Cavity theory - Dosimetry for small volumes

Lesson FYSKJM4710

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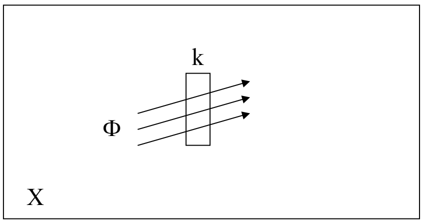
Cavity theory

- Problem: the dose to e.g. water is to be determined, but the measurement is performed with a detector (a dosimeter) having a different composition (Z, ρ)
- How determine D_X from D_{dos}?
- Dosimetry involves both measurements *and* theory
- Cavity theory: dosimetry for small volumes, or volumes of low density – useful for charged particles

Cavity theory

- Consider a field of charged particles in a medium X, where a cavity k is inserted:



- If the particle fluence does not change over the cavity, one has:

$$D_k = \Phi_k \left(\frac{dT}{\rho dx} \right)_{col}$$

Cavity theory 2

- If the cavity is not present, the dose to the medium X is:

$$D_x = \Phi_x \left(\frac{dT}{\rho dx} \right)_{col}$$

- The *dose ratio* becomes:

$$\frac{D_x}{D_k} = \frac{\Phi_x \left(\frac{dT}{\rho dx} \right)_{col}}{\Phi_k \left(\frac{dT}{\rho dx} \right)_{col}} = {}^{x}_{k}\left(\frac{dT}{\rho dx} \right)_{col}$$

→ The *Bragg-Gray* relation

Bragg-Gray cavity theory

- The B-G relation states that the dose ratio between the cavity and the medium medium of interest is determined by the stopping power ratio
- Assumptions (B-G *conditions*):
  - The dose is solely due to charged particles
  - The particle fluence is constant over the cavity

Example, Bragg-Gray theory

- The cavity is of air. The number of ionizations (measurable) is proportional to the dose to air. If the cavity is placed in water, what is the dose to water, as determined from the dose in air?
- Dose ratio:

$$\frac{D_{water}}{D_{air}} = {}^{water}_{air}\left(\frac{dT}{\rho dx}\right)_{col} \quad \Rightarrow \quad D_{water} = {}^{water}_{air}\left(\frac{dT}{\rho dx}\right)_{col} D_{air}$$

- Stopping power ratio may be calculated or reliable tables may be used

Example, Bragg-Gray theory

- Ratio

$$\left(\frac{dT}{\rho dx}\right)_{col}{}^{water}_{air} = \frac{1.85\ \mathrm{MeV\ cm^2/g}}{1.66\ \mathrm{MeV\ cm^2/g}}$$

- The dose water is thus:

$$D_{water} = 1.11\ D_{air}$$

- The cavity theory relates the dose in a sensitive volume (the measureble quantity) to the dose in the medium of interest
- If only the dose to the cavity is determined, we are left with doing relative dosimetry only

Spectrum of charged particles

- Spectrum may be provided by differential fluence; Φ_T
- The dose contribution from the different particles must be summed:

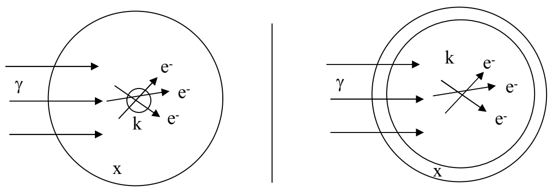
$$D = \int_0^{T_{max}} \Phi_T \left(\frac{dT}{\rho dx}\right)_{col} dT = \frac{\Phi}{\Phi} \int_0^{T_{max}} \Phi_T \left(\frac{dT}{\rho dx}\right)_{col} dT$$

$$= \Phi \overline{\left(\frac{dT}{\rho dx}\right)_{col}}$$

- The dose ratio is thus given by the average s.p.r.

Common theory for electrons and photons

- What happens if the cavity increases (or density increases), so that photons are also absorbed?
- Have to extremes:



B-G conditions

$$\frac{D_x}{D_k} = {}_k\left(\frac{dT}{\rho dx}\right)^x_{col}$$

CPE

$$\frac{D_x}{D_k} = \left(\frac{\mu_{en}}{\rho}\right)^x_k$$

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Burlin cavity theory

- Burlin derived a theory where both electron- and photon contributions to the dose is included:

$$\frac{D_x}{D_k} = d\,{}_k\left(\frac{dT}{\rho dx}\right)^x_{col} + (1-d)\left(\frac{\mu_{en}}{\rho}\right)^x_k \qquad 0 \le d \le 1$$

- d=1 : no photon absorption → B-G theory
- Range of electrons is important – if high, d > 0

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Burlin cavity theory