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CHEMISTRY – MCQ BOOKLET

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1. Atomic Structure

Atomic Orbitals (Shapes and energies of s, p, d, f orbitals, nodal surfaces)

1. Which one of the following is the shape of BrF_5?

A. Octahedral
B. Square planar
C. Square pyramidal
D. Trigonal bipyramidal

Ans: C

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To determine the shape of a molecule, VSEPR theory is used. Bromine (Br) is the central atom in BrF_5, having 7 valence electrons. Five Fluorine (F) atoms are bonded to Br, each forming a single bond. This accounts for 5 valence electrons from Br being used in bonding, forming 5 bond pairs. The remaining 7 - 5 = 2 valence electrons form one lone pair on the central Br atom.

2. The number of angular and radial nodes for 4d orbital is respectively

A. 2 and 1
B. 1 and 2
C. 3 and 1
D. 4 and 0

Ans: A

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For an atomic orbital described by the principal quantum number n and azimuthal (angular momentum) quantum number l: - The number of angular nodes is equal to l. - The total number of nodes is equal to n - 1. - The number of radial nodes is the total number of nodes minus the number of angular nodes, i.e., (n - 1) - l. For a 4d orbital: - Principal quantum number n = 4. - For a d orbital, the azimuthal quantum number l = 2 (s=0, p=1, d=2, f=3). - Number of angular nodes = l = 2. - Number of radial nodes = (n - 1) - l = (4 - 1) - 2 = 3 - 2 = 1. The question asks for the number of angular and radial nodes respectively.

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3. What is the order of increasing energy of the orbitals within a single energy level?

A. d < s < f < p
B. s < p < d < f
C. p < s < f < d
D. f < d < p < s

Ans: B

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Within the same principal energy level (n), the energy of subshells increases with the azimuthal quantum number (l): s (l=0)

4. The shape of I_3^- is - - (5) Question not attempted

A. Triangular planar
B. Seesaw
C. Bent
D. Linear

Ans: D

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The shape of the I$_3^-$ ion is determined by its VSEPR theory configuration.

5. The total number of nodal planes in dxy orbital is - - Question not attempted

A. 4
B. 2
C. 1
D. 3

Ans: B

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The number of nodal planes in an atomic orbital is equal to the value of the azimuthal quantum number, l. For d orbitals, $l=2$. The d_{xy} orbital has nodal planes in the xz and yz planes.

6. Which of the following elements have half-filled f-orbitals in their ground state? (Given: atomic number, Sm = 62, Eu = 63, Tb = 65, Gd = 64, Pm = 61) - (A) Sm - (B) Eu - (C) Tb - (D) Gd - (E) Pm Choose the correct answer from the options given below - - (5) Question not attempted

A. C and D only
B. A and E only
C. A and B only
D. B and D only

Ans: D

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The stability of an electronic configuration increases significantly when subshells are completely filled or half-filled. For f-orbitals, a half-filled configuration means having 7 electrons (f^7). - Europium (Eu, Z=63) has the electronic configuration $ [Xe] 4f^7 6s^2 $. Its $4f$ subshell is half-filled. - Gadolinium (Gd, Z=64) has the electronic configuration $ [Xe] 4f^7 5d^1 6s^2 $. Its $4f$ subshell is half-filled. The other elements given do not have half-filled f-orbitals in their ground state: - Samarium (Sm, Z=62): $ [Xe] 4f^6 6s^2 $ - Terbium (Tb, Z=65): $ [Xe] 4f^8 5d^1 6s^2 $ - Promethium (Pm, Z=61): $ [Xe] 4f^5 6s^2 $ Thus, Eu and Gd are the elements with half-filled f-orbitals.

7. The number of significant figures in 6.02×10^{23} is

A. 26
B. 4
C. 23
D. 3

Ans: D

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Rules for significant figures: 1. Non-zero digits are always significant. 2. Any zeros between two significant digits are significant. 3. Leading zeros (zeros to the left of the first non-zero digit) are not significant. 4. Trailing zeros (zeros to the right of the last non-zero digit) are significant if the number contains a decimal point. In scientific notation, all

digits in the mantissa (the part before the exponent) are considered significant.

8. A pi-bond is formed by the overlap of

A. s and s orbital
B. s and p orbital
C. p and p orbital
D. d and d orbital

Ans: C

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Sigma (σ) bonds are formed by head-on overlap of orbitals (s-s, s-p, p-p, d-d). Pi (π) bonds are formed by sideways overlap of orbitals, most commonly p-orbitals.

Atomic Spectra (Origin, Types, Fine Structure - brief)

9. Which transitions are studied by UV spectrometer?

A. Rotational
B. Electronic
C. Nuclear
D. Vibrational

Ans: B

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UV-Vis (Ultraviolet-Visible) spectroscopy involves the absorption of electromagnetic radiation in the UV and visible regions, which causes transitions between different electronic energy levels within molecules.

Electronic Configuration Principles (Aufbau Principle, Pauli's Exclusion Principle, Hund's Rule)

10. For an element with atomic number 35, which one of the following will be the correct number of electrons in its valence shell based on Bohr's model of an atom?

A. 1
B. 3
C. 5
D. 7

Ans: D

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- Bohr's model describes electrons orbiting the nucleus in specific energy levels or shells (K, L, M, N, etc.). - The maximum number of electrons a shell can hold is generally given by $2n^2$, where n is the shell number (n=1 for K, n=2 for L, etc.). - For atomic number 35 (Bromine), we fill the shells sequentially: - K shell (n=1): 2 electrons (capacity 2) - L shell (n=2): 8 electrons (capacity 8) - M shell (n=3): 18 electrons (capacity 18) - N shell (n=4): The remaining electrons: 35 - (2 + 8 + 18) = 35 - 28 = 7 electrons. - The outermost shell is the valence shell, which is the N shell in this case. - The number of electrons in the valence shell is 7.

11. Which one of the following statements is correct ?

A. Covalent bonds are directional
B. Ionic bonds are directional
C. Both covalent and ionic bonds are directional
D. Both covalent and ionic bonds are non-directional

Ans: A

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Covalent bonds involve the sharing of electrons between specific atoms, leading to electron density concentrated in defined regions (orbitals) oriented in space. This directional nature of covalent bonds determines the geometry and shape of molecules, including bond angles and lengths.

12. The number of maximum electrons in N Shell is

A. 2
B. 8
C. 18
D. 32

Ans: D

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- Electron shells are designated by principal quantum numbers (n), starting from n=1 for the innermost shell (K shell). - The formula for the maximum number of electrons that can occupy a shell with principal quantum number 'n' is $2n^2$. - For the N shell, n=4.

13. What is the maximum number of electrons in the M-Shell ?

A. 6
B. 8
C. 18
D. 32

Ans: C

UPSC NDA-2-2021

The formula for the maximum number of electrons in a shell with principal quantum number 'n' is $2n^2$. K-shell (n=1): $2 \times 1^2 = 2$ electrons. L-shell (n=2): $2 \times 2^2 = 8$ electrons. M-shell (n=3): $2 \times 3^2 = 18$ electrons. N-shell (n=4): $2 \times 4^2 = 32$ electrons.

14. What is the maximum number of electrons that can occupy the first shell of an atom ?

A. 2
B. 4
C. 8
D. 16

Ans: A

UPSC NDA-2-2024

- Electron shells (also called energy levels) surround the nucleus of an atom. They are denoted by the principal quantum number, n (n=1, 2, 3, ...), where n=1 is the shell closest to the nucleus. - The maximum number of electrons that can occupy a given shell is determined by the formula $2n^2$, where n is the shell number. - For the first shell (n=1), the maximum number of electrons is $2 (1)^2 = 2 1 = 2$. - For the second shell (n=2), the maximum number of electrons is $2 (2)^2 = 2 4 = 8$. - For the third shell (n=3), the maximum number of electrons is $2 (3)^2 = 2 9 = 18$, and so on.

15. How many atoms are there in one mole atom of an element?

A. 5.015×10^{15}
B. 6.022×10^{23}
C. 4.397×10^{26}
D. 6.589×10^{20}

Ans: B

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A mole is a unit of amount of substance. One mole contains Avogadro's number of particles. Avogadro's number ≈ 6.022×10^{23}.

16. Law of definite proportion is obeyed in

A. Stoichiometry
B. electrometry
C. photometry
D. spectrometer

Ans: A

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The Law of Definite Proportions, also known as Proust's Law, states that a pure chemical compound always contains the same elements in the same proportion by mass. This fundamental principle forms the basis of stoichiometric calculations.

17. Which structure has delocalized π electrons?

A. O$_3$
B. Co
C. HCN
D. CO$_2$

Ans: A

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Ozone (O$_3$) has a bent molecular structure and exhibits resonance. The π electron density is not confined to one specific oxygen-oxygen bond but is spread over all three oxygen atoms through resonance structures. This delocalization of π electrons enhances the stability of the molecule.

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18. Which of the following does not have coordinate bond?

A. SO$_2$
B. HNO$_2$
C. HNO$_3$
D. H$_2$SO$_4$

Ans: B

WBCS_Main-Paper-4-2019

- SO$_2$: Typically represented with resonance structures involving formal charges or dative bonding character. - HNO$_2$ (Nitrous acid): H-O-N=O. The standard Lewis structure minimizes formal charges to zero for all atoms and is drawn using only single and double covalent bonds without requiring a coordinate bond. - HNO$_3$ (Nitric acid): H-O-N(=O)O with resonance. Commonly represented with a coordinate bond N->O to account for formal charges (+1 on N, -1 on one O). - H$_2$SO$_4$ (Sulfuric acid): (H-O)$_2$S(=O)$_2$. A standard representation uses an expanded octet for sulfur and results in zero formal charges without requiring coordinate bonds. However, representations using coordinate bonds (S->O) are also possible. Among the given options, HNO$_2$ is the molecule that is consistently represented without coordinate bonds in its standard Lewis structure, which adheres to the octet rule and results in zero formal charges.

19. In NO_3^- ion, the number of bond pairs and lone pairs of electrons on Nitrogen atom are, respectively – (1) 1, 3 (2) 2, 2 (3) 3, 1 (4) 4, 0 (5) Question not attempted

A. 1, 3
B. 2, 2
C. 3, 1
D. 4, 0

Ans: C

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The number of bond pairs and lone pairs around a central atom in an ion or molecule is determined by drawing its Lewis structure and applying VSEPR theory. For NO$_3^-$, standard analysis leads to 3 bond pairs and 0 lone pairs on the central nitrogen atom, consistent with sp^2 hybridization and trigonal planar geometry. However, if option (C) is considered correct, it suggests an interpretation where Nitrogen forms 3 sigma bonds and has 1 lone pair, accounting for its 5 valence electrons.

20. The number of elements in 5th period of the periodic table will be - (1) 32 (2) 8 (3) 10 (4) 18 (5) Question not attempted

A. 32
B. 8
C. 10
D. 18

Ans: D

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The number of elements in a period is determined by the number of electrons that can be accommodated in the outermost s and p subshells, and for periods 4 and beyond, the d and f subshells as well.

21. The chemical behavior of an atom is mostly determined by its

A. Mass number
B. Valence electrons
C. Atomic weight
D. Neutron count

Ans: B

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Valence electrons are the key to an atom's reactivity. Atoms tend to gain, lose, or share valence electrons to achieve a stable electron configuration, usually resembling that of noble gases.

Electronic Configurations of Multi-electron Atoms and Ions

22. The chemical properties of an element depend upon

A. the number of isotopes of the element
B. the mass number of the element
C. the total number of neutrons in the element
D. the number of electrons in the outermost shell of the element