Chapter 2

Structure of Atom

Solutions

SECTION - A

Objective Type Questions (One option is correct)

1. How many maximum spectral lines are possible if electron is present in 4th shell and only two atom are present in sample?

(1) 6 (2) 4 (3) 3 (4) 2

Sol. Answer (2)

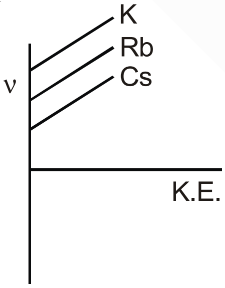
In two and two path is possible.

$4 \rightarrow 3$ $4 \rightarrow 2$

$3 \rightarrow 2$ $2 \rightarrow 1$

$2 \rightarrow 1$

2. The correct graph regarding ν vs KE. (Incident)

(1)


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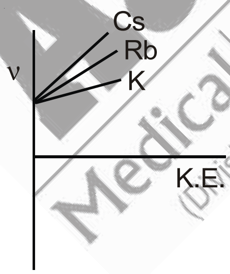

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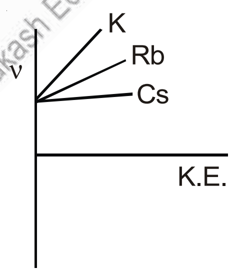

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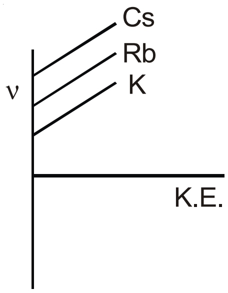


Sol. Answer (1)

$$\nu = \nu_0 + \frac{\text{K.E.}}{r}$$

For Cs, ν_0 is minimum.

3. Maximum electron in 3rd shell having $m_l = 2$ will be

(1) 2 (2) 0 (3) 12 (4) 24

Sol. Answer (1)

	Electrons
n = 3, l = 2, m = +2	2

4. What about degeneracy of 2*p* orbitals in a magnetic field?

(1) No degenerate orbital
(2) Three degenerate orbital
(3) Two degenerate orbital
(4) Cannot be stated any thing about degeneracy

Sol. Answer (1)

Splitting in 2*p* orbitals takes place.

5. In electric field which have maximum angle of deflection? (Assume all have same velocity)

(1) α rays (2) H^+ rays (3) D^+ ray (4) All have equal

Sol. Answer (2)

Angle of deflection is directly proportional to $\frac{e}{m}$.

6 Which of the following value of n have highest elliptical character?

(1) 1 (2) 2 (3) 3 (4) 4

Sol. Answer (4)

As n increases, elliptical character increases.

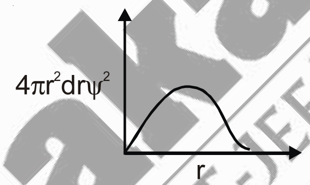
7. The orbital having zero probability of finding electron on the surface of nucleus is

(1) *s* (2) p_x (3) $d_{x^2-y^2}$ (4) Both (2) & (3)

Sol. Answer (4)

p, *d* & *f* orbital have zero probability at nucleus surface.

8. Given graph may belong with



(1) 1*s* (2) 2*p* (3) 3*d* (4) All of these

Sol. Answer (4)

For all orbitals $4\pi r^2 dr.\psi^2$ is zero at surface of nucleus.

9. An electron in hydrogen jumps to a shell in which four fold degenracy is present, then correct about that shell is

(1) 3
(2) 4
(3) 2
(4) This type of transition is not possible

Sol. Answer (3)

For hydrogen, in 2nd shell, four fold degeneracy is present.

10. Largest wavelength is associated with which one of the following, if all of these travel with same velocity?

(1) CO_2 (2) He (3) H_2 (4) NO_2

Sol. Answer (3)

According to de Broglie equation,

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

11. Choose the correct statement.

    (1) Atomic emission spectrum are generally line spectrum

    (2) Gap between two successive lines in spectrum remain same

    (3) During transition spin inversion is frequently allowed

    (4) All of these

Sol. Answer (1)

Atomic spectrum are line spectrum.

12. Which electronic configuration is not allowed for a neutral atom or an ion in ground state?

    (1) $1s^2\,2s^2\,2p^6\,3s^1$ (2) $1s^2\,2s^1\,2p^6\,3d^5$ (3) $1s^2\,2s^2\,2p^6$ (4) $1s^2\,2s^2\,2p^6\,3s^2$

Sol. Answer (2)

$1s^2\,2s^1\,2p^6\,3d^5$ is not allowed because in $2s$ there should be 2 electrons i.e. $2s^2$

13. Choose the correct statement.

    (1) Ionisation energy of H is equal to $_1H^2$ (2) Ionisation energy of $_1H^1$ is greater than $_1H^2$

    (3) Ionisation energy of $_1H^2$ is greater than $_1H^1$ (4) IE of $_1H^1$ may be greater than or less than $_1H^2$

Sol. Answer (3)

For isotope, heavier isotopes have high I.E.

14. An ion which carries +3 charge posseses magnetic moment of 4.9 B.M. and its last electron possesses orbital angular momentum of $\sqrt{6}\hbar$. Identify that element if highest value of n in the E.C. of that ion is 3.

    (1) Mn (2) Fe (3) Cu (4) Zn

Sol. Answer (1)

$\sqrt{n(n+2)} = 4.9$

$n(n + 2) = 24$

$n^2 + 2n - 24 = 0$

$(n + 6)(n - 4) = 0$

$n = 4$

4 unpaired electrons

$\sqrt{l(l+1)}\dfrac{h}{2\pi} = \sqrt{6}\dfrac{h}{2\pi}$

$l = 2$

$\Rightarrow$ last subshell is d subshell, highest value of n is 3.

A^{+3} contains 4 unpaired electron .

possible subshells

$1s\ 2s\ 2p\ 3s\ 3p\ 4s\ 3d$

unpaired in $A^{+3} = 4$

In removal of total $3e^-$, $2e^-$ will be removed from $4s$ and $1e^-$ from $3d$.

$3d$ must contain 4 unpaired e^- in A^{+3}.

$A^{+3} = 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^4$

$A = 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5,\ 4s^2$

Z = 25

Element is Mn.

15. For 2s orbital $\Psi_r = \frac{1}{\sqrt{8}}\left(\frac{z}{a_0}\right)^{\frac{3}{2}}\left(2-\frac{zr}{a_0}\right)e^{-\frac{zr}{2a_0}}$ then, hydrogen radial node will be at the distance of

(1) a_0 (2) $2a_0$ (3) $\frac{a_0}{2}$ (4) $\frac{a_0}{3}$

Sol. Answer (2)

At $2a_0$, $\psi^2 = 0$

16. How many nodal planes are present in $4d_{z^2}$?

(1) 2 (2) 1 (3) Zero (4) 3

Sol. Answer (3)

Due to its shape.

SECTION - B

Objective Type Questions (More than one options are correct)

1. Choose the correct statements

(1) The nature of cathode rays does not depend on the nature of gas taken in discharge tube

(2) Anode rays cause sputtering when incident on metal

(3) Cathode rays produce X rays when they are abruptly stopped by metallic obstacle and nature of X rays produced depends only on metal and not on cathode rays

(4) The degree of deflection in same magnetic field vary in case of anode rays produced from different gases taken in discharge tube

Sol. Answer (1, 2, 4)

Nature of anode rays (not cathode rays) depend on nature of gas taken in discharge tube.

Anode rays sputter when incident on metal

For different gases, charge on particles produced is different, hence deflection will be different

2. Which is/are incorrect observations related to photoelectric effect?

(1) When intensity of light is increased then kinetic energy of photoelectron increases

(2) If frequency of incident light is less than threshold frequency, photoelectron is ejected from the metal surface, if we increase the intensity of light

(3) Number of photoelectrons ejected is proportional to the frequency of incident light only

(4) When frequency of light is increased, velocity of photoelectron increased

Sol. Answer (1, 2, 3)

Kinetic energy $\propto$ frequency.

Number of photoelectrons $\propto$ Intensity.

Photoelectric current $\propto$ Intensity.

If frequency of incident light is less than threshold, photoelectron cannot be emitted by increasing intensity of light.

3. The work function for Ag metal is 7.5×10^{-19} J. Ag metal is being exposed to the light of frequency 1220 Å. Which is/are correct statements?

(1) Threshold frequency of metal is $1.135 \times 10^{15}\ s^{-1}$

(2) Threshold frequency of metal is $8.33 \times 10^{15}\ s^{-1}$

(3) Stopping potential is 5.46 volt

(4) If light of wavelength 3600 Å is used then photoelectric effect take place

Sol. Answer (1, 3)

$w = 7.5 \times 10^{-19}$ J

$\lambda = 1220$ Å

$w = h\nu_0$

$$\Rightarrow \nu_0 = \frac{w}{h} = \frac{7.5\times10^{-19}\ J}{6.67\times10^{-34}\ J\ s}$$

$\nu_0 = 1.135 \times 10^{15}\ s^{-1}$

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

$$\left(\frac{1}{2}mv^2 = ev\right)$$

$$\Rightarrow \frac{hc}{\lambda} = \frac{hc}{\lambda_0} + ev$$

$$v = \frac{hc}{e\lambda} - \frac{h\nu_0}{e}$$

$$= \frac{6.6\times10^{-34}\times3\times10^{8}}{1.6\times10^{-19}\times360\times10^{-10}} - \frac{6.6\times10^{-34}\times1.135\times10^{15}}{1.6\times10^{-19}}$$

$= 34.375 - 4.68$

$h\nu_0 + 1.6 \times 10^{-19} \times 5.46$

$7.49 \times 10^{-19} + 8.736 \times 10^{-19}$

$$1.6226\times10^{-8} = \frac{6.6\times10^{-34}\times3\times10^{10}}{\lambda}$$

$\lambda = 1.220 \times 10^{-7}$

$\Rightarrow$ $\lambda = 1220 \times 10^{-7}$ m

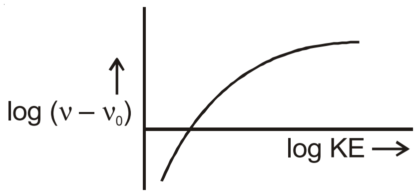
$$\boxed{\lambda = 1220\,\text{Å}}$$

$$\nu = \frac{c}{\lambda} = \frac{3\times10^{8}}{1220\times10^{-7}}$$

$\nu = 2.45 \times 10^{12}$

4. Photoelectric effect can be represented as

(1)



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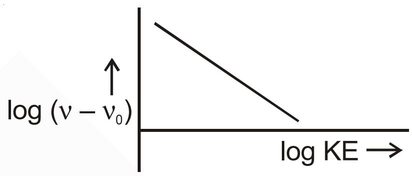

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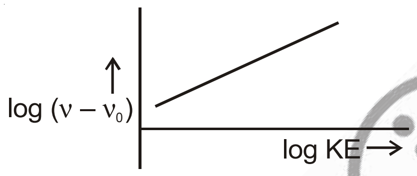

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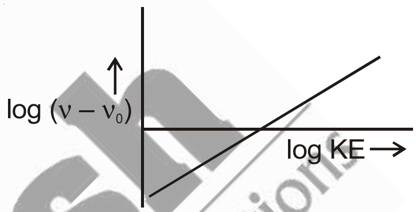


Sol. Answer (3)

Factual (see graph).

5. In a certain electronic transition in hydrogen atom from an initial state to a final state, the difference of orbit radius is 8 times the first Bohr radius. Which transition does not satisfy the given condition?

(1) $7 \rightarrow 1$ (2) $6 \rightarrow 1$ (3) $5 \rightarrow 1$ (4) $3 \rightarrow 1$

Sol. Answer (1, 2, 3)

$$r_n = a_0 \times \frac{n^2}{z}$$

$$r_7 - r_1 = a_0 \times \frac{7^2}{1} - a_0 \times \frac{1^2}{1} = a_0\,(49 - 1) = a_0.\,48$$

$$r_6 - r_1 = a_0 \times \frac{6^2}{1} - a_0 \times \frac{1^2}{1} = a_0\,.35$$

$$r_5 - r_1 = a_0 \times \frac{5^2}{1} - a_0 \times \frac{1^2}{1} = a_0\,.24$$

6. Choose the correct statement regarding Bohr model.

(1) It introduce the concept of quantisation of energy

(2) Radius of shell is given by $r = \dfrac{0.529\,n^2}{z}$ Å

(3) K.E. of electron is given by $\dfrac{2\pi^2 Me^4 z^2 k^2}{n^2 h^2}$

(4) Two isotopes have same ionisation energy

Sol. Answer (1, 2, 3)

KE will be positive and isotopes have different ionization energies.

7. Which statement is/are correct about hydrogen spectrum?

(1) Energy of 2nd orbit is different for ${}_1H^1$, ${}_1H^2$ and ${}_1H^3$

(2) Visible spectrum can be obtained in Lyman series and Balmer series

(3) Infrared spectrum is obtained in Paschen, Brackett and Pfund series

(4) Total number of emission lines obtained in Balmer series is n – 2, where n is principal quantum number and n > 2

Sol. Answer (1, 3, 4)

Since masses are different, hence, 2nd orbit of ${}_1H^1$, ${}_1H^2$, ${}_1H^3$ will have different energies.

Lyman – UV

Balmer – Visible

$\left.\begin{array}{l}\text{Paschen}\\\text{Brackett}\\\text{Pfund}\end{array}\right]\text{Infrared}$

Number of lines = 1 = 3 –2 = n – 2
for n > 2

Number of lines = 2 = 4 – 2 = n – 2
for n > 2

8. In hydrogen atom, electron is present in 6th energy level, which is/are correct about the hydrogen spectrum?

(1) Total 15 emission lines are observed in spectrum

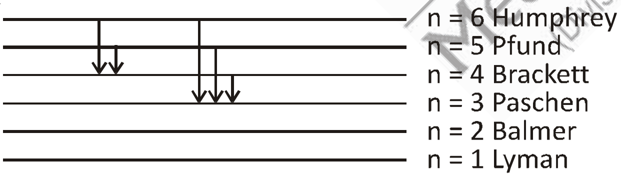
(2) 4 emission lines belong to Lyman series and 5 emission lines belong to Balmer series

(3) 2 emission lines belong to Brackett series and 3 emission lines belong to Paschen series

(4) One emission line belongs to Humphrey series

Sol. Answer (1, 3)

Total emission lines = $\dfrac{6(6-1)}{2} = \dfrac{30}{2} = 15$



9. Velocity of an electron in the second stationary orbit of hydrogen atom is

(1) Equal to velocity of light

(2) Equal to $\dfrac{1}{137}$ times velocity of light

(3) Equal to velocity of an electron in sixth stationary orbit of Li^{+2}

(4) Equal to $\dfrac{1}{274}$ times of the velocity of light

Sol. Answer (3, 4)

$2\pi r = n\lambda$

$2\pi r_2 = n\frac{h}{mv}$

$2\pi a_0 \times \frac{n^2}{Z} = n\frac{h}{mv}$

$2\pi a_0 \times \frac{n}{Z} = \frac{h}{mv}$

$\boxed{v = \frac{hZ}{2\pi a_0 \times nm}}$

$v = \frac{h \times 1}{2\pi a_0 \times 2 \times m}$

$v = \frac{h}{4\pi a_0 m}$

a_0 = Bohr's radius

For sixth orbit of Li^{+2}

$v' = \frac{h \times 3}{2\pi a_0 \times 6\,m}$ for Li, Z = 3

$= \frac{h}{2\pi a_0 \times 2\,m} = \frac{h}{4\pi a_0 m}$

$v = \frac{h}{4\pi a_0 m} = \frac{6.6 \times 10^{-34}}{4 \times 3.14 \times 0.529 \times 10^{-10} \times 9.1 \times 10^{-31}}$

$v = 1.09 \times 10^{-6}$ m/s

$\frac{c}{274} = 1.09 \times 10^{6}$ m/s

10. Choose the correct match.

(1) γ line in Lyman series in H – U.V.

(2) β line in Balmer series in He^+ – U.V.

(3) δ line in Balmer series in H – Visible

(4) δ line in Paschen series in H – Infrared

Sol. Answer (1, 2, 3, 4)

For He^+ (Z = 2)

Lines of Balmer series are observed in U.V region $\left(\frac{1}{\lambda} \propto z^2\right)$.

11. Energy of level 1, 2, 3 of a certain atom corresponds to increasing value of energy $E_1 < E_2 < E_3$. If λ_1, λ_2 and λ_3 are the wavelength of radiation corresponding to transition $3 \to 2$, $2 \to 1$ and $3 \to 1$ respectively. Which of following statement is/are correct?

(1) $\frac{1}{\lambda_3} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2}$

(2) $\lambda_3 = \frac{\lambda_1\lambda_2}{\lambda_1 + \lambda_2}$

(3) $\frac{1}{\lambda_2} = \frac{1}{\lambda_1} + \frac{1}{\lambda_3}$

(4) $\lambda_2 = \frac{\lambda_1\lambda_3}{\lambda_1 + \lambda_2}$

Sol. Answer (1, 2)

$3 \rightarrow 2$

$$\Delta E = \frac{hc}{\lambda_1}$$

$$E_3 - E_2 = \frac{hc}{\lambda_1} \quad \ldots(i)$$

$2 \rightarrow 1$

$$E_2 - E_1 = \frac{hc}{\lambda_2} \quad \ldots(ii)$$

$3 \rightarrow 1$

$$E_3 - E_1 = \frac{hc}{\lambda_3} \quad \ldots(iii)$$

(i) + (ii) = (iii)

$$\frac{hc}{\lambda_1} + \frac{hc}{\lambda_2} = \frac{hc}{\lambda_3}$$

$$\frac{1}{\lambda_3} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2}$$

$$\lambda_3 = \frac{\lambda_1 \lambda_2}{\lambda_1 + \lambda_2}$$

12. An electron is moving in 3rd orbit of hydrogen atom and radius of first orbit is *x* then

(1) de-Broglie wavelength is $6\pi x$

(2) de-Broglie wavelength is $2\pi x$

(3) Velocity of electron is $\frac{h}{6\pi xm}$

(4) Velocity of electron is $\frac{h}{2\pi xm}$

Sol. Answer (1, 3)

$2\pi r_3 = n\lambda$

$$2\pi a_0 \times \frac{n^2}{Z} = n\lambda$$

$$2\pi a_0 \times \frac{3^2}{1} = 3\lambda$$

$\lambda = 6\pi a_0$

$\lambda = 6\pi x \quad \because \quad a_0 = x$

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

$$v = \frac{h}{m\lambda} = \frac{h}{6\pi xm}$$

13. Which of the following suggested de-Broglie wavelength(s) is/are possible for electron in a Bohr orbit of hydrogen atom?

(1) 19.92 Å (2) 9.96 Å (3) 4.98 Å (4) 3.32 Å

Sol. Answer (1, 2, 4)

$2\pi r = n\lambda$

$$\lambda = \frac{2\pi r}{n} = \frac{2\times3.14\times0.529}{1}$$

$\Rightarrow \lambda = 3.32$ Å

For 2nd orbit,

$$n = 2,\ r = a_0 \times \frac{n^2}{Z}$$

$a_0 = 0.529$

$$\lambda = \frac{2\pi a_0 \times \frac{n^2}{Z}}{n} \qquad \left(\because r = a_0 \times \frac{n^2}{Z}\right)$$

$$\lambda = \frac{2\pi a_0 n}{Z} = 3.32\ n$$

$\lambda = 3.32 \times 2 = 6.64$ Å

for n = 3 $\lambda = 3.32 \times 3 = 9.96$ Å

for n = 6 $\lambda = 3.32 \times 6 = 19.92$ Å

14. $|\psi^2|$ can have

(1) Any value from zero to 1 (2) Any value from –1 to +1

(3) A positive non-zero value (4) A non-zero value

Sol. Answer (1)

15. Choose the correct pair regarding properties given in bracket.

(1) 4*d* > 5*s* (angular node) (2) 4*s* = 4*p* (energy in hydrogen)

(3) 3*d* > 4*s* (radial node) (4) 4*s* > 3*s* (radial node)

Sol. Answer (1, 2, 4)

Fact.

16. Which orbital/orbitals cannot exist?

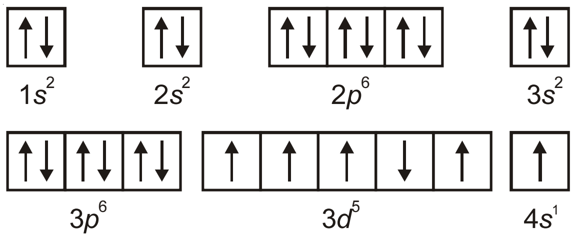
(1) 2*d* (2) 1*p* (3) 3*g* (4) 4*f*

Sol. Answer (1, 2, 3)

Those orbitals do not exist for which $n \le l$.

17. Electronic configuration of an atom

$$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^1$$



Choose the correct statement regarding this E.C.

(1) It represents the ground state of Cr

(2) It violates Aufbau principle

(3) It violates Hund's rule of maximum multiplicity

(4) It is E.C. of Cu in ground state

Sol. Answer (2, 3, 4)

The given electronic configuration violates Hund's rule and Aufbau principle. Therefore, it does not represent ground state electronic configuration of any atom.

18. In which of the following orbital/orbitals radial node and angular nodes are same?

(1) 4*p* (2) 3*p* (3) 5*d* (4) 6*f*

Sol. Answer (2, 3)

$n - l - 1$ = no. of radial nodes;

l = no. of angular nodes.

$n - 1$ = Total no. of nodes

$n - l - 1 = l \Rightarrow n - 1 = 2l$

Subshell	l
s	0
p	1
d	2
f	3

Subshell	n – 1	2*l*
4p	4 – 1 ≠	2 × 1
3p	3 – 1 =	2 × 1
5d	5 – 1 =	2 × 2
6f	6 – 1 ≠	2 × 3

19. How many degenerate orbitals are present in a subshell if electron associated with that subshell possesses orbital angular momentum $= 2\sqrt{3}\hbar$?

(1) No degenerate orbitals

(2) Seven degenerate orbitals

(3) Three degenerate orbitals

(4) Number of degenerate orbitals are same as in subshell which possesses μ_L = 3.46 B.M.

Sol. Answer (2, 4)

$$\sqrt{l(l+1)}\frac{h}{2\pi} = 2\sqrt{3}\ \hbar = 2\sqrt{3}\frac{h}{2\pi}$$

$l(l + 1) = 12$

$l^2 + l - 12 = 0$

$(l + 4)(l - 3) = 0$

$l = 3 \Rightarrow f$ subshell

f subshell has 7 degenerate orbitals.

$\mu_L = \sqrt{l(l+1)}$ BM

$3.46 = \sqrt{l(l+1)}$

$11.97 = l(l + 1)$

$l(l + 1) = 12$

$l^2 + l - 12 = 0$

$(l + 4)(l - 3) = 0$

$l = 3 \Rightarrow f$ subshell has

f subshell has 7 degenerate orbital.

20. Which of the following species expected to have same magnetic moment?

(1) Cr^{+3} (2) Fe^{+3} (3) Co^{+2} (4) Ni^{+2}

Sol. Answer (1, 3)

Cr (24) = $4s^1\ 3d^5$

$Cr^{+3} = 3d^3$

3 unpaired

Fe (26) = $4s^2\ .\ 3d^6$

$Fe^{+3} = 3d^5$

5 unpaired

Co(27) = $4s^2\ 3d^7$

$Co^{+2} = 3d^7$

3 unpaired

Ni (28) = $4s^2\ 3d^8$

$Ni^{+2} = 3d^8$

2 unpaired

Cr^{+3} and Co^{+2} have same number of unpaired electron, hence, same magnetic moment.

SECTION - C

Linked Comprehension Type Questions

Comprehension I

The energy of n^{th} orbit is given by

$$E_n = \frac{-Rhc}{n^2}$$

When electron jumps from one orbit to another orbit then wavelength associated with the radiation is given by

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

1. When electron of 1.0 g atom of hydrogen undergoes transition giving the spectral line of lowest energy in visible region of its atomic spectra, the wavelength of radiation is

(1) 6564 Å (2) 3640 Å (3) 5000 Å (4) 4312 Å

Sol. Answer (1)

$$\frac{1}{\lambda} = R\left(\frac{1}{4} - \frac{1}{9}\right)$$

$$\frac{1}{\lambda} = \frac{R \times 5}{36}$$

$$\lambda = \frac{36}{5R}$$

$$\lambda = \frac{36}{5 \times 1.097 \times 10^7}$$

$\lambda = 6.563 \times 10^{-7}$m

$\lambda = 6563$ Å

2. The series that belongs to visible region is

(1) Lyman Series (2) Balmer Series (3) Pfund Series (4) Humphrey Series

Sol. Answer (2)

Balmer series belong to visible region.

3. The ratio of wavelength H_α of Lyman Series and H_α of Pfund Series is

(1) 54.7 : 1 (2) 0.0183 : 1 (3) 61.4 : 1 (4) 0.0163 : 1

Sol. Answer (4)

$$\frac{1}{\lambda_1} = RZ^2\left(\frac{1}{1^2} - \frac{1}{2^2}\right) \quad \text{...(i)}$$

$$\frac{1}{\lambda_2} = RZ^2\left(\frac{1}{5^2} - \frac{1}{6^2}\right) \quad \text{...(ii)}$$

Divide equation (i) by (ii),

$$\frac{\lambda_2}{\lambda_1} = \frac{1-\frac{1}{4}}{\frac{1}{25}-\frac{1}{36}}$$

$$\frac{\lambda_1}{\lambda_2} = \frac{\frac{11}{25\times36}}{\frac{3}{4}}$$

$$\frac{\lambda_1}{\lambda_2} = \frac{11}{25\times36}\times\frac{4}{3}$$

$$\frac{\lambda_1}{\lambda_2} = \frac{0.0163}{1}$$

$\lambda_1 : \lambda_2 = 0.0163 : 1$

Comprehension II

In photoelectric effect, light of certain frequency (> threshold frequency) is incident on a metal surface, whereby, an e^- (with certain K.E.) moves towards the collector plate and a flow of current is initiated. In order to stop the current flow, an opposite potential, on the two metal plates, is applied.

1. The work function of a metal is 4 eV. If light of frequency 2.3×10^{15} Hz is incident on metal surface, then,

   (1) No photoelectron will be ejected

   (2) 2 photoelectron of zero kinetic energy are ejected

   (3) 1 photoelectron of zero kinetic energy is ejected

   (4) 1 photoelectron is ejected, which required the stopping potential of 5.52 volt

Sol. Answer (4)

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

$E = h\nu = 6.67 \times 10^{-34} \times 2.3 \times 10^{15}$

$E = 1.51 \times 10^{-18}$

$$E\,(eV) = \frac{1.51\times10^{-18}}{1.6\times10^{-19}}$$

E(eV) = 9.52

$\because$ E > work function

Hence photoelectron will eject.

$$E = w + \frac{1}{2}mv^2$$

E = w + eV

9.52 = 4 + eV

eV = 5.52 eV

V = 5.52 V

2. The work function of metal is 6 eV. If light of frequency 1×10^{15} Hz is incident on the metal, intensity of light is increased 4 times, then

(1) No photoelectron will be ejected

(2) 8 photoelectrons of zero kinetic energy shall be ejected

(3) 2 photoelectrons of 2 eV kinetic energy are ejected

(4) Only one photoelectron is ejected

Sol. Answer (1)

$E = h\nu$

$= 6.67 \times 10^{-34} \times 1 \times 10^{15}$

$= 6.67 \times 10^{-19}$

$= 4.16875$ eV

$E < w$

Hence no photoelectron will eject.

3. A light of frequency 2.5×10^{15} Hz is incident on a metal surface having work function 4 eV. The velocity of photoelectron is (in cm s^{-1})

(1) 1.5×10^6 (2) 1.5×10^8 (3) 2×10^8 (4) 2.5×10^4

Sol. Answer (2)

$$E = w + \frac{1}{2}mv^2$$

$$6.63 \times 10^{-34} \times 2.5 \times 10^{15} = 4 \times 1.6 \times 10^{-19} + \frac{1}{2} \times 9.1 \times 10^{-31} v^2$$

$$1.66 \times 10^{-18} = 6.4 \times 10^{-19} + \frac{1}{2} \times 9.1 \times 10^{-31} v^2$$

$$1.02 \times 10^{-18} = \frac{1}{2} \times 9.1 \times 10^{-31} v^2$$

$v^2 = 2.24 \times 10^{12}$

$v = 1.49 \times 10^6$

$v = 1.5 \times 10^6$

$v = 1.5 \times 10^6$ m/s

$v = 1.5 \times 10^8$ cm/s

Comprehension III

Orbitals are the pictorial representation of Ψ or Ψ^2.

$$\Psi = \underbrace{\Psi_r}_{\text{Radial wave function}} \; \underbrace{\Psi_{\theta.\phi}}_{\text{Angular wave function}}$$

Ψ^2 tell about the probability of finding electron.

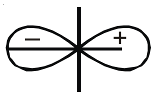
1. Which of the following orbital is non directional?

(1) s (2) $2p_x$ (3) $4d_{x^2-y^2}$ (4) d_{z^2}

Sol. Answer (1)

s-orbital is non-directional.

2. A $2p_x$ orbital is shown by given diagram



Correct regarding diagram is

(1) Sign represent charge only

(2) Sign represent sign of wave function only

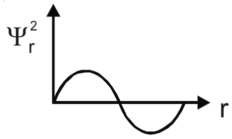
(3) Both (1) & (2)

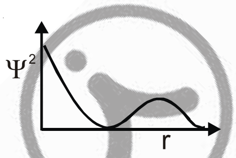
(4) Sign represent sign of Ψ^2

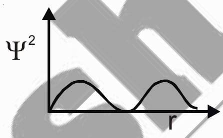
Sol. Answer (2)

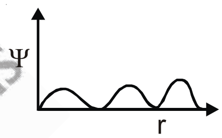
Sign represent sign of wave function.

3. Which of the following graph is correct for 3*p*?

(1) 

(2) 

(3) 

(4) 

Sol. Answer (3)

For p-orbital, at nucleus surface, Ψ^2 is zero.

Comprehension IV

Arrangement of the electron in various orbital is done by

(i) Aufbau principle

(ii) Pauli's exclusion principle

(iii) Hund's rule of maximum multiplicity

1. Which of the following has highest energy (Z > 1)?

(1) 4*s* (2) 4*p* (3) 4*d* (4) 4*f*

Sol. Answer (4)

On the basis of (n + l) rule.

2. For hydrogen or hydrogen like ion, energy of orbital depend on

(1) n (2) n + l (3) n + l + m (4) n + l + m + s

Sol. Answer (1)

In hydrogen energy depend on n only.

3. In given E.C. which violates Hund's rule

(1) | ↑ | ↑ | ↑ | ↑ | ↓ | (2) | ↑↓ | ↑ | ↑ | (3) | ↑ | ↑ | ↑ | ↑ | ↑ | (4) | ↓ | ↓ | ↓ |

Sol. Answer (1)

Spin of E.C. should be maximum.

SECTION - D

Matrix-Match Type Questions

1. Match the following :

Column I		Column II
(A) Velocity	(p)	Increased, n↑ z↓
(B) Potential Energy	(q)	Increased, n↓ z↑
(C) $E_n - E_{n-1}$ (E = Total energy for H atom) ($n \neq 1$)	(r)	Decreased, n↑
(D) Separation energy (For H atom)	(s)	No change n↑

Sol. Answer : A(q, r), B(p), C(r), D(r)

$V \propto \frac{Z}{n}$ $\Rightarrow$ Velocity $\rightarrow$ q

$PE \propto \left(-\frac{Z^2}{n^2}\right)$ $\Rightarrow$ PE $\rightarrow$ p

$E_n - E_{n-1} \propto \frac{1}{n^2}$ $\Rightarrow$ Decreases when $n \uparrow \rightarrow r$

Separation energy = $E_\infty - E_n \propto \frac{1}{n^2} \Rightarrow r$

2. Match the following :

Column I (Rays)		Column II (Wavelength (Å))
(A) Ultraviolet Rays	(p)	0.001 to Zero
(B) Gamma Rays	(q)	100 to 0.01
(C) Cosmic Rays	(r)	0.1 to 0.0001
(D) X-Rays	(s)	3800 to 1

Sol. Answer : A(s), B(r), C(p), D(q)

3. Match the following :

Column I (Electronic configuration)		Column II
(A) d^5	(p)	Colourless
(B) d^6	(q)	μ = 1.73 BM
(C) d^9	(r)	Total spin = 2
(D) d^{10}	(s)	μ = 5.92 BM

Sol. Answer : A(s), B(r), C(q), D(p)

d^5 has 5 unpaired electrons.

d^9 has 1 unpaired electrons.

d^{10} has 0 unpaired electrons, so colorless.

d^6 has 4 unpaired electrons.

$\Rightarrow$ $4\times\left(+\frac{1}{2}\right)=2$ = Total spin.

4. Match the following :

Column I (Orbitals)		Column II (Nature and No. of Nodes)
(A) $4d_{z^2}$	(p)	One spherical node
(B) $3s$	(q)	One nodal plane
(C) $2p_x$	(r)	Two spherical nodes
(D) $3d_{xy}$	(s)	Two nodal planes

Sol. Answer : A(p), B(r), C(q), D(s)

5. Match Column I (ions) with Column II (indicated properties) :

Column I		Column II
(A) Fe^{2+}	(p)	No unpaired electron
(B) Cr^{3+}	(q)	5 unpaired electrons
(C) Mn^{2+}	(r)	4 unpaired electrons
(D) Ca^{2+}	(s)	3 unpaired electrons

Sol. Answer : A(r), B(s), C(q), D(p)

SECTION - E

Assertion-Reason Type Questions

1. STATEMENT-1 : Electronic configuration of Cr^{+3} (containing 21 electrons) is same as that of Sc i.e. isoelectronic species have the same configuration.

and

STATEMENT-2 : Orbitals of an atom are filled in order of increasing energy.

Sol. Answer (4)

$Cr \rightarrow 4s^1\,3d^5$

$Cr^{+3} \rightarrow 3d^3$

$Sc \rightarrow 4s^2\,3d^1$

Both configuration are different from each other.

Orbitals of atom are filled in increasing order of energy – Aufbau rule

2. STATEMENT-1 : The orbital angular momentum of an e^- in $4f$ atomic orbital is $\sqrt{12}\,\frac{h}{2\pi}$

and

STATEMENT-2 : The orbital angular momentum of an electron is given by $\sqrt{l(l+1)}\,\frac{h}{2\pi}$ and for f-subshell, l = 3.

Sol. Answer (1)

4f

For *f* subshell $l = 3$

Orbital angular momentum

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

$$= \sqrt{3(3+1)}\frac{h}{2\pi}$$

$$= \sqrt{12}\frac{h}{2\pi}$$

3. STATEMENT-1 : The maximum number of electrons in subshell *p* is 6.

and

STATEMENT-2 : The maximum number of electrons in a subshell is given by (4l + 2), where l is the Azimuthal quantum number and for p-subshell l = 1.

Sol. Answer (1)

p subshell has 3 orbitals and each orbital can take 2 electrons, hence, total 6 electrons can be accommodated.

A subshell has $2l + 1$ orbitals and each subshell can have $2e^-$, hence, total number of electrons $= 2(2l + 1)$

$= 4l + 2$

for *p* subshell $l = 1$

4. STATEMENT-1 : The energy of an electron depends only upon principal quantum number in case of hydrogen and hydrogen like ions.

and

STATEMENT-2 : The energy of an electron depends on principal quantum number as well as Azimuthal quantum number for other atoms.

Sol. Answer (2)

For multi-electron system, energy depends on *n* and *l*.

5. STATEMENT-1 : The de-Broglie wavelength of an electron decreases as kinetic energy decreases.

and

STATEMENT-2 : The de-Broglie wavelength $\lambda = \frac{h}{\sqrt{2mKE}}$.

Sol. Answer (4)

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

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

$mv^2 = 2KE$

$m^2v^2 = 2mKE$

$mv = \sqrt{2mKE}$

$\lambda = \dfrac{h}{\sqrt{2mKE}}$

$\lambda \propto \dfrac{1}{KE}$

Hence, as KE decreases, λ increases.

6. STATEMENT-1 : The 19th electron in potassium atom enters into 4*s*-orbital than in 3*d*-orbital.

and

STATEMENT-2 : (n + l) rule is followed for determining the orbital of lowest energy state.

Sol. Answer (1)

Factual.

7. STATEMENT-1 : A spectral line will not be seen for a $2p_x - 2p_y$ transition.

and

STATEMENT-2 : Only Balmer lines are observed in the visible region.

Sol. Answer (2)

Both the statements are correct.

8. STATEMENT-1 : Orbital angular momentum is given by $\sqrt{l(l+1)}\dfrac{h}{2\pi}$

and

STATEMENT-2 : l (Quantum number) decides the shape of orbital.

Sol. Answer (2)

Fact

9. STATEMENT-1 : Among 5*p* and 6*s*, 6*s* orbital have high energy.

and

STATEMENT-2 : (n + l) for 5*p* and 6*s* is same.

Sol. Answer (2)

If (n + l) is same, then higher will be value of n, higher will be energy.

10. STATEMENT-1 : Principal Quantum number of outermost electron in Fe is 4.

and

STATEMENT-2 : Last electron is filled in 3*d*.

Sol. Answer (2)

Fact

SECTION - F

Integer Answer Type Questions

1. An electron in hydrogen atom (ground state) jumps to higher energy level x, such that the potential energy of electron becomes half of its total energy at ground state. What is the value of x ?

Sol. Answer (2)

Total energy in ground state = – E

Potential energy at excited state = $-\frac{2E}{x^2}$

$\frac{-2E}{x^2} = -\frac{E}{2}$, $\quad x^2 = 4$, $\quad x = 2$

2. In an atom the last electron is present in *f*-orbital and for its outermost shell the graph of ψ^2 has 6 maximas. What is the sum of group and period of that element ?

Sol. Answer (9)

As the last electron enter 'f' orbital hence group = 3

As there are 6 maximas therefore largest principal quantum number (n) = 6 $\quad \therefore$ period = 6

Group + period = 9

3. What is number of radial nodes in 4*f* orbital?

Sol. Answer (0)

Radial nodes = n – l – 1

4. An electron jumps to higher excited state of a orbital which is non directional and have 4 radial node then shell with which electron belong?

Sol. Answer (5)

Electron is in 5*s* orbital.

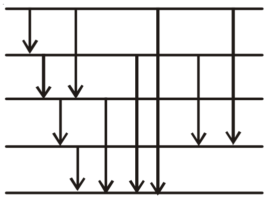
5. Magnetic momentum of an ion M^{+3} is $\sqrt{35}$ BM. Then, number of electron in *d* orbital of M element will be _____.

Sol. Answer (6)

The atom have E.C. $3d^6 4s^2$.

6. A sample contain only hydrogen atoms and in all atom electron are present at 4th excited state. How many minimum number of atoms required if total seven lines are observed in emmission spectrum?

Sol. Answer (3)



7. Electron in a single electron species having atomic number Z make a transition from 2 to 1. The emitted photon is absorbed by excited electron of Li^{2+} in n_1 orbit and further excite to n_2 orbit. The $\left(\frac{2n_1 + 3n_2 + 6Z}{5}\right)$. [Given energy of atom is – 13.6 (Z^2/n^2)eV/atom in nth orbit]

Sol. Answer (6)

Energy emitted = $13.6\ Z^2 \left(1-\frac{1}{4}\right)$

$= \frac{13.6\times 3}{4} Z^2$

$= 10.2\ Z^2$ eV

This energy excite the already excited electron but not ionise the Li^{2+}

so $10.2\ Z^2 < 30.6$

$Z^2 < 3$

so only possible Z = 1

Energy emitted = 10.2

So electron jump from $n_1 = 3$ to $n_2 = 6$

So $\frac{2\times 3+3\times 6+6\times 1}{5} = 6$

8. Consider the following statements and identify how many statements are correct.

(i) $\Psi_{3,2,0}$ represent the orbital which has no angular node.

(ii) Spin magnetic moment of Fe atom and Ni^{2+} ion are the same

(iii) At given temperature intensity of radiations emitted from black body always keep on increasing with decrease in wavelength.

(iv) For a hypothetical electron moving in 2D, then only any two parameter can change out of r, θ and ϕ.

(v) For $2p_x$ orbital, number of angular node or nodal plane are the same.

(vi) The actual electronic configuration of Cr ([Ar].$4s^1 3d^5$) is more stable than theoretical electronic configuration of Cr([Ar],$4s^2$,$3d^4$) due to both maximum multiplicity and maximum exchange energy.

(vii) The electromagnetic wave radiated from it's source ultimately dissipates away in space, but the de-Broglie matter wave never gets separated from its source.

(viii) Heisenberg's uncertainity principle can be applicable for any conjugate pair of variables (eg momentum and position, energy and time)

(ix) Sixth line of Balmer series in hydrogen atom belong to ultraviolet region of spectrum.

Sol. Answer (7)

i, iv, v, vi, vii, viii and ix are correct.

(i) $\Psi_{3,2,0}$ represent $3d_z^2(z)$ orbital

(ii) Fe(26). [Ar] $4s^2$, $3d^6$ $\Rightarrow$ 4 unpaired electron

Ni^{2+}(26). [Ar] $4s^0$, $3d^8$ $\Rightarrow$ 2 unpaired electron

(iii) It first increases and then decreases

(iv) For 2D motion, any two coordinate are required.

(v) Angular nodes and angular planes are the same

(vi) For Cr[Ar] $4s^1$, $3d^5$ for both multiplicity and exchange energy an higher.

(vii) Fact

(viii) $\Delta p.\ \Delta x \geq \frac{h}{4\pi}$; $\Delta E.\Delta t \geq \frac{h}{4\pi}$

(ix) $\frac{1}{\lambda} = 109678\left[\frac{1}{2^2} - \frac{1}{8^2}\right]$

9. If kinetic energy of an electron is reduced by (1/9) then how many times its de Broglie wavelength will increase?

Sol. Answer (3)

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

$$\frac{\lambda_2}{\lambda_1} = \sqrt{\frac{KE_1}{KE_2}}$$

10. The energy corresponding to one of the lines in the Paschen series for H-atom is 18.16×10^{-20} J. Find the quantum numbers for the transition which produce this line.

Sol. Answer (6)

$$\Delta E = 2.18 \times 10^{-18}\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$18.16 \times 10^{-20} = 2.18 \times 10^{-18}\left[\frac{1}{9} - \frac{1}{n^2}\right]$$

On solving n = 6

11. The angular momentum of electron in the shell in which the *g*-subshell first appears is $x \times \frac{h}{2\pi}$. The value of *x* will be

Sol. Answer (5)

l = 4 for *g*-subshell

Thus, the subshell will first appear in (*n* = *l* + 1 = 5) 5th shell.

Angular momentum $(mvr) = n\frac{h}{2\pi} = 5\frac{h}{2\pi}$

$\therefore$ $x = 5$

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