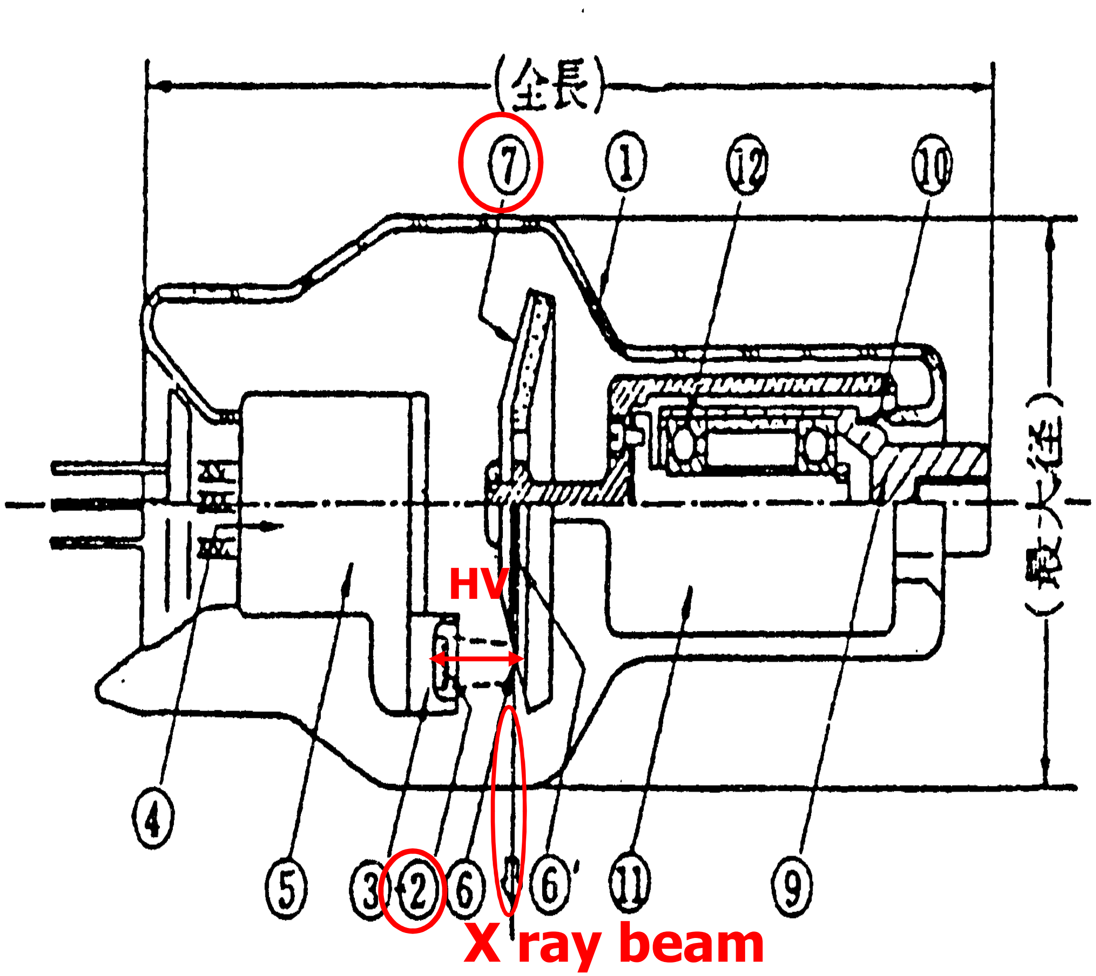
- Bremsstrahlung
  - Light emitted by acceleration of charged-particles
  - continuous spectrum





$$E = hc/\lambda_{K\alpha} = W_K - W_L$$

1.2 X-ray tube



1.Glass valve

2. W coil filament

3. Focus electrode (Fe, NI)

4. Stem (Lead thru)

5.Cathode sleeve (Fe, NI)

6. Focus point (X-ray source)

6’.Focus trace (ring)

7. Target (Fe, W alloy etc)

9. Anode axis for rotation

10. Kobal ring (Fe alloy-glass)

11. Anode Rotor

12. Bearing with lubricant

1.3 Interaction of X-rays with materials

1.3.1 Attenuation & Absorption

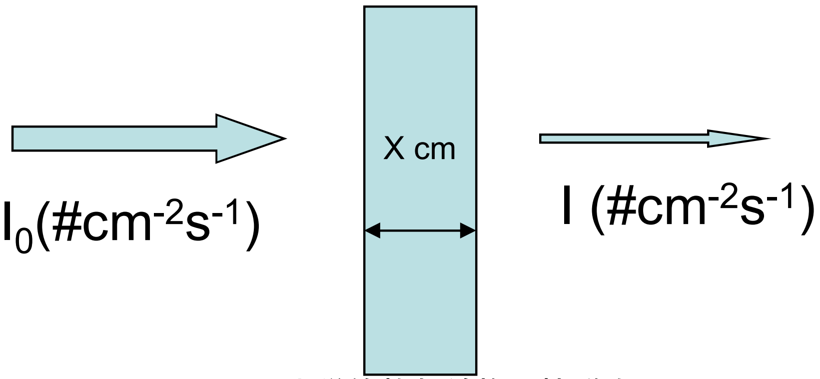
Incident flux I_0 (cm^{-2}・s^{-1}), Transmitted flux I (cm^{-2}・s^{-1})

$$-\frac{dI}{I} \propto x = \mu x, \quad I = I_0 \exp(-\mu x) = I_0 \exp(-\left(\frac{\mu}{\rho}\right)\rho x),$$

μ: linear attenuation coefficient (cm^{-1})

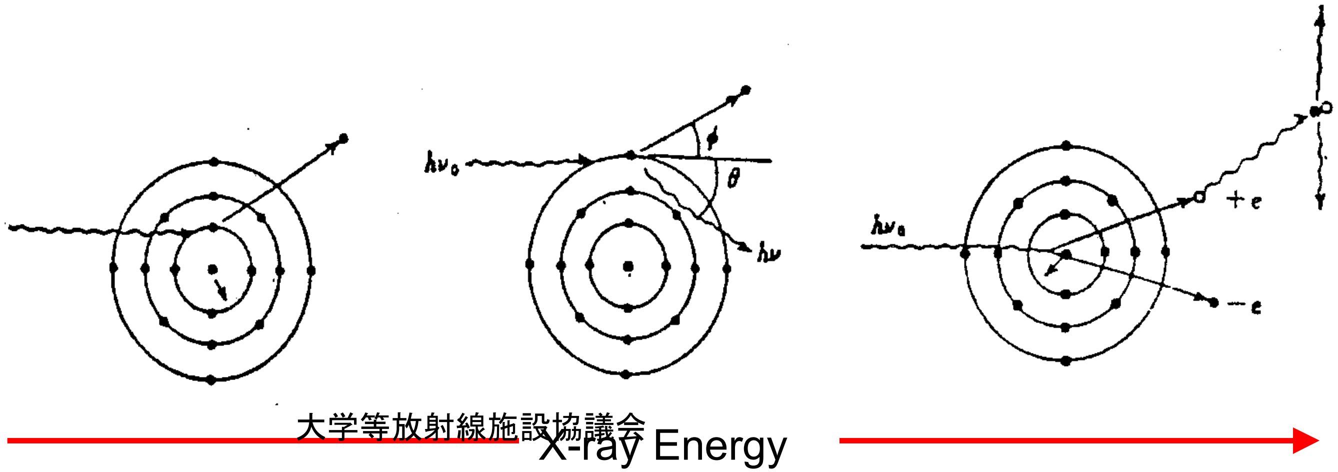
μ/ρ: mass attenuation coefficient (cm^2/g)

state independent (Ex. Water vs. vapor)



1.3.2 Photoelectric effect
1.3.3 Compton scattering
1.3.4 Electron-pair creation

	Photoelectric effect	Compton scattering	Electron-pair creation
description	μ(pht)	μ(com)	μ(ept)
product	electron	electron and photon	a pair of e^- and e^+
energy	$Ee=E_X- Wn$	$Ee= 0 \sim E_{max}$	2 x 0.511MeV



1.4 X-ray intensity

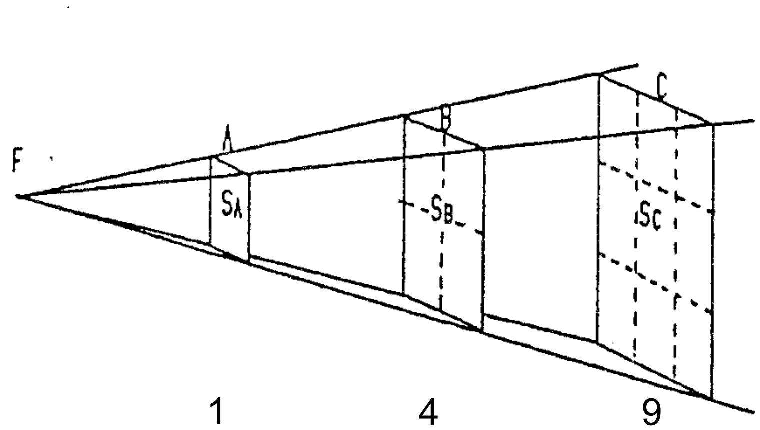
X-ray intensity at x cm from the source:

$$I\ [\frac{\#}{cm^2 \cdot s}] = S[\frac{\#}{s}] \cdot \frac{1}{4\pi d^2} \cdot \exp(-\mu x)$$

d: distance from the source F, [cm]

x: thickness of absorber, [cm]

μ: linear attenuation coefficient of absorber [cm^{-1}]



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1.5 X-ray survey meter

Type	Advantages	Disadvantages
Ionization Chamber Effective Range 30 keV ～ 1.5 MeV	Accurate Good energy response (Sv/D)	Low sensitivity for all kinds of X rays (Low detectivity)
GM (Geiger-Mullar) Proportional Counters Effective Range 100 keV ～ 1.5 MeV	High sensitivity Gas Multiplication Convenient for usual leakage check	Long dead-time (~200 μS) → Count loss and suffocation Low sensitivity for low energy
Scintillation Counter Semiconductor Counter Effective Range 100 keV ～ 1.5 MeV	High sensitivity Large μ value (solid state)	Low sensitivity for Low energy X or γ-rays

2. Radiation protection
2.1 Basics of radiation protection

- The principles of radiological protection (ICRP2007)
  - Justification
  - Optimization of Protection
    - individual doses should all be kept as low as reasonably achievable (ALARA)
  - Application of Dose Limits

- The principles of protection from external exposure
  - Shorten working time
  - Keep distance from radiation source
  - Use shielding

2.2 Tips for safe handling of X-ray generators

- Never put any parts of your body into X-ray beams
- Shut down the generator power when exchanging your sample
- When the above is impractical, confirm the shutter being closed
- Improve working process or equipment to make exposure time shorter
- Make radiation shields effective
- Take care of scattering and leakage of X-rays

2.3 Shielding of X-rays

- You should enclose X-ray equipment
  - Using lead sheet, lead glass, transparent plastic sheet including heavy metals depending on the produced X-ray energy.
- Thickness of shielding should be calculated
  - based on the highest energy from an X-ray generator.
  - for example, X-rays from a 50 kV generator can be shielded by a 1-mm thick lead sheet.

2.4 Radiation controlled area

- Area where the effective dose from radiation sources may exceed 1.3 mSv / 3 months.
- Effective dose for accessible area should be less than 1 mSv / week.
- Notification by a sign noting “Radiation Controlled Area”.
- Radiation is shielded by wall and screen.

2.5 Personal dosimeters

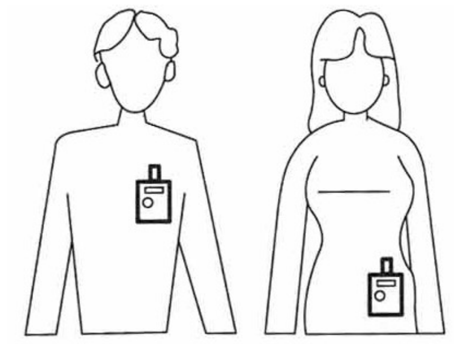
Type	Film badge	Thermo Lumine-scence	Luxel Badge	Glass badge	Electric SSD
Detection limit (H1cm)	100μSv	1 μSv	0.5 μSv	1μSv	0.01μSv
Measuring range (Sv)	100μ ~ 0.1	10μ ~ a few	10μ ~ 10	10μ ~ 10	0.01 ~ 99.9μ 1.0 ~ 999 μ
Energy dependency	Strong	Strong	Medium	Strong	Weak
Fading	No	Medium	Weak	No	No
Remarks	Not used now	Repeated use	Repeated Use	Repeated read out	Real time Electric noise

Luxel badge (Nagase) Glass badge (Chiyoda) Electrical dosimeter

For dosimetry in stationary work with small fluctuation of dose rate

For dosimetry in a short working period with big fluctuation of dose rate

Men



Women

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