Solutions to Workbook-1 [Chemistry] | Atomic Structure

Daily Tutorial Sheet	Level - 0

Very Short Answer Type (1 Mark)

1. 4s (The electronic configuration of Nickel is 1s2, 2s2, 2p6, 3s2,3p6,4s2,3d8 where the outermost electron is present in 4s.)

2. For 3p orbital n = 3, l = 1
Number of angular nodes = l = 1
Number of radial nodes = n – l – 1 = 3 – 1 – 1 = 1

3. A = 13, A – Z = 7 $\therefore$ Z = 6
Atomic number (Z) = 6

4. $\ell = 3$; $m = -3, -2, -1, 0, 1, 2, 3$ (As m goes from $-\ell$ to $+\ell$)

5. **(a)** 1 s **(b)** 2 s **(c)** 3 p **(d)** 4 d

6. Yes, angular momentum of an electron in an atom is quantized. One of the propositions in the Bohr's model suggested that angular momentum of an electron (mvr) is an integral multiple of (h/2π)

Short Answer Type-I (2 Marks)

7. $\bar{v} = 109677\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]\text{cm}^{-1}$

For $n_2 = 4$ to $n_1 = 2$ transition in Balmer series. $\therefore$ $\bar{v} = 109677\left[\frac{1}{2^2} - \frac{1}{4^2}\right]\text{cm}^{-1}$

$= 109677\left[\frac{1}{4} - \frac{1}{16}\right]\text{cm}^{-1} = 20564.44\ \text{cm}^{-1}$

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

m = 100 g = 0.1 kg.

v = 100 km/hr = $\frac{100 \times 1000\,\text{m}}{60 \times 60\,\text{s}} = \frac{1000}{36}\text{ms}^{-1}$

$h = 6.626 \times 10^{-34}\,\text{Js}$

$\lambda = \frac{6.626 \times 10^{-34}\,\text{Js}}{0.1\text{kg} \times \frac{1000}{36}\text{ms}^{-1}} = 6.626 \times 10^{-36} \times 36\,\text{m} = 238.5 \times 10^{-36}\,\text{m}$

Since the wavelength is very small, the wave nature cannot be detected.

9. $\lambda = \frac{c}{\upsilon} = \frac{3.0 \times 10^{8}\text{ms}^{-1}}{4.620 \times 10^{14}\text{Hz}} = 0.6494 \times 10^{-6}$ m = 649.4 nm; Visible light

10. Uncertainty in the speed of ball = $\frac{90 \times 4}{100} = \frac{360}{100} = 3.6\,\text{ms}^{-1}$

Uncertainty in position = $\frac{h}{4\pi m\Delta v}$

$$= \frac{6.626 \times 10^{-34} \text{Js}}{4 \times 3.14 \times 10 \times 10^{-3} \text{kg} \times 3.6 \text{ms}^{-1}} = 1.46 \times 10^{-33} \text{m}$$

11. The energy of electron is determined by the value of '*n*' in hydrogen atom and by '*n* + *l*' in multi-electron species. So for a given principal quantum number, electrons of *s*, *p*, *d* and *f* orbitals have different energy.

12. $r = 0.529 \frac{n^2}{Z} \text{Å}$

$$r_4 - r_3 = 0.529\left(\frac{16}{2} - \frac{9}{2}\right)\text{Å} = 1.851 \times 10^{-10} \text{m}$$

13. Total number of spectral lines given by

$$\frac{1}{2}[n-1] \times n = 15; \quad \therefore \quad n = 6$$

Thus, electron is excited upto 6th energy level from ground state. Therefore,

$$\frac{1}{\lambda} = R_H\left[\frac{1}{1^2} - \frac{1}{n^2}\right] = 109737 \times \frac{35}{36};$$

$$\lambda - 9.373 \times 10^{-6} \text{cm} = 937.7 \text{Å}$$

Short Answer Type-II (3 Marks)

14. This model was not according to classical theory of electromagnetism proposed by Maxwell. According to this theory, every accelerated charge particle must emit radiation in the form of electromagnetic radiations and hence loses its energy. Since energy of electron keeps on decreasing, so radius of circular orbit should also decrease and ultimately the electron should spiral into nucleus. It suggests that the atom should be unstable. This discrepancy could not be explained at that time with the help of Rutherford's model.

15. After the excitation of atom, electrons come down to lower energy levels and in the process they emit electromagnetic radiations. The energy of these electromagnetic radiations is exactly equal to the difference in the energy levels where the transition has occurred. For a given atom when these radiations are brought on a photographic plate, a number of radiations constitute to form Emission spectrum of atom. It is the characteristic of an atom.

16. The laws of photoelectric emission are as follows:

(A) The number of electrons emitted per second is directly proportional to the intensity of radiation.

(B) The maximum kinetic energy of electrons emitted increases with the frequency of the radiation.

(C) There is a minimum frequency called threshold frequency below which no emission occurs.

17. The orbits of an atom actually represent the energy levels of the electrons in it. The energy value of these energy level increases as the shell number increases. These energy levels are also known as stationary orbits. The orbits are named according to the energy levels of electrons in it. Hence orbits are also called energy levels.

18. Transition: $4 \longrightarrow 1$

Number of photons $= \frac{n(n-1)}{2} = \frac{(3)(4)}{2} = 6$

For 1 mole of H-atom = 6 × N_A

19. **(A)** 4s $(n + \ell) = (4 + 0)$ **(B)** 3p $(3 + 1)$ **(C)** 3d $(3 + 2)$ **(D)** 3s $(3 + 0)$

So energy order = (C) > (A) > (B) > (D)

Long Answer Type (5 Marks)

20. **(A)** Mass of one electron = 9.11×10^{-31} kg, i.e., 9.11×10^{-31} kg = 1 electron

$$1 \text{ g i.e. } 10^{-3} \text{ kg} = \frac{1}{9.11 \times 10^{-31}} \times 10^{-3} \text{ electrons} = 1.098 \times 10^{27} \text{electrons.}$$

(B) Mass of one electron = 9.11×10^{-31} kg

Mass of one mole of electrons = $(9.11 \times 10^{-31}) \times (6.022 \times 10^{23}) = 5.486 \times 10^{-7}$ kg

Charge on one electron = 1.602×10^{-19} coulomb

Charge on one mole of electrons = $(1.602 \times 10^{-19}) \times (6.022 \times 10^{23}) = 9.65 \times 10^{4}$ coulombs.

21. **(A)** 1 molecule of CH_4 contains electrons = 6 + 4 = 10

1 mole, i.e., 6.022×10^{23} molecules will contain electrons = 6.022×10^{24}

(B) (*a*) 1 g atom of ^{14}C = 14 g = 6.022×10^{23} atoms = $6.022 \times 10^{23} \times 8$ neutrons.

Thus, 14g or 14000 mg have $8 \times 6.022 \times 10^{23}$ neutrons

$$7 \text{ mg will have neutrons} = \frac{8 \times 6.022 \times 10^{23}}{14000} \times 7 = 2.4088 \times 10^{21}$$

(*b*) Mass of 1 neutron = 1.675×10^{-27} kg

Mass of 2.4088×10^{21} neutrons = $(2.4088 \times 10^{21})(1.675 \times 10^{-27} \text{ kg}) = 4.0347 \times 10^{-6}$ kg

(C) (*a*) 1 mol of NH_3 = 17 g NH_3 = 6.022×10^{23} molecules of NH_3

$= (6.022 \times 10^{23}) \times (7 + 3)$ protons = 6.022×10^{24} protons

$$\text{In 34 mg, i.e., 0.034 g } NH_3\text{, protons} = \frac{6.022 \times 10^{24}}{17} \times 0.034 = 1.2044 \times 10^{22}$$

(*b*) Mass of one proton = 1.6726×10^{-27} kg

Mass of 1.2044×10^{22} protons = $(1.6726 \times 10^{-27}) \times (1.2044 \times 10^{22})$ kg = 2.0145×10^{-5} kg

22. **(A)** $$\text{Energy of the photon (E)} = h\nu = \frac{hc}{\lambda} = \frac{(6.626 \times 10^{-34} \text{Js}) \times (3 \times 10^{8} \text{ms}^{-1})}{4 \times 10^{-7} \text{m}} = 4.97 \times 10^{-19} \text{J}$$

$$= \frac{4.97 \times 10^{-19}}{1.602 \times 10^{-19}} \text{eV} = 3.10 \text{ eV}$$

(B) Kinetic energy of emission $\left(\frac{1}{2}mv^2\right) = h\nu - h\nu_o = 3.10 - 2.13 = 0.97$ eV

(C) $\frac{1}{2}mv^2 = 0.97 \text{ eV} = 0.97 \times 1.602 \times 10^{-19}$ J

i.e. $\frac{1}{2} \times (9.11 \times 10^{-31} \text{kg}) \times v^2 = 0.97 \times 1.602 \times 10^{-19}$ J

or $v^2 = 0.341 \times 10^{12} = 34.1 \times 10^{10}$ or $v = 5.84 \times 10^{5}$ ms^{-1}

23. Energy emitted by the bulb = 25 watt = 25 J s^{-1} (1 watt = 1 J s^{-1})

Energy of one photon (E) = $h\nu = h\frac{c}{\lambda}$

Here, $\lambda = 0.57 \mu m = 0.57 \times 10^{-6}$ m

Putting $c = 3 \times 10^{8}$ ms^{-1}, $h = 6.62 \times 10^{-34}$ Js, we get

$$E = \frac{\left(6.62 \times 10^{-34}\ \text{Js}\right)\left(3 \times 10^{8}\ \text{ms}^{-1}\right)}{0.57 \times 10^{-6}\text{m}} = 3.48 \times 10^{-19}\ \text{J}$$

No. of photons emitted per sec = $\frac{25\ \text{Js}^{-1}}{3.48 \times 10^{-19}\ \text{J}} = 7.18 \times 10^{19}$

24. $E_n = -\frac{21.8 \times 10^{-19}}{n^2}$ J atom^{-1}

For ionisation from 5th orbit, $n_1 = 5$, $n_2 = \infty$

$$= \Delta E = E_2 - E_1 = -21.8 \times 10^{-19}\left(\frac{1}{n_2^2} - \frac{1}{n_1^2}\right) = 21.8 \times 10^{-19}\left(\frac{1}{5^2} - \frac{1}{\infty^2}\right)$$

$= 8.72 \times 10^{-20}$ J

For ionization from 1st orbit, $n_1 = 1$, $n_2 = \infty$

$$\Delta E' = 21.8 \times 10^{-19}\left(\frac{1}{1^2} - \frac{1}{\infty}\right) = 21.8 \times 10^{-19}\text{J}$$

$$\frac{\Delta E'}{\Delta E} = \frac{21.8 \times 10^{-19}}{8.72 \times 10^{-20}} = 25$$

Thus, the energy required to remove electron from 1st orbit is 25 times than that required to remove electron from 5th orbit.

25. Suppose threshold wavelength $= \lambda_0$ nm $= \lambda_0 \times 10^{-9}$m

Also, $h\left(v - v_0\right) = \frac{1}{2}mv^2$ or $hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right) = \frac{1}{2}mv^2$

Substituting the given results of the three experiments, we get

$$\frac{hc}{10^{-9}}\left(\frac{1}{500} - \frac{1}{\lambda_0}\right) = \frac{1}{2}m\left(2.55 \times 10^{6}\right)^2 \quad \text{. . . A}$$

$$\frac{hc}{10^{-9}}\left(\frac{1}{450} - \frac{1}{\lambda_0}\right) = \frac{1}{2}m\left(4.35 \times 10^{6}\right)^2 \quad \text{. . . B}$$

$$\frac{hc}{10^{-9}}\left(\frac{1}{400} - \frac{1}{\lambda_0}\right) = \frac{1}{2}m\left(5.20 \times 10^{6}\right)^2 \quad \text{. . . C}$$

Dividing eqn.(B) by eqn. (A), we get

Or $\frac{\lambda_0 - 450}{\lambda_0 - 500} \times \frac{450}{500} = \left(\frac{4.35}{2.55}\right)^2 = 2.910$ or $\lambda_0 - 450 = 2.619\lambda_0 - 1309.5$

Or $1.619\ \lambda_0 = 859.5 \therefore\ \lambda_0 = 531$ nm

Substituting this value in eqn. (C), we get

$$\frac{h \times \left(3 \times 10^{8}\right)}{10^{-9}}\left(\frac{1}{400} - \frac{1}{531}\right) = \frac{1}{2}\left(9.11 \times 10^{-31}\right)\left(5.20 \times 10^{6}\right)^2 \quad \text{or} \quad h = 6.66 \times 10^{-34}\ \text{Js}$$