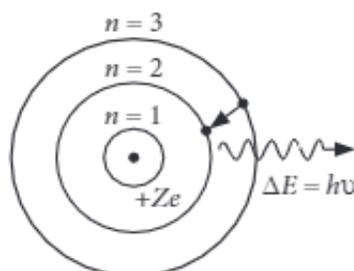# Atoms

Questions 1-7 are Case Study based questions and are compulsory. Attempt any 4 sub parts from each question. Each question carries 1 mark.

1

Bohr's Model of Hydrogen Atom

Niels Bohr introduced the atomic Hydrogen model in 1913. He described it as a positively charged nucleus, comprised of protons and neutrons, surrounded by a negatively charged electron cloud. In the model, electrons orbit the nucleus in atomic shells. The atom is held together by electrostatic forces between the positive nucleus and negative surroundings.

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

Bohr correctly proposed that the energy and radii of the orbits of electrons in atoms are quantized, with energy for transitions between orbits given by

$\Delta E = h\upsilon = E_i - E_f$, where ΔE is the change in energy between the initial and final orbits and $h\upsilon$ is the energy of an absorbed or emitted photon.

(i) In the Bohr model of the hydrogen atom, discrete radii and energy states result when an electron circles the atom in an integer number of
  (a) de Broglie wavelengths
  (b) wave frequencies
  (c) quantum numbers
  (d) diffraction patterns.

(ii) The angular speed of the electron in the nth orbit of Bohr's hydrogen atom is
  (a) directly proportional to n
  (b) inversely proportional to $\sqrt{n}$
  (c) inversely proportional to n^2
  (d) inversely proportional to n^3

(iii) When electron jumps from $n = 4$ level to $n = 1$ level, the angular momentum of electron changes by
  (a) $\dfrac{h}{2\pi}$
  (b) $\dfrac{h}{\pi}$
  (c) $\dfrac{3h}{2\pi}$
  (d) $\dfrac{2h}{\pi}$

(iv) The lowest Bohr orbit in hydrogen atom has

    (a) the maximum energy   (b) the least energy

    (c) infinite energy   (d) zero energy

(v) Which of the following postulates of the Bohr model led to the quantization of energy of the hydrogen atom?

    (a) The electron goes around the nucleus in circular orbits.

    (b) The angular momentum of the electron can only be an integral multiple of $h/2\pi$.

    (c) The magnitude of the linear momentum of the electron is quantized.

   (d) Quantization of energy is itself a postulate of the Bohr model.

② α-particle Scattering Experiment

In 1911, Rutherford, along with his assistants, H. Geiger and E. Marsden, performed the alpha particle scattering experiment. H. Geiger and E. Marsden took radioactive source ($^{214}_{83}$Bi) for α-particles. A collimated beam of α-particles of energy 5.5 MeV was allowed to fall on 2.1×10^{-7} m thick gold foil. The α-particles were observed through a rotatable detector consisting of a Zinc sulphide screen and microscope. It was found that α-particles got scattered. These scattered α-particles produced scintillations on the zinc sulphide screen. Observations of this experiment are as follows

(I) Most of the α-particles passed through the foil without deflection.

(II) Only about 0.14% of the incident α-particles scattered by more than 1°.

(III) Only about one α-particle in every 8000 α-particles deflected by more than 90°.

These observations led to many arguments and conclusions which laid down the structure of the nuclear model of an atom.
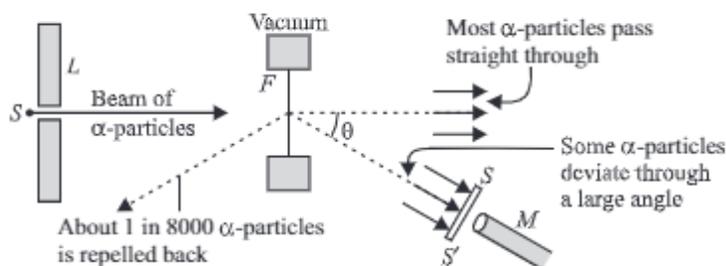
(i) Rutherford's atomic model can be visualised as

**(ii)** Gold foil used in Geiger-Marsden experiment is about 10^{-8} m thick. This ensures

    (a) gold foil's gravitational pull is small or possible

    (b) gold foil is deflected when α-particle stream is not incident centrally over it

    (c) gold foil provides no resistance to passage of α-particles

    (d) most α-particle will not suffer more than 1° scattering during passage through gold foil

(iii) In Geiger-Marsden scattering experiment, the trajectory traced by an α-particle depends on

(a) number of collision
(b) number of scattered α- particles
(c) impact parameter
(d) none of these

(iv) In the Geiger-Marsden scattering experiment, in case of head-on collision, the impact parameter should be

(a) maximum
(b) minimum
(c) infinite
(d) zero

(v) The fact only a small fraction of the number of incident particles rebound back in Rutherford scattering indicates that

(a) number of α-particles undergoing head-on-collision is small
(b) mass of the atom is concentrated in a small volume
(c) mass of the atom is concentrated in a large volume
(d) both (a) and (b).

③

Excited State of Atom

At room temperature, most of the H-atoms are in ground state. When an atom receives some energy (*i.e.*, by electron collisions), the atom may acquire sufficient energy to raise electron to higher energy state. In this condition, the atom is said to be in excited state. From the excited state, the electron can fall back to a state of lower energy emitting a photon equal to the energy difference of the orbit.
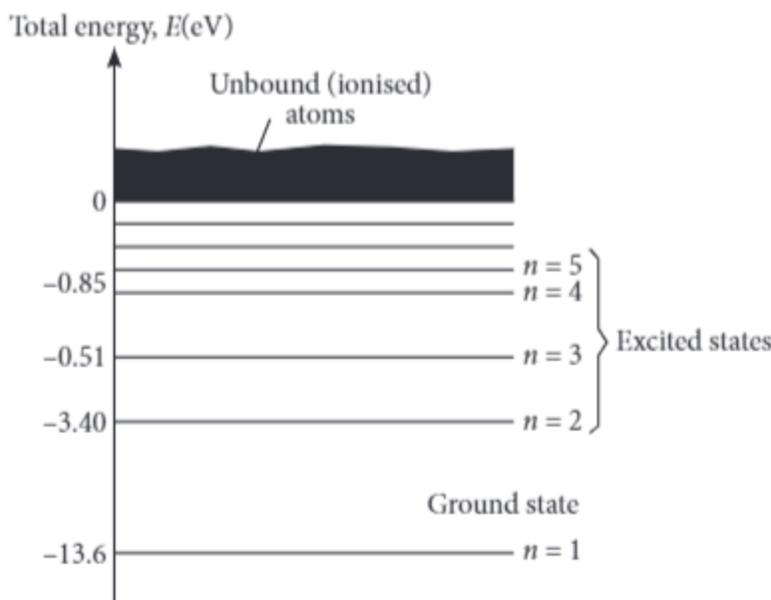
In a mixture of H—He$^+$ gas (He$^+$ is single ionized He atom), H-atoms and He$^+$ ions are excited to their respective first excited states. Subsequently, H-atoms transfer their total excitation energy to He$^+$ ions (by collisions).

(i) The quantum number n of the state finally populated in He$^+$ ions is

(a) 2
(b) 3
(c) 4
(d) 5

(ii) The wavelength of light emitted in the visible region by He$^+$ ions after collisions with H-atoms is

(a) 6.5×10^{-7} m
(b) 5.6×10^{-7} m
(c) 4.8×10^{-7} m
(d) 4.0×10^{-7} m

(iii) The ratio of kinetic energy of the electrons for the H-atoms to that of He^+ ion for $n = 2$ is

(a) $\dfrac{1}{4}$
(b) $\dfrac{1}{2}$
(c) 1
(d) 2

(iv) The radius of the ground state orbit of H-atoms is

(a) $\dfrac{\varepsilon_0}{h\pi me^2}$
(b) $\dfrac{h^2\varepsilon_0}{\pi me^2}$
(c) $\dfrac{\pi me^2}{h}$
(d) $\dfrac{2\pi h\varepsilon_0}{me^2}$

(v) Angular momentum of an electron in H-atom in first excited state is

(a) $\dfrac{h}{\pi}$
(b) $\dfrac{h}{2\pi}$
(c) $\dfrac{2\pi}{h}$
(d) $\dfrac{\pi}{h}$

4

Electron Transitions for the Hydrogen Atom

Bohr's model explains the spectral lines of hydrogen atomic emission spectrum. While the electron of the atom remains in the ground state, its energy is unchanged. When the atom absorbs one or more quanta of energy, the electrons moves from the ground state orbit to an excited state orbit that is further away.
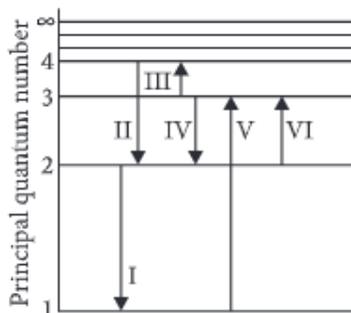
The given figure shows an energy level diagram of the hydrogen atom. Several transitions are marked as I, II, III and so on. The diagram is only indicative and not to scale.

(i) In which transition is a Balmer series photon absorbed?

(a) II
(b) III
(c) IV
(d) VI

(ii) The wavelength of the radiation involved in transition II is

(a) 291 nm
(b) 364 nm
(c) 487 nm
(d) 652 nm

(iii) Which transition will occur when a hydrogen atom is irradiated with radiation of wavelength 103 nm?

(a) I
(b) II
(c) IV
(d) V

(iv) The electron in a hydrogen atom makes a transition from $n = n_1$ to $n = n_2$ state. The time period of the electron in the initial state is eight times that in the final state. The possible values of n_1 and n_2 are

(a) $n_1 = 4, n_2 = 2$
(b) $n_1 = 8, n_2 = 2$
(c) $n_1 = 8, n_2 = 3$
(d) $n_1 = 6, n_2 = 2$

(v) The Balmer series for the H-atom can be observed

(a) if we measure the frequencies of light emitted when an excited atom falls to the ground state
(b) if we measure the frequencies of light emitted due to transitions between excited states and the first excited state
(c) in any transition in a H-atom
(d) none of these.

5

Line Spectra of the Hydrogen Atom

The spectral series of hydrogen atom were accounted for by Bohr using the relation $\bar{v} = R\left(\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right)$, where R = Rydberg constant = 1.097×10^7 m^{-1}.

Lyman series is obtained when an electron jumps to first orbit from any subsequent orbit. Similarly, Balmer series is obtained when an electron jumps to 2nd orbit from any subsequent orbit, Paschen series is obtained when an electron jumps to 3rd orbit from any subsequent orbit. Whereas Lyman series lies in U.V. region, Balmer series is in visible region and Paschen series lies in infrared region. Series limit is obtained when $n_2 = \infty$.

(i)   The wavelength of first spectral line of Lyman series is
    (a) 1215.4 Å   (b) 1215.4 cm   (c) 1215.4 m   (d) 1215.4 mm

(ii) The wavelength limit of Lyman series is
    (a) 1215.4 Å   (b) 511.9 Å   (c) 951.6 Å   (d) 911.6 Å

(iii) The frequency of first spectral line of Balmer series is
    (a) 1.097×10^7 Hz   (b) 4.57×10^{14} Hz   (c) 4.57×10^{15} Hz   (d) 4.57×10^{16} Hz

(iv) Which of the following transitions in hydrogen atoms emit photons of highest frequency ?
    (a) $n = 1$ to $n = 2$ (b) $n = 2$ to $n = 6$ (c) $n = 6$ to $n = 2$ (d) $n = 2$ to $n = 1$

(v) The ratio of minimum to maximum wavelength in Balmer series is
    (a) $5 : 9$ (b) $5 : 36$ (c) $1 : 4$ (d) $3 : 4$

6

Second Postulate of Bohr's Theory

Hydrogen is the simplest atom of nature. There is one proton in its nucleus and an electron moves around the nucleus in a circular orbit. According to Niels Bohr, this electron moves in a stationary orbit. When this electron is in the stationary orbit, it emits no electromagnetic radiation. The angular momentum of the electron is quantized, i.e., $mvr = (nh/2\pi)$, where m = mass of the electron, v = velocity of the electron in the orbit, r = radius of the orbit and $n = 1, 2, 3, ...$ When transition takes place from K^{th} orbit to J^{th} orbit, energy photon is emitted. If the wavelength of the emitted photon is λ, we find that $\dfrac{1}{\lambda} = R\left[\dfrac{1}{J^2} - \dfrac{1}{K^2}\right]$, where R is Rydberg's constant.

On a different planet, the hydrogen atom's structure was somewhat different from ours. The angular momentum of electron was $P = 2n(h/2\pi)$, i.e., an even multiple of $(h/2\pi)$.
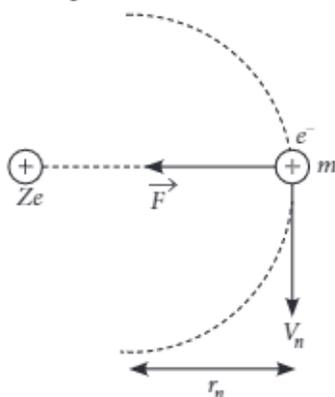
(i) The minimum permissible radius of the orbit will be

(a) $\dfrac{2\varepsilon_0 h^2}{m\pi e^2}$

(b) $\dfrac{4\varepsilon_0 h^2}{m\pi e^2}$

(c) $\dfrac{\varepsilon_0 h^2}{m\pi e^2}$

(d) $\dfrac{\varepsilon_0 h^2}{2m\pi e^2}$

(ii) In our world, the velocity of electron is v_0 when the hydrogen atom is in the ground state. The velocity of electron in this state on the other planet should be

(a) v_0

(b) $v_0/2$

(c) $v_0/4$

(d) $v_0/8$

(iii) In our world, the ionization potential energy of a hydrogen atom is 13.6 eV. On the other planet, this ionization potential energy will be

(a) 13.6 eV

(b) 3.4 eV

(c) 1.5 eV

(d) 0.85 eV

(iv) Check the correctness of the following statements about the Bohr model of hydrogen atom.
  (i) The acceleration of the electron in $n = 2$ orbit is more than that in $n = 1$ orbit.
  (ii) The angular momentum of the electron in $n = 2$ orbit is more than that in $n = 1$ orbit.
  (iii) The kinetic energy of the electron in $n = 2$ orbit is less than that in $n = 1$ orbit.

(a) Only (iii) and (i) are correct.

(b) Only (i) and (ii) are correct.

(c) Only (ii) and (iii) are correct.

(d) All the statements are correct.

(v) In Bohr's model of hydrogen atom, let PE represent potential energy and TE the total energy. In going to a higher orbit

(a) PE increases, TE decreases

(b) PE decreases, TE increases

(c) PE increases, TE increases

(d) PE decreases, TE decreases

7

Hydrogen Emission Spectrum

Hydrogen spectrum consists of discrete bright lines in a dark background and it is specifically known as hydrogen emission spectrum. There is one more type of hydrogen spectrum that exists where we get dark lines on the bright background, it is known as absorption spectrum. Balmer found an empirical formula by the observation of a small part of this spectrum and it is represented by

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right), \text{ where } n = 3, 4, 5, \ldots .$$

For Lyman series, the emission is from first state to n^{th} state, for Paschen series, it is from third state to n^{th} state, for Brackett series, it is from fourth state to n^{th} state and for Pfund series, it is from fifth state to n^{th} state.

(i) Number of spectral lines in hydrogen atom is

(a) 8

(b) 6

(c) 15

(d) ∞

(ii) Which series of hydrogen spectrum corresponds to ultraviolet region?

(a) Balmer series

(b) Brackett series

(c) Paschen series

(d) Lyman series

(iii) Which of the following lines of the H-atom spectrum belongs to the Balmer series?

(a) 1025 Å

(b) 1218 Å

(c) 4861 Å

(d) 18751 Å

(iv) Rydberg constant is

(a) a universal constant

(b) same for same elements

(c) different for different elements

(d) none of these

(v) Hydrogen atom is excited from ground state to another state with principal quantum number equal to 4. Then the number of spectral lines in the emission spectra will be

(a) 3

(b) 5

(c) 6

(d) 2

For question numbers 8-25, two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

(a) Both A and R are true and R is the correct explanation of A

(b) Both A and R are true but R is NOT the correct explanation of A

(c) A is true but R is false

(d) A is false and R is also false

8. **Assertion (A) :** The force of repulsion between atomic nucleus and α-particle varies with distance according to inverse square law.
   Reason (R) : Rutherford did α-particle scattering experiment.

9. **Assertion (A) :** According to classical theory, the proposed path of an electron in Rutherford atom model will be circular.
   Reason (R) : According to electromagnetic theory an accelerated particle continuously emits radiation.

10. **Assertion (A) :** Fraunhofer lines are observed in the spectrum of the sun.
    Reason (R) : The different elements have different spectra.

11. **Assertion (A) :** Hydrogen atom consists of only one electron but its emission spectrum has many lines.
    Reason (R) : Only Lyman series is found in the absorption spectrum of hydrogen atom whereas in the emission spectrum, all the series are found.

12. **Assertion (A) :** It is essential that all the lines available in the emission spectrum will not be available in the absorption spectrum.
    Reason (R) : The spectrum of hydrogen atom is only absorption spectrum.

13. **Assertion (A) :** For the scattering of α-particles at a large angles, only the nucleus of the atom is responsible.
    Reason (R) : Nucleus is very heavy in comparison to electrons.

14. **Assertion (A) :** Between any two given energy levels, the number of absorption transitions is always less than the number of emission transitions.
    Reason (R) : Absorption transitions start from the lowest energy level only and may end at any higher energy level. But emission transitions may start from any higher energy level and end at any energy level below it.

15. **Assertion (A) :** Smoky flame of Bunsen burner gives continuous spectrum whereas its blue flame gives band spectrum.
    Reason (R) : The band spectrum consists of coloured bands of light on a dark background.

16. **Assertion (A) :** Bohr had postulated that the electrons in stationary orbits around the nucleus do not radiate.
    Reason (R) : According to classical physics all moving electrons radiate.

17. **Assertion (A) :** Laser is used to measure distant object like moon.
    Reason (R) : They are highly coherent source of light.

18. **Assertion (A) :** Total energy of electron in an hydrogen atom is negative.
    Reason (R) : It is bounded to the nucleus.

19. **Assertion (A) :** Electrons in the atom are held due to coulomb forces.
    Reason (R) : The atom is stable only because the centripetal force due to Coulomb's law is balanced by the centrifugal force.

20. **Assertion (A) :** The positively charged nucleus of an atom has a radius of almost 10^{-15} m.
    Reason (R) : In α-particle scattering experiment, the distance of closest approach for α-particles is 10^{-15} m.

21. **Assertion (A)** : An electron in hydrogen atom passes from $n = 4$ to $n = 1$ level. The maximum number of photons that can be emitted is 4.
    Reason (R) : Maximum number of photons emitted can only be 4.

22. **Assertion (A)** : A tube light emits white light.
    Reason (R) : Emission of light in a tube takes place at a very high temperature.

23. **Assertion (A)** : In He-Ne laser, population inversion takes place between energy levels of neon atoms.
    Reason (R) : Helium atoms have a meta-stable energy level.

24. **Assertion (A)** : Total energy of revolving electron in any stationary orbit is negative.
    Reason (R) : Energy is a scalar quantity. It can have positive or negative value.

25. **Assertion (A)** : Balmer series lies in the visible region of electromagnetic spectrum.
    Reason (R) : $\dfrac{1}{\lambda} = R\left(\dfrac{1}{2^2} - \dfrac{1}{K^2}\right)$, , where $K = 3, 4, 5, ...$

HINTS & EXPLANATIONS

1. (i) (c)

(ii) (d): $\omega = \dfrac{v}{r}$. Further $v \propto \dfrac{1}{n}$ and $r \propto n^2$,
Hence $\omega \propto (1/n^3)$.

(iii) (c)

(iv) (b): The energy of nth Bohr orbit in hydrogen atom is

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

For lowest orbit, $n = 1$
$\therefore \quad E_1 = -13.6 \text{ eV}$
Thus, the lowest Bohr orbit in hydrogen atom has the least energy.

(v) (b)

2. (i) (d) : Rutherford's atom had a positively charged centre and electrons were revolving outside it. It is also called the planetary model of the atom as in option (d).

(ii) (d): As the gold foil is very thin, it can be assumed that α-particles will suffer not more than one scattering during their passage through it. Therefore, computation of the trajectory of an α-particle scattered by a single nucleus is enough.

(iii) (c) : Trajectory of α-particles depends on impact parameter which is the perpendicular distance of the initial velocity vector of the α particles from the centre of the nucleus. For small impact parameter α particle close to the nucleus suffers larger scattering.

(iv) (b): At minimum impact parameter, α particles rebound back ($\theta \approx \pi$) and suffers large scattering.

(v) (d): In case of head-on-collision, the impact parameter is minimum and the α-particle rebounds back. So, the fact that only a small fraction of the number of incident particles rebound back indicates that the number of α-particles undergoing head-on collision is small. This in turn implies that the mass of the atom is concentrated in a small volume. Hence, option (a) and (b) are correct.

3. (i) (c) : $E_n = \dfrac{-13.6}{n^2}(Z^2)$

In first excited state, $E_{H_2} = 3.4 \text{ eV}$ and $E_{He} = -13.6 \text{ eV}$
So, H_2 atom gives excitation energy
($13.6 - 3.4 = 10.2 \text{ eV}$) to helium atom
Now, energy of He ion $= -13.6 + 10.2 = -3.4 \text{ eV}$
Again, $E = \dfrac{-13.6}{n^2} \times Z^2$

$\Rightarrow \quad -3.4 = \dfrac{-13.6}{n^2} \times (2)^2 \Rightarrow n = 4$

(ii) (c): $\dfrac{1}{\lambda} = \dfrac{13.6Z^2}{hc}\left[\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right]$

Here, $n_1 = 3$ and $n_2 = 4 \Rightarrow \lambda = 4.8 \times 10^{-7} \text{ m}$

(iii) (a): Kinetic energy, $K \propto \dfrac{Z^2}{n^2}$

$\dfrac{K_{H_2}}{K_{He}} = \left(\dfrac{Z_{H_2}}{Z_{He}}\right)^2 = \left(\dfrac{1}{2}\right)^2 = \dfrac{1}{4}$

(iv) (b): Radius of the permitted orbit is $r = \dfrac{n^2 h^2 \varepsilon_0}{\pi m Z e^2}$

For hydrogen atom in ground state, i.e.,

$n = 1, Z = 1 \Rightarrow r = \dfrac{h^2 \varepsilon_0}{\pi m e^2}$

(v) (a): Angular momentum for hydrogen atom is

$L = \dfrac{nh}{2\pi}$

For first excited state, $n = 2$, $L = \dfrac{h}{\pi}$

4. **(i) (d)** : For Balmer series, $n_1 = 2$; $n_2 = 3, 4,\ldots$
                                        (lower) (higher)

Therefore, in transition (VI), photon of Balmer series is absorbed.

(ii) (c): In transition II,

$E_2 = -3.4$ eV, $E_4 = -0.85$ eV,

$\Delta E = 2.55$ eV $\Rightarrow \Delta E = \dfrac{hc}{\lambda} \Rightarrow \lambda = \dfrac{hc}{\Delta E} = 487$ nm

(iii) (d): Wavelength of radiation = 1030 Å

$\Delta E = \dfrac{12400}{1030\ \text{Å}} = 12.0$ eV

So, difference of energy should be 12.0 eV (approx.)

Hence for $n_1 = 1$ to $n_2 = 3$

$E_{n_3} - E_{n_1} = -1.51$ eV $-(-13.6$ eV$) \approx 12$ eV

Therefore, transition V will occur.

(iv) (a): $T^2 \propto r^3$ and $r \propto n^2 \Rightarrow T^2 \propto n^6 \Rightarrow T \propto n^3$

$\dfrac{T_1}{T_2} = \left(\dfrac{n_1}{n_2}\right)^3 \Rightarrow 8 = \left(\dfrac{n_1}{n_2}\right)^3$ or $\dfrac{n_1}{n_2} = 2$

(v) (b)

5. **(i) (a)** : From, $\bar{v} = \dfrac{1}{\lambda} = R\left(\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right)$

$n_1 = 1, n_2 = 2$ for first spectral line of Lyman series,

$\dfrac{1}{\lambda} = 1.097 \times 10^7 \left(\dfrac{1}{1^2} - \dfrac{1}{2^2}\right) = \dfrac{3 \times 1.097 \times 10^7}{4}$ m^{-1}

$\lambda = \dfrac{4 \times 10^{-7}\ \text{m}}{3 \times 1.097} = \dfrac{4000}{3 \times 1.097}$ Å $= 1215.4$ Å

(ii) (d): For wavelength limit, we put $n_2 = \infty$

$\therefore \quad \dfrac{1}{\lambda} = 1.097 \times 10^7 \left(\dfrac{1}{1^2} - \dfrac{1}{\infty}\right)$

$\lambda = \dfrac{1}{1.097 \times 10^7}$ m $= \dfrac{1000}{1.097}$ Å $= 911.6$ Å

(iii) (b): For first line of Balmer series, $n_1 = 2$, $n_2 = 3$

$\bar{v} = \dfrac{1}{\lambda} = R\left(\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right)$

$v = \dfrac{c}{\lambda} = Rc\left(\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right)$

$= 1.097 \times 10^7 \times 3 \times 10^8 \left(\dfrac{1}{2^2} - \dfrac{1}{3^2}\right)$

$= 1.097 \times 3 \times 10^{15} \times \dfrac{5}{36} = 4.57 \times 10^{14}$ Hz

(iv) (d): $h\nu_{2 \to 1} = -13.6\left(\dfrac{1}{2^2} - \dfrac{1}{1^2}\right)$ eV $= 10.2$ eV

Emission is $n = 2 \to n = 1$ i.e., higher n to lower n.

Transition from lower to higher levels are absorption lines.

$-13.6\left(\dfrac{1}{6^2} - \dfrac{1}{2^2}\right) = +13.6 \times \dfrac{2}{9}$

This is $< E_n = 2 \to E_n = 1$

(v) (a): $\dfrac{1}{\lambda_{max}} = R\left[\dfrac{1}{2^2} - \dfrac{1}{3^2}\right] = \dfrac{5R}{36}$

$\dfrac{1}{\lambda_{min}} = R\left[\dfrac{1}{2^2} - \dfrac{1}{\infty}\right] = \dfrac{R}{4} \Rightarrow \dfrac{\lambda_{min}}{\lambda_{max}} = \dfrac{5R}{36} \times \dfrac{4}{R} = \dfrac{5}{9}$

6. **(i) (b)** : On other planet: $mvr = 2n\dfrac{h}{2\pi} \Rightarrow v = \dfrac{nh}{\pi m r}$

$\dfrac{mv^2}{r} = \dfrac{1}{4\pi\varepsilon_0}\dfrac{e^2}{r^2} \Rightarrow \dfrac{mn^2 h^2}{n^2 m^2 r^3} = \dfrac{1}{4\pi\varepsilon_0}\dfrac{e^2}{r^2}$

Putting $n = 1$, we get $r = \dfrac{4h^2 \varepsilon_0}{m\pi e^2}$

(ii) (b): On our planet : $v_0 = \dfrac{e^2}{2\varepsilon_0 n h}$

On other planet : $v = \dfrac{e^2}{2\varepsilon_0 (2n)h} = \dfrac{v_0}{2}$

(iii) (b): On our planet : $E_n = -\dfrac{13.6}{n^2}$

On other planet : $E_n' = -\dfrac{13.6}{(2n)^2}$

$\Rightarrow \quad E_n' = \dfrac{E_n}{4} = -3.4$ eV

(iv) (c): Centripetal acceleration $= mv^2/r$

Further, as n increases, r also increases. Therefore, centripetal acceleration for $n = 2$ is less than that for $n = 1$. So, statement (i) is wrong. Statement (ii) and (iii) are correct.

(v) (c) : Potential energy $= -C/r^2$ and total energy $= -Rhc/n^2$. With higher orbit, both r and n increase. So, both become less negative; hence both increase.

7. (i) (d) : Number of spectral lines in hydrogen atom is ∞.

(ii) (d): Lyman series lies in the ultraviolet region.

(iii) (c) : The shortest Balmer line has energy
$= |(3.4 - 1.51)|\ eV = 1.89\ eV$
and the highest energy $= |(0 - 3.4)| = 3.4\ eV$
The corresponding wavelengths are

$$\frac{12400\ eV\text{Å}}{1.89\ eV} = 6561\ \text{Å} \text{ and } \frac{12400\ eV\text{Å}}{3.4\ eV} = 3647\ \text{Å}$$

Only 4861 Å is between the first and last line of the Balmer series.

(iv) (a)

(v) (c)

8. (b): In Rutherford's α-particle scattering experiment, some of α-particles were found to be scattered at very large angles inspite of having very high kinetic energy. This shows that there are α-particles which will be passing very close to nucleus. Rutherford confirmed the repulsive force on α-particles due to nucleus varies with distance according to inverse square law and that the positive charges are concentrated at the centre and not distributed throughout the atom. This is the nuclear model of Rutherford.

9. (b): According to classical electromagnetic theory, an accelerated charge continuously emits radiation. As electrons revolving in circular paths are constantly experiencing centripetal acceleration, hence they will be losing their energy continuously and the orbital radius will go on decreasing and form spiral and finally the electron will fall into the nucleus.

10. (b): When white light from the photosphere (central portion of the sun) passes through vapours of various elements present in the outer chromosphere, then these elements absorb those wavelengths which they themselves emit to bring incandescent. Hence dark lines (absence of light) appear in the continuous solar spectrum, due to absorption of these lines. Absorption is possible in the sun, not only from the ground state but also in higher states because of the high temperature of the sun.

11. (b): Every atom has certain definite energy level. In the normal state, the electron in the hydrogen atom stays in lowest energy level. When the atom gets appropriate energy from outside, then this electron rises to some higher energy level *i.e.*, atom is excited. Within nearly 10^{-8} sec, the electron leaves the higher energy level. Now, it can return either directly to the lowest energy level (or the ground state) or come to the ground state after passing through other lower energy levels. Since there are a large number of atoms in a light – source (hydrogen lamp), hence all possible transitions take place in the source and many lines are seen in the spectrum. The slit gives the shape of the spectrum and the large number of lines are obtained because a large number of atoms are getting excited and de-excited to different energy levels.

12. (c) : Emission transitions can take place between any higher energy level and any energy level below it while absorption transitions start from the lowest energy level only and may end at any higher energy level. Hence number of absorptions transitions between two given energy levels is always less than the number of emission transitions between same two levels.

13. (a): We know that an electron is very light particle as compared to an α-particle. Hence electron cannot scatter the α-particle at large angles, according to law of conservation of momentum. On the other hand, mass of nucleus is comparable with the mass of α-particle, hence only the nucleus of atom is responsible for scattering of α-particles.

14. (a) : Absorption transition

Two possibilities in absorption transition.
Emission transition
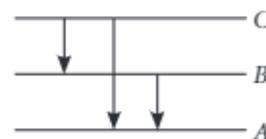
Three possibilities in emission transition. Therefore number of absorption transition < number of emission transition.

For any two states A and B such that $E_A < E_B$ we have absorption spectrum for $A \rightarrow B$ transition and emission $B \rightarrow A$. But most of the time atoms are in ground state, absorption is only from the ground state.

15. (b): When the flame of Bunsen burner is smoky, the carbon particles in it are in the incandescent state. Hence the flame gives a continuous spectrum. But when the Burner gives a blue flame, then it has carbon, cynogen etc., in the molecular state. Hence it gives band spectrum.

16. (b): According to classical physics, all moving charged particle radiate electromagnetic radiation. So moving electrons will also radiate energy. If we see the atomic structure we find that electrons revolve around the nucleus in some particular orbits. Bohr termed these orbits as the stationary orbits as the electrons do not radiate energy as long as they are moving in these orbits. This is one of Bohr's postulates. This postulate is based on the fact that if the moving electrons radiate thereby losing energy, they have got a chance to finally fall back onto the nucleus and the atom will be collapsed.

17. (a): As laser is highly monochromatic and highly coherent, we can send as a laser beam to the moon, from where it comes back reflected without much loss of intensity. That's why the large distances can be measured accurately with the help of laser.

18. (a): We know that $E = -\dfrac{13.6}{n^2}$ eV

It shows that total energy of electron in a stationary orbit in a hydrogen atom is negative, which means the electron is bound to the nucleus and is not free to leave it.

19. (c): According to postulates of Bohr's atom model, the electron revolve around the nucleus in fixed orbit of definite radii. As long as the electron is in a certain orbits it does not radiate any energy. Not only the centripetal force has to be the centrifugal force, even the stable orbits are fixed by Bohr's theory.
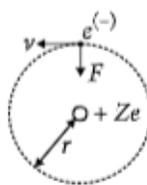
20. (a): In α-particle scattering experiment, Rutherford found a small number of α-particles which were scattered back through an angle approaching to 180°. This is possible only if the positive charges are concentrated at the centre or nucleus of the atom.

21. (d): The maximum number of photons emitted = 6 corresponding to the transitions $4 \to 3$; $3 \to 2$, $2 \to 1$, $4 \to 2$, $4 \to 1$ and $3 \to 1$.

22. (d): The tube light is nothing but a gas discharge tube, which can emit light of different colours. This colour depends mainly upon the nature of the gas inside the tube and the nature of the glass. For neon gas the colour is bright red and for CO_2 it is bluish. Again the fluorescent glow looks yellowish green for soda glass. So it is the nature of the glass and the gas inside the tube which determines the colour of the fluorescent glow. As argon is filled inside a tube light, the colour of the light is white.

23. (a): Helium-neon laser uses a gaseous mixture of helium and neon. An electric discharge in the gas pumps the helium atoms to higher energy level, (which is meta stable energy level).
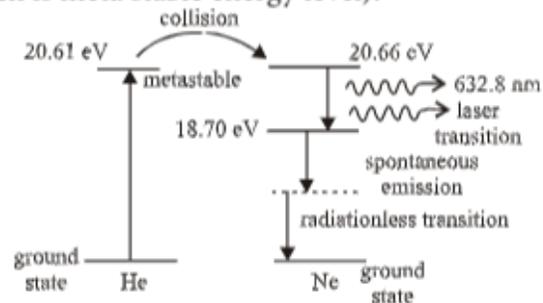
Sequence of transitions in He-Ne laser.

Then these helium atom excite the neon atoms to higher level by collision and produce an inverted population of neon atom which emit radiation when they are stimulated to fall to lower level.

24. (b): The reason is correct, but does not explain the assertion properly. Negative energy of revolving electron indicates that it is bound to the nucleus. The electron is not free to leave the nucleus.

25. (b): When we put $R = 10^7$ m^{-1} and $K = 3, 4, 5$ in the given formula, values of λ calculated lie between 4000 Å and 8000 Å, which is the visible region. The reason is true, but does not explain the assertion properly.