

Chapter 2: Structure of Atom

NCERT Exemplar · Class 11 · Chemistry

Multiple Choice Questions (Type-I)

Question 1

Which of the following conclusions could not be derived from Rutherford's α -particle scattering experiment?

- (i) Most of the space in the atom is empty.
- (ii) The radius of the atom is about 10^{-10} m while that of nucleus is 10^{-15} m.
- (iii) Electrons move in a circular path of fixed energy called orbits.
- (iv) Electrons and the nucleus are held together by electrostatic forces of attraction.

Solution

Ans: (iii) Electrons move in a circular path of fixed energy called orbits

As per Rutherford's α -particle scattering experiment the nucleus is surrounded by electrons that move around the nucleus with a very high speed in circular paths called orbits. It does not mention the energy or stability of the electrons revolving around the nucleus.

Question 2

Which of the following options does not represent ground state electronic configuration of an atom?

- (i) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8 4s^2$
- (ii) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^9 4s^2$
- (iii) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^1$
- (iv) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^1$

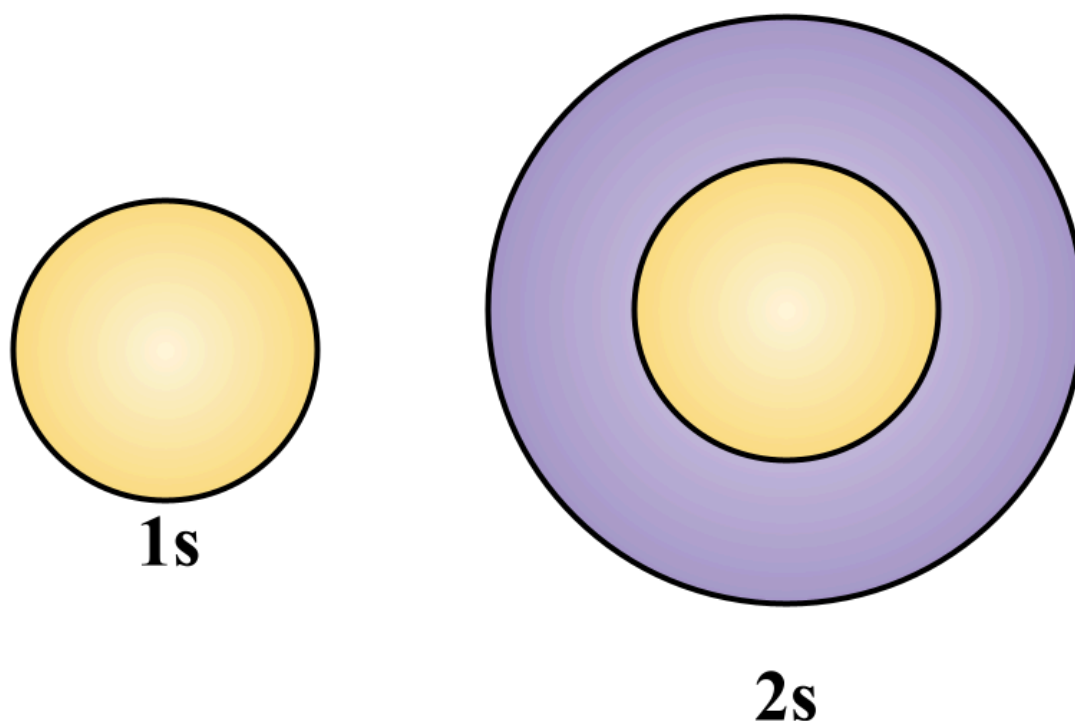
Solution

Ans: (ii) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^9 4s^2$

As per the Hund's rule the half filled and fully filled orbital leads to the extra stability due to the symmetry thus fully filled 3d and half filled 4s is preferred.

Question 3

The probability density plots of 1s and 2s orbitals are given in Fig. 2.1:



The density of dots in a region represents the probability density of finding electrons in the region.

On the basis of above diagram which of the following statements is incorrect?

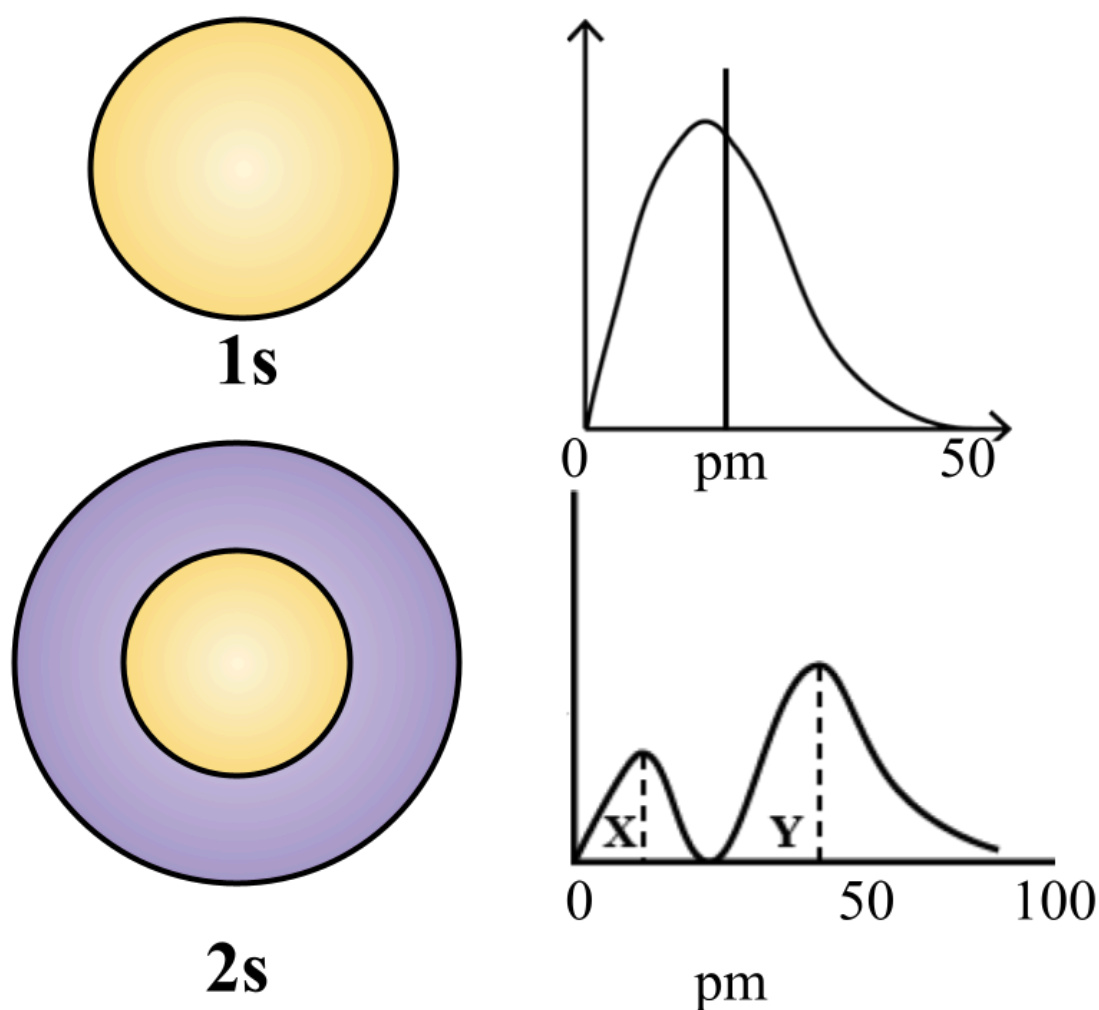
- (i) 1s and 2s orbitals are spherical in shape.
- (ii) The probability of finding the electron is maximum near the nucleus.

(iii) The probability of finding the electron at a given distance is equal in all directions.

(iv) The probability density of electrons for 2s orbital decreases uniformly as distance from the nucleus increases.

Solution

Ans: (iv) The probability density of electrons for 2s orbital decreases uniformly as distance from the nucleus increases.



As per the probability density curve, the probability of finding the electrons at the 1s orbital decreases as we move far from the nucleus, however in case of 2s the probability decreases initially then it increases with the distance and thereafter at a certain point it starts decreasing with the distance.

Question 4

Which of the following statements is not correct about the characteristics of cathode rays?

- (i) They start from the cathode and move towards the anode.
- (ii) They travel in a straight line in the absence of an external electrical or magnetic field.
- (iii) Characteristics of cathode rays do not depend upon the material of electrodes in the cathode ray tube.
- (iv) Characteristics of cathode rays depend upon the nature of gas present in the cathode ray tube.

Solution

Ans: (iv) Characteristics of cathode rays depend upon the nature of gas present in the cathode ray tube.

As per the result obtained from the cathode ray discharge tube experiment the characteristics of cathode rays (electrons) does not depend upon the material of electrodes and the nature of the gas present in the cathode ray tube. Which concludes that electrons are the basic constituent of all the atoms.

Question 5

Which of the following statements about the electron is incorrect?

- (i) It is a negatively charged particle.
- (ii) The mass of an electron is equal to the mass of a neutron.
- (iii) It is a basic constituent of all atoms.
- (iv) It is a constituent of cathode rays.

Solution

Ans: (ii) The mass of an electron is equal to the mass of a neutron.

The neutron is heavier than the electron as

Mass of the neutron = 1.67×10^{-27} kg

Mass of the electron = 9.11×10^{-31} kg

Question 6

Which of the following properties of an atom could be explained correctly by Thomson Model of atom?

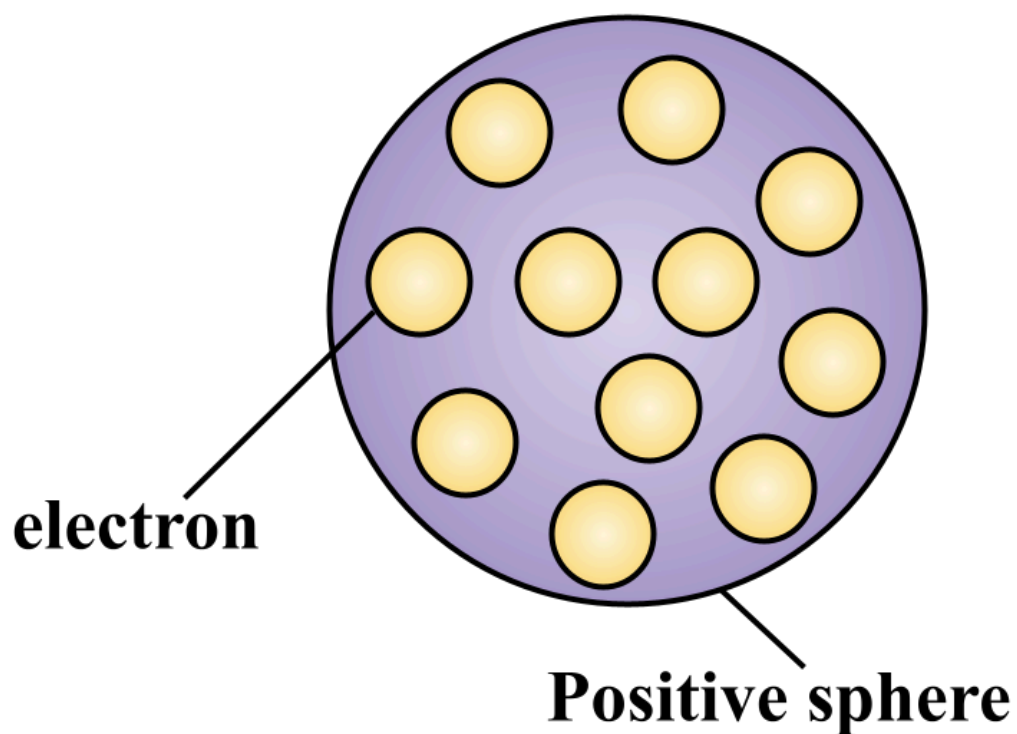
- (i) Overall neutrality of atom.
- (ii) Spectra of hydrogen atom.
- (iii) Position of electrons, protons and neutrons in atom.
- (iv) Stability of atom.

Solution

Ans: (i) Overall neutrality of atom.

According to the J.J Thomson model the positive charge is uniformly distributed and the electrons are embedded into it in such a manner as to give the most stable electrostatic arrangement just as watermelon of positive charge with plums or seeds (electrons) embedded into it. Thus this model is able to explain the overall neutrality of the atom.

Thomson model of atom



Question 7

Two atoms are said to be isobars if.

- (i) they have same atomic number but different mass number.
- (ii) they have same number of electrons but different number of neutrons.
- (iii) they have same number of neutrons but different number of electrons.
- (iv) sum of the number of protons and neutrons is same but the number of protons is different

Solution

Ans: (iv) sum of the number of protons and neutrons is same but the number of protons is different

Isobars are the atoms which have same mass number (sum of number of neutrons and protons) but different atomic number (i.e. different proton number)

For example, $^{64}_{14}\text{C}$ and $^{14}_7\text{N}$.

Question 8

The number of radial nodes for 3p orbital is _____.

- (i) 3
- (ii) 4
- (iii) 2
- (iv) 1

Solution

Ans: (iv) 1

The number of radial nodes is given by $n-l-1$

where n is principal quantum number, l is azimuthal quantum number

For 3p orbital, $n=3$ and $l=1$

Thus, the number of radial nodes $= n-l-1 = 3-1-1 = 1$

Question 9

Number of angular nodes for 4d orbital is _____.

- (i) 4
- (ii) 3
- (iii) 2
- (iv) 1

Solution

Ans: (iii) 2

The number of angular nodes is given by $n-l$

where n is principal quantum number, l is azimuthal quantum number

For 4d orbital, $n=4$ and $l=2$

Thus, the number of angular nodes $= n - l = 4 - 2 = 2$

Question 10

Which of the following is responsible to rule out the existence of definite paths or trajectories of electrons?

- (i) Pauli's exclusion principle.
- (ii) Heisenberg's uncertainty principle.
- (iii) Hund's rule of maximum multiplicity.
- (iv) Aufbau principle.

Solution

Ans: (ii) Heisenberg's uncertainty principle.

According to Heisenberg's uncertainty principle it is impossible to determine simultaneously the exact position and exact momentum (or velocity) of an electron. Thus it implies that determining the trajectory of an electron is impossible as it requires exact position and velocity which is not possible as per the uncertainty principle.

Question 11

Total number of orbitals associated with the third shell will be _____.

- (i) 2
- (ii) 4
- (iii) 9
- (iv) 3

Solution

Ans: (iii) 9

The total number of orbitals is given by n^2 , where n is the principal quantum number or the principal shell.

Thus for the third shell number of orbitals is 32 i.e. 9

Question 12

Orbital angular momentum depends on _____.

- (i) l
- (ii) n and l
- (iii) n and m
- (iv) m and s

Solution

Ans: (i) l

" l " which is known as Azimuthal quantum number or orbital angular momentum or subsidiary quantum number depicts the three dimensional shape of the orbital.

Question 13

Chlorine exists in two isotopic forms, Cl-37 and Cl-35 but its atomic mass is 35.5. This indicates the ratio of Cl-37 and Cl-35 is approximately

- (i) 1:2
- (ii) 1:1
- (iii) 1:3
- (iv) 3:1

Solution

Ans: (iii) 1:3

The chlorine is a mixture of two isotopes with atomic masses 37U and 35U and its atomic mass is 35.5U. The atomic mass depicts that % composition of Cl-35 is much higher than that of Cl-37 and they are present in the ratio 1:3.

Question 14

The pair of ions having the same electronic configuration is _____.

- (i) Cr^{3+} , Fe^{3+}
- (ii) Fe^{3+} , Mn^{2+}
- (iii) Fe^{3+} , Co^{3+}
- (iv) Sc^{3+} , Cr^{3+}

Solution

Ans: (ii) Fe^{3+} , Mn^{2+}

Fe^{3+} electronic configuration is $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^2$

Mn^{2+} electronic configuration is $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^2$

Question 15

For the electrons of oxygen atom, which of the following statements is correct?

- (i) Z_{eff} for an electron in a 2s orbital is the same as Z_{eff} for an electron in a 2p orbital.
- (ii) An electron in the 2s orbital has the same energy as an electron in the 2p orbital.
- (iii) Z_{eff} for an electron in 1s orbital is the same as Z_{eff} for an electron in a 2s orbital.
- (iv) The two electrons present in the 2s orbital have spin quantum numbers m_s but of opposite sign.

Solution

Ans: (iv) The two electrons present in the 2s orbital have spin quantum numbers m_s but of opposite sign.

According to Pauli's Exclusion Principle no two electrons should possess the same set of four quantum numbers. Thus the two electrons present in the 2s orbital have spin quantum numbers m_s but of opposite sign.

Question 16

If travelling at same speeds, which of the following matter waves have the shortest wavelength?

(i) Electron

(ii) Alpha particle (He^{2+})

(iii) Neutron

(iv) Proton

Solution

Ans: (ii) Alpha particle (He^{2+})

As the wavelength is inversely proportional to the mass of the particles thus the alpha particles would possess shortest wavelength among the above given option

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

Multiple Choice Questions (Type-II)

Question 17

Identify the pairs which are not of isotopes?

(i) $^{12}_6\text{X}$, $^{13}_6\text{Y}$

(ii) $^{35}_{17}\text{X}$, $^{37}_{17}\text{Y}$

(iii) ^{146}X , ^{147}Y

(iv) ^{84}X , ^{85}Y

Solution

Ans: (iii) & (iv)

The isotopes are defined as atoms with identical atomic numbers but different mass numbers are known as isotopes.

Question 18

Out of the following pairs of electrons, identify the pairs of electrons present in degenerate orbitals :

(i) (a) $n = 3, l = 2, m_l = -2, m_s = -1/2$

(b) $n = 3, l = 2, m_l = -1, m_s = -1/2$

(ii) (a) $n = 3, l = 1, m_l = 1, m_s = +1/2$

(b) $n = 3, l = 2, m_l = 1, m_s = +1/2$

(iii) (a) $n = 4, l = 1, m_l = 1, m_s = +1/2$

(b) $n = 3, l = 2, m_l = 1, m_s = +1/2$

(iv) (a) $n = 3, l = 2, m_l = +2, m_s = -1/2$

(b) $n = 3, l = 2, m_l = +2, m_s = +1/2$

Solution

Ans: (i)&(iv)

In a multielectron atomic system the energy of an electron depends not only on its principal quantum number (shell), but also on its azimuthal quantum number (subshell). Electrons having the same shells and same subshells have the same energy and they are known as degenerate orbitals.

Question 19

Which of the following sets of quantum numbers are correct?

	n	l	m _l
(i)	1	1	+2
(ii)	2	1	1
(iii)	3	2	-2
(iv)	3	4	-2

Solution

Ans: (ii) & (iii)

For the given value of n (principal quantum number) the value of l (Azimuthal quantum number) varies from 0 to n-1.

However for the given value of l the m_l(magnetic quantum number) varies from -l to +l

Question 20

In which of the following pairs, the ions are iso-electronic?

(i) Na⁺, Mg²⁺

(ii) Al³⁺, O⁻

(iii) Na⁺, O²⁻

(iv) N³⁻, Cl⁻

Solution

Ans: (i)&(iii)

Isoelectronic species are those species that possess the same number of electrons.

Here both Na⁺, Mg²⁺ possess 10 electrons and both Na⁺, O²⁻ possess 10 electrons.

Question 21

Which of the following statements concerning the quantum numbers are correct?

- (i) Angular quantum number determines the three dimensional shape of the orbital.
- (ii) The principal quantum number determines the orientation and energy of the orbital.
- (iii) Magnetic quantum number determines the size of the orbital.
- (iv) Spin quantum number of an electron determines the orientation of the spin of electron relative to the chosen axis.

Solution

Ans: (i)&(iv)

- a. Principal quantum number (n): It represents the size and energy of orbitals.
- b. Azimuthal quantum number (l): It represents the subshell and shape of orbitals.
- c. Magnetic quantum number (ml): It represents the orientation of the orbitals.
- d. Spin quantum number (ms): It represents the direction of spin of electrons in the orbitals.

Short Answer Questions

Question 22

Arrange s, p and d sub-shells of a shell in the increasing order of effective nuclear charge (Z_{eff}) experienced by the electron present in them.

Solution

Ans: The effective nuclear charge(Z_{eff}) is defined as the net positive charge experienced by the outermost electrons in the atom. With the increase of Azimuthal quantum number(l) the Z_{eff} experienced by the electron decreases .

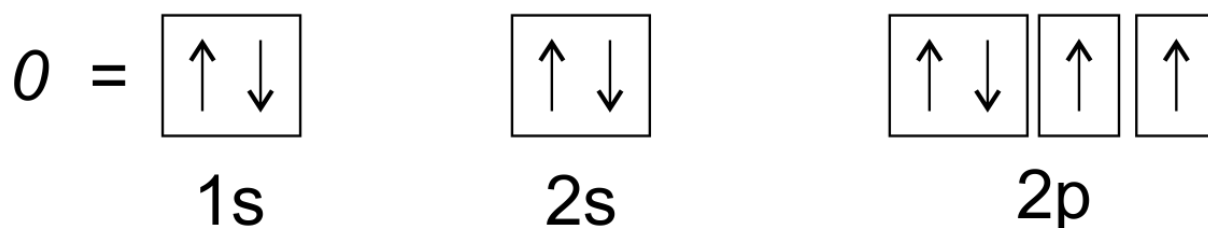
Hence the arrangement of subshells in the increasing order of Z_{eff} is: $d < p < s$

Question 23

Show the distribution of electrons in oxygen atoms (atomic number 8) using an orbital diagram.

Solution

Ans: The electronic configuration of oxygen atom is $1s^2 2s^2 2p^4$ and its orbital diagram is given by

**Question 24**

Nickel atom can lose two electrons to form Ni^{2+} ion. The atomic number of nickel is 28. From which orbital will nickel lose two electrons.

Solution

Ans: The electronic configuration of nickel is $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8 4s^2$, thus it loses electrons from its 4s orbital as its energy is higher compared to the other orbital.

Question 25

Which of the following orbitals are degenerate?

$3d_{xy}$, $4d_{xy}$, $3d_{z^2}$, $3d_{yz}$, $4d_{yz}$, $4d_{z^2}$

Solution

Ans: In a multielectron atomic system the energy of an electron depends not only on its principal quantum number (shell), but also on its azimuthal quantum number (subshell). Electrons having the same shells and same subshells have the same energy and they are known as degenerate orbitals.

Thus $3d_{xy}$, $3d_{z^2}$, $3d_{yz}$ and $4d_{xy}$, $4d_{yz}$, $4d_{z^2}$ are degenerate.

Question 26

Calculate the total number of angular nodes and radial nodes present in 3p orbital

Solution

Ans: The number of radial nodes is given by $n-l-1$, where n is principal quantum number, l is azimuthal quantum number.

The number of angular nodes is given by $n-l$, where n is principal quantum number, l is azimuthal quantum number.

Here $n=3$ and $l=1$

Thus, angular nodes = $3-1 = 2$ and radial node = $3-1-1 = 1$

Question 27

The arrangement of orbitals on the basis of energy is based upon their $(n+l)$ value. Lower the value of $(n+l)$, lower is the energy. For orbitals having same values of $(n+l)$, the orbital with lower value of n will have lower energy.

I. Based upon the above information, arrange the following orbitals in the increasing order of energy.

(a) 1s, 2s, 3s, 2p

(b) 4s, 3s, 3p, 4d

(c) 5p, 4d, 5d, 4f, 6s

(d) 5f, 6d, 7s, 7p

II. Based upon the above information, solve the questions given below :

(a) Which of the following orbitals has the lowest energy? 4d, 4f, 5s, 5p

(b) Which of the following orbitals has the highest energy? 5p, 5d, 5f, 6s, 6p

Solution

Ans:

Orbitals	s	p	d	f
l	0	1	2	3

(a)

orbitals	n	n+l
1s	1	1
2s	2	2
3s	3	3
2p	2	3

Thus the increasing order of energy is $1s < 2s < 2p < 3s$

(b)

orbitals	n	n+l
4s	4	4
3s	3	3
3p	3	4

4d	4	6
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Thus the increasing order of energy is $3s < 3p < 4s < 4d$

(c)

orbitals	n	n+l
5p	5	6
4d	4	6
5d	5	7
4f	4	7
6s	6	6

Thus the increasing order of energy is $4d < 5p < 6s < 4f < 5d$

(d)

orbitals	n	n+l
5f	5	8
6d	6	8
7s	7	7
7p	7	8

Thus the increasing order of energy is $7s < 5f < 6d < 7p$

II.

(a)

Orbitals	n	n+l
4d	4	6
4f	4	7
5s	5	5
5p	5	6

The lowest energy orbital is 5s

(b)

Orbitals	n	n+l
5p	5	6
5d	5	7
5f	5	8
6s	6	6
6p	6	7

The highest energy orbital is 5f

Question 28

Which of the following will not show deflection from the path on passing through an electric field?

Proton, cathode rays, electron, neutron

Solution

Ans: The charged particles get deflected by the electric field. As among the given option only neutron is the particle that is neutral thus it does not get deflected by the electric field.

Question 29

An atom having atomic mass number 13 has 7 neutrons. What is the atomic number of the atom?

Solution

Ans: The mass number (A) is defined as the sum of the number of protons and neutrons present in the nucleus and the atomic number is defined as the number of protons or electrons present in an atom.

Thus $A=13$, the number of neutrons is 7 so the number of protons is 6.

Thus the atomic number is 6.

Question 30

Wavelengths of different radiations are given below :

$$\lambda(A) = 300 \text{ nm} \quad \lambda(B) = 300 \mu\text{m} \quad \lambda(C) = 3 \text{ nm} \quad \lambda(D) = 30 \text{ \AA}$$

Arrange these radiations in the increasing order of their energies.

Solution

Ans:

1nm	10^{-9}m
$1\mu\text{m}$	10^{-6}m
1A0	10^{-10}m

We know that energy is inversely proportional to the wavelength.

300 nm	$3 \times 10^{-7}\text{m}$
$300\mu\text{m}$	$3 \times 10^{-4}\text{m}$

3 nm	$3 \times 10^{-9} \text{m}$
30 Å	$3 \times 10^{-9} \text{m}$

Thus the increasing order of energy is $B < A < C = D$

Question 31

The electronic configuration of valence shell of Cu is $3d^{10}4s^1$ and not $3d^94s^2$. How is this configuration explained?

Solution

Ans: As per the Hund's rule the half filled and fully filled orbital leads to the extra stability due to the symmetry thus fully filled 3d and half filled 4s is preferred.

Question 32

The Balmer series in the hydrogen spectrum corresponds to the transition from $n = 2$ to $n = 3, 4, \dots$. This series lies in the visible region. Calculate the wave number of line associated with the transition in Balmer series when the electron moves to $n = 4$ orbit. ($R_H = 109677 \text{ cm}^{-1}$)

Solution

Ans: We have

$$\bar{\nu}$$

$$= 109677 [1/n_i^2 - 1/n_f^2] \text{ cm}^{-1}$$

Given, $n_i = 2$, $n_f = 4$

$$\bar{\nu}$$

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

Question 33

According to de Broglie, matter should exhibit dual behaviour, that is both particle and wave like properties. However, a cricket ball of mass 100 g does not move like a wave when it is thrown by a bowler at a speed of 100 km/h. Calculate the wavelength of the ball and explain why it does not show wave nature.

Solution

Ans: As per de Broglie, every object in motion has a wave character i.e. every object/matter have dual nature both particle and wave nature. But the wavelengths associated with ordinary objects are so short (because of their large masses) that their wave properties cannot be detected.

Given, m (mass) = 100g, v = 100km/hr

We have

$$\lambda = h/mv = 238.5 \times 10^{-34} \text{ m}$$

As the wavelength associated with the cricket ball is so small that it can't be detected.

Question 34

What is the experimental evidence in support of the idea that electronic energies in an atom are quantized?

Solution

Ans: The line spectrum associated with any element possesses lines corresponding to specific wavelengths and these lines are obtained as a result of electronic transitions between the energy levels. Hence, the electrons in these levels have fixed energy i.e., quantized values.

Question 35

Out of electron and proton which one will have, a higher velocity to produce matter waves of the same wavelength? Explain it.

Solution

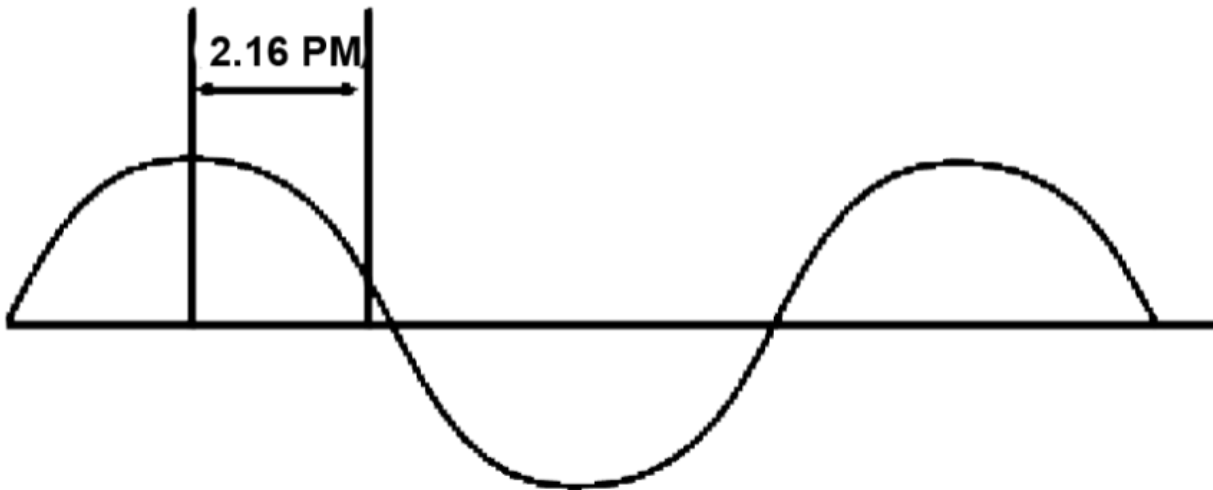
Ans: We have

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

Thus the equation signifies that in order to have the same wavelength the electron should have higher velocity as the mass of the proton is higher than that of the electron.

Question 36

A hypothetical electromagnetic wave is shown in Fig. 2.2. Find out the wavelength of the radiation.



Solution

Ans: The wavelength is defined as the distance between two consecutive crests or troughs of a wave and it is denoted by

$$\lambda$$

.

$$\lambda$$

$$= 4 \times 2.16 \text{ pm} = 8.64 \text{ pm}$$

Question 37

Chlorophyll present in green leaves of plants absorbs light at 4.620×10^{14} Hz. Calculate the wavelength of radiation in nanometers. Which part of the electromagnetic spectrum does it belong to?

Solution

Ans:

We know that

$$\lambda = c/\nu$$

Given, $\nu = 4.620 \times 10^{14}$ Hz

Thus, $\lambda = c/\nu = (3.0 \times 10^8 \text{ m/s}) / (4.620 \times 10^{14} \text{ Hz}) = 649.4 \text{ nm}$

This frequency falls under visible range.

Question 38

What is the difference between the terms orbit and orbital?

Solution

Ans:

Orbit	Orbital
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It is an well defined circular path around the nucleus in which electrons revolve	It is an three dimensional space around the nucleus around which the probability of find the electron is maximum
It represent planar motion of electron around the nucleus	It is the three dimensional motion around the nucleus
It have circular or disc like shape	Different orbitals have different shapes such as s-orbital spherical shapes.

Question 39

Table-tennis ball has a mass 10 g and a speed of 90 m/s. If speed can be measured within an accuracy of 4% what will be the uncertainty in speed and position?

Solution

Ans: Given, m (mass) = 10g, v(speed) = 90 m/s and accuracy = 4%

$$\text{Uncertainty in speed} = \frac{90 \times 4}{100} = 3.6 \text{ ms}^{-1}$$

$$\begin{aligned} \text{Uncertainty in position} &= \frac{h}{4\pi m \Delta v} = \frac{6.626 \times 10^{-34}}{4 \times 3.14 \times 10 \times 3.6} \\ &= 1.36 \times 10^{-33} \text{m} \end{aligned}$$

Question 40

The effect of uncertainty principle is significant only for motion of microscopic particles and is negligible for the macroscopic particles. Justify the statement with the help of a suitable example.

Solution

Ans: The uncertainty principle is significantly only for the microscopic particles and not for the macroscopic particles can be concluded by considering the following example.

Let us consider a particle or an object of mass 1 milligram i.e. 10^{-6} kg

Then its uncertainty can be calculated as,

$$\Delta x \cdot \Delta \nu = 6.626 \times 10^{-34} / 4\pi \times 3.14 \times 10^{-6}$$

$$= 10^{-28} \text{ m}^2 \text{ s}^{-1}$$

Thus the value obtained is negligible and insignificant for the uncertainty principle to be applied to this particle.

Question 41

Hydrogen atom has only one electron, so mutual repulsion between electrons is absent. However, in multielectron atoms mutual repulsion between the electrons is significant. How does this affect the energy of an electron in the orbitals of the same principal quantum number in multielectron atoms?

Solution

Ans: The energy of electrons is determined by the value of n in the hydrogen atom and by $n + l$ in the multielectron atom. Thus for a given principal quantum number the electrons of different orbitals would have different energy.

Matching Type

Question 42

Match the following species with their corresponding ground state electronic configuration. Atom / Ion
Electronic configuration

- | | |
|------------------------|---|
| (i) Cu | (a) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$ |
| (ii) Cu^{2+} | (b) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2$ |
| (iii) Zn^{2+} | (c) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^1$ |
| (iv) Cr^{3+} | (d) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^9$ |
| | (e) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3$ |

Solution

Ans:

(i) Cu	(c) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^1$
(ii) Cu^{2+}	(d) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^9$
(iii) Zn^{2+}	(a) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$
(iv) Cr^{3+}	(e) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3$

Question 43

Match the quantum numbers with the information provided by these. Quantum number Information provided

- | | |
|-------------------------------|--------------------------------|
| (i) Principal quantum number | (a) orientation of the orbital |
| (ii) Azimuthal quantum number | (b) energy and size of orbital |
| (iii) Magnetic quantum number | (c) spin of electron |
| (iv) Spin quantum number | (d) shape of the orbital |

Solution

Ans:

(i) Principal quantum number	(b) energy and size of orbital
(ii) Azimuthal quantum number	(d) shape of the orbital
(iii) Magnetic quantum number	(a) orientation of the orbital
(iv) Spin quantum number	(c) spin of electron

Question 44

Match the following rules with their statements :

Rules	Statements
(i) Hund's Rule	(a) No two electrons in an atom can have the same set of four quantum numbers.
(ii) Aufbau Principle	(b) Half-filled and completely filled orbitals have extra stability.
(iii) Pauli Exclusion Principle	(c) Pairing of electrons in the orbitals belonging to the same subshell does not take place until each orbital is singly occupied.
(iv) Heisenberg's Uncertainty Principle	(d) It is impossible to determine the exact position and exact momentum of a subatomic particle simultaneously
	(e) In the ground state of atoms, orbitals are filled in the order of their increasing energies.

Solution

Ans:

(i) Hund's Rule	(c) Pairing of electrons in the orbitals belonging to the same subshell does not take place until each orbital is singly occupied.
(ii) Aufbau Principle	(e) In the ground state of atoms, orbitals are filled in the order of their increasing energies.
(iii) Pauli Exclusion Principle	(a) No two electrons in an atom can have the same set of four quantum numbers.
(iv) Heisenberg's Uncertainty Principle	(d) It is impossible to determine the exact position and exact momentum of a subatomic particle simultaneously

Question 45

Match the following

i) X-rays	(a) $\nu = 100\text{-}104\text{ Hz}$
ii) UV	(b) $\nu = 10^{10}\text{ Hz}$
iii) Long radio waves	(c) $\nu = 10^{16}\text{Hz}$
iv) Microwave	(d) $\nu = 10^{18}\text{Hz}$

Solution

Ans:

i) X-rays	(d) $\nu = 10^{18}\text{Hz}$
ii) UV	(c) $\nu = 10^{16}\text{Hz}$
iii) Long radio waves	(a) $\nu = 100\text{-}104\text{ Hz}$
iv) Microwave	(b) $\nu = 10^{10}\text{ Hz}$

Question 46

Match the following

(i) Photon	(a) Value is 4 for N shell
(ii) Electron	(b) Probability density
(iii) ψ^2	(c) Always positive value
(iv) Principal quantum number n	(d) Exhibits both momentum and wavelength

Solution

Ans:

(i) Photon	(d) Exhibits both momentum and wavelength
(ii) Electron	(d) Exhibits both momentum and wavelength
(iii) ψ^2	(b) Probability density (c) Always positive value
(iv) Principal quantum number n	(a) Value is 4 for N shell (c) Always positive value

Question 47

Match species given in Column I with the electronic configuration given in Column II

Column I	Column II
(i) Cr	(a) $[\text{Ar}]3d^84s^0$
(ii) Fe^{2+}	(b) $[\text{Ar}]3d^{10}4s^1$
(iii) Ni^{2+}	(c) $[\text{Ar}]3d^64s^0$
(iv) Cu	(d) $[\text{Ar}] 3d^54s^1$
	(e) $[\text{Ar}]3d^64s^2$

Solution

Ans:

(i) Cr	(d) $[\text{Ar}] 3d^54s^1$
(ii) Fe^{2+}	(c) $[\text{Ar}]3d^64s^0$

(iii) Ni^{2+}	(a) $[\text{Ar}]3d^8 4s^0$
(iv) Cu	(b) $[\text{Ar}]3d^{10} 4s^1$

Assertion and Reason Type

Question 48

Assertion (A) : All isotopes of a given element show the same type of chemical behaviour.

Reason (R) : The chemical properties of an atom are controlled by the number of electrons in the atom.

- (i) Both A and R are true and R is the correct explanation of A.
- (ii) Both A and R are true but R is not the correct explanation of A.
- (iii) A is true but R is false.
- (iv) Both A and R are false.

Solution

Ans: (i)

As the chemical properties depend upon the number of electrons present in the atom thus the isotopes resemble the same chemical properties as they have the same number of electrons i.e. atomic number.

Question 49

Assertion (A) : Black body is an ideal body that emits and absorbs radiations of all frequencies.

Reason (R) : The frequency of radiation emitted by a body goes from a lower frequency to higher frequency with an increase in temperature.

- (i) Both A and R are true and R is the correct explanation of A.
- (ii) Both A and R are true but R is not the explanation of A.
- (iii) A is true and R is false.
- (iv) Both A and R are false.

Solution

Ans: (ii)

The black body is the ideal body that absorbs and emits radiation of all frequencies. The radiation that it emits is said to be black body radiation.

With an increase of temperature the frequency of the black body radiation increases.

Question 50

Assertion (A) : It is impossible to determine the exact position and exact momentum of an electron simultaneously.

Reason (R) : The path of an electron in an atom is clearly defined.

(i) Both A and R are true and R is the correct explanation of A.

(ii) Both A and R are true and R is not the correct explanation of A.

(iii) A is true and R is false.

(iv) Both A and R are false.

Solution

Ans: (iii)

According to Heisenberg's uncertainty principle it is impossible to determine simultaneously the exact position and exact momentum (or velocity) of an electron. Thus it implies that determining the trajectory of an electron is impossible as it requires exact position and velocity which is not possible as per the uncertainty principle.

Long Answer Questions

Question 51

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

Solution

Ans: When the beam of light gets exposed to the metal surface then the electrons get emitted from the metal. This effect is said to be photoelectric effect and the emitted electrons are said to be photoelectrons.

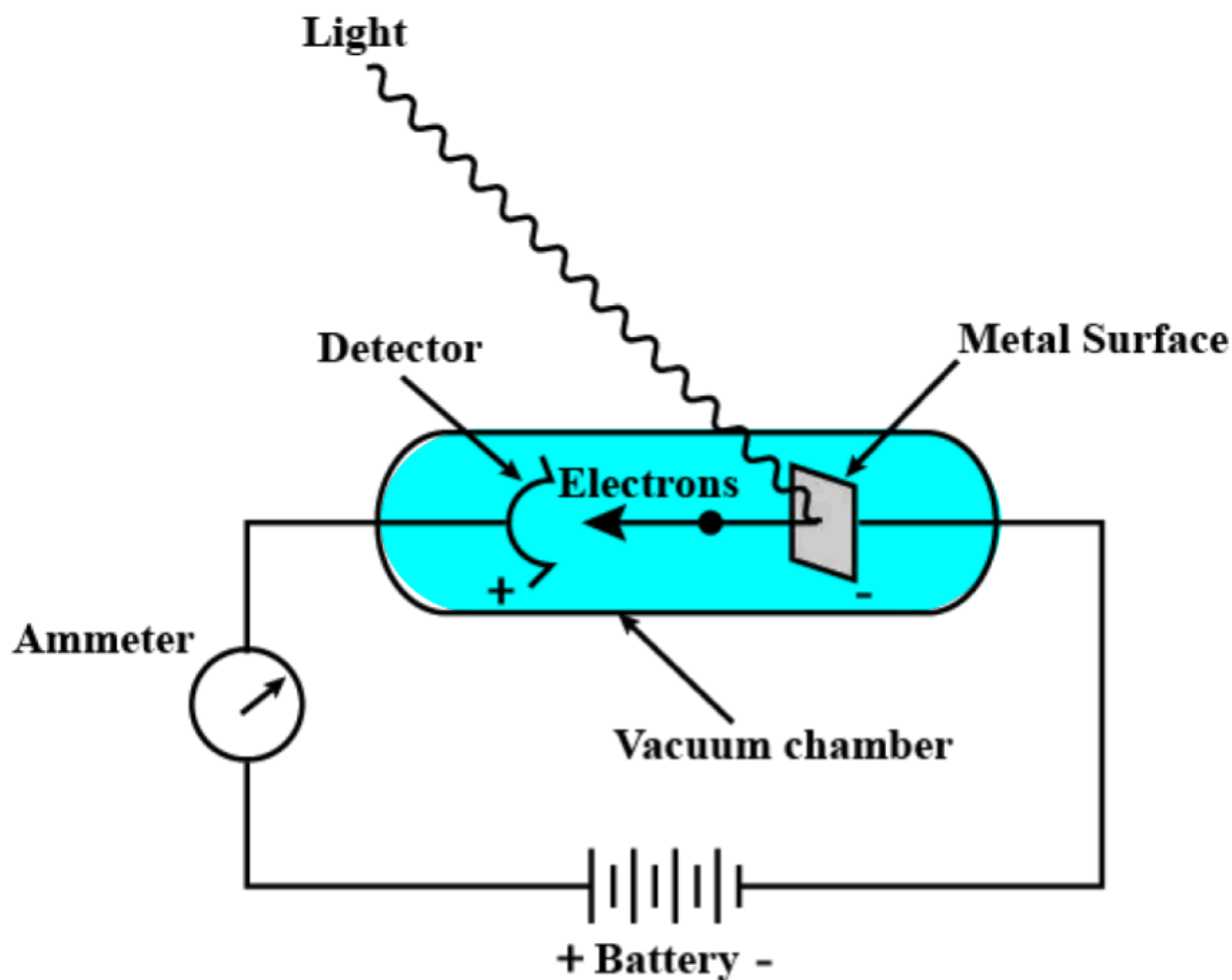
The result of photoelectric experiment are as follows:-

(i) There is no time gap between the striking of a light beam and the ejection of electrons from the metal surface i.e. electrons emit as soon as a beam of light strikes the metal surface.

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

(iii) For every metal there is minimum emitting frequency which is said to be threshold frequency, ν_0 . The kinetic energies of these electrons is directly proportional to the frequency of the light used.

As per the quantum theory of electromagnetic radiation when a photon with energy greater than the threshold energy of the metal strikes the metal then the electrons get emitted from the metal without any delay and its kinetic energy depends upon the frequency of the light .



Question 52

Threshold frequency, ν_0 is the minimum frequency which a photon must possess to eject an electron from a metal. It is different for different metals. When a photon of frequency $1.0 \times 10^{15} \text{ s}^{-1}$ was allowed to hit a metal surface, an electron having $1.988 \times 10^{-19} \text{ J}$ of kinetic energy was emitted. Calculate the threshold frequency of this metal. Show that an electron will not be emitted if a photon with a wavelength equal to 600 nm hits the metal surface.

Solution

Ans: For the emission of electrons from metal the frequency of the striking light should be higher than that of its threshold frequency.

We have

$$h\nu = h\nu_0 + \text{K.E}$$

$$\nu_0 = \nu - \text{K.E}/h \dots\dots(1)$$

Given

$$\nu = 1015 \text{ s}^{-1}, \text{ K.E} = 1.988 \times 10^{-19} \text{ J}$$

Thus (1) gives

$$\nu_0 = 7 \times 10^{14} \text{ s}^{-1}$$

Given

$$\lambda = 600 \text{ nm}$$

$$\nu = c/\lambda = 5 \times 10^{14} \text{ s}^{-1}$$

As $\nu_0 > \nu$, thus the electrons do not emit.

Question 53

When an electric discharge is passed through hydrogen gas, the hydrogen molecules dissociate to produce excited hydrogen atoms. These excited atoms emit electromagnetic radiation of discrete frequencies which can be given by the general formula

$$\bar{\nu} = 109677 [1/n_i^2 - 1/n_f^2]$$

What points of Bohr's model of an atom can be used to arrive at this formula? Based on these points derive the above formula giving description of each step and each term.

Solution

Ans: The points of the Bohr's model that can be consider are as follows:-

- (i) Electrons revolve around the nucleus in a fixed orbit with fixed energy
- (ii) The energy is absorbed or released when the electron moves from one energy level to another.

The energy for the nth stationary state is given by

$$E_n = -2\pi^2 m e^4 / n^2 h^2$$

Where

m = mass of the electron

e = charge of the electron

h = Planck's constant

If an electron jumps from n_i to n_f then we have

$$\Delta E = E_f - E_i = 2\pi^2me^4/h^2 [(1/n_i^2) - (1/n_f^2)]$$

$$\bar{\nu} = \Delta E/hc = 109677 [(1/n_i^2) - (1/n_f^2)]$$

Question 54

Calculate the energy and frequency of the radiation emitted when an electron jumps from $n = 3$ to $n = 2$ in a hydrogen atom.

Solution

Ans: We have

$$\bar{\nu} = 109766 [1/n_i^2 - 1/n_f^2]$$

Given, $n_i = 3$ and $n_f = 2$

$$\Delta E = hc\bar{\nu} = 109677 [1/n_i^2 - 1/n_f^2]$$

$$\Delta E = -3.052 \times 10^{-19} \text{ J}$$

$$\nu = \Delta E/h = 4.606 \times 10^{16} \text{ Hz}$$

Question 55

Why was a change in the Bohr Model of atom required? Due to which important development (s), concept of movement of an electron in an orbit was replaced by, the concept of probability of finding electron in an orbital? What is the name given to the changed model of atom?

Solution

Ans: The drawbacks of Bohr's model were (i) it was unable to explain the spectra for multi-electron systems (ii) it could not explain the molecule formation through chemical bonds.

The two important developments that contributed significantly towards the change of concept of movement of an electron in an orbit was replaced by, the concept of probability of finding an electron in an orbital were (i) Dual nature of matter (ii) Uncertainty Principle.

Quantum mechanical model of the atom is the name of the new model.

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