1. Details of unit revision and its structure

Subject Name	Physics
Course Name	Physics 04 (Physics Part-2, Class XII)
Title	Revision Unit-08_Study Guide
Pre-requisites	Content of Unit 08: Atoms and Nuclei
Objectives	After going through this study guide, the learners will be able to: • How to consolidate the unit? • How to prepare notes?
Keywords	Atoms, Nucleus, atomic models

2. Development Team

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STUDY GUIDE

UNIT 8 Physics 04

Atoms and Nuclei

Chapter 12 Atoms

Alpha particle scattering experiment, Rutherford's model of atom, Bohr model, energy levels, hydrogen spectrum

Chapter 13 Nuclei

Composition and size of nucleus, radioactivity, alpha, beta and gamma particles/rays and their properties, radioactive decay laws

Mass energy relations, mass defect, binding energy per nucleon and its variation with mass number, nuclear fission and nuclear fusion

Before we start consolidating the unit let us ask and answer these.

- **Why did we do this unit? and**
- **What is its importance for the physics course?**

This unit forms the base for all study related to atom and its structure. Many arguments are placed saying, "so many new discoveries and advanced experimentation has led to a better and newer understanding using quantum mechanics **why should we study the old theories?"**

The most relevant answer is that starting with Rutherford's experiment, which led to realisation of the nucleus and its position in the atom. Bohr's proposal of orbital theory for a single electron atom (hydrogen) which explained that there was a possibility for the single electron in the hydrogen atom of acquiring energy from outside and changing its stationary state. Making us realise that both the radius of the electron orbit and, its velocity (kinetic energy) could change.

Electrons can only be in allowed energy states and the transition from one state to another involves gain or loss of energy by the atom.

The explanation of hydrogen emission spectrum and other ideas followed from it. Further researches involved wave particle duality. So though basic, this section of the course is very important.

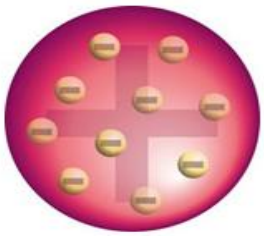
Study of nucleus, mass defect, binding energy and getting energy from it for useful purposes are ongoing research subjects and as such must be there for basic physics course. Radioactivity is a phenomenon that has made big contribution in the field of medicine. Knowledge of emission of alpha beta particles and gamma radiations from naturally occurring or artificially of radioactive isotopes is of great importance.

So gear yourself with positive thoughts and appreciate the unit.

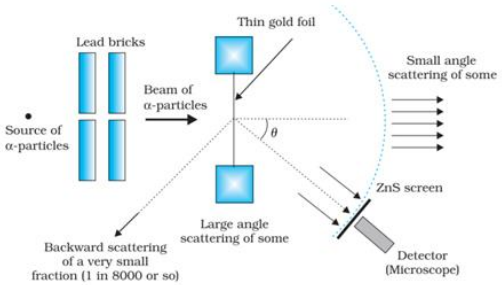
Since there are a lot of new ideas from recent researches including the famous CERN experiment, we will limit our study to the very basic, so that our appreciation of initial work is understood and we may apply these ideas to modern physics.

Study list:

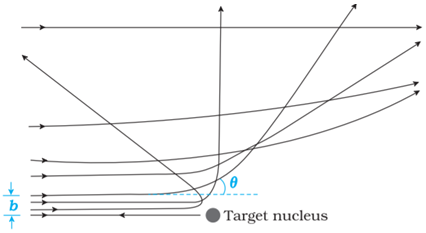
Following is the list of important topics to be read in this unit. Use the list and tick against each after completing it.



1. History of atomic models
2. Rutherford atomic model
3. Alpha particle scattering



a. Trajectory of alpha particle
b. Impact parameter
c. Angle of scattering
d. Distance of closest approach



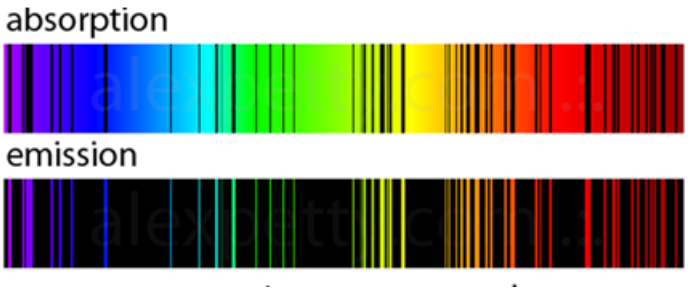
4. Result of Rutherford experiment
5. Limitations of the Rutherford model

6. The problem of explaining the spectrum

Atomic spectra

a. Emission spectrum

b. Absorption spectrum



c. Single electrum Hydrogen spectrum

7. Bohr model of hydrogen atom

a. Basic postulates

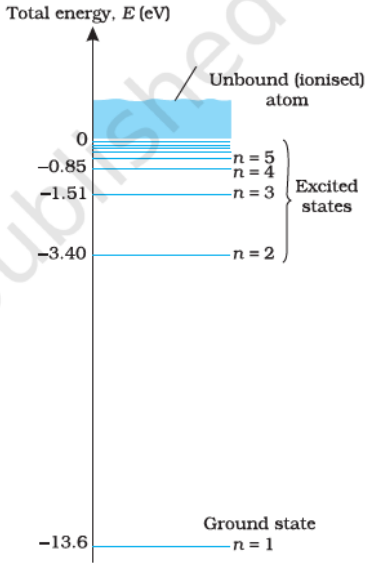
b. Velocity of electron

c. Frequency of the electron

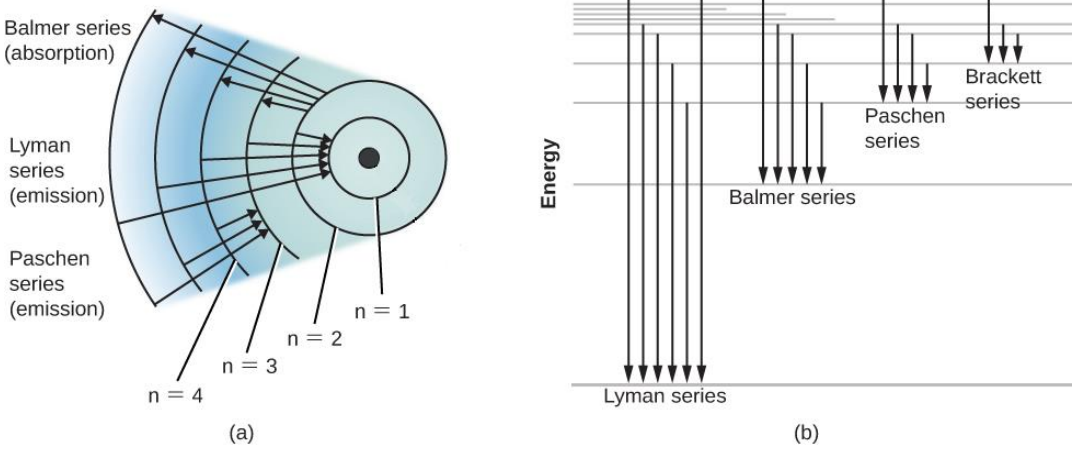
d. Size of the orbit

e. Energy of the orbiting electron

8. Energy levels in the atom



9. Explanation of Line spectra of hydrogen atom



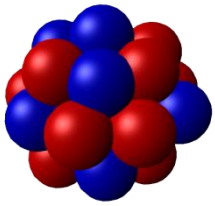
10. Quantization of angular momentum

11. Limitation of Bohr's model

12. Atomic masses

13. Composition of nucleus

a. Discovery of neutron
b. Isotopes
c. Isobars
d. Isotones

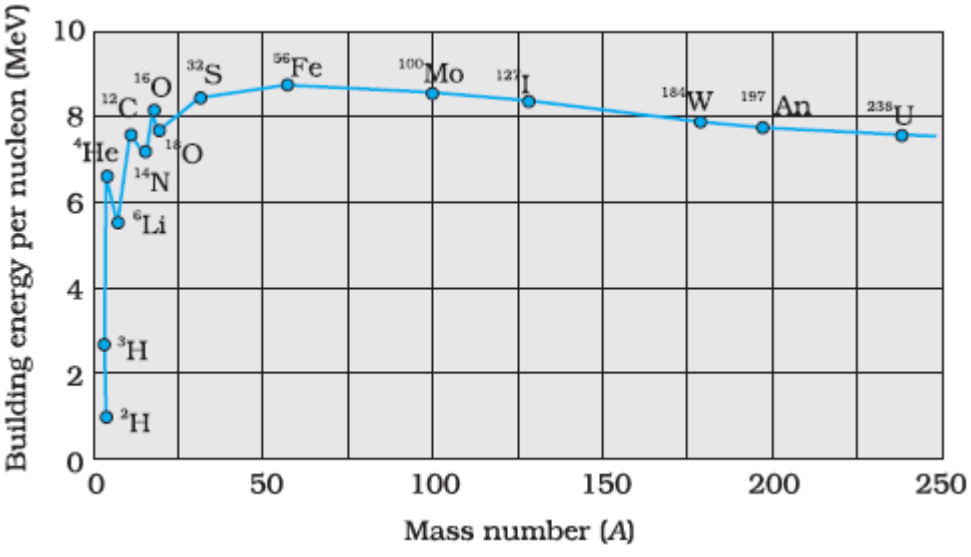


14. Size of the nucleus

15. Mass energy relation

16. Nuclear binding energy

a. Concept of binding energy and mass defect

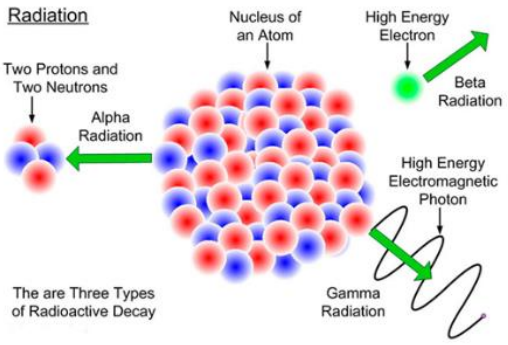


b. Binding energy per nucleon mass number curve

17. Nuclear force

18. Radioactivity

a. Laws of radioactive decay
b. Decay constant
c. Activity
d. Half life
e. Mean life



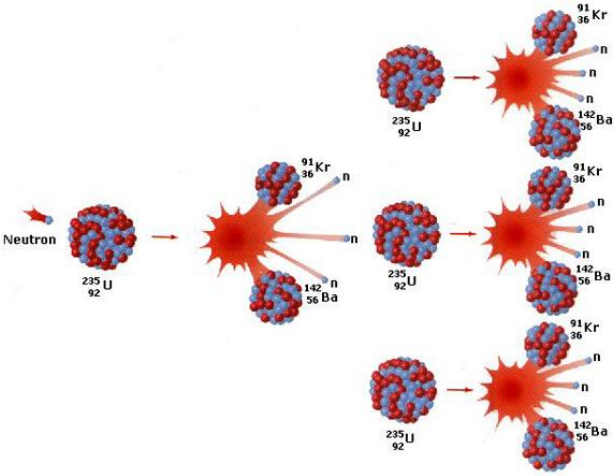
19. Alpha decay

20. Beta decay

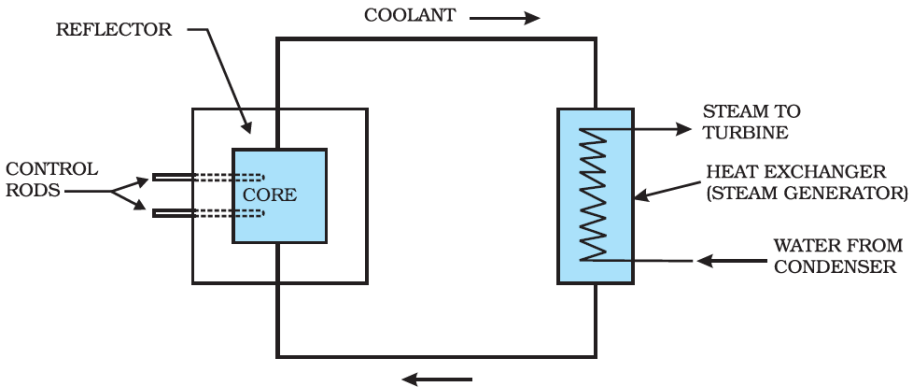
21. Gamma decay

22. Nuclear energy

a. Types of nuclear reaction
b. Nuclear fission



c. Nuclear reactors



i) Types of nuclear reactor
ii) Working of nuclear reactor

d. Nuclear fusion
i) Power generation in stars
ii) Controlled nuclear fusion
iii) Nuclear fuel

23. Nuclear holocaust

24. India's atomic energy programme

List of the derivations:

The following is the list of important derivations which are incorporated in the different modules of the unit after doing these derivations it will be easier for you to attempt the related problems and enhance your understanding of the topic.

So do all the derivations and tick against each after completing it.

1. Distance of closest approach
2. Radius of Bohr's stationary orbit
3. Velocity of electron in Bohr's orbit
4. Frequency of electron in Bohr's orbit
5. Total energy of electron in Bohr's orbit
6. Expression for Rydberg formula
7. Quantization of orbital momentum
8. Expression for binding energy
9. Derivation for disintegration constant

10. Expression for half-life of radioactive element
11. Expression for the average life of radioactive element

List of important formulae:

1. Number of alpha particle scattered per unit area

$$N(\theta) \propto \frac{1}{\sin^4(\theta/2)}$$

2. Impact parameter

$$b = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2 \cot\theta/2}{E}$$

Where θ is the angle of scattering

3. Angular momentum of electron

$$mvr = \frac{nh}{2\pi}$$

Where n is any positive integer

4. Radii of Bohr's stationary orbit

$$r = \frac{n^2h^2}{4\pi^2 mKe^2}$$

5. Velocity of electron in Bohr's orbit

$$v = \frac{2\pi Ke^2}{nh}$$

6. Frequency of electron in Bohr's orbit

$$\nu = \frac{KZe^2}{nhr}$$

7. Total energy of electron in Bohr's orbit

$$E = -\frac{2\pi^2 mK^2Z^2e^4}{n^2h^2}$$

$$or\ E = -\frac{13.6Z^2}{n^2}eV$$

For hydrogen atom Z=1

$$E = -\frac{13.6}{n^2}eV$$

8. Rydberg formula

$$\bar{\nu} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

9. 1 a.m.u. = 1.66×10^{-27} kg

10. 1 eV = 1.602×10^{-19} joule

11. 1 a.m.u. = 931 MeV

12. Nuclear size

$$R = R_0 A^{1/3}$$

Where $R_0 = 1.2 \times 10^{-15} m$

13. Packing fraction $= \frac{mass\ excess}{mass\ number} = \frac{M-A}{A}$

M is the actual weight of a nuclide

A is the mass number

14. Rate of disintegration

$$= -\frac{dN}{dt} = \lambda N$$

dN = a small number of atoms that disintegrate in small interval of time dt

λ = disintegration constant or decay constant

in exponential form $N = N_0 e^{-\lambda t}$

15. Half-life of radioactive element

$$T = \frac{0.6931}{\lambda}$$

16. Average life or mean life of radioactive element

$$\tau = \frac{T}{0.6931} = 1.44T$$

Where T is the half-life of a radioactive element

17. Alpha decay

$$^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He + Q$$

Where, $^{4}_{2}He$ is an alpha particle

Q is energy released in decay

18. Beta decay

$$^{A}_{Z}X \rightarrow {}_{Z+1}{}^{A}Y + {}^{0}_{-1}e + Q$$

Where, ${}_{-1}^{0}e$ is a beta particle

19. Gamma decay

$$ {}_{Z}^{A}X \rightarrow {}_{Z}^{A}X + \gamma $$

Where, γ denoted gamma ray

20. Nuclear reaction

$$ {}_{Z}^{A}X + {}_{2}^{4}He \rightarrow {}_{Z+1}^{A+3}Y + {}_{1}^{1}H + Q $$

Where, X is the target nucleus
Y is the product nucleus
${}_{1}^{1}H$ is the product particle
Q is the energy liberated

21. Nuclear fission

$$ {}_{92}^{235}U + {}_{0}^{1}n \rightarrow {}_{56}^{141}Ba + {}_{36}^{92}Kr + 3{}_{0}^{1}n + Q $$

This reaction shows the mechanism of single fission process
(${}_{92}^{235}U$ is bombarded with thermal neutrons, it splits up into ${}_{56}^{141}Ba$ and ${}_{36}^{92}Kr$ with the emission of 3 neutrons and 200 MeV energy per fission)

22. Units of Radioactivity:

a. Curie: it is defined as the activity of radioactive substance which gives 3.7×10^{10} disintegration/sec which is also equal to the radioactivity of 1g of pure radium.

b. Rutherford: it is defined as the activity of radioactive substance which gives rise to 10^{6} disintegration/second

c. Becquerel: in SI system the unit of radioactivity is Becquerel.
1 Becquerel = 1 disintegration/second

ALL THE BEST