UNIT 2

STRUCTURE OF ATOM

Answer the questions. (1 Score each)

Multiple choice questions and answers

1. Representation of the orbital with Quantum numbers n = 3 , l = 1 is .....

a) 3s b) 3d c) 3p d) 1s

Ans . C) 3p

2. Shape of an orbital is determined by

a) Spin quantum number b) Magnetic quantum number

c) Azimuthal quantum number d) Principal quantum number

Ans :- c) Azimuthal quantum number

3. Which point doesn't pertain to Bohr's model of atom ?

a) Angular momentum is an integral multiple of h/2π .

b) The path of the electron is circular .

c) Force of attraction towards the nucleus is equal to centrifugal force.

d) The energy changes are taking place continuously.

Ans – d) The energy changes are taking place continuously.

4.Which expression represents de Broglie relationship ?

a) $p = \frac{h}{mv}$ b) $\lambda = \frac{h}{mv}$ c) $\lambda = \frac{h}{mp}$ d) $\lambda m = \frac{v}{p}$

Ans :- b) $\lambda = \frac{h}{mv}$

5. The electronic configuration of an atom / ion determined by

a) Aufbau principle b) Hund's rule c) Pauli's exclusion principle d) All of the above

Ans :- d) All of the above

6. The number of unpaired electrons present in the 3d sub- shell of an element having atomic number 29 is,

a) 0 b) 2 c) 3 d) 4

Ans :- a) 0

7) The Balmer series for atomic hydrogen is observed in the following spectral region

a) Infrared b) Ultraviolet c) Visible d) Far IR

Ans :- c) Visible

8) Rutherford scattering experiment is related to the size of the .....

a) nucleus b) atom c) electron d) neutron

Ans : a) nucleus

9) Which of the following set of quantum numbers belongs to highest energy ?

a) n = 4 , l = 0 , m = 0 , s = +1/2 b) n = 3 , l = 0 , m = 0 , s = +1/2

c) n = 3 , l = 1 , m = +1 , s = +1/2 d) n = 3 , l = 2 , m = +1 , s = +1/2

Ans :- d) n = 3 , l = 2 , m = +1 , s = +1/2

10) The total number of orbitals in a shell having principal quantum number (n) is

a) 2n b) n^2 c) $2n^2$ d) (n+1)

Ans : b) n^2

Answer the following

11. Represent the orbital with quantum numbers n = 5 and l = 3.

Ans: 5*f*

12. i) Write the electronic configuration of chromium (z = 24)

ii) Maximum number of electrons in the sub-shell with azimuthal quantum number *l* =2

iii) Represent the orbital with quantum numbers n = 1 and $l = 0$

Ans;

i) $_{24}Cr$: [Ar] $3d^5\ 4s^1$ or $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^1$

(ii) $l = 2$ denotes *d* subshell, which can accommodate a maximum of 10 electrons.

(iii) 1s

13. The number of electrons ejected in the photoelectric effect is proportional to the ..... of light used.

Ans : intensity

14. State the dual behaviour of matter.

Ans: Matter has both particle nature and wave nature. This is known as dual behaviour of matter.

15. The photon has a momentum as well as a wavelength. Which property is revealed in the above statement?

Ans: Dual behaviour of energy.

16. State Heisenberg's uncertainty principle.

Ans: It states that "it is impossible to determine simultaneously, the exact position and momentum (or velocity) of a moving microscopic particle like electron".

17. Write the important demerits of Rutherford's atom model.

Ans: (i) Rutherford's model could not explain the stability of the atom.

(ii) It could not explain the electronic structure of atom.

Answer the questions. (2 Score each)

18. Write two important results observed during photoelectric effect.

Ans:

(i) The electrons are ejected from the metal surface as soon as the beam of light strikes the surface.

(ii) The number of electrons ejected is proportional to the intensity or brightness of light.

(iii) For each metal, there is a minimum frequency called threshold frequency below which no electrons are emitted.

(iv) The kinetic energy of the ejected electrons is directly proportional to the frequency of the incident light. [Any 2 required]

19. Write the postulates of Rutherford Model of atom.

Ans

- The whole mass and all the positive charge of an atom is concentrated in a very small region at the centre of the atom called nucleus.
- Most of the space in an atom is empty.
- The nucleus is surrounded by negatively charged electrons.
- The electrons and the nucleus are held together by electrostatic forces of attraction.

20. Give the names of series of spectral lines of atomic hydrogen and their region in electromagnetic spectrum.

Ans

- Lyman series, Balmer series , Paschen series, Brackett series , Pfund Series
- Lyman series - UV region
- Balmer series - Visible region
- Paschen series – IR region
- Brackett Series – IR region
- Pfund Series – IR region

21. Write any two observations of Photoelectric effect .

Ans

- The number of electrons ejected is proportional to the intensity of light.
- The kinetic energy of the electrons ejected depends on the frequency of incident radiation.

22. Give the postulates of Bohr's model of atom.

Ans

- Electrons are revolving around the nucleus in certain circular path called orbit.
- As long as the electron remains in an orbit, it doesn't lose or gain energy.
- Only those orbits are permitted in which the angular momentum of the electron is the integral multiple of $\frac{h}{2\pi}$
- Energy is emitted or absorbed by an atom only when an electron moves from one orbit to another.

23 . Represent the subshell given below.

i) n = 1 , $l = 0$ ii) n = 2 $l = 1$

Ans i) 1s ii) 2 p

24. Write the subshell electronic configuration of the following elements.

i) Cu (Z=29) ii) Cr (Z=24)

Give reason for the extra stability of these atoms.

Ans Cr (z=24) [Ar] $3d^5\ 4s^1$

Cu (z=29) [Ar] $3d^{10}\ 4s^1$

The extra stability of half filled and completely filled subshell is due to their symmetry and larger exchange energy.

25. State Heisenberg's Uncertainty Principle and give the mathematical expression.

Ans; Heisenberg's Uncertainty Principle states that it is not possible to determine both the position and momentum of microscopic particles simultaneously with accuracy .

$\Delta x \cdot \Delta p \geq \frac{h}{4\pi}$

Δx = Uncertainty in position

Δp = Uncertainty in momentum

26. State Pauli's exclusion principle and Hund's rule of maximum multiplicity.

Ans : Pauli's exclusion principle states that no two electrons in an atom can have the same value for all the four quantum numbers.

Hund's rule states that the pairing of electrons in orbitals of same energy will takes place only after each orbital is singly occupied.

27. i) Which of the following sets of quantum numbers are not possible?

1) $n = 2, l = 2, m_l = 0, m_s = +½$
2) $n=1, l = 0, m_l = 0, m_s = -½$
3) $n = 3, l = 2, m_l = -3, m_s = +½$
4) $n = 2, l = 1, m_l = 1, m_s = +½$

ii) Justify your answer.

Ans:

i) $n = 2,\ l = 2, m_l = 0, m_s = +\frac{1}{2}$

$n = 3, l = 2, m_l = -3, m_s = +\frac{1}{2}$

ii) When $n = 2$, the values of l are 0 and 1. i.e. l cannot be 2

When $l = 2$, the values of m_l are -2, -1, 0, +1 and +2. i.e. m_l cannot be -3.

28. Among the following electronic configurations, which one is correct? Substantiate your answer.

i) ↑↓ ↑↓ ↑ ↓ ↑
ii) ↑↓ ↑↓ ↑↓ ↑
iii) ↑↓ ↑↓ ↑ ↑ ↑

Ans: iii) is correct. This is because according to Hund's rule, the electron pairing occurs only after partially filling all the degenerate orbitals with maximum multiplicity.

29. The threshold frequency for a metal is $7.0 \times 10^{14}\ s^{-1}$. Calculate the kinetic energy of an emitted electron when radiation of frequency $1.0 \times 10^{15}\ s^{-1}$ (ν) hits the metal.

Ans:

Here threshold frequency $(\nu_0) = 7.0 \times 10^{14}\ s^{-1}$ *and frequency of radiation* $(\nu) = 1.0 \times 10^{15}\ s^{-1}$

K.E of emitted electron $= h\nu - h\nu_0 = h(\nu - \nu_0) = 6.626 \times 10^{-34} (1.0 \times 10^{15} - 7.0 \times 10^{14}) = 19.878 \times 10^{-20}$ J

30. Calculate the wavelength of the first line in Lyman series of the hydrogen spectrum .

(R = 109677 cm^{-1})

For the first line in Lyman series, $n_1 = 1$ and $n_2 = 2$

Wave number, $\bar{\nu} = \frac{\nu}{c} = \frac{R_H}{hc}\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right)$

$$= \frac{3.29\times10^{15}\,s^{-1}}{3\times10^{8}\,m\,s^{-s}}\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right)$$

$$= 1.09677\times10^{7}\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right) m^{-1}$$

Wave number, $\bar{\upsilon} = \frac{1}{\lambda} = 109677\ (\frac{1}{n_i^2} - \frac{1}{n_f^2}) = 109677\ (\frac{1}{1^2} - \frac{1}{2^2})$

$= 109677 \times \frac{3}{4} = 82257.75\ cm^{-1}$

31. A microscope with suitable photons is employed to locate an electron in an atom within a distance of 0.4 A^o . What is the uncertainty involved in the measurement of its velocity?

Ans: We know that $\Delta x.m.\Delta v = \frac{h}{4\pi}$

Here Δx = 0.4 A^o . = 0.4 x 10^{-10} m,

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

m = 9.1 $\times 10^{-31}$ kg.

Δv = ?

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

$$\Delta v = \frac{6.626\times10^{-34}}{4\times3.14\times9.1\times10^{-31}\times0.4\times10^{-10}} = 0.145 \times 10^{7}\ m/s$$

32. The Balmer series of lines in the hydrogen spectrum appear in the visible region of the electromagnetic spectrum. Calculate the wave number of the second line in the Balmer series. (R = 109677 cm^{-1})

Ans: For the second line in Balmer series, n_1=2 and n_2 = 4

Wave number, $\bar{\upsilon} = \frac{1}{\lambda} = 109677\ (\frac{1}{n_i^2} - \frac{1}{n_f^2}) = 109677\ (\frac{1}{2^2} - \frac{1}{4^2})$

$= 109677 \times \frac{3}{16} = 20564.4\ cm^{-1}$

33. A photon has a mass of 8.6×10^{-30} Kg. Calculate its wave length .

(Plank's constant = 6.626×10^{-34} Js)

Ans: For photon , velocity (c) = 3×10^{8} m/s

From the de Broglie equation , $\lambda = \frac{h}{mc}$

$= 6.626 \times 10^{-34} / (8.6 \times 10^{-30} \times 3 \times 10^{8}) = 0.257 \times 10^{-12}$ m = 0.257 pm.

34. Calculate the uncertainty in the velocity of a cricket ball of mass 130 g, if the uncertainty in its position is of the order of 1.2 Å.

Ans: We know that $\Delta x . m . \Delta v = \frac{h}{4\pi}$

Here m = 130 g = 130×10^{-3} kg

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

$\Delta x = \frac{6.626 \times 10^{-34}}{4 \times 3.14 \times 130 \times 10^{-3} \times 1.2 \times 10^{-10}} = 3.382 \times 10^{-24}$

Answer the questions. (4 Score each)

35. What are the important observations and conclusions made by Rutherford from his alpha ray scattering experiment? Give any two limitations of Rutherford's nuclear model of atom.

Ans: The important observations made by Rutherford are

(i)Most of the α– particles passed through the gold foil without any deviation.

(ii)A small fraction of the α–particles was deflected by small angles.

(iii)A very few α– particles bounced back

Conclusions:

(i)Most space in the atom is empty.

(ii)The positive charge of the atom is concentrated in a very small volume at the centre called nucleus.

(iii)The volume occupied by the nucleus is negligibly small as compared to the total volume of the atom.

Limitations:

(i) Rutherford's model cannot explain the stability of the atom.

(ii) He cannot explain the electronic structure of atom.

36. Explain quantum numbers. Give the importance of quantum numbers in Pauli's Exclusion Principle.

Ans: Quantum Numbers are certain numbers used to explain the size, shape and orientation of orbitals. Or, Quantum numbers are the address of an electron.

There are four quantum numbers - Principal Quantum number (n), Azimuthal Quantum number (l), Magnetic Quantum number (m) and Spin Quantum number (s)

i). Principal Quantum Number :

It gives the size the orbit, the energy of electron in an orbit, the shell in which the electron is found and the average distance between the electron and the nucleus.

The possible values are 1, 2, 3, 4, 5 etc.

ii). Azimuthal Quantum Number:

It gives the shape of the orbital, the sub shell in which the electron is located and the orbital angular momentum of the electron.

The possible values of l are : l = 0, 1, 2, ... (n-1).

iii). Magnetic Quantum Number

It gives the orientation of orbitals in space. For a given 'l' value, there are 2l+1 possible values for m and these values are – l to 0 to + l

iv). Spin Quantum Number

It is the only experimental Quantum number and it gives the spin orientation of electrons. The values for s may be + ½ or – ½

According to Pauli's exclusion principle, no two electrons in an atom can have the same set of four quantum numbers. i.e. an orbital can accommodate a maximum of only 2 electrons with opposite spin.

37. Explain how, the different series of lines are formed in the hydrogen spectrum. Derive an equation to find the wave number of a line in the hydrogen spectrum.

Ans: According to Bohr atom model, line spectrum is formed by the excitation (de-excitation) of electron from one energy level to another.

Consider two energy levels E_1 and E_2 in Hydrogen atom. The energy gap between the two orbits is given by equation. $\Delta E = E_2 - E_1$

But $E_1 = \frac{-R_H}{n_1^2}$ and $E_2 = \frac{-R_H}{n_2^2}$

Therefore, $\Delta E = R_H \left(\frac{1}{{n_i}^2} - \frac{1}{{n_f}^2}\right)$

$= 2.18 \times 10^{-18} \left(\frac{1}{{n_i}^2} - \frac{1}{{n_f}^2}\right)$

The frequency associated with the absorption and emission of the photon can be given as

$$v = \frac{\Delta E}{h} = \frac{R_H}{h}\left(\frac{1}{{n_i}^2} - \frac{1}{{n_f}^2}\right)$$

$$= \frac{2.18 \times 10^{-18}}{6.626 \times 10^{-34}}\left(\frac{1}{{n_i}^2} - \frac{1}{{n_f}^2}\right)$$

$$= 3.29 \times 10^{15}\left(\frac{1}{{n_i}^2} - \frac{1}{{n_f}^2}\right)$$

Wave number, $\bar{\nu} = \frac{\nu}{c} = \frac{R_H}{hc}\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right)$

$$= \frac{3.29\times10^{15}\,s^{-1}}{3\times10^{8}\,m\,s^{-s}}\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right)$$

$$= 1.09677\times10^{7}\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right) m^{-1}$$

Wave number, $\bar{\upsilon} = \frac{1}{\lambda} = 109677\left(\frac{1}{{n_i}^2} - \frac{1}{{n_f}^2}\right)\ cm^{-1}$

38. Give the postulates of Bohr model of hydrogen atom. Also write two merits and two limitations of this model.

Ans: The important postulates of Bohr model of hydrogen atom are:

(i) The electron in the hydrogen atom can move around the nucleus in circular paths of fixed radius and energy. These paths are called orbits or stationary states or allowed energy states.

(ii) The energy of an electron in an orbit does not change with time. However, when an electron absorbs energy, it will move away from the nucleus.

(iii) The radius of orbits can be given by the equation $r_n = a_0 n^2$ where $a_0 = 52.9\ pm$.

(iv) The energy of electron in an orbit is given by the expression: $En = -R_H \frac{1}{n^2}$, where n =1,2,3... and R_H is a constant called Rydberg constant. Its value is 2.18 x 10^{-18} J

(v) The frequency of radiation absorbed or emitted when transition occurs between two stationary states that differ in energy by ΔE, is given by :

$$v = \frac{\Delta E}{h} = \frac{E_2 - E_1}{h}$$

(vi) The angular momentum of an electron is an integral multiple of $\frac{h}{2\pi}$ ie, $m_e vr = \frac{nh}{2\pi}$

Merits:

(i) It could explain the stability of atom

(ii) It could explain the line spectra of hydrogen atom and hydrogen like ions.

Demerits:

(i) It could not explain the fine spectrum of hydrogen atom.

(ii) It could not explain the spectrum of atoms other than hydrogen.