Comment: First attempt at writing ....

**BRAINSTORM**

Interactions with Matter

* Charged particles
  + Heavy charged particles
  + Electrons (positrons?)
  + Range (distance in alpide)
  + Multiple coulomb scattering
  + (Bragg peak?) is this relevant??
* neutrons
* photons
  + photoelectric effect
  + compton scattering
  + pair production

Definitions

* Scattering: In physics, scattering is the change in direction of motion (velocity vector) of a particle due to collision with another particle
* Collision: A collision is an event where two or more particles exert a force on one another. The particles do not have to be in physical contact, collisions can occur between repelling particles, such as to protons (or electrons).
  + In physics, collision can occur between particles that repel one another, such as two positive (or negative) ions, and need not involve physical contact of the particles.

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**14/03/2020**

**15/03/2020**

**03/04/2020**

**Particle interaction with matter**

In principal there are two effects that can happen when a particle traverses a medium. The particle can lose energy and its direction of motion can be changed, ~~i.e the incident particle is scattered.~~ There are five interaction which can cause these effects:

1. Inelastic collision with valence electrons
2. Elastic scattering ~~collision~~ from nuclei
3. Bremsstrahlung radiation
4. Cherenkov
5. Transition radiation (?)

When talking about particle interactions with matter it is necessary to distinguish between different categories of particles; heavy charged particles, electrons and positrons, and neutrons.

Inelastic collision and elastic scattering occur for both charged and neutral particles. Bremsstrahlung, Cherenkov and transition radiation specifically applies for charged particles and are therefore not relevant when discussing neutrons, since they are neutral particles.

**03/04/2020**

**Comment:** It’s inelastic COLLISION, not scattering

**Inelastic collision with valence electrons**

A collision is an event where two or more particles exert a force on one another. The particles do not have to be in physical contact, collisions can also occur between repelling particles. Particles of equal charge sign repel each other owing to the coulomb force exerted on one another, such as two protons (or electrons). It is said to be an inelastic collision when the total kinetic energy of the system is not conserved.

Both neutral and charged particles collide inelastically with valence electrons. Neutral particles come in direct contact while charged particles act with electromagnetic forces on atomic electrons to transfers energy.

Depending on how much energy is transferred, the atom is either ionize or excite. If an atomic electron receives energy greater than or equal to its binding energy, the electron is liber and the atom is **ionized**. Should the energy transferred be less than the critical (?) binding energy the electron is merely elevated to a higher energy level causing the atom to enter an **excited** state. Either way (ionized or exited), the electron gains potential energy at the cost of loss in the system kinetic energy, thus making it an inelastic interaction.

**Elastic scattering from nuclei**

Scattering is when a particles trajectory is altered from its original path, due to a collision with another particle, and if the total kinetic energy is conserved it is said to be an elastic scatter. When a particle traverses through matter it loses energy until it is in equilibrium with

MORE HERE…. READ??

**Bremsstrahlung, Cherenkov and transition radiation** are all electromagnetic radiation resulting from a charged particle traversing matter. If a charged particle deaccelerates and/or is deflected by an strong electric field it radiated **bremsstrahlung**, German for “breaking radiation”. **Cherenkov radiation** occurs when a charged particle traverses a homogeneous dielectric medium at a speed greater than the group velocity of electromagnetic waves in that medium. **Transition radiation** is emitted when a charged particle passes through inhomogeneous media, such as boundary between two media. Magnitude of the energy loss due to these processes depend on the particles mass and/or energy. For instance, if incident particle is an electron, bremsstrahlung can cause up to 100% energy loss, while if a heavy charged particle it is insignificant in the precence of inelastic collision.

**15/03/2020**

**Inelastic scattering with valence electrons**

Scattering is when a particles trajectory is altered from its original path, due to a collision with another particle. Note that a collision does not always imply physical contact between the colliding particles, it can also occur between repelling particles, such as two protons/electrons. Particles of equal charge sign repel each other owing to the coulomb force exerted on one another. ~~A~~ **~~collision~~** ~~where the total kinetic energy of~~ **~~a~~****~~system~~** ~~is not conserved is an inelastic collision~~. ~~On the other hand~~ When talking about particles **scattering, if** the kinetic energy of the **incident particle** is not conserved the interaction classifies as inelastic scattering.

Through inelastic scattering a charged particle acts with electromagnetic forces on and transfers energy to atomic electrons. Depending on how much energy is transferred the atom is either ionize or excite. To **ionize** an atom, an atomic electron must receive a critical amount of energy, equal to or greater than the binding energy of the electron~~, to free itself from the atom~~. If the electron receives an energy greater than its binding energy, it is liberated from the atom. With one less electron the atom has become an ion, charged one positive elementary charege. can be liberated from the atom the excess is gained by the electron as kinetic energy. If received energy falls short of the binding energy, instead of escaping, the electron jump to an higher energy state, leaving the atom in an exited rather than an ionized state. Either way (ionized or exited), kinetic energy of the incident particle is not conserved, and the interaction is therefor an inelastic one.

…. NOT FINISHED

*Inelastic scattering implies two things: kinetic energy of a system is not conserved and the incident particles trajectory has been altered from its original path (i.e, it has been scattered). Scattering occurs due to a collision between two particles. A collision*

**Elastic collision from nuclei**

Bremsstrahlung, Cherenkov and transisiton radiation are all electromagnetic radiation resulting from a charged particle traversing matter. If a charged particle deaccelerated it radiated bremsstrahlung. Bremsstrahlung occurs when a charged particle is deaccelerated. Cherenkov radiation

**Bremsstrahlung radiation**

* Electromagnetic radiation
* Deacceleration of a charged particle
* Typically reflected by
  + Atomic nucleus
  + electron

**Cherenkov radiation** is electromagnetic radiation and occurs when a charged particle traverses a homogeneous dielectric medium at a speed greater than the group velocity of electromagnetic waves in that medium.

**Transition radiation** is electromagnetic radiation emitted when a charged particle passes through inhomogeneous media, such as boundary between two media.

**Heavy charged particles** are, by definition, particles with one atomic mass unit or greater, such as proton, ions (e.g. carbon ions) and alpha particles, and experience all five interactions listed above. Inelastic collision and elastic scattering are the main causes of trajectory diversion and energy loss; and Bremsstrahlung, Cherenkov and transistion radiation are insignificant in comparison.

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14/03/2020

Though all aforementioned interactions can occur when a particle traverses matter, they do not contribute equally to energy loss and/or scattering of the particle.

Main contributors are the first two interaction: (1) inelastic scattering with valence electrons and (2) elastic collision from nuclei. The other interactions also transpire, however, infrequent relative to the occurrence of scatter and collision. For this reason th

Heavy charged particles are, by definition, particles with one atomic mass unit or greater. Examples of heavy charged particles are proton, ions (e.g. carbon ions) and alpha particles.

**Charged particle interaction with matter**

* Inelastic scattering with valence electrons:
  + Inelastic implies kinetic energy in the system is not conserved, however, the total energy of the system is.
  + Through inelastic scattering a charged particle acts with electromagnetic forces on atomic electrons and can do either of the following to the atom which it interacts with
    - Ionize
    - Excite
  + Both require energy transfer from the charged particle to an/the atomic electron(s). After energy has been transfered, the charged particle has a new direction of motion, i.e. it has been scattered.
    - To **ionize** an atom, an atomic electron must receive a critical amount of energy, equal to or greater than the binding energy of the electron, to free itself from the atoms grasp. The, now free, electrons have greater kinetic energy and the charged particle has less (than..). The total kinetic energy of the system has also changed, i.e. is not conserved, since some of the energy being transferred goes to overcoming the binding energy. The interaction is there for an inelastic one.
    - For an atom to be left in an **excited state**, the charged particle transfers energy to atomic electrons, though not enough for them to escape the atom completely, and causes them to enter a higher energy state.
    - *Alternatively: If the binding energy is not conquered, the electron does not escape the atom. It can, however, jump to an higher energy state, leaving the atom in an exited state.* 
      * Slow particles excite atoms instead of ionizing them. BUT WHY?
        + Longer interaction time?
  + The charged particle losses some of it’s kinetic energy and the atomic electrons ga
* Inelastic collision
* Elastic collision
* Bremsstrahlung radiation: when a charged particle deaccelerated loss of kinetic energy radiated as photons.
* Cerenkov (?)
* Transition radiation (?)

Heavy charged particles

* Energy loss by ionization
* Bethe block
* …

Electrons and positrons (?)

* …

Neutrons

* Attenuations (Lamber-Beers law?)
* Exception, absorption and…
* …

Photons

* Lambert beers law
* Attenuation

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Particle | **Inelastic scattering with valence electrons** | **Elastic collision with the atomic shell** | **Elastic collision with nuclei** | **Inelastic collision with nuclei** | **Bremsstrahlung radiation** | **Cerenkov radiation** | **Transition radiation** |
| **Heavy charged** | D |  |  |  |  |  |  |
| **Electrons & positrons** | D |  |  |  | Back Scatter Electrons (BSE) |  |  |
| **Neutrons** | ? |  |  |  |  |  |  |

D: dominant

References:

* Inspiration from Viljars thesis structure
* Introduction to Health physics
  + https://drive.google.com/file/d/1Tar1J6TVoXqGEZqxAghruwNxpGY\_RSbI/view