20. Nuclear Physics I

Definitions

Mass defect (atom): The difference in mass between the constituent particles and the atom
Mass defect (nucleus): The difference in mass between the constituent particles and the nucleus
Nuclide: An atom with a particular proton-neutron combination

Nuclear Binding Energy: The energy required to break a nucleus into its constituent particles.

Ionising power: The ability of the radiation to remove electrons from atoms
Penetrating power: The ability of the radiation to pass through a material before being completely absorbed

- Energy released is released in the form of Ek in particles produced and EM radiation in the form of gamma rays.
- Radiation with high ionising power has low penetrating power.
- When particles are absorbed by a material, their energies are converted into internal energy of the material.
- Note that in calculating the mass defect, energy released is given by the mass of the **reactants** minus the mass of the **products** (reactant minus product)
- To measure stability, nuclear binding energy per nucleon is used, NOT binding energy.
- At higher nucleon numbers, BE per nucleon decreases as coulomb repulsion between protons overcome the attractive nuclear forces between nucleons.

Questions

1. Explain why the velocity of neutrons cannot be determined directly?
Ans: Neutrons are electrically neutral and hardly interact with matter (only nuclear force, which is very short range and hence low chance of occurrence). Therefore, the neutron, which is highly penetrating, will not leave any trace in the cloud chamber and hence cannot be detected directly.

2. How does alpha particle scattering give evidence for the existence and small size but massiveness of the nucleus?
Ans:
- Large number small deflections, only small fraction experienced large deflections, i.e. only a small fraction experienced large repulsive forces.
- This is possible only if the positive charges are confined to a very small volume. (Therefore, small)
- Furthemore, the large deflections of alpha particles shows that the nucleus is more massive. (Therefore, massive)

3. Distinguish between scattering of alpha particles by thin gold foil and bombardment of atoms by slow neutrons
Ans:

Alpha particle scattering	Neutron bombardment
Interaction through electrostatic forces	Interaction through the strong nuclear force
No nuclear transmission	Bombardment forms highly unstable composite particle which quickly disintegrates into smaller nuclides

20. Nuclear Physics II

Definitions

Radioactivity: The spontaneous decay of a radionuclide to form more stable nuclide by emitting some forms of ionizing radiation.
Decay constant: The probability that a nucleus will decay per unit time.

Activity: The rate of radioactive decay OR the number of radioactive decay per unit time.

- A radioactive nuclide is an atom with an unstable nucleus.
- Radioactive decay is spontaneous → unaffected by external factors
- Radioactive decay is random → impossible to predict when a particular nucleus will decay.
- Alpha particle **CANNOT** pass through **paper**
- Beta particle can pass through **paper** but **NOT aluminium sheet**
- Gamma ray can pass through **paper, aluminium sheet, concrete block** but **NOT thick lead**
- A = dN/dt

Questions

1. Why is the energy of the alpha particle found to have lesser energy than calculated?
Ans: The thallium nucleus is in an excited state with higher energy. So the energy released by the decay is lower than 6.54 MeV. Therefore α-particle has an energy lower than 6.42 MeV.

2. Why energy absorbed by ____ is less than energy released by the source.
Ans: (usually when gamma ray is emitted) Most of the gamma rays are not absorbed by the ____ as gamma rays are not highly ionizing.

3. Why is another beta source with a shorter half life preferred?
Ans:
- Smaller amount of ___ required to deliver the same dosage over a shorter period of time
- Exposure to beta radiation negligible after a few days due to shorter half life.

4. Questions on the inaccuracy of a measuring half life of a composite source.
Ans: Even though the activities of the two sources vary exponentially with time individually, the total activity does not and hence, it is not possible to define the half-life of a composite source.

5. Suggest a method to confirm that the radiation is uncharged.
Ans: Pass the radiation into an E field in a direction perpendicular, if not deflected, radiation is uncharged.

6. Suggest a method of measuring the speed of protons.
Ans: Pass the protons into a magnetic field at right angles, the radius of the path of the protons is a measure of its speed OR pass the protons through sheets of Al, the thickness of Al it can pass through before being stopped is a measure of its thickness.

7. Why is the build up of ___ of concern and explain why it is unlikely to accumulate in sufficient quantity to be harmful?
Ans: Gas mixes with air and can be breathed in. It emits alpha and beta particles which are highly ionizing and ingested radioisotopes could cause cancer. The half life or radon is very short compared with the rate at which it is produced and therefore build up is unlikely.

8. What are the problems associated with storage of nuclides with 1) very long half lives and 2) very short half lives?
Ans: Firstly the long half life of a nuclide means that the nuclide remains radioactive for a long time and hence radioactive waste has to be stored in a secure location for hundreds of thousands of years. Secondly, the high activities of nuclides with very short half-lives means that the storage tank must be stored deep underground so that their harmful radiation does not reach the surface of the Earth.