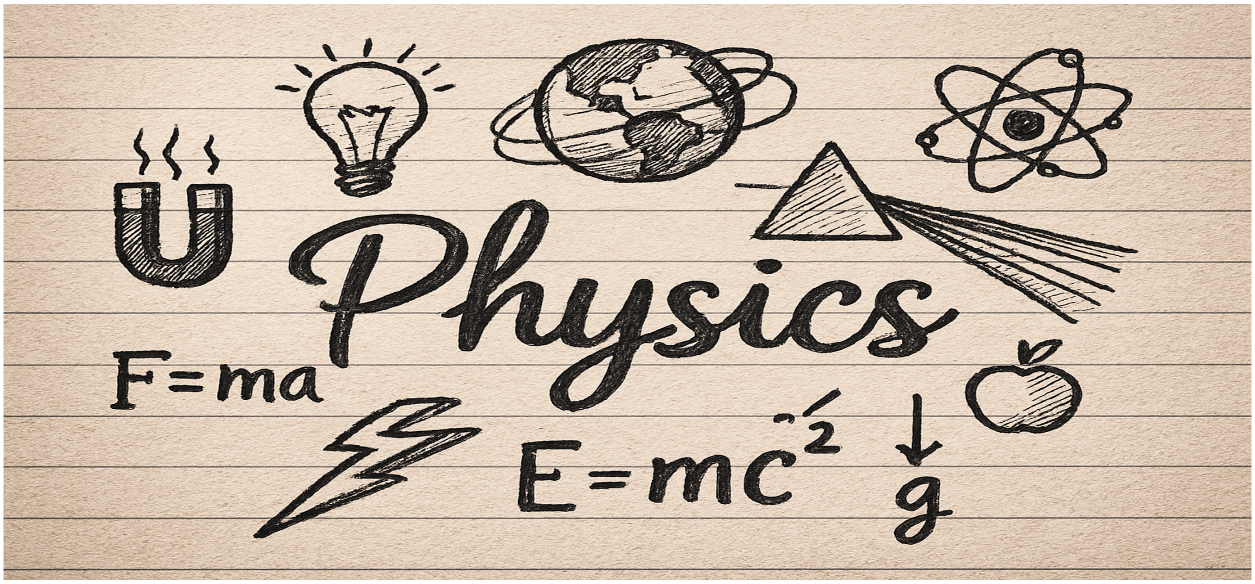


Class: 12th

Subject: Physics

Chapter 20: ATOMIC SPECTRA

🩸 Important MCQs (From Summary)

1. Atomic line spectrum is obtained when atomic gas or vapour is:

(a) At atmospheric pressure

(b) At high pressure

(c) At low pressure and excited by electric current ✅

(d) At very high temperature

2. The spectrum emitted by an excited atomic gas contains:

(a) All wavelengths

(b) Random wavelengths

(c) Certain specific wavelengths only ✅

(d) Only continuous wavelengths

3. According to Bohr's first postulate, an electron in a stationary orbit:

(a) Radiates energy continuously

(b) Absorbs energy

(c) Does not radiate energy ✅

(d) Loses mass

4. Bohr's angular momentum condition is given by:

(a) mvr = h

(b) mvr = n(h / 2π) ✅

(c) mvr = h²

(d) mvr = 2nh

5. A photon is emitted when an electron:

(a) Moves in circular orbit

(b) Gains energy

(c) Jumps from higher to lower energy level ✅

(d) Remains stationary

6. Transitions of electrons in light elements produce spectral lines in:

(a) X-ray region only

(b) Microwave region

(c) Infrared, visible or ultraviolet region ✅

(d) Gamma-ray region

7. X-rays produced due to inner shell transitions are called:

(a) Continuous X-rays

(b) Soft X-rays

(c) Characteristic X-rays ✅

(d) Gamma rays

8. Continuous X-rays are emitted:

(a) In fixed directions only

(b) With discrete wavelengths

(c) In all directions with continuous range of frequencies ✅

(d) Only by light atoms

9. LASER stands for:

(a) Light Absorption by Stimulated Emission of Radiation

(b) Light Amplified Source of Emission Radiation

(c) Light Amplification by Stimulated Emission of Radiation ✅

(d) Light Absorbed by Spontaneous Emission Radiation

10. Stimulated emission produces photons that are:

(a) Random in direction

(b) Different in phase

(c) Same direction and same phase as incident photon ✅

(d) Lower in energy

🩸 **Important MCQs:**

1. The branch of physics that deals with atomic spectra is called:

(a) Mechanics

(b) Optics

(c) Spectroscopy ✅

(d) Thermodynamics

2. Atomic spectra consist of:

(a) Continuous wavelengths

(b) Band wavelengths

(c) Discrete wavelengths ✅

(d) Random wavelengths

3. Black body radiation is an example of:

(a) Line spectrum

(b) Band spectrum

(c) Continuous spectrum ✅

(d) Absorption spectrum

4. Molecular spectra are classified as:

(a) Line spectra

(b) Band spectra ✅

(c) Continuous spectra

(d) X-ray spectra

5. Atomic line spectra are obtained when gas pressure is:

(a) High

(b) Atmospheric

(c) Very low ✅

(d) Extremely high

6. The Balmer series of hydrogen lies in the:

(a) Ultraviolet region

(b) Infrared region

(c) Visible region ✅

(d) X-ray region

7. The Balmer series was discovered in:

(a) 1896

(b) 1885 ✅

(c) 1913

(d) 1900

8. The mathematical expression of hydrogen spectrum was given by:

(a) Bohr

(b) Planck

(c) Rydberg ✅

(d) Einstein

9. The value of Rydberg constant is approximately:

(a) 1.097×10^6 m^{-1}

(b) $1.097 \times 10^7\ m^{-1}$ ✅

(c) $1.097 \times 10^8\ m^{-1}$

(d) $1.097 \times 10^5\ m^{-1}$

10. Lyman series belongs to the:

(a) Visible region

(b) Infrared region

(c) Ultraviolet region ✅

(d) Microwave region

11. According to Bohr's first postulate, an electron in stationary orbit:

(a) Radiates energy

(b) Absorbs energy

(c) Does not radiate energy ✅

(d) Loses energy continuously

12. Bohr's angular momentum is quantized as:

(a) mvr = nh

(b) mvr = n(h/2π) ✅

(c) mvr = h^2

(d) mvr = 2nh

13. The principal quantum number is represented by:

(a) l

(b) m

(c) s

(d) n ✅

14. Emission of photon occurs when electron:

(a) Gains energy

(b) Remains stationary

(c) Jumps to lower energy level ✅

(d) Revolves faster

15. Energy of emitted photon is given by:

(a) $E = mc^2$

(b) $E = mv^2$

(c) $E = hf$ ✅

(d) $E = h/\lambda^2$

16. The radius of nth Bohr orbit is proportional to:

(a) n

(b) n^2 ✅

(c) 1/n

(d) $1/n^2$

17. The radius of first Bohr orbit is approximately:

(a) 5.3×10^{-10} m

(b) 5.3×10^{-11} m ✅

(c) 5.3×10^{-12} m

(d) 0.53 m

18. The energy of electron in hydrogen atom varies as:

(a) n

(b) n^2

(c) $1/n^2$ ✅

(d) 1/n

19. The minimum energy required to remove electron from ground state is called:

(a) Excitation energy

(b) Kinetic energy

(c) Ionization energy ✅

(d) Potential energy

20. Ground state of hydrogen atom corresponds to:

(a) n = 0

(b) n = 1 ✅

(c) n = 2

(d) n = 3

21. Inner shell electron transitions in heavy atoms produce:

(a) Infrared rays

(b) Visible light

(c) Ultraviolet rays

(d) X-rays ✅

22. In heavy atoms, the shell closest to the nucleus is called:

(a) L-shell

(b) M-shell

(c) K-shell ✅

(d) N-shell

23. Characteristic X-rays are produced due to:

(a) Outer shell transitions

(b) Nuclear reactions

(c) Inner shell electron transitions ✅

(d) Molecular vibrations

24. Characteristic X-rays are called so because their energy depends on:

(a) Accelerating voltage only

(b) Temperature of filament

(c) Target material ✅

(d) Size of X-ray tube

25. In an X-ray tube, electrons are produced by:

(a) Anode

(b) Heated cathode ✅

(c) Target

(d) Cooling oil

26. The kinetic energy of electrons striking the target in X-ray tube is given by:

(a) K.E. = h f

(b) K.E. = mv^2

(c) K.E. = Ve ✅

(d) K.E. = e/V

27. Kα X-rays are produced when an electron jumps from:

(a) M-shell to L-shell

(b) L-shell to K-shell ✅

(c) N-shell to M-shell

(d) K-shell to L-shell

28. Continuous X-ray spectrum is produced due to:

(a) Inner shell transitions

(b) Outer shell transitions

(c) Bremsstrahlung (braking radiation) ✅

(d) Atomic excitation

29. Bremsstrahlung radiation is produced when electrons are:

(a) Accelerated uniformly

(b) Absorbed by nucleus

(c) Suddenly decelerated by target ✅

(d) Reflected by target

30. Bones appear lighter than flesh in X-ray photographs because bones:

(a) Transmit more X-rays

(b) Contain light elements

(c) Absorb more X-rays due to high atomic number ✅

(d) Reflect X-rays

31. Heisenberg uncertainty principle is related to the uncertainty in simultaneous measurement of:

(a) Energy and time

(b) Mass and velocity

(c) Position and momentum ✅

(d) Charge and mass

32. The uncertainty principle is most significant in the:

(a) Macroscopic world

(b) Astronomical scale

(c) Atomic scale ✅

(d) Classical mechanics

33. The mathematical form of uncertainty principle is:

(a) $\Delta p \, \Delta x = h$

(b) $\Delta p \, \Delta x \geq h / (2\pi)$ ✅

(c) $\Delta p / \Delta x = h$

(d) $\Delta x / \Delta p = h$

34. An electron cannot exist inside the nucleus because its required speed would be:

(a) Very small

(b) Equal to sound speed

(c) Less than light speed

(d) Greater than speed of light ✅

35. The typical diameter of a nucleus is of the order of:

(a) 10^{-10} m

(b) 10^{-14} m ✅

(c) 10^{-6} m

(d) 10^{-2} m

36. According to uncertainty principle, an electron can exist inside the atom because its calculated speed is:

(a) Greater than speed of light

(b) Equal to speed of light

(c) Less than speed of light ✅

(d) Zero

37. The radius of hydrogen atom is approximately:

(a) 10^{-14} m

(b) 5×10^{-11} m ✅

(c) 10^{-8} m

(d) 10^{-6} m

38. LASER stands for:

(a) Light Amplified Source of Emission Radiation

(b) Light Absorption by Stimulated Emission of Radiation

(c) Light Amplification by Stimulated Emission of Radiation ✅

(d) Light Absorbed by Spontaneous Emission Radiation

39. Laser light is:

(a) Polychromatic and divergent

(b) Non-coherent

(c) Monochromatic, coherent and unidirectional ✅

(d) Random in direction

40. Spontaneous emission occurs when an excited atom:

(a) Absorbs photon

(b) Emits photon in fixed direction

(c) Emits photon in random direction ✅

(d) Remains stable

41. Stimulated emission produces photons that are:

(a) Random in phase

(b) Different in direction

(c) Same phase and same direction ✅

(d) Lower in energy

42. Population inversion means:

(a) More atoms in ground state

(b) Equal atoms in all states

(c) More atoms in excited state than ground state ✅

(d) No atoms in excited state

43. Population inversion is necessary for:

(a) X-ray production

(b) Photoelectric effect

(c) Laser action ✅

(d) Nuclear fission

44. A metastable state is an excited state in which an electron:

(a) Falls immediately

(b) Is completely stable

(c) Remains for relatively longer time ✅

(d) Cannot emit radiation

45. In a laser, mirrors are used to:

(a) Absorb photons

(b) Reduce intensity

(c) Confine photons for amplification ✅

(d) Change wavelength

46. In He-Ne laser, the active (lasing) medium is:

(a) Helium

(b) Neon ✅

(c) Argon

(d) Hydrogen

47. The wavelength of light produced by He-Ne laser is approximately:

(a) 486 nm

(b) 400 nm

(c) 632.8 nm ✅

(d) 750 nm

48. In He-Ne laser, population inversion in neon is achieved by:

(a) Heating neon gas

(b) Magnetic field

(c) Collisions with excited helium atoms ✅

(d) Ultraviolet radiation

49. Lasers are used in medicine mainly because they are:

(a) Cheap

(b) Wide beam

(c) Highly focused and intense ✅

(d) Low energy

50. The process of producing three-dimensional images using laser is called:

(a) Diffraction

(b) Interference

(c) Holography ✅

(d) Polarization

🩸 Important Short Questions (From Summary)

1. What is an atomic line spectrum?

Answer:

👉 An atomic line spectrum is a spectrum that contains only specific wavelengths emitted by an excited atomic gas at low pressure.

2. What are stationary states in Bohr's model?

Answer:

👉 Stationary states are fixed circular orbits in which an electron moves around the nucleus without radiating energy.

3. What is Bohr's angular momentum condition?

Answer:

👉 According to Bohr, only those orbits are allowed for which the angular momentum of the electron is quantized as $mvr = n(h / 2\pi)$.

4. When is a photon emitted by an electron in an atom?

Answer:

👉 A photon is emitted when an electron jumps from a higher energy level to a lower energy level.

5. Why does an atomic spectrum contain only specific wavelengths?

Answer:

👉 Because electrons can make transitions only between definite energy levels.

6. In which regions do light elements produce spectral lines?

Answer:

👉 Light elements produce spectral lines in the infrared, visible, and ultraviolet regions.

7. What are characteristic X-rays?

Answer:

👉 Characteristic X-rays are X-rays emitted due to inner shell electron transitions, and their energy depends on the target material.

8. What are continuous X-rays?

Answer:

👉 Continuous X-rays are X-rays emitted in all directions with a continuous range of frequencies.

9. What is stimulated absorption?

Answer:

👉 Stimulated absorption is the process in which an atom absorbs an incident photon and moves from the ground state to an excited state.

10. What is stimulated emission?

Answer:

👉 Stimulated emission is the process in which an incident photon induces an excited atom to emit another photon in the same direction and phase.

🩸 Important Short Questions:

1. What is spectroscopy?

Answer:

👉 Spectroscopy is the branch of physics that studies the wavelengths and intensities of electromagnetic radiation emitted or absorbed by atoms.

2. Name the three types of spectra.

Answer:

👉 (i) Continuous spectra, (ii) Band spectra, (iii) Discrete or line spectra.

3. What is an atomic line spectrum?

Answer:

👉 It is a spectrum containing specific wavelengths emitted by atoms of a gas or vapour at low pressure.

4. Who discovered the Balmer series and in which year?

Answer:

👉 J.J. Balmer discovered the Balmer series in 1885.

5. State the first postulate of Bohr's model.

Answer:

👉 An electron moves in certain circular orbits around the nucleus without radiating energy; these orbits are called stationary states.

6. State Bohr's second postulate.

Answer:

👉 Only those orbits are allowed for which the electron's angular momentum is quantized as $mvr = n(h/2\pi)$.

7. State Bohr's third postulate.

Answer:

👉 When an electron jumps from a higher to a lower energy level, it emits a photon of energy $hf = E_{high} - E_{low}$.

8. What is the ground state of an atom?

Answer:

👉 The lowest energy state of an atom, corresponding to $n = 1$, is called the ground state.

9. What is the excitation potential?

Answer:

👉 It is the minimum potential through which an external electron must be accelerated to excite an atom from its ground state to a higher state.

10. Give the Rydberg formula for hydrogen spectrum.

Answer:

👉 $1/\lambda = R_H (1/p^2 - 1/n^2)$, where $p < n$, and R_H is the Rydberg constant.

11. What are characteristic X-rays?

Answer:

👉 X-rays emitted due to transitions of inner shell electrons in heavy atoms. Their energy depends on the type of target material.

12. What is bremsstrahlung or braking radiation?

Answer:

👉 Radiation emitted when fast-moving electrons are suddenly decelerated upon hitting a target, producing a continuous X-ray spectrum.

13. How are X-rays produced in an X-ray tube?

Answer:

👉 Electrons emitted by a heated cathode are accelerated towards the anode. Collisions with the target produce X-rays by inner shell transitions and deceleration.

14. What is the difference between continuous and characteristic X-rays?

Answer:

- 👉 **Continuous X-rays:** emitted in all directions with a range of energies.
- 👉 **Characteristic X-rays:** emitted in discrete energies specific to the target material.

15. Name one medical application of X-rays.

Answer:

👉 X-rays are used to visualize fractured bones, detect tumors, and in CAT-Scanners for imaging internal structures.

16. What is Heisenberg's Uncertainty Principle?

Answer:

👉 It states that there is a fundamental limit to the accuracy of simultaneously measuring the position and momentum of a particle, given by $\Delta p \, \Delta x \geq h/(2\pi)$.

17. Why can an electron not exist inside the nucleus?

Answer:

👉 To be confined in a nucleus, the electron's speed would have to exceed the speed of light, which is impossible.

18. Can an electron exist in the atom outside the nucleus? Explain.

Answer:

👉 Yes, using the uncertainty principle, the electron's speed in the atom is less than the speed of light, so it can exist outside the nucleus.

19. What does LASER stand for?

Answer:

👉 LASER stands for Light Amplification by Stimulated Emission of Radiation.

20. What is stimulated or induced absorption?

Answer:

👉 When an incident photon is absorbed by an atom in the ground state, raising it to an excited state, it is called stimulated or induced absorption.

21. Define spontaneous emission.

Answer:

👉 Emission of a photon in any arbitrary direction by an atom in an excited state is called spontaneous emission.

22. Define stimulated or induced emission.

Answer:

👉 Emission of a photon in the direction of the incident photon by an excited atom, producing a coherent and amplified beam, is called stimulated emission.

23. What is population inversion?

Answer:

👉 It is a condition where more atoms exist in a higher energy metastable state than in the lower energy ground state, essential for laser action.

24. Describe the working of a Helium-Neon laser.

Answer:

👉 Helium atoms are excited by high-voltage discharge. Excited helium atoms collide with neon atoms, transferring energy to excite them. Stimulated emission from neon produces a red laser beam of wavelength 632.8 nm.

25. Name three applications of lasers in medicine and industry.

Answer:

👉 (1) Welding detached retinas, (2) Destroying cancerous cells, (3) Drilling tiny holes in metals or hard materials.

🩸 Important long questions:

🌟 Q.1: Explain Bohr's Model of Hydrogen Atom. Describe its postulates, quantized orbits, and energies.

❖ Explain Bohr's Model of Hydrogen Atom

In 1913, Niels Bohr proposed a theoretical model of the hydrogen atom to explain the stability of atoms and the discrete line spectrum of hydrogen. Bohr combined classical mechanics with Planck's quantum theory. His model successfully explained atomic spectra and the quantized nature of atomic energy.

✦ Postulates of Bohr's Model

Postulate I: Stationary Orbits

An electron revolves around the nucleus in certain fixed circular orbits without emitting any radiation.

These permitted orbits are called stationary states or energy levels.

➡️ While moving in a stationary orbit, the energy of the electron remains constant.

Postulate II: Quantization of Angular Momentum

Only those orbits are allowed in which the angular momentum of the electron is quantized.

The condition is:

$m v r = n h / (2\pi)$

where:

m = mass of electron

v = velocity of electron

r = radius of orbit

h = Planck’s constant

n = 1, 2, 3, … (principal quantum number)

➡️ This means the electron cannot have arbitrary motion; only specific orbits are allowed.

Postulate III: Emission and Absorption of Radiation

Radiation is emitted or absorbed only when an electron jumps from one energy level to another.

If an electron jumps from a higher energy level En to a lower energy level Em, a photon is emitted:

$hf = E_n - E_m$

where:

h = Planck’s constant

f = frequency of emitted radiation

➡️ **This explains** the line spectrum of hydrogen.

Derivation of Radius of Bohr Orbits

For an electron to move in a circular orbit, the centripetal force is provided by electrostatic (Coulomb) force.

Centripetal force: $m v^2 / r$

Electrostatic force: $k e^2 / r^2$

Equating both forces:

$m v^2 / r = k e^2 / r^2$

From Postulate II: $v = n h / (2\pi m r)$

Substituting and simplifying, the radius of the nth orbit is:

$r_n = n^2 r_1$

where: $r_1 = 5.3 \times 10^{-11}$ m (radius of first Bohr orbit)

➡️ **Hence**, radii of allowed orbits are quantized: r_1, $4r_1$, $9r_1$, $16r_1$, …

Allowed Energy Levels of Electron

The total energy of an electron is the sum of kinetic energy and potential energy.

After substitution and simplification, the energy of the nth orbit is:

$E_n = -13.6 \text{ eV} / n^2$

For example:

$n = 1 \rightarrow E_1 = -13.6$ eV

$n = 2 \rightarrow E_2 = -3.4$ eV

$n = 3 \rightarrow E_3 = -1.51$ eV

➡️ Negative sign shows that the electron is **bound to the nucleus.**

Ground State and Excited State

Ground State:

- The lowest energy state of the atom ($n = 1$).
- The atom is most stable in this state.

Excited State:

- When an electron absorbs energy and moves to a higher orbit ($n > 1$), the atom is said to be excited.

Ionization Energy

- Ionization energy is the minimum energy required to completely remove an electron from the ground state of an atom.
- For hydrogen atom: Ionization energy = 13.6 eV

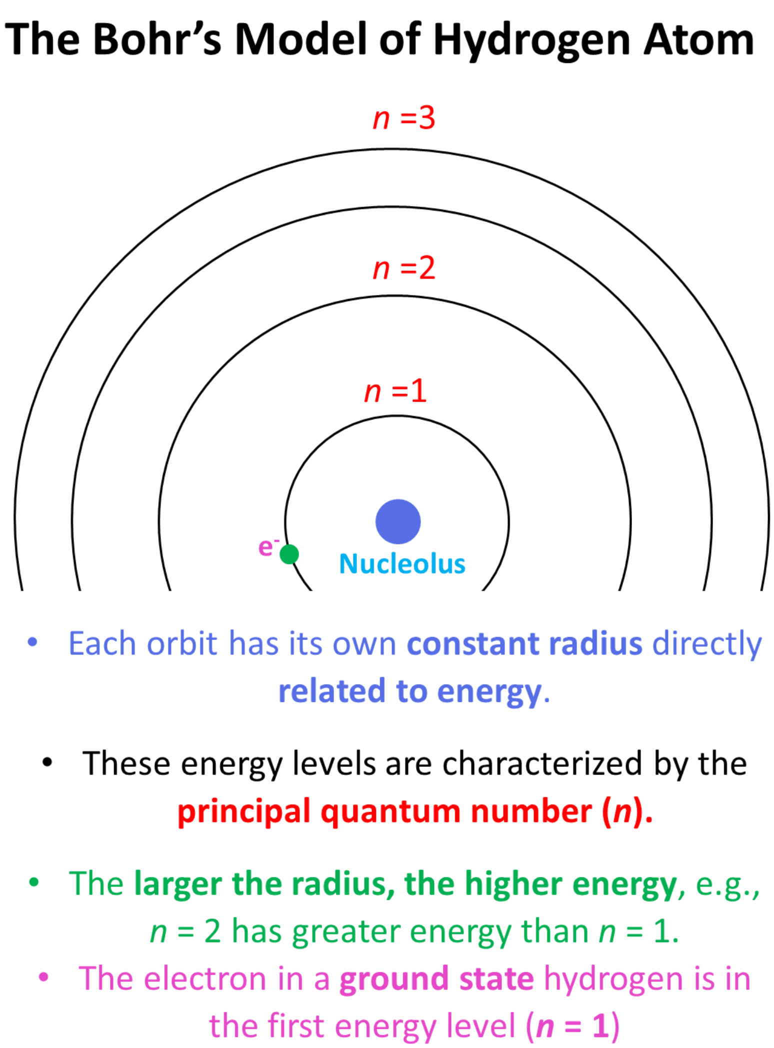
➡️ It corresponds to moving the electron from $n = 1$ to $n = \infty$.

Excitation Potential

Excitation potential is the minimum potential difference required to raise an electron from the ground state to a higher energy state without removing it from the atom.

➡️ It is always less than ionization potential.

✦ **Digram:**



✦ **Summary:**

Bohr's model explains the structure of the hydrogen atom using three main postulates. It introduces the idea of quantized orbits, where electrons revolve without radiating energy. Radiation is emitted only during transitions between energy levels. The model successfully explains atomic stability, hydrogen line spectrum, quantized radii, and discrete energy levels. Although it applies mainly to hydrogen-like atoms, it played a crucial role in the development of modern atomic physics.

🌟 **Q.2. Describe the Hydrogen Atomic Spectra. Explain the Lyman, Balmer, and Paschen series.**

Atomic Spectra

- When an atomic gas or vapour at low pressure is excited (usually by passing an electric current through it), the atoms emit electromagnetic radiation. This emitted radiation does not contain all wavelengths; instead, it consists of certain definite wavelengths only.
- This pattern of emitted wavelengths is called the atomic spectrum.

- **Since the spectrum consists of sharp,** discrete lines, it is also known as a line spectrum. Each element has its own unique atomic spectrum, which acts like a fingerprint for identifying that element.

Spectral Series

- The spectral lines of hydrogen are not random. They follow definite regular patterns and are grouped into sets called spectral series.
- Each series corresponds to electronic transitions ending at a particular lower energy level.

Rydberg Formula

The wavelengths of hydrogen spectral lines are given by the Rydberg formula:

$1/\lambda = R\,(1/p^2 - 1/n^2)$

where:

λ = wavelength of emitted radiation

R = Rydberg constant = $1.097 \times 10^7\ m^{-1}$

p = lower energy level (fixed for a series)

n = higher energy level (n > p)

➡️ This formula successfully explains all hydrogen spectral series.

Hydrogen Spectral Series

1. Lyman Series

- Occurs when an electron falls to the first energy level (p = 1)
- **Higher levels**: n = 2, 3, 4, ...
- **Region of spectrum:** Ultraviolet (UV)
- **Condition**: p = 1, n = 2, 3, 4, ...

➡️ These lines have short wavelengths and high energy.

2. Balmer Series

- Occurs when an electron falls to the second energy level (p = 2)
- **Higher levels:** n = 3, 4, 5, ...
- **Region of spectrum:** Visible light

Condition: p = 2, n = 3, 4, 5, ...

➡️ This is the only hydrogen series visible to the human eye.

3. Paschen Series

- Occurs when an electron falls to the third energy level (p = 3)
- **Higher levels:** n = 4, 5, 6, ...
- **Region of spectrum:** Infrared (IR)
- **Condition**: p = 3, n = 4, 5, 6, ...

➡️ These lines have longer wavelengths and lower energy.

Example: Calculation of Wavelength (Balmer Series)

Find the wavelength of radiation emitted when an electron in hydrogen jumps from n = 3 to n = 2.

Given: $R = 1.097 \times 10^7\ m^{-1}$

$p = 2$

$n = 3$

Using Rydberg formula:

$1/\lambda = R\ (1/2^2 - 1/3^2)$

$1/\lambda = 1.097 \times 10^7\ (1/4 - 1/9)$

$1/\lambda = 1.097 \times 10^7\ (5/36)$

$1/\lambda = 1.524 \times 10^6\ m^{-1}$

$\lambda = 6.56 \times 10^{-7}\ m$

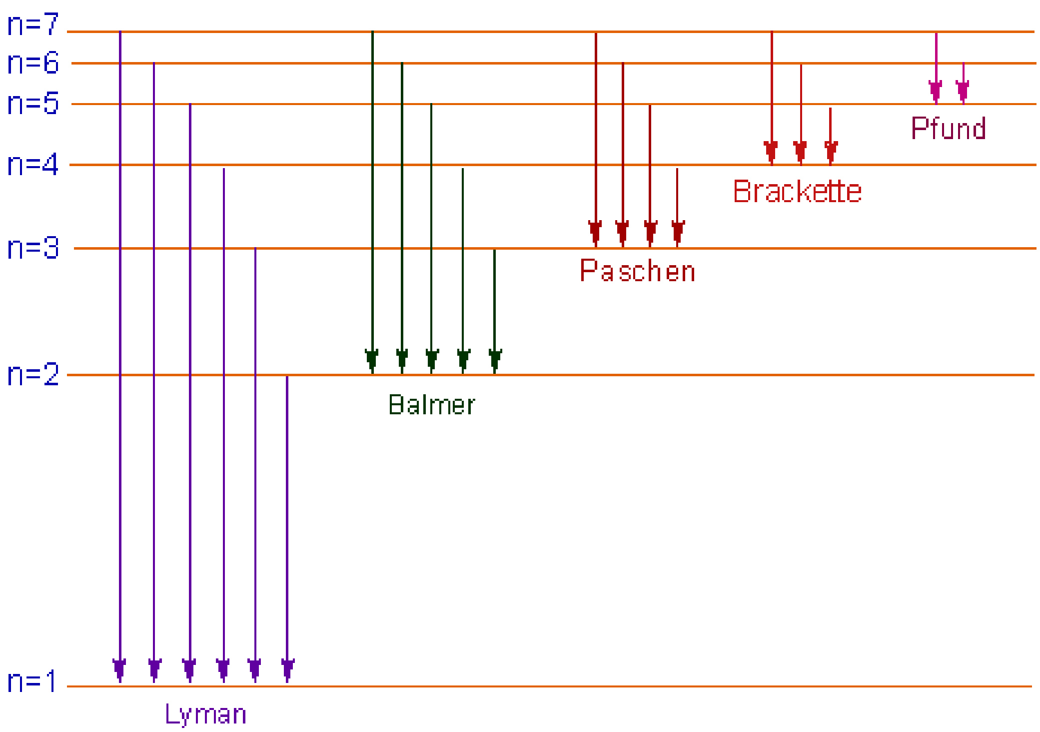
$\lambda = 656\ nm$

➡️ This wavelength lies in the red region of the visible spectrum, confirming it belongs to the Balmer series.

Importance of Hydrogen Spectrum

- Confirms the existence of quantized energy levels
- Strong evidence in support of Bohr's atomic model
- Helps in identifying elements in stars and gases
- Forms the foundation of modern atomic physics

✦ **Digram:**



✦ Summary:

The hydrogen atomic spectrum consists of discrete spectral lines produced due to electronic transitions between quantized energy levels. These lines are grouped into spectral series such as Lyman (ultraviolet), Balmer (visible), and Paschen (infrared). The wavelengths of all these lines are accurately explained by the Rydberg formula. The study of hydrogen spectra provided strong experimental support for Bohr's theory and helped in understanding atomic structure.

🌟 Q.3: Explain Inner Shell Transitions and Characteristic X-Rays. Include continuous X-ray spectrum and their uses.

Inner Shell Transitions

- **In heavy atoms,** electrons are arranged in concentric shells known as K, L, M, N, … shells, where the **K-shell** is closest to the nucleus.
- **Electrons** in the **inner shells** are strongly bound to the **nucleus** and require a large amount of energy to be removed.
- **When a fast moving,** high-energy electron strikes a heavy target atom (such as tungsten), it can knock out an electron from an inner shell (K or L shell). This creates a vacancy (hole) in that shell.
- **To restore stability**, an electron from a higher shell jumps down to fill this vacancy. During this transition, a high-energy photon is emitted.

Characteristic X-Rays

- The X-rays emitted due to these inner shell transitions are called characteristic X-rays.

Reason for the name

👉 Their energies and wavelengths depend on the type of target element, not on the accelerating voltage.

Examples

- **Kα X-ray:** Electron jumps from L shell to K shell
- **Kβ X-ray:** Electron jumps from M shell to K shell

Energy of emitted photon is given by:

$hf = E_1 - E_2$

where

E_1 = energy of higher shell

E_2 = energy of lower shell

Characteristic X-rays appear as sharp discrete lines superimposed on a continuous background.

Production of X-Rays (X-Ray Tube)

An X-ray tube consists of:

- Heated cathode (emits electrons)
- High potential difference V
- Heavy metal target (tungsten)
- High vacuum

Electrons emitted from the cathode are accelerated towards the target. Their kinetic energy is:

K.E. = eV

When these electrons strike the target:

1. Inner shell electrons may be ejected $\longrightarrow$ Characteristic X-rays

2. Electrons may slow down ⟶ Continuous X-rays

Continuous X-Ray Spectrum (Bremsstrahlung)

The continuous X-ray spectrum is produced due to bremsstrahlung, meaning braking radiation.

When fast electrons strike the target, they are suddenly decelerated due to strong electric fields near the nuclei of target atoms.

Since accelerating or decelerating charges emit radiation, X-rays are produced.

- Some electrons lose all their kinetic energy in one collision
- K.E. = hf
- Others lose energy gradually, producing photons of different energies

👉 This results in a continuous range of wavelengths.

✦ Difference Between Characteristic and Continuous X-Rays

- Characteristic X-rays $\longrightarrow$ Discrete lines, element-dependent
- Continuous X-rays $\longrightarrow$ Continuous spectrum, voltage-dependent

Properties and Uses of X-Rays

Medical Uses

- Detection of fractured bones
- Dental imaging
- Cancer treatment (radiotherapy)
- CAT-scan for detailed internal imaging

Industrial Uses

- Detecting cracks in metal structures
- Quality control in welding
- Thickness measurement of materials

Scientific Uses

- Study of crystal structure (X-ray diffraction)

- Identification of elements
- Research in atomic physics
- Biological Effects of X-Rays
- X-rays can damage living tissues
- They break molecular bonds and create free radicals
- Excessive exposure may cause cancer or genetic mutations

Therefore, protective measures are essential

✦ **Summary:**

When high-energy electrons strike a heavy target, inner shell electrons may be ejected. The filling of these vacancies by outer electrons produces characteristic X-rays, which have discrete wavelengths depending on the target material. In addition, the deceleration of electrons produces a continuous X-ray spectrum called bremsstrahlung. X-rays have wide applications in medicine, industry, and scientific research but can be harmful if not properly controlled.

🌟 **Q.4: Explain the Heisenberg Uncertainty Principle and its significance in atoms.**

Heisenberg Uncertainty Principle

The Heisenberg Uncertainty Principle, proposed by Werner Heisenberg in 1927, states that it is impossible to simultaneously measure the exact position and exact momentum of a particle with complete accuracy.

This principle is fundamental in quantum mechanics and applies to very small particles such as electrons, protons, and neutrons.

Mathematical Statement

The uncertainty principle is given by:

$\Delta x \cdot \Delta p \geq h / 4\pi$

where:

Δx = uncertainty in position

Δp = uncertainty in momentum

h = Planck’s constant

Momentum is:

$p = m v$

So:

$\Delta x \cdot \Delta v \geq h / (4\pi m)$

This shows that if the position of a particle is measured more accurately, its momentum becomes more uncertain, and vice versa.

Physical Explanation

To observe an electron, radiation (like light) must interact with it.

If short-wavelength radiation is used to locate the electron precisely, it has high energy, which disturbs the electron's motion and changes its momentum.

Thus:

- Precise position → large uncertainty in momentum
- Precise momentum → large uncertainty in position

This uncertainty is not due to instrument limitations, but is a natural property of matter.

Significance of the Uncertainty Principle

1. Non-existence of Fixed Orbits

According to classical physics, electrons move in fixed circular orbits around the nucleus.

However, if an electron had a fixed orbit:

- Its position would be known exactly
- Its momentum would also be known exactly

This would violate the uncertainty principle.

👉 **Therefore**, electrons do not move in fixed orbits, but exist in probability regions (orbitals).

2. Stability of Atoms

If the uncertainty principle did not exist, electrons would spiral into the nucleus due to electrostatic attraction.

Because of uncertainty:

- Electron cannot be confined to the nucleus
- Minimum kinetic energy is always present
- This prevents atomic collapse and ensures atomic stability.

3. Wave Nature of Matter

- The uncertainty principle supports de Broglie's wave nature of matter.

For very small particles like electrons:

- Wave effects are significant
- Uncertainty becomes important

For large objects (balls, cars):

- Mass is large
- Uncertainty is negligible

Hence, classical mechanics works for macroscopic objects.

4. Electron Cloud Model

Electrons are described by probability distributions rather than exact paths.

This led to:

- Quantum mechanical model of atom
- Electron clouds instead of orbits

5. Zero-Point Energy

Even at absolute zero temperature:

- Particles cannot be completely at rest
- They possess minimum kinetic energy
- This is due to the uncertainty principle.

Limitations in Classical Physics

The uncertainty principle shows the failure of classical mechanics at atomic and subatomic scales.

Classical laws are only valid for macroscopic objects.

✦ **Summary:**

The Heisenberg Uncertainty Principle states that the exact position and momentum of a particle cannot be measured simultaneously. This principle explains why electrons do not move in fixed orbits and why atoms are stable. It plays a fundamental role in quantum mechanics, supports the wave nature of matter, and replaces classical ideas with probability-based descriptions of atomic behavior.

🌟 **Q.5: Describe the principle, working, and applications of a LASER.**

Definition of LASER:

- LASER stands for Light Amplification by Stimulated Emission of Radiation.
- A LASER is a device that produces a highly intense, monochromatic, coherent, and unidirectional beam of light.

Principle of LASER

- The working principle of a LASER is based on stimulated emission of radiation.
- When an atom in an excited state (E2) is struck by an incident photon having energy equal to the energy difference between two levels, the atom is forced to return to the lower energy state (E1) by emitting a second photon.

The emitted photon:

- Has the same energy
- Moves in the same direction
- Has the same phase
- Has the same frequency

Thus, light gets amplified.

Energy relation: $hf = E2 - E1$

Basic Components of a LASER

A LASER consists of the following three essential parts:

1. Active Medium

- The material in which laser action occurs.

Examples: ruby crystal, helium-neon gas, semiconductor crystal.

2. Pumping Source

- Supplies energy to excite atoms from lower to higher energy levels.

Examples: electric discharge, flash lamp.

3. Optical Resonator

Consists of two parallel mirrors:

- One fully reflecting mirror
- One partially reflecting mirror
- These mirrors cause multiple reflections and amplification of light.

Working of a LASER

Step 1: Excitation (Pumping)

- Energy is supplied to the active medium using a pumping source.
- Atoms absorb energy and move from ground state (E1) to excited state (E2).

Step 2: Population Inversion

- More atoms accumulate in the excited state than in the ground state.
- This condition is called population inversion, which is essential for laser action.

Step 3: Stimulated Emission

- An incident photon causes excited atoms to emit identical photons.
- Each stimulated emission produces two photons, doubling the intensity.

Step 4: Amplification

- Photons reflect back and forth between mirrors, producing more stimulated emissions.
- Light intensity increases rapidly.

Step 5: Laser Beam Output

The partially reflecting mirror allows a narrow, intense beam of coherent light to escape as a laser beam.

Characteristics of Laser Light

Laser light has the following special properties:

1. Monochromatic – single wavelength
2. Coherent – waves are in phase
3. Highly Directional – travels in a straight line

4. Very Intense – high energy concentration

Applications of LASER

1. Medical Field

- Eye surgery (LASIK)
- Removal of kidney stones
- Bloodless surgeries

2. Industrial Uses

- Cutting and welding of metals
- Drilling hard materials
- Precision manufacturing

3. Communication

- Optical fiber communication
- High-speed data transmission

4. Scientific Research

- Spectroscopy

- Holography
- Measurement of very small distances

5. Everyday Uses

- Barcode scanners
- Laser printers
- CD and DVD players

6. Military Uses

- Range finding
- Missile guidance
- Target designation

✦ **Summary:**

A LASER works on the principle of stimulated emission of radiation. It consists of an active medium, a pumping source, and an optical resonator. Due to population inversion and repeated stimulated emission, laser light becomes highly amplified, coherent, monochromatic, and directional. LASERS have wide applications in medicine, industry, communication, science, and daily life.

🩸 Exercise Questions:

🌟 20.1 Bohr's theory of hydrogen atom is based upon several assumptions. Do any of these assumptions contradict classical physics?

❖ Answer:

Yes, some assumptions of Bohr's theory of the hydrogen atom clearly contradict classical physics, while others are consistent with it.

Assumptions that Contradict Classical Physics

1. Non-radiating Orbits

According to Bohr's first postulate, an electron moves in certain fixed circular orbits around the nucleus without emitting radiation.

👉 Contradiction:

Classical electromagnetic theory states that any accelerating charge must radiate energy. Since an electron moving in a circular path is continuously accelerating, it should lose energy and spiral into the nucleus. Bohr's assumption directly contradicts this classical prediction.

2. Quantization of Angular Momentum

Bohr assumed that the angular momentum of an electron is quantized:

$$mvr = n h / 2\pi$$

👉 **Contradiction:**

In classical physics, angular momentum can have any continuous value. There is no restriction to discrete values. Thus, the idea of quantized angular momentum is not supported by classical mechanics.

Assumptions Consistent with Classical Physics

3. Emission and Absorption of Radiation

Bohr assumed that radiation is emitted or absorbed when an electron jumps between energy levels, according to:

$hf = E_2 - E_1$

👉 **Agreement:**

This is consistent with Planck's quantum theory and does not directly violate classical energy conservation principles.

Conclusion:

Bohr's model was semi-classical in nature. While it successfully explained the stability of atoms and hydrogen spectra, its key assumptions—such as non-radiating orbits and quantized angular momentum—contradict classical physics. These contradictions highlighted the limitations of classical theory and led to the development of modern quantum mechanics.

🌟 **20.2 What is meant by a line spectrum? Explain, how line spectrum can be used for the identification of elements?**

Line Spectrum

A line spectrum is a spectrum that consists of a set of discrete, sharp, and well-defined lines at specific wavelengths, rather than a continuous range of colors. It is produced when excited atoms of an element emit or absorb radiation at particular wavelengths.

Each line corresponds to a specific electronic transition between fixed energy levels of the atom.

Explanation of Line Spectrum

When an atom is supplied with energy (for example, by electric discharge or heating), its electrons are excited to higher energy levels. These electrons are unstable and return to lower energy levels after a short time. During this transition, photons of definite energy and wavelength are emitted.

Because the energy levels of atoms are quantized, only certain transitions are allowed. As a result, the emitted radiation appears as separate spectral lines instead of a continuous spectrum.

Identification of Elements Using Line Spectrum

Each element has a unique arrangement of energy levels, so the wavelengths of spectral lines emitted or absorbed by one element are different from those of any other element.

This makes the line spectrum a fingerprint of an element.

Identification method:

- The spectrum of an unknown substance is obtained using a spectroscope.
- The positions (wavelengths) of its spectral lines are measured.
- These wavelengths are compared with standard spectral data of known elements.
- A match confirms the presence of that particular element.

Conclusion:

A line spectrum consists of discrete wavelengths emitted or absorbed by atoms due to electronic transitions. Since each element has a unique line spectrum, it is a powerful and reliable tool for the identification of elements in laboratories, astronomy, and chemical analysis.

🌟 20.3 Can the Electron in the Ground State of Hydrogen Absorb a Photon of Energy 13.6 eV or Greater than 13.6 eV?

❖ **Answer**:

No, an electron in the ground state of hydrogen cannot absorb a photon of exactly 13.6 eV, nor can it absorb a photon of energy greater than 13.6 eV in a bound state.

Explanation

The ground state of a hydrogen atom corresponds to the lowest energy level ($n = 1$).

The ionization energy of hydrogen is 13.6 eV, which is the minimum energy required to completely remove the electron from the atom.

Case 1: Photon Energy = 13.6 eV

- If a photon of exactly 13.6 eV is incident on a hydrogen atom in the ground state,
- The electron absorbs the photon completely and is ejected from the atom.
- The hydrogen atom becomes ionized.
- The electron does not move to a higher bound orbit; instead, it becomes a free electron with zero kinetic energy.

Case 2: Photon Energy > 13.6 eV

- If the photon energy is greater than 13.6 eV,
- The electron is again ejected from the atom.
- The excess energy appears as kinetic energy of the free electron.
- The atom remains ionized.

Important Conclusion:

- An electron in the ground state can absorb photons only of discrete energies corresponding to allowed excited states.

- Photons with energy equal to or greater than 13.6 eV do not excite the electron to a higher orbit, but instead cause ionization.

Therefore, no bound excited state exists for absorption of 13.6 eV or more.

✦ **Summary:**

- An electron in the ground state of hydrogen cannot remain bound after absorbing a photon of 13.6 eV or more.
- Such absorption results in ionization of the atom, not excitation to a higher energy level.

🌟 20.4 How Can the Spectrum of Hydrogen Contain So Many Lines When Hydrogen Contains Only One Electron?

❖ **Answer:**

Although a hydrogen atom has only one electron, its spectrum contains a large number of spectral lines because the electron can exist in many different allowed energy levels and can make numerous possible transitions between these levels.

Explanation

According to Bohr's be atomic model, the electron in a hydrogen atom does not move randomly. Instead, it occupies discrete (quantized) energy levels labeled by principal quantum numbers

$n = 1, 2, 3, 4, \ldots$

Each energy level has a fixed energy. When the electron:

- Jumps from a higher energy level to a lower energy level,
- It emits a photon whose energy equals the difference between the two energy levels.

Since there are many possible higher energy levels and many possible transitions, a large number of photons with different energies (or wavelengths) are emitted.

Multiple Transitions ⟶ Multiple Spectral Lines

Even with one electron, the following transitions are possible:

$n = 2 \longrightarrow n = 1$

$n = 3 \longrightarrow n = 2$

$n = 3 \longrightarrow n = 1$

$n = 4 \longrightarrow n = 3$

$n = 4 \longrightarrow n = 2$

$n = 4 \longrightarrow n = 1$

and so on...

Each transition produces a photon of different wavelength, which appears as a separate line in the spectrum.

Spectral Series

These numerous lines are grouped into spectral series, depending on the final energy level:

- Lyman series (transitions to n = 1) – ultraviolet

- Balmer series (transitions to n = 2) – visible
- Paschen series (transitions to n = 3) – infrared
- and higher series

Conclusion:

Even though hydrogen has only one electron, the presence of many quantized energy levels allows many possible electronic transitions.

Each transition produces a distinct spectral line, resulting in a spectrum containing a large number of lines.

✦ **Summary:**

The hydrogen spectrum contains many lines because its single electron can jump between numerous allowed energy levels, and each transition produces a photon of a different wavelength.

🌟 20.5 Is Energy Conserved When an Atom Emits a Photon of Light?

❖ **Answer:**

Yes, energy is conserved when an atom emits a photon. The energy lost by the atom equals the energy carried by the emitted photon.

✦ Explanation

1. Electron Transition

- An electron moves from a higher energy level En to a lower energy level Em.

Energy difference:

Delta E = En - Em

2. Photon Emission

The energy lost by the atom is emitted as a photon:

E_photon = h * f

where h is Planck's constant and f is the frequency of the photon.

Energy conservation:

En - Em = h * f

3. Bohr's Model Relations

- **Radius of nth orbit:**

rn = n^2 * r1

- **Energy of electron in nth orbit:**

En = -E1 / n^2

Energy difference when electron jumps from n to m:

Delta E = Em - En = h * f

Example

Electron drops from n = 3 to n = 2 in hydrogen:

E3 = -13.6 / 3^2 = -1.51 eV

E2 = -13.6 / 2^2 = -3.4 eV

Energy difference:

Delta E = E2 - E3 = -3.4 - (-1.51) = -1.89 eV

Photon emitted has energy:

E_photon = 1.89 eV (visible light)

✦ **Summary:**

- Energy lost by electron = Energy of photon (h * f)
- Energy is fully conserved
- Bohr orbit radius: rn = n^2 * r1
- Electron energy: En = -E1 / n^2

🌟 **20.6 Explain why a glowing gas gives only certain wavelengths of light and why that gas is capable of absorbing the same wavelengths? Give a reason why it is transparent to other wavelengths?**

❖ **Answer:**

A glowing gas emits only certain wavelengths because its electrons occupy discrete energy levels. The gas can absorb photons of exactly the same energies corresponding to these energy level differences, but it is transparent to photons of other energies.

✦ Explanation

1. Discrete Energy Levels

- Electrons in atoms can occupy only specific energy levels.
- When an electron jumps from a higher energy level En to a lower level Em, it emits a photon:

$$E_{photon} = E_n - E_m = h * f$$

Only photons with these specific energies (wavelengths) are emitted.

2. Absorption of Light

- If a photon of exactly the same energy (wavelength) hits an atom in the ground state, it can be absorbed and raise the electron to a higher energy level:

$E\_photon = Em - En$

3. Transparency to Other Wavelengths

- Photons that do not match any energy difference between the electron's levels cannot be absorbed.
- Such photons pass through the gas, making it transparent to those wavelengths.

✦ **Reasoning Summary:**

- **Emission**: Only photons corresponding to energy level differences are emitted $\longrightarrow$ line spectrum.
- **Absorption**: Only photons of matching energies can be absorbed $\longrightarrow$ same wavelengths as emission.
- **Transparency**: Photons of other energies do not interact $\longrightarrow$ gas is transparent.

✅ **Key Concept:** This is the basis of spectroscopy. Each element has a unique set of energy levels, so its emission and absorption lines act like a “fingerprint.”

🌟 **20.7 What do we mean when we say that the atom is excited?**

❖ **Answer:**

An atom is said to be excited when one or more of its electrons absorb energy and move from their ground state (lowest energy level) to a higher energy level.

✦ **Explanation**

1. Ground State:

The lowest energy state of an atom, where all electrons occupy the lowest possible energy levels.

2. Excited State:

- When energy is supplied to the atom (for example, by heat, light, or electric current), an electron can jump to a higher orbit or energy level.
- This state is unstable, and the electron eventually returns to a lower energy level, emitting energy in the form of a photon.

3. Energy Relation:

Energy absorbed = $E_{excited} - E_{ground}$

Emitted photon energy = $E_{excited} - E_{lower}$

✦ **Summary:**

- Excited atom = electron temporarily at higher energy level
- Return to ground state → emission of light
- This principle explains the line spectrum of atoms.

🌟 **20.8 Can X-rays be reflected, refracted, diffracted and polarized just like any other waves? Explain.**

❖ **Answer:**

Yes, X-rays can undergo reflection, refraction, diffraction, and polarization just like other electromagnetic waves, but with some specific conditions due to their very short wavelengths.

Explanation

1. Reflection and Refraction:

- X-rays can be reflected and refracted, but the angles are extremely small because their wavelength (~0.01–10 nm) is much smaller than visible light.
- Special grazing incidence techniques are used to observe reflection or refraction.

2. Diffraction:

- X-rays are easily diffracted by crystals, because the spacing between atomic planes in a crystal is comparable to X-ray wavelengths.
- This is the principle behind X-ray crystallography, which is used to determine atomic structures.

3. Polarization:

- X-rays can be polarized by scattering at specific angles.
- Polarization occurs when the electric field oscillates in a particular direction, just like visible light.

✦ **Summary:**

- X-rays are electromagnetic waves, so they obey wave properties.

Their short wavelength makes reflection and refraction difficult at normal incidence, but diffraction and polarization are observable.

🌟 20.9 What are the advantages of lasers over ordinary light?

❖ **Answer:**

Lasers have several advantages over ordinary light because of their unique properties of coherence, monochromaticity, and directionality.

1. Monochromatic Light: Laser light has a single wavelength, while ordinary light contains many wavelengths. This allows for precise targeting in applications such as surgery and spectroscopy.

2. Coherence: Laser light is coherent, meaning the waves are in phase in both space and time. This produces sharp and well-defined beams, which is useful in holography and interferometry.

3. Highly Directional: Laser beams are very narrow and spread very little, unlike ordinary light which diverges. This makes lasers ideal for long-distance communication, cutting, and welding materials.

4. High Intensity: Laser light can be focused onto a very small spot, producing extremely high power density. This property is used in medical surgery, industrial cutting and drilling, and scientific experiments.

5. Precision Control: Lasers can be accurately controlled in terms of intensity, timing, and direction. This is important for measuring distances, guiding instruments, and optical storage.

✦ **Summary:**

In short, lasers are more precise, intense, and directional than ordinary light, which makes them suitable for specialized applications in medicine, industry, communication, and scientific research.

🌟 **20.10 Explain why laser action could not occur without population inversion between atomic levels?**

❖ **Answer:**

Laser action relies on stimulated emission, where an incident photon causes an excited atom to emit a second photon that is coherent with the first. For this process to produce an amplified beam of light, there must be more atoms in the excited state than in the lower energy state. This condition is called population inversion.

1. Normal Population: Under normal conditions, most atoms are in the ground state. If a photon interacts with such atoms, it is more likely to be absorbed than to cause stimulated emission. This prevents amplification of light.

2. Population Inversion: When more atoms occupy the metastable excited state, an incident photon is more likely to induce emission than to be absorbed. Each stimulated emission produces a photon identical in phase, frequency, and direction to the incident photon.

3. Amplification of Light: This repeated stimulated emission from many excited atoms leads to a coherent, intense, and unidirectional laser beam. Without population inversion, stimulated emission cannot dominate, and the laser cannot function.

✦ **Summary:**

Population inversion is essential for laser action because it ensures that stimulated emission exceeds absorption, allowing the laser beam to grow in intensity and maintain coherence

Note:

This chapter is designed to provide a solid foundation of knowledge, with the goal of deepening understanding and encouraging further exploration of the subject. The content has been carefully selected to support effective learning and inspire students to engage with the topic more deeply.

Author: Muhammad Asghar

Purpose: To contribute to education by offering insightful, valuable content that enhances learning and understanding.

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