

Ksp, precipitation and the common ion effect

AP Chemistry · Worksheet answers

Each answer starts with the dissolving equation, then the Ksp expression, then the substitution. Final values are in bold. Check that your answers use the right power of s, because that is the most common source of lost marks.

Level: AP Chemistry · **Curriculum:** AP Chem Unit 7

Problem 1 Write the Ksp expressions

- (a) $\text{BaSO}_4(\text{s}) \rightleftharpoons \text{Ba}^{2+} + \text{SO}_4^{2-}$; **$K_{\text{sp}} = [\text{Ba}^{2+}][\text{SO}_4^{2-}]$** .
(b) $\text{PbI}_2(\text{s}) \rightleftharpoons \text{Pb}^{2+} + 2\text{I}^-$; **$K_{\text{sp}} = [\text{Pb}^{2+}][\text{I}^-]^2$** .
(c) $\text{Ag}_3\text{PO}_4(\text{s}) \rightleftharpoons 3\text{Ag}^+ + \text{PO}_4^{3-}$; **$K_{\text{sp}} = [\text{Ag}^+]^3[\text{PO}_4^{3-}]$** .

Problem 2 Solubility of silver bromide

$$s = \sqrt{5.4 \times 10^{-13}} = \mathbf{7.35 \times 10^{-7} \text{ mol/dm}^3}.$$

Problem 3 Precipitate or not

$Q = 3.0 \times 10^{-9}$ is larger than $K_{\text{sp}} = 1.8 \times 10^{-10}$, so the solution is supersaturated and **a precipitate of AgCl forms** until Q falls to Ksp.

Problem 4 Ksp from mass solubility

- $s = 0.043 / 303.3 = \mathbf{1.42 \times 10^{-4} \text{ mol/dm}^3}$.
- $K_{\text{sp}} = s^2 = \mathbf{2.01 \times 10^{-8}}$.

Problem 5 Ksp of calcium carbonate

- $K_{\text{sp}} = s^2 = (7.1 \times 10^{-5})^2 = \mathbf{5.04 \times 10^{-9}}$.
- $m = 7.1 \times 10^{-5} \times 100.1 = \mathbf{7.1 \text{ mg/dm}^3}$.

Problem 6 Which salts like acid?

Acid helps when the anion is basic. CO_3^{2-} and OH^- react with H_3O^+ ; Cl^- and SO_4^{2-} are very weak bases. **CaCO_3 and $\text{Mg}(\text{OH})_2$** dissolve better.

Problem 7 Lead(II) iodide

- $K_{\text{sp}} = 4s^3$, so $s = \sqrt[3]{(2.45 \times 10^{-9})} = \mathbf{1.348 \times 10^{-3} \text{ mol/dm}^3}$.
- $[\text{I}^-] = 2s = \mathbf{2.696 \times 10^{-3} \text{ mol/dm}^3}$.

Problem 8 Silver chromate

$s = \sqrt[3]{(1.1 \times 10^{-12} / 4)} = \sqrt[3]{(2.75 \times 10^{-13})} = 6.50 \times 10^{-5} \text{ mol/dm}^3$. $[\text{Ag}^+] = 2s = 1.30 \times 10^{-4} \text{ mol/dm}^3$.

Problem 9 Ksp of calcium hydroxide

$[\text{Ca}^{2+}] = 0.011$ and $[\text{OH}^-] = 0.022 \text{ mol/dm}^3$. $K_{sp} = 0.011 \times 0.022^2 = 5.32 \times 10^{-6}$. $\text{pOH} = 1.66$, so $\text{pH} = 12.34$.

Problem 10 Common ion effect

$[\text{Cl}^-] \approx 0.050$, so $s = 1.8 \times 10^{-10} / 0.050 = 3.60 \times 10^{-9} \text{ mol/dm}^3$. In pure water $s = 1.34 \times 10^{-5} \text{ mol/dm}^3$, so the solubility falls by a factor of 3727.

Problem 11 CaF_2 in fluoride solution

$[\text{F}^-] \approx 0.020$, so $s = [\text{Ca}^{2+}] = K_{sp}/[\text{F}^-]^2 = 3.5 \times 10^{-11} / (0.020)^2 = 8.75 \times 10^{-8} \text{ mol/dm}^3$. In pure water $s = 2.06 \times 10^{-4} \text{ mol/dm}^3$, about 2355 times larger.

Problem 12 Mixing two solutions

1. The volume doubles to 200.0 cm^3 , so $[\text{Ag}^+] = 1.0 \times 10^{-4}$ and $[\text{Cl}^-] = 2.0 \times 10^{-4} \text{ mol/dm}^3$.
2. $Q = (1.0 \times 10^{-4})(2.0 \times 10^{-4}) = 2.00 \times 10^{-8}$.
3. Q is greater than K_{sp} , so **AgCl precipitates**.

Problem 13 Magnesium hydroxide and acid

$\text{Mg}(\text{OH})_2(\text{s}) \rightleftharpoons \text{Mg}^{2+} + 2\text{OH}^-$. Added H_3O^+ reacts with OH^- : $\text{H}_3\text{O}^+ + \text{OH}^- \rightarrow 2\text{H}_2\text{O}$. Removing OH^- makes Q smaller than K_{sp} , so the equilibrium shifts right and **the solid dissolves**.

Problem 14 Which precipitates first?

1. $[\text{Ag}^+] = 1.8 \times 10^{-10} / 0.010 = 1.80 \times 10^{-8} \text{ mol/dm}^3$.
2. $[\text{Ag}^+] = \sqrt{(1.1 \times 10^{-12} / 0.010)} = 1.05 \times 10^{-5} \text{ mol/dm}^3$.
3. AgCl needs far less Ag^+ , so **AgCl precipitates first**.

Problem 15 Barium sulfate in a drink

$s = \sqrt{(1.1 \times 10^{-10})} = 1.05 \times 10^{-5} \text{ mol/dm}^3$. $n = 1.05 \times 10^{-5} \times 0.500 = 5.24 \times 10^{-6} \text{ mol}$. $m = 5.24 \times 10^{-6} \times 233.4 = 1.22 \text{ mg}$.

Problem 16 Buffered magnesium hydroxide

1. $s = \sqrt[3]{(5.6 \times 10^{-12} / 4)} = 1.12 \times 10^{-4} \text{ mol/dm}^3$; $[\text{OH}^-] = 2.24 \times 10^{-4}$; pH = **10.35**.
2. $[\text{OH}^-] = 1.0 \times 10^{-4}$, so $s = 5.6 \times 10^{-12} / (1.0 \times 10^{-4})^2 = \mathbf{5.60 \times 10^{-4} \text{ mol/dm}^3}$.
3. The buffer holds $[\text{OH}^-]$ below the value the dissolving would produce (2.2×10^{-4}), so more solid dissolves to reach K_{sp} .

Problem 17 Separating by precipitation

1. $[\text{Ag}^+] = \mathbf{1.05 \times 10^{-5} \text{ mol/dm}^3}$.
2. $[\text{Cl}^-] = 1.8 \times 10^{-10} / 1.05 \times 10^{-5} = \mathbf{1.72 \times 10^{-5} \text{ mol/dm}^3}$.
3. Remaining = 0.17 % of the original 0.010 mol/dm^3 . So **about 99.8 % of the chloride has been removed first**, which is a good separation.

Problem 18 Calcium fluoride precipitation

1. The volume doubles, so $[\text{Ca}^{2+}] = \mathbf{0.0020}$ and $[\text{F}^-] = \mathbf{5.0 \times 10^{-4} \text{ mol/dm}^3}$.
2. $Q = (0.0020)(5.0 \times 10^{-4})^2 = \mathbf{5.00 \times 10^{-10}}$, which is greater than K_{sp} , so **CaF_2 precipitates**.
3. $[\text{F}^-] = \sqrt{(3.5 \times 10^{-11} / 0.0020)} = \mathbf{1.32 \times 10^{-4} \text{ mol/dm}^3}$.

Problem 19 Iron(III) hydroxide and pH

1. $K_{sp} = [\text{Fe}^{3+}][\text{OH}^-]^3$.
2. $[\text{OH}^-] = 1.0 \times 10^{-7}$, so $[\text{Fe}^{3+}] = 2.8 \times 10^{-39} / (1.0 \times 10^{-7})^3 = \mathbf{2.8 \times 10^{-18} \text{ mol/dm}^3}$.
3. $[\text{OH}^-] = 1.0 \times 10^{-11}$, so $[\text{Fe}^{3+}] = \mathbf{2.8 \times 10^{-6} \text{ mol/dm}^3}$.
4. The solubility depends on $[\text{OH}^-]^3$. At pH 7 almost no iron stays dissolved, so brown $\text{Fe}(\text{OH})_3$ precipitates. At pH 3 it is a trillion times more soluble.

Problem 20 Error in the setup

1. The student used the 1:1 formula $s = \sqrt{K_{sp}}$, but Ag_2CrO_4 gives $2\text{Ag}^+ + \text{CrO}_4^{2-}$, so $K_{sp} = (2s)^2s = 4s^3$.
2. $s = \sqrt[3]{(2.75 \times 10^{-13})} = \mathbf{6.50 \times 10^{-5} \text{ mol/dm}^3}$.
3. Factor = $6.503 \times 10^{-5} / 1.049 \times 10^{-6} = \mathbf{\text{about } 62}$ times too small.