ATOMIC STRUCTURES

MULTIPLE CHOICE QUESTIONS

1. The wave function ψ of 2s – orbital is given by

$$\psi_{2s} = \frac{1}{2\sqrt{2\pi}}\left(\frac{1}{a_0}\right)^{1/2}\left(2-\frac{r}{a_0}\right)e^{-r/2a_0}$$

At $r = r_0$, radial node is formed. Which of the following is correct?

(a) $r_0 = 2a_0$ (b) $2r_0 = a_0$

(c) $r_0 = 3a_0$ (d) None of these is correct

Explanation: (a)

At $r = r_0$ $\psi_{2s}^2 = 0$

It is possible only when $2-\frac{r}{a_0}=0$

$\therefore r_0 = \mathbf{2a_0}$

2. Which of the following set of quantum numbers belong to highest energy?

(a) n = 2, *l* = 1, m = 0, s = + $\frac{1}{2}$

(b) n = 3, *l* = 0, m = 0, s = + $\frac{1}{2}$

(c) n = 4, *l* = 0, m = 1, s = + $\frac{1}{2}$

(d) n = 4, *l* = 1, m = 1, s = + $\frac{1}{2}$

Explanation: (d)

For (d), the value of n + *l* = 3 + 2 = 5. In other cases the value of (n + *l*) is less than 5.
The orbital having higher (n + *l*) value has higher energy.

3. An electron is accelerated through V voltage. Its de Broglie wavelength is

(a) $\frac{h}{\sqrt{2m.eV}}$ (b) $\frac{12.27}{\sqrt{V}}$ Å

(c) $\left[\frac{150}{V}\right]^{\frac{1}{2}}$ Å (d) all of these

Explanation: (d)

$$\lambda = \frac{h}{\sqrt{2\,m\,KE}}\text{; (K.E. = e·V);}\ \lambda = \left[\frac{h}{\sqrt{2\,m\,e\cdot V}}\right] = \left[\frac{h^2}{2m\cdot eV}\times 10^{20}\right]^{\frac{1}{2}} A^o$$

$$= \left[\frac{150}{V}\right]^{\frac{1}{2}} A^o = \frac{12.27}{\sqrt{V}} A^o$$

4. Which one among the following statements is correct?

(a) An orbital containing an electron having quantum numbers *n* = 2; *l* = 0; m= 0 and *s* = +1/2 is spherical.

(b) The frequency of X-rays is less than that of radio-waves.

(c) All photons have same energy.

(d) As intensity of light increases, its frequency also increases.

Explanation: (a)

Any orbital with $l = 0$ has spherical symmetry irrespective of the value of its principal quantum number.

5. The ratio of radii of first orbits of H, He^+ and Li^{2+} is

(a) 1: 2: 3 (b) 6: 3: 2

(c) 1: 4: 9 (d) 9: 4: 1

Explanation: (b)

$r = \frac{n^2}{Z} \times 0.529$ Å

$r_H : r_{He^+} : r_{Li^{2+}} = 1 : \frac{1}{2} : \frac{1}{3} = \mathbf{6 : 3 : 2}$

6. How many electrons will have m (magnetic quantum number) = 0 in Fe^{3+} ion?

(a) 12 (b) 13

(c) 11 (d) 14

Explanation: (c)

Fe: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$

Fe^{3+}: $\underline{1s}^2\underline{2s}^2\underline{2p}^6\underline{3s}^2\underline{3p}^6\underline{3d}^5$

Electron with m = 0 are 11.

7. The radius of second stationary orbit in Bohr's atom is R. The radius of the third orbit will be

(a) 3 R (b) 9 R

(c) $\frac{9}{4}$R (d) 4 R

Explanation: (c)

$r_n = 0.529\ \frac{n^2}{Z}$ Å

$r_2 = 0.529 \times \frac{4}{Z} = R$ (for n = 2)

$r_3 = 0.529 \times \frac{9}{Z} = 9 \times \frac{R}{4}$ (for n = 3)

8. The work function for a metal is 4 eV. To emit a photo-electron of zero velocity from the surface of the metal, the wavelength of incident light should be

(a) 2700 Å (b) 1700 Å

(c) 5900 Å (d) 3100 Å

Explanation: (d)

$\frac{hc}{\lambda} = w_0$ + KE(but KE = 0) ;$\lambda = \frac{6.626\times10^{-34}\times3\times10^{8}}{4\times1.6\times10^{-19}} = 3.1 \times 10^{-7}$

m = **3100 Å**.

9. The maximum amount of $BaSO_4$ that can be obtained on mixing 0.5 mol $BaCl_2$ with 1 mol H_2SO_4 is

(a) 0.5 mol (b) 0.1 mol

(c) 0.15 mol (d) 0.2 mol

Explanation: (a)

$BaCl_2 + H_2SO_4 \longrightarrow BaSO_4 + 2HCl$

Moles taken initially 0.5 mol 1 mol 0 0

0 0.5 mol 0.5 mol1 mol

The limiting reagent is $BaCl_2$. Hence, a maximum of 0.5 mole of $BaSO_4$ will be obtained.

10. The wave number of the first emission line in the H–atom spectrum in the Balmer series in terms of Rydberg's constant (R_H) is given by

(a) $\frac{5R_H}{36}\ cm^{-1}$ (b) $\frac{3R_H}{4}\ cm^{-1}$

(c) $\frac{7R_H}{144}\ cm^{-1}$ (d) $\frac{9R_H}{400}\ m^{-1}$

Explanation: (a)

$\frac{1}{\lambda} = RZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$ $n_1 = 2, n_2 = 3, Z = 1$

$\frac{1}{\lambda} = R\left[\frac{1}{4} - \frac{1}{9}\right]$ $\frac{1}{\lambda} = \frac{5R}{36}\ cm^{-1}$

11. It 'λ_0' is the threshold wavelength for photoelectric emission, 'λ' the wavelength of light falling on the surface of a metal and 'm' is the mass of the electron, then the velocity of ejected electron is given by

(a) $\left[\frac{2h}{m}(\lambda_0 - \lambda)\right]^{1/2}$ (b) $\left[\frac{2hc}{m}(\lambda_0 - \lambda)\right]^{1/2}$

(c) $\left[\frac{2hc}{m}\left(\frac{\lambda_0 - \lambda}{\lambda_0 \lambda}\right)\right]^{1/2}$ (d) $\left[\frac{2h}{m}\left(\frac{1}{\lambda_0} - \frac{1}{\lambda}\right)\right]^{1/2}$

Explanation: (c)

$h\nu = h\nu_0 + KE$ i.e. $\frac{hc}{\lambda} = \frac{hc}{\lambda_0} + \frac{1}{2}mv^2$

$v = \left(\frac{2hc}{m}\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right)\right)^{1/2}$

12. Energy of the third orbit of Bohr's atom is

(a) –13.6 eV (b) –34 eV

(c) –1.5 eV (d) none of the three

Explanation: (c)

$E_n = \frac{-13.6 \times Z^2 \text{ eV}}{n^2}$ [Z = 1, n = 3]

$= \frac{-13.6}{9} = \mathbf{-1.5\ eV}$.

13. The electronic velocity in the fourth Bohr's orbit of hydrogen is V. The velocity of the electron in the first orbit would be:

(a) 4 V (b) 16 V

(c) V/4 (d) V/16

Explanation: (a)

14. The ratio of the difference between 1st and 2nd Bohr's orbits energy to that between 2nd and

3rd orbits energy is

(a) 1/2 (b) 1/3

(c) 27/5 (d) 5/27

Explanation: (c)

$E = -13.6 \times \frac{Z}{n^2} \text{eV}$;

$E_1 = -13.6$ eV ;

$E_2 = -13.6 \times \frac{1}{4} = -3.4$ eV.

$\therefore$ $E_2 - E_1 = -3.4 - (-13.6)\text{eV} = 10.2$ eV.

$E_3 = -13.6 \times \frac{1}{9} = -1.51$ eV ; $E_4 = -13.6 \times \frac{1}{16} = -0.85$ eV

$E_4 - E_3 = -0.85 + 1.51 = 0.66$ eV.

$\therefore \frac{E_2 - E_1}{E_4 - E_3} = \frac{10.2}{0.66} = \frac{27}{5}$.

15. If the radius of first Bohr orbit is x, then de Broglie wavelength of electron in 4th orbit is nearly

(a) $8\pi x$ (b) $6\pi x$

(c) $4\pi x$ (d) $2\pi x$

Explanation: (a)

$r_1 = x$

$r_4 = 16x$ $(\because r \propto n^2)$

Also, $\lambda = \frac{h}{mv}$ ……(i) (from de Broglie equation)

And $mvr = \frac{nh}{2\pi}$ ……(ii)

From (i) and (ii)

$2\pi r = n\lambda$

$\lambda = \frac{2\pi r}{n}$

$\therefore$ Wavelength of electron in 3rd orbit.

$\lambda_3 = \frac{2\pi r_3}{n_3} = \frac{2\pi\, 16x}{4} = 8\pi x$.

16. According to Bohr's Model of hydrogen atom

(a) total energy of the electron is quantized

(b) angular momentum of the electron is quantized and given as $\sqrt{l(l+1)} \cdot \frac{h}{2\pi}$

(c) both (a) and (b)

(d) none of these

Explanation: (c)

According to Bohr's model of H-atom, both

(i) total energy of the electron is quantized and

(ii) Angular momentum of the electron is quantized and is given as $\sqrt{l(l+1)} \cdot \frac{h}{2\pi}$ and true.

(iii)

17. Photoelectric emission is observed from a surface for frequencies ν_1 and ν_2 of incident radiations ($\nu_1>\nu_2$). If the maximum kinetic energy of photoelectrons in the two cases are in the ratio of 2: 1, then threshold frequency ν_0 is given by

(a) $\frac{\nu_2 - \nu_1}{2-1}$

(b) $\frac{2\nu_1 - \nu_2}{2-1}$

(c) $\frac{2\nu_2 - \nu_1}{2-1}$

(d) $\frac{\nu_2 - \nu_1}{2}$

Explanation: (c)

$KE_1 = h\nu_1 - h\nu_0$

$KE_2 = h\nu_2 - h\nu_0$

$$\frac{KE_1}{KE_2}=\frac{h(\nu_1-\nu_0)}{h(\nu_2-\nu_0)};\ \frac{2}{1}=\frac{\nu_1-\nu_0}{\nu_2-\nu_0};\quad \nu_0=\frac{\mathbf{2\nu_2-\nu_1}}{\mathbf{2-1}}.$$

18. Correct order of radius of the 1st orbit of H, He^+, Li^{2+}, Be^{3+} is

(a) H > He^+> Li^{2+}> Be^{3+}

(b) Be^{3+}> Li^{2+}> He^+> H

(c) He^+> Be^{3+}> Li^{2+}> H

(d) He^+> H > Li^{2+}> Be^{3+}

Explanation: (a)

For the same orbit radius $\propto \frac{1}{\text{atomic number}}$

19. The calculated value of magnetic moment of $_{26}Fe^{3+}$ is

(a) 3.89 B.M | (b) 1.73 B.M

(c) 4.90 B.M | (d) 5.92 B.M

Explanation: (d)

Magnetic moment = $\sqrt{n(n+2)}$ B.M where n is the number of unpaired electrons.

For Fe^{3+} ion n = 5 so, $\mu=\sqrt{5(5+2)}$ = $\sqrt{35}$ B.M

20. If the K.E. of a particle is doubled, its de Broglie wavelength becomes

(a) 2 times | (b) 4 times

(c) $\sqrt{2}$ times | (d) $\frac{1}{\sqrt{2}}$ times

Explanation: (d)

$\frac{\lambda_1}{\lambda_2} = \sqrt{\frac{E_2}{E_1}}$ where 'E' is the K.E. of a particle.

As per the above relation, when K.E. is doubled, its wavelength becomes $\frac{1}{\sqrt{2}}$ times.

21. Which of the following statement is correct in relation to the hydrogen atom?

(a) 3s–orbital is lower in energy than 3p–orbital.

(b) 3p–orbital is lower in energy than 3d–orbital.

(c) 3s and 3p–orbitals are of lower energy than 3d–orbitals.

(d) 3s, 3p and 3d–orbitals all have same energy.

Explanation: (d)

Energy of single electron system is only depend on the principle quantum number, so that energy of different orbitals of same principle quantum number is same.

22. The outermost electronic configuration of the most electronegative element is

(a) ns^2np^3 (b) ns^2np^4

(c) ns^2np^5 (d) ns^2np^6

Explanation: (c) ns^2np^5

INTEGER TYPE QUESTIONS

23. According to Bohr's theory, the electronic energy of H– atom in n^{th} Bohr orbit is given by $E_n = -\frac{21.76\times10^{-19}}{n^2}$ joule. Calculate the longest λ of light that will be needed to remove an electron from III Bohr's orbit of He^+ ion. Express your answer in Å units.

Explanation: (2053 Å)

$E_{3H} = \frac{-21.76\times10^{-19}}{3^2} = -2.42 \times 10^{-19}$ joule

$E_{3He^+} = Z^2 \times E_{3H} = -2.42 \times 10^{-19} \times 4 = -9.68 \times 10^{-19}$ joule.

Now if electron is to be removed from III orbit energy equivalent to 9.64×10^{-19} must be provided. Therefore,

$$E_3 = \frac{hc}{\lambda}$$

$$\text{or } \lambda = \frac{hc}{E_3} = \frac{6.625\times10^{-34}\times3.0\times10^{8}}{9.68\times10^{-19}} = 2.053 \times 10^{-7} \text{ m}$$

$= 2053 \times 10^{-10}$ m = **2053 Å**.

24. An element with atomic number 20 will be placed in the period of the periodic table

Explanation: (4)

Atomic number 20 $\longrightarrow$ $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$

25. The radius of the first Bohr orbit of hydrogen atom (n = 1) is approximately 0.530 Å. The radius of the first excited state (n = 2) of hydrogen atom is

Explanation: (2.12 Å)

$r_n = r_1 \times n^2$ [for hydrogen atom]

$r_n = 0.53 \times n^2$ Å [n = 2]

$= 0.53 \times 4$

r_n =**2.12 Å**.

26. In Mn^{2+} ion, the number of unpaired electrons is

Explanation: (5)

27. If electrons are excited to 4^{th} shell in He^+ ion, the number of wavelengths emitted by electrons during de–excitation are

Explanation: (6)

By ${}^{n}C_2$ formula ie. Total number of transitions = $\frac{n(n-1)}{2}$.

28. The first excitation energy for hydrogen atom would be

Explanation: (10.2 eV)

$E_2 - E_1 = \frac{-13.6}{4} + 13.6 = 10.2$ eV.

29. Assuming Rydberg's constant (R_H) to be 109670 cm^{-1}, the longest wavelength line in the Lyman series of the hydrogen spectrum is

Explanation: (1215.8 Å)

$$\frac{1}{\lambda} = R_H Z^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) = 109670\left(\frac{1}{1} - \frac{1}{4}\right) = \frac{3}{4}(109670)\ cm^{-1}$$

$\lambda = 1215.8 \times 10^{-8}$cm i.e.,

λ = **1215.8 Å**

30. The ratio of ($E_2 - E_1$) to ($E_4 - E_3$) for the hydrogen atom is approximately equal to

Explanation: (15)

$$E_2 - E_1 = \left[\frac{-E_1}{4} + E_1\right] = \frac{+3E_1}{4}, \quad E_4 - E_3 = \frac{-E_1}{16} + \frac{E_1}{9} = \frac{7E_1}{16 \times 9}$$

$$\frac{E_2 - E_1}{E_4 - E_3} = \frac{3}{4} \times \frac{144}{7} = \frac{108}{7} = \frac{108}{7} \simeq \mathbf{15}.$$