Exercise walk-through

Introduction to Solubility Equilibria ▪ 7.11

eXercise

You must be able to

- write the **solubility product** 溶度积 K_{sp} expression
- relate **molar solubility** 摩尔溶解度 to K_{sp}
- calculate one from the other

Method — The Ksp expression

For a sparingly soluble salt dissolving, e.g. $AgCl(s) \rightleftharpoons Ag^+ + Cl^-$:

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

The solid is omitted.

Method — Molar solubility

Let s be the moles of salt that dissolve per litre. Each formula unit gives ions according to its formula: for AgCl, $[\mathrm{Ag}^+] = [\mathrm{Cl}^-] = s$, so $K_{sp} = s^2$.

Method — A worked calculation

If $K_{sp}(\mathrm{AgCl}) = 1.8 \times 10^{-10}$, then $s = \sqrt{K_{sp}} = \sqrt{1.8 \times 10^{-10}} = 1.3 \times 10^{-5}$ M.

Method — Salts giving more ions

For $CaF_2 \rightleftharpoons Ca^{2+} + 2F^-$: $[Ca^{2+}] = s$, $[F^-] = 2s$, so $K_{sp} = s(2s)^2 = 4s^3$.

Practice 2.1 ▪ 1 mark

Write the K_{sp} expression for $BaSO_4 \rightleftharpoons Ba^{2+} + SO_4^{2-}$.

Solution 2.1

Method: The Ksp expression

Worked steps

$K_{sp} = [\mathrm{Ba}^{2+}][\mathrm{SO}_4^{2-}]$ **B1**.

Practice 2.2 ▪ 1 mark

For a 1:1 salt with molar solubility s, write K_{sp} in terms of s.

Solution 2.2

Method: Molar solubility

Worked steps

$K_{sp} = s^2$ B1.

Practice 2.3 ▪ 2 marks

If $K_{sp} = 4 \times 10^{-10}$ for a 1:1 salt, find s.

Solution 2.3

Worked steps

$s = \sqrt{4 \times 10^{-10}} = 2 \times 10^{-5}$ M **M1** **A1**.

Exam-style 3.1 ▪ 1 mark

For $AgCl \rightleftharpoons Ag^+ + Cl^-$ with molar solubility s, $K_{sp} =$

A s

B s^2

C $2s$

D $4s^3$

Solution 3.1

Method: Molar solubility

A s

B s^2 ✓

C $2s$

D $4s^3$

Worked steps

B — $K_{sp} = s^2$ for a 1:1 salt.

Exam-style 3.2 ▪ 2 marks

$PbCl_2 \rightleftharpoons Pb^{2+} + 2Cl^-$ has molar solubility s.
(a) Write $[Pb^{2+}]$ and $[Cl^-]$ in terms of s.
(b) Write K_{sp} in terms of s.

Solution 3.2

Method: Molar solubility

Worked steps

(a) $[Pb^{2+}] = s$, $[Cl^-] = 2s$ M1 A1. (b) $K_{sp} = s(2s)^2 = 4s^3$ M1 A1.

Exam-style 3.3 ▪ 3 marks

$K_{sp}(\mathrm{CaF_2}) = 3.2 \times 10^{-11}$, with $K_{sp} = 4s^3$. Find the molar solubility s.

Solution 3.3

Method: Molar solubility

Worked steps

$4s^3 = 3.2 \times 10^{-11}$ M1; $s^3 = 8 \times 10^{-12}$ M1; $s = 2 \times 10^{-4}$ M A1.