CHARGED-PARTICLE
AND RADIATION
EQUILIBRIUM

BAEN-625 Advances in Food Engineering
A smaller internal volume \( \nu \) exists about a point of interest, \( P \).

\( V \) is larger enough so the max. distance of penetration \( d \) of any emitted rays plus their scattered and secondary electrons is less than the minimum separation \( s \) of the boundaries of \( V \) and \( \nu \).

Radioactivity is emitted isotropically on the average.

Volume \( V \) containing a radioactive source.
RE EXISTS IN ν

- The atomic composition of the medium is homogeneous
- The density of the medium is homogeneous
- The radioactive source is uniformly distributed
- There are no electric or magnetic fields present to perturb the charged-particle paths
Image a plane $T$ that is tangent to the volume $V$ at a point $P'$.

Consider the rays crossing the plane per unit area.

There will be perfect reciprocity of rays for all possible orientation of tangent planes around $V$.

For each type and energy of ray entering $V$, another identical ray leaves.
Reversing the positions of a point detector and a point source within an infinite homogeneous medium does not change the amount of radiation detected.
RADIATION EQUILIBRIUM

\[
\begin{align*}
\left( \overline{R_{\text{in}}} \right)_u &= \left( \overline{R_{\text{out}}} \right)_u \\
\left( \overline{R_{\text{in}}} \right)_c &= \left( \overline{R_{\text{out}}} \right)_c
\end{align*}
\]

- The energy carried in and out of $v$ are balanced for both indirectly and directly IR.
- The bars signify expectation values.
Under RE conditions the expected value of the energy imparted to the matter in $\nu$ is equals to that emitted by the radioactive material in $\nu$
If RE exists at a point in a medium, the absorbed dose is equal to the expectation value of the energy released by the radioactive material per unit mass.
CPE exist for the volume $v$ if each CP of a given type and energy leaving $v$ is replaced by an identical particle of the same energy entering.

If RE exists so CPE exists!
CPE FOR INDIRECTLY IR FROM EXTERNAL SOURCES

- The volume $V$ contains a homogeneous medium, uniformly irradiated throughout by photons.
- Secondary CP are thus produced uniformly throughout $V$ with the same direction and energy distribution everywhere.
- If the small distance separating the boundaries of $V$ and $\nu$ is greater than the max. range of CP present, CPE exists.
Photon with fluence energy is present in media A and B having 2 different average energy absorption coefficients.
CPE IN THE MEASUREMENT OF $X$

$$X = \Psi \left( \frac{\mu_{en}}{\rho} \right)_{E, air} \left( \frac{e}{W} \right)_{air} = (K_c)_{air} \left( \frac{e}{W} \right)_{air} = \frac{(K_c)_{air}}{33.97}$$

- Measurement of $X$ (only defined by photons) is described by this equation.
- Difficult because $K_c$ cannot be measured by any direct means.
- With CPE in an ionization chamber allows for the measurement of $X$. 
The average X in air volume \( v \) equals the total charge released in air by all electrons \( (e_1) \) that originate in \( v \), divided by the air mass \( m \) in \( v \).

IF CPE exists, each electron carrying an energy \( T \) out of \( v \) is compensated by another electron \( (e_2) \) carrying the same energy in.

Thus the same ionization occurs in \( v \) as if all \( e_1 \) remained there.

So, the measurement of \( Q/m \) ~ average X in \( v \).

\[
\overline{X}_v = \frac{Q}{m}
\]
RELATING D TO X FOR PHOTONS

\[ D_{\text{air}}^{\text{CPE}} = (K_c)_{\text{air}} = X \left( \frac{W}{e} \right)_{\text{air}} \]

\[ 0.01D_{\text{air}}^{\text{CPE}} = 0.01(K_c)_{\text{air}} = 2.58 \times 10^{-4} \times 33.97X \]

\[ D_{\text{air}}^{\text{CPE}} = (K_c)_{\text{air}} = 0.876X \]
CPE FAILURE IN A FIELD OF PHOTONS

- Atomic composition within $V$ is not homogeneous
- Density in $V$ is not homogeneous
- Field of photons in $V$ is non-uniform
- Electric or magnetic field is present in $V$ and it is non-homogeneous
V is too close to the source of IIR
- More particles $e_3$ are produced at point $P_3$ than $e_1$ at $P_1$
- More particles will enter $v$ than leave it

$V$ is divided by a boundary between different media
- # CP arriving in $v$ is different due to change in CP production, or/and change in the range or geometry for scattering of those particles

High energy radiation
- Penetration power of secondary CP increases more rapidly than the penetration power of the photons
- The # CP at $P_3$ > than at $P_1$