Chemistry 12

Solubility Equilibrium IV

III. 10
pg 105-108

Name: Notes
Date:
Block:

1. Common Ion Effect

Common Ion Effect

In a saturated solution, equilibrium is established between the **dissolving (increase solubility)** and **recrystallization (decrease solubility)** of a salt.

recrystallizing / ↓ solubility / shift left

$$AgCl_{(s)} \rightleftharpoons Ag^{+}_{(aq)} + Cl^{-}_{(aq)}$$

dissolving / ↑ solubility / shift right

$K_{sp} = [Ag^+][Cl^-]$

⇒ Which of the following will shift this equilibrium? If it shifts, in which direction will it shift?

- ❖ Add more $AgCl_{(s)}$? adding solids have no impact on equilibrium } no shift
- ❖ Remove $AgCl_{(s)}$? (not really an option since there is no $AgCl_{(s)}$ to remove) } no shift
- ❖ Add $Ag^+_{(aq)}$? shift left (↓ solubility)
- ❖ Remove $Ag^+_{(aq)}$? shift right (↑ solubility)
- ❖ Add $Cl^-_{(aq)}$? shift left (↓ solubility)
- ❖ Remove $Cl^-_{(aq)}$? shift right (↑ solubility)

$$AgCl_{(s)} \rightleftharpoons Ag^{+}_{(aq)} + Cl^{-}_{(aq)}$$

INCREASE the Solubility of a Salt:

- Dissolve more of the solid (if it exists)
- Equilibrium will shift to the right.
- Rate of dissolving > Rate of recrystallization
- Can be accomplished by:
  - ~~add reactants?~~
  - remove Ag^+
  - remove Cl^-

How do we REMOVE $Ag^{+}_{(aq)}$ or $Cl^{-}_{(aq)}$?

- To remove an ion from solution, we must find **another ion** to react with it. → create low solubility (ppt)
  - To remove Ag^+... SO_4^{2-}, Br^-, I^-, ~~Cl^-~~, S^{2-}, OH^-, PO_4^{3-}, CO_3^{2-}, SO_3^{2-}
  - To remove Cl^-... Pb^{2+}, Cu^+, ~~Ag^+~~

Which of the following salts could be added to ~~INCREASE~~ the solubility of AgCl?

~~AgCl~~ (Ag^+ ~~Cl^-~~) | $CaSO_4$ (Ca^{2+} SO_4^{2-} ✓) | ~~KNO_3~~ (~~K^+~~ ~~NO_3^-~~) | ZnS (Zn^{2+} S^{2-} ✓) | ~~$CaCl_2$~~ (Ca^{2+} Cl^-) | ~~AgBr~~ (Ag^+ Br^- ✓) | $Mg(OH)_2$ (Mg^{2+} OH^- ✓) | NH_4CO_3 (NH_4^+ CO_3^- ✓)

don't want to add more Ag^+

By introducing $CaSO_4$, SO_4^{2-} precipitates the Ag^+ as $AgSO_{4(s)}$.
This decreases $[Ag^+]$ and shifts the equilibrium to the right

Original equation: $AgCl_{(s)} \rightleftharpoons Ag^+_{(aq)} + Cl^-_{(aq)}$

$\downarrow AgSO_{4(s)}$

Adding in: $CaSO_{4(s)} \rightleftharpoons Ca^{2+}_{(aq)} + SO_4^{2-}_{(aq)}$

$AgCl_{(s)} \rightleftharpoons Ag^+_{(aq)} + Cl^-_{(aq)}$

DECREASE the Solubility of a Salt:

- Equilibrium will shift to the left.
- Cause more solid to form.
- Rate of dissolving < Rate of recrystallization
- Can be accomplished by:
  - adding Ag^+
  - adding Cl^-

~~removing reactant?~~

How do we ADD $Ag^+_{(aq)}$ or $Cl^-_{(aq)}$?

- Introducing another salt, which has an ion in common with the first salt, is called the **"Common Ion Effect"**
  - To add Ag^+... ex. add $AgNO_3$ → pair with ion that won't cause Ag^+ or Cl^- to precipitate
  - To add Cl^-... ex. add $NaCl$

Which of the following salts could be added to DECREASE the solubility of AgCl?

AgCl	$CaSO_4$	KNO_3	ZnS	$CaCl_2$	AgBr	$Mg(OH)_2$	NH_4CO_3
Ag^+ Cl^- no	Ca^{2+} SO_4^{2-}	K^+ NO_3^-	Zn^{2+} S^{2-}	Ca^{2+} Cl^- ✓	Ag^+ Br^-	Mg^{2+} OH^-	NH_4^+ CO_3^-

By introducing $CaCl_2$, the $[Cl^-]$ is increased and therefore the equilibrium for the reaction shifts to the left

Original equation: $AgCl_{(s)} \rightleftharpoons Ag^+_{(aq)} + Cl^-_{(aq)}$

Adding in: $CaCl_{2\,(aq)} \rightleftharpoons Ca^{2+}_{(aq)} + 2Cl^-_{(aq)}$

Ca^{2+} is a spectator (won't precipitate any ions out)

1. Consider the following reaction:

$$Al_2(SO_4)_{3(s)} \leftrightharpoons 2\ Al^{3+}{}_{(aq)} + 3\ SO_4{}^{2-}{}_{(aq)}$$

If the following compounds were added,

I. Na_2S (Na^+ spectator, S^{2-}) — forms a ppt w/ Al^{3+} - shift right (↑ solubility)
II. $Al_2(SO_4)_3$ (Al^{3+}, SO_4^{2-}) no shift
III. $NaNO_3$ (Na^+ spectator, NO_3^- spectator) no shift
IV. K_2SO_4 (K^+ spectator, SO_4^{2-}) shift left (↓ solubility)

a) Solubility would increase:
   A. I only
   B. I & II
   C. II & IV
   D. III & IV
   E. IV only

b) Solubility would decrease:
   A. I only
   B. I & II
   C. II & IV
   D. III & IV
   E. IV only

2. Consider a solution of NaBr.

a. Write the solubility equilibrium reaction:

$$NaBr_{(s)} \rightleftharpoons Na^+_{(aq)} + Br^-_{(aq)}$$

b. Each of the following solutions is added to the solution of NaBr. State whether each will increase or decrease the solubility. Order the solutions in order of decreasing solubility.

	1.0 M NaCl (Na^+ Cl^-)	1.0 M $AgNO_3$ (Ag^+ NO_3^- → $AgBr_{(s)}$)	1.0 M KNO_3 (K^+ NO_3^-)	1.0 M Na_2SO_4 (Na^+ SO_4^{2-})	2.0 M $AgNO_3$ (Ag^+ NO_3^- → $AgBr_{(s)}$)
Increase or decrease solubility?	↓ sol.	↑ sol.	no change	↓ sol.	↑ sol.

2.0M $AgNO_3$ 1.0M $AgNO_3$ 1.0M KNO_3 1.0M $NaCl$ 1.0M Na_2SO_4

Increase solubility — Decrease solubility

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