Interaction between Radiation and Matter

Jon Petter Omtvedt

Nuclear Chemistry,
Department of
Chemistry
University of Oslo

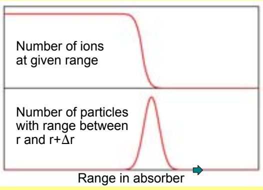
Directly Ionizing Radiation

- Directly Ionizing Radiation are *rays* of charged particles.
- The most important interaction with the surroundings is Coulomb interaction.
- The charged particles interacts with many atomic electrons in the media they pass through.
  - This implies that the particles lose their energy gradually.
- If the media is thick enough, the particles will be completely stopped at some point.
  - This implies that the particles have a certain range in the material.

Direct Ionizing Radiation = Direkte ioniserende stråling.
Range = Rekkevidde.
Absorber = Absorbator.
Bremsstrahlung (German) = Bremsestråling.

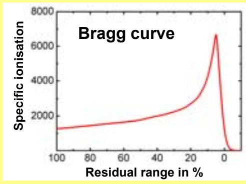
Range

- Deceleration of the particles (gradually loss of kinetic energy) is due to energy being transferred to the atoms or molecules in the absorber (media).
- The atoms in the absorber will thus be
  - ionised and/or
  - excited and/or
  - pushed (elastic collisions)



Interaction between particle and absorber

- For each particle which is decelerated many thousands of atoms will be excited and ionised.
- In addition, the particles will change direction due to the electrical field of the nuclei. This leads to brems-strahlung (braking radiation).
  - Bremsstrahlung is very week electromagnetic radiation.



Bremsestrahlung

- Charged particles change direction due to the electrical field surrounding the nuclei they pass.
- This is especially important for β-particles, because they are so light. They will therefore change directions to a much larger extent than heavier ions.
- The change in direction is what causes the bremsstrahlung. The amount can be estimated according to:

$$f = 3{,}5 \cdot 10^{-4} Z \cdot E_{\beta,max}$$

We never use heavier elements than aluminum (Z=13) to shield against β-radiation. This is due to the sharp increase in bremsstrahlung when Z increases.

Indirectly Ionising Radiation

- Uncharged particles, i.e. γ quanta or neutrons, can not interact as charged particles do.
- Here we will only discuss how γ-quanta interacts with matter:
  - A γ quantum can "collide" with an electron.
  - In addition, if the γ quantum has more energy than 1,022 MeV we can get pair formation. I.e. an electron-positron pair is created by converting 1.022 MeV of the γ quantas energy to two electron masses.

Note that the γ quanta do not lose their energy gradually, as do charged particles. Therefore, until absorbed, the γ quanta's *energy* will remain constant!

Absorption of γ radiation

- Rays of γ quanta are absorbed by complete removal of given quanta.
- Thus, the intensity (number of quanta) will be reduced along the path through the absorber.
- Note that the remaining ray of γ quanta will have less quanta, but they will all have the original energy.
- This is a statistical process, where the probability for absorption of a γ quantum is expressed by the *absorption coefficient*, μ.
- From this fact one can deduce that the intensity as a function of amount of absorber is given by:

$$I(x) = I_0 e^{-\mu x}$$

x is the path length through the absorber, I_0 is the original intensity and I(x) is the resulting intensity

Absorption of γ radiation

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Secondary processes (during γ- absorption)

- When a γ quantum transfers its energy to an electron, the electron will be accelerated to high speeds.
- Such an electron will behave in a similar way to a β-particle.
- As a secondary process during γ absorption we will get a high number of high-kinetic electrons along the path of the γ ray.
- These electrons will lose their energy in a much shorter path then the γ's (by *direct* ionisation).
- Along the path of the γ ray there will therefore be a track of ionised and exited atoms.

Ionising Radiation - Summary

Beams of charged particles:

- The particle energy gradually diminishes.
- The number of particles is constant on the path through the absorber.
- The beam has a given range.

γ radiation:

- The number of quanta gradually diminishes
- The energy of the original quanta is constant through the absorber.
- There is no absolute range.