Chemistry 3.6
Aqueous Systems

Aqueous Solutions
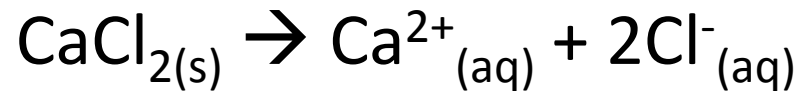
Dissolving solid

- When a **solid** substance (crystal) is **dissolved**, the **crystal break apart** into its **individual particle**.
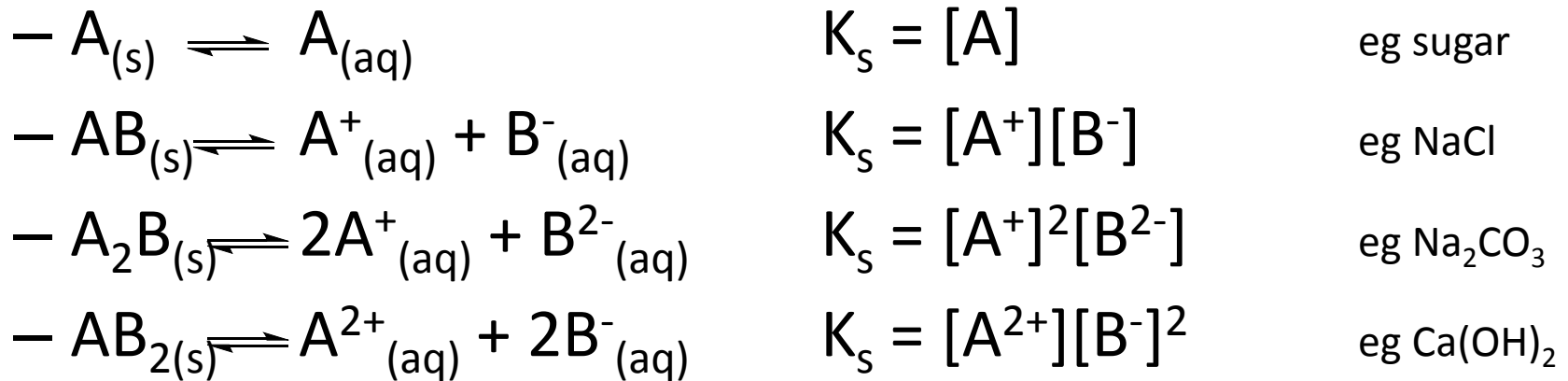 - Molecular substances → individual molecules

  $$C_6H_{12}O_{6\,(s)} \rightarrow C_6H_{12}O_{6(aq)}$$

  - Ionic substances → individual ions

  $$CaCl_{2(s)} \rightarrow Ca^{2+}_{(aq)} + 2Cl^-_{(aq)}$$

Solubility Constant

- **Solubility Constant (K_s)** is the **equilibrium constant** for **dissolving a substance**

- Depending on the nature of the solute, there are different way to **express K_s**

  - $A_{(s)} \rightleftharpoons A_{(aq)}$ $\qquad$ $K_S = [A]$ $\qquad$ eg sugar

  - $AB_{(s)} \rightleftharpoons A^+_{(aq)} + B^-_{(aq)}$ $\qquad$ $K_S = [A^+][B^-]$ $\qquad$ eg NaCl

  - $A_2B_{(s)} \rightleftharpoons 2A^+_{(aq)} + B^{2-}_{(aq)}$ $\qquad$ $K_S = [A^+]^2[B^{2-}]$ $\qquad$ eg Na_2CO_3

  - $AB_{2(s)} \rightleftharpoons A^{2+}_{(aq)} + 2B^-_{(aq)}$ $\qquad$ $K_S = [A^{2+}][B^-]^2$ $\qquad$ eg $Ca(OH)_2$

Ionic product

- **Ionic product (IP)** is the **Reaction Quotient (Q)** of a solution at a given moment of time.
- When **IP < K$_s$**, the solution is **unsaturated**, meaning it is **possible to dissolve more** solute into the solution.
- When **IP = K$_s$**, the solution is at the **point of saturation**. It reaches it **maximum solubility**.
- When **IP > K$_s$**, the solution is **over saturated**, meaning it is not possible to dissolve more solute into the solution and **precipitate will form**.
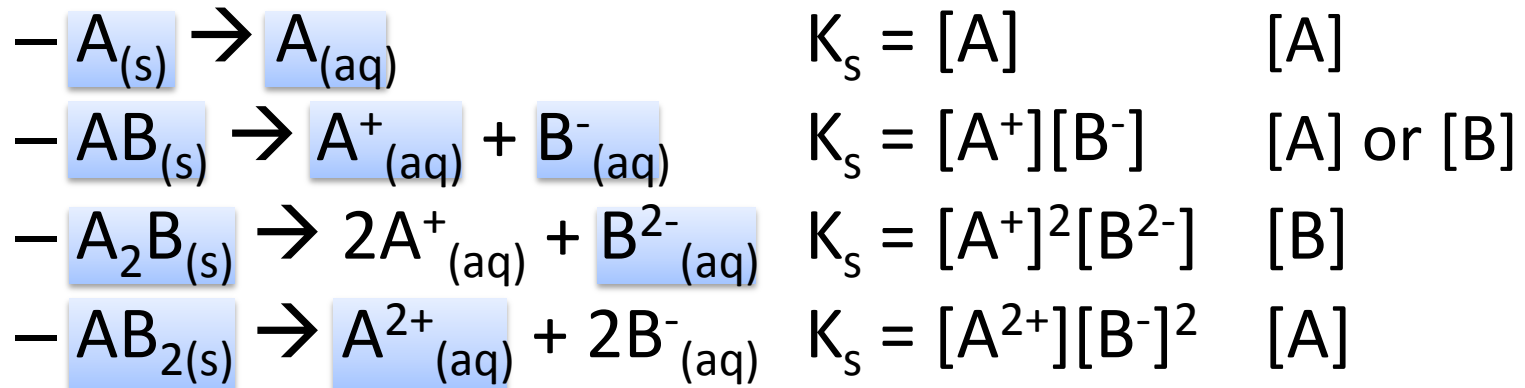
Try This

Determine **whether** a **precipitate** of silver chromate (**Ag_2CrO_4**), will form when **25.0 mL** of **1.20×10^{-3} molL^{-1}** silver nitrate solution (**$AgNO_3$**) is mixed with **25.0 mL** of **4.50×10^{-4} molL^{-1}** potassium chromate solution (**K_2CrO_4**).

K_s (Ag_2CrO_4) = 1.9×10^{-12}

Answer

Solubility

- Solubility of a substance is the **maximum concentration** (in molL^{-1}) the solute can dissolves at a particular temperature

- This can be calculated by solving the 1:1 species concentration from K$_s$

  Solubility

  - $A_{(s)} \rightarrow A_{(aq)}$ $K_s = [A]$ [A]
  - $AB_{(s)} \rightarrow A^+_{(aq)} + B^-_{(aq)}$ $K_s = [A^+][B^-]$ [A] or [B]
  - $A_2B_{(s)} \rightarrow 2A^+_{(aq)} + B^{2-}_{(aq)}$ $K_s = [A^+]^2[B^{2-}]$ [B]
  - $AB_{2(s)} \rightarrow A^{2+}_{(aq)} + 2B^-_{(aq)}$ $K_s = [A^{2+}][B^-]^2$ [A]

Calculating solubility for AB

- **Calculating** the **solubility** for ionic compound **AB** when **given the K$_s$**

1. Given that $AB_{(s)} \rightleftharpoons A^+_{(aq)} + B^-_{(aq)}$
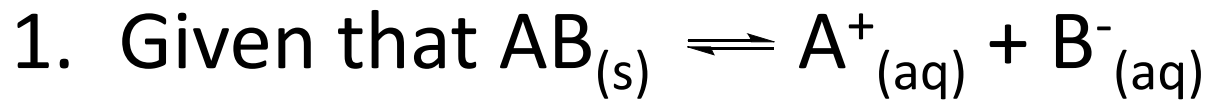
2. $K_s = [A^+][B^-]$

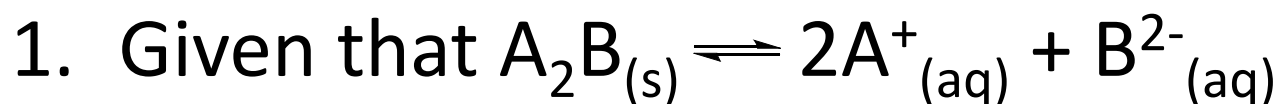3. $[A^+] = [B^-]$

4. Therefore $K_s = [A^+]^2$ or $[B^-]^2$

5. As a result

$$Solubility\, of\ AB\ = [A] = \ \sqrt{K_s}$$

Calculating solubility for A_2B

- **Calculating** the solubility for ionic compound **A_2B** when **given the K_s**

1. Given that $A_2B_{(s)} \rightleftharpoons 2A^+_{(aq)} + B^{2-}_{(aq)}$

2. $K_s = [A^+]^2[B^{2-}]$

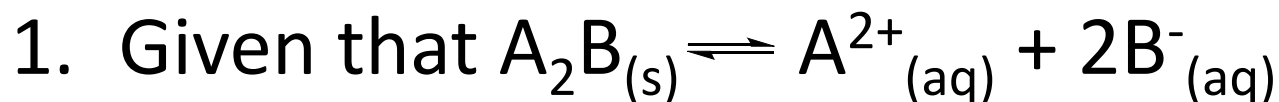3. The solubility $= [B^{2-}]$

4. Which means $2[B^{2-}] = [A^+]$

5. Therefore $K_s = (2[B^{2-}])^2\,[B^{2-}] = 4[B^{2-}]^3$

6. As a result

$$Solubility\ of\ A_2B = \sqrt[3]{\frac{K_s}{4}}$$

Calculating solubility for AB_2

- **Calculating** the solubility for ionic compound AB_2 when **given the K_s**

1. Given that $A_2B_{(s)} \rightleftharpoons A^{2+}_{(aq)} + 2B^-_{(aq)}$

2. $K_s = [A^{2+}][B^-]^2$

3. The solubility $= [A^{2+}]$

4. Which means $2[A^{2+}] = [B^-]$

5. Therefore $K_s = (2[A^{2+}])^2 [A^{2+}] = 4[A^{2+}]^3$

6. As a result

$$Solubility \ of \ AB_2 = \sqrt[3]{\dfrac{K_s}{4}}$$

Example

The solubility product (K_s) for silver chromate (Ag_2CrO_4) is 1.9×10^{-12}. Calculate the solubility, in $molL^{-1}$, of Ag_2CrO_4 in water at 25^oC

Common ion effect

- Common ion effect is the **decrease in solubility** due to addition of a "**common ion**".
  - Eg. Common ion of NaCl are Na^+ or Cl^-
- Addition of **common ion increases** the **concentration** of the **product**, since K_s does **not change**, therefore the **solubility** has to **decrease** in order for K_s to remain the same.
- Once again if the **IP is higher than K_s, precipitation** will occur

Example

Addition of silver nitrate ($AgNO_3$) solution to a **saturated** solution of silver chromate (Ag_2CrO_4) causes silver chromate to **precipitate out**.

Discuss this observation

Answers

Removing ion from solution

- **Opposite** to addition of **common ion**, **removing ion** from the solution will **increase** the **solubility**
- This can be done in two ways
  - Reacting under **acid and base reaction**
    - Adding **acid to oxide or hydroxide** solution
  - Forming **complex ions** (in particular NH_3)
    - $FeSCN^{2+}$
    - $[Ag(NH_3)_2]^+$
    - $[Al(OH)_4]^-$
    - $[Pb(OH)_4]^{2-}$
    - $[Zn(OH)_4]^{2-}$
    - $[Zn(NH_3)_4]^{2+}$
    - $[Cu(NH_4)_4]^{2+}$

Example

Explain why the precipitate of $Cu(OH)_2$ re-dissolved when aqueous NH_3 is added