MPM: 203 NUCLEAR AND PARTICLE PHYSICS

UNIT –I: Nuclei And Its Properties

Lecture-2

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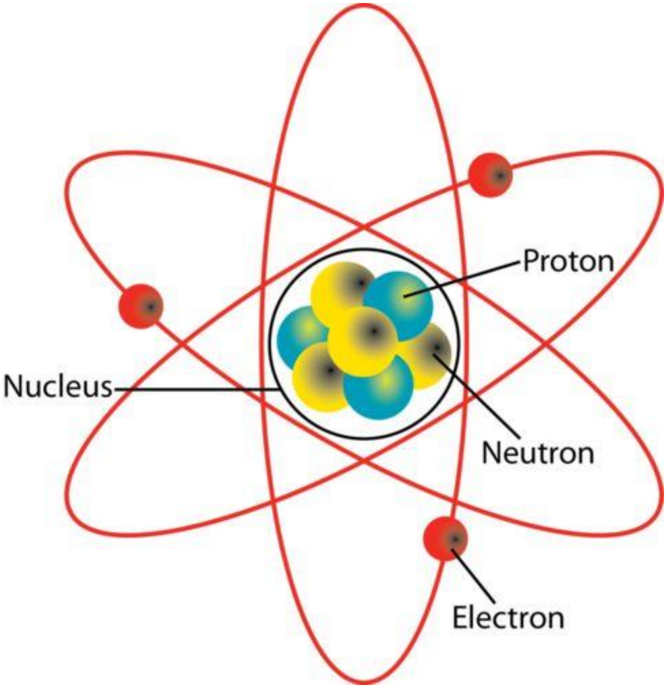

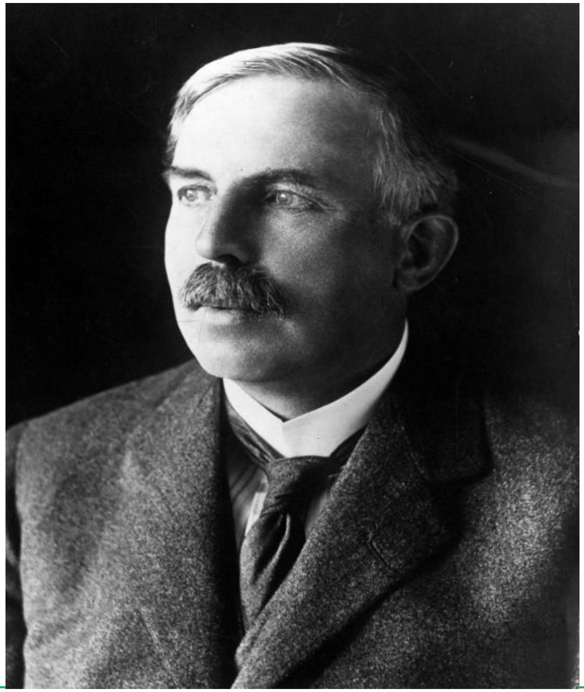

During the last year of the first world war Ernest Rutherford failed to attend a meeting of British Committee of Experts appointed to advise on new system of defense against enemy submarines. When he was censured for his absence, he replies that I have been engaged in experiments which suggest that the atom can be disintegrated artificially. If it is true, it is of far greater importance than war.

……………………………Ernest Rutherford

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CONTENT OF FIRST UNIT

- Discovery of the nucleus Rutherford scattering: Scattering cross-section
- Form factors, Kinematics of (non-) relativistic scattering
- Properties of nuclei: size, mass, and charge
- Angular momentum and magnetic moment
- Parity, quadrupole moment
- Charge and mass distribution
- Mass defect, Binding-energy statistics
- Bethe-Weiszacker mass formula Magic numbers
- Characteristics of nuclear forces -Range and strength

Discovery of the Nucleus

- In the early days of atomic theory, many physicists tried to explain the model of an atom.

- In 1902, Ernest Rutherford showed that alpha particles emitted from the decay of unstable radioactive materials were electrically charged helium nuclei travelling at high speed.

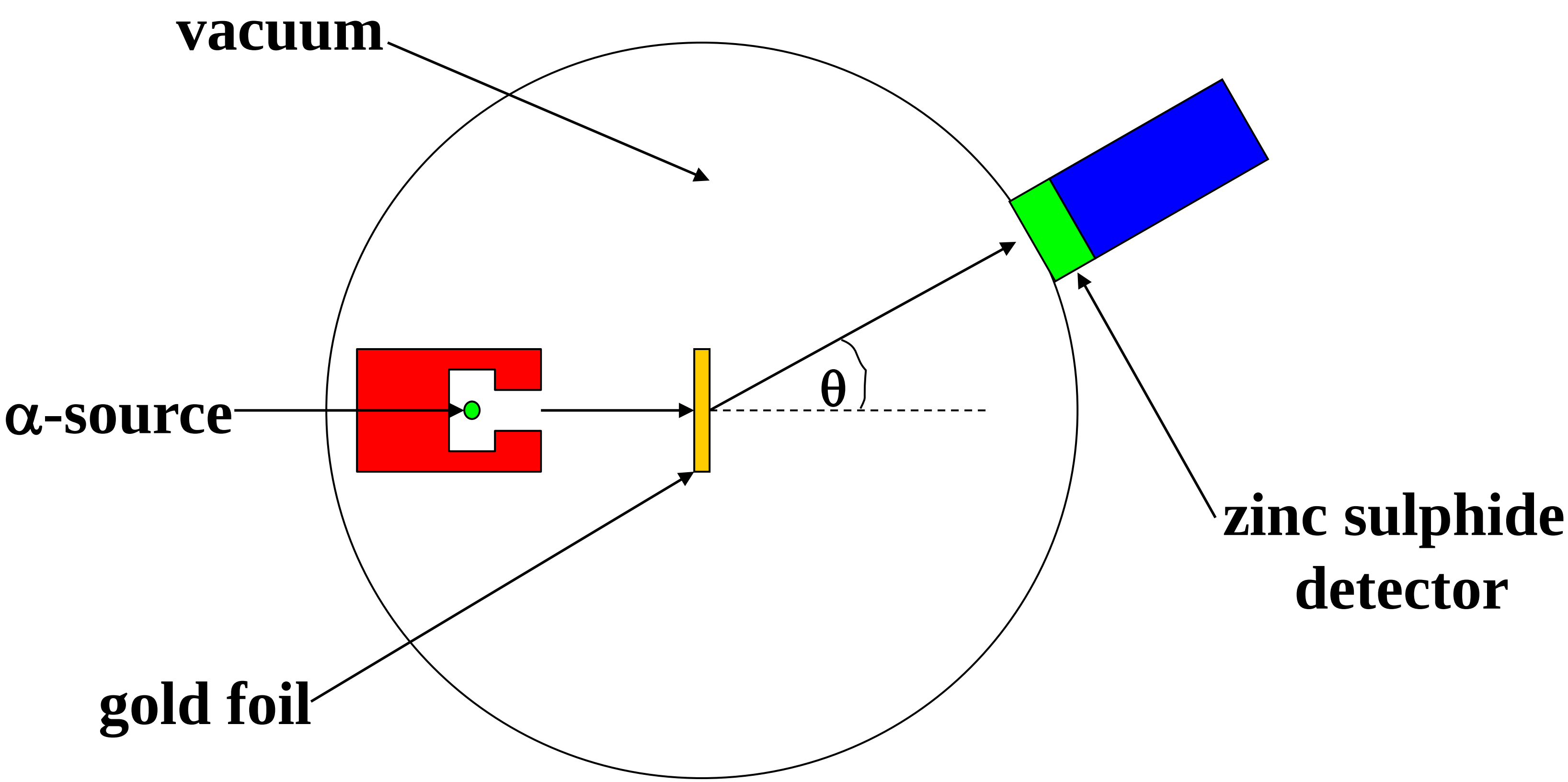
- In 1909, Rutherford used alpha particles to investigate the composition of gold foil (i.e. to explain the model of an atom).

Aim

To investigate the composition of gold foil using alpha particles (i.e. to explain the model of an atom).

Apparatus

Rutherford's alpha scattering apparatus:



Procedure

Rutherford fired alpha particles through a piece of gold foil and used a zinc sulphide detector to detect the scattered alpha particles and their location.

Results

Rutherford's experiment found that:

- **Most of the alpha particles passed through the gold foil undeviated.**
- **A few alpha particles were deflected from their path but continued through the gold foil.**
- **A small number of alpha particles rebounded.**

Conclusion

From the results of his experiment, Rutherford explained:

- **As most alpha particles passed through the gold foil atoms undeviated, Rutherford concluded that most of the atom was actually empty space.**

- **The deviation of some alpha particles from their original path were due to positive charges within the foil.**

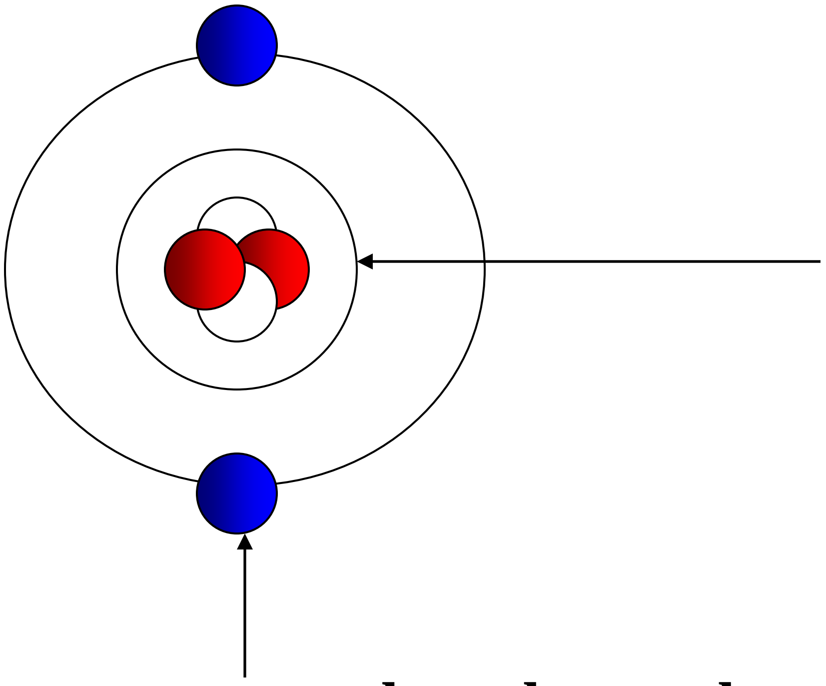
Conclusion

From the results of his experiment, Rutherford explained:

- **A small number of alpha particles had rebounded because they collided with something much larger and heavier and which contains a concentrated region of positive charge.**

Conclusion

As a result of his observations, Rutherford suggested that the atom had a positively charged centre which contained most of the mass.



He called the heavy positively charged centre the nucleus.

He went on to suggest that the nucleus was surrounded by orbiting electrons required for electrical neutrality.

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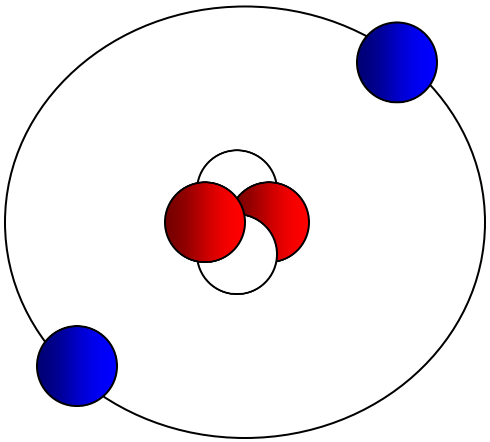

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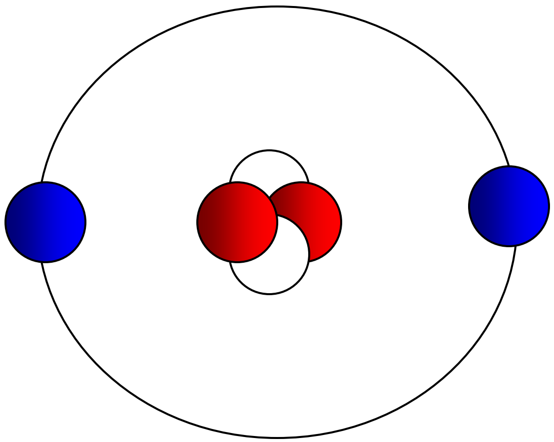

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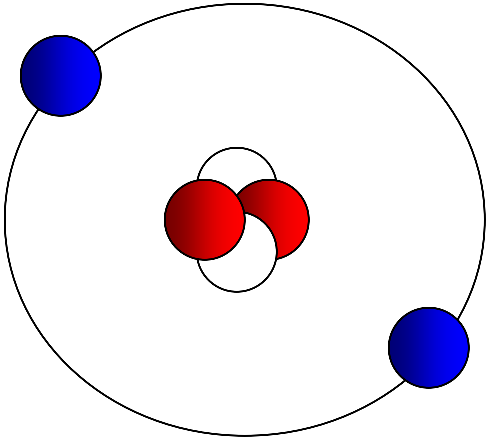

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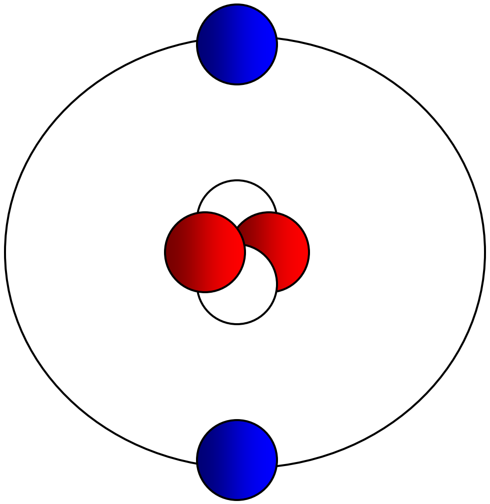

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Modern measurements show that the average nucleus has a radius in the order of 10^{-15} m. This is 100, 000 times smaller than the radius of a typical atom.

Nuclear Properties

- The symbol of an atomic nucleus is $^{A}_{Z}X_{N}$

  where *Z* = atomic number (number of protons)

  N = neutron number (number of neutrons)

  A = mass number (*Z* + *N*)

  X = chemical element symbol
- Each nuclear species with a given *Z* and *A* is called a **nuclide**.
- *Z* characterizes a chemical element.
- The dependence of the chemical properties on *N* is negligible, certain physical properties, e.g thermal expansion show measurable differences due to isotope effects.
- Nuclides with the same neutron number are called *isotones* and the same value of *A* are called *isobars*.

Nuclear Properties

- The nuclear charge is +*e* times the number (*Z*) of protons.

- Hydrogen's **isotopes**:
  - **Deuterium**: Heavy hydrogen. Has a neutron as well as a proton in its nucleus.
  - **Tritium**: Has two neutrons and one proton, is radioactive, about 40 tons on earth.

- The nuclei of the deuterium and tritium atoms are called *deuterons* and *tritons*.
- Atoms with the same *Z*, but different mass number *A*, are called **isotopes**.

Nuclear Properties

- **Atomic masses are denoted by the symbol u.**
- **1 u = 1.66054 × 10^{-27} kg = 931.49 MeV/c^2**

Table 12.1 Some Nucleon and Electron Properties

Particle	Symbol	Rest Energy (MeV)	Charge	Mass (u)	Spin	Magnetic Moment
Proton	p	938.272	$+e$	1.0072765	1/2	2.79 μ_N
Neutron	n	939.566	0	1.0086649	1/2	−1.91 μ_N
Electron	e	0.51100	$-e$	5.4858×10^{-4}	1/2	−1.00116 μ_B

- **Both neutrons and protons, collectively called nucleons, are constructed of other particles called *quarks*.**

1 proton plus 1 neutron = 2.0159414 u = mass of the nucleus of deutrium ???