Chemistry Worksheet on Chapter 2 Structure of Atom with Answers – Set 1

Q1. Which of the following orbitals do not make sense?

a.) 6s
b.) 3p
c.) 2d
d.) 4f

Correct Answer – (c.) 2d

Q2. Orbital angular momentum depends on:

a.) l
b.) n and l
c.) n and m
d.) m and s

Correct Answer – (a.) l

Q3. In the manganese atom, Mn (Z = 25), the total number of orbitals populated by one or more electrons (in the ground state) is:

a.) 15
b.) 14
c.) 12
d.) 10

Correct Answer – (a.) 15

Q4. The following quantum numbers are possible for how many orbitals?
$n = 3, l = 2, m_l = +2$

a.) 1
b.) 2
c.) 3
d.) 4

Correct Answer – (a.) 1

Q5. In Bohr's orbit, the ratio of total kinetic energy and the total energy of the electron is:

a.) –2
b.) –1
c.) +2
d.) 0

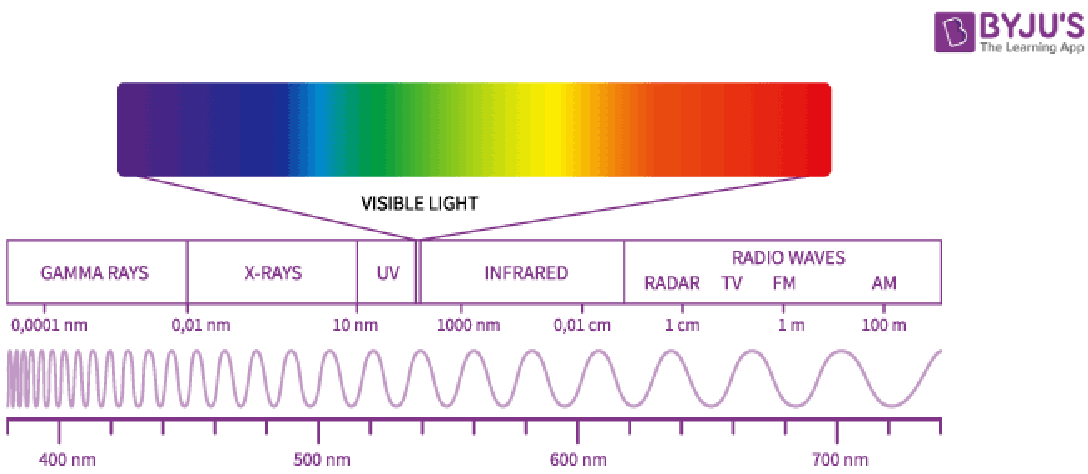
Correct Answer – (b.) –1

Q6. Define Hund's rule of maximum multiplicity.

Answer: Hund's rule of maximum multiplicity states that the pairing of electrons in orbitals of the same subshell cannot take place until all orbitals are singly occupied with parallel spin.
For example, there are three p-orbitals (p_x, p_y and p_z) of the p subshell in a principal energy level. According to Hund's rule, each of the three orbitals must get one electron of parallel spin before any one of them receives the second electron of opposite spin.

Q7. Define electromagnetic spectrum.

Answer: The arrangement of different types of electromagnetic radiation in order of increasing wavelengths or decreasing frequencies is known as the electromagnetic spectrum.



Q8. How many protons, electrons, and neutrons are there in the following nuclei?
i.) ${}^{17}_{8}O$
ii.) ${}^{25}_{12}Mg$
iii.) ${}^{80}_{35}Br$

Answer:
i.) ${}^{17}_{8}O$

Atomic Number Z = 8, Mass number, A = 17
Number of protons = Number of electrons = 8
Number of neutrons = A – Number of protons = 17 – 8 = 9

ii.) ${}^{25}_{12}Mg$
Atomic Number Z = 12, Mass number, A = 25
Number of protons = Number of electrons = 12
Number of neutrons = A – Number of protons = 25 – 12 = 13

iii.) ${}^{80}_{35}Br$
Atomic Number Z = 35, Mass number, A = 80
Number of protons = Number of electrons = 35
Number of neutrons = A – Number of protons = 80 – 35 = 45

Q9. State the drawbacks of the Rutherford Model of an atom.

Answer: According to Rutherford's model, electrons follow a circular path around the nucleus. However, particles moving in a circular path experience acceleration, and acceleration causes charged particles to emit energy. Electrons should eventually lose energy and fall into the nucleus. This points to the atom's instability. This, however, is not possible because atoms are stable. As a result, Rutherford's model could not explain the stability of an atom.

Q10. Calculate and compare the energies of two radiations, one with a wavelength of 800 nm and the other with a wavelength of 400 nm.

Answer: Energy of photon,

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

$c = 3.0 \times 10^8$ m s^{-1}.

Case 1:
λ = 800 nm = 800×10^{-9} m

$$E_1 = \frac{(6.626 \times 10^{-34} Js) \times (3 \times 10^8 ms^{-1})}{800 \times 10^{-9} m}$$

$E_1 = 2.48 \times 10^{-19}$ J

Case 2:
λ = 400 nm = 400×10^{-9} m

$$E_2 = \frac{(6.626 \times 10^{-34} Js) \times (3 \times 10^8 ms^{-1})}{400 \times 10^{-9} m}$$

$E_2 = 4.96 \times 10^{-19}$ J
Ratio of E_1 and E_2

$$\frac{E_1}{E_1} = \frac{2.48 \times 10^{-19} J}{4.96 \times 10^{-19} J} = \frac{1}{2}$$

∴ $E_1 : E_2 = 1 : 2$

Or $E_2 = 2E_1$

Thus, the energy of the radiation with a wavelength of 400 nm is twice that of the radiation with a wavelength of 800 nm.

Q11. State Heisenberg's Uncertainty principle.

Answer: Heisenberg's Uncertainty principle states that it is not possible to simultaneously measure both the position and momentum (or velocity) of a microscopic particle with absolute accuracy.

Mathematically, this law may be expressed as:

$$\triangle x \times \triangle p \geq \frac{h}{4\pi}$$

where $\triangle x$ = uncertainty in position

$\triangle p$ = uncertainty in momentum

The sign ≥ means that the product of $\triangle x$ and $\triangle p$ can be either greater than or equal to $h/4\pi$. It can never be less than $h/4\pi$.

If the position of a particle is measured accurately, there will be more errors in the measurement of momentum. Conversely, if momentum is measured more accurately, the position will not be accurately known.

Since momentum p = mv, $\triangle p = m\triangle v$ because mass is constant. Therefore, the equation can be written as:

$\triangle x \times m(\triangle v) \geq h/4\pi$

This means that the position and velocity of an object cannot be simultaneously known with accuracy.

Q12. i.) An atomic orbital has n = 3. What are the possible values of l and m_l?

ii.) List the quantum numbers (m_l and l) of electrons for the 3-d orbital.

iii.) Which of the following orbitals are possible 1p, 2s, 2p and 3f?

Answer:

i.) An atomic orbital has n = 3. What are the possible values of l and m_l?

When n = 0, l = 0, 1, 2

When l = 0, m_l = 0

When l = 1, m_l = –1, 0, +1

When l = 2, m_l = –2, –1, 0, +1, +2

ii.) List the quantum numbers (m_l and l) of electrons for 3-d orbital:

For 3-d orbitals, n = 3, l = 2

For l = 2, m_l = –2, –1, 0, +1, +2

iii.) Which of the following orbitals are possible 1s, 2s, 2p and 3f?

Only the orbitals 2s and 2p are possible from the given set. 1p and 3f are not possible.

For p-orbital, l = 1. For a given value of n, l can have values ranging from zero to one (n – 1).
∴ When l equals 1, the minimum value of n is 2.
Similarly, l = 3 for f-orbital.
The minimum value of n for l = 3 is 4.
As a result, 1p and 3f do not exist.

Q13. The radius of the fourth orbit in a hydrogen atom is 0.85 nm. Calculate the velocity of the electron in this orbit (mass of electron = 9.1×10^{-31} kg).

Answer: According to Bohr's postulate, the angular momentum (mvr) is given as:

$$mvr = \frac{nh}{2\pi} \ or \ v = \frac{nh}{2\pi mr}$$

n = 4, m = 9.1×10^{-31} kg, r = 0.85×10^{-9} m

∴ v = $$= \frac{4 \times 6.626 \times 10^{-34}}{2 \times \frac{22}{7} \times 9.1 \times 10^{-31} \times 0.85 \times 10^{-9}}$$

v = 5.45×10^{5} m s^{-1}.

Q14. State and explain Pauli's exclusion principle. Write the electronic configuration of the element with atomic number 24.

Answer: Pauli's exclusion principle states that in a single atom, no two electrons will have the same quantum number.
2 salient rules:

- An orbital can accommodate a maximum of two electrons.
- These electrons must have opposite spins.

The expected electronic configuration of the element with atomic number 24 is $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^4$, but in reality, the electronic configuration is $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^5$ as this gives a more stable atom due to the d orbital being half filled.

Q15. a.) What is the Aufbau principle? Write electronic configurations of the elements with atomic numbers 16, 20 and 35.
b.) Explain why half-filled and completely filled orbitals have extra stability?

Answer: a.)The Aufbau principle states that electrons are filled into atomic orbitals in the order of increasing orbital energy level. According to this principle, the available atomic orbitals with the lowest energy levels are occupied before those with higher energy levels.
The electronic configurations are as follows:
16 = $1s^2 2s^2 2p^6 3s^2 3p^4$
20 = $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$
35 = $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^5$

b.) The half-filled and fully-filled orbitals are extremely stable for the following reasons:
i.) The electron distribution is symmetrical in the completely filled and half-filled subshells. Electrons in the same subshell have the same energy but are arranged differently in space. They become extra stable due to their symmetrical distribution.
(ii) When two or more electrons with the same spin are present in the degenerate orbitals of a subshell, the stabilising effect occurs. They exchange their positions. The energy released resulting from this exchange is referred to as exchange energy. When the subshell is half full or completely full, the number of exchanges is maximised. As a result, exchange energy is maximised, and thus stability is maximised.

Q16. How many unpaired electrons are present in the ground state of
i.) P (Z = 15)
ii.) Fe^{2+} (Z = 26)
iii.) Cl^- (Z = 17)

Answer: The number of unpaired electrons can be predicted by writing the electronic configurations:
i.) P (Z = 15)
$1s^22s^22p^63s^23p_x^13p_y^13p_z^1$
Therefore, the number of unpaired electrons = 3

ii.) Fe^{2+} (Z = 26)
The electronic configuration of Fe is $1s^22s^22p^63s^23p^63d^64s^2$.
For Fe^{2+}, 2 electrons will be removed from 4s orbital, Therefore, the electronic configuration will be $1s^22s^22p^63s^23p^63d^6$
All orbitals are completely filled except for 3d. Therefore, the number of unpaired electrons will be 4.

iii.) Cl^- (Z = 17)
The electronic configuration of Cl is $1s^22s^22p^63s^23p^5$.
For Cl^-, one electron will be extra in the 3p orbital, and the electronic configuration will be $1s^22s^22p^63s^23p^6$. All orbitals are completely filled. Therefore, there is no unpaired electron.

Q17. On the basis of Heisenberg's uncertainty principle, show that an electron cannot exist within the atomic nucleus of a radius of 10^{-15} m.

Answer: Radius of the atomic nucleus = 10^{-15} m.
If an electron had to exist in the nucleus, the maximum uncertainty in its position would have been 10^{-15} m.
According to the uncertainty principle

$$\triangle x \times \triangle p \geq \frac{h}{4\pi}$$

Or $\triangle x \times m(\triangle v) \geq h/4\pi$

Or $\Delta v \geq \frac{h}{4\Pi m \Delta x}$

Mass of electron, m = 9.1 × 10^{-31} kg, Δx = 10^{-15} m

$\therefore \Delta v \geq \frac{6.6 \times 10^{-34}}{4 \times 3.14 \times 9.1 \times 10^{-31} \times 10^{-15}}$

△v ≥ 5.77 × 10^{10} ms^{-1}

The value of uncertainty in velocity, △v, is much higher than the velocity of light and is, therefore, not possible. Hence, an electron cannot be found within the atomic nucleus.

Q18. An electron is moving with a kinetic energy of 2.275 × 10^{-25} J. Calculate its de-Broglie wavelength. (Mass of electron = 9.1 × 10^{-31} kg, h = 6.6 × 10^{-34} J s)

Answer: Kinetic energy of electrons,

½ mv^2 = 2.275 × 10^{-25} J

v^2 = (2 × 2.275 × 10^{-25})/m

m = 9.1 × 10^{-31} kg

$$v^2 = \frac{2 \times 2.275 \times 10^{-25} kg\ m^2 s^{-2}}{9.1 \times 10^{-31} kg}$$

v^2 = 0.5 × 10^6 m^2s^{-2}

v = 0.707 m/s

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

$$\lambda = \frac{6.6 \times 10^{-34} kg\ m^2 s^{-1}}{(9.1 \times 10^{-31} kg) \times (0.707 \times 10^3 ms^{-1})}$$

λ = 1.025 × 10^6 m = 1026 nm

Q19. In the Rydberg equation, a spectral line corresponds to n_1 = 3 and n_2 = 5.

i.) Calculate the wavelength and frequency of this spectral line.

ii) To which spectral series does this line belong?

iii.) In which region of the electromagnetic spectrum will this line fall?

Answer:

i.) According to the Rydberg equation,

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

R = 109677 cm^{-1}, n_1 = 3 and n_2 = 5

Substituting the values,

$$\frac{1}{\lambda} = 109677\left[\frac{1}{3^2} - \frac{1}{5^2}\right]$$

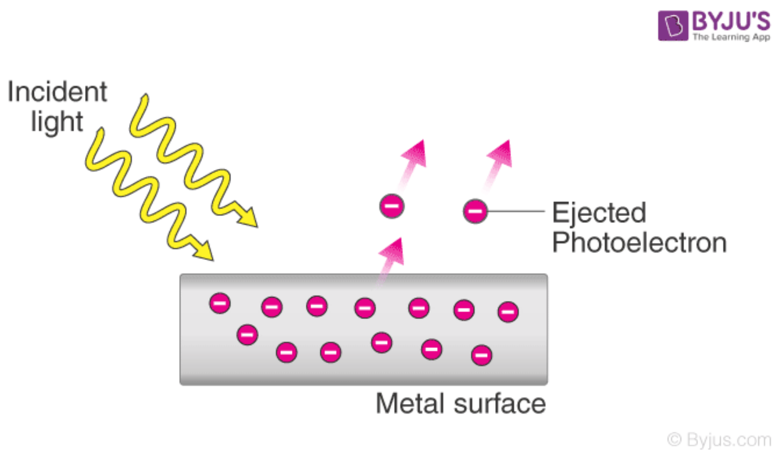
$$\frac{1}{\lambda} = 109677\left[\frac{1}{9} - \frac{1}{25}\right]$$
$$= 109677 \times \frac{16}{225}$$
$\lambda = 12.82 \times 10^{-5}$ cm $= 1282 \times 10^{-9}$ m
$\lambda = 1282$ nm

$\lambda \times v = c$ or $v = \frac{c}{\lambda}$
where $c = 3.0 \times 10^{8}$ m/s, $\lambda = 1282$ nm
$$v = \frac{3.0 \times 10^{8} ms^{-1}}{1282 \times 10^{-9} m} = \frac{3}{1282} \times 10^{17} s^{-1}$$
$v = 2.34 \times 10^{14}\ s^{-1}$

ii.) Since this line corresponds to $n_2 = 3$, it belongs to the Paschen series.
iii.) The spectral line will fall in the infra-red region.

Q20. What is the photoelectric effect? State the results of the photoelectric effect experiment that could not be explained based on the laws of classical physics. Explain this effect based on the quantum theory of electromagnetic radiations.

Answer:
When specific metals are exposed to a light beam, the metal ejects electrons. This is referred to as the photoelectric effect. The ejected electrons are known as photoelectrons.
The following were the outcomes of this experiment:
i.) Electrons are ejected from the metal surface only when a light beam strikes it.
ii.) The number of electrons is proportional to radiation intensity.
iii.) There is a minimum frequency (v_0) for each metal below which the photoelectric effect is not observed.
iv.) The electron's kinetic energy is proportional to the frequency of light.



Photoelectric effect based on the quantum theory of electromagnetic radiations:
When a photon with sufficient energy strikes an electron in a metal atom, it transfers its energy to the electron, and the electron is expelled without delay. The greater the energy of the photon, the greater the kinetic energy of the ejected electron.