ASSIGNMENT

CHEM-2201

CHEMISTRY

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5. (a) Give the defects of Rutherford's model of atom. What suggestions were given by Bohr to remove these defects?

Answer:

Defects of Rutherford's Model of Atom:

1. **Instability of Atom:** According to classical electromagnetic theory, an accelerating electron should continuously emit energy in the form of radiation. As a result, the electron should spiral into the nucleus, causing the atom to collapse. But atoms are stable in nature, which the model couldn't explain.
2. **Continuous Spectrum Prediction:** Rutherford's model suggested that the electron could have any energy while orbiting the nucleus. This would imply that atoms should emit a continuous spectrum of light, but in reality, atoms like hydrogen show *line spectra* (specific lines at certain wavelengths).
3. **No Explanation for Atomic Size:** Rutherford's model could not explain why atoms have definite sizes, even though the electron could theoretically orbit at any distance from the nucleus.

Bohr's Suggestions to Remove These Defects:

1. **Quantized Orbits:** Bohr proposed that electrons move in fixed circular orbits around the nucleus without radiating energy. These orbits are called "stationary orbits" or "energy levels."
2. **Energy Quantization:** An electron can only gain or lose energy by jumping from one allowed orbit to another. The energy absorbed or emitted corresponds to the difference between the energy levels.
3. **Fixed Angular Momentum:** Bohr suggested that the angular momentum of the electron in an orbit is quantized and is an integral multiple of $h/2\pi$ (where h is Planck's constant).
4. **Explanation of Line Spectrum:** Using the idea of quantized energy levels, Bohr successfully explained the line spectra of the hydrogen atom — each spectral line corresponds to a transition between two specific energy levels.

5. (b) *What do you understand by the term, "Quantum number"? How many quantum numbers has an electron in an orbital? Explain the significance of each quantum number.*

Answer:

Quantum Number:

The **quantum numbers** are a set of numerical values that describe the unique quantum state of an electron in an atom. They provide information about the electron's energy, shape, orientation, and spin within an atom.

In simple terms, **quantum numbers tell us where an electron is likely to be found and how it behaves inside an atom**.

How many quantum numbers does an electron have?

An electron in an orbital is described by **four quantum numbers**:

1. **Principal Quantum Number (n)**
2. **Azimuthal (or Angular Momentum) Quantum Number (l)**
3. **Magnetic Quantum Number (m)**
4. **Spin Quantum Number (s)**

Significance of Each Quantum Number:

1. **Principal Quantum Number (n):**
    - It represents the **main energy level** or **shell** of the electron.
    - It determines the **size** and **energy** of the orbital.
    - Possible values: $n=1,2,3,4,\ldots$
    - Higher n means the electron is farther from the nucleus and has higher energy.
2. **Azimuthal Quantum Number (l):**
    - It represents the **shape** of the orbital (also called a **subshell**).
    - Values of l range from 0 to $(n-1)$.
    - Each value of lll corresponds to a type of orbital:
        - $l=0 \rightarrow$ **s-orbital** (spherical shape)
        - $l=1 \rightarrow$ **p-orbital** (dumbbell shape)
        - $l=2 \rightarrow$ **d-orbital** (cloverleaf shape)
        - $l=3 \rightarrow$ **f-orbital** (complex shape)
3. **Magnetic Quantum Number (m):**
    - It represents the **orientation** of the orbital in space.
    - Values of m range from $-l$ to $+l$(including zero).
    - Example: If $l=1$ (p-orbital), m can be $-1,0,+1$ indicating the three different orientations of p-orbitals.
4. **Spin Quantum Number (s):**
    - It represents the **spin direction** of the electron.
    - An electron can spin either **clockwise** or **counterclockwise**.
    - Values of msm_sms are +1/2 or -1/2.

Summary Table:

Quantum Number	Symbol	Describes	Values
Principal	n	Energy level (shell)	1, 2, 3, 4, ...
Azimuthal	l	Shape of orbital (subshell)	0 to (n-1)
Magnetic	m	Orientation of orbital	−l to +l
Spin	s	Direction of electron spin	+1/2, -1/2

6. (a) *Compare the properties of ionic and covalent compounds. Give two examples of each type of compounds*

Comparison between Ionic and Covalent Compounds

Property	Ionic Compounds	Covalent Compounds
Bond Formation	Formed by **transfer of electrons** from one atom to another (usually between a metal and a non-metal).	Formed by **sharing of electrons** between two non-metal atoms.
Nature of Bond	Strong electrostatic forces between oppositely charged ions.	Strong bonds due to shared electron pairs.
Physical State	Generally solid at room temperature (often crystalline).	Can be solid, liquid, or gas at room temperature.
Melting and Boiling Points	High melting and boiling points due to strong ionic bonds.	Lower melting and boiling points compared to ionic compounds.
Solubility	Soluble in water but insoluble in organic solvents.	Soluble in organic solvents but less soluble in water.
Electrical Conductivity	Conduct electricity in molten state or when dissolved in water (due to free ions).	Do not conduct electricity in any state (except a few like acids when dissolved in water).
Hardness	Hard and brittle.	Usually soft and flexible (in solid state).

Examples:

- **Ionic Compounds:**
  1. Sodium chloride ($NaCl$)
  2. Magnesium oxide (MgO)
- **Covalent Compounds:**
  1. Water (H_2O)
  2. Carbon dioxide (CO_2)

6.(b) *What is a co-ordinate covalent bond? How does it differ from a normal covalent bond?*

Answer:

co-ordinate Covalent Bond (also called Dative Bond):

A **co-ordinate covalent bond** is a special type of covalent bond where **both electrons shared between two atoms come from the same atom**.

- One atom **donates** a lone pair of electrons.
- The other atom **accepts** this pair to form a bond.

Example:
In the formation of an ammonium ion (NH_4^+), a nitrogen atom donates a lone pair to bond with a proton (H^+), forming a co-ordinate bond.

Difference between Normal Covalent Bond and Co-ordinate Covalent Bond:

Property	Normal Covalent Bond	Co-ordinate Covalent Bond
Electron Contribution	Each atom contributes **one electron** to the shared pair.	Only **one atom donates both electrons** to form the bond.
Representation	Usually shown by a single line (—) between atoms.	Usually shown by an arrow (→) pointing from donor to acceptor atom.
Example	H_2, O_2, H_2O (normal covalent molecules).	NH_4^+, CO, SO_2 (molecules with co-ordinate bonds).

Quick Visual:

- Normal Covalent Bond:
  H — H (each H shares one electron)
- Co-ordinate Covalent Bond:
  N → H^+ (Nitrogen donates a lone pair to H^+)

7.(a) *What do you understand by hydrogen bonds? Classify them with examples. Explain why water has abnormally high boiling point.*

Answer:

Hydrogen Bond:

A **hydrogen bond** is a special type of attractive force that occurs when a **hydrogen atom**, which is covalently bonded to a highly electronegative atom (like oxygen, nitrogen, or fluorine), experiences an additional attraction to another nearby electronegative atom.

- It is **weaker than a covalent bond** but **stronger than van der Waals forces**.
- Hydrogen bonding plays a crucial role in determining the physical properties of many substances.

Classification of Hydrogen Bonds:

1. **Intermolecular Hydrogen Bond:**
   - Occurs **between molecules**.
   - Example:
     - In water (H_2O), hydrogen bonds form between different water molecules.
     - In hydrogen fluoride (HF), hydrogen bonds form between HF molecules.
2. **Intramolecular Hydrogen Bond:**
   - Occurs **within the same molecule**.
   - Example:
     - In ortho-nitrophenol (a type of organic molecule), a hydrogen bond forms between the –OH group and the NO_2 group inside the same molecule.

Examples:

- **Intermolecular:**
  H_2O, HF, NH_3 (ammonia)
- **Intramolecular:**
  Ortho-nitrophenol, salicylaldehyde

Why Does Water Have an Abnormally High Boiling Point?

- Water molecules are **strongly held together by intermolecular hydrogen bonds**.
- A lot of energy is required to **break these hydrogen bonds** during the boiling process.
- As a result, **water has a much higher boiling point** compared to other molecules of similar size and molecular weight (like H_2S, which has no hydrogen bonding).

7.(b) *Why bond angles of H2O and NH3 are 104.5° and 107° respectively although central atoms are sp3 hybridized?*

Answer:

Why bond angles are different in H_2O and NH_3 despite sp^3 hybridization:

Both **water (H_2O)** and **ammonia (NH_3)** have a **central atom (O or N)** that is **sp^3 hybridized**, meaning they ideally would have a tetrahedral bond angle of **109.5°**.
However, **actual bond angles are less** because of the presence of **lone pairs** on the central atom.

- In **NH_3 (ammonia)**:
  - Nitrogen has **one lone pair** and **three bond pairs** (N–H bonds).
  - **Lone pair–bond pair repulsion** is stronger than **bond pair–bond pair repulsion**.
  - This extra repulsion **pushes the N–H bonds closer together**, reducing the bond angle from 109.5° to about **107°**.
- In **H_2O (water)**:
  - Oxygen has **two lone pairs** and **two bond pairs** (O–H bonds).
  - The **repulsion between two lone pairs** is even **stronger**, and it pushes the O–H bonds even closer.
  - Therefore, the bond angle reduces further to about **104.5°**.

In short:

- **More lone pairs = greater repulsion = smaller bond angle.**
- NH_3 (one lone pair) → **107°**
- H_2O (two lone pairs) → **104.5°**

Quick Visual (summary):

Molecule	Lone Pairs	Bond Pairs	Bond Angle
NH_3	1	3	107°
H_2O	2	2	104.5°

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8. (a) *What do you mean by the 'ionization potential' of an element? Why the first ionization potential of an element is less than the second ionization potential? How does the ionization potential of an element vary with atomic volume?*

Answer:

Ionization Potential (Ionization Energy):

The **ionization potential** (or **ionization energy**) of an element is the **amount of energy required to remove the most loosely bound electron** from an isolated gaseous atom to form a positive ion.

- It is usually expressed in units like **kJ/mol** or **eV**.

Why is the First Ionization Potential Less than the Second?

- The **first ionization potential** refers to the energy needed to remove the **first electron** from a neutral atom.
- After losing one electron, the atom becomes a **positively charged ion**.
- **Positive ions** attract their remaining electrons **more strongly** due to the increased effective nuclear charge.
- Therefore, **more energy** is required to remove a second electron, making the **second ionization potential higher** than the first.

In simple words: It is harder to remove an electron from a positively charged ion than from a neutral atom.

Variation of Ionization Potential with Atomic Volume:

- **Atomic volume** means the size of the atom.
- As the **atomic volume increases** (the atom gets bigger), the **outermost electron is farther from the nucleus** and experiences **less attraction**.
- Therefore, it becomes **easier to remove the electron**, and the **ionization potential decreases**.
- **Trend across a period (left to right):**
  - Atomic volume **decreases**, so ionization potential **increases**.
- **Trend down a group (top to bottom):**
  - Atomic volume **increases**, so ionization potential **decreases**.

Quick Summary:

Factor	**Effect on Ionization Potential**
Increase in atomic volume	Decrease in ionization potential
Decrease in atomic volume	Increase in ionization potential

8. (b) *What do you mean by f-block elements? Why f-block elements are called inner transition elements?*

Answer:

What are f-block Elements?

- **f-block elements** are the elements in which the last electron enters the **f-orbital** (specifically, the (n-2)f subshell).
- They are found at the **bottom of the periodic table**, separated from the main table to keep the structure compact.
- These elements include two series:
    1. **Lanthanides** (elements with atomic numbers 58 to 71, following Lanthanum, La)
    2. **Actinides** (elements with atomic numbers 90 to 103, following Actinium, Ac)

Why are f-block Elements Called Inner Transition Elements?

- In f-block elements, the filling of electrons takes place in the **inner (penultimate)** energy level (the third last shell), not in the outermost shell.
- Although electrons are added internally (to the (n-2)f orbital), the outermost shells (n and n-1) remain the same.
- Because the electron transition happens **inside** the atom rather than in the outer shells, they are called **inner transition elements**.

Simple meaning:
Electrons "transition" (get added) **inside the atom**, not on the surface — so they are "inner" transition elements!

Quick facts:

- **Lanthanides:** Shiny metals, mostly +3 oxidation state, used in magnets, lasers, etc.
- **Actinides:** Mostly radioactive, includes elements like uranium (U) and thorium (Th).