EXERCISE *J-MAINS*

1. If the kinetic energy of an electron is increased four times, the wavelength of the de-Broglie wave associated with it would become :- **[JEE-Main(online) 2012]**

(1) Two times (2) Half (3) One fourth (4) Four times

AS0171

$(KE) = \frac{1}{2}mv^2$

or, $2m(KE) = m^2v^2$

$\Rightarrow mv = \sqrt{2m(KE)}$

$\because \lambda = \frac{h}{mv}$

or, $\lambda = \frac{h}{\sqrt{2m(KE)}}$

$\therefore \lambda \propto \frac{1}{\sqrt{KE}}$

Given $(KE)_2 = 4(KE)_1$

$\therefore \frac{\lambda_1}{\lambda_2} = \sqrt{\frac{(KE)_2}{(KE)_1}}$

or, $\frac{\lambda_1}{\lambda_2} = \sqrt{\frac{4}{1}} \Rightarrow \frac{\lambda_1}{\lambda_2} = 2$

$\Rightarrow \boxed{\lambda_2 = \frac{\lambda_1}{2}}$ Ans.

AS0171

2. If the radius of first orbit of H atom is a_0, the de-Broglie wavelength of an electron in the third orbit is :-

[JEE-Main(online) 2012]

(1) $6\pi a_0$ (2) $8\pi a_0$ (3) $2\pi a_0$ (4) $4\pi a_0$

AS0172

For 3rd Bohr orbit of H-atom,

$n=3$, $r = \dfrac{a_0 n^2}{Z}$

or, $r = \dfrac{9a_0}{1} = 9a_0$

$\because$ $mvr = \dfrac{nh}{2\pi}$

or, $mv = \dfrac{3h}{2\pi r} = \dfrac{3h}{2\pi \times 9a_0}$

or, $mv = \dfrac{h}{6\pi a_0}$ — (1)

$\therefore$ $\lambda = \dfrac{h}{mv}$

or, $\lambda = \dfrac{h}{\dfrac{h}{6\pi a_0}}$

or, $\boxed{\lambda = 6\pi a_0}$

AS0172

3. The wave number of the first emission line in the Balmer series of H-Spectrum is :
(R = Rydberg constant) : [JEE-Main(online) 2013]

(1) $\frac{3}{4}R$ (2) $\frac{9}{400}R$ (3) $\frac{5}{36}R$ (4) $\frac{7}{6}R$

AS0173

For 1st line of Balmer, $n_1 = 2$, $n_2 = 3$

$$\bar{\nu} = \frac{1}{\lambda} = RZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] = R \times 1^2 \times \left[\frac{1}{4} - \frac{1}{9}\right] = \boxed{\frac{5R}{36}}$$

4. The de Broglie wavelength of a car of mass 1000 kg and velocity 36 km/hr is :
($h = 6.63 \times 10^{-34}$ Js) **[JEE-Main(online) 2013]**

(1) 6.626×10^{-31} m
(2) 6.626×10^{-34} m
(3) 6.626×10^{-38} m
(4) 6.626×10^{-30} m

$$v = 36 \text{ km/hr} = \frac{36 \times 1000}{3600} = 10\, ms^{-1}.$$

$$\lambda = \frac{h}{mv} = \frac{6.626 \times 10^{-34}}{1000 \times 10} = \boxed{6.626 \times 10^{-38}\, m}$$

5. For which of the following particles will it be most difficult to experimentally verify the de-Broglie relationship? [JEE-Main(online) 2014]

(1) a dust particle (2) an electron (3) a proton (4) an α-particle.

AS0175

$\lambda = \frac{h}{mv} \Rightarrow \lambda \propto \frac{1}{m}$, for heavier particle λ will be smaller, so difficult to measure. Dust is the heaviest among the all four particles.

6. If the binding energy of the electron in a hydrogen atom is 13.6 eV, the energy required to remove the electron from the first excited state of Li^{++} is : [JEE-Main(online) 2014]

(1) 13.6 eV (2) 30.6 eV (3) 122.4 eV (4) 3.4 eV

AS0176

For 1st excited state of Li^{2+} ion : $n=2$, $z=3$

$$E = \frac{-13.6z^2}{n^2} = \frac{-13.6\times 9}{4} = -30.6 eV.$$

$\therefore$ Energy required to remove the electron $= +30.6 eV$.

AS0176

7. Based on the equation [JEE-Main(online) 2014]

$$\Delta E = -2.0\times10^{-18}\,J\left(\frac{1}{n_2^2}-\frac{1}{n_1^2}\right)$$

the wavelength of the light that must be absorbed to excite hydrogen electron from level n = 1 to level n = 2 will be ($h = 6.625 \times 10^{-34}$ Js, $C = 3 \times 10^8\ ms^{-1}$) [JEE-Main(online) 2014]

(1) 2.650×10^{-7} m
(2) 1.325×10^{-7} m
(3) 1.325×10^{-10} m
(4) 5.300×10^{-10} m

$$\Delta E = \frac{hc}{\lambda} = 2\times10^{-18}\left(\frac{1}{1^2}-\frac{1}{2^2}\right)$$

or, $$\frac{1}{\lambda} = \frac{2\times10^{-18}}{6.625\times10^{-34}\times3\times10^{8}}\left(1-\frac{1}{4}\right)$$

or, $$\frac{1}{\lambda} = \frac{2\times10^{8}}{6.625\times3}\times\frac{3}{4}$$

or, $$\lambda = 6.625\times2\times10^{-8} = 13.25\times10^{-8}$$

$$= \boxed{1.325\times10^{-7}\,m}$$ Ans.

AS0177

8. If λ_0 and λ be the threshold wavelength and wavelength of incident light, the velocity of photoelectron ejected from the metal surface is [JEE-Main(online) 2014]

(1) $\sqrt{\frac{2hc}{m}\left(\frac{\lambda_0-\lambda}{\lambda\lambda_0}\right)}$ (2) $\sqrt{\frac{2h}{m}\left(\frac{1}{\lambda_0}-\frac{1}{\lambda}\right)}$ (3) $\sqrt{\frac{2h}{m}(\lambda_0-\lambda)}$ (4) $\sqrt{\frac{2hc}{m}(\lambda_0-\lambda)}$

AS0178

$h\nu = h\nu_0 + (KE)_{max}$.

or, $\frac{hc}{\lambda} = \frac{hc}{\lambda_0} + \frac{1}{2}mv^2$

or, $\frac{1}{2}mv^2 = hc\left[\frac{1}{\lambda} - \frac{1}{\lambda_0}\right]$

or, $v^2 = \frac{2hc}{m}\left[\frac{\lambda_0-\lambda}{\lambda\lambda_0}\right]$

or, $\boxed{v = \sqrt{\frac{2hc}{m}\left[\frac{\lambda_0-\lambda}{\lambda\lambda_0}\right]}}$

9. Ionization energy of gaseous Na atoms is 495.5 kjmol^{-1}. The lowest possible frequency of light that ionizes a sodium atom is

($h = 6.626 \times 10^{-34}$ Js, $N_A = 6.022 \times 10^{23}$ mol^{-1}) **[JEE-Main(online) 2014]**

(1) 3.15×10^{15} s^{-1} (2) 4.76×10^{14} s^{-1} (3) 1.24×10^{15} s^{-1} (4) 7.50×10^{4} s^{-1}

AS0179

$$E = h\nu$$

or, $$\frac{495.5 \times 10^{3}}{6.022 \times 10^{23}} = 6.626 \times 10^{-34} \times \nu$$

or, $$\nu = \frac{495.5 \times 10^{14}}{6.022 \times 6.626} = \boxed{1.24 \times 10^{15}\ \text{sec}^{-1}}$$

10. Which of the following is the energy of a possible excited state of hydrogen?

[JEE-Main(offline) 2015]

(1) –3.4 eV (2) +6.8 eV (3) +13.6 eV (4) –6.8 eV

AS0180

$$E = \frac{-13.6}{n^2}$$

$E_1 = -13.6$ eV. → Ground state.

$E_2 = \frac{-13.6}{2^2} = -3.4$ eV — These are possible energy of an excited state.

$E_3 = \frac{-13.6}{3^2} = -1.51$ eV. —

11. At temperature T, the average kinetic energy of any particle is $\frac{3}{2}$ kT- The de Broglie wavelength follows the order : **[JEE-Main(online) 2015]**

(1) Visible photon > Thermal electron > Thermal neutron

(2) Thermal proton > Thermal electron > Visible photon

(3) Visible photon > Thermal neutron > Thermal electron

(4) Thermal proton > Visible photon > Thermal electron

$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2m(KE)}}$. Clearly, $\lambda \propto \frac{1}{\sqrt{m}}$

mass of neutron > e > photon.

$\therefore \lambda_{photon} > \lambda_e > \lambda_{neutron}$.

AS0181

12. A stream of electrons from a heated filament was passed between two charged plates kept at a potential difference V volts. If e and m are charge and mass of an electron respectively, then the value of h/λ (where λ is wavelength associated with electron wave) is given by : **[JEE-Main(online) 2016]**

(1) $\sqrt{2meV}$ ✓ (2) meV (3) 2meV (4) $\sqrt{meV}$

$$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2m(KE)}} \qquad \because KE = eV.$$

or, $$\lambda = \frac{h}{\sqrt{2meV}}$$

or, $$\boxed{\frac{h}{\lambda} = \sqrt{2meV}}$$

13. The radius of the second Bohr orbit for hydrogen atom is : [JEE-Main(offline) 2017]
(Plank's const. $h = 6.6262 \times 10^{-34}$ Js ; mass of electron $= 9.1091 \times 10^{-31}$ kg ; charge of electron $e = 1.60210 \times 10^{-19}$ C ; permittivity of vaccum
$\epsilon_0 = 8.854185 \times 10^{-12}\ kg^{-1}\ m^{-3}\ A^2$)
(1) 1.65Å (2) 4.76Å (3) 0.529Å (4) 2.12Å ✓

For 2nd Bohr orbit of H-atom,

$Z=1,\ n=2$

$$r = \frac{0.529 n^2}{Z} \mathring{A}$$

or, $r = 0.529 \times 4 = 2.116\ \mathring{A} \simeq 2.12\ \mathring{A}$.

AS0183

$Z=1$

14. If the shortest wavelength in Lyman series of hydrogen atom is A, then the longest wavelength in Paschen series of He^+ is : [JEE-Main(online) 2017]

$Z=2$

(1) $\frac{36A}{5}$ (2) $\frac{9A}{5}$ (3) $\frac{36A}{7}$ (4) $\frac{5A}{9}$

for shortest wavelength, $n_2=\infty$

for Lyman $n_1=1$

$$\frac{1}{\lambda}=RZ^2\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]$$

or, $\frac{1}{A}=R\left[\frac{1}{1^2}-\frac{1}{\infty}\right]$

$\Rightarrow \boxed{R=\frac{1}{A}}$

$\therefore$ for longest wavelength in Paschen of He^+, $Z=2$

$n_1=3,\ n_2=4$

$$\frac{1}{\lambda}=RZ^2\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]$$

or, $\frac{1}{\lambda}=\frac{1}{A}\times 4\left[\frac{1}{9}-\frac{1}{16}\right]$

or, $\frac{1}{\lambda}=\frac{4}{A}\times\frac{7}{9\times16}=\frac{7}{36A}$

or, $\boxed{\lambda=\frac{36A}{7}}$ Ans.

15. The electron in the hydrogen atom undergoes transition from higher orbitals to orbital of radius 211.6 pm. This transition is associated with:- $z=1$ **[JEE-Main(online) 2017]**

(1) Brackett series (2) Balmer series (3) Lyman series (4) Paschen series

$$r = \frac{0.529\, n^2}{z}$$

$$r = 211.6\ \text{pm} = 2.116\ \text{Å}$$

or, $2.116 = 0.529 \times n^2$

or, $n^2 = 4 \Rightarrow n = 2 \Rightarrow$ Balmer series.

16. The de-Broglie's wavelength of electron present in first Bohr orbit of 'H' atom is :-

[JEE-Main(online) 2018]

(1) $\frac{0.529}{2\pi}$Å (2) $2\pi \times 0.529$Å (3) 0.529Å (4) 4×0.529Å

For 1st orbit of H-atom,

$n=1, Z=1, r=0.529 A^\circ$

$\because \quad mvr = \frac{nh}{2\pi} \Rightarrow mv = \frac{nh}{2\pi r}$ — (1)

$$\lambda = \frac{h}{mv} = \frac{h}{\frac{nh}{2\pi r}} = \frac{2\pi r}{n}$$

or, $\lambda = \frac{2\pi}{1} \times 0.529 A^\circ = \boxed{2\pi \times 0.529 A^\circ}$ Ans.

17. Ejection of the photoelectron from metal in the photoelectric effect experiment can be stopped by applying 0.5 V when the radiation of 250 nm is used. The work function of the metal is :

(1) 5 eV (2) 4 eV (3) 5.5 eV ✓(4) 4.5 eV **[JEE-Main(online) 2018]**

$(KE)_{max} = 0.5\ eV.$

$\lambda = 250\ nm \quad \therefore E = \frac{1240}{\lambda} = \frac{1240}{250} = \frac{124}{25}\ eV.$

$E = \phi + (KE)_{max}$ (where ϕ = work fn).

$\frac{124}{25} = \phi + 0.5$

or, $5 = \phi + 0.5$

or, $\phi = 5 - 0.5 = \boxed{4.5\ eV}$

18. Which of the following statements is false ? **[JEE-Main(online) 2018]**

(1) Photon has momentum as well as wavelength.

(2) Splitting of spectral lines in electrical field is called Stark effect.

(3) Frequency of emitted radiation from a black body goes from a lower wavelength to higher wavelength as the temperature increases.

(4) Rydberg constant has unit of energy.

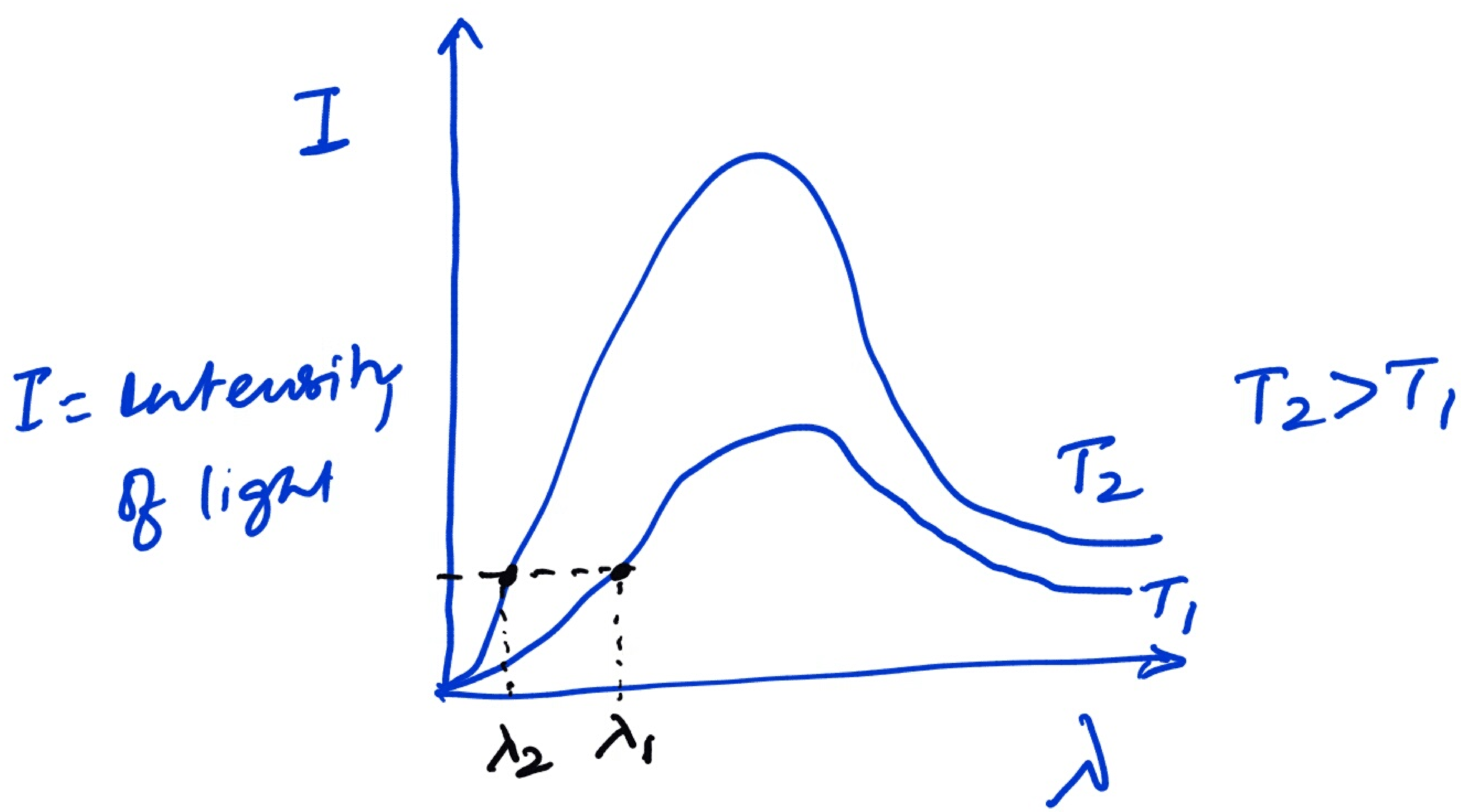
1) correct.

2) correct.

3) false

4) correct.

As $T \uparrow$ $\lambda \downarrow$ in a black body radiation.



19. If p is the momentum of the fastest electron ejected from a metal surface after the irradiation of light having wavelength λ, then for 1.5 p momentum of the photoelectron, the wavelength of the light should be: **[JEE-Main(online) 2019]**

(Assume kinetic energy of ejected photoelectron to be very high in comparison to work function)

(1) $\frac{1}{2}\lambda$ (2) $\frac{3}{4}\lambda$ (3) $\frac{2}{3}\lambda$ (4) $\frac{4}{9}\lambda$

$$\frac{hc}{\lambda} = \phi + (KE)_{max}$$

$\because (KE)_{max} >> \phi$ (where ϕ = work fn)

$\therefore (KE)_{max} + \phi \simeq (KE)_{max}$

$\therefore \frac{hc}{\lambda} = (KE)_{max}$

or, $\frac{hc}{\lambda} = \frac{p^2}{2m}$ —— (1)

$\because KE = \frac{1}{2}mv^2$

or, $2m(KE) = m^2v^2 = p^2$

or, $(KE) = \frac{p^2}{2m}$

Similarly, $\dfrac{hc}{\lambda'} = \dfrac{(1.5\,P)^2}{2m}$ —— (2)

$\dfrac{(1)}{(2)} \Rightarrow \dfrac{\lambda'}{\lambda} = \dfrac{1}{2.25} = \dfrac{100}{225} = \dfrac{4}{9}$

or, $\boxed{\lambda' = \dfrac{4}{9}\lambda}$ Ans.

20. The quantum number of four electrons are given below - [JEE-Main(online) 2019]

I. $n = 4, l = 2, m_l = -2, m_s = -\frac{1}{2}$ II. $n = 3, l = 2, m_l = 1, m_s = +\frac{1}{2}$

III. $n = 4, l = 1, m_l = 0, m_s = +\frac{1}{2}$ IV. $n = 3, l = 1, m_l = 1, m_s = -\frac{1}{2}$

The correct order of their increasing energies will be -

(1) IV < III < II < I (2) IV < II < III < I (3) I < II < III < IV (4) I < III < II < IV

Use $(n+l)$ rule,

→ smaller the value of $(n+l)$, smaller is the energy

→ If two orbitals have same $(n+l)$ then smaller the value of 'n' smaller is the energy:

	$n+l$	n
I)	$4+2=6$	4
II)	$3+2=5$	3
III)	$4+1=5$	4
IV)	$3+1=4$	3

IV < II < III < I

21. For any given series of spectral lines of atomic hydrogen, let $\Delta\bar{v} = \bar{v}_{max} - \bar{v}_{min}$ be the difference in maximum and minimum frequencies in cm^{-1}. The ratio $\Delta\bar{v}_{Lyman} / \Delta\bar{v}_{Balmer}$ is :

(1) 27 : 5
(2) 4 : 1
(3) 5 : 4
(4) 9 : 4

[JEE-Main(online) 2019]

For Lyman, $n_1 = 1$, for max^m frequency $n_2 = \infty$

$$\bar{\nu}_{max} = \frac{1}{\lambda} = R\left[\frac{1}{1^2} - \frac{1}{\infty}\right] = R$$

for min^m frequency, $n_2 = n_1 + 1 = 2$

$$\bar{\nu}_{min^m} = \frac{1}{\lambda} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = \frac{3R}{4}$$

$$\therefore \Delta\bar{\nu} = \bar{\nu}_{max} - \bar{\nu}_{min} = R - \frac{3R}{4} = \frac{R}{4}.$$

$$\therefore \Delta\bar{\nu}_{Lyman} = \frac{R}{4}.$$

Similarly for Balmer lines: $n_1 = 2$ and for max^{m} frequency $n_2 = \infty$

$$\bar{\nu}_{max} = \frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{\infty}\right] = \frac{R}{4}$$

For min^{m} frequency, $n_2 = n_1 + 1 = 2 + 1 = 3$.

$$\bar{\nu}_{min} = \frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = R\left\{\frac{1}{4} - \frac{1}{9}\right\} = \frac{5R}{36}$$

$$\therefore \Delta\bar{\nu} = \bar{\nu}_{max} - \bar{\nu}_{min} = \frac{R}{4} - \frac{5R}{36} = \frac{9R - 5R}{36} = \frac{4R}{36} = \frac{R}{9}$$

$$\therefore \Delta\bar{\nu}_{Balmer} = \frac{R}{9}$$

$$\therefore \frac{\Delta\bar{\nu}_{Lyman}}{\Delta\bar{\nu}_{Balmer}} = \frac{R/4}{R/9} = \boxed{\frac{9}{4}}$$ Ans.

22. The ratio of the shortest wavelength of two spectral series of hydrogen spectrum is found to be about 9.
The spectral series are: $z=1$ **[JEE-Main(online) 2019]**

(1) Paschen and P fund
(2) Lyman and Paschen
(3) Brackett and Piund
(4) Balmer and Brackett

$$\frac{1}{\lambda_1} = R\times 1^2\left[\frac{1}{n_1^2}-0\right]$$ for shortest λ, $n_2=\infty$

$$\frac{1}{\lambda_2} = R\times 1^2\left[\frac{1}{n_1'^2}-0\right]$$

Given, $\frac{\lambda_2}{\lambda_1} = 9$

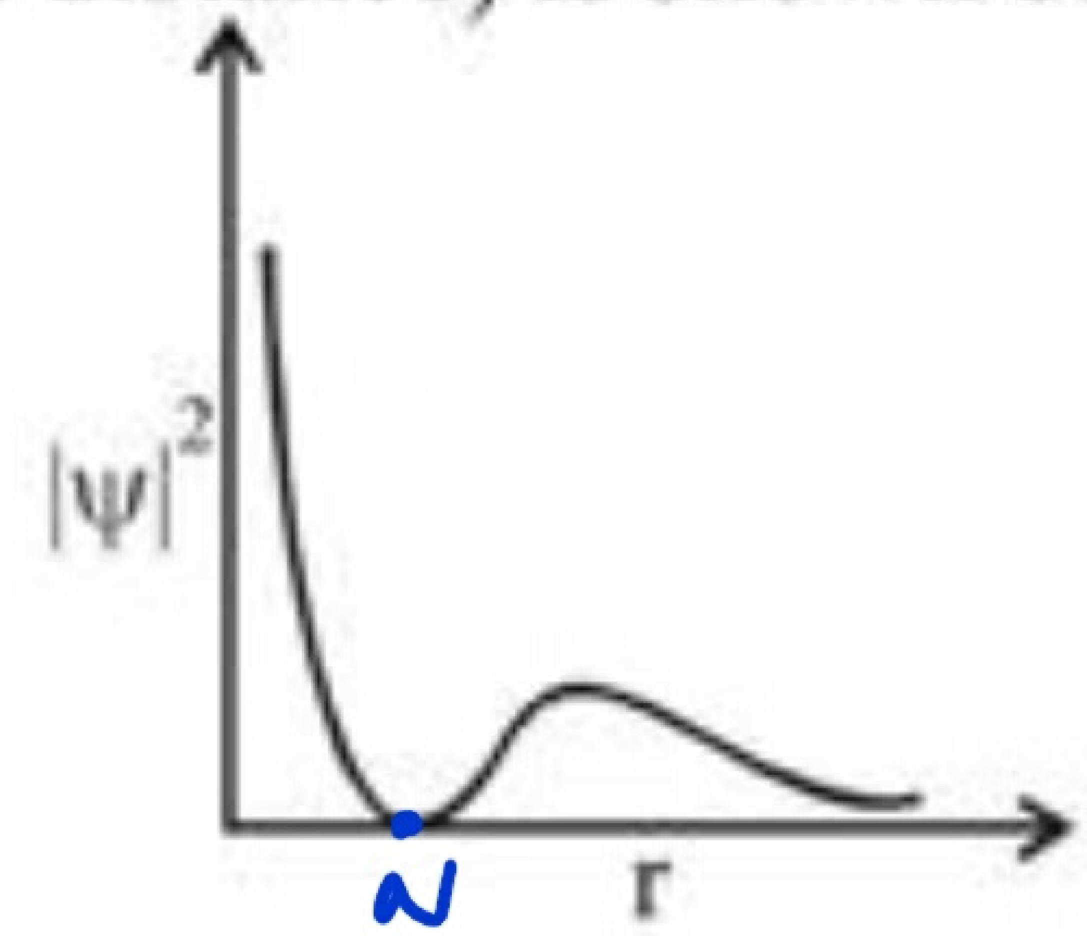
$$\therefore \frac{1}{\lambda_1}\times\frac{\lambda_2}{1} = \frac{1}{n_1^2}\times\frac{n_1'^2}{1}$$

or, $9 = \left(\frac{n_1'}{n_1}\right)^2 \Rightarrow \frac{n_1'}{n_1} = \frac{3}{1} \Rightarrow$

$3 \rightarrow$ Pashen.

$1 \rightarrow$ Lyman

23. The graph betweeen $|\psi|^2$ and r(radial distance) is shown below. This represents :-



(1) 3s orbital
(2) 1s orbital
[JEE-Main(online) 2019]
(3) 2p orbital
(4) 2s orbital

Graph is not starting from origin ⇒ s orbital. ⇒ $\boxed{l=0}$

no. of radial node = 1

or, $n-l-1=1$

or, $n-0-1=1$

$\Rightarrow \boxed{n=2}$

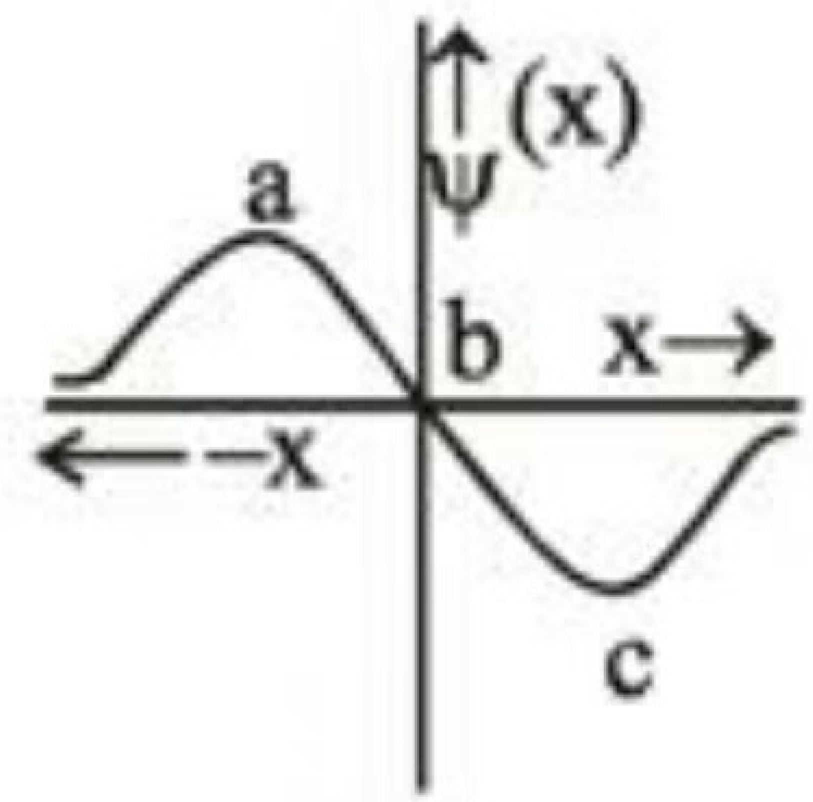
$\therefore$ $\boxed{\text{2s orbital.}}$

24. Among the following, the energy of 2s orbital is lowest in : **[JEE-Main(online) 2019]**

(1) K (2) Na (3) Li (4) H

Higher 'Z' higher is the energy.

25. The electrons are more likely to be found : [JEE-Main(online) 2019]



(1) in the region a and b

(2) in the region a and c

(3) only in the region c

(4) only in the region a

In the region 'a' and 'c' electron Probability density will be highest.

So (2) is the correct answer.

26. What is the work function of the metal if the light of wavelength 4000 Å generates photoelectrons of velocity $6 \times 10^5\ ms^{-1}$ form it ? **[JEE-Main(online) 2019]**

(Mass of electron = 9×10^{-31} kg

Velocity of light = $3 \times 10^8\ ms^{-1}$

Planck's constant = 6.626×10^{-34} Js

Charge of electron = $1.6 \times 10^{-19}\ JeV^{-1}$)

(1) 0.9 eV (2) 4.0 eV (3) 2.1 eV (4) 3.1 eV

$$E = \frac{12400}{\lambda} = \frac{12400}{4000} = 3.1\,eV$$

$$(KE)_{max} = \frac{1}{2}mv^2 = \frac{1}{2} \times 9 \times 10^{-31} \times (6 \times 10^{5})^2 = 162 \times 10^{-21}\,J = \frac{162 \times 10^{-21}}{1.6 \times 10^{-19}} \simeq 1\,eV$$

$$E = \phi + (KE)_{max}$$

or, $3.1 = \phi + 1 \Rightarrow \boxed{\phi = 2.1\,eV}$ Ans.

27. If the de Broglie wavelength of the electron in n^{th} Bohr orbit in a hydrogenic atom is equal to $1.5\,\pi a_0$ (a_0 is Bohr radius), then the value of n/z is : **[JEE-Main(online) 2019]**

(1) 1.0 (2) 0.75 (3) 0.40 (4) 1.50

$\lambda = 1.5\pi a_0$.

For nth Bohr orbit, $r = \frac{a_0 n^2}{Z}$

Also, $mvr = \frac{nh}{2\pi}$

or, $mv \times \frac{a_0 n^{\cancel{2}}}{Z} = \frac{\cancel{n}h}{2\pi} \Rightarrow \frac{n}{Z} = \frac{h}{2\pi m v a_0}$ — (1)

$\therefore \lambda = 1.5\pi a_0$

or, $\frac{h}{mv} = 1.5\pi a_0 \Rightarrow mv = \frac{h}{1.5\pi a_0}$ — (2)

From (1) and (2), $\frac{n}{Z} = \frac{\cancel{h} \times 1.5\cancel{\pi}\cancel{a_0}}{2\cancel{\pi} \times \cancel{h} \times \cancel{a_0}} = \frac{1.5}{2} = \boxed{0.75}$

28. The upper stratosphere consisting of the ozone layer protects us from the sun's radiation that falls in the wavelength region of : **[JEE-Main(online) 2019]**

(1) 600-750 nm (2) 0.8-1.5 nm (3) 400-550 nm (4) 200-315 nm

Information based question.

29. Heat treatment of muscular pain involves radiation of wavelength of about 900 nm. Which spectral line of H-atom is suitable for this purpose ? **[JEE-Main(online) 2019]**

$[R_H = 1 \times 10^5\ cm^{-1},\ h = 6.6 \times 10^{-34}\ Js,\ \ c = 3 \times 10^8\ ms^{-1}]$

(1) Paschen, $5 \to 3$ (2) Paschen, $\infty \to 3$ (3) Lyman, $\infty \to 1$ (4) Balmer, $\infty \to 2$

$\hookrightarrow$ 13.6 eV $\hookrightarrow$ 3.4 eV

$$E = \frac{1240}{900} = 1.38\ eV. \Rightarrow$$

(1) $$E = 13.6\left[\frac{1}{3^2} - \frac{1}{5^2}\right] = \frac{13.6 \times 16}{9 \times 25} = 0.97\ eV.$$

(2) $$E = 13.6\left[\frac{1}{3^2} - \frac{1}{\infty}\right] = \frac{13.6}{9} = 1.51\ eV. \rightarrow \text{closest value}$$

$\therefore$ (2) is correct.

30. The de Broglie wavelength (λ) associated with a photoelectron varies with the frequency (v) of the incident radiation as, [v_0 is thershold frequency] : **[JEE-Main(online) 2019]**

(1) $\lambda \propto \dfrac{1}{(v - v_0)^{\frac{3}{2}}}$ (2) $\lambda \propto \dfrac{1}{(v - v_0)^{\frac{1}{2}}}$ (3) $\lambda \propto \dfrac{1}{(v - v_0)^{\frac{1}{4}}}$ (4) $\lambda \propto \dfrac{1}{(v - v_0)}$

$$KE = \frac{1}{2}mv^2 \Rightarrow m \times (KE) = \frac{1}{2}m^2v^2 \Rightarrow mv = \sqrt{2m(KE)} \quad \text{—} \; (1)$$

$$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2m(KE)}} \Rightarrow \sqrt{2m(KE)} = \frac{h}{\lambda} \Rightarrow 2mKE = \frac{h^2}{\lambda^2}$$

$$\Rightarrow KE = \frac{h^2}{2m\lambda^2} \quad \text{—} \; (2)$$

$$E = \phi + (KE)_{max}$$

$$\text{or, } \cancel{h}\nu = \cancel{h}\nu_0 + \frac{h^{\cancel{2}}}{2m\lambda^2} \Rightarrow \nu - \nu_0 = \frac{h}{2m\lambda^2}$$

$$\text{or, } \lambda^2 = \frac{h}{2m(\nu - \nu_0)} \Rightarrow \lambda = \sqrt{\frac{h}{2m(\nu - \nu_0)}} \Rightarrow \boxed{\lambda \propto \frac{1}{\sqrt{\nu - \nu_0}}}$$

Ans.

31. The ground state energy of hydrogen atom is –13.6 eV. The energy of second excited state He^+ ion in eV is : **[JEE-Main(online) 2019]**

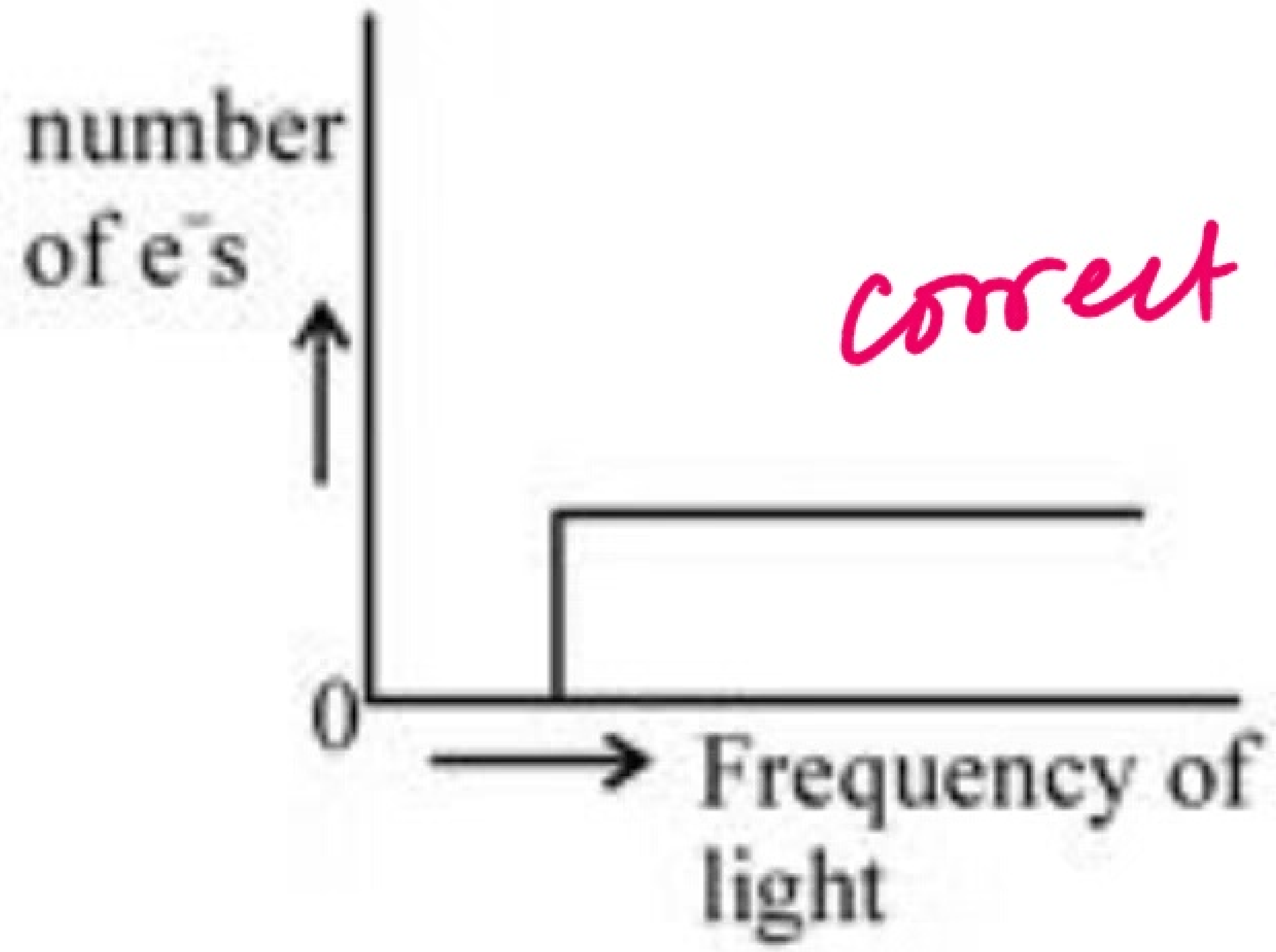
(1) –6.04 (2) –27.2 (3) –54.4 (4) –3.4

for 2nd excited state of He^+ ion : $Z=2$, $n=3$.

$$E = \frac{-13.6 Z^2}{n^2} = \frac{-13.6 \times 4}{9} = \boxed{-6.04\,eV}$$ Ans.

32. Which of the graphs shown below does not represent the relationship between incident light and the electron ejected form metal surface ? [JEE-Main(online) 2019]

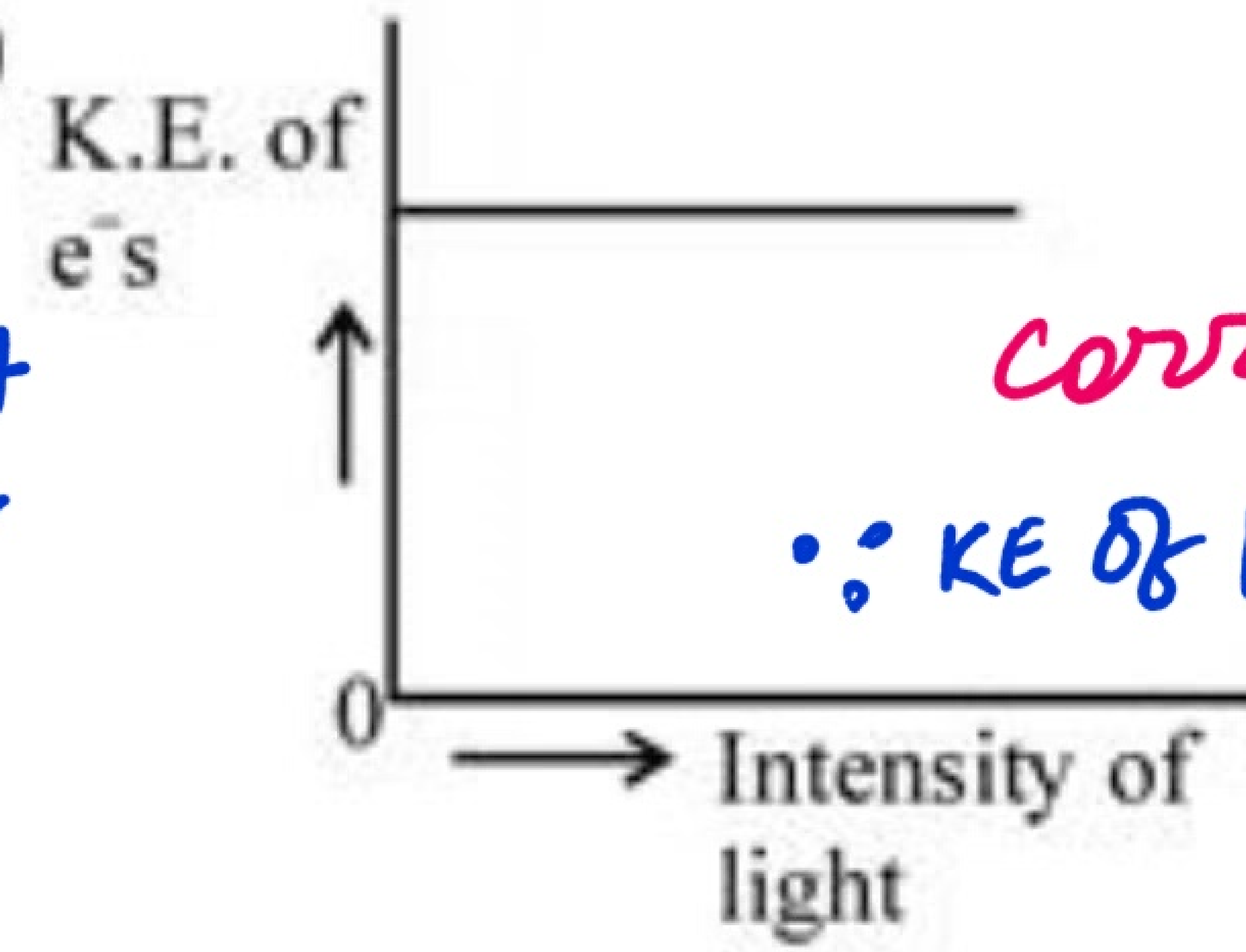
(1)



correct.

no. of Photoelectrons is independent of frequency of light.

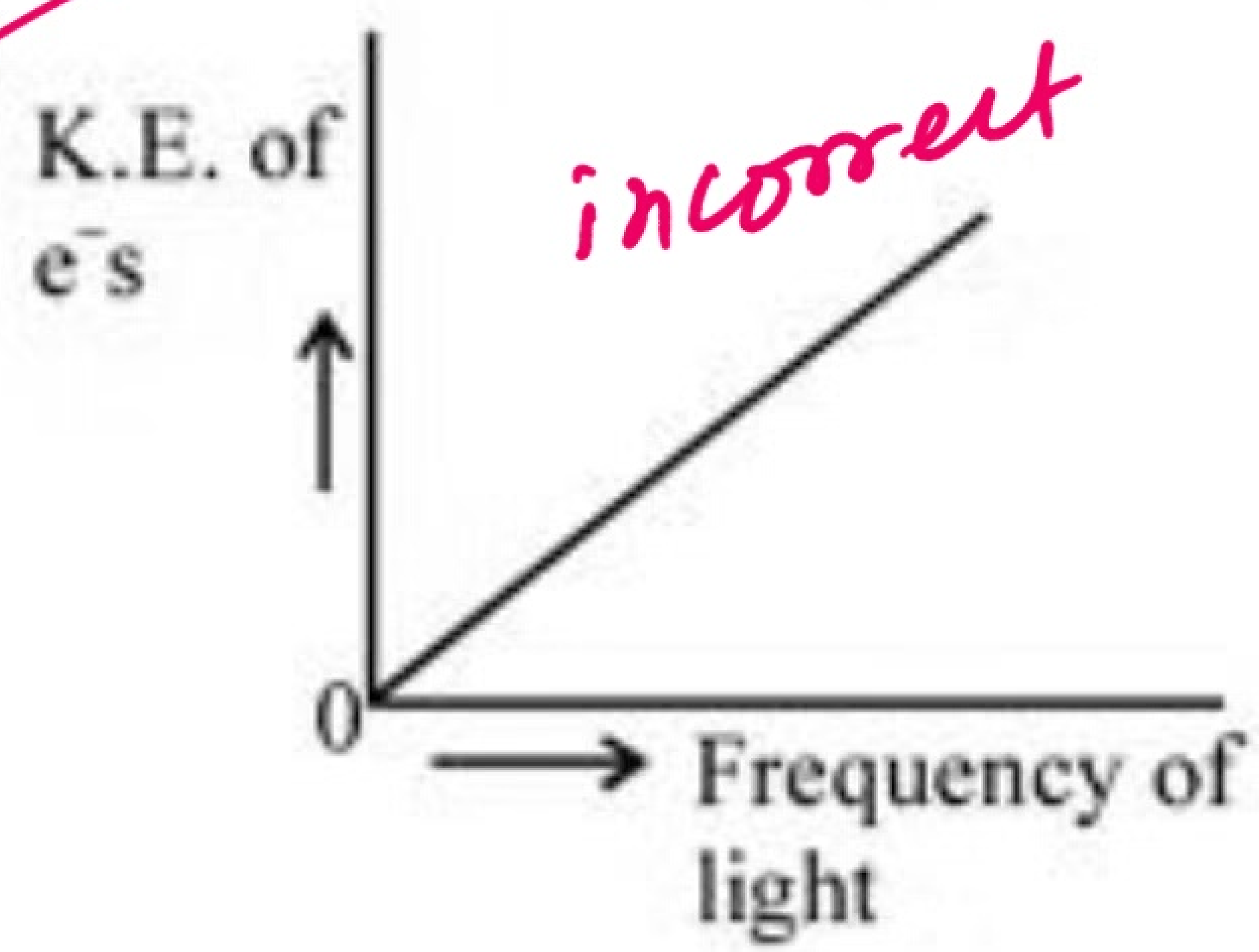
(2)



correct.

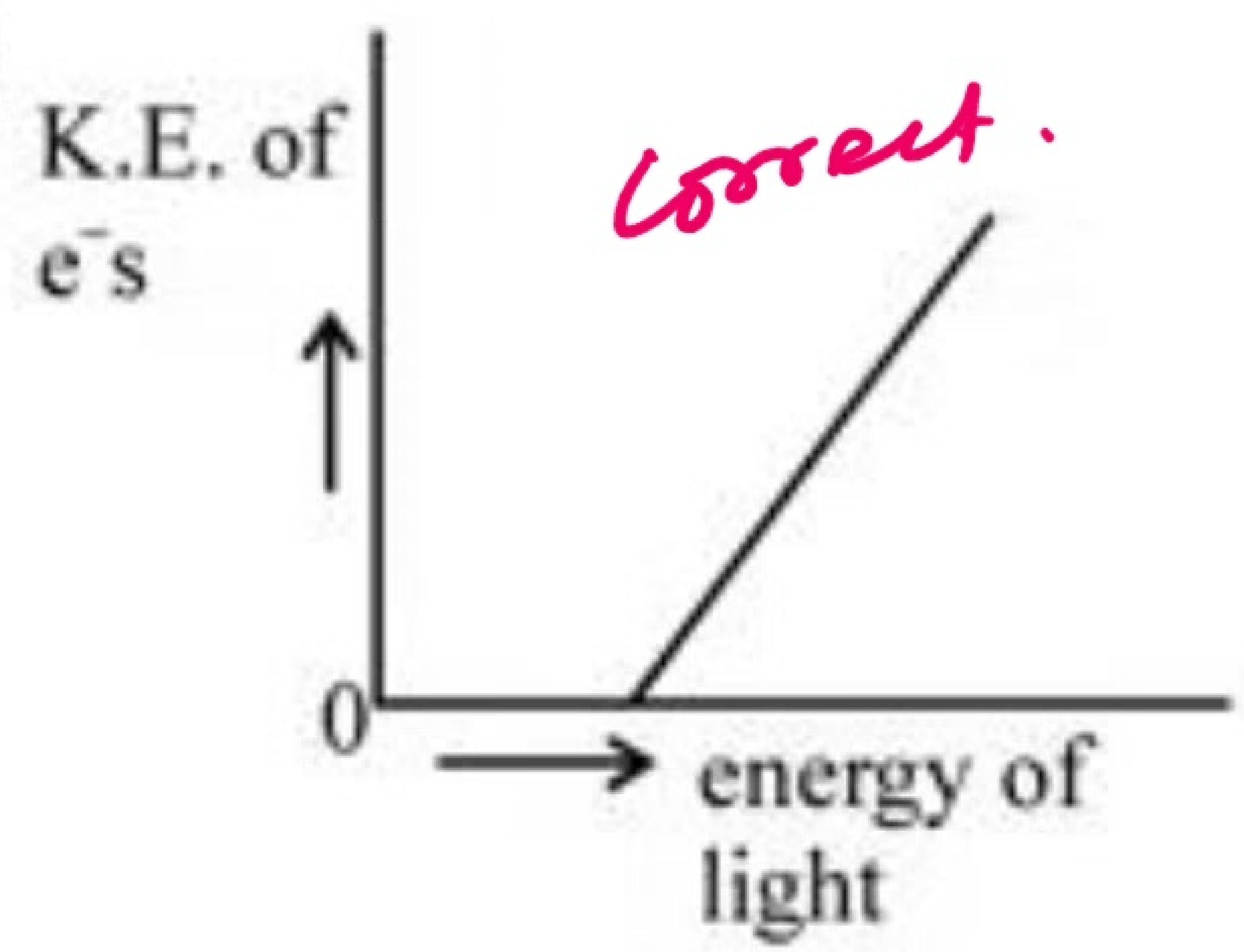
$\because$ KE of photoelectron is independent of intensity of light.

(3)



incorrect

(4)



correct.

$E = \phi + (KE)$

As E increases, KE increases.

$\because$ KE of photoelectron is independent of frequency of light.

33. Which of the following combination of statements is true regarding the interpretation of the atomic orbitals ? **[JEE-Main(online) 2019]**

(a) An electron in an orbital of high angular momentum stays away from the nucleus than an electron in the orbital of lower angular momentum.

(b) For a given value of the principal quantum number, the size of the orbit is inversely proportional to the azimuthal quantum number.

(c) According to wave mechanics, the ground state angular momentum is equal to $\frac{h}{2\pi}$.

(d) The plot of ψ Vs r for various azimuthal quantum numbers, shows peak shifting towards higher r value.

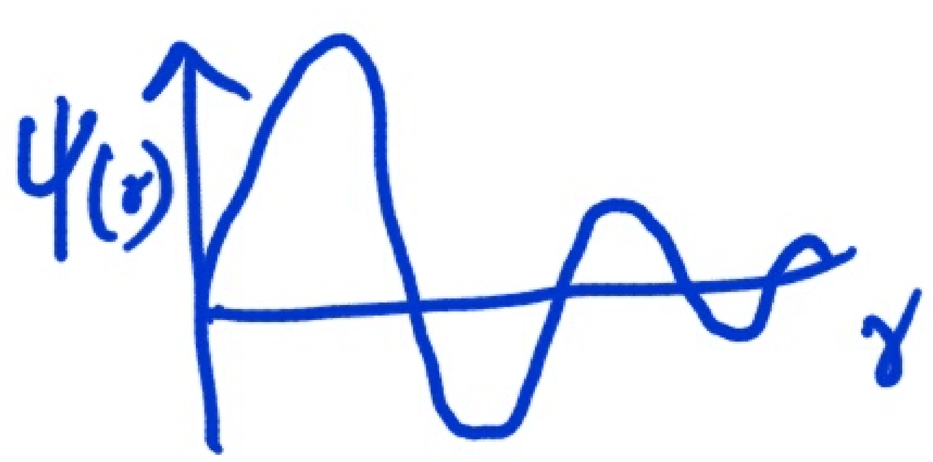
(1) (b), (c) (2) (a), (d) (3) (a), (b) (4) (a), (c)

(a) higher angular momentum means high 'n' ($\because mvr = \frac{nh}{2\pi}$)

high 'n' means away from nucleus ⇒ (a) is correct.

(b) false, size of orbit depends upon 'n' only. ∴ false statement.

(c) $n=1$, Ang momentum, $mvr = \frac{nh}{2\pi} = \frac{h}{2\pi}$ ($\because n=1$) ∴ (c) is correct.

(d) 

, clearly peak shifting towards lower 'r' value.

∴ (d) is wrong statement.

34. For emission line of atomic hydrogen from $n_i = 8$ to $n_f = n$ the plot of wave number $(\bar{v})$ against $\left(\frac{1}{n^2}\right)$ will be (The Rydberg constant, R_H is in wave number unit). **[JEE-Main(online) 2019]**

(1) Linear with slope - R_H

(2) Linear with intercept - R_H

(3) Non linear

(4) Linear with slope R_H

8 to n

$$\bar{\nu} = \frac{1}{\lambda} = R_H\left[\frac{1}{n^2} - \frac{1}{64}\right]$$

or,

$$\underbrace{\bar{\nu}}_{y} = \underbrace{R_H}_{m} \times \underbrace{\frac{1}{n^2}}_{x} - \underbrace{\frac{R_H}{64}}_{c}$$

linear with slope = R_H.

35. The region in the electromagnetic spectrum where the Balmer series lines appear is

[JEE-Main(online) 2020]

(1) Visible (2) Microwave (3) Ultraviolet (4) Infrared

Lyman → ultraviolet.

Balmer → visible

Paschen
Brackett
P-fund

$\left.\begin{array}{l}\text{Paschen}\\ \text{Brackett}\\ \text{P-fund}\end{array}\right\}$ infrared

36. The correct statement about probability density (except at infinite distance from nucleus) is :

[JEE-Main(online) 2020]

× (1) It cn be negative for 2p orbital

✓ (2) It can be zero for 3p orbital

× (3) It can be zero for 1s orbital

× (4) It can never be zero for 2s orbital

Probability density = $\psi^2 \Rightarrow$ always (+)ve and will be zero only at node.

2) 3p $\Rightarrow$ no. of radial node = $n - \ell - 1 = 3 - 1 - 1 = 1$

3) 1s $\Rightarrow$ " " " " $= 1 - 0 - 1 = 0$

4) 2s $\Rightarrow$ " " " " $= 2 - 0 - 1 = 1$

37. The difference between the radii of 3^{rd} and 4^{th} orbits of Li^{2+} is ΔR_1. The difference between the radii of 3^{rd} and 4^{th} orbits of He^+ is ΔR_2. Ratio $\Delta R_1 : \Delta R_2$ is : **[JEE-Main(online) 2020]**

(1) 8 : 3 (2) 3 : 2 (3) 3 : 8 (4) 2 : 3

For Li^{2+}, $n=3$, $z=3$, $r_3 = \frac{0.529n^2}{z} = \frac{a_0 \times 9}{3} = 3a_0$ (where $a_0 = 0.529\ \mathring{A}$)

when $n=4$, $r_4 = \frac{a_0 \times 16}{3} = \frac{16a_0}{3}$

$\Delta R_1 = r_4 - r_3 = \frac{16a_0}{3} - 3a_0 = \frac{7a_0}{3}$

Similarly, for He^+, $z=2$, $n=3$, $r_3 = \frac{a_0 \times 9}{2} = \frac{9a_0}{2}$

$n=4$, $r_4 = \frac{a_0 \times 16}{2} = 8a_0$

$\therefore \Delta R_2 = r_4 - r_3 = 8a_0 - \frac{9a_0}{2} = \frac{7a_0}{2}$

$\therefore \frac{\Delta R_1}{\Delta R_2} = \frac{\cancel{7a_0}}{3} \times \frac{2}{\cancel{7a_0}} = \boxed{\frac{2}{3}}$ Ans.

38. The work function of sodium metal is 4.41×10^{-19} J. If the photons of wavelength 300 nm are incident on the metal, the kinetic energy of the ejected electrons will be **[JEE-Main(online) 2020]**
($h = 6.63 \times 10^{-34}$ Js; $c = 3 \times 10^{8}$ m/s) 222 $\times 10^{-21}$ J.

$$E = \phi + KE_{max}$$

or, $$\frac{hc}{\lambda} = 4.41 \times 10^{-19} + (KE)_{max}$$

or, $$\frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{300 \times 10^{-9}} = 4.41 \times 10^{-19} + (KE)_{max}$$

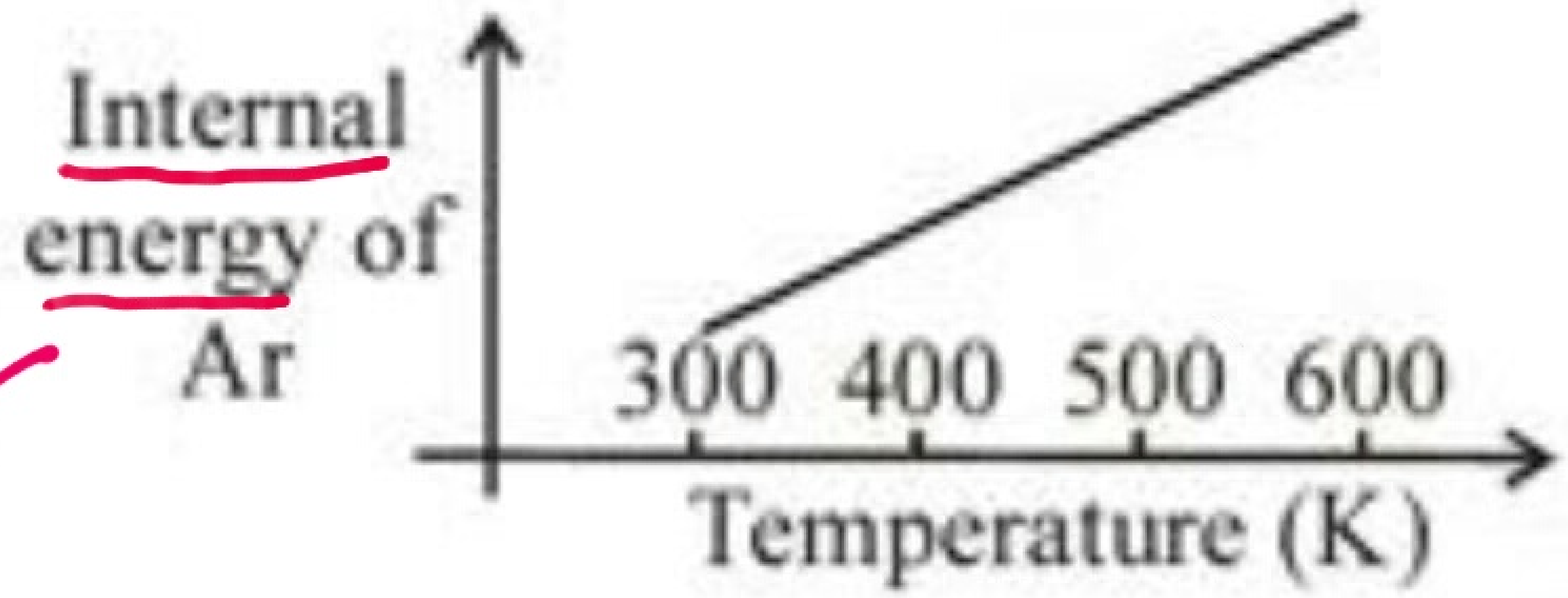
or, $$6.63 \times 10^{-19} = 4.41 \times 10^{-19} + (KE)_{max}$$

or, $$(KE)_{max} = 2.22 \times 10^{-19}\ J$$

$$= \boxed{222 \times 10^{-21}\ J}$$

39. The figure that is not a direct manifestation of the quantum nature of atoms is :

[JEE-Main(online) 2020]

(1) 

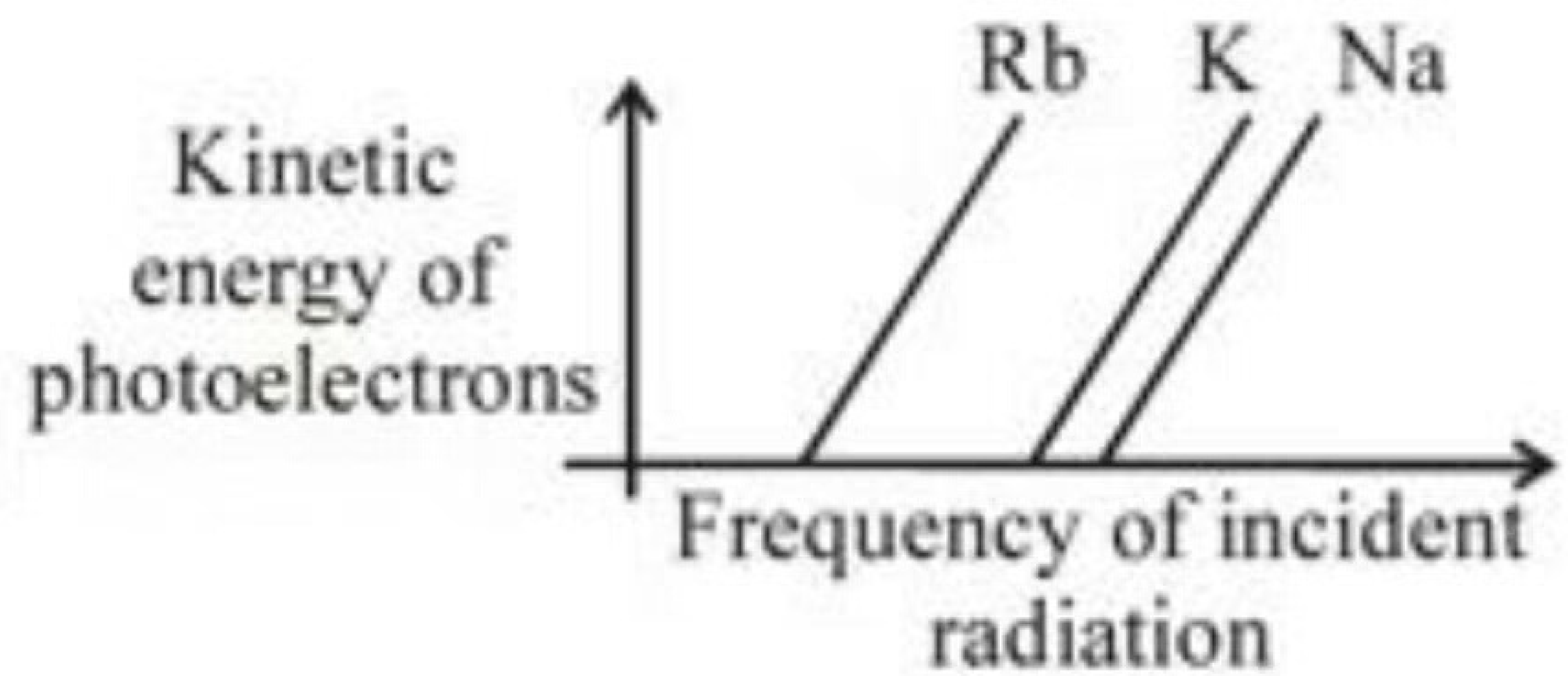
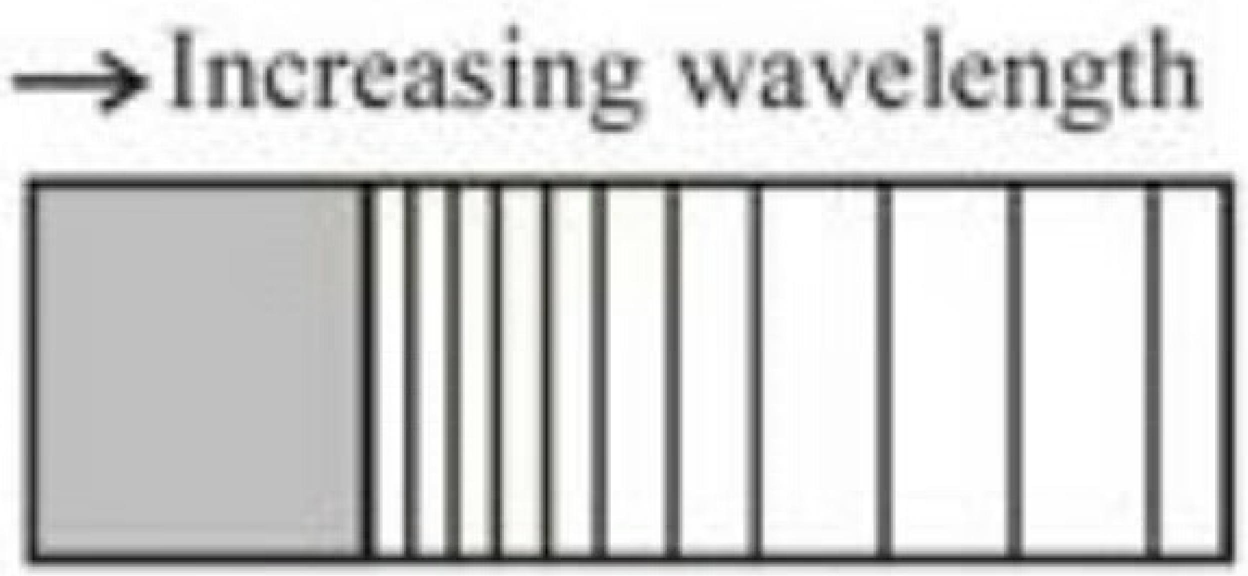
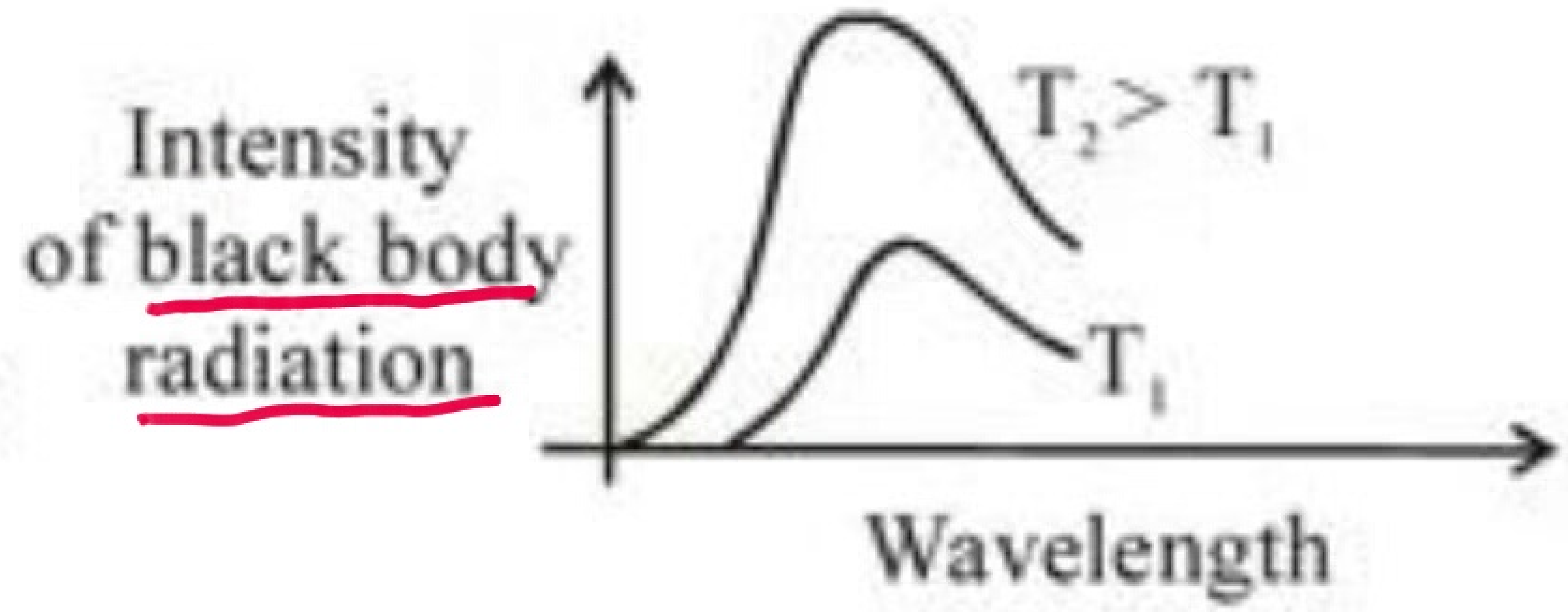
(2) 

Photo electric effect.

(3) 

Absorption spectrum (line spectrum)

(4) 

Plank's quantum theory explains

(2) → Photo-electric effect

(3) → line spectrum of atom

(4) → Black body radiation.

But it can't explain internal energy of a substance.

40. The metal mainly used in devising photoelectric cells is: **[JEE-Main(online) 2020]**

(1) Na (2) Rb (3) Li (4) Cs

'Cs' is used in photoelectric cell.

41. The shortest wavelength of H atom is the Lyman series is λ_1. The longest wavelength in the Balmer series of He^+ is :- **[JEE-Main(online) 2020]**

(1) $\frac{5\lambda_1}{9}$ (2) $\frac{27\lambda_1}{5}$ (3) $\frac{9\lambda_1}{5}$ (4) $\frac{36\lambda_1}{5}$

For shortest wavelength in Lyman, $n_1 = 1$, $n_2 = \infty$

$$\frac{1}{\lambda_1} = R \times 1^2 \left[\frac{1}{1^2} - \frac{1}{\infty}\right] \Rightarrow \frac{1}{\lambda_1} = R \quad \text{—— (1)}$$

for longest wavelength in Balmer of He^+, $(z=2)$, $n_1 = 2$, $n_2 = 3$

$$\frac{1}{\lambda_2} = R \times 2^2 \left[\frac{1}{2^2} - \frac{1}{3^2}\right]$$

or, $$\frac{1}{\lambda_2} = \frac{1}{\lambda_1}\left[1 - \frac{4}{9}\right] = \frac{1}{\lambda_1}\left[\frac{5}{9}\right]$$

or, $$\boxed{\lambda_2 = \frac{9\lambda_1}{5}}$$