STRUCTURE OF ATOM

2

MCQs with One Correct Answer

1. The potential energy of electron present in ground state of Li^{2+} ion is represented by :

(a) $\frac{+3e^2}{4\pi\varepsilon_0 r}$ (b) $\frac{-3e}{4\pi\varepsilon_0 r}$

(c) $\frac{-3e^2}{4\pi\varepsilon_0 r^2}$ (d) $\frac{-3e^2}{4\pi\varepsilon_0 r}$

2. Let m_p be the mass of a proton, m_n that of a neutron, M_1 that of a $^{20}_{10}Ne$ nucleus and M_2 that of a $^{40}_{20}Ca$ nucleus. Then

(a) $M_2 = 2M_1$
(b) $M_1 < 10(m_p + m_n)$
(c) $M_2 > 2M_1$
(d) $M_1 = M_2$

3. Which of the following pairs of nucleides are isodiaphers ?

(a) $^{13}_{6}C$ and $^{16}_{8}O$ (b) $^{1}_{1}H$ and $^{2}_{1}H$

(c) $^{3}_{1}H$ and $^{4}_{2}He$ (d) $^{55}_{25}Mn$ and $^{65}_{30}Zn$

4. Based on equation $E = -2.178 \times 10^{-18} J\left(\frac{Z^2}{n^2}\right)$, certain conclusions are written. Which of them is not correct ?

(a) Larger the value of n, the larger is the orbit radius.
(b) Equation can be used to calculate the change in energy when the electron changes orbit.
(c) For n = 1, the electron has a more negative energy than it does for n = 6 which mean that the electron is more loosely bound in the smallest allowed orbit.
(d) The negative sign in equation simply means that the energy or electron bound to the nucleus is lower than it would be if the electrons were at the infinite distance from the nucleus.

5. An electron in the ground state of hydrogen was excited to a higher energy level using monochromatic radiations of wave length (λ) 975 Å. The longest wave length that appears in the resulting spectrum is due to transition from:

(a) $n_4 \longrightarrow n_1$ (b) $n_4 \longrightarrow n_3$

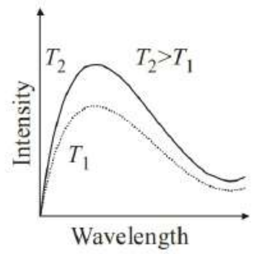
(c) $n_5 \longrightarrow n_4$ (d) $n_5 \longrightarrow n_1$

6. If m and e are the mass and charge of the revolving electron in the orbit of radius r for hydrogen atom, the total energy of the revolving electron will be:

(a) $\frac{1}{2}\frac{e^2}{r}$ (b) $-\frac{e^2}{r}$

(c) $\frac{me^2}{r}$ (d) $-\frac{1}{2}\frac{e^2}{r}$

7. The correct representation of wavelength intensity relationship of an ideal black body radiation at two different temperatures T_1 and T_2 is

(a)


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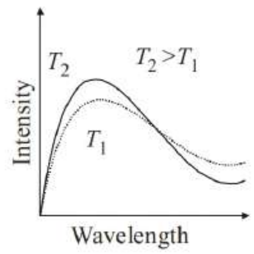

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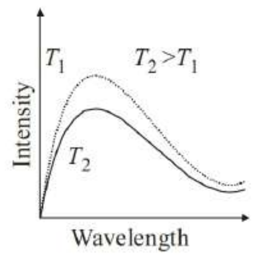

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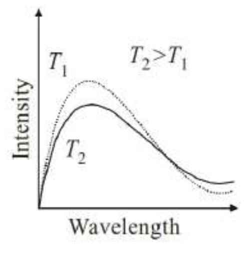


8. Among the following, the incorrect statement is

(a) No two electrons in an atom can have the same set of four quantum numbers

(b) The maximum number of electrons in the shell with principal quantum number, n is equal to $n^2 + 2$

(c) Electrons in an orbital must, have opposite spin

(d) In the ground state, atomic orbitals are filled in the order of their increasing energies

9. What transition in He^+ ion shall have the same wave number as the first line in Balmer series of H atom?

(a) $7 \rightarrow 5$ (b) $6 \rightarrow 4$

(c) $5 \rightarrow 3$ (d) $4 \rightarrow 2$

10. The velocity of an electron in excited state of H-atom is 1.093×10^6 m/s. What is the circumference of this orbit?

(a) 3.32×10^{-10} m (b) 6.64×10^{-10} m

(c) 13.30×10^{-10} m (d) 13.28×10^{-8} m

11. The angular momentum of an electron in a Bohr's orbit of He^+ is 3.1652×10^{-34} kg-m²/sec. What is the wave number in terms of Rydberg constant (R) of the spectral line emitted when an electron falls from this level to the first excited state. [Use $h = 6.626 \times 10^{-34}$ J · s]

(a) 3R (b) $\frac{5R}{9}$

(c) $\frac{3R}{4}$ (d) $\frac{8R}{9}$

12. A electron in a hydrogen atom in its ground state absorbs 1.5 times as much energy as the minimum required for it to escape from the atom. What is the velocity of the emitted electron?

(a) 1.54×10^6 m/s

(b) 1.54×10^8 m/s

(c) 1.54×10^3 m/s

(d) 1.54×10^4 m/s

13. For a multi-electron atom, the highest energy level among the following is

(a) $n = 5, l = 0, m = 0, s = +½$

(b) $n = 4, l = 2, m = 0, s = +½$

(c) $n = 4, l = 1, m = 0, s = +½$

(d) $n = 5, l = 1, m = 0, s = +½$

14. For Balmer series in the spectrum of atomic hydrogen, the wave number of each line is given by $\bar{v} = R_H \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$ where R_H is a constant and n_1 and n_2 are integers. Which of the following statement(s) is (are) correct?

I. As wavelength decreases, the lines in the series converge.

II. The integer n_1 is equal to 2.

III. The ionization energy of hydrogen can be calculated from the wave number of these lines.

IV. The line of longest wavelength corresponds to $n_2 = 3$.

(a) I, II and III
(b) II, III and IV only
(c) I, II and IV
(d) II and IV only

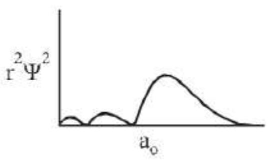
15. Calculate the minimum and maximum number of electrons which may have magnetic quantum number, m = +1 and spin quantum number, $s = -\frac{1}{2}$ in chromium (Cr):

(a) 0, 1 (b) 1, 2
(c) 4, 6 (d) 2, 3

16. The correct order of energy of 2*s*-orbitals in H, Li, Na and K, is

(a) K < Na < Li < H
(b) Na < Li < K < H
(c) Na < K < H < Li
(d) H < Na < Li < K

17. Which of the following radial distribution graphs correspond to $\ell = 2$ for the H atom ?

(a)


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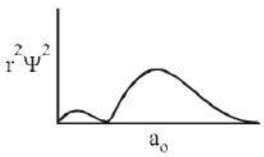

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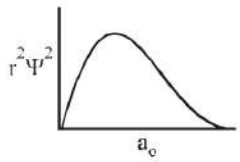

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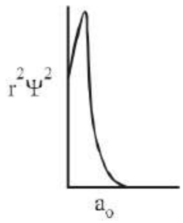


18. The electrons, identified by quantum numbers n and l,

(I) n = 3, ℓ = 2 (II) n = 5, ℓ = 0
(III) n = 4, ℓ = 1 (IV) n = 4, ℓ = 2
(V) n = 4, ℓ = 0 can be placed in order of increasing energy, as

(a) I < V < III < IV < II (b) I < V < III, II, IV
(c) V < I < III < II < IV (d) V < I < II < III < IV

18. The energies E_1 and E_2 of two radiations are 25 eV and 50 eV, respectively. The relation between their wavelengths i.e., λ_1 and λ_2 will be :

(a) $\lambda_1 = \lambda_2$ (b) $\lambda_1 = 2\lambda_2$
(c) $\lambda_1 = 4\lambda_2$ (d) $\lambda_1 = \frac{1}{2}\lambda_2$

19. Among the following, the correct statement about cathode ray discharge tube is

(a) the electrical discharge can only be observed at high pressure and at low voltages.
(b) in the absence of external electrical or magnetic field, cathode rays travel in straight lines.
(c) the characteristics of cathode rays depend upon the material of electrodes.
(d) the characteristics of cathode rays depend upon the gas present in the cathode ray tube.

20. A 600 W mercury lamp emits monochromatic radiation of wavelength 331.3 nm. How many photons are emitted from the lamp per second? $h = 6.62 \times 10^{-34}$ Js velocity of light = 3×10^8 ms^{-1}

(a) 1.0×10^{19} (b) 1.0×10^{23}
(c) 1.0×10^{21} (d) 2.0×10^{23}

Numeric Value Answer

21. An electron has a speed of 30,000 cm sec^{-1} accurate upto 0.001%. What is the uncertainty in locating it's position.

22. If the energies of two radiations of wavelength 800 nm and 400 nm are E_1 and E_2 respectively. Then calculate the value of E_2/E_1.

23. Determine the Bohr orbit of Li^{2+} ion in which electron is moving at speed equal to the speed of electron in the first Bohr orbit of H-atom.

24. A hydrogen atom with an electron in the first shell absorbs ultraviolet light with a wavelength of 1.03×10^{-7} m. To what shell does the electron jump?

25. What is the sum of radial node(s) and nodal plane(s) for $4d_{z^2}$–orbital?

26. An electron with de Broglie wavelength 4×10^{-6} m makes transition to a state with de Broglie wavelength 6×10^{-6} m. The wavelength of photon generated is $\frac{mc}{h} \times x \times 10^{-11}$ m. What is the value of x?

27. Calculate the ratio of wavelength of first line of Balmer series of H-atom to the wavelength of first line of Lyman series of 10 times ionized sodium atom.

28. To stop the flow of photoelectrons produced by electromagnetic radiation incident on a certain metal, a negative potential of 300 V is required. If the photoelectric threshold of metal is 1500 Å, what is the frequency of the incident radiation (in terms of 10^{16} Hz)?

29. The energy of the electron in the second and the third Bohr's orbits of the hydrogen atom is -5.42×10^{-12} erg and -2.41×10^{-12} erg respectively. Calculate the wavelength of the emitted radiation when the electron drops from the third to the second orbit.

30. Naturally occurring boron consists of two isotopes whose atomic weights are 10.01 and 11.01. The atomic weight of natural boron is 10.81. Calculate the percentage of isotope with atomic weight 11.01 in natural boron.

ANSWER KEY

1	(d)	**4**	(c)	**7**	(a)	**10**	(c)	**13**	(d)	**16**	(a)	**19**	(b)	**22**	(2)	**25**	(1)	**28**	(7.45)
2	(a)	**5**	(b)	**8**	(b)	**11**	(b)	**14**	(c)	**17**	(c)	**20**	(c)	**23**	(3)	**26**	(576)	**29**	(6.604)
3	(d)	**6**	(d)	**9**	(b)	**12**	(a)	**15**	(d)	**18**	(b)	**21**	(2)	**24**	(3)	**27**	(653.4)	**30**	(80)

Hints & Solutions

CHAPTER 2
Structure of Atom

1. **(d)** In S.I. units the P.E. $= \frac{-Ze^2}{4\pi\varepsilon_0 r}$. For Li^{2+}, Z = 3.

$\therefore$ P.E. $= \frac{-3e^2}{4\pi\varepsilon_0 r}$.

2. **(a)** $^{20}_{10}Ne$ contains 10 protons and 10 neutrons

$\therefore M_1 = 10 m_p + 10 m_n$

$^{40}_{20}Ca$ contains 20 protons and 20 neutrons

$\therefore M_2 = 20 m_p + 20 m_n$

$\therefore M_2 = 2M_1$

3. **(d)** Isodiaphers have same difference of number of neutrons and protons or (A – 2Z) must be same.

4. **(c)** Energy of an electron at infinite distance from the nucleus is zero. As an electron approaches the nucleus, the electron attraction increases and hence the energy of electron decreases and thus becomes negative. Thus as the value of n decreases, i.e. lower the orbit is, more negative is the energy of the electron in it.

5. **(b)** The energy associated with radiation of wave length 975 Å is given by

$E = \frac{12400}{975} eV = 12.72\ eV$

[For a radiation of wavelength x Å, we know $E = \frac{12400}{x} eV$]

$$E = 13.6\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] eV$$

or $E = 13.6\left[\frac{1}{1} - \frac{1}{n_2^2}\right] eV$ $\quad [\because n_1 = 1]$

or $12.72 = 13.6\left[1 - \frac{1}{n_2^2}\right]$ $\quad [\because E = 12.72\ eV]$

or $1 - \frac{1}{n_2^2} = \frac{12.72}{13.6}$

or $\frac{1}{n_2^2} = \frac{13.6 - 12.72}{13.6} = \frac{0.88}{13.6} \simeq \frac{1}{16}$

or $n_2^2 \simeq 16$

or $n_2 \simeq 4$

The transition $n_4 \longrightarrow n_3$ will give the **longest wave length**.

6. **(d)** Total energy of a revolving electron is the sum of its kinetic and potential energy.

Total energy $= K.E. + P.E.$

$$= \frac{e^2}{2r} + \left(-\frac{e^2}{r}\right) = \frac{e^2 - 2e^2}{2r}$$

$$= -\frac{e^2}{2r}$$

7. **(a)** The frequency distribution of the emitted radiation from black body depends only on its temperature. The maximum value of intensity of radiation emitted will be more for higher temperature. Thus, correct representation is shown in option (a).

8. **(b)** The maximum number of electrons in the shell with principle quantum number (n) is $2n^2$.

9. **(b)** For H atom, first Balmer line in series is

$$E_3 - E_2 = \frac{-E_1(H)}{(3)^2} + \frac{E_1(H)}{(2)^2} = \frac{5E_1(H)}{36}$$

For He^+ ion (Z = 2)

$$E_6 - E_4 = -\frac{E_1(H) \times (2)^2}{6^2} - \frac{E_1(H) \times (2)^2}{4^2}$$

$$= -E_1(H) \times 2^2 \left| \frac{16-36}{16 \times 36} \right|$$

$$= \frac{4 \times 20}{36 \times 16} E_1(H) = \frac{5E_1(H)}{36}$$

10. **(c)** $v_n = 2.186 \times 10^6$

$$\Rightarrow 1.093 \times 10^6 = 2.186 \times 10^6 \times \frac{1}{n}; n = 2$$

from Bohr theory we know $2\pi r = n\lambda$

$= 2\lambda$, where $\lambda = \frac{h}{mv}$

or $r = 0.529 \frac{n^2}{Z} \Rightarrow 0.529 \times 4$ Å

$\therefore$ Circumference of the orbit

$\Rightarrow 2 \times \times 0.529 \times 4 \times 10^{-10}$

$\Rightarrow 13.30 \times 10^{-10}$ m

11. **(b)** Angular momentum $= \frac{nh}{2\pi}$

$$3.1652 \times 10^{-34} = \frac{n \times 6.626 \times 10^{-34}}{2\pi};$$

n = 3

$$\therefore \quad \bar{v} = R \cdot Z^2 \cdot \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right);$$

$$\bar{v} = R \cdot 2^2 \cdot \left(\frac{1}{2^2} - \frac{1}{3^2}\right) \Rightarrow \frac{5R}{9}$$

12. **(a)** Energy absorbed = 13.6 × 1.5 = 20.4 eV out of this 6.8 eV is converted to K.E.

$6.8 \text{ eV} \Rightarrow 6.8 \times 1.6 \times 10^{-19}$ J;

$$6.8 \times 1.6 \times 10^{-19} = \text{K.E.} \Rightarrow \left(\frac{1}{2}\right) mv^2$$

$$v = \sqrt{\frac{2KE}{m}} = \sqrt{\frac{2 \times 1.088 \times 10^{-18}}{9.1 \times 10^{-31}}}$$

$= 1.54 \times 10^6$ m/s

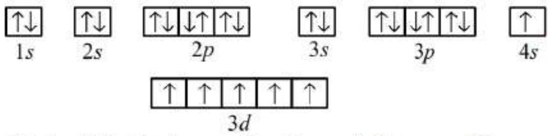
13. **(d)** According to $(n + l)$ rule, maximum is the $(n + l)$ value higher is the energy level. If two level has same $(n + l)$ value then the level which has higher value of n will have higher energy.

14. **(c)** (I) Beyond a certain wavelength the line spectrum becomes band spectrum.

(II) For Balmer series $n_1 = 2$

(IV) For calculation of longest wavelength use nearest value of n_2. Hence for longest wavelength in Balmer series of hydrogen spectrum, $n_1 = 2$ & $n_2 = 3$.

15. **(d)**



Out of 6 electrons in $2p$ and $3p$ must have one electron with m = + 1 and $s = -\frac{1}{2}$ but in $3d$-subshell an orbital having m = + 1 may have spin quantum no.

Therefore, minimum an maximum possible values are 2 and 3 respectively.

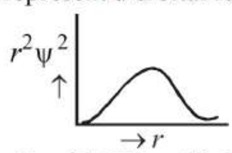
16. **(a)** As we know that,

$$E_n \propto \frac{-Z^2}{n^2}$$

$$\text{or } E_{2s} \propto \frac{-Z}{(2)^2}$$

Therefore, as the atomic number increases, the energy of orbital decreases. The atomic number of H, Li, Na and K respectively, are 1, 3, 11 and 19. Thus, the correct order of energy of $2s$-orbitals is K < Na < Li < H.

17. **(c)** $\ell = 2$ represent d orbital for which



18. **(b)** Given $E_1 = 25$eV $E_2 = 50$ eV

$$E_1 = \frac{hc}{\lambda_1} \quad E_2 = \frac{hc}{\lambda_2} \qquad \therefore \frac{E_1}{E_2} = \frac{\lambda_2}{\lambda_1}$$

$$\therefore \frac{\lambda_2}{\lambda_1} = \frac{25}{50} = \frac{1}{2} \quad \therefore \lambda_1 = 2\lambda_2$$

19. **(b)** Cathode rays are independent of the nature of the gas and electrodes placed in discharge tube. They travel in a straight line in the absence of external electrical or magnetic field.

20. **(c)** Energy emitted by the bulb = 600 W = 600 Js^{-1} ($1W = 1\ Js^{-1}$)

$\lambda = 331.3 \times 10^{-9}$ m

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

$= \dfrac{6.62 \times 10^{-34} \times 3 \times 10^{8}}{331.3 \times 10^{-9}}$

$= 0.059 \times 10^{-17} \approx 0.06 \times 10^{-17}$ J

No. of photon emitted from the lamp per second

$= \dfrac{600}{0.06 \times 10^{-17}} = 1.0 \times 10^{21}$

21. **(2)** $\Delta v = \dfrac{0.001}{100} \times 30{,}000 = 0.3$ cm sec^{-1}

According to uncertainty principle,

$\Delta x \, . \, \Delta p \approx \dfrac{h}{4\pi}$; $\quad \Delta x . \Delta v \approx \dfrac{h}{4\pi m}$

$\Delta x \times 9.1 \times 10^{-28} \times 0.3 \approx \dfrac{6.625 \times 10^{27} \times 7}{4 \times 22}$

$\Delta x \approx 1.93$ cm. ≈ 2

22. **(2)** Energy of photon, $\quad E = h\nu = \dfrac{hc}{\lambda}$

Here, $c = 3.0 \times 10^{8}\ ms^{-1}$

In first case, $\lambda = 800$ nm $= 800 \times 10^{-9}$ m

$\therefore E_1 = \dfrac{(6.626 \times 10^{-34}\ Js) \times (3 \times 10^{8}\ ms^{-1})}{800 \times 10^{-9}\ m}$

$= 2.48 \times 10^{-19}$ J

In second case, $\lambda = 400$ nm $= 400 \times 10^{-9}$ m

$\therefore E_2 = \dfrac{(6.626 \times 10^{-34}\ Js) \times (3 \times 10^{8}\ ms^{-1})}{400 \times 10^{-9}\ m}$

$= 4.91 \times 10^{-19}$ J

Ratio of energy of first and second radiations,

$\dfrac{E_1}{E_2} = \dfrac{2.48 \times 10^{-19}\ J}{4.97 \times 10^{-19}\ J} = \dfrac{1}{2}$

$E_1 : E_2 = 1 : 2$ or $E_2 = 2E_1$

Thus, energy of the radiation with wavelength 400 nm is twice that of the radiation of wavelength 800 nm.

23. **(3)** In the 1st Bohr orbit of H :

$v = 2.18 \times 10^{6}\ ms^{-1}$.

Now, let us consider that in Li^{2+} the electron is in nth orbit. Speed of electron in nth Bohr orbit of Li^{2+} is

$v = (Li^{2+}) = 2.18 \times 10^{6} \times \dfrac{3}{n}$

Now, applying the condition of equal speed :

$2.18 \times 10^{6} \times \dfrac{3}{n} = 2.18 \times 10^{6} \Rightarrow n = 3$

24. **(3)** $\Delta E = \dfrac{hc}{\lambda} = \dfrac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{1.03 \times 10^{-7}}$

$= 1.93 \times 10^{-18}$ J

Also: $\Delta E = kZ^2 \ \dfrac{1}{n_1^2} - \dfrac{1}{n_2^2} \ = 2.18 \times 10^{-18}$

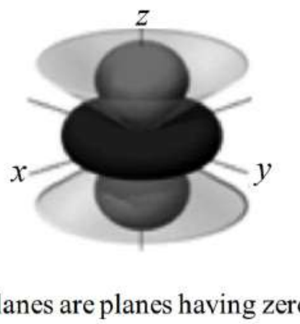
$\left(\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right)$

$\Rightarrow 1.93 \times 10^{-18} = 2.18 \times 10^{-18} \left(1 - \dfrac{1}{n^2}\right)$

$\Rightarrow n = 3$.

25. **(1)** For $4d_{z^2}$–orbital, $n = 4$ and $l = 2$.

Number of radial nodes $= n - \ell - 1 = 4 - 2 - 1 = 1$



Nodal planes are planes having zero probability of finding electron. Due to unusual shape of d_{z^2}–orbital, it does not have a nodal plane but it does possess 2 nodal cones or 2 angular nodes.

26. **(576)** $\lambda = \frac{h}{mv} \Rightarrow v_1 = \frac{h}{m\lambda_1}$ and $v_2 = \frac{h}{m\lambda_2}$

$$E = \frac{1}{2}mv^2 \Rightarrow E_1 - E_2 = \frac{1}{2}m(v_1^2 - v_2^2)$$

$$\Rightarrow \frac{hc}{\lambda} = \frac{h^2}{2m}\left(\frac{1}{\lambda_1^2} - \frac{1}{\lambda_2^2}\right)$$

$$\Rightarrow \frac{1}{\lambda} = \frac{h}{2mc}\left(\frac{1}{4^2} - \frac{1}{6^2}\right)\frac{1}{(10^{-6})^2}$$

$$\Rightarrow \frac{1}{\lambda} = \frac{h}{2mc}\left(\frac{20}{36\times16}\right)\frac{1}{10^{-12}}$$

$$\lambda = \frac{mc}{h}\left(\frac{36\times16}{10}\right)10^{-12}\text{ m} = \frac{mc}{h}\times576\times10^{-11}\text{ m}$$

$$\Rightarrow x = 576$$

27. **(653.4)** $\overline{v} = \frac{1}{\lambda} = RZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

$$\frac{1}{\lambda_H} = R\times1^2\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = \frac{5}{36}R$$

$$\frac{1}{\lambda_{Na+}} = R\times11^2\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = \frac{363}{4}R$$

Hence $\frac{\lambda_H}{\lambda_{Na^+}} = \frac{\frac{363R}{4}}{\frac{5R}{36}} = \mathbf{653.4}$

28. **(7.45)**

K.E. of photoelectron $= e^- \times$ stopping potential

$= 1.602 \times 10^{-19} \times 300$

$= 4.806 \times 10^{-17}$ J

K.E. of photoelectron $= h(\nu - \nu_0) = h\left(\nu - \frac{c}{\lambda_0}\right)$

(ν_0 = Threshold frequency)

$$4.806\times10^{-17} = 6.626\times10^{34}\left(\nu - \frac{3\times10^8}{1500\times10^{-10}}\right)$$

$$= 6.626\times10^{-34}(\nu - 2\times10^{15})$$

$$\nu - 2\times10^{15} = \frac{4.806\times10^{-17}}{6.626\times10^{-34}} = 72.53\times10^{15}$$

$$\Rightarrow \nu = \mathbf{7.45\times10^{16}\ Hz}$$

29. **(6.604)** $\Delta E = E_3 - E_2 = h\nu = \frac{hc}{\lambda}$ or

$$\lambda = \frac{hc}{E_3 - E_2}$$

Given $E_2 = -5.42\times10^{-12}$ erg

$E_3 = -2.41\times10^{-12}$ erg

$$\therefore\ \lambda = \frac{6.626\times10^{-27}\times3\times10^{10}}{-2.41\times10^{-12} - (-5.42\times10^{-12})}$$

$$= \frac{19.878\times10^{-17}}{3.01\times10^{-12}} = 6.604\times10^{-5}\text{ cm} = \mathbf{6.604Å}$$

30. **(80)** Let the % of isotope with At. wt. 10.01 = x

$\therefore$ % of isotope with At. wt. 11.01 = (100 – x)

$$\text{At. wt. of boron} = \frac{x\times10.01 + (100-x)\times11.01}{100}$$

$$\Rightarrow 10.81 = \frac{x\times10.01 + (100-x)\times11.01}{100}$$

$\therefore x = 20$

Hence % of isotope with At. wt. 10.01 = 20%

$\therefore$ % of isotope with At. wt. 11.01 = 100 – 20 = **80%**