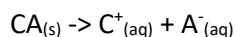


### Patterns in Calculations Involving Molar Solubility and $K_{sp}$

1. For a simple binary ionic compound with low solubility, the chemical equation for dissolution is:



and the solubility product (equilibrium constant) for the reaction is:

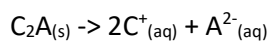
$$K_{sp} = [C^+] [A^-]$$

where  $[C^+]$  is the molar concentration of the cation and  $[A^-]$  is the molar concentration of the anion.

If the only species in solution are the products of CA, and its molar solubility is x, then

$$K_{sp} = x^2$$

2. If the compound has the formula  $C_2A$ :



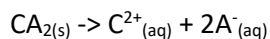
and

$$K_{sp} = [2C^+]^2 [A^{2-}]$$

If the only species in solution are the products of  $C_2A$ , and its molar solubility is x, then

$$K_{sp} = 4x^3$$

For  $CA_2$



and

$$K_{sp} = [C^{2+}] [2A^-]^2$$

Like  $C_2A$ ,  $CA_2$  with a molar solubility of x is

$$K_{sp} = 4x^3$$

3.  $C_2A_2$  is less common, but results in:

$$K_{sp} = 16x^4$$

4.  $C_3A$  and  $CA_3$  result in:

$$K_{sp} = 27x^4$$

5.  $C_3A_2$  and  $C_2A_3$  result in:

$$K_{sp} = 108x^5$$

Although other ion ratios are possible, they are rare. Follow the pattern demonstrated above to solve those questions.

Summarizing, to find  $K_{sp}$  when molar solubility is known:

Formula	$K_{sp}$
CA	$K_{sp} = x^2$
$C_2A$ or $CA_2$	$K_{sp} = 4x^3$
$C_2A_2$	$K_{sp} = 16x^4$
$C_3A$ or $CA_3$	$K_{sp} = 27x^4$
$C_3A_2$ or $C_2A_3$	$K_{sp} = 108x^5$

To find the molar solubility when  $K_{sp}$  is known:

Formula	Molar Solubility, x
CA	$x = \sqrt{K_{sp}}$
$C_2A$ or $CA_2$	$x = \sqrt[3]{K_{sp}/4}$
$C_2A_2$	$x = \sqrt[4]{K_{sp}/16}$
$C_3A$ or $CA_3$	$x = \sqrt[4]{K_{sp}/27}$
$C_3A_2$ or $C_2A_3$	$x = \sqrt[5]{K_{sp}/108}$

When two or more compounds contribute to the ions in solution, the common ion effect determines whether precipitation will take place. To determine whether a particular concentration of ion pairs will create a precipitate, and  $K_{sp}$  is known:

Formula	Solubility Quotient, $Q_{sp}$
CA	$Q_{sp} = [C^+] [A^-]$
$C_2A$	$Q_{sp} = [C^+]^2 [A^{2-}]$
$CA_2$	$Q_{sp} = [C^{2+}] [A^-]^2$
$C_2A_2$	$Q_{sp} = [C^+]^2 [A^-]^2$
$C_3A$	$Q_{sp} = [C^+]^3 [A^{3-}]$
$CA_3$	$Q_{sp} = [C^{3+}] [A^-]^3$
$C_3A_2$	$Q_{sp} = [C^{2+}]^3 [A^{3-}]^2$
$C_2A_3$	$Q_{sp} = [C^{3+}]^2 [A^{2-}]^3$

Calculate the  $Q_{sp}$  based on the given concentrations and the formula.

If  $Q_{sp} > K_{sp}$  then a precipitate will form.

If  $Q_{sp} < K_{sp}$  then a precipitate will not form.

If  $Q_{sp} = K_{sp}$  the system is at equilibrium.