CHAPTER 2

Structure of Atom

1. In a hydrogen atom, if energy of an electron in ground state is 13.6. ev, then that in the 2nd excited state is **[2002]**

(a) 1.51 eV (b) 3.4 eV

(c) 6.04 eV (d) 13.6 eV.

2. Uncertainty in position of a minute particle of mass 25 g in space is 10^{-5} m. What is the uncertainty in its velocity (in ms^{-1})? ($h = 6.6 \times 10^{-34}$ Js) **[2002]**

(a) 2.1×10^{-34} (b) 0.5×10^{-34}

(c) 2.1×10^{-28} (d) 0.5×10^{-23}.

3. The number of d-electrons retained in Fe^{2+} (At. no. of Fe = 26) ion is **[2003]**

(a) 4 (b) 5

(c) 6 (d) 3

4. The orbital angular momentum for an electron revolving in an orbit is given by $\sqrt{l(l+1)}.\frac{h}{2\pi}$. This momentum for an s-electron will be given by **[2003]**

(a) zero (b) $\frac{h}{2\pi}$

(c) $\sqrt{2}.\frac{h}{2\pi}$ (d) $+\frac{1}{2}.\frac{h}{2\pi}$

5. Which one of the following groupings represents a collection of isoelectronic species ?(At. nos. : Cs : 55, Br : 35) **[2003]**

(a) N^{3-}, F^-, Na^+ (b) Be, Al^{3+}, Cl^-

(c) Ca^{2+}, Cs^+, Br (d) Na^+, Ca^{2+}, Mg^{2+}

6. In Bohr series of lines of hydrogen spectrum, the third line from the red end corresponds to which one of the following inter-orbit jumps of the electron for Bohr orbits in an atom of hydrogen **[2003]**

(a) $5 \rightarrow 2$ (b) $4 \rightarrow 1$

(c) $2 \rightarrow 5$ (d) $3 \rightarrow 2$

7. The de Broglie wavelength of a tennis ball of mass 60 g moving with a velocity of 10 metres per second is approximately **[2003]**

(a) 10^{-31} metres (b) 10^{-16} metres

(c) 10^{-25} metres (d) 10^{-33} metres

Planck's constant, $h = 6.63 \times 10^{-34}$ Js

8. Which of the following sets of quantum numbers is correct for an electron in 4f orbital ? **[2004]**

(a) $n = 4, \ell = 3, m = +1, s = +½$

(b) $n = 4, \ell = 4, m = -4, s = -½$

(c) $n = 4, \ell = 3, m = +4, s = +½$

(d) $n = 3, \ell = 2, m = -2, s = +½$

9. Consider the ground state of Cr atom (X = 24). The number of electrons with the azimuthal quantum numbers, $\ell = 1$ and 2 are, respectively **[2004]**

(a) 16 and 4 (b) 12 and 5

(c) 12 and 4 (d) 16 and 5

10. The wavelength of the radiation emitted, when in a hydrogen atom electron falls from infinity to stationary state 1, would be (Rydberg constant $= 1.097 \times 10^7 m^{-1}$) **[2004]**

(a) 406 nm (b) 192 nm

(c) 91 nm (d) 9.1×10^{-8} nm

11. Which one of the following sets of ions represents the collection of isoelectronic species? **[2004]**

(a) $K^+, Cl^-, Mg^{2+}, Sc^{3+}$

(b) $Na^+, Ca^{2+}, Sc^{3+}, F^-$

(c) $K^+, Ca^{2+}, Sc^{3+}, Cl^-$

(d) $Na^+, Mg^{2+}, Al^{3+}, Cl^-$

(Atomic nos. : F = 9, Cl = 17, Na = 11, Mg = 12, Al = 13, K = 19, Ca = 20, Sc = 21)

12. In a multi-electron atom, which of the following orbitals described by the three quantum members will have the same energy in the absence of magnetic and electric fields? **[2005]**

(A) $n=1, l=0, m=0$ (B) $n=2, l=0, m=0$
(C) $n=2, l=1, m=1$ (D) $n=3, l=2, m=1$
(E) $n=3, l=2, m=0$
(a) (D) and (E) (b) (C) and (D)
(c) (B) and (C) (d) (A) and (B)

13. Of the following sets which one does NOT contain isoelectronic species? **[2005]**

(a) $BO_3^{3-}, CO_3^{2-}, NO_3^-$

(b) $SO_3^{2-}, CO_3^{2-}, NO_3^-$

(c) CN^-, N_2, C_2^{2-}

(d) $PO_4^{3-}, SO_4^{2-}, ClO_4^-$

14. According to Bohr's theory, the angular momentum of an electron in 5th orbit is **[2006]**

(a) $10\ h/\pi$ (b) $2.5\ h/\pi$
(c) $25\ h/\pi$ (d) $1.0\ h/\pi$

15. Uncertainty in the position of an electron (mass $= 9.1 \times 10^{-31}$ kg) moving with a velocity 300 ms^{-1}, accurate upto 0.001% will be **[2006]**

(a) 1.92×10^{-2} m (b) 3.84×10^{-2} m
(c) 19.2×10^{-2} m (d) 5.76×10^{-2} m
($h = 6.63 \times 10^{-34}$ Js)

16. Which one of the following sets of ions represents a collection of isoelectronic species? **[2006]**

(a) $N^{3-}, O^{2-}, F^-, S^{2-}$
(b) $Li^+, Na^+, Mg^{2+}, Ca^{2+}$
(c) $K^+, Cl^-, Ca^{2+}, Sc^{3+}$
(d) $Ba^{2+}, Sr^{2+}, K^+, Ca^{2+}$

17. Which of the following sets of quantum numbers represents the highest energy of an atom? **[2007]**

(a) $n=3, l=0, m=0, s=+1/2$
(b) $n=3, l=1, m=1, s=+1/2$
(c) $n=3, l=2, m=1, s=+1/2$
(d) $n=4, l=0, m=0, s=+1/2$.

18. Which one of the following constitutes a group of the isoelectronic species? **[2008]**

(a) C_2^{2-}, O_2^-, CO, NO

(b) $NO^+, C_2^{2-}, CN^-, N_2$

(c) $CN^-, N_2, O_2^{2-}, C_2^{2-}$

(d) N_2, O_2^-, NO^+, CO

19. The ionization enthalpy of hydrogen atom is 1.312×10^6 J mol^{-1}. The energy required to excite the electron in the atom from n = 1 to n = 2 is **[2008]**

(a) 8.51×10^5 J mol^{-1} (b) 6.56×10^5 J mol^{-1}
(c) 7.56×10^5 J mol^{-1} (d) 9.84×10^5 J mol^{-1}

20. Calculate the wavelength (in nanometer) associated with a proton moving at 1.0×10^3 ms^{-1}. (Mass of proton $= 1.67 \times 10^{-27}$ kg and $h = 6.63 \times 10^{-34}$ Js) **[2009]**

(a) 0.40 nm (b) 2.5 nm
(c) 14.0 nm (d) 0.32 nm

21. In an atom, an electron is moving with a speed of 600 m/s with an accuracy of 0.005%. Certainity with which the position of the electron can be located is ($h = 6.6 \times 10^{-34}$ kg $m^2 s^{-1}$, mass of electron, $e_m = 9.1 \times 10^{-31}$ kg) : **[2009]**

(a) 5.10×10^{-3} m (b) 1.92×10^{-3} m
(c) 3.84×10^{-3} m (d) 1.52×10^{-4} m

22. The energy required to break one mole of Cl – Cl bonds in Cl_2 is 242 kJ mol^{-1}. The longest wavelength of light capable of breaking a single Cl – Cl bond is ($c = 3 \times 10^8$ ms^{-1} and $N_A = 6.02 \times 10^{23}$ mol^{-1}). **[2010]**

(a) 594 nm (b) 640 nm
(c) 700 nm (d) 494 nm

23. Ionisation energy of He^+ is 19.6×10^{-18} J $atom^{-1}$. The energy of the first stationary state ($n = 1$) of Li^{2+} is **[2010]**

(a) 4.41×10^{-16} J $atom^{-1}$
(b) -4.41×10^{-17} J $atom^{-1}$
(c) -2.2×10^{-15} J $atom^{-1}$
(d) 8.82×10^{-17} J $atom^{-1}$

24. The frequency of light emitted for the transition n = 4 to n = 2 of the He^+ is equal to the transition in H atom corresponding to which of the following? **[2011RS]**

(a) n = 2 to n = 1 (b) n = 3 to n = 2
(c) n = 4 to n = 3 (d) n = 3 to n = 1

25. The electrons identified by quantum numbers n and ℓ : **[2012]**

(*A*) $n = 4, \ell = 1$ (*B*) $n = 4, \ell = 0$
(*C*) $n = 3, \ell = 2$ (*D*) $n = 3, \ell = 1$

can be placed in order of increasing energy as :

(a) $(C) < (D) < (B) < (A)$
(b) $(D) < (B) < (C) < (A)$
(c) $(B) < (D) < (A) < (C)$
(d) $(A) < (C) < (B) < (D)$

26. The increasing order of the ionic radii of the given isoelectronic species is : **[2012]**
(a) $Cl^-, Ca^{2+}, K^+, S^{2-}$ (b) $S^{2-}, Cl^-, Ca^{2+}, K^+$
(c) $Ca^{2+}, K^+, Cl^-, S^{2-}$ (d) $K^+, S^{2-}, Ca^{2+}, Cl^-$

27. Energy of an electron is given by $E = -2.178 \times 10^{-18} J\left(\frac{Z^2}{n^2}\right)$. Wavelength of light required to excite an electron in an hydrogen atom from level n = 1 to n = 2 will be : **[2013]**
(h = 6.62 × 10 $^{-34}$ Js and c = 3.0 × 10^8 ms^{-1})
(a) 1.214×10^{-7} m (b) $2.816 \times 10.^{-7}$ m
(c) 6.500×10^{-7} m (d) 8.500×10^{-7} m

28. The correct set of four quantum numbers for the valence electrons of rubidium atom ($Z = 37$) is: **[2014]**
(a) $5, 0, 0, +\frac{1}{2}$ (b) $5, 1, 0, +\frac{1}{2}$
(c) $5, 1, 1, +\frac{1}{2}$ (d) $5, 0, 1, +\frac{1}{2}$

29. Which of the following is the energy of a possible excited state of hydrogen? **[JEE M 2015]**
(a) –3.4 eV (b) +6.8 eV
(c) +13.6 eV (d) –6.8 eV

30. A stream of electrons from a heated filaments was passed two charged plates kept at a potential difference V esu. If e and m are charge and mass of an electron, respectively, then the value of h/λ (where λ is wavelength associated with electron wave) is given by: **[JEE M 2016]**
(a) $\sqrt{meV}$ (b) $\sqrt{2meV}$
(c) meV (d) $2meV$

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

32. The group having isoelectronic species is : **[JEE M 2017]**
(a) $O^{2-}, F^-, Na^+, Mg^{2+}$
(b) O^-, F^-, Na, Mg^+
(c) O^{2-}, F^-, Na, Mg^{2+}
(d) O^-, F^-, Na^+, Mg^{2+}

Answer Key														
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
(a)	(c)	(c)	(a)	(a)	(a)	(d)	(a)	(b)	(c)	(c)	(a)	(b)	(b)	(a)
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
(c)	(c)	(b)	(d)	(a)	(b)	(d)	(b)	(a)	(b)	(c)	(a)	(a)	(a)	(b)
31	32													
(d)	(a)													

SOLUTIONS

1. **(a)** 2nd excited state will be the 3rd energy level.

$$E_n = \frac{13.6}{n^2}\text{eV} \quad \text{or} \quad E = \frac{13.6}{9}\text{eV} = 1.51 \text{ eV}.$$

2. **(c)** **TIPS / Formulae**

$$\Delta x.\Delta p = \frac{h}{4\pi}; \quad \text{or} \quad \Delta x.m.\Delta v = \frac{h}{4\pi}$$

$$\therefore \Delta v = \frac{6.62\times10^{-34}}{4\times3.14\times0.025\times10^{-5}}$$

$$= 2.1\times10^{-28}\,ms^{-1}$$

3. **(c)** $Fe^{++}(26 - 2 = 24) = 1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^0\,3d^6$ hence no. of d electrons retained is 6.
[Two 4s electron are removed]

4. (a) TIPS / Formulae

For s-electron, $\ell = 0$

$\therefore$ Orbital angular momentum = $\sqrt{0(0+1)}\,\frac{h}{2\pi} = 0$

5. (a) N^{3-}, F^- and Na^+ contain 10 electrons each.

6. (a) The lines falling in the visible region comprise Balmer series. Hence the third line from red would be $n_1 = 2,\ n_2 = 5$ i.e. $5 \rightarrow 2$.

7. (d) $\lambda = \frac{h}{mv} = \frac{6.6\times10^{-34}}{60\times10^{-3}\times10} = 10^{-33}\,m$

8. (a) The possible quantum numbers for 4f electron are

$n = 4,\ \ell = 3,\ m = -3, -2, -1, 0, 1, 2, 3$ and $s = \pm\frac{1}{2}$

Of various possiblities only option (a) is possible.

9. (b) Electronic configuration of Cr atom $(z = 24) = 1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^5, 4s^1$

when $\ell = 1$, p - subshell,

Numbers of electrons = 12

when $\ell = 2$, d - subshell,

Numbers of electrons = 5

10. (c) TIPS / Formulae

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

$$\frac{1}{\lambda} = 1.097\times10^7\left(\frac{1}{1} - \frac{1}{\infty}\right) = 1.097\times10^7$$

$$\lambda = 91.15\times10^{-9}\,m \approx 91nm$$

11. (c) ${}_{19}K^+,\ {}_{20}Ca^{2+},\ {}_{21}Sc^{3+},\ {}_{17}Cl^-$

each contains 18 electrons.

12. (a) The energy of an orbital is given by $(n + l)$ in (d) and (c). $(n + l)$ value is $(3 + 2) = 5$ hence they will have same energy, since there n values are also same.

13. (b) Calculating number of electrons

1. $BO_3^{3-} \longrightarrow 5 + 8\times3 + 3 = 32$
   $CO_3^{2-} \longrightarrow 6 + 8\times3 + 2 = 32$
   $NO_3^- \longrightarrow 7 + 8\times3 + 1 = 32$
   } iso-electronic species

2. $SO_3^{2-} \longrightarrow 16 + 8\times3 + 2 = 42$
   $CO_3^{2-} \longrightarrow 32$
   $NO_3^- \longrightarrow 32$
   } not iso-electronic species

3. $CN^- \longrightarrow 6 + 7 + 1 = 14$
   $N_2 \longrightarrow 7\times2 = 14$
   $C_2^- \longrightarrow 6\times2 + 2 = 14$
   } iso-electronic species

4. $PO_4^{3-} \longrightarrow 15 + 8\times4 + 3 = 50$
   $SO_4^{2-} \longrightarrow 16 + 8 + 2 = 50$
   $ClO_4^- \longrightarrow 17 + 8\times4 + 1 = 50$
   } iso-electronic species

Hence the species in option (b) are not iso-electronic.

14. (b) Angular momentum of an electron in nth orbital is given by ,

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

For n = 5, we have

Angular momentum of electron

$$= \frac{5h}{2\pi} = \frac{2.5h}{\pi}$$

15. (a) Given $m = 9.1\times10^{-31}kg$

$h = 6.6\times10^{-34}Js$

$$\Delta v = \frac{300\times.001}{100} = 0.003ms^{-1}$$

From Heisenberg's uncertainity principle

$$\Delta x = \frac{6.62\times10^{-34}}{4\times3.14\times0.003\times9.1\times10^{-31}}$$

$$= 1.92\times10^{-2}\,m$$

16. (c) (a) $N^{3-} = 7+3 = 10e^-$, $O^{--} \longrightarrow 8+2 = 10e^-$

$F^- = 9+1 = 10e^-$, $S^{--} \longrightarrow 16+2 = 18e^-$ (not iso electronic)

(b) $Li^+ = 3+1 = 4e^-$, $Na^+ = 11-1 = 10e^-$, $Mg^{++} = 12-2 = 10e^-$

$Ca^{++} = 20-2 = 18e^-$ (not isoelectronic)

(c) $K^+ = 19-1 = 18e^-$, $C\ell^- = 17+1 = 18e^-$, $Ca^{++} = 20-2 = 18e$, $Sc^{3+} = 21-3 = 18e^-$ (isoelectronic)

(d) Ba^{++} $56-2 = 54e$, Sr^{++} $38-2 = 36e^-$

$K^+ = 9-1 = 18e^-$, $Ca^{++} = 20-2 = 18e^-$ (not isoelectronic)

17. (c) (a) $n = 3$, $\ell = 0$ means 3s-orbital and $n + l = 3$

(b) $n = 3$, $\ell = 1$ means 3p-orbital $n + l = 4$

(c) $n = 3$, $\ell = 2$ means 3d-orbital $n + l = 5$

(d) $n = 4$, $\ell = 0$ means 4s-orbital $n + l = 4$

Increasing order of energy among these orbitals is

$3s < 3p < 4s < 3d$

$\therefore$ 3d has highest energy.

18. (b) Species having same number of electrons are **isoelectronic** calculating the number of electrons in each species given here, we get.

CN^- $(6+7+1 = 14)$; N_2 $(7+7 = 14)$;

O_2^{2-} $(8+8+2 = 18)$; C_2^{2-} $(6+6+2 = 14)$;

O_2^- $(8+8+1 = 17)$; NO^+ $(7+8-1 = 14)$

CO $(6+8 = 14)$; NO $(7+8 = 15)$

From the above calculation we find that all the species listed in choice (b) have 14 electrons each so it is the correct answer.

19. (d) (ΔE), The energy required to excite an electron in an atom of hydrogen from $n = 1$ to $n = 2$ is ΔE (difference in energy E_2 and E_1)

Values of E_2 and E_1 are,

$$E_2 = \frac{-1.312 \times 10^6 \times (1)^2}{(2)^2}$$

$$= -3.28 \times 10^5 \text{ J mol}^{-1}$$

ΔE is given by the relation,

$E_1 = -1.312 \times 10^6 \text{ J mol}^{-1}$

$\therefore \Delta E = E_2 - E_1 = [-3.28 \times 10^5] - [-1.312 \times 10^6] \text{ J mol}^{-1}$

$= (-3.28 \times 10^5 + 1.312 \times 10^6) \text{ J mol}^{-1}$

$= 9.84 \times 10^5 \text{ J mol}^{-1}$

Thus the correct answer is (d)

20. (a) $$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{1.67 \times 10^{-27} \times 1 \times 10^3}$$

$= 3.97 \times 10^{-10}$ meter $= 0.397$ nanometer

21. (b) According to Heisenberg uncertainty principle.

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

Here $$\Delta v = \frac{600 \times 0.005}{100} = 0.03$$

So, $$\Delta x = \frac{6.6 \times 10^{-34}}{4 \times 3.14 \times 9.1 \times 10^{-31} \times 0.03}$$

$= 1.92 \times 10^{-3}$ meter

22. (d) Energy required to break one mole of Cl – Cl bonds in Cl_2

$$= \frac{242 \times 10^3}{6.023 \times 10^{23}} = \frac{hc}{\lambda}$$

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

$$\therefore \lambda = \frac{6.626 \times 10^{-34} \times 3 \times 10^8 \times 6.023 \times 10^{23}}{242 \times 10^8}$$

$= 0.4947 \times 10^{-6}$ m $= 494.7$ nm

23. (b) I. E $= \frac{Z^2}{n^2} \times 13.6 \text{ eV}$ ...(i)

or $$\frac{I_1}{I_2} = \frac{Z_1^2}{n_1^2} \times \frac{n_2^2}{Z_2^2}$$ ...(ii)

Given $I_1 = -19.6 \times 10^{-18}$, $Z_1 = 2$, $n_1 = 1$, $Z_2 = 3$ and $n_2 = 1$

Substituting these values in equation (ii).

$$-\frac{19.6 \times 10^{-18}}{I_2} = \frac{4}{1} \times \frac{1}{9}$$

or $I_2 = -19.6 \times 10^{-18} \times \frac{9}{4}$

$= -4.41 \times 10^{-17}$ J/atom

24. (a) For He^+

$$\bar{v} = \frac{1}{\lambda} = R_H Z^2 \left(\frac{1}{2^2} - \frac{1}{4^2}\right)$$

For H

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

For same frequency,

$$z^2 = \left(\frac{1}{2^2} - \frac{1}{4^2}\right) = \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

Since, z = 2

$\therefore \quad \frac{1}{n_1^2} - \frac{1}{n_2^2} = \frac{1}{1^2} - \frac{1}{2^2}$

$\therefore \quad n_1 = 1$ & $n_2 = 2$

25. (b) (a) 4 p (b) 4 s
(c) 3 d (d) 3 p

Accroding to Bohr Bury's $(n + \ell)$ rule, increasing order of energy (D) < (B) < (C) < (A).

Note : If the two orbitals have same value of $(n + \ell)$ then the orbital with lower value of n will be filled first.

26. (c) Among isoelectronic species ionic radii increases as the charge increases.
Order of ionic radii $Ca^{2+} < K^+ < Cl^- < S^{2-}$
The number of electrons remains the same but nuclear charge increases with increase in the atomic number causing decrease in size.

27. (a) $\Delta E = 2.178 \times 10^{-18} \left(\frac{1}{1^2} - \frac{1}{2^2}\right) = \frac{hc}{\lambda}$

$\Rightarrow 2.178 \times 10^{-18} \times \frac{3}{4} = \frac{hc}{\lambda}$

$= \frac{6.62 \times 10^{-34} \times 3 \times 10^8}{\lambda}$

$\lambda = \frac{6.62 \times 10^{-34}}{2.178 \times 10^{-18}} \frac{3 \times 10^8 \times 4}{\times 3}$

$= 1.214 \times 10^{-7}$m

28. (a) The electronic configuration of Rubidium (Rb = 37) is

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 5s^1$

Since last electron enters in 5*s* orbital

Hence $n = 5, l = 0, m = 0, s = \pm\frac{1}{2}$

29. (a) Total energy =
where n = 2, 3, 4 ....
Putting n = 2
E_T =

30. (b) As electron of charge 'e' is passed through 'V' volt, kinetic energy of electron will be eV
Wavelength of electron wave (λ) =
λ = $\Rightarrow \therefore$ =

31. (d) Radius of n^{th} Bohr orbit in H-atom
$= 0.53\ n^2$Å
Radius of II Bohr orbit = $0.53 \times (2)^2$
= 2.12 Å

32. (a) Isoelectronic species have same no. of electrons.

ions	O^{-2}	F^-	Na^+	Mg^{2+}
	8+2	9+1	11–1	12–2
No. of e^- =	10	10	10	10

therefore O^{2-}, F^-, Na^+, Mg^{2+} are isoelectronic