A. Bohr's Theory

1. Express the energy of a photon in the light of wavelength 5000 A.U. in joule and in eV. **(3.978×10^{-19} J; 2.49 eV)**

2. Yellow light has a wavelength of 5.986×10^{-7} m. How many photons are emitted per second by a sodium lamp working at a power of 10 watt ? **(2.996×10^{19})**

3. Find the velocity of an electron of 1 eV energy. Take mass of electron as 9.1×10^{-31} kg. **(5.9×10^{5} m/s)**

4. Find the velocity of electron in the ground state of Hydrogen atom. Hence find the velocities when the electron is in the second and fourth orbits. Radius of first Bohr orbit = 0.53×10^{-10} m and mass of electron = 9.1×10^{-31} kg.

   (2.18×10^{6} m/s; 1.09×10^{6} m/s; 5.45×10^{5} m/s)

5. Calculate the frequency of revolution of an electron in the first orbit of Hydrogen atom if the radius of the first orbit is 0.5 A° and the velocity of electron in the first orbit is 2.24×10^{6} m/s. **(7.1×10^{15} Hz)**

6. Calculate the energy of the electron in the first three permissible orbits in the Hydrogen atom. 1 eV = 1.6×10^{-19} J. **(– 13.6 eV; – 3.4 eV; – 1.51 eV)**

7. The difference in energy between two energy levels in H_2 atom is 2.3 eV. Find the frequency of the line emitted in the transition of the electron from higher to lower level. Take $e = 1.6 \times 10^{-19}$ C and $h = 6.63 \times 10^{-24}$ J. **(5.5×10^{14} Hz)**

8. Given that the energy of the electron in the ground state of the H_2 atom is - 13.6 eV, find the frequency and the wave number of radiation emitted when the electron jumps from orbit $n = 4$ to orbit $n = 2$. **(6.15×10^{14} Hz ; 2×10^6 m^{-1})**

9. In the case of H_2 atom, for the transition $n = 5$ to $n = 1$ what are the energy, wavelength and frequency of the emitted photon ?

(13.1 eV; 94.9 nm; 3.16×10^{15} Hz)

10. Calculate the wave number, wavelength and frequency of a spectral line in the H_2 spectrum arising from the transition $n_2 = 3$ to $n_1 = 1$. In which region of the spectrum does this line make its appearance? R = 1.097×10^7 m^{-1}.

(9.75×10^6 m^{-1} ; 1026 A° ; 2.924×10^{15} Hz)

11. A photon of energy 12.1 eV absorbed by the H_2 atom in the ground state (energy – 13.6 eV) raises it to an excited state. Find the quantum number of this state. **(3)**

12. An H_2 atom in an excited state has energy – 0.544 eV. Calculate the wavelength of photon emitted when it makes a transition to another level of energy – 3.4 eV. Identify the quantum numbers of these states. **(4353 A°; 5 and 2 respectively)**

13. Calculate the radii of the first two permissible orbits of the electron in the Hydrogen atom. Which orbit will have a radius 212 A° ? $m = 9.1 \times 10^{-31}$ kg. $e = 1.6 \times 10^{-19}$ C, $h = 6.63 \times 10^{-34}$ J s. **(0.53×10^{-10} m; 2.12×10^{-10} m; 20)**

14. The radius of the first orbit of the electron in the Hydrogen atom is 0.5 A°. What would be its radius when in the fourth orbit? **(8 A°)**

15. The energy of an electron in an excited H_2 atom is – 3.4 eV. Calculate the angular momentum of the electron in this state. $h = 6.63 \times 10^{-34}$ Js.

$\left(\textbf{Hint :}\ E = \frac{-13.6}{n^2} = -3.4. \text{ Calculate } n \text{ and hence } \frac{nh}{2\pi}\right)$ **(2.1×10^{-34} kg m^2/s)**

16. The energy of an electron is an excited H_2 atom is -0.85 eV. Calculate the angular momentum of the electron in this state. **(4.2×10^{-34} kg m^2 s^{-1})**

17. Calculate the change in the angular momentum of an electron when it jumps from the orbit $n = 4$ to the orbit $n = 1$ in the H_2 atom. What happens to this angular momentum? **(3.17×10^{-34} kg m^2/s)**

18. Find the angular momentum of the electron in the ground state of Hydrogen atom. Hence find the angular momentum of the electron when it is in the fifth orbit. $h = 6.63 \times 10^{-34}$ Js **(1.056×10^{-34} kg m^2/s; 5.28×10^{-34} kg m^2/s)**

19. For the ground state of H_2 atom, calculate the following quantities for the orbiting electron : (1) Radius of orbit, (2) Linear momentum, (3) Angular momentum, (4) K. E. (5) P. E., (6) Total energy.

(0.532 A°, 1.98×10^{-24} kg m/s; 1.056×10^{-34} kg m^2/s;13.53 eV; -27.06 eV; – 13.53 eV)

20. The electron in the H_2 atom jumps from state $n = 1$ to state $n = 3$. Find the energy absorbed by the electron. What is the frequency of radiation emitted when the electron returns to the initial state? **(12.09 eV; 2.92×10^{15} Hz)**

21. Find the energy absorbed by electron in the ground state of the H_2 atom when it is raised to the state $n = 4$. What wavelength does it emit when it returns to the ground state? **(12.75 eV; 975 A°)**

22. The H_β line of Balmer series of Hydrogen atom has a wavelength of 4860 A° Find the wavelength and the wave number of H_α line. **(6561 A°; 1.524×10^6 m^{-1})**

23. The H_α line in the Balmer series of Hydrogen has a wavelength of 6562.8 A°. Calculate the Rydberg constant. **(1.097×10^7 m^{-1})**

24. The first member of the Balmer series of Hydrogen atom has a wavelength of 6563 A°. Find the wavelengths of the second and third members of the same series. **(4861.5 A° and 4340.6 A°)**

25. Calculate the Rydberg constant for H_2 if the wavelength of the first member of the Lyman series is 1215 A°. Hence find the wavelength of the third member of the Balmer series. **(1.097×10^7 m^{-1}; 4339 A°)**

26. How much energy must be given to an electron in the level $n = 2$ of an H_2 atom so as to enable it to emit H_β line in the Balmer series? **(2.557 eV)**

27. In 1953, Humphrays discovered a new series of lines in the H_2 spectrum with $n_1 = 6$, $n_2 = 7, 8, 9, ...$ Find the frequency of the first line of this series. $R = 1.097 \times 10^7$ m^{-1} **(2.4×10^{13} Hz)**

28. Calculate the wavelength of the first member and the series limit of Lyman series of H_2 given $R_{H_2} = 1.096 \times 10^7$ m^{-1}. **(1217 A°; 912 A°)**

29. Taking the wavelength of H_α line is 6563 A°, calculate the wavelength of the first line of the Lyman series. **(1215.4 A°)**

30. The wavelength of the longest line of the Balmer series is 6560 A. U. Calculate the wavelength of the first line of (i) Lyman series (ii) Paschen series. **(1214.8 A°; 18742.8 A°)**

31. Calculate the smallest wavelength of the Paschen series. **(8204 A°)**

32. Calculate the energy of the photon emitted and the longest and the shortest wavelengths in the Balmer series of Hydrogen given $R = 1.097 \times 10^7$ m^{-1}. **(1.9 eV; 3.42 e V; 6563 A°; 3646 A°)**

33. Find the frequency and energy of the most energetic photon in the visible part of Hydrogen spectrum. **(3.291×10^{15} Hz ; 13.6 eV)**

34. The wavelength of H_α line of the Balmer series of H^2 is 6563 A°. Find (1) the wavelength of the Hz line of the series and (2) shortest wavelength of Brackett series. **(4340.6 A°; 14584.4 A°)**

35. The shortest wavelength line in the Lyman series is 912 A°. Find the shortest wavelength line in (1) Balmer series (2) Paschen series. **(3648 A°; 8208 A°)**

36. The energy of the electron in the ground state of Hydrogen is– 13.6 eV. Find the Rydberg constant and the wavelength of the first line of Paschen series. $e = 1.6 \times 10^{-19}$ C ; $h = 6.63 \times 10^{-34}$ J s. **(1.094×10^7 m^{-1}; 18.75×10^{-7} m)**

37. If the first member of the Lyman series is at 121.5 nanometres, calculate the wavelengths of the first members of Brackett and Paschen series.

(4050 nm, 1874.6 nm)

38. The series limit of the visible region in the hydrogen spectrum is 3646 A°. Calculate the longest wavelength of the series, its wave number and frequency. Find also the Rydberg constant.

(6563 A°; 1.524×10^6 m^{-1}; 4.57×10^{14} Hz; 1.097×10^7 m^{-1})

39. An H_2 atom is an excited state emits a photon of energy 12.73 eV. What is the wavelength of emitted light and in which region of the spectrum does it lie? $h = 6.63 \times 10^{-34}$ Js; $c = 3 \times 10^8$ m/s and 1 eV = 1.6×10^{-19} J.

(976.5 A°; Lyman series; ultraviolet)

40. Find the speed at which the electron in the ground state must revolve around the nucleus of a H_2 atom so as not to fall into the nucleus? $h = 6.63 \times 10^{-34}$ Js; $e = 1.6 \times 10^{-19}$ C. **(2.18×10^6 m/s)**

41. An electron transition occurs in hydrogen from $n = 4$ to $n = 2$ energy level. Given that the PE of the orbital electron in the 10^{th} stationary orbit is − 0.272 eV, find the wavelength of photon emitted. $h = 6.625 \times 10^{-34}$ Js; $c = 3 \times 10^8$ m/s; $e = 1.6 \times 10^{-19}$ C **(4871 A°)**

42. The wavelength of the first member of the Lyman series is 1215 A°. Find R and calculate the wavelength of the third member of the Balmer series.

(1.097×10^7 m^{-1}; 4341 A°)

43. The ionisation potential of H_2 atom when the electron is in the ground state is 13.6 eV. Find R. Given $h = 6.63 \times 10^{-34}$ Js; $e = 1.6 \times 10^{-19}$ C and $c = 3 \times 10^8$ m/s.

(1.094×10^7 m^{-1})

De Broglie Theory

1. What is the momentum of a photon of wavelength 6.63×10^{-7} m? **(10^{-27} kg ms^{-1})**

2. Find the de Broglie wavelength of (a) an electron with a KE of 144 eV and (b) a proton with a speed of 2×10^5 m/s. $M_p = 1.67 \times 10^{-27}$ kg. **(1.03 A°; 1.98×10^{-12} m/s)**

3. Calculate the de Broglie wavelength corresponding to a 50 keV electron. $e = 1.6 \times 10^{-19}$ C, $m = 9 \times 10^{-28}$ g, $h = 6.6 \times 10^{-34}$ J.s. **(0.055 A°)**

4. Find the de Broglie wavelength of a proton of energy 1 eV. Mass of proton = 1.673×10^{-27} kg **(2.865×10^{-11} m)**

5. If electrons in a T.V. picture tube are accelerated through 10000 volt, what is the de Broglie wavelength associated with these electrons? **(0.1229 A°)**

6. Through what voltage must an electron be accelerated so that its associated de Broglie wavelength is 0.15 A°? $h = 6.63 \times 10^{-34}$ Js; $m = 9.1 \times 10^{-31}$ kg. **(6700 V)**

7. Find the wavelength of electrons that have been accelerated from rest through a p.d. of (a) 10^2 V (b) 10^5 V. $h = 6.63 \times 10^{-34}$ J.s, $m = 9.11 \times 10^{-31}$ kg, 1 eV = 1.6×10^{-19} J. **[(a) 1.23 A° (b) 3.9×10^{-2} A°]**

8. What is the wavelength of de Broglie waves associated with a beam of electrons accelerated from rest by a P.D. of 1000 volt? Given specific charge on electron = 1.72×10^{11} C/kg, $h = 6.63 \times 10^{-34}$ Js and mass of electron = 9×10^{-31} kg. **(0.389 A.U.)**

9. Calculate de Broglie wavelength for a beam of neutrons of energy 0.10 eV. $h = 6.62 \times 10^{-34}$ Js, $M_n = 1.67 \times 10^{-27}$ kg. **(0.907 A°)**

10. Calculate the de Broglie wavelength of waves associated with an alpha particle of mass 6.62×10^{-24} g moving with a velocity of 8×10^{8} cm/s. **(1.25×10^{-14} m)**

11. The wavelength of a photon is 10^{-10} m and is the same as the de Broglie wavelength of an electron. Which has more kinetic energy? **(Photon 823 times)**

12. If a proton and an electron have the same KE, which particle has greater de Broglie wavelength? If both particles have the same de Broglie wavelength, which particle has greater KE? **(Electron; Electron)**

13. Show that for non-relativistic speed, the de Broglie wavelength λ associated with an electron accelerated from rest through a P.D. V volt can be written as $\lambda = \frac{12.26}{\sqrt{V}}$ A°. $h = 6.63 \times 10^{-34}$ Js. mass of electron $= 9 \times 10^{-31}$ kg and $e = 1.6 \times 10^{-19}$ C.

14. An electron of mass m when accelerated through a P.D. of V volt has a de Broglie wavelength λ. Show that the de Broglie wavelength associated with a proton of mass M accelerated through the same P.D. is $\lambda\sqrt{\frac{m}{M}}$.

15. Find the P.D. through which an electron should be accelerated from rest so that de Broglie wavelength associated with the electron is 0.5 A°. **(603.8 V)**

16. Calculate the de Broglie wavelength of the electron in the ground state of H_2 atom. Radius of electron orbit in the ground state of H_2 atom is 0.5 A°. What would be the de Broglie wavelengths of the electron when in the states $n = 3$ and $n = 4$?

(Hint : $\lambda = \frac{h}{mv}$ and in an orbit $mvr = \frac{hn}{2\pi}$. For H_2 atom, radius of orbit varies as n^2)
(3π A°; 4π A°)

17. Calculate the frequency and wave number of H_α line in the Balmer series of H_2.
(4.572×10^{14} Hz; 1.524×10^{6} m^{-1})

18. Find the minimum wave number of the spectral line in the Balmer series of H_2.
(1.52×10^{6} m^{-1})

19. What is the de Broglie wavelength of an electron when in the second orbit of H_2 atom? Radius of orbit of electron when in the ground state is 0.5 A°. **(6.28 A°)**

20. Obtain Bohr's quantisation condition on angular momentum of electron in H_2 atom on the basis of de Broglie theory.

(Hint : $p = \frac{h}{\lambda} = \frac{h}{2\pi r}$. $\therefore p = \frac{nh}{2\pi r}$. Hence the condition).

21. The de Broglie wavelength of a particle of kinetic energy E is λ. For a similar particle of kinetic energy E/4, what would the de Broglie wavelength be? **(2 λ)**

22. An electron has a de Broglie wavelength of 0.5 A°. What is its velocity and momentum? What is the P.D. required to accelerate the electron from rest to this velocity?

$m = 9.1 \times 10^{-31}$ kg ; $e = 1.6 \times 10^{-19}$ C and $h = 6.63 \times 10^{-34}$ Js.
(1.457×10^{7} m/s; 1.326×10^{-19} kg m^2/s; 604V)

23. If a photon and a particle of mass M have the same de Broglie wavelength λ, show that the ratio of photon energy to the KE of the particle is $\frac{2 \lambda M c}{h}$.

24. When light of wavelength λ is incident on a photoemitting surface, the electrons emitted have a de Broglie wavelength λ_1. Assuming that the work function of surface is negligible, show $\lambda = \left(\frac{2 m c}{h}\right) \lambda_1^2$.