Chapter 4 Semi Classical Theory and Introduction to Quantum Mechanics
Solution of Worksheet

MCQ (Multiple Choice Questions)

Ans. 1: (d)

Solution: $\Delta x.\Delta p_x \geq \frac{h}{4\pi}$

$$p_x = \frac{h}{\lambda} \Rightarrow \Delta p_x = \frac{h}{\lambda^2}\Delta\lambda \text{ so } \Delta x.\Delta\lambda.\frac{h}{\lambda^2} \geq \frac{h}{4\pi} \Rightarrow \Delta x.\Delta\lambda \geq \frac{\lambda^2}{4\pi}$$

Ans. 2: (b)

Solution: According to uncertainty principle

$\Delta E \cdot \Delta t = \hbar$ where ΔE is the uncertainty in energy and Δt that in time.

Given $\Delta t = 10^{-8}$ sec $\Delta E = \frac{\hbar}{\Delta t} = \frac{1.05\times 10^{-34}\, joule\text{-sec}}{10^{-8}} = 1.05\times 10^{-26}\, joule\text{-sec}$

$= \frac{1.05\times 10^{-26}}{1.6\times 10^{-19}} = 6.56\times 10^{-8} eV$ uncertainty in energy $= 6.56\times 10^{-8} eV$

Ans. 3: (b)

Solution: According to uncertainty principle

$$\Delta J \Delta\theta = \hbar$$

where ΔJ is the uncertainty in the angular momentum and $\Delta\theta$ is the uncertainty in the corresponding angle.

$$\Delta J = \frac{5}{100}\times 2\hbar = \frac{\hbar}{10} \quad \Rightarrow \Delta\theta = \frac{\hbar}{2J} = \frac{\hbar}{\hbar/10} = 10 \text{ radians}$$

Ans. 4: (c)

Solution: $\Delta q \Delta p = \hbar \quad \Rightarrow \Delta p = \frac{\hbar}{\Delta q} \quad \hbar = 1.05\times 10^{-34}$ joule-sec, $\Delta q = 0.01\times 10^{-2}\, m$

$$\therefore \Delta p = \frac{1.05\times 10^{-34}}{0.01\times 10^{-2}} = 1.05\times 10^{-30} kg.m/s$$

Ans. 5: (b)

Solution: We can use Bohr Sommerfield theory

$$V(x) = cx^8 \quad \Rightarrow \oint P dx = nh \Rightarrow 4\int_0^{\left(\frac{E}{C}\right)^{1/8}} \sqrt{2m\left(E - cx^8\right)}dx = nh$$

$$\sqrt{2mE}\left(\frac{E}{C}\right)^{1/8}\int_0^t\sqrt{1-t^8}\,dt=nh\Rightarrow E^{1/2+1/8}\propto n=E^{\frac{4+1}{8}}\propto n$$

$E\propto n^{8/5}$ therefore correct option is (b)

Ans. 6: (c)

Solution: The amount of energy required to remove an electron moving in ground state of the atom, so that electron go off from the atom is called Ionisation energy and potential corresponding to this energy is called Ionisation potential. For hydrogen, this is given as:

$E=13.6eV$.

Since, positronium is a system in which electron revolves round the positron hence reduced mass of the positronium

$\mu=\frac{M_eM_p}{M_e+M_p}=\frac{1}{2}M_e$ (Since $M_p=M_e$)

and $E\propto \text{mass}$ so, for positronium $E=\frac{13.6}{2}eV=6.8eV$

if ionization energy is $6.8eV$,then ground state energy is $-6.8eV$

Ans. 7: (a)

Solution: One can calculate the ionization energy from finding the ionization energy for He for He+, then subtracting it from the given ionization energy. Since He+ is a hydrogenic atom, one can apply Bohr Theory.

In Bohr Theory, the energy to remove an electron is $E=Z^2E_1$. For Helium, since it has two protons,

$Z=2$. Thus, $E=52eV$ is the ionization energy. ($E_1=13.6eV$ is just 1 Rydberg or the energy of the ground state of Hydrogen.)

Subtract this from the ionization energy for He given in the problem to be $79eV-52eV=27$, to get an answer close to choice (a).

Ans. 8: (d)

Solution: The energy is highly relativistic, so that E = pc = 100 x 10^6 eV.

$$\lambda=\frac{hc}{pc}=\left(1.24\times10^{-6}eV\cdot m\right)/\left(2\times10^{8}eV\right)$$

Ans. 9: (d)

Solution: $F_{ext}=-\frac{-dV}{dr}=-k$

For circular orbit $\frac{mv^2}{r} = F_{ext}$

$$\frac{mv^2}{r} = k \qquad \text{(i)}$$

$$L = mvr = n\hbar \qquad \text{(ii)}$$

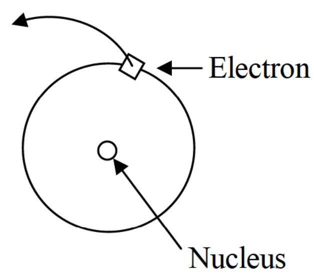
Using (i) and (ii) $r \propto n^{2/3}$

Ans. 10: (c)

Solution: According to Bohr Quantization condition, the electron wave can be adjusted around an orbit only when the circumference of the orbit is equal to an integral multiple of the wavelength i.e., $2\pi R = n\lambda$

Ans. 11: (c)

Solution: The electrostatic force = centripetal force



i.e., $\frac{mv^2}{r} = \frac{Ze^2}{kr^2}$

$$\Rightarrow \qquad mv^2 r = \frac{Ze^2}{k} \qquad \text{(i)}$$

By Bohr theory $mvr = n\hbar$ (ii)

Dividing equation (i) by, equation (ii), we get

$$v = \frac{Ze^2}{kn\hbar} \Rightarrow v = \frac{1}{n}\left(\frac{Ze^2}{k\hbar}\right) \Rightarrow v \propto \frac{1}{n} \Rightarrow \frac{v_1}{v_2} = \frac{n_2}{n_1} \Rightarrow v_2 = \frac{n_1}{n_2} v_1 \Rightarrow v_n = \frac{v_1}{n}$$

Ans. 12: (a)

Solution: The maximum number of electrons in an orbit are $2n^2$. If $n > 4$ is not allowed, the maximum number of electrons that can lie in first four orbits are

$2(1)^2 + 2(2)^2 + 2(3)^2 + 2(4)^2 = 2 + 8 + 18 + 32 = 60$ $\therefore$ Possible elements can be 60.

Ans. 13: (d)

Solution: $\frac{1}{\lambda} = RZ^2\left(\frac{1}{n_2^2} - \frac{1}{n_1^2}\right)$ $\qquad \therefore \frac{1}{\lambda} \propto Z^2$.

λ is shortest if Z is largest. Z is largest for doubly ionized lithium atom $(Z = 3)$ among the given elements.

Hence wavelength for doubly ionized lithium will be the least.

Ans. 14: (b)

Solution: In the second excited state, $n = 3$

$\therefore l_H = l_{Li} = 3\left(\frac{h}{2\pi}\right)$ $Z_H = 1, Z_{Li} = 3$, $E \propto Z^2 \therefore |E_{Li}| = 9|E_H| \quad \Rightarrow |E_H| < |E_{Li}|$

Ans. 15: (d)

Solution: When one of the electrons is removed from a neutral helium atom, energy is given by E_n.

$$E_n = -\frac{13.6Z^2}{n^2} eV$$

For helium ion, $Z = 2$, when doubly ionized

For first orbit, $n = 1$

$$\therefore E_1 = -\frac{13.6}{(1)^2} \times (2)^2 = -54.4\, eV$$

$\therefore$ Energy required to remove it $54.4\, eV$

$\therefore$ Total energy required $= 54.4 + 24.6 = 79\, eV$

Ans. 16: (b)

Solution: (a) $r_n \propto n^2$. Option (a) is correct

(b) Total energy of electron is

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

Option (b) is not correct

(c) Angular momentum of electron $= \frac{nh}{2\pi}$

Option (c) is correct

(d) Potential energy of electron $= \left(\frac{-27.2}{n^2}\right) eV$ for hydrogen atom.

Kinetic energy of electrons $= \left(\frac{13.6}{n^2}\right) eV$

$$\therefore |P.E.| = 2 \times |K.E.|$$

$$\therefore |P.E.| = \frac{27.2}{n^2}$$

The option (d) is correct

Ans. 17: (a)

Solution: $\therefore$ Potential energy $U = eV \quad \Rightarrow U = eV_0 \ln \frac{r}{r_0} \Rightarrow \frac{dU}{dr} = eV_0 \left(\frac{r_0}{r}\right) \frac{1}{r_0} \quad \Rightarrow |\text{force}| = \frac{eV_0}{r}$

This force provides the necessary centripetal force, hence $\frac{mv^2}{r}=\frac{eV_0}{r}\Rightarrow v=\sqrt{\frac{eV_0}{m}}$

By Bohr's postulate, $mvr=\frac{nh}{2\pi}\Rightarrow v=\frac{nh}{2\pi mr}$

Thus $\frac{nh}{2\pi mr}=\sqrt{\frac{eV_0}{m}}\quad\Rightarrow r=\frac{nh}{2\pi m}\times\sqrt{\frac{m}{eV_0}}\Rightarrow r=\left[\frac{h}{2\pi}\sqrt{\frac{1}{meV_0}}\right]\times n\qquad\therefore r_n\propto n$

Ans. 18: (c)

Solution: K_α corresponds to: $n=2$ to $n=1$

K_β Corresponds to: $n=3$ to $n=1$

$\frac{1}{\lambda_\alpha}=R\left[\frac{1}{1}-\frac{1}{4}\right]$ or $\frac{1}{0.64\overset{0}{A}}=\frac{3R}{4}\Rightarrow\frac{1}{\lambda_\beta}=R\left[\frac{1}{1^2}-\frac{1}{3^2}\right]=\frac{8R}{9}$

$\therefore\frac{\lambda_\beta}{0.32\overset{0}{\text{A}}}=\frac{3R}{4}\times\frac{9}{8R}$ or $\lambda_\beta=\frac{27}{32}\times0.64\overset{0}{\text{A}}$ or $\lambda_\beta=0.54\overset{0}{\text{A}}$

Ans. 19: (b)

Solution: $K=eV=20\times10^3eV$

The energy of photon $=0.05\times20\times10^3eV$

Thus, $\frac{hc}{\lambda}=10^3eV\Rightarrow\lambda=\frac{1242nm}{10^3}=1.24nm$

Ans. 20: (a)

Solution: Let K be the kinetic energy of the incident electron. Its linear momentum $p=\sqrt{2mK}$.

The de-Broglie wavelength is related to the linear momentum as

$\lambda=\frac{h}{p}=\frac{h}{\sqrt{2mK}}\qquad$ or $K=\frac{h^2}{2m\lambda^2}$

The cut-off wavelength of the emitted $X-$ray is related to the kinetic energy of incident electron as $\frac{hc}{\lambda_0}=K=\frac{h^2}{2m\lambda^2}\Rightarrow\lambda_0=\frac{2mc\lambda^2}{h}$

Ans. 21: (b)

Solution: In $X-$ray tube, $\lambda_{\min}=\frac{12375}{V(volt)}$ where $\lambda_{\min}$ is in Å

All wavelengths greater than $\lambda_{\min}$ are found.

Option (b) is correct

MSQ (Multiple Select Questions)

Ans. 22: (a), (b), (d)

Solution: The uncertainty in the position of the electron is

$\hbar = 1.05\times10^{-34}$ joule-sec, $m = 9\times10^{-31} kg$

Solution: The uncertainty in velocity $=\frac{0.01}{100}\times1.05\times10^{4} m/s = 1.05 m/\sec$

∵ The uncertainty in momentum

$$\Delta p = m\Delta v = 9\times10^{-31}\times\frac{0.01}{100}\times1.05\times10^{4} = 9.45\times10^{-31} kg.m/\sec$$

But $\Delta p\Delta q = \hbar \Rightarrow \Delta q = \frac{\hbar}{\Delta p} = \frac{1.05\times100\times10^{-34}}{9\times10^{-31}\times0.01\times1.05\times10^{4}}$ meters $= 1.1\times10^{-4} m$

Ans. 23: (c), (d)

Solution: Calculate the minimum uncertainty in the momentum of the nucleon. Also, calculate the minimum kinetic energy of the nucleon.

Given $m = 1.67\times10^{-27} kg$ and $\hbar = 1.05\times10^{-34}$ joule-sec

$(\Delta p)_{\min}(\Delta q)_{\max} = \hbar \quad (\Delta q)_{\max} = 2\times5\times10^{-15}$ meters

and $\hbar = 1.05\times10^{-34}$ joule-sec

$$\therefore \quad (\Delta p)_{\min} = \frac{\hbar}{(\Delta p)_{\max}} = \frac{1.05\times10^{-34}}{2\times5\times10^{-15}} kgm/\sec = 1.05\times10^{-29} kgm/\sec$$

Since p cannot be less than $(\Delta p)_{\max}$, so we have $p_{\min} = (\Delta p)_{\min}$

$$E_{\min} = \frac{p_{\min}^2}{2m}, = \frac{(1.05\times10^{-20})^2}{2\times1.67\times10^{-27}} \text{joule} = 3.3\times10^{-14} Joule$$

Ans. 24: (a), (b), (c)

Ans. 25: (a), (b), (c) and (d)

Solution: (a) $r_n \propto n^2$. Option (a) is correct

(b) Total energy of electron $T.E.$ $T.E = \frac{-13.6Z^2}{n^2}$.

Option (b) is correct

(c) Angular momentum of electron $= \frac{nh}{2\pi}$.

Option (c) is correct

(d) Potential energy of electron $=\left(\frac{-27.2}{n^2}\right)eV$ for hydrogen atom.

Kinetic energy of electrons $=\left(\frac{13.6}{n^2}\right)eV$

$\therefore |P.E.| = 2\times|K.E.|\quad \therefore |P.E.| = \frac{27.2}{n^2}$ The option (d) is correct

Ans. 26: (a), (c) and (d)

Solution: (a) $r_n \propto n^2$. Option (a) is correct

(b) Total energy of electron is

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

Option (b) is not correct

(c) Angular momentum of electron $=\frac{nh}{2\pi}$

Option (c) is correct

(d) Potential energy of electron $=\left(\frac{-27.2}{n^2}\right)eV$ for hydrogen atom.

Kinetic energy of electrons $=\left(\frac{13.6}{n^2}\right)eV$

$$\therefore |P.E.| = 2\times|K.E.|$$

$$\therefore |P.E.| = \frac{27.2}{n^2}$$

The option (d) is correct

Ans. 27: (b) and (c)

Solution: The kinetic energy of an electron in n[th] orbit of hydrogen atom is

$$K = \frac{me^4}{8\varepsilon_0^2 h^2 n^2},\qquad V = -\frac{e^2}{4\pi\varepsilon_0 r} = E = \frac{-me^{-4}}{8\varepsilon_0^2 h^2 n^2}$$

The total energy of an electron in n[th] orbit of hydrogen atom is $E = \frac{-me^{-4}}{8\varepsilon_0^2 h^2 n^2}\quad \therefore \frac{K}{E} = -1$

Ans. 28: (a), (b) and (c)

Solution: In hydrogen like atoms: $\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

Transition of electron occurs from n_2 to n_1, $\frac{1}{\lambda}$ is proportional to energy

From $n=4$ to $n=3$, ultraviolet radiation is obtained $\frac{1}{\lambda}=R\left(\frac{1}{3^2}-\frac{1}{4^2}\right)=\frac{7R}{144}=0.048R$

(a) $\frac{1}{\lambda}=R\left(\frac{1}{1^2}-\frac{1}{2^2}\right)=\frac{3R}{4}=0.75R$ (b) $\frac{1}{\lambda}=R\left(\frac{1}{2^2}-\frac{1}{3^2}\right)=\frac{5R}{36}=0.14R$

(c) $\frac{1}{\lambda}=R\left(\frac{1}{2^2}-\frac{1}{4^2}\right)=\frac{3R}{16}=0.2R$ (d) $\frac{1}{\lambda}=R\left(\frac{1}{4^2}-\frac{1}{5^2}\right)=\frac{9R}{400}=0.02$

λ is smaller than ultra violet in (a), (b) and (c)

λ is greater than ultra violet in (d). Greater the λ, less the energy of radiation

Ans. 29: (a) and (d)

Solution: According to Bohr model, $r_n \propto n^2$ (i) $v_n \propto \frac{1}{n}$ (ii)

now $T_n=\frac{2\pi}{\omega}=\frac{2\pi r_n}{v_n}$ or $T_n \propto \frac{r_n}{v_n}$ or $T_n \propto \frac{n^2}{1/n} \Rightarrow T_n \propto n^3$

$\therefore \frac{(T_n)_1}{(T_n)_2}=\frac{n_1^3}{n_2^3}$ or $8=\left(\frac{n_1}{n_2}\right)^3$ or $n_1=2n_2$

Option (a): $n_1=4,\ n_2=2$ It fulfils condition

Option (d): $n_1=6, n_2=3$ It fulfils condition

Options (a) and (d) are correct

Ans. 30: (a), (b), (c) and (d)

Solution: Linear momentum is conserved in the recoil process.

Momentum of recoil hydrogen atom $=mv$

Momentum of emitted photon $=\frac{\Delta E}{c}$

$$\Delta E=E_5-E_1=-13.6\left[\frac{1}{5^2}-\frac{1}{1^2}\right]eV=(13.6)\left(\frac{24}{25}\right)eV=\frac{13.6\times 24}{25}\times\left(1.6\times10^{-19}\right)J$$

$$\Delta E=2.1\times10^{-18}J$$

$$\therefore mv=\frac{\Delta E}{c}\ \therefore mv=\frac{\Delta E}{c}=\frac{2.1\times10^{-18}}{3\times10^{8}}=7\times10^{-27}\,kg\,m/\sec$$

or $v=\frac{\Delta E}{mc}$ or $v=\frac{2.1\times10^{-18}}{\left(1.67\times10^{-27}\right)\times\left(3\times10^{8}\right)}=4.19\,m/s$

Ans. 31: (b) and (d)

Solution: $X-$rays emitted from an $X-$ray tube depend upon:

(i) The accelerating voltage applied to tube. When accelerated, the electrons acquire greater energy before striking the target.

$X-$rays emitted from target therefore possess greater energy. X - rays with shorter wavelength possess greater energy. Hence wavelength of emitted $X-$rays depends on the voltage applied to tube.

(ii) According to Moseley's law, frequency $\nu = a^2(Z-b)^2$. Frequency depends upon atomic number of target from which X - ray are emitted.

Ans. 32: (c) and (d)

Solution: for $X-$ray tube,

$$\lambda_m\left(\overset{0}{A}\right)=\frac{12375}{V}$$

As accelerating voltage is increased, λ_m will decrease.

Number of electrons bombarding the target determine the intensity (or quantity) of emitted radiation. Accelerating voltage does not change the intensity of $X-$rays emitted.

NAT (Numerical Answer Type)

Ans. 33: 1

Solution: According to uncertainty relation

$$\Delta q \Delta p = \hbar$$

so that if Δq is maximum, Δp must be minimum, i.e.,

$$(\Delta q)_{\max}(\Delta p)_{\min} = \hbar,$$

Given $(\Delta q)_{\min}$ = minimum uncertainty in position $= 1.1\times10^{-8}$ meter; $\hbar = 1.05\times10^{-34}$ joule-

$$(\Delta p)_{\min} = \frac{\hbar}{(\Delta q)_{\max}} = \frac{1.05\times10^{-34}}{1.1\times10^{-8}} kgm/\sec \;\; = 9.1\times10^{-27}\, kgm/s$$

$$(\Delta p)_{\min} = m(\Delta v)_{\min} \quad m(\Delta v)_{\min} = 9.1\times10^{-27}$$

$$(\Delta v)_{\min} = \frac{9.1\times10^{-27}}{m} = \frac{9.1\times10^{-27}}{9.1\times10^{-31}} m/s \;\; = 1.0\times10^{4} m/s$$

Ans. 34: 31.4

Solution: $\Delta p = m\Delta v$ from uncertainty principle $\Delta q m\Delta v \cong \hbar \quad \Delta v \cong \dfrac{\hbar}{m\Delta q}$

Mass of α particle $= 4\times$ mass of proton = $4\times 1.67\times 10^{-27} = 6.68\times 10^{-27}\,kg$

$$\Delta q = 5\times 10^{-10}m \quad \Delta v = \frac{1.05\times 10^{-34}}{6.68\times 10^{-27}\times 5\times 10^{-10}} = 31.4\,m/s$$

Ans. 35: 1

Solution: We can use Bohr Sommerfield theory

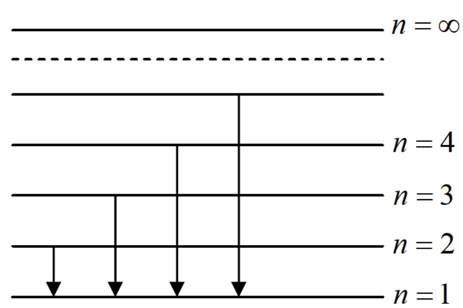
$$V(x) = cx^8 \;\Rightarrow \oint Pdx = nh \Rightarrow 4\int_0^{\left(\frac{E}{C}\right)^{1/2}} \sqrt{2m\left(E - cx^2\right)}dx = nh$$

$$\sqrt{2mE}\left(\frac{E}{c}\right)^{1/2} \int_0^t \sqrt{1-t^2}\,dt = nh \Rightarrow E^{1/2+1/8} \propto n = E^{\frac{4+1}{8}} \propto n$$

$$E \propto n^1$$

Ans. 36: $13.6eV$

Solution: Since, energy $\propto Z^2$ Energy for



$$He^+ = (4)\left(\frac{-13.6}{n^2}\right)eV = -\frac{4\times 13.6}{n^2}eV$$

The first excited state with principal quantum number $n = 2$

So, binding energy $= -\dfrac{4\times 13.6}{4} = -13.6eV$

Ans. 37: $68.4nm$

Solution: When electron moving in n_i the orbit transited to n_f orbit the frequency of radiation and so

wavelength is given by $\dfrac{1}{\lambda} = R\left(\dfrac{1}{n_f^2} - \dfrac{1}{n_i^2}\right)$

where R is Rydberg's constant.

when $n_i = 1$, then the series of spectral lines are known as Lyman series.

Thus, Lyman series is given as $\dfrac{1}{\lambda} = R\left(\dfrac{1}{1^2} - \dfrac{1}{n_i^2}\right) \qquad (\therefore n_f = 1)$

$$\Rightarrow \frac{1}{\lambda_{\max}} = \frac{R}{1^2} \Rightarrow \lambda_{\max} = \frac{1}{R} \text{ and } \frac{1}{\lambda_{\min}} = R\left(\frac{1}{1^2} - \frac{1}{2^2}\right) \Rightarrow \frac{1}{\lambda_{\min}} = R\left(1 - \frac{1}{4}\right) \Rightarrow \lambda_{\min} = \left(\frac{4}{3R}\right)$$

By equation (i) and (ii), we have $\frac{\lambda_{\max}}{\lambda_{\min}}=\frac{4}{3}\Rightarrow\lambda_{\max}=\frac{3}{4}\times\lambda_{\min}=\frac{3}{4}\times 91.2\,nm=68.4\,nm$

Ans. 38: 4.33 m/s

Solution: Linear momentum is conserved in the recoil process.

Momentum of recoil hydrogen atom $=mv$

Momentum of emitted photon $=\frac{\Delta E}{c}$

$$\Delta E=E_5-E_1=-13.6\left[\frac{1}{5^2}-\frac{1}{1^2}\right]eV=(13.6)\left(\frac{24}{25}\right)eV=\frac{13.6\times 24}{25}\times\left(1.6\times 10^{-19}\right)J\quad \Delta E=20.8\times 10^{-18}J$$

$$\therefore mv=\frac{\Delta E}{c}\quad\text{or}\quad v=\frac{\Delta E}{mc}\quad v=\frac{20.8\times 10^{-18}}{\left(1.67\times 10^{-27}\right)\times\left(3\times 10^{8}\right)}=4.33\ m/s$$

Ans. 39: $-122.4eV$

Solution: For hydrogen atom and hydrogen like atoms

$E_n=-\frac{13.6z^2}{n^2}eV$ Therefore, ground state energy of doubly ionized lithium atom

$(Z=3,n=1)$ will be $\therefore E_1=\frac{-13.6\times(3)^2}{(1)^2}=-13.6\times 9$ or $E_1=-122.4eV$

Ans. 40: 1215

Solution: $\frac{1}{\lambda}=RZ^2\left(\frac{1}{n_f^2}-\frac{1}{n_i^2}\right)$

$$\frac{\lambda_2}{\lambda_1}=\frac{Z_1^{\,2}\left(\frac{1}{n_f^2}-\frac{1}{n_i^2}\right)_1}{Z_2^{\,2}\left(\frac{1}{n_f^2}-\frac{1}{n_i^2}\right)_2}\Rightarrow\lambda_2=\frac{6561\times 1^2\left(\frac{1}{2^2}-\frac{1}{3^2}\right)}{2^2\left(\frac{1}{2^2}-\frac{1}{4^2}\right)}=1215A^0$$

Ans. 41: 4.19

Solution: Linear momentum is conserved in the recoil process

Momentum of recoil hydrogen atom $=mv$

Momentum of emitted photon $=\frac{\Delta E}{c}$

$$\Delta E=E_5-E_1=-13.6\left[\frac{1}{5^2}-\frac{1}{1^2}\right]eV=(13.6)\left(\frac{24}{25}\right)eV=\frac{13.6\times 24}{25}\times\left(1.6\times 10^{-19}\right)J$$

$$=\frac{522.24\times 10^{-19}}{25}=20.88\times 10^{-19}J$$

$\Delta E \simeq 2.1\times10^{-18} J \qquad \therefore mv = \frac{\Delta E}{c}$ or $v = \frac{\Delta E}{mc}$

or $\quad v = \frac{2.1\times10^{-18}}{\left(1.67\times10^{-27}\right)\times\left(3\times10^{8}\right)} = 4.19\, m/s$

Ans. 42: 3.81

Solution: The fifth valence electron of phosphorous lies in its third shell i.e. $n=3$

$\therefore$ Bohr radius $= r_n$

$\therefore r_n = \left[\frac{n^2}{Z}\varepsilon_r\right] r_0$ or $r_n = \left[\frac{3^2}{15}\times12\right]\times0.53\,\overset{0}{A}$

or $r_n = 3.81\,\overset{0}{A}$

Ans. 43: 3.85

Solution: Linear momentum is conserved in the recoil process.

Momentum of recoil hydrogen atom $= mv$

Momentum of emitted photon $= \frac{\Delta E}{c}$

$$\Delta E = E_3 - E_1 = -13.6\left[\frac{1}{3^2}-\frac{1}{1^2}\right]eV = (13.6)\left(\frac{8}{9}\right)eV = \frac{13.6\times8}{9}\times\left(1.6\times10^{-19}\right)J$$

$\Delta E = 19.3\times10^{-19} J \qquad \therefore mv = \frac{\Delta E}{c}$ or $v = \frac{\Delta E}{mc} = \frac{19.3\times10^{-19}}{\left(1.67\times10^{-27}\right)\times\left(3\times10^{8}\right)} = 3.85\ m/s$

Ans. 44: $79eV$

Solution: When one of the electrons is removed from a neutral helium atom, energy is given by

$E_n = -\frac{13.6Z^2}{n^2}eV$ per atom

For helium ion, $Z=2$, when doubly ionized

For first orbit, $n=1 \therefore E_1 = -\frac{13.6}{(1)^2}\times(2)^2 = -54.4eV$

$\therefore$ Energy required removing it $54.4eV$ $\quad\therefore$ Total energy required $= 54.4+24.6 = 79eV$

Ans. 45: 1.8

Solution: $E_\gamma = \frac{m_\pi c^2}{2} = \frac{135}{2} = 67.5MeV$

$$\lambda = \frac{hc}{p} = \frac{6.6\times10^{-34}\times3\times10^{8}}{67.5\times1.6\times10^{-13}} = 1.8\times10^{-14}m$$

Ans. 46: 300

Solution: $X-$ rays are electromagnetic waves which travel with speed $3\times10^{8}m/s$ in vacuum. The speed of emitted $X-$ rays does not depend on the accelerating potential applied to electrons.

$\therefore$ The speed of X-rays $=3\times10^{8}m/s$

Ans. 47: $0.27\overset{0}{A}$

Solution: K_{α} corresponds to: $n=2$ to $n=1$ K_{β} corresponds to: $n=3$ to $n=1$

$$\frac{1}{\lambda_{\alpha}}=R\left[\frac{1}{1}-\frac{1}{4}\right] \text{ or } \frac{1}{0.32\overset{0}{A}}=\frac{3R}{4}\rightarrow\frac{1}{\lambda_{\beta}}=R\left[\frac{1}{1^{2}}-\frac{1}{3^{2}}\right]=\frac{8R}{9}$$

$$\therefore\frac{\lambda_{\beta}}{0.32\overset{0}{A}}=\frac{3R}{4}\times\frac{9}{8R} \quad \text{or} \quad \lambda_{\beta}=\frac{27}{32}\times0.32\overset{0}{A} \quad \text{or} \quad \lambda_{\beta}=0.27\overset{0}{A}$$