Chapter – 2

Quantum Mechanical Model of Atom

I. Choose the correct answer

Question 1.
Electronic configuration of species M^{2+} is $1s^2\ 2s^2\ 2p^6 3s^2\ 3p^6\ 3d^6$ and its atomic weight is 56. The number of neutrons in the nucleus of species M is ………..
(a) 26
(b) 22
(c) 30
(d) 24

Answer:
(c) 30

Solution:
M^{2+} : $1s^2\ 2s^2\ 2p^6 3s^2\ 3p^6\ 3d^6$
M : $1s^2\ 2s^2\ 2p^6 3s^2\ 3p^6\ 3d^8$
Atomic number = 26
Mass number = 56
No. of neutrons = 56 – 26 = 30.

Question 2.
The energy of light of wavelength 45 nm is
(a) 6.67×10^{15} J
(b) 6.67×10^{11} J
(c) $4.42 . \times 10^{18}$ J
(d) 4.42×10^{-15} J

Answer:
(c) 4.42×10^{18} J

Solution:
$E = hv = hc / \lambda$
$$\frac{6.626 \times 10^{-34} Js \times 3 \times 10^{8} ms^{-1}}{45 \times 10^{-9} m} = 4.42 . \times 10^{18} J.$$

Question 3.
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) $\frac{\lambda_1}{\lambda_2} = 1$

(b) $\lambda_1 = 2\lambda_2$

(c) $\lambda_1 = \sqrt{25 \times 50}\lambda_2$

(d) $2\lambda_1 = \lambda_2$

Answer:
(b) $\lambda_1 = 2\lambda_2$

Solution:
$\frac{El}{E2} = \frac{25eV}{50eV} = \frac{1}{2}$
$\frac{\mathrm{hc}}{\lambda_1} \times \frac{\lambda_2}{\mathrm{hc}} = \frac{1}{2}$
$2\lambda_2 = \lambda_1$.

Question 4.
Splitting of spectral lines in an electric field is called ……………
(a) Zeeman effect
(b) Shielding effect
(c) Compton effect
(d) Stark effect

Answer:
(d) Stark effect

Solution:
The splitting of spectral lines in a magnetic field is called the Zeeman effect and the splitting of spectral lines in an electric field is called the Stark effect.

Question 5.
Based on equation $E = -2.178 \times 10^{18}\ \mathrm{J} \left(\frac{z^2}{n^2}\right)$ certain conclusions are written. Which of them is not correct? (NEET)
(a) Equation can be used to calculate the change in energy when the electron changes orbit

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

Answer:
(b) For n = 1, the electron has more negative energy than it does for n = 6 which means that the electron is more loosely bound in the smallest allowed orbit

Solution:
Correct statement:
For n = 6, the electron has more negative energy than it does for n = 6 which means that the electron is strongly bound in the smallest allowed orbit.

Question 6.
According to the Bohr Theory, which of the following transitions in the hydrogen atom will give rise to the least energetic photon?
(a) n = 6 to n = 1
(b) n = 5 to n = 4
(c) n = 5 to n = 3
(d) n = 6 to n = 5

Answer:
(d) n = 6 to n = 5

Solution:
n = 6 to n = 5
$E_6 = -13.6 / 6^2$; $E_5 = -13.6 / 5^2$
$E_6 - E_5 = (-13.6 / 6^2) - (-13.6 / 5^2)$
$= 0.166$ eV $atom^{-1}$
$E_5 - E_4 = (-13.6 / 5^2) - (-13.6 / 4^2)$
$= 0.306$ eV $atom^{-1}$

Question 7.
Assertion: The spectrum of He^+ is expected to be similar to that of hydrogen.

Reason: He^+ is also a one-electron system.
(a) If both assertion and reason are true and the reason is the correct explanation of assertion.
(b) If both assertion and reason are true but the reason is not the correct explanation of assertion.
(c) If the assertion is true but the reason is false
(d) If both assertion and reason are false

Answer:
(a) If both assertion and reason are true and the reason is the correct explanation of assertion.

Question 8.
Which of the following pairs of d-orbitals will have electron density along the axes ? (NEET Phase – II)
(a) d_{z^2}, d_{xz}

(b) d_{xz}, d_{yz}

(c) d_{z^2}, $d_{x^2-y^2}$

(d) d_{xy}, $d_{x^2-y^2}$

Answer:
(c) d_{z^2}, $d_{x^2-y^2}$

Question 9.
Two electrons occupying the same orbital are distinguished by ………..
(a) azimuthal quantum number
(b) spin quantum number
(c) magnetic quantum number
(d) orbital quantum number

Answer:
(b) spin quantum number

Solution:
Spin quantum number For the first electron ms = $+\frac{1}{2}$

For the second electron ms = $-\frac{1}{2}$.

Question 10.
The electronic configuration of Eu (atomic no. 63) Gd (atomic no. 64) and Tb (atomic no. 65) are (NEET – Phase II)
(a) [Xe] $4f^7$ $5d^1$ $6s^2$, [Xe] $4f^7$ $5d^1$ $6s^2$ and [Xe] $4f^8$ $5d^1$ $6s^2$
(b) [Xe] $4f^7$, $6s^2$, [Xe] $4f^7$ $5d^1$ $6s^2$ and [Xe] $4f^9$ $6s^2$
(c) [Xe] $4f^7$, $6s^2$, [Xe] $4f^8$ $6s^2$ and [Xe] $4f^8$ $5d^1$ $6s^2$
(d) [Xe] $4f^8$ $5d^1$ $6s^2$[Xe] $4f^7$ $5d^1$ $6s^2$ and [Xe] $4f^9$ $6s^2$

Answer:
(b) [Xe] $4f^7$, $6s^2$, [Xe] $4f^7$ $5d^1$ $6s^2$ and [Xe] $4f^9$ $6s^2$

Solution:
Eu : [Xe] $4f^7$, $5d^0$, $6s^2$
Gd : [Xe] $4f^7$, $5d^1$, $6s^2$
Tb : [Xe] $4f^9$, $5d^0$,$6s^2$

Question 11.
The maximum number of electrons in a subshell is given by the expression …………..
(a) $2n^2$
(b) 21 + 1
(c) 41 + 2
(d) none of these

Answer:
(c) 41 + 2

Solution:
2 (21 + 1) = 41 + 2.

Question 12.
For d-electron, the orbital angular momentum is …………
(a) $\frac{\sqrt{2}h}{2\pi}$
(b) $\frac{\sqrt{2\mathrm{h}}}{2\pi}$
(c) $\sqrt{2 \times 4}$
(d) $\frac{\sqrt{6}h}{2\pi}$

Answer:

Solution:

Orbital angular momentum

= $\sqrt{(1(1+1))}h/2\pi$

For d orbital = $\sqrt{(2 \times 3)}h/2\pi$ = $\sqrt{6}h/2\pi$.

Question 13.
What is the maximum numbers of electrons that can be associated with the following set of quantum numbers ? n = 3,l = 1 and m = -1
(a) 4
(b) 6
(c) 2
(d) 10

Answer:
(c) 2

Solution:
n = 3; l = 1; m = -1 either $3p_x$ or $3p_y$

Question 14.
Assertion: The number of radials and angular nodes for 3p orbital are l, l respectively.
Reason: The number of radials and angular nodes depends only on the principal quantum number.

(a) both assertion and reason are true and the reason is the correct explanation of assertion.
(b) both assertion and reason are true but the reason is not the correct explanation of assertion.
(c) the assertion is true but the reason is false
(d) both assertion and reason are false

Answer:
(c) assertion is true but reason is false

Solution:
No. of radial node = n- l – 1

No. of angular node = l for 3p orbital
No. of angular node = l = 1
No. of radial node = n – l – 1 = 3 – 1 – 1 = 1.

Question 15.
The total number of orbitals associated with the principal quantum number n = 3 is ………..
(a) 9
(b) 8
(c) 5
(d) 7

Answer:
(a) 9
Solution:
n = 3; l = 0; m_1 = 0 – one's orbital n = 3; l = 1; m_1 = -1, 0, 1 – three p orbitals n = 3; l = 2; m_1 = -2, -1, 0, 1, 2 – five d orbitals, overall nine orbitals are possible.

Question 16.
If n = 6, the correct sequence for filling of electrons will be, …………
(a) ns → (n – 2) f → (n – 1)d → np
(b) ns → (n – 1) d → (n – 2) f → np
(c) ns → (n – 2) f → np → (n – 1) d
(d) none of these are correct

Answer:
(a) ns → (n – 2)f → (n – l)d → np

Solution:
n = 6 According Aufbau principle,
6s → 4f → 5d → 6p
ns → (n – 1)f → (n – 2)d → np.

Question 17.
Consider the following sets of quantum numbers:

	n	l	m	s
(*i*)	3	0	0	+ ½
(*ii*)	2	2	1	– ½
(*iii*)	4	3	–2	+ ½
(*iv*)	1	0	–1	+ ½
(*v*)	3	4	3	– ½

Which of the following sets of quantum numbers is not possible?
(a) (i), (ii), (iii) and (iv)
(b) (ii), (iv) and (v)
(c) (z) and (iii)
(d) (ii), (iii) and (iv)

Answer:
(b) (ii), (iv) and (v)

Solution:
(ii) l can have the values from 0 to n – 1 n = 2; possible l values are 0, 1 hence l = 2 is not possible.
(iv) for l = 0; m = -1 not possible
(v) for n = 3 l = 4 and m = 3 not possible.

Question 18.
How many electrons in an atom with atomic number 105 can have (n + 1) = 8?
(a) 30
(6) 17
(c) 15
(d) unpredictable

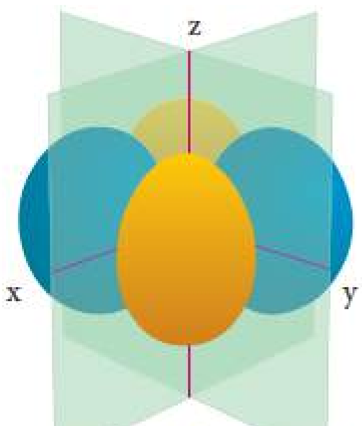
Answer:
(b) 17

Solution:
n + 1 = 8
Electronic configuration of atom with atomic number 105 is [Rn] $5f^{14}$ $6d^3$ $7s^2$

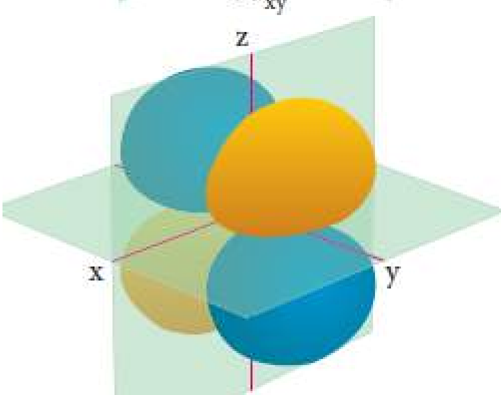
Orbital	(n+1)	No. of electrons
5f	$5 + 3 = 8$	14
6d	$6 + 2 = 8$	3
7s	$7 + 0 = 0$	2
No. of electrons $= 14 + 3 = 17$		

Question 19.
Electron density in the yz plane of 3 $d_{x^2-y^2}$ orbitals is ……………
(a) zero
(b) 0.50
(c) 0.75
(d) 0.90

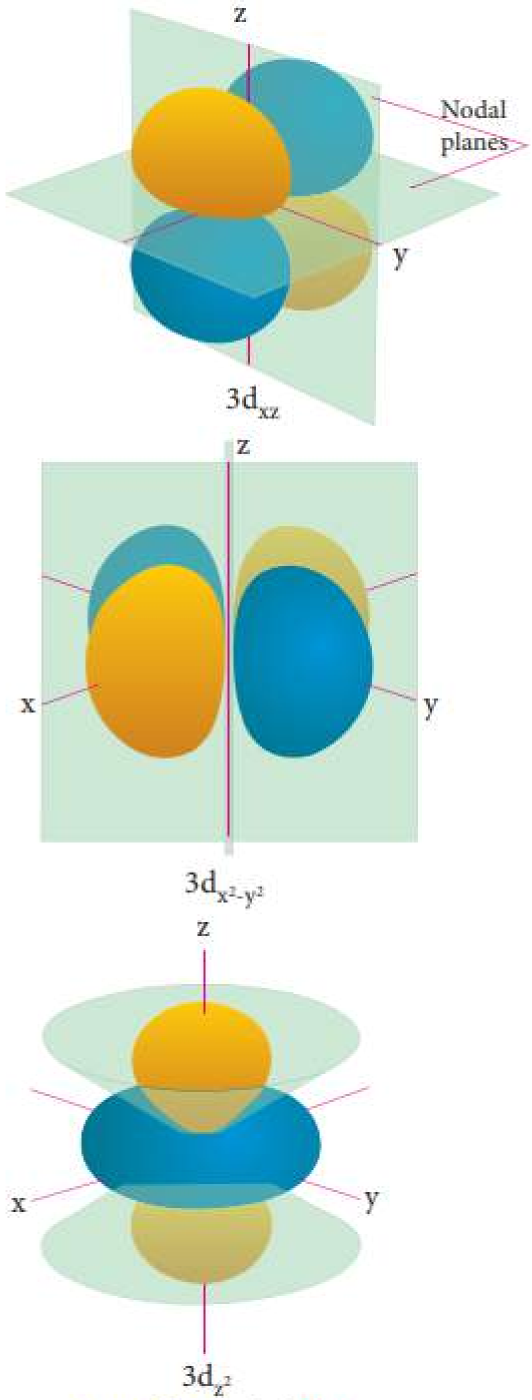
Answer:
(a) zero



$3d_{xy}$



$3d_{yz}$



shapes of d orbitals

Question 20.
If uncertainty in position and momentum are equal, then minimum uncertainty in velocity is ……….

(a) $\frac{1}{m}\sqrt{\frac{h}{\pi}}$
(b) $\sqrt{\frac{h}{\pi}}$
(c) $\frac{1}{2m}\sqrt{\frac{h}{\pi}}$
(d) $\frac{h}{4\pi}$

Answer:
(c) $\frac{1}{2m}\sqrt{\frac{h}{\pi}}$

Solution:

$$\Delta x.\Delta p \geq \frac{h}{4\pi}$$

$$\Delta p.\Delta p \geq \frac{h}{4\pi}$$

$$\Delta p^2 \geq \frac{h}{4\pi}$$

$$m^2 (\Delta v)^2 \geq \frac{h}{4\pi}$$

$$(\Delta v) \geq \sqrt{\frac{h}{4\pi m^2}}$$

$$\Delta v \geq \frac{1}{2m}\sqrt{\frac{h}{\pi}}$$

Question 21.
A macroscopic particle of mass 100 g and moving at a velocity of 100 cm s^{-1}d will have a de Broglie wavelength of ………...
(a) 6.6 x 10^{-29} cm
(b) 6.6 x 10^{-30} cm
(c) 6.6 x 10^{-31} cm
(d) 6.6 x 10^{-32} cm

Answer:
(c) 6.6 x 10^{-31} cm

Solution:
m = 100 g = 100 x 10^{-3} kg
v = 100 cm s^{-1} = 100 x 10^{-2} m s^{-1}

$$\lambda = \frac{h}{mv} = \frac{6.626\times10^{-34}\,Js^{-1}}{100\times10^{-3}\ kg\times100\times10^{-2}\,ms^{-1}}$$

$= 6.626 \times 10^{-31}\ ms^{-1}$

$= 6.626 \times 10^{-31}\ cm\ s^{-1}$

Question 22.
The ratio of de Broglie wavelengths of a deuterium atom to that of an α-particle, when the velocity of the former is five times greater than that of later, is ……………
(a) 4
(b) 0.2
(c) 2.5
(d) 0.4

Answer:
(d) 0.4

Question 23.
The energy of an electron in the 3rd orbit of a hydrogen atom is -E. The energy of an electron in the first orbit will be ……………..
(a) – 3E
(b) – E /3
(c) – E / 9
(d) – 9E

Answer:
(c) – E / 9

Solution:

$E_n = \frac{-13.6}{n^2}$ eV atom^{-1}

$E_1 = \frac{-13.6}{1^2}\,13.6 = \frac{-13.6}{9}$

Given that,

$E_3 = -E$

$\frac{-13.6}{9} = -E$

$13.6 = -9E = E_1 = -9E$

$E_1 = -9E$

Question 24.
Time independent Schrodinger wave equation is …………

(a) $\hat{H}\psi = E\psi$

(b) $\nabla^2\psi + \frac{8\pi^2 m}{h^2}(E+V)\psi = 0$

(c) $\frac{\partial^2\psi}{\partial x^2} + \frac{\partial^2\psi}{\partial y^2} + \frac{\partial^2\psi}{\partial z^2} + \frac{2m}{h^2}(E-V)\psi = 0$

(d) all of these

Answer:
(a) $\hat{H}\psi = E\psi$.

Question 25.
Which of the following does not represent the mathematical expression for the Heisenberg uncertainty principle?
(a) $\Delta E.\Delta p \geq h/4\pi$
(b) $\Delta E.\Delta v \geq h/4\pi m$
(c) $\Delta E.\Delta t \geq h/4\pi$
(d) $\Delta E.\Delta x \geq h/4\pi$

Answer:
(d) $\Delta E.\Delta x \geq h/4\pi$.

II. Write brief answer to the following questions

Question 26.
Which quantum number reveals information about the shape, energy, orientation, and size of orbitals?

Answer:
The information about the shape, energy, orientation, and size of the orbitals are respectively given by Azimuthal, spin, magnetic, and principal quantum numbers.

Question 27.
How many orbitals are possible for n = 4?

Answer:
If n = 4, the possible number of orbitals are calculated as follows –
n = 4, main shell = N
If n = 4, l values are 0, 1, 2, 3
If l = 0, 4s orbital = 1 orbital
If l = 1, m = -1,0, +1 = 3 orbitals
If l = 2, m = -2,-1,0, +1,+2 = 5 orbitals
If l = 3, m = -3,-2,-1,0, +1,+2,+3 = 7 orbitals
∴ Total number of orbitals = 16 orbitals

Question 28.
How many radial nodes for 2s, 4p, 5d, and 4f orbitals exhibit? How many angular nodes?

Answer:
The formula for the total number of nodes = n – 1

1. For 2s orbital: Number of radial nodes =1.

2. For 4p orbital: Number of radial nodes = n – l – 1. = 4 – 1 – 1 = 2
Number of angular nodes = l
∴ Number of angular nodes = 1
So, 4p orbital has 2 radial nodes and 1 angular node.

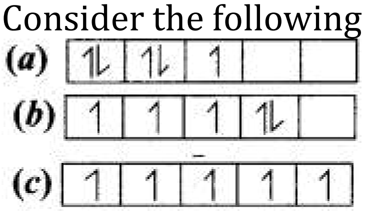
3. For 5d orbital:
Total number of nodes = n – 1 = 5 – 1 = 4 nodes
Number of radial nodes = n – l – 1 = 5 – 2 – 1 = 2 radial nodes.
Number of angular nodes = l = 2
∴ 5d orbital have 2 radial nodes and 2 angular nodes.

4. For 4f orbital:
Total number of nodes = n – 1 = 4 – 1 = 3 nodes
Number of radial nodes = n – 7 – 1 = 4 – 3 – 1 = 0 node.
Number of angular nodes = l = 3 nodes
∴ 4f orbital have 0 radial node and 3 angular nodes.

Question 29.
The stabilization of a half-filled d-orbital is more pronounced than that of the p-orbital why?

Answer:
The half-filled orbitals are more stable due to symmetry and exchange energy. In the case of half-filled d-orbitals, there are ten possible exchanges whereas in p-orbitals three possible exchanges only, If more exchanges are possible, more exchange energy is released and more stable. Hence, the stabilization of a half-filled d-orbital is more pronounced than that of the p-orbital.

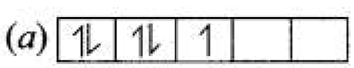
Question 30.
Consider the following electronic arrangements for the d5 configuration.



(1) Which of these represents the ground state
(2) Which configuration has the maximum exchange energy.

Answer:

(1)  – This represents the ground state.

(2)  – This represents the maximum exchange energy.

Question 31.
State and explain Pauli's exclusion principle.

Answer:
Pauli's exclusion principle states that "No two electrons in an atom can have the same set of values of all four quantum numbers". It means that each electron must have unique values for the four quantum numbers.

For the lone electron present in hydrogen atom, the four quantum numbers are: n = 1, l = 0, m = 0 and s = +1/2. For the two electrons present in helium, one electron has the quantum numbers same as the electron of the hydrogen atom,
n = 1, l = 0, m = 0, and s = +1/2

For other electron, the fourth quantum number is different, i.e., n = 1, l = 0, m = 0 and s = -1/2.

Question 32.
Define orbital? What are the n and l values for $3p_x$ and 4 $d_{x^2-y^2}$ electron?

Answer:
(i) Orbital is a three-dimensional space in which the probability of finding the electron is maximum.

(ii) For $3p_x$ electron: n value = 3, l value = 1

(iii) For $4d_{x^2-y^2}$ electron: n value = 4, l value = 2

Question 33.
Explain briefly the time-independent Schrodinger wave equation?

Answer:
The time independent Schrodinger equation can be expressed as

$\hat{H}\,\Psi = E\Psi$ ....(1)

Where $\hat{H}$ is called Hamiltonian operator.

Ψ is the wave function.
E is the energy of the system.

$$\hat{H} = \left[\frac{-h^2}{8\pi^2 m} \left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2} \right) + V \right] \quad ....(2)$$

Since Ψ is a function of position coordinates of the particle and is denoted by Ψ (x, y, z)

∴ Equation (1) can be written as,

$$\left[\frac{-h^2}{8\pi^2 m} \left(\frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2 \psi}{\partial y^2} + \frac{\partial^2 \psi}{\partial z^2} \right) + V\psi \right] = E\psi \quad ....(3)$$

Multiply the equation (3) by $\hat{H}$ and rearranging

$$\frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2 \psi}{\partial y^2} + \frac{\partial^2 \psi}{\partial z^2} + \frac{8\pi^2 m}{h^2}(E - V)\psi = 0 \quad ....(4)$$

The above equation (4) Schrodinger wave equation does not contain time as a variable and is referred to as time-independent Schrodinger wave equation.

Question 34.

Calculate the uncertainty in position of an electron, if Δv = 0.1% and n = 2.2 x 10^6 ms^{-1}.

Answer:

Mass of an electron = m = 9.1 x 10^{-31} kg.

Δv = Uncertainty in velocity = $\frac{0.1}{100}$ x 2.2 x 10^3 ms^{-1} .

Δv = 0.22 x 10^4 = 2.2 x 10^3 ms^{-1}

Δx . Δv . m = $\frac{h}{4\pi}$

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

$$= \frac{6.626 \times 10^{-34}}{2.2 \times 10^3 \times 9.1 \times 10^{-31} \times 4 \times 3.14}$$

$$= \frac{6.626 \times 10^{-34} \times 10^{-3} \times 10^{31}}{2.2 \times 9.1 \times 4 \times 3.14}$$

$$= \frac{6.626 \times 10^{-6}}{251.45}$$

= 0.02635 x 10^{-6}

Δx = 2.635 x 10^{-8}

Uncertainty in position = 2.635 x 10^{-8}.

Question 35.
Determine the values of all the four quantum numbers of the 8th electron in O – atom and 15th electron in Cl atom and the last electron in chromium.

Answer:
Electronic configuration of Oxygen (Atomic Number = 8) is
$1s^2\ 2s^2\ 2py^2\ 2pz^1\ 2px^1$

The eighth electron is present in 2px orbital and the quantum numbers are n = 2, l = 1, m = +1 or -1 and s = +1/2.

Electronic configuration of Chlorine (Atomic Number = 17) is
$1s^2\ 1s^2\ 2p^6\ 3s^2\ 3p^5$. Therefore, 15th (last) electron is present in 3pz orbital and the quantum numbers are n = 32, l = 1, m = +1 or -1 and s = +1/2

Electronic configuration of Chromium (Atomic Number = 24) is
$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^1$. Therefore, last electron is present in 4s orbital and the quantum numbers are n = 4, l = 0, m = 0 and s = +1/2.

Question 36.
The quantum mechanical treatment of the hydrogen atom gives the energy value:
$E_n = \frac{-13.6}{n^2}$ eV $atom^{-1}$

1. use this expression to find ΔE between n = 3 and n = 4
2. Calculate the wavelength corresponding to the above transition.

Answer:
(1) When n = 3
$E_3 = \frac{-13.6}{3^2} = \frac{-13.6}{9} = -1.511$ eV $atom^{-1}$
When n = 4 $E_4 = \frac{-13.6}{4^2} = -0.85$ eV $atom^{-1}$
$\Delta E = E_4 - E_3 = -0.85 - (-1.511) = +0.661$ eV atom
$\Delta E = E_3 - E_4$
$= -1.511 - (-0.85)$
$= -0.661$ eV $atom^{-1}$

(2) Wave length = λ

$$\Delta E = \frac{hc}{\lambda}$$

$$\lambda = \frac{hc}{\Delta E}$$

h = Planck's constant = 6.626×10^{-34} Js^{-1}

c = 3×10^{8} m/s

$$\lambda = \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{0.661}$$

$= 10.02 \times 10^{-34} \times 3 \times 10^{8}$

$= 30 \times 10^{-26}$

$\lambda = 3 \times 10^{-25}$ m.

Question 37.
How fast must a 54 g tennis ball travel in order to have a de Broglie wavelength that is equal to that of a photon of green light 5400 Å?

Answer:
m = mass of tennis ball = 54 g = 5.4×10^{-2} kg.
λ = de Broglie wavelength = 5400 Å. = 5400×10^{-10} m.
V = velocity of the ball = ?

$$\lambda = \frac{h}{mV}$$

$$V = \frac{h}{\lambda . m}$$

$$= \frac{6.626 \times 10^{-34}}{5400 \times 10^{-10} \times 5.4 \times 10^{-2}}$$

$$= \frac{6.626 \times 10^{-34} \times 10^{10} \times \cancel{10^{2}}}{54\cancel{00} \times 5.4}$$

$$= \frac{6.626 \times 10^{-24}}{54 \times 5.4}$$

$$= \frac{6.626 \times 10^{-24}}{29.6}$$

$= 0.2238 \times 10^{-24}$
$= 2.238 \times 10^{-25}$ m.

Question 38.
For each of the following, give the sub level designation, the allowable m values and the number of orbitals.

1. n = 4, l = 2,
2. n = 5, l = 3
3. n = 7, l = 0

Answer:
1. n = 4, l = 2
If l = 2, 'm' values are -2, -1, 0, +1, +2
So, 5 orbitals such as d_{xy}, d_{yz}, d_{xz}, $d_{x^2-y^2}$ and d_{z^2}

2. n = 5, l = 3
If l = 3, 'm' values are -3, -2, -1, 0, +1, +2, +3
So, 7 orbitals such as f z, fxz, fyz, fxyz, fz(x2 y2)' ^x(x2-3y2)' ^y(3×2 ??y

3. n = 7, l = 0
If l = 0, 'm' values are 0. Only one value.
So, 1 orbital such as 7s orbital.

Question 39.
Give the electronic configuration of Mn^{2+} and Cr^{3+}

Answer:
Mn (z = 25). Electronic configuration of
$Mn^{2+} = 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^0\ 3d^5$.
Cr (z =24) Electronic configuration of
$Cr^{3+} = 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^0\ 3d^3$.

Question 40.
Describe the Aufbau principle.

Answer:
In the ground state of the atoms, the orbitals are filled in the order of their increasing energies. That is the electrons first occupy the lowest energy orbital available to them. Once the lower energy orbitals are completely filled, then the electrons enter the next higher energy orbitals.
The order of filling of various orbitals as per the Aufbau principle is –

$1s < 2s < 2p < 3s < 3p < 4s < 3d < 4p < 5s < 4d$ ………..
For e.g., K (Z =19)
The electronic configuration is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$.
After filling 4s orbital only we have to fill up 3d orbital.

Question 41.
An n atom of an element contains 35 electrons and 45 neutrons. Deduce

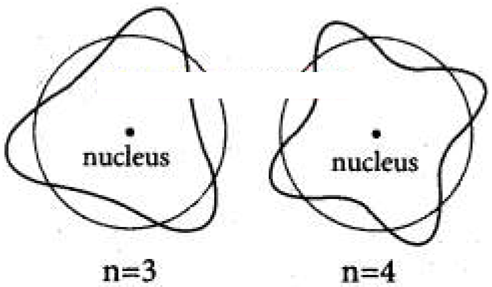
1. the number of protons
2. the electronic configuration for the element
3. All the four quantum numbers for the last electron

Answer:
An element X contains 35 electrons, 45 neutrons

1. The number of protons must be equal to the number of electrons. So the number of protons = 35.
2. Number of electrons = 35. So the electronic configuration is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^5$.
3. The last electron i.e. 5^{th} electron in 4p orbital has the following quantum numbers. $n = 4, l = 1, m = +1, s = +\frac{1}{2}$

Question 42.
Show that the circumference of the Bohr orbit for the hydrogen atom is an integral multiple of the de Broglie wavelength associated with the electron revolving around the nucleus.

Answer:
In order for the electron wave to exist in phase, the circumference of the orbit should be an integral multiple of the wavelength of the electron wave. Otherwise, the electron wave is out of phase.
$mvr = nh / 2\pi$, $2\pi r = n\lambda$,
where mvr = angular momentum
where $2\pi r$ = circumference of the orbit



n = 3, n = 4

Question 43.
Calculate the energy required for the process.
$He^{+}_{(g)} \rightarrow He^{2+}_{(g)} + e^{-}$
The ionization energy for the H atom in its ground state is – 13.6 eV $atom^{-1}$.

Answer:
The ionization energy for the H atom in its ground state =-13.6 eV $atom^{-1}$.

Ionization energy = $\frac{13.6z^2}{n^2}$ eV

Z = atomic number

n = principal quantum number or shell number

For He, n = 1, z = 2

IE = $\frac{-13.6\times2^2}{1^2}$ eV.

Question 44.
An ion with mass number 37 possesses a unit negative charge. If the ion contains 11.1% more neutrons than electrons. Find the symbol of the ion.

Answer:
Mass number (A) = Number of Protons + Number of neutrons = 37.
Number of neutrons = Number of electrons (x) + 11.1 % of x.
Given:
(x – 1) ion + 1.111x = 37.
x = $\frac{38}{2}$. 11 = 18 = 18.

Atomic Number(z) = 18 – 1 = 17.

Symbol of the ion is $^{37}_{17}X$.

Question 45.
The Li^{2+} ion is a hydrogen-like ion that can be described by the Bohr model. Calculate the Bohr radius of the third orbit and calculate the energy of an electron in 4th orbit.

Answer:
Li^{2+} hydrogen-like ion.

Bohr radius of the third orbit = r_3 = ?

$r_3 = \frac{(0.529)n^2}{Z}$ A

Where n = shell number, Z = atomic number.

$r_3 = \frac{(0.529)3^2}{3}$ A [∴for lithium Z = 3, n = 3]

$= \frac{0.529x9}{3}$

r_3 = l.587Å

$E_n = \frac{(-13.6)Z^2}{n^2}$ eV atom^{-1}.

E_4 = Energy of the fourth orbit = ?

$E_4 = \frac{(-13.6)\times 3^2}{4^2} = \frac{-13.6\times 9}{16}$ = -7.65 eV atom^{-1}

E_4 = – 7.65 eV atom^{-1}

Question 46.
Protons can be accelerated in particle accelerators. Calculate the wavelength (in Å) of such accelerated proton moving at 2.85 × 108 ms^{-1} (the mass of proton is 1.673 x 10^{-27} Kg).

Answer:
m = mass of the proton = 1.673 x 10^{-27} Kg
v = velocity of the proton = 2.85 x 10^8 ms^{-1}

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

h = Planck's constant = 6.626 x 10^{34} Kg m^2 s^{-1}

$$= \frac{6.626 \times 10^{-34} \cancel{Kg}\ m^{\cancel{2}} \cancel{s^{-1}}}{1.673 \times 10^{-27} \cancel{Kg} \times 2.85 \times 10^{8} \cancel{ms^{-1}}}$$

$$= \frac{6.626 \times 10^{-34} \times 10^{27} \times 10^{-8}}{1.673 \times 2.85} \text{ m}$$

$$= \frac{6.626 \times 10^{-15}}{4.768}$$

$$= 1.389 \times 10^{-15} \text{ m}$$

Wavelength of proton = λ = 1.389×10^{-15} m.

Question 47.
What is the de Broglie wavelength (in cm) of a 160g cricket ball travelling at 140 Km hr^{-1}.

Answer:
m = mass of the cricket ball = 160g = 0.16 kg.
v = velocity of the cricket ball =140 Km h^{-1}

$$= \frac{140x5}{18} = 38.88 \text{ ms}^{-1}$$

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

h = Planck's constant = 6.626×10^{-34} kg m^2 s^{-1}

$$= \frac{6.626 \times 10^{-34} \cancel{Kg}\ m^{\cancel{2}} \cancel{s^{-1}}}{0.16 \cancel{Kg} \times 38.88 \cancel{ms^{-1}}}$$

$$\lambda = \frac{6.626 \times 10^{-34}}{6.2208}$$

$\lambda = 1.065 \times 10^{-34}$m
Wave length in cm = $1.065 \times 10^{-34} \times 100$
= 1.065×10^{-32} cm.

Question 48.
Suppose that the uncertainty in determining the position of an electron in an orbit is 0.6 A. What is the uncertainty in its momentum?.

Answer:
Δx = uncertainty in position of an electron = 0.6 Å = 0.6×10^{-10} m.
Δp = uncertainty in momentum =?
Heisenberg's uncertainty principle states that,

$\Delta x.\Delta p \geq \frac{h}{4\pi}$

$\Delta p = \frac{h}{4\pi.\Delta x}$

h = Planck's constant = 6.626 x 10^{-34} kg m^2 s^{-1}

$\therefore \Delta p = \frac{6.626 \times 10^{-34} \text{ Kg } \cancel{m^2} s^{-1}}{4 \times 3.14 \times 0.6 \times 10^{-10} \cancel{m}}$

$= \frac{6.626 \times 10^{-34} \times 10^{10}}{7.536}$

Uncertainty in momentum = 0.8792 x 10^{-24} kg ms^{-1} (or) = 8.792 x 10^{-25} kg ms^{-1}

Question 49.

Show that if the measurement of the uncertainty in. the location of the particle is equal to its de Broglie wavelength, the minimum uncertainty in its velocity is equal to its velocity /4π

Answer:

If, uncertainty in position = Δx = λ, the value of uncertainty in velocity = v/4π

Heisenberg's principle states that

$\Delta x.\Delta v.\, m = \frac{h}{4\pi}$ ....(1)

de Broglie equation states that

$\lambda = \frac{h}{mv}$ ....(2)

$\therefore$ h = λ .m.v ....(3)

$\Delta x = \frac{h}{\Delta v.4\pi}$ ....(4)

Substituting the value of h in equation (4)

$\Delta x = \frac{\lambda x m.v}{\Delta v.4\pi.m}$

if Δx = λ

$\Delta v = \frac{\cancel{x}.\, \cancel{m}.v}{\cancel{x}\, .4\pi\, .\, \cancel{m}} = \frac{v}{4\pi}$

Question 50.

What is the de Broglie wave length of an electron, which is accelerated from the rest, through a potential difference of 100V?

Answer:
Potential difference = V = 100 V
Potential energy = eV = 1.609×10^{-19}c x 100V

$$\frac{v}{4\pi} m v^2 = 1.609 \times 10^{-19} \times 100$$

$$\frac{v}{4\pi} m v^2 = 1.609 \times 10^{-19} \text{ J}$$

$$v^2 = \frac{2 \times 1.609 \times 10^{-17}}{m}$$

m = mass of electron = 9.1×10^{-31} Kg

$$\therefore v^2 = \frac{2 \times 1.609 \times 10^{-17}}{9.1 \times 10^{-31}}$$

$$\therefore v = \sqrt{\frac{2 \times 1.609 \times 10^{-17}}{9.1 \times 10^{-31}}}$$

$$= \sqrt{\frac{2 \times 1.609 \times 10^{-17} \times 10^{31}}{9.1}}$$

$$v = \sqrt{\frac{3.218 \times 10^{14}}{9.1}}$$

$$v = 5.93 \times 10^{6} \text{ m/s}$$

$\lambda = \frac{h}{mv}$ where h = 6.62×10^{-34} JS

$$= \frac{6.62 \times 10^{-34}}{9.1 \times 10^{-31} \times 5.93 \times 10^{6}}$$

$$= 1.2 \times 10^{-10} \text{m}$$

A= 1.2 Å.

Question 51.
Identify the missing quantum numbers and the sub energy level

n	l	m	Sub energy level
?	?	0	4d
3	1	0	?
?	?	?	5p
?	?	–2	3d

Answer:

n	l	m	Sub energy level
4	2	0	4d
3	1	0	3p
5	1	–1	5p
3	2	–2	3d