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Structure of Atom

Important Questions

- Theory based
- Numerical based

With Answers

Structure of Atom Important Questions Theory based

Q1. Define the term wavelength.

Q2. What is meant by electromagnetic nature of light?

Q3. Define the term frequency.

Q4. What is the speed of light in vacuum?

Q5. Give the significance of principal quantum number.

Q6. Give the significance of azimuthal quantum number.

Q7. Give the significance of magnetic quantum number.

Q8. Give the significance of spin quantum number.

Q9. (a) An atomic orbital has $n=3$. What are the possible values of l ?

(b) An atomic orbital has $l=3$. What are the possible values of m ?

Q10. The line spectrum observed when electrons fall from higher quantum levels to L level is referred to as (a) Balmer series (b) Lyman series (c) Paschen series (d) Brackett series

Q11. Define the term black body and black body radiation.

Q12. Define the tern photoelectric effect.

Q13. Write the Bohr rule relating the energy difference to the frequency of radiation.

Q14. What is the energy of lowest energy level of hydrogen atom?

Q15. Write the mathematical expression of de Broglie equation.

Q16. State Aufbau principle.

Q17. State Heisenberg's Uncertainty Principle.

Q18. State Pauli's Exclusion Principle.

Q19. State Hund's Rule of Maximum Multiplicity.

Q20. Name the four quantum numbers.

Q21. Arrange s, p and d sub-shells of a shell in the increasing order of effective nuclear charge experienced by the electron present in them.

Q22. Nickel atom can lose two electrons to form Ni^{2+} ion. The atomic number of nickel is 28 . From which orbital will nickel lose two electrons?

Q23. Which of the following orbitals are degenerate?

$$3d_{xy}, 4d_{xy}, 3d_{z^2}, 3d_{yz}, 4d_{yz}, 4d_{z^2}$$

Q24. Write the electronic configuration of Cu^{+} (At. No. Cu = 29)

Q25. Describe the orbital with $n=4$ and $l=0$.

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^1$

Q26. Write the electronic configuration of Cr^{3+} (Atomic number of Cr = 24).

Q27. Explain Thomson model of atom.

Q28. Write the properties of Cathode rays.

Q29. Give the general mathematical expression (Balmer formula for calculation of wavenumber ($\bar{v}$) when the one electron of hydrogen is exited from one orbit to another.

Q30. The electronic configuration of valence shell of Cu is $3d^{10}4s^1$ and not $3d^9 4s^2$. How is this configuration explained?

Q31. What is the total number of orbitals associated with the principal quantum number $n = 3$?

Q32. Give the drawbacks of Rutherford's atomic model.

Q33. What is $(n + l)$ rule? Explain it with an example.

Q34. The arrangement of orbitals on the basis of energy is based upon their $(n + l)$ value. Lower the value of $(n + l)$, lower is the energy. For orbitals having same values of $(n + l)$, the orbital with lower value of n will have lower energy.

I. Based upon the above information, arrange the following orbitals in the increasing order of energy.

(a) $1s, 2s, 3s, 2p$ (b) $4s, 3s, 3p, 4d$

(c) $5p, 4d, 5d, 4f, 6s$ (d) $5f, 6d, 7s, 7p$

II. Based upon the above information, solve the questions given below :

(a) Which of the following orbitas has the lowest energy?

$4d, 4f, 5s, 5p$

(b) Which of the following orbital has the highest energy?

$5p, 5d, 5f, 6s, 6p$

Q35. What designation is given to a subshell having (i) $n = 2,1 = 0$; (ii) $n = 4,1 = 1$; (iii) $n = 4,1 = 2$ $n = 4,1 = 3$?

Q36. (a) What are degenerate orbitals? Give examples.

(b) Show that the circumference of the Bohr's orbit for H atom is an integral multiple of de Broglie's wavelength associated with the electron revolving around the orbit.

Q37. (a) Mention the difference between electromagnetic wave theory and Planck's quantum theory.

(b) How many electron can have quantum number values $n = 4, m_s = \frac{1}{2}$?

Q38. What the different line spectrum are obtained in the case of hydrogen atom?

Q39. Write in detail about the postulates of Bohr's atomic model of hydrogen atom. atom:

Q40. The ionization energy of He^+ is 19.6×10^{-18} J atom $^{-1}$. Calculate the energy of the first stationary state of Li^{2+}.

Q41. Draw (a) a plot between orbital wave function $\psi(r)$, (b) the variation of probability density $\psi^2(r)$ as function of distance r of the electron from the nucleus for 1 s and 2 s orbitals.

Q42. What is the lowest value of n that allows g orbitals to exist?

Q43. The unpaired electrons in Al and Si are present in 3p orbital. Which electrons will experience more effective nuclear charge from the nucleus?

Q44. Indicate the number of unpaired electron in: (a) P (b) Si (c) Cr (d) Fe (e) Kr

Q45. (a) How many sub-shells are associated with $n = 4$?

(b) How many electrons will be present in the sub-shell having m_s value of $-\frac{1}{2}$ for $n = 4$?

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Structure of Atom Important Questions Numerical based

Q1. Calculate (a) wavenumber and (b) frequency of yellow radiation having wavelength 5800Å.

Q2. Derive de Buglie's equation.

Q3. Calculate energy of one mole of photons of radiation whose frequency is 5×10^{14} Hz.

Q4. What is the wavelength of light emitted when the electron in a hydrogen atom undergoes transition an energy level with $n = 4$ to an energy level with $n = 2$?

Q5. A 100-watt bulb emits monochromatic light of wavelength 400 nm. Calculate the number of photons emitted per second by the bulb.

Q6. The threshold frequency v_0 for a metal is $7.0 \times 10^{14}\ s^{-1}$. Calculate the kinetic energy of an cmittat when matiation of froquency $v = 1.0 \times 10^{15}\ s^{-1}$ hits the metal.

Q7. Calculate the energy associated with the first orbit of He^+. What is the radius of this orbit?

Q8. What will be the wavelength of a ball of mass 0.1 kg moving with a velocity of $10\ m\ s^{-1}$?

Q9. The mass of an electron is 9.1×10^{-31} kg. If its K.E. is 3.0×10^{-25} J, calculate its wavelength.

Q10. A microscope using suitable photons is employed to locate an electron in an atom within a distance of 0.1Å. What is the uncertainty involved in the measurement of its velocity?

Q11. According to de Broglie, matter should exhibit dual behavior, that is both particle and wave like properties. However, a cricket ball of mass 100 g does not move like a wave when it is thrown by a bowler at a speed of 100 km/h. Calculate the wavelength of the ball and explain why it does not show wave nature.

Q12. Calculate the wavelength and energy of radiation emitted for the electronic transition from infinity to stationary state of the hydrogen atom.
[Given $R = 1.09677 \times 10^7\ m^{-1}$]

Q13. (a) What is the green light)

(a) What is the shape of : (i) an s-orbital (ii) a p-orbital and (iii) d-orbitals

(b) Which of the following orbitals are spherically symmetric? (i) p_x (ii) s (iii) p_y.

Q14. What is the number of photons of light with a wavelength of 4000 pm that provide 1J of energy?

Q15. A 25 watt bulb emits monochromatic yellow light of wavelength $0.57\mu m$. Calculate the rate of emission of quanta per second.

Q16. The electron energy in hydrogen atom is given by $E_n = \left(-2.18 \times 10^{-18}\right) / n^2 J$. Calculate the energy required to remove an electron completely from the n = 2 orbit. What is the longest wavelength of light in cm that can be used to cause this transition?

Q17. The work function for cesium atom is

1.9 eV. Calculate

(a) the threshold wavelength and

(b) the threshold frequency of the radiation.

If the cesium element is irradiated with a wavelength 500 nm, calculate the kinetic energy and the velocity of the ejected photoelectron.

Theory based- Answers

1. Wavelength is defined as the distance between

two neighboring or consecutive crests or troughs of a wave. It is denoted by Greek letter (λ) and is expressed in Å or m or cm or nm (nanometer) or pm (picometer). $1Å = 10^{-8}$ cm $= 10^{-10}$ m, 1 nm $= 10^{-9}$ m, 1pm $= 10^{-12}$ m. See figure 2.15 below :

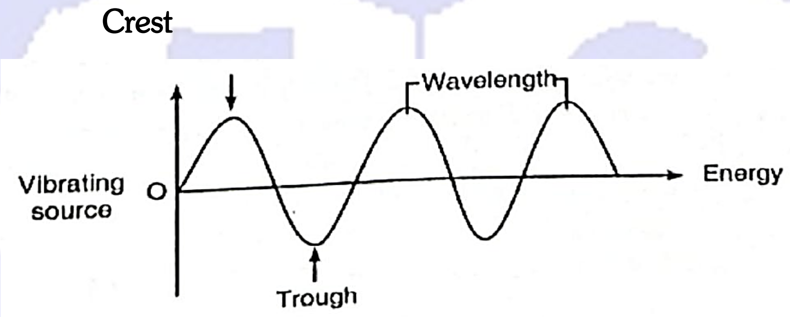

Fig. 2.15 Wave motion

2. Ans. Light may be described as electromagnetic waves or radiations as it is associated with both electric hand magnetic fields.

3. Ans. Frequency is defined as the number of waves which passes a given point in one second, it is denoted by Greek letter

simply s^{-1}. 1 Hz = 1 cycle s^{-1}.

4. Ans. The speed of light has been found to be constant in vacuum and its value 3.0×10^8 m s^{-1}

5. Ans. (i) This represents the shape of the orbital i.e., whether the cloud is spherical, dumb-bell or even more complicated.

(ii) l can have values from 0 to $(n-1)$.

(iii) The orbitals with $l = 0,1,2$ and 3 are respectively called s, p, d and f orbitals.

6. Ans. (i) It refers to the number of way in which an orbitals can be arranged in space relative to X, Y, Z co-ordinates. It is represented by m.

(ii) The permitted value of m are dependent upon l. For a given value of l, m can have values $-l$ and $+l$ including zero.

7. Ans. (i) It indicates the direction in which the electron is spinning about its own axis. It is denoted by s.

(ii) Conventionally clockwise spin is represented by (↑) and anticlockwise by (↓).

(iii) There are only two possible values of this quantum number namely $+1/2$ (for clockwise) and $-1/2$ (for anticlockwise).

8. Ans. (a) When $n = 3$, the possible values of l are 0,1,2.

(b) When $l=3$, the possible values of m are
$-3,-2,-1,0,1,2,3$.

9. Ans. (a) Balmer series.

10. Ans. An ideal body, which emits and absorbs all frequencies, is called a black body and the radiation emitted by the betimes the term photoelectric effect.

11. Ans. It is the phenomenon in which the surface of alkali metals (e.g., Na, K) having low ionization cnergy emit electrons, when a beam of light with high frequency falls on it. The ejected electrons are called photoelectrons.

12. Ans. The above relation may be written as:

$$\begin{aligned} E_2 - E_1 &= h\mathrm{v} \\ \text{or} \quad \Delta E &= h\mathrm{v} \end{aligned}$$

where $h=$ Planck's constant $(6.626 \times 10^{-34}$ J s) and $v=$ frequency of a photon emitted or absorbed.

13. Ans. It will be -1312 kJ mol^{-1} as the value of $n=1$ in this case.

14. Ans. $\lambda=h/p=h/mv$.

15. Ans. Aufbau principle states that electrons enter the various orbitals to their respective capacities in increasing order of energy. The filling takes place as given below:

$$1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, 5s, 4d, 5p, 6s, 4f, 5d, 6p, 7s, 5f, 6d, 7p$$

16. Ans. It is impossible to determine simultaneously the exact position and exact velocity of an electron

17. Ans. It states that "two electrons in the same atom cannot have all the set of four quantum numbers identical".

18. Ans. It states that "when several orbitals of the same type are available, the electrons first fill all the orbitals singly with parallel spins, before pairing in anyone orbital takes place".

19. Ans. The four quantum numbers are:

(i) Principal quantum number (n)

(ii) Azimuthal or subsidiary or orbital quantum number (l)

(iii) Magnetic quantum number (in)

(iv) Spin quantum number (s).

20. Ans. Increasing order of effective nuclear charge $\left(Z_{\text{eff}}\right)$ is given as under :

$$d<p<s$$

21. Ans. Nickel will lose two electrons from $4s$ orbital.

22. Ans. The following combinations are degenerate:

$3d_{xy}, 3d_{z^2}, 3d_{yz}$
$4d_{xy}, 4d_{yz}, 4d_{z^2}$

23. Ans. Cu^+has the following electronic configuration:

24. Ans. 4s orbital.

25. Ans. No. of electrons = 29

No. of protons = 29

The element is copper. The electronic configuration of the element is

$$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^1$$

26. Ans. Cr^{3+} has the following electronic configuration:

$$1s^2 2s^2 2p^6 3s^2 3p^6 3d^3$$

27. Ans. J. J. Thomson in the year 1898 proposed a model of an atom which consists of a uniform sphere (radius approx. 10^{-10} m) having electrons embeded into it in such a way to give the most stable electrostatic arrangement. See Fig. 2.16 below:

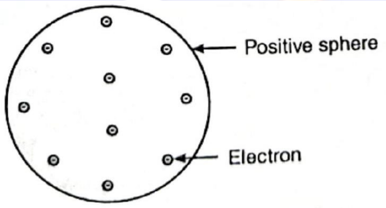

Fig. 2.16 Thomson model of atom

In this model atom is visualized as a cake of positive charge with raisins (electrons) embedded into it. This model is, therefore, sometimes called the resin pudding model.

28. Ans, (i) The Cathode rays travel in straight lines,

(ii) The cathode rays can penetrate a thin sheet of metal.

(iii) The cathode rays can cause mechanical movement and they move in a direction aba from the cathode.

(iv) A beam of Cathode rays is deflected by an external magnetic field in a direction both right angles to the direction of the beam and the direction of the lines of forces of the magnetic field.

(v) A beam of cathode rays is deflected by an electrical field again in a direction indicating is negative nature.

(iv) Cathode rays cause fluorescence, when they impinge on substances like ZnS.

(vii) The properties of the cathode rays are independent of the nature of the cathode materials

29. Ans. The mathematical expression is given as:

$$\frac{1}{\lambda}\ \bar{\nu}(\text{cm}^{-1}) = 109{,}677\left(\frac{1}{n_i^2} - \frac{1}{n_j^2}\right)\text{cm}^{-1}$$

Where λ = wavelength, $\bar{\nu}$ = wavelength.

109,677 a Rydberg constant and n_1 and n_2 the number of orbits.

30. Ans. Completely filled and half-filled orbitals have extra stability.

In $3d^{10}4s^1$, d-orbital is completely filled and s-orbital is half-filled. So it is more stable configuration.

31. Ans. For $n = 3$, the possible values of I are 0,1 and 2 .

Thus, there is one 3 s orbital $(11 = 3,1 = 0$ and $m = 0)$

There are three $3p$ orbitals $(n = 3,1 = 1$ and $m_1 = -1,0,+1)$: there are five $3d$ orbitals $(n = 3\ l = 2$ and $m_l = -2,-1,0,+1,+2)$.

Therefore, the total number of orbitals is $1 + 3 + 5 = 9$.

The same value can also be obtained by using the relation; number of orbitals $= n^2$, i.e., $3^2 = 9$

32. Ans. Drawbacks of Rutherford's atomic model:

(i) According to Rutherford's model, electrons are orbiting the nucleus; hence, the direction of their velocity is constantly changing, i.e., the electrons are accelerating. This will cause the electrons to emit or radiate energy; and consequently, the electrons will have lesser and lesser energy and will get closer and closer to the nucleus, until at last it spirals into the nucleus. See Fig. 2.19 below:

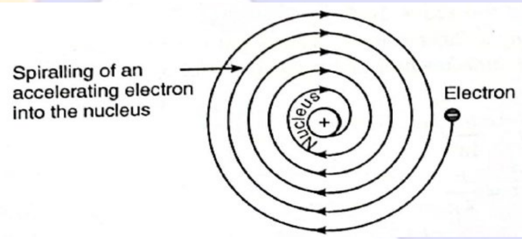

Fig. 2.19 Spiralling of an accelerating electron into the nucleus with progressive loss of energy.

(ii) An electron moving inward along a spiral path must continuously radiate energy. However, in actual practice spectral lines of fixed wavelength are observed.

33. Ans. According to this the new electron enters that orbital where $(n + l)$ has minimum value. However, if $(n + l)$ is the same in two or more cases, the new electron would enter where n is minimum.

Example: Suppose, we want to know whether a new electron would enter $2p$ or $3s$ orbital. The value of $(n + l)$ is $(2 + 1) = 3$ for $2p$ orbital, and $(3 + 0) = 3$ for $3s$-orbital, that is 3 in each case. However, n is lower in case of $2p$ orbital, thus, the new electron would enter $2p$-orbital and not $3s$-orbital.

34. Ans. I. (a) $1s < 2s < 2p < 3s$

(b) $3s < 3p < 4s < 4d$

(c) $4d < 5p < 6s < 4f < 5d$

(d) $7s < 5f < 6d < 7p$

II. (a) $5s$ (b) $5f$

35. Ans. (i) $2s$, (ii) $4p$, (iii) $4d$ and (iv) $4f$.

36. Ans. (a) Orbitals which possess equal energies are calle degenerate. Similarly
and $2p_z$ orbitals which are oriented along X, Y and Z axes are de
$d_{yz} d_{zx}, d_{x^2} - y^2$ and $d_z 2$ are degenerate orbitals.

(b) The angular momentum of an electron in a given stationary state can be expressed

or

$$mvr = n\frac{h}{2\pi} \text{ where } n = 1,2,3, \ldots \text{ (Bohr equation)}$$

But

$$\frac{h}{mv} = \lambda(\text{ de Broglie equation})$$

From the two equations, we have

$$2\pi r = n\lambda$$

or circumference of Bohr orbit $= n\lambda$

Thus, we can say that circumference of Bohr's orbit is an integral multiple of de Broglie wavelength

Ond theory.

37. Ans. (a) Electromagnetic wave theory : When an electrically charged particle moves under acceleration, alternating electrical and magnetic fields are produced and transmitted. These fields an transmitted in the form of waves called electromagnetic waves. The electric and magnetic fields produces are perpendicular to each other and both are perpendicular to the direction of propagation of the wave.

Planck's quantum theory : When solids are heated, they emit radiations over a wide range of wavelengths. The radiation emitted goes from a lower frequency to a higher frequency as the temperature is increased. Planck gave the name to the smallest quantity of energy that can be absorbed or emitted

(b) When $n = 4$, we have one s, three p, five d and seven f orbital. That means a total of $2(1 + 3 + 5 + 7) = 32$ electrons 16 of them will have $m_s = +\frac{1}{2}$.

38. Ans. When the energy is given to hydrogen atom, electron gets excited and jump to a higher energy level by absorbing energy. When the excited electron returns to lower energy level, it emits men's in the form of light of certain frequency and thus give rise to line spectrum Lyman series of spectral lines are observed when electron jumps from the energy level 2nd, 3rd, the ctiv, to the first energy level.

Bulmer series is obtained when electron jumps from the energy level 3rd, 4 th, 5 th etc. to 2 nd mengy level. Similarly, Paschen, Bracket and Pfund series of spectral lines are obtained. See Fig. 2.22 below:

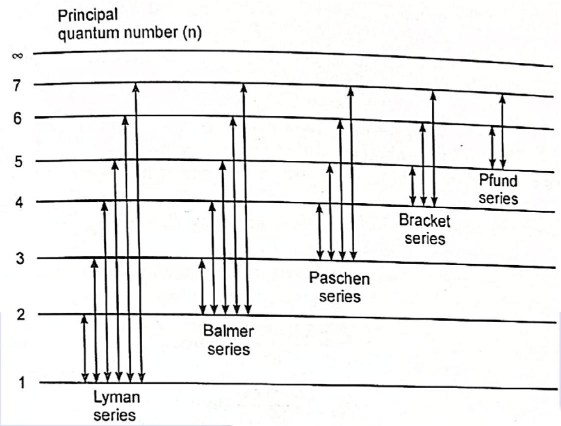

Fig. 2.22 Spectrum of hydrogen atom

39. Ans. Bohr's (1913) applied quantum theory and gave the following postulates for hydrogen

(i) an atom consists of positive charged central core called nucleus and the electrons revolve. specific permitted circular orbits.

(ii) while in these specific orbits, an electron does not radiate or absorb energy. (iii) the angular momentum of an electron orbiting around the nucleus is an integral multiple,

of Planck's constant divided by 2π. Mathematically,

$$\text{Angular momentum } = m_e v r = \frac{nh}{2\pi}.$$

(iv) an electron can jump from one energy level to another by absorption or emission of energy.

(v) the energy absorbed or emitted, when an electron jumps to a higher level or to a lower energy level, is equal to the difference in energies of initial and final states i.e.,

$$\Delta E = E_{\text{final}} - E_{\text{initial}}$$

(vi) the frequency of emitted or absorbed radiation, when an electron jumps from one energy: level to another is given by Planck's relation.

$$\begin{aligned} \Delta E &= hv \\ \text{or} \quad E_2 - E_1 &= hv_2 - hv_1 = hv \end{aligned}$$

where v is the frequency of photon emitted or absorbed.

(vii) Bohr's model of an atom is successful in the case of hydrogen and hydrogen like atoms.

(viii) the energy of an electron in the orbit is given by $E_n = \frac{-2\pi^2 m_e Z^2 e^4}{n^2 h^2}$

If the values of m_e, e, h and π are substituted in the equation the energy of ground state works out to be

$$\begin{aligned} E_1 &= \frac{-2.18 \times 10^{-18}\ \mathrm{J}^2\ \text{atom}^{-1}}{n^2} \\ &= -\frac{13.595\mathrm{eV}}{n^2}\ \text{atom}^{-1} \end{aligned}$$

(ix) the radius of the orbit of hydrogen atom is given by

$$r_n = \frac{-0.529\text{Å}(n^2)}{Z}$$

where Z is the atomic number and n is the number of the orbit.

(x) the Bohr model of hydrogen atom is applicable to hydrogen atom as well as hydrogen like atoms e.g., $\text{He}^+, \text{Li}^{2+}$ etc., where value of $Z = 2$ for He and $\text{Z} = 3$ for Li.

40. Ans. According to Bohr's atomic postulates (vii) above, it is applicable to hydrogen and hydrogen atoms. like atoms.

In this question $\text{He}^+$and Li^{2+} are like hydrogen atom.

And $(E_{\text{H}^+}) = -Z_{\text{He}}^2 \times$ constant

[Postulate no. (viii)]

$\therefore\ (E_{\text{Li}^{2+}}) = -\text{Z}_{\text{Li}}^2 \times$ constant

$\therefore$ Energy of the first orbit of Li^{2+},

$$(E_{\text{Li}^{2+}}) = \frac{Z_{\text{Li}}^2}{Z_{\text{He}}^2} \qquad Z \text{ for Li} = 3, \quad \text{Z for He} = 2$$

$$= \frac{3^2}{2^2} \times 19.6 \times 10^{-18}\text{Jatom}^{-1}$$

$$= 44.1 \times 10^{-18}\ \text{J atom}^{-1}.$$

41. Ans. See Fig 2.26 below:

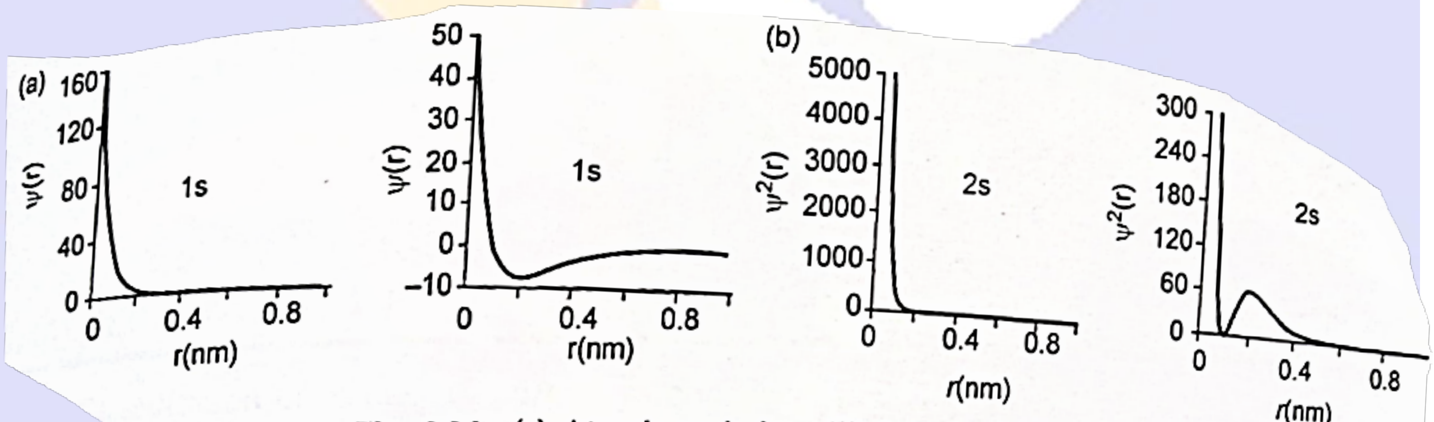

Fig. 2.26 (*a*) Atomic emission, (*b*) Atomic absorption

Fig. 2.26 (a) Atomic emission, (b) Atomic absorption

42. Sol. For g subshell l = 4 and to have l = 4 minimum value of n = 5

[because the value of l = 0 to (n – 1)]

43. Sol.

$_{13}\text{Al} = 1s^2, 2s^2, 2p^6, 3s^2, 3p^1$

$_{14}\text{Si} = 1s^2, 2s^2, 2p^6, 3s^2, 3p^2$

Si (+4) has greater nuclear charge than aluminium (+3).
Hence, 3p unpaired electrons of Si experience greater effective nuclear charge than Al.

44. Sol.

(a)	${}_{15}P = 1s^2, 2s^2, 2p^6, 3s^2, 3p^3$	3 unpaired electrons
(b)	${}_{14}Si = 1s^2, 2s^2, 2p^6, 3s^2, 3p^2$	2 unpaired electrons
(c)	${}_{24}Cr = 1s^2, 2p^6 3s^2, 3p^6, 3d^5, 4s^1$	6 unpaired electrons
(d)	${}_{26}Fe = 1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^6, 4s^2$	4 unpaired electrons
(e)	${}_{36}Kr = 1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^{10}, 4s^2, 4p^6$	No unpaired electrons

45. Sol. (a) $n = 4, l = 0, 1, 2, 3,\ s\ p\ d\ f\ (4\ \text{subshells})$

(b) Number of orbitals in 4th shell $= n^2 = 4^2 = 16$
The maximum number of electrons present in any orbital is two and each orbital has one electrons with $m_s = -\frac{1}{2}$. Hence, there are 16 electrons with $m_s = -\frac{1}{2}$.

Numerical based - Answers

1. Ans. (a) Calculation of wavenumber ($\bar{v}$)

We know: $\bar{v}=\frac{1}{\lambda}$

Given: $\lambda=5800\text{Å}=5800\times10^{-8}\ \text{cm}=5800\times10^{-10}\ \text{m}$

Substituting the given values in above equation, we get

$$\begin{aligned}&=\frac{1}{5800\times10^{-10}\ \text{m}}\\&=1.724\times10^{6}\ \text{m}^{-1}\\&=1.724\times10^{4}\ \text{cm}^{-1}\end{aligned}$$

(b) Calculation of the frequency (v)

$$\begin{aligned}v&=\frac{c}{\lambda}=\frac{3\times10^{8}\ \text{m s}^{-1}}{5800\times10^{-10}\ \text{m}}\\&=5.172\times10^{14}\ \text{s}^{-1}\end{aligned}$$

2. Ans. We know:

and

$$\begin{aligned}&E=M^{2}\ \text{(Iinsteln's equation)}\\&E=\text{IN}=\frac{\text{lic}}{\lambda}\ \text{(Irom Planck's quantum theory)}\end{aligned}$$

Equating (i) and (ii), we get

or

$$\begin{aligned}mc^{2}&=\frac{m}{\lambda}\\\lambda&=\frac{l}{mc}=\frac{l}{p}\ (\because mc=\text{p})\end{aligned}$$

3. Ans. We know :

$$E\equiv\text{hv}$$

Substituting the given values, we get

$$\begin{aligned}E&=6.626\times10^{-34}\ \text{J s},\text{v}=5\times10^{14}\ \text{s}^{-1}\\&=(6.626\times10^{-34}\ \text{J s})\times(5\times10^{14}\ \text{s}^{-1})\\&=3.313\times10^{-19}\ \text{J}\end{aligned}$$

Energy of one mole of photons

$$\begin{aligned}&=(3.313\times10^{-19}\ \text{J})\times(6.022\times10^{23}\ \text{mol}^{-1})\\&=199.51\ \text{kJ mol}^{-1}.\end{aligned}$$

4. Ans. $\bar{v}=1.09677\times10^{7}\left(\frac{1}{4^{2}}-\frac{1}{2^{2}}\right)\text{m}^{-1}$

or

$$\bar{\nu} = 1.09677 \times 10^7 \left(\frac{1}{16} - \frac{1}{4}\right) \mathrm{m}^{-1}$$

or

$$\bar{\nu} = 1.09677 \times 10^7 \left(-\frac{3}{16}\right) \mathrm{m}^{-1}$$

or $\bar{\nu} = 2.0564 \times 10^6\ \mathrm{m}^{-1}$ (Ignoring negative sign)

5. Ans. Power of the bulb = 100 watt = $100\ \mathrm{J\ s^{-1}}$

Energy of one photon $E = h\nu = \frac{hc}{\lambda}$

$$= \frac{6.626 \times 10^{-34}\ \mathrm{J\ s} \times 3 \times 10^8\ \mathrm{m\ s^{-1}}}{400 \times 10^{-9}\ \mathrm{m}}$$
$$= 4.969 \times 10^{-19}\ \mathrm{J}$$

Number of photons emitted $= \frac{100\ \mathrm{J\ s^{-1}}}{4.969 \times 10^{-19}\ \mathrm{J}} = 2.012 \times 10^{20}\ \mathrm{s^{-1}}$.

6. Ans. We know :

$$\text{K.E.} = \frac{1}{2} m_e v^2 = h(\nu - \nu_0)$$
$$= (6.626 \times 10^{-34}\ \mathrm{J\ s})(1.0 \times 10^{15}\ \mathrm{s^{-1}} - 7.0 \times 10^{14}\ \mathrm{s^{-1}})$$
$$= (6.626 \times 10^{-34}\ \mathrm{J\ s})(10.0 \times 10^{14}\ \mathrm{s^{-1}} - 7.0 \times 10^{4}\ \mathrm{s^{-1}})$$
$$= (6.626 \times 10^{-34}\ \mathrm{J\ s}) \times (3.0 \times 10^{14}\ \mathrm{s^{-1}})$$
$$= 1.988 \times 10^{-19}\ \mathrm{J}$$

7. Ans. Using: $E_n = -\frac{(2.18 \times 10^{-18}\ \mathrm{J}) Z^2}{n^2}$ atom $^{-1}$

For $He^+, n = 1, Z = 2$

or

$$E_1 = -\frac{2.18 \times 10^{-18}\ \mathrm{J} \times 2^2}{1^2} = -8.72 \times 10^{-18}\ \mathrm{J}$$

We know: $r_n = \frac{(0.0529\ \mathrm{nm}) n^2}{Z}$

Here $n = 1, Z = 2$

$\therefore\ r_n = \frac{(0.0529\ \mathrm{nm}) \times 1^2}{2} = 0.02645$ nm.

8. Ans. Using : $\lambda = \frac{h}{mv} = \frac{6.626 \times 10^{-34}\ \mathrm{J\ s}}{0.1\ \mathrm{kg} \times 10\ \mathrm{m\ s^{-1}}} = 6.626 \times 10^{-34}$ m.

9. Ans. Since K.E. $= \frac{1}{2} mv^2$

Now,

$$v = \left(\frac{2\text{ K.E.}}{m}\right)^{\frac{1}{2}} = \left(\frac{2 \times 3.0 \times 10^{-25}\text{ kg m}^2\text{ s}^{-2}}{9.1 \times 10^{-31}\text{ kg}}\right)^{\frac{1}{2}}$$
$$= 812\text{ m s}^{-1}.$$
$$\lambda = \frac{h}{mv} = \frac{6.626 \times 10^{-34}\text{ J s}}{(9.1 \times 10^{-31}\text{ kg})(812\text{ m s}^{-1})}$$
$$= 8967 \times 10^{-10}\text{ m} = 896.7\text{ nm}.$$

10. Ans. Using: $\Delta x \times \Delta p = \frac{h}{4\pi}$

or

$$\Delta x \times m\Delta v = \frac{h}{4\pi}$$

or

$$\Delta v = \frac{h}{4\pi\Delta x \times m}$$

Substituting the given values, we get

$$\Delta v = \frac{6.626 \times 10^{-34}\text{Js}}{4 \times 3.14 \times 0.1 \times 10^{-10}\text{ m} \times 9.11 \times 10^{-31}\text{ kg}}$$
$$= 0.579 \times 10^{7}\text{ m s}^{-1}(1\text{ J} = 1\text{ kg m}^2\text{ s}^{-2})$$
$$= 5.79 \times 10^{6}\text{ m s}^{-1}.$$

11. Ans. $\lambda = \frac{h}{mv}$

Here,

$$m = 100\text{ g} = 0.1\text{ kg}$$
$$v = \frac{100\text{ km}}{\text{h}} = \frac{100 \times 1000\text{ m}}{60 \times 60\text{ s}} = \frac{1000}{36}\text{ m s}^{-1}$$
$$h = 6.626 \times 10^{-34}\text{ J s}$$
$$\therefore \lambda = \frac{6.626 \times 10^{-34}\text{ J s}}{0.1\text{ kg} \times \frac{1000}{36}\text{ m s}^{-1}} = 6.626 \times 10^{-36} \times 36\text{ m}^{-1} = 238.5 \times 10^{-36}\text{ m}^{-1}$$

Since the wavelength is very small, the wave nature cannot be detected.

12. Ans. We know:

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

Given: $n_1 = 1$ and $n_2 = \infty$ and $R = 1.09677 \times 10^{7}\text{ m}^{-1}$

or

$$\frac{1}{\lambda} = 1.09677 \times 10^{7}\text{ m}^{-1}\left(\frac{1}{1^2} - \frac{1}{\infty^2}\right)$$
$$= 1.09677 \times 10^{7}\text{ m}^{-1}$$
$$\lambda = \frac{1}{1.09677 \times 10^{7}\text{ m}^{-1}} = 9.11 \times 10^{-8}\text{ m}$$

or

Also, energy,

$$\begin{aligned} E &= h\nu = \frac{hc}{\lambda} \\ &= \frac{6.6256 \times 10^{-34} \text{ J s} \times 3 \times 10^{8} \text{ m s}^{-1}}{9.11 \times 10^{-8} \text{ m}}. \\ &= 2.181 \times 10^{-18} \text{ J} \\ &= 2.181 \times 10^{-21} \text{ kJ}. \end{aligned}$$

13. Ans. (a) (i) An s-orbital is spherically symmetrical about the nucleus. See Fig. 2.23 below.

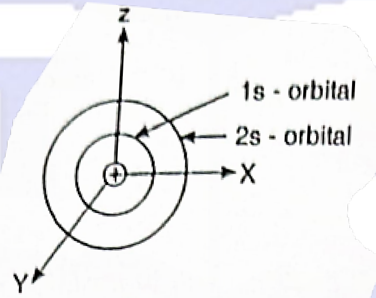

Fig. 2.23 Shape of *s*-orbital

(ii) A p-orbital is dumble shaped. The shapes of three p-orbitals are shown in Fig. 2.24 below:

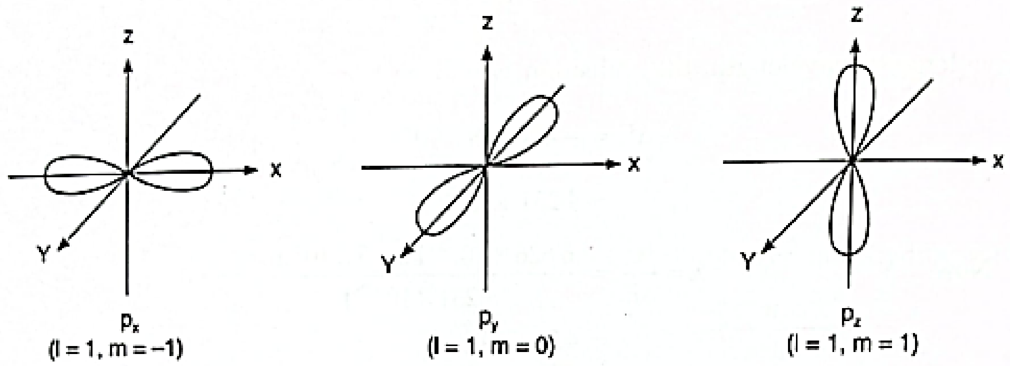

Fig. 2.24 Shape of *p*-orbitals

(iii) The five d-orbitals are designated as $d_{xy}, d_{yz}, d_{xz} d_{x^2} - y^2$ and d_z. The shapes of first four d-orbitals are similar to each other, whereas that of the fifth one, d_z is different from others, but all five d-orbitals are equivalent in energy. See Fig. 2.25 below :

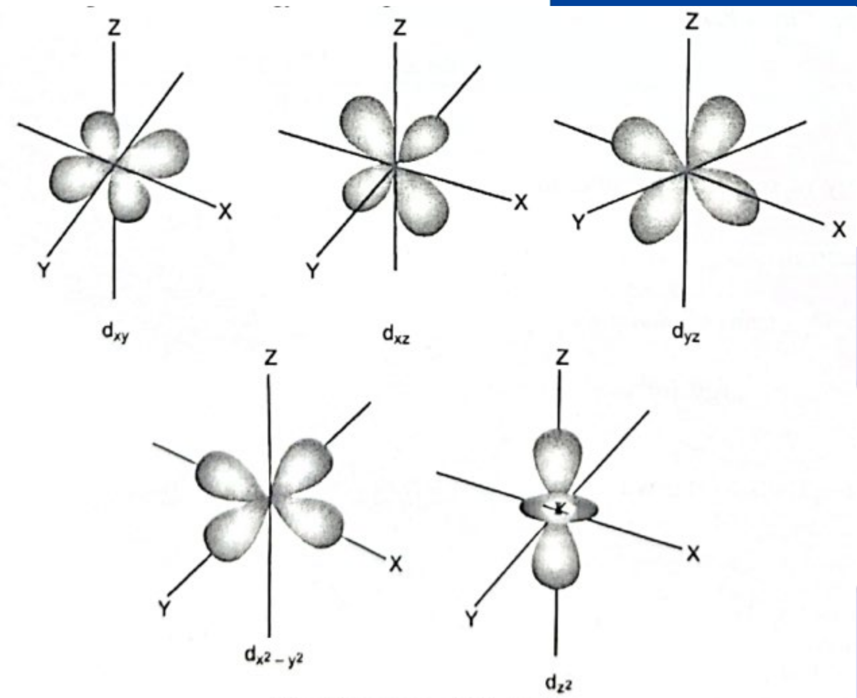

Fig. 2.25 Shape of *d*-orbitals

(c) s-orbital is spherically symmetrical.

14. Sol. Energy, $E = \frac{hc}{\lambda} = \frac{6.626 \times 10^{-34}\,Js \times 3.0 \times 10^{8}\,ms^{-1}}{4000 \times 10^{-12}\,m} = 4.9695 \times 10^{-17}\,J$

Number of photons,

$$N = \frac{1J}{4.9695 \times 10^{-17}\,J} = 2.0122 \times 10^{16}\,\text{photons}$$

15. Sol. $25\text{ watt} = 25Js^{-1}$

Wavelength, $\lambda = 0.57\mu m = 0.57 \times 10^{-6}\,m$

Energy of one photon,

$$E = \frac{hc}{\lambda} = \frac{6.626 \times 10^{-34}\,Js \times 3.0 \times 10^{8}\,ms^{-1}}{0.57 \times 10^{-6}\,m}$$

$E = 34.87 \times 10^{-20}\,J$

Number of photons emitted per second

$$= \frac{\text{Total energy per second}}{\text{Energy of one photon}}$$

$$= \frac{25Js^{-1}}{34.87 \times 10^{-20}\,J} = 0.7169 \times 10^{20}\ \text{photons per second}$$

7.169×10^{19} photons per second

16. Sol. Energy required to shift an electron from $n=2$ to $n=\infty$.

$$\Delta E = E_\infty - E_2 = 0 - \left(\frac{2.18\times10^{-18}\,J\,atom^{-1}}{2^2}\right)$$

$$= 0.545\times10^{-18}\,J\ atom^{-1} = 5.45\times10^{-19}\,J\ atom^{-1}$$

Wavelength, $\lambda = \frac{hc}{\Delta E} = \frac{6.626\times10^{-34}\,Js\times3.0\times10^{8}\,ms^{-1}}{5.45\times10^{-19}\,J}$

$$= 3.647\times10^{-7}\,m = 3.647\times10^{-5}\,cm$$

17. Sol. (a) Work function, $W_0 = h\nu_0$

$$W_0 = 1.9\,eV = 1.9\times1.602\times10^{-19}\,J$$

Threshold frequency, $\nu_0 = \frac{W_0}{h} = \frac{1.9\times1.602\times10^{-19}\,J}{6.626\times10^{-34}\,Js}$

$$\nu_0 = 4.59\times10^{14}\,s^{-1}$$

(b) Threshold wavelength, $\lambda_0 = \frac{c}{\nu_0} = \frac{3.0\times10^{8}\,ms^{-1}}{4.59\times10^{14}\,s^{-1}} = 6.536\times10^{-7}\,m$

$$= 653.6\times10^{-9}\,m = 653.6\,nm$$

(c) KE of ejected photoelectron $= h(\nu-\nu_0)$

λ of striking radiation $= 500\,nm = 500\times10^{-9}\,m$

$$\nu = \frac{c}{\lambda} = \frac{3.0\times10^{8}\,ms^{-1}}{500\times10^{-9}\,m} = 6.0\times10^{14}\,s^{-1}$$

$$KE = 6.626\times10^{-34}\,Js$$

$$\left(6.0\times10^{14}\,s^{-1} - 4.59\times10^{14}\,s^{-1}\right)$$

$$KE = 9.34\times10^{-20}\,J$$

(d) K.E. $= \frac{1}{2}m\upsilon^2 = 9.4\times10^{-20}\,J$

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$$= \frac{1}{2} \times 9.11 \times 10^{-31} \text{kg} \times v^2$$

$$\therefore \; v^2 = 2.050 \times 10^{11} \text{m}^2 \text{s}^{-2}$$

$$\text{or } v = \sqrt{20.50 \times 10^{10} \text{m}^2 \text{s}^{-2}}$$

$$\text{or } v = 4.527 \times 10^{5} \text{ms}^{-1}$$