Chemistry Fundamentals

Lecture 14: Hydrate Compounds

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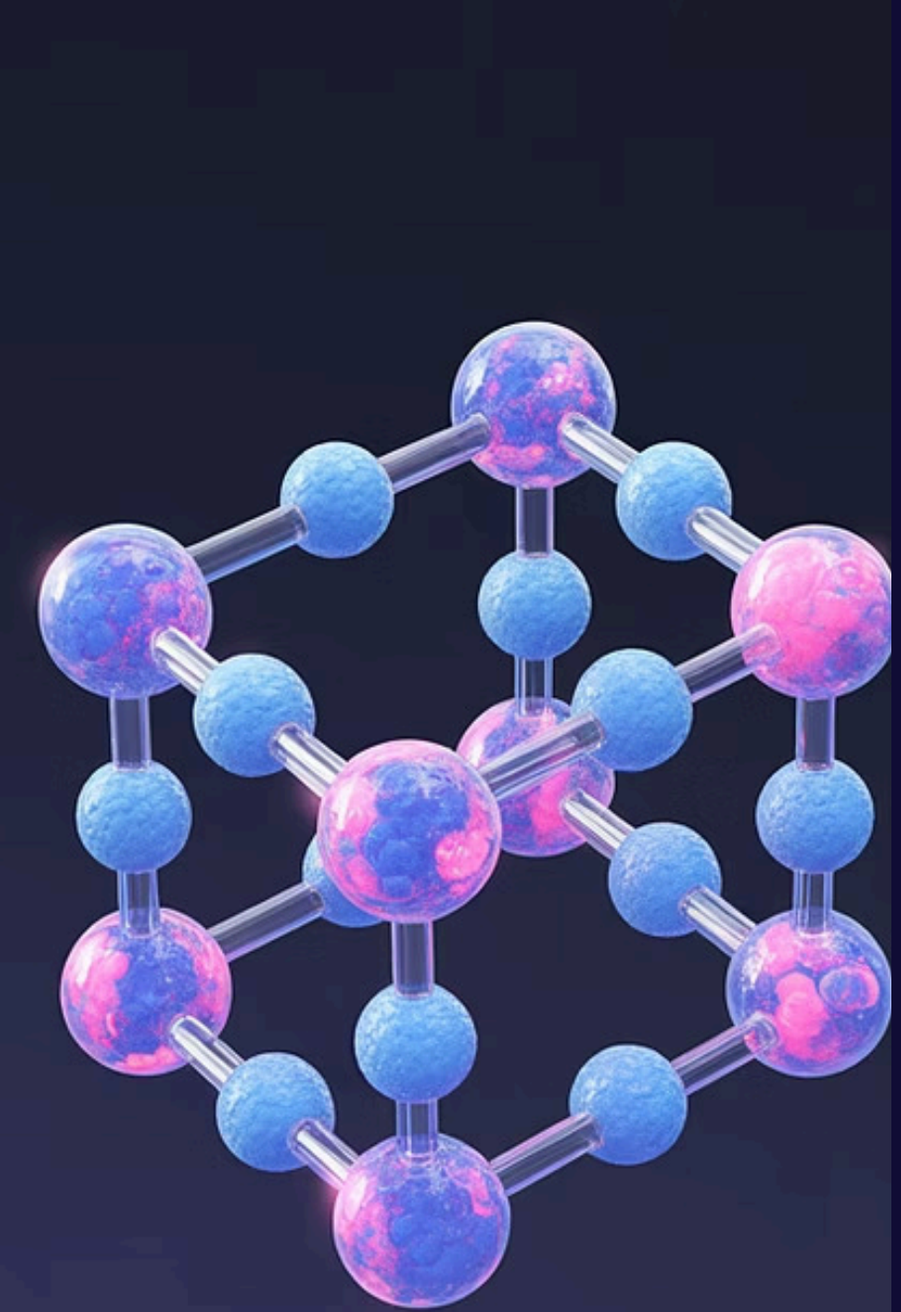


Hydrates – Ionic Compounds with Water

Definition & Structure

Ionic compounds containing specific numbers of water molecules. Water molecules occupy specific positions in the crystal lattice as "water of crystallization."

Formation & Notation

Water molecules become trapped during crystallization. Dot notation (·) separates the compound from water molecules (e.g., $CuSO_4 \cdot 5H_2O$).

Properties

Not solutions - water is part of the solid compound. Many hydrates lose water when heated in a reversible process.

Common Hydrate Examples and Properties

1

Copper(II) Sulfate Pentahydrate

$CuSO_4 \cdot 5H_2O$: Bright blue crystals that turn white when heated (anhydrous). Used as fungicide and in electroplating.

2

Sodium Carbonate Decahydrate

$Na_2CO_3 \cdot 10H_2O$: Known as washing soda. Loses 9 water molecules at room temperature. Used in glass manufacturing and water softening.

1

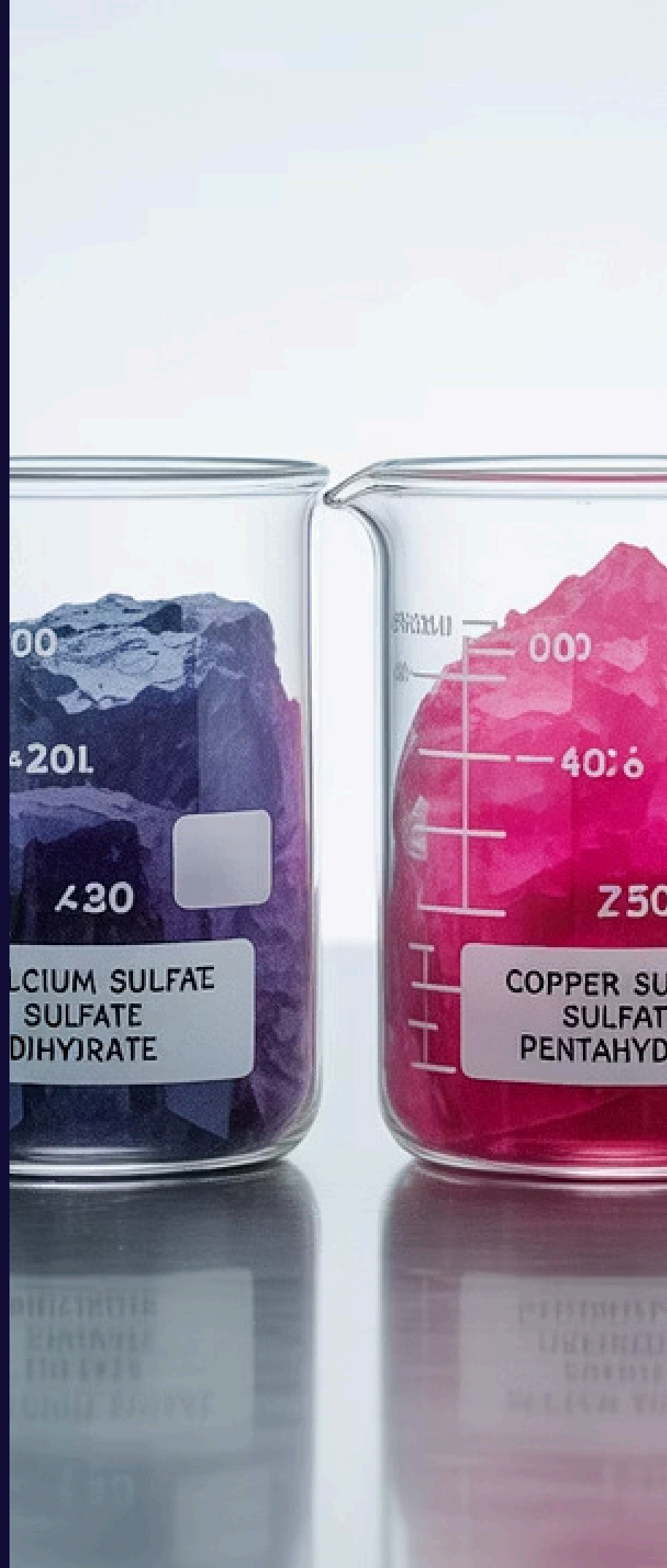
Calcium Chloride Dihydrate

$CaCl_2 \cdot 2H_2O$: Hygroscopic (absorbs water from air). Used as drying agent and ice melter.

2

Magnesium Sulfate Heptahydrate

$MgSO_4 \cdot 7H_2O$: Known as Epsom salt. Dissolves readily in water. Used medicinally and in agriculture.



Naming Hydrate Compounds

Naming follows the pattern: [Ionic compound name] + [prefix]hydrate

Water Molecule Prefixes

1 H_2O	monohydrate
2 H_2O	dihydrate
3 H_2O	trihydrate
4 H_2O	tetrahydrate
5 H_2O	pentahydrate

More Prefixes

6 H_2O	hexahydrate
7 H_2O	heptahydrate
8 H_2O	octahydrate
10 H_2O	decahydrate

Examples:

- $CaSO_4 \cdot 2H_2O$: calcium sulfate dihydrate
- $FeCl_3 \cdot 6H_2O$: iron(III) chloride hexahydrate
- $Al_2(SO_4)_3 \cdot 18H_2O$: aluminum sulfate octadecahydrate

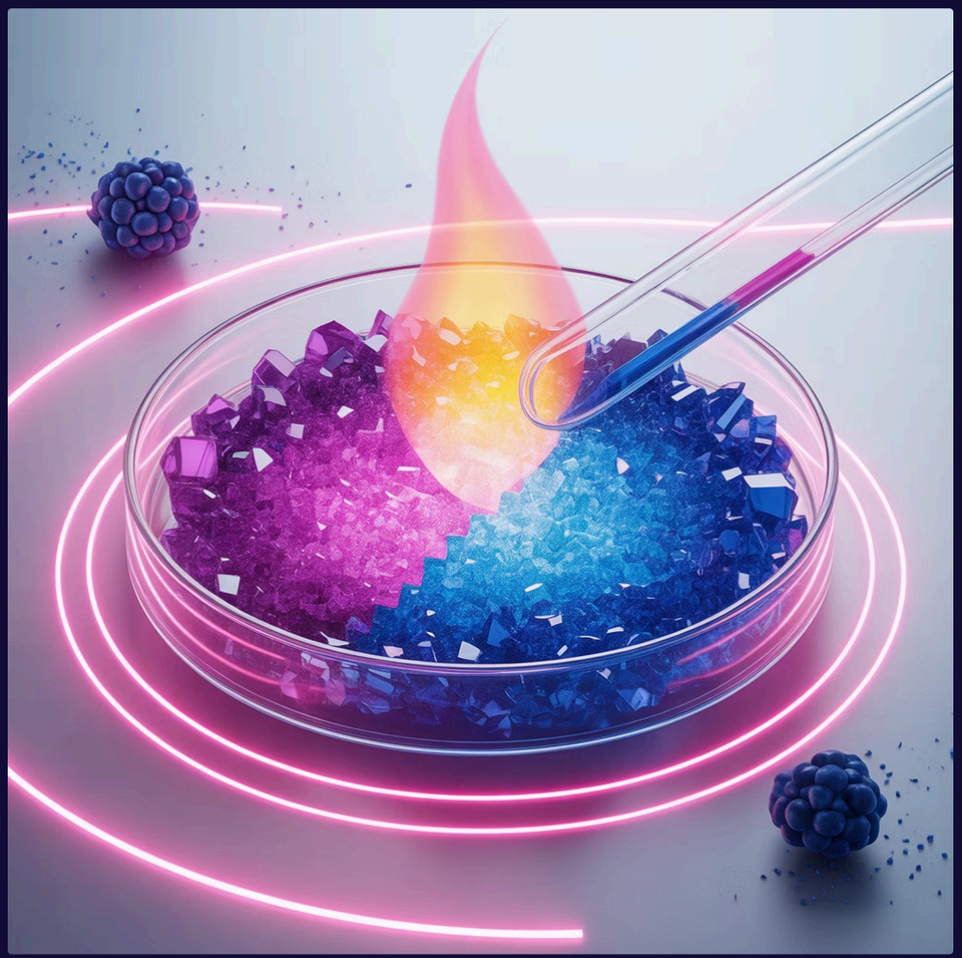
Anhydrous vs. Hydrated Forms

Key Terms

- Anhydrous: "Without water" - compound with no water molecules
- Hydrated: Contains water of crystallization
- Dehydration: Process of removing water from hydrate
- Rehydration: Process of adding water back to anhydrous compound

Many hydrates can undergo reversible dehydration and rehydration. Dehydration requires heat input, while rehydration releases heat.

Example: Cobalt(II) Chloride



- $CoCl_2 \cdot 6H_2O$: Pink hydrated form
- $CoCl_2$: Blue anhydrous form
- Used as humidity indicator

Determining Water Content in Hydrates

Experimental Method

1. Weigh original hydrate sample
2. Heat to constant mass (all water removed)
3. Weigh anhydrous residue
4. Calculate water mass = original mass - final mass

Example Calculation

- Original $CuSO_4 \cdot xH_2O$: 12.50 g
- After heating $CuSO_4$: 8.00 g
- Water lost: 12.50 - 8.00 = 4.50 g
- Moles H_2O: 4.50 g ÷ 18.02 g/mol = 0.250 mol
- Moles $CuSO_4$: 8.00 g ÷ 159.6 g/mol = 0.0501 mol
- Ratio: 0.250 ÷ 0.0501 = 5.0 → $CuSO_4 \cdot 5H_2O$

Calculating Percent Water in Hydrates

Percent Water Formula

$$(mass\ of\ water / total\ mass\ of\ hydrate) \times 100\%$$

Example: $CuSO_4 \cdot 5H_2O$

- Molar mass $CuSO_4$: 159.6 g/mol
- Molar mass $5H_2O$: 5 × 18.02 = 90.1 g/mol
- Total molar mass: 159.6 + 90.1 = 249.7 g/mol
- Percent water: (90.1 ÷ 249.7) × 100% = 36.1%

Considerations

- Theoretical vs. Experimental: Compare calculated and measured percentages
- Sources of Error:
  - Incomplete dehydration
  - Decomposition
  - Absorption of moisture
- Applications: Quality control, purity analysis

Hydrate Formation and Stability

Formation Conditions

- Temperature: Lower temperatures favor hydrate formation
- Humidity: Higher humidity promotes hydrate formation
- Pressure: Generally favors hydrate formation

Stability Factors

- Crystal structure: How well water fits into lattice
- Hydrogen bonding: Between water and ions
- Temperature: Higher temperatures destabilize hydrates

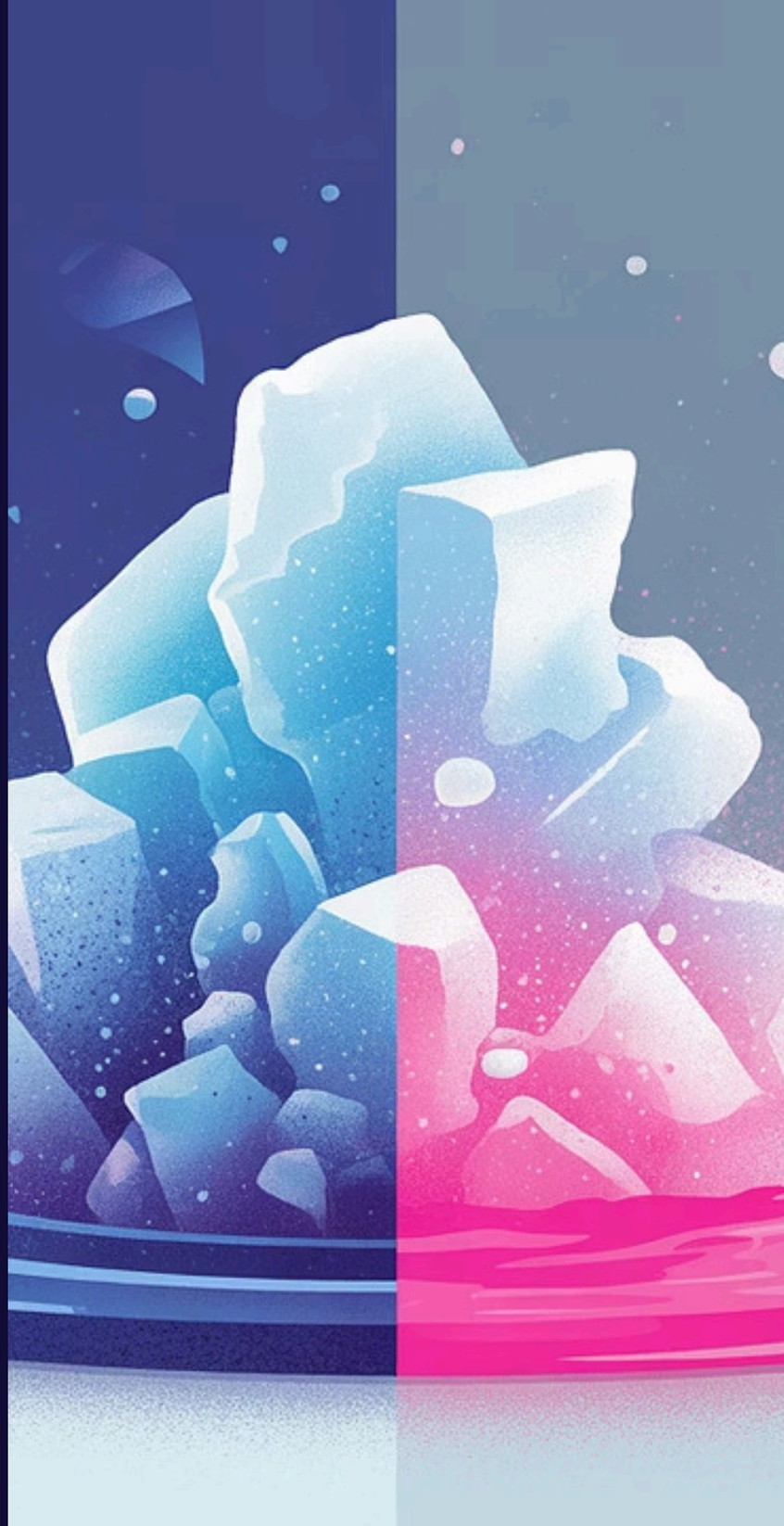
Special Phenomena

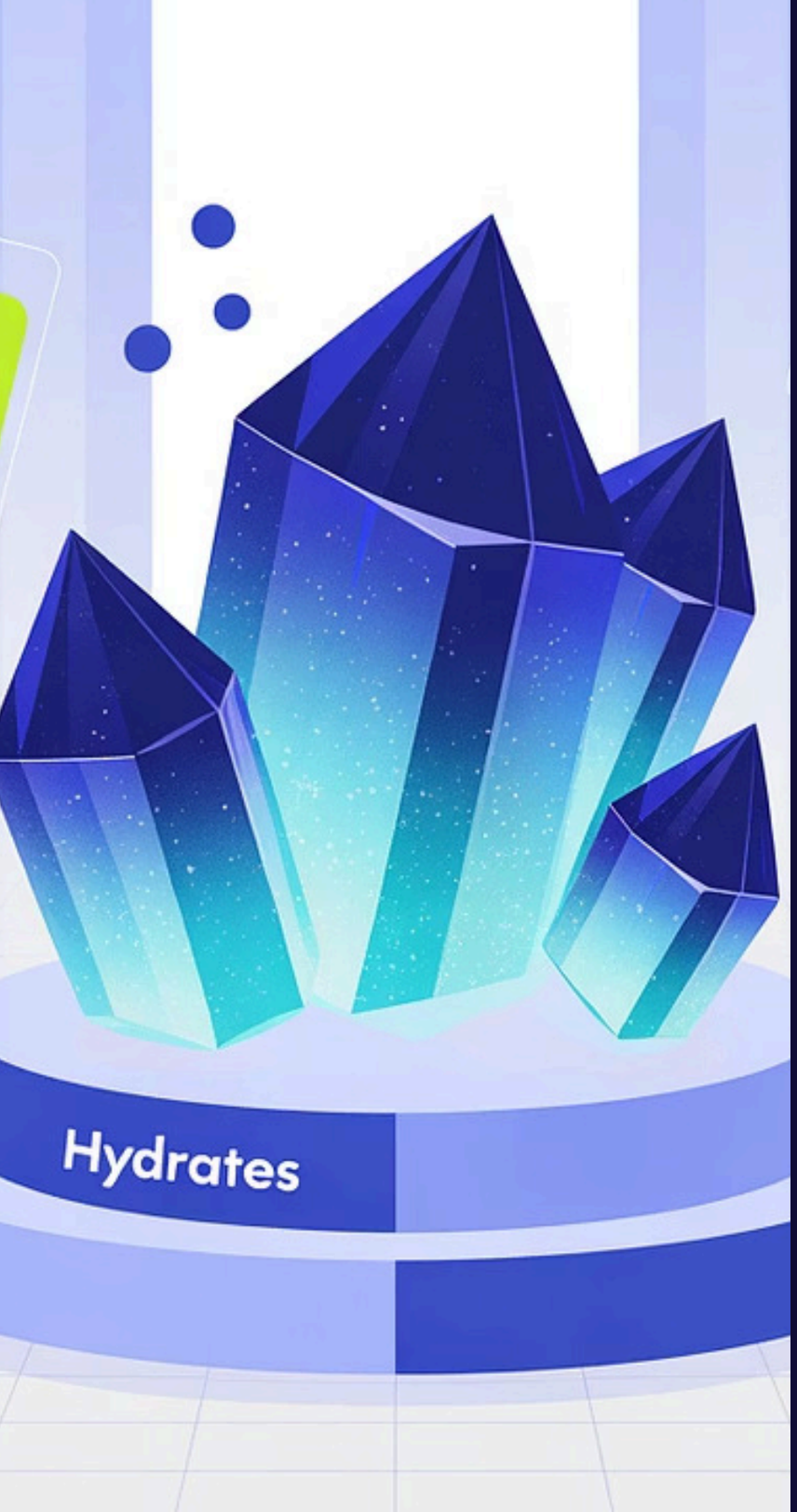
Efflorescence

Spontaneous loss of water at room temperature (e.g., $Na_2CO_3 \cdot 10H_2O$ effloresces to $Na_2CO_3 \cdot H_2O$)

Deliquescence

Absorption of water from air until compound dissolves (e.g., $CaCl_2$ deliquesces in humid air)





Applications and Industrial Uses

Drying Agents

Anhydrous forms absorb water

- $CaCl_2$: Desiccant for gases
- $MgSO_4$: Laboratory drying agent

Water Indicators

Color changes show hydration state

- $CoCl_2$: Blue (dry) to pink (humid)
- $CuSO_4$: White (dry) to blue (hydrated)

Other Applications

- Controlled Release: Plaster of Paris ($CaSO_4 \cdot ½H_2O + H_2O \rightarrow CaSO_4 \cdot 2H_2O$)
- Thermal Energy Storage: Hydration/dehydration stores/releases heat
- Pharmaceutical Industry: Hydrate forms affect drug properties
- Construction: Cement hydration creates strong materials

Next Lecture:

The Mole Concept

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