

## Solubility as an equilibrium process

SOLUTION: Homogeneous mixture of substances Solutions contain:

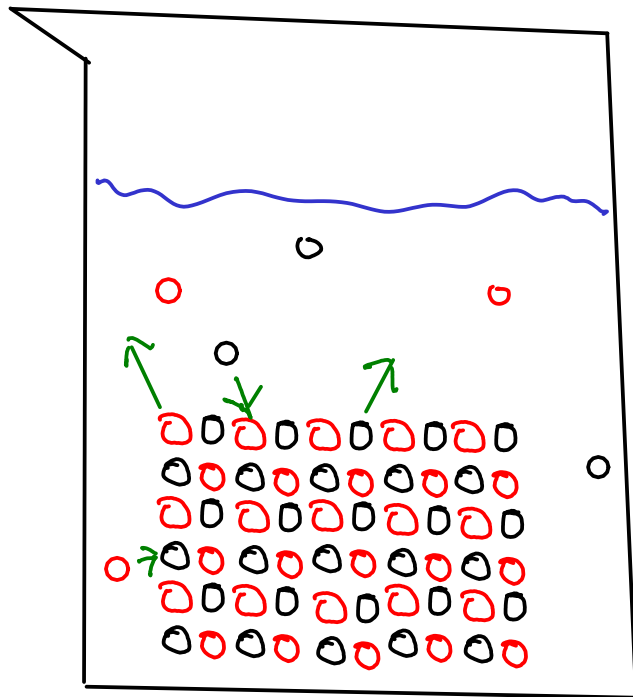
SOLUTE: Component(s) of a solution present in small amount

SOLVENT: Component of a solution present in greatest amount

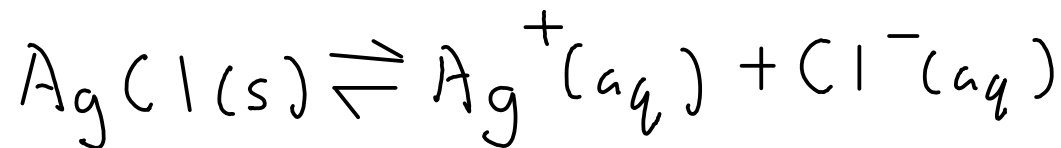
SOLUBILITY: The amount of a solute that will dissolve in a given volume of solvent

SATURATED SOLUTION: Contains the maximum amount of solute that it is possible to dissolve in a given volume of solvent!

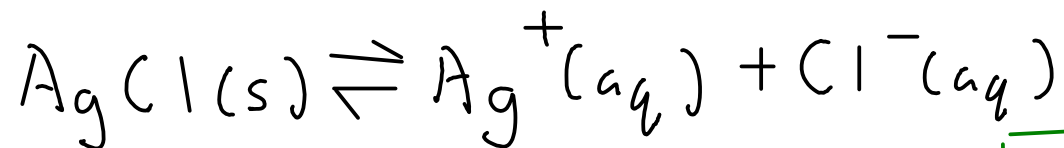
A SATURATED SOLUTION is a solute where dissolved solute exists in an EQUILIBRIUM with undissolved solute!



Example: Consider a saturated solution of silver chloride:

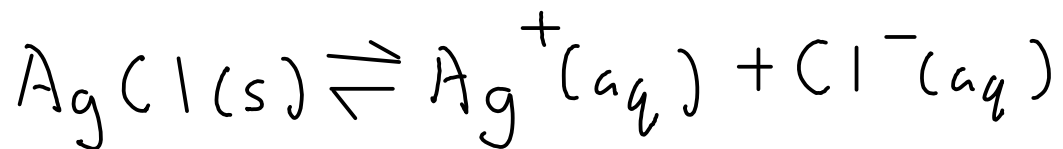


At equilibrium, the rate of dissolving equals the rate of crystallization!



$$K_c = [\text{Ag}^+][\text{Cl}^-] = 1.8 \times 10^{-10}$$

... what does this equilibrium constant tell us? That silver chloride isn't very soluble!

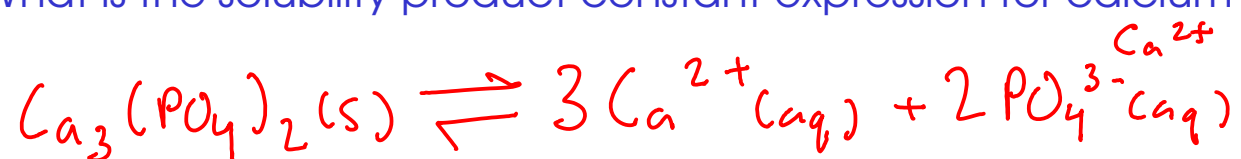


$$K_{sp} = [\text{Ag}^+][\text{Cl}^-]$$

↪ This equilibrium constant is given a special name - the SOLUBILITY PRODUCT CONSTANT - because the equilibrium expression for the dissolving of a salt always appears as a PRODUCT of the concentrations of the ions in the compound!

Remember,  $K_{sp}$  is an equilibrium constant, so everything that applies to equilibrium constants applies to the solubility constant - including what to do with coefficients:

What is the solubility product constant expression for calcium phosphate?



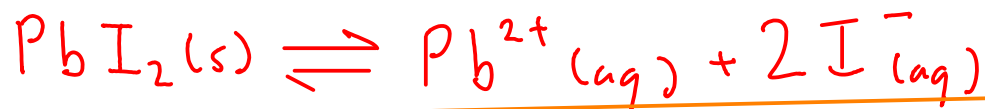
$$K_{sp} = [\text{Ca}^{2+}]^3 [\text{PO}_4^{3-}]^2$$

## Solubility calculations and K<sub>sp</sub>

You can calculate the solubility of a compound if you know K<sub>sp</sub>!

Calculate the solubility (in g/L) of lead iodide at 25°C. (see p A-15 in book)

$$K_{sp} = 6.5 \times 10^{-9} ; \text{FW} = 461.0 \text{ g/mol}$$



$$K_{sp} = 6.5 \times 10^{-9} = [\text{Pb}^{2+}][\text{I}^{-}]^2$$

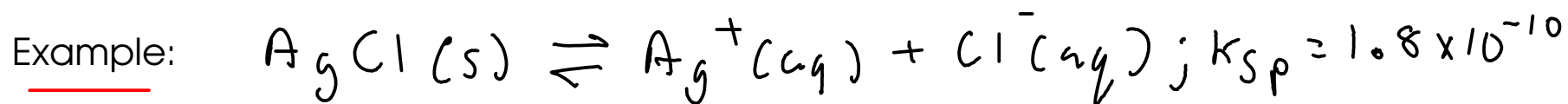
species	initial	$\Delta$	equilibrium
$\text{Pb}^{2+}$	0	+x	x
$\text{I}^{-}$	0	+2x	2x

$$6.5 \times 10^{-9} = (x)(2x)^2$$
$$6.5 \times 10^{-9} = 4x^3 \quad \left| \begin{array}{l} \rightarrow x = 0.0011756673 = [\text{Pb}^{2+}] \\ = \text{molar } [\text{PbI}_2] \text{ in solution, in M} \end{array} \right.$$

$$\frac{0.0011756673 \text{ mol PbI}_2}{\text{L}} \times \frac{461.0 \text{ g PbI}_2}{\text{mol PbI}_2} = \boxed{0.54 \text{ g/L}} = 540 \text{ ppm (mg/L)}$$

## Precipitation - also known as the reaction quotient

To predict whether a salt at a given concentration will precipitate out, calculate the reaction quotient  $Q$  and compare it to the  $K_{sp}$



$$Q = [Ag^+][Cl^-]$$

IF...

- \*  $Q < K_{sp}$  ; the reaction proceeds to produce more products (dissolved ions), so more solid is able to dissolve: NO PRECIPITATION
- \*  $Q > K_{sp}$  ; the reaction proceeds to produce more reactants (solid), so solid falls out of solution: PRECIPITATION OCCURS
- \*  $Q = K_{sp}$  ; the reaction is at equilibrium. PRECIPITATION IS JUST BEGINNING

Would a solution with  $(Ag^+) = 0.014$  M and  $(Cl^-) = 0.00042$  M precipitate?

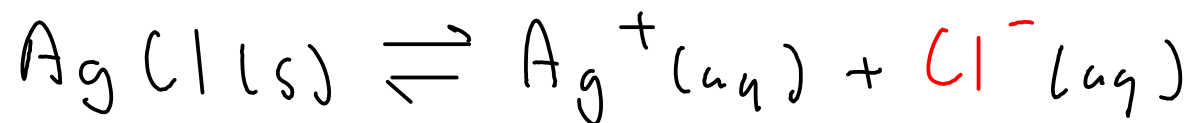
$$Q = [Ag^+][Cl^-] = (0.014)(0.00042) = 5.88 \times 10^{-6}$$

$$Q = 5.88 \times 10^{-6} > 1.8 \times 10^{-10}$$

$Q > K_{sp}$ , so PRECIPITATION OCCURS!

## Le Chateleur's Principle

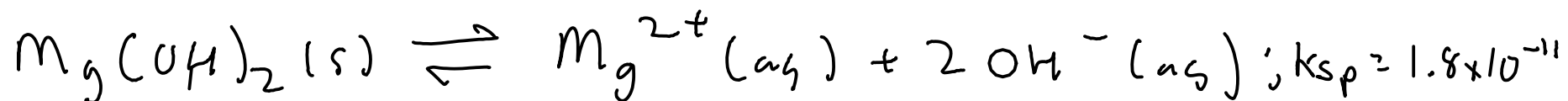
The "common ion effect" affects the solubility of a compound in solution. The presence of one of the ions in a salt in the solution will REDUCE THE SOLUBILITY of that salt!



Silver chloride is much less soluble in a solution of 0.1 M NaCl than it is in distilled water. Why? The presence of CHLORIDE ION forces the solubility equilibrium back to the left, meaning less silver chloride can dissolve!

Solubility can also be affected by pH - depending on the acidic or basic properties of the salt!

## pH AND SOLUBILITY



This salt's solubility is pH dependent. How?

- \* In a BASIC solution, the concentration of hydroxide ion in solution is high, so solubility is LOWER than in pure water.
- \* In an ACIDIC solution, we have a significant amount of hydronium, which can react with hydroxide. This lowers the hydroxide concentration and makes magnesium hydroxide MORE SOLUBLE

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### Generalizing

If a compound is BASIC, then it will be LESS SOLUBLE in basic solutions, and MORE SOLUBLE in acidic solutions!

If a compound is ACIDIC, then it will be MORE SOLUBLE in basic solutions, and LESS SOLUBLE in acidic solutions!

If a compound is NEUTRAL (neither acidic nor basic), then its solubility will be UNAFFECTED by pH