SOLUTIONS

Module - 1 / JEE-2022

Chemistry	Chapter - 2	Atomic Structure

EXERCISE-A

1. No. of photons $= \dfrac{E_{Total}}{E_{per\ photon}} = \dfrac{10^{-17}}{\frac{hc}{\lambda}} = \dfrac{10^{-17}}{\frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{550 \times 10^{-9}}} = 27.67$

$\Rightarrow$ Min. number of photons = 28

2. $E_{Photon\ absorbed} = E_{Photon\ 1\ emitted} + E_{Photon\ 2\ emitted}$

$\Rightarrow \dfrac{hc}{\lambda_{absorbed}} = \dfrac{hc}{\lambda_1} + \dfrac{hc}{\lambda_2} \quad \Rightarrow \quad \dfrac{1}{300} = \dfrac{1}{400} + \dfrac{1}{\lambda_2} \quad \Rightarrow \quad \lambda_2 = 1200\,\text{nm}$

$\Rightarrow E_{Photon(2)} = \dfrac{1240}{1200}\text{eV} = 1.03\text{eV}$

3. Decelerating potential = 0.24 V $\Rightarrow$ $\underset{(Photoelectron)}{K.E._{Emitted\,e^-}} = 0.24\,\text{eV}.$

Using Einstein's Photoelectric equation: $E_{absorbed} = K.E_{e^-} + W_0$ **. . . . (i)**

$\Rightarrow E_{absorbed} = \dfrac{1240}{300}\,\text{eV} = 4.14\,\text{eV}$

Using (i): $W_0 = 4.14 - 0.24 = 3.9\text{eV}$

4. $W_0 = 7.52 \times 10^{-19}$ J; $E_{Photon} = \dfrac{hc}{\lambda} = \dfrac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{360 \times 10^{-10}} = 5.52 \times 10^{-18}$ J

$\Rightarrow K.E._{Photoelectron} = (5.52 \times 10^{-18} - 7.52 \times 10^{-19})\text{ J} = 4.77 \times 10^{-18}$ J

Note **:** $K.E_{e^-}$ as calculated using Einstein's Photoelectric eq. is max. possible value. When e^-s are released (knocked out) in photoelectric effect, not all the e^-s have $K.E_{max}$.

$\Rightarrow 0 \le K.E._{any\ e^-\ from\ Photoelectric\ exp.} \le KE_{max}$.

5. No. of e^-s $= \dfrac{\text{Total Charge}}{\text{Charge per } e^-} = \dfrac{6.39 \times 10^{-19}}{1.6 \times 10^{-19}} = 4$

6.(B) Cathode Rays – consists of e^-s: e^-s have a fixed e/m ratio.

7.(C) 20W = 20 J/s

$\Rightarrow$ No. of Photons/sec. $= \dfrac{E_{Total/s}}{E_{Per\ Photon}} = \dfrac{20}{\frac{hc}{\lambda}} = \dfrac{20}{\frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{600 \times 10^{-9}}} = 6.02 \times 10^{19}$ per sec

$\equiv \dfrac{6.02 \times 10^{19}}{6.\ 02 \times 10^{23}} N_{av.} = 10^{-4}\ N_{av.}$

8.(D) In Rutherford experiment, $\underset{(He^{2+}\ ion)}{\alpha - \text{particles}}$ were used.

9.(B) $\lambda_{X\ Rays} < \lambda_{UV} < \lambda_{IR} < \lambda_{Radio}$

10.(B) $I : h\nu_1 = W_0 + K.E_1$ ....(i)
$II : h\nu_2 = W_0 + (K.E_1) \times 2$ (given) ....(ii) $\left.\right\} \dfrac{h\nu_1 - W_0}{h\nu_2 - W_0} = \dfrac{1}{2}$ $[W_0 = h\nu_0]$

$\Rightarrow$ $\nu_0 = 8 \times 10^{15}$ Hz = Threshold freq.

11.(C) The energy of each photon is :

$E = \dfrac{hc}{\lambda} = 3.14 \times 10^{-19}$ J.

energy emmited per second by the laser is 5×10^{-3} J.

$\Rightarrow$ no. of photons $= \dfrac{5 \times 10^{-3}\text{ J}}{3.14 \times 10^{-19}} = 1.6 \times 10^{16}$

12.(C) As we know

$h\nu = W_0 + K.E.$

And K.E α stopping potential.

If $\nu' = 2\nu$

$\Rightarrow$ stopping potential will become more than double.

EXERCISE-B

1. Here, longest wavelength corresponds to the energy that will just ionize the Li^{2+} ion i.e. ejected e^- has a K.E. = 0

$\Rightarrow$ Transition $2 \longrightarrow \infty$ in Li^{2+} ion. $\Rightarrow$ $\dfrac{1}{\lambda} = 109677 \times 3^2 \times \left(\dfrac{1}{2^2} - \dfrac{1}{\infty^2}\right)$ $\Rightarrow$ $\lambda = 405.2$ Å

2. As explained in the illustrations, Balmer series transition $4 \longrightarrow 2$ in He^+ ion.

$\Rightarrow$ $\dfrac{1}{\lambda_{\text{Photon}}} = 109677 \times 2^2 \times \left(\dfrac{1}{2^2} - \dfrac{1}{4^2}\right)$ **....(i)**

Let $n_2 \longrightarrow n_1$ be the transition in H – atom.

$\Rightarrow$ $\dfrac{1}{\lambda_{\text{Photon}}} = 109677 \times 1^2 \times \left(\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right)$ **....(ii)**

Comparing (i) and (ii), $n_1 = 1, n_2 = 2$ $\Rightarrow$ $2 \longrightarrow 1$ transition in H – atom.

3. $434.1\text{ nm} = 4341$ Å in H – atom. (Balmer series) $n_1 = 2$ $\Rightarrow$ $\dfrac{1}{\lambda_{\text{Photon}}} = 109677 \times 1^2 \times \left(\dfrac{1}{2^2} - \dfrac{1}{n_2^2}\right) = \dfrac{1}{4341 \times 10^{-10}}$ $\Rightarrow$ $n_2 = 5$

4. $\Delta E_{3 \to 1}$ in H – atom $= 13.6 \times 1^2 \left(\dfrac{1}{1^2} - \dfrac{1}{3^2}\right)$ eV = 12.09 eV

$\Delta P.E_{3 \to 1} = 2\Delta E_{3 \to 1}$ ($\because P.E_n = 2E_n$) = 24.18 eV

5. H_β in Balmer series: $4 \to 2 : \dfrac{1}{\lambda} = 109677 \times 1^2 \times \left(\dfrac{1}{2^2} - \dfrac{1}{4^2}\right)$ cm^{-1} $\Rightarrow$ $\lambda = 4862.76$ Å

$\Rightarrow$ $\nu = \dfrac{c}{\lambda} = 6.17 \times 10^{14}$ Hz

6. Series limit for Balmer Series in H : $\infty \to 2$

(a) $\frac{1}{\lambda} = 109677 \times 1^2 \times \left(\frac{1}{2^2} - \frac{1}{\infty^2}\right) \Rightarrow \lambda = 3647.07\,Å$

(b) $I.E._H = 2.18 \times 10^{-18}\,J$

(c) $2.18 \times 10^{-18} = \frac{hc}{\lambda} \Rightarrow \lambda = 911.8\,Å$

7. $I.E = 100\ \text{kcal mol}^{-1} = 100 \times \frac{10^3 \times 4.184}{6.02 \times 10^{23}}\,J/\text{atom} = 6.95 \times 10^{-19}\,J/\text{atom} = h\nu \Rightarrow \nu = 1.05 \times 10^{15}\,Hz$

8.(BC) $\Delta E \propto Z^2 \Rightarrow \frac{hc}{\lambda} \propto Z^2 \Rightarrow \lambda \propto \frac{1}{Z^2}$

9.(C) As $n \uparrow$, $\Delta E_{\text{b/w two shells}} \downarrow \Rightarrow \Delta E_{max.}$ for $3 \to 2$

10.(C) $r_n \propto \frac{n^2}{Z} \Rightarrow \frac{(r_1)_H}{(r_2)_{Li^{2+}}} = \frac{Z_{Li^{2+}}}{Z_H} \Rightarrow r_{Li^{2+}} = \frac{r}{3}$

11.(C) 4341 Å : Visible region in H – atom (Balmer series : $n_1 = 2$)

$\Rightarrow \frac{1}{\lambda} = RZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \Rightarrow \frac{1}{4341 \times 10^{-8}} = 109677 \times 1^2 \times \left(\frac{1}{2^2} - \frac{1}{n^2}\right) \Rightarrow n_2 = 5$

12.(A) $\frac{n(n-1)}{2} = 10 \Rightarrow$ n = 5; Transitions in visible region in H atom: $5 \to 2$; $4 \to 2$; $3 \to 2$

$\Rightarrow$ 3 transitions

13.(B) Angular Momentum $(L) = \frac{nh}{2\pi} = \frac{3h}{2\pi}$

14.(B) $K.E_n = -E_n = 2.18 \times 10^{-18} \times \frac{Z^2}{n^2}\,J = 5.45 \times 10^{-19}\,J \Rightarrow n = 2$

15. (D) $6 \to 3$: For visible region, final n should be equal to 2 in H – atom $\Rightarrow$ No transition in visible region.

16.(ABD)

17.(D) Learn it as a fact.

18.(BC) $L = \frac{nh}{2\pi}$; check yourself that (B) is a correct statement.

19.(D) $\Delta p \geq \frac{h}{4\pi\,\Delta x} \Rightarrow$ If $\Delta x = 0$; $\Delta p = \infty$

20.(A) $\lambda_{Particle} = \frac{h}{\sqrt{2m\,K.E.}} \Rightarrow$ <u>for same λ</u> : m . K.E. = const. $\Rightarrow$ Lighter particle will have higher K.E.

21.(ABC) $r_n \propto \frac{n^2}{Z}$ $\quad V_n \propto \frac{Z}{n}$ $\quad E_n \propto \frac{Z^2}{n^2}$ $\quad L = \frac{nh}{2\pi}$ (doesn't depend on Z)

22.(A) H_β in lyman series $\Rightarrow h\nu = 2.18 \times 10^{-18} \times 1^2 \times \left(\frac{1}{1^2} - \frac{1}{3^2}\right) \Rightarrow \nu = 2.92 \times 10^{15}\,Hz$

23.(D) As we know $r \propto \frac{n^2}{Z}$; For Li^{2+}, Z = 3 $\Rightarrow$ r is minimum

24.(D) As we know

$$\frac{1}{\lambda}=RZ^2,\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right) \quad ; \quad \text{higher Z means lower } \lambda.$$

25.(C) As we know

$$E_n \propto -13.6\frac{z^2}{n^2}$$

Since $E_1 = -54.4$ eV

Hence He^+ ion.

26.(A) If 10.2 eV of energy is absorbed then electron goes from $1 \to 2$. $\Rightarrow$ Increase in angular momentum $= \frac{h}{2\pi} = 1.05 \times 10^{-34}$ Js

27.(A) Since one visible quanta is there, hence the transition must be to the second quantum number. Hence the final transition is $2 \to 1$.

28.(B) Radio wave have maximum wavelength

29.(A) Zeeman effect explains splitting in magnetic field.

EXERCISE-C

1. $$\lambda_e = \frac{h}{\sqrt{2m_e K.E_e}}$$

$K.E_{e^-} = 1\,eV = 1.6 \times 10^{-19}$ J $\Rightarrow$ $\lambda_e = \dfrac{6.626 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 1.6 \times 10^{-19}}} = 12.26$ Å

2. $\lambda = \dfrac{h}{p}$ $\Rightarrow$ If $p\downarrow, \lambda\uparrow$ $\Rightarrow$ when $p_{new} = \dfrac{1}{2}p_{old}, \lambda_{new} = 2\lambda_{old} = 10^{-7}\,m = 1000$ Å

3. **(a)** First find the no. of unpaired e^-s in each of the atom by writing their electronic configuration.

(b) Use $\mu = \sqrt{n(n+2)}$ B.M. where n = No of unpaired e^-s.

4. **(a)** $2p_x$ or $2p_y$ **(b)** $4d_{z^2}$ **(c)** $3p_z$ **(d)** $3d_{xy}$ and $3d_{x^2-y^2}$ **(d)** $4p_x$ and $4p_y$

5. Do it yourself.

6. Use the electronic configuration table in the chapter.

7. Orbital Angular Momentum $= \sqrt{\ell(\ell+1)}\,\dfrac{h}{2\pi}$

$\Rightarrow$ 4s : 0; 3p : $\sqrt{2}\,\dfrac{h}{2\pi}$; 3d : $\sqrt{6}\,\dfrac{h}{2\pi}$

8. $$\Delta v \geq \frac{h}{4\pi m\,\Delta x} = \frac{6.626 \times 10^{-34}}{4\pi \times 9.1 \times 10^{-31} \times 10^{-10}} = 5.8 \times 10^5\ ms^{-1}$$

9. (B) 2s : $\ell = 0 \Rightarrow$ orbital Angular momentum $\sqrt{\ell(\ell+1)}\,\dfrac{h}{2\pi} = 0$

10. (D) F (Z = 9) : $1s^2\,2s^2\,2p^5$: p-orbital has $5e^-$s.

Na(Z = 11); $1s^2\,2s^2\,2p^6\,3s^1$: s-orbital has $5e^-$s

Fe^{3+} (Z = 26) : $1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,3d^5$: d-orbital has $5e^-$s.

Mn (Z = 25) : $1s^2\,2s^2\,2p^6\,3s^2\,3p^6 3d^5\,4s^2$: d-orbital has $5e^-$s.

11. (C) $\lambda_{Ball} = \dfrac{h}{mv}\ \dfrac{6.626 \times 10^{-34} \times 3600}{0.2 \times 5} = 2.38 \times 10^{-30}\ m$.

12. (C) 3s is more closer to the nucleus. $3s > 3p > 3d$.

13. (A) Rb(Z = 37): $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ \mathbf{5s^1}$ **: Outermost e^-**

14. (A) d orbital e^- : Orbital angular momentum $= \sqrt{\ell(\ell+1)}\ \dfrac{h}{2\pi} = \sqrt{6}\ \hbar \left(\hbar = \dfrac{h}{2\pi}\right)$
$(\ell = 2)$

15. (C) $C\ell$: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$: Unpaired e^-:

16. (A) M-shell: (n = 3) $\Rightarrow$ No. of orbitals = $n^2 = 9$

17. (B) $r = 8.46 A° = 0.53 \dfrac{n^2}{Z} A°$ $\Rightarrow$ $n = 4$

Max. e^-s in n = 4 : $= 2n^2 = 32$

18. (C) In any shell, max. no. of $e^-s = 2(2\ell + 1)$ — 50% $\uparrow$, 50% $\downarrow$ $\Rightarrow$ Max no. of e^-s with same spin $= 2\ell + 1$

19. (C) Value of $\ell <$ 'n' $\quad -\ell \le m \le +\ell,\ m_s = \pm \dfrac{1}{2}$

20. (D) Fe^{2+}: d-orbitals have $6e^-$s.

Na:	$1s^2\ 2s^2\ 2p^6\ 3s^1$	:	5 s-orbital e^-s
Li:	$1s^2\ 2s^1$	:	3 s-orbital e^-s
N:	$1s^2\ 2s^2\ 2p^3$	:	4 s-orbital e^-s
P:	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$	:	6 s-orbital e^-s

21.(D) Hund's rule is related to the degenerate orbitals.

22.(C) 6s will be closest.

23.(C) $2.5\ \hbar$ means $\dfrac{5h}{3\pi}$ can not be correct value of angular momentum.

24.(D) To emit a photon, e^- has to go to lower energy level. In n = 1, e^- can't go to a lower energy level further.

25.(A) All half filled orbitals so are most stable.

26.(A) Zero probability will be for Pz.

27.(A) A nodal plane is the one where probability of finding electron is zero.