Lesson 7
Solubility Calculations

Learning Goals

- ❑ I will be able to use the solubility product constant to calculate the solubility of a solute in water, and vice versa.

Example 1

Calculate the molar solubility of lead(II) chloride in water at 25 °C.

$$PbCl_2(s) \rightleftharpoons Pb^{2+}(aq) + 2\,Cl^-(aq) \qquad K_{sp} = 1.2\times10^{-5}$$

$x_{\text{ICE table}}$ = molar solubility

Step 1: ICE Table

	$PbCl_2(s)$	$\rightleftharpoons$	$Pb^{2+}(aq)$	+	$2\,Cl^-(aq)$
INITIAL CONCENTRATION	—		0		0
CHANGE IN CONCENTRATION	—		+x		+2x
EQUILIBRIUM CONCENTRATION	—		x		2x

SOLUBILITY PRODUCT CONSTANTS

Compound	K_{sp}
barium carbonate	2.6×10^{-9}
barium chromate	1.2×10^{-10}
barium sulfate	1.1×10^{-10}
calcium carbonate	5.0×10^{-9}
calcium hydroxide	5.0×10^{-6}
calcium phosphate	2.1×10^{-33}
calcium sulfate	7.1×10^{-5}
copper(I) chloride	1.7×10^{-7}
copper(I) iodide	1.3×10^{-12}
copper(II) iodate	6.9×10^{-8}
copper(II) sulfide	6.0×10^{-37}
iron(II) hydroxide	4.9×10^{-17}
iron(II) sulfide	6.0×10^{-19}
iron(III) hydroxide	2.6×10^{-39}
lead(II) bromide	6.6×10^{-6}
lead(II) chloride	1.2×10^{-5}
lead(II) iodate	3.7×10^{-13}
lead(II) iodide	8.5×10^{-9}
lead(II) sulfate	1.8×10^{-8}
magnesium carbonate	6.8×10^{-6}
magnesium fluoride	6.4×10^{-9}
magnesium hydroxide	5.6×10^{-12}
silver bromate	5.3×10^{-5}
silver bromide	5.4×10^{-13}
silver carbonate	8.5×10^{-12}
silver chloride	1.8×10^{-10}
silver chromate	1.1×10^{-12}
silver iodate	3.2×10^{-8}
silver iodide	8.5×10^{-17}
strontium carbonate	5.6×10^{-10}
strontium fluoride	4.3×10^{-9}
strontium sulfate	3.4×10^{-7}
zinc hydroxide	7.7×10^{-17}
zinc sulfide	2.0×10^{-25}

EQUILIBRIUM CONCENTRATION	—	x	2x

Step 2: **Calculate x**

$$K_{sp} = [Pb^{2+}][Cl^-]^2$$

$$1.2\times10^{-5} = (x)(2x)^2$$

$$1.2\times10^{-5} = 4x^3$$

$$\sqrt[3]{\frac{1.2\times10^{-5}}{4}} = x$$

$$0.014422... = x$$

Therefore, the molar solubility of lead(II) chloride in water at 25°C is 0.014 mol/L.

Example 2

$X_{ICE\ Table}$

A saturated aqueous solution of silver phosphate at 25 °C has a concentration of 4.26×10^{-5} mol/L. Calculate the solubility product constant for silver phosphate at 25 °C.

$$Ag_3PO_4(s) \rightleftharpoons 3\,Ag^+(aq) + PO_4^{3-}(aq) \qquad K_{sp} = ?$$

Step 1: **ICE Table**

	$Ag_3PO_4(s)$	$\rightleftharpoons$	$3\,Ag^+(aq)$	+	$PO_4^{3-}(aq)$
INITIAL CONCENTRATION	—		0		0
CHANGE IN CONCENTRATION	—		+3x		+x
EQUILIBRIUM CONCENTRATION	—		3x		x

EQUILIBRIUM CONCENTRATION	—	3x	x

Step 2: **Calculate K**

$$K_{sp} = [Ag^+]^3 [PO_4^{3-}]$$

$$= (3x)^3(x)$$

$$= 27x^4$$

$$= 27(4.26\times10^{-5})^4$$

$$= 8.8920...\times10^{-17}$$

Therefore, the solubility product constant for silver phosphate at 25°C is 8.89×10^{-17}.

Success Criteria

- ❑ I can use the solubility product to calculate the solubility of a solute in water, and vice versa.

PRACTICE:

- Worksheet: ‘PRACTICE: **SOLUBILITY CALCULATIONS**’