Chemistry Fundamentals

Lecture 13: Ions and Ionic Compounds

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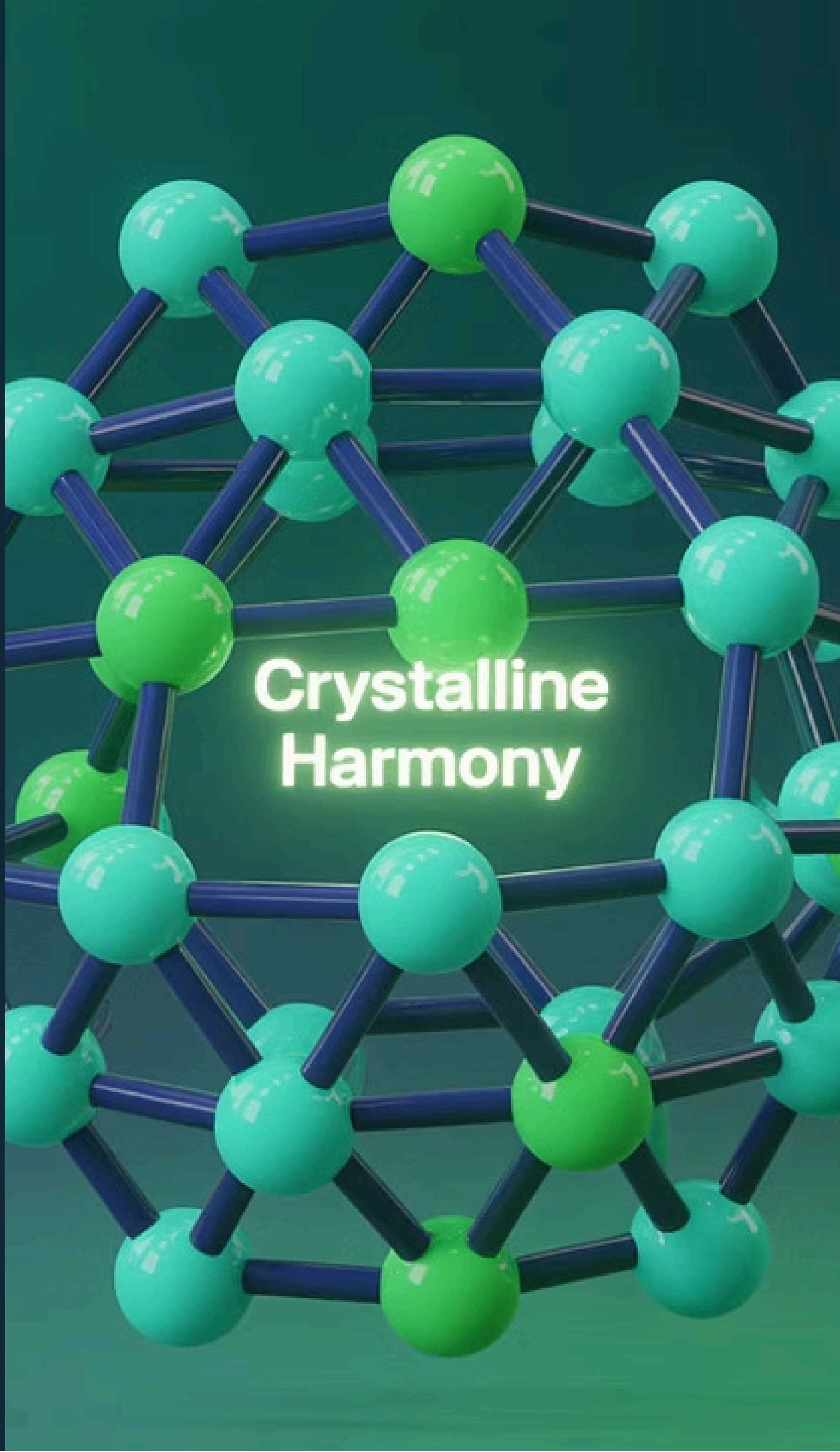

Ion Formation - Gaining and Losing Electrons

Ion Definition

Atom or group of atoms with net electrical charge

Cation Formation

Metal atoms lose electrons → positive charge

Anion Formation

Nonmetal atoms gain electrons → negative charge

Examples:

- $Na \rightarrow Na^{+} + e^{-}$ (loses 1 electron, becomes +1)
- $Cl + e^{-} \rightarrow Cl^{-}$ (gains 1 electron, becomes -1)
- $Mg \rightarrow Mg^{2+} + 2e^{-}$ (loses 2 electrons, becomes +2)

Ions have same electron configuration as nearest noble gas. Cations are smaller than atoms, anions larger than atoms.

Predicting Ion Charges from Periodic Table

Group 1 (Alkali Metals)

Form +1 ions (Li^{+}, Na^{+}, K^{+})

Group 15

Form -3 ions (N^{3-}, P^{3-})

Group 2 (Alkaline Earth)

Form +2 ions (Mg^{2+}, Ca^{2+}, Ba^{2+})

Group 16

Form -2 ions (O^{2-}, S^{2-})

Group 13

Form +3 ions (Al^{3+}, Ga^{3+})

Group 17 (Halogens)

Form -1 ions (F^{-}, Cl^{-}, Br^{-}, I^{-})

Transition Metals: Variable charges (Fe^{2+}, Fe^{3+}, Cu^{+}, Cu^{2+})

Memory Device: Group number for metals = positive charge

Pattern: Gain/lose electrons to achieve nearest noble gas configuration

Polyatomic Ions - Charged Molecular Groups

Definition: Groups of atoms covalently bonded with overall charge

NH_4^+ (ammonium)	+1 charge
SO_4^{2-} (sulfate)	-2 charge
PO_4^{3-} (phosphate)	-3 charge
NO_3^- (nitrate)	-1 charge
CO_3^{2-} (carbonate)	-2 charge

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Naming Patterns

- -ate ending: more oxygen (SO_4^{2-} sulfate)
- -ite ending: less oxygen (SO_3^{2-} sulfite)

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Behavior

Act as single units in compound formation

Common polyatomic ions must be memorized

Ionic Compound Formation and Formulas

Fundamental Rule: Total positive charge = total negative charge

Step 1

Identify cation and anion

Step 2

Determine charges

Step 3

Balance charges with subscripts

Step 4

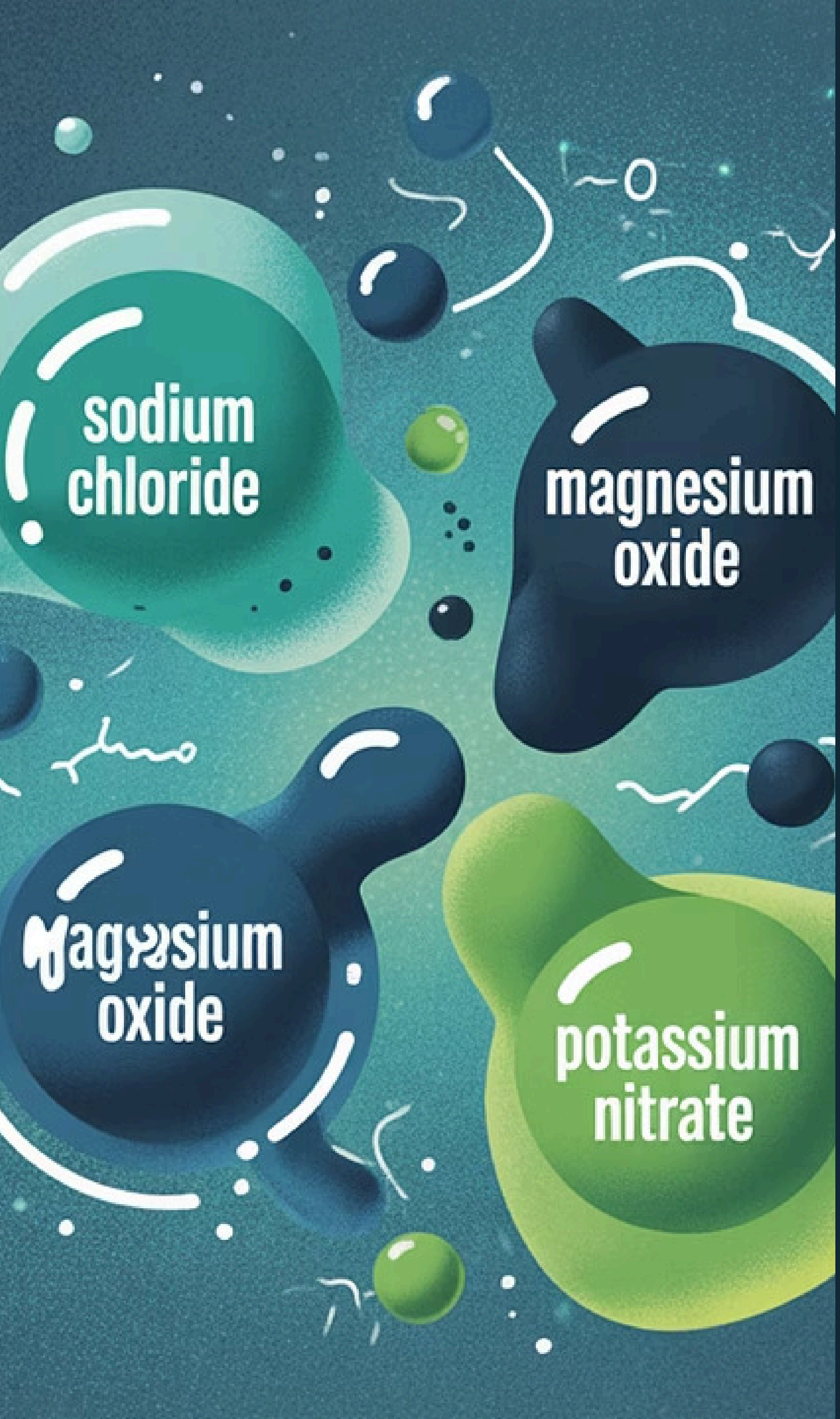
Write cation first, then anion

Example: Aluminum Oxide

- Al^{3+} and O^{2-}
- Need 2 Al^{3+} and 3 O^{2-} to balance
- Formula: Al_2O_3

Criss-Cross Method: Use charge numbers as subscripts (then simplify)

Polyatomic Examples: Ca^{2+} and SO_4^{2-} → $CaSO_4$, Al^{3+} and PO_4^{3-} → $AlPO_4$



Naming Ionic Compounds

Binary Ionic Compounds

Metal name + nonmetal root + "-ide"

- NaCl (sodium chloride)
- MgO (magnesium oxide)

Compounds with Polyatomic Ions

Use polyatomic ion name

- $CaSO_4$ (calcium sulfate)
- NH_4Cl (ammonium chloride)

Transition Metal Compounds

Include charge in Roman numerals

- $FeCl_2$ (iron(II) chloride)
- $FeCl_3$ (iron(III) chloride)

Naming Systems

- Stock System: Modern method using Roman numerals
- Older System: -ous (lower charge), -ic (higher charge)

Properties of Ionic Compounds

Crystal Structure

Regular 3D arrangement of ions

Melting/Boiling Points

High due to strong electrostatic forces

Brittleness

Stress causes like charges to align and repel

Electrical Conductivity

- Solid: No (ions fixed in place)
- Molten: Yes (ions mobile)
- Aqueous solution: Yes (ions separated)

Examples

$NaCl$	mp 801°C, soluble in water
$CaCO_3$	mp 825°C, insoluble in water
MgO	mp 2852°C, slightly soluble

Dissolution of Ionic Compounds

Dissolution Process

Water molecules surround and separate ions

Hydration: Water molecules orient around ions

Equation Example: $NaCl(s) \rightarrow Na^{+}(aq) + Cl^{-}(aq)$

Energy Considerations

- Lattice energy: Energy to separate ions
- Hydration energy: Energy released when ions hydrate
- Solubility depends on balance

Solubility Rules

- All nitrates (NO_3^-) soluble
- All acetates (CH_3COO^-) soluble
- Most chlorides soluble (except $AgCl$, $PbCl_2$)
- Most sulfates soluble (except $BaSO_4$, $PbSO_4$)
- Most carbonates insoluble (except Group 1)

Ionic Compounds in Everyday Life

Table Salt (NaCl)

Food preservation, seasoning

Calcium Carbonate ($CaCO_3$)

Limestone, marble, antacids

Sodium Bicarbonate ($NaHCO_3$)

Baking soda, antacid

Applications

- Medicine: Electrolyte balance, treatments
- Agriculture: Fertilizers provide essential ions
- Industry: Ceramics, glass, metallurgy

Other examples: Calcium Phosphate ($Ca_3(PO_4)_2$) in bones, Potassium Chloride (KCl) as salt substitute, Magnesium Sulfate ($MgSO_4 \cdot 7H_2O$) as Epsom salt

Next Lecture:

Hydrate Compounds

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