Year 13 Science: Solubility and Ks

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. Write the Ks expression for $PbCl_2$.

2. $Ks(BaSO_4) = 1.1 \times 10^{-10}$ at 25 °C. Calculate its solubility.

3. The solubility of CaF_2 is 2.1×10^{-4} mol L^{-1}. Calculate $Ks(CaF_2)$.

4. What happens to the solubility of AgCl when concentrated ammonia is added, and why?

5. Equal volumes of 2.0×10^{-4} mol L^{-1} $AgNO_3$ and 2.0×10^{-4} mol L^{-1} NaCl are mixed. Does AgCl precipitate? $Ks(AgCl) = 1.8 \times 10^{-10}$.

Exam-style question: zinc hydroxide

Zinc hydroxide, $Zn(OH)_2$, is a sparingly soluble white solid. $Ks(Zn(OH)_2) = 3.0 \times 10^{-17}$ at 25 °C.

6. Write the equation for the equilibrium in a saturated solution, and the Ks expression.

7. Calculate the solubility of $Zn(OH)_2$ in pure water.

8. Calculate its solubility in a solution of pH 12.00, and explain the difference.

9. When concentrated NaOH is added a little at a time, a white precipitate forms and then dissolves. Explain.

10. 10.0 mL of 2.0×10^{-4} mol L^{-1} $ZnSO_4$ is mixed with 10.0 mL of NaOH of pH 9.00. Will a precipitate form?

Fix the mistake

11. Correct this statement: "For PbI_2, $Ks = s \times 2s = 2s^2$."

12. Correct this statement: "Ag_2CrO_4 has a smaller Ks than AgCl, so it must be less soluble."

13. Correct this statement: "Adding NaCl to saturated AgCl lowers Ks."

14. Correct this statement: "Q is worked out from the concentrations of the two solutions before they are mixed."

Answer key (for parents and tutors)

1. Write the Ks expression for $PbCl_2$.
   $Ks = [Pb^{2+}][Cl^-]^2$.

2. $Ks(BaSO_4) = 1.1 \times 10^{-10}$ at 25 °C. Calculate its solubility.
   $s = \sqrt{(1.1 \times 10^{-10})} = 1.0 \times 10^{-5}$ mol L^{-1}.

3. The solubility of CaF_2 is 2.1×10^{-4} mol L^{-1}. Calculate $Ks(CaF_2)$.
   $Ks = 4s^3 = 4 \times (2.1 \times 10^{-4})^3 = 3.7 \times 10^{-11}$.

4. What happens to the solubility of AgCl when concentrated ammonia is added, and why?
   It increases: $Ag^+ + 2NH_3 \rightarrow [Ag(NH_3)_2]^+$ removes Ag^+, so the equilibrium shifts right and more AgCl dissolves.

5. Equal volumes of 2.0×10^{-4} mol L^{-1} $AgNO_3$ and 2.0×10^{-4} mol L^{-1} NaCl are mixed. Does AgCl precipitate? $Ks(AgCl) = 1.8 \times 10^{-10}$.
   After mixing each ion is 1.0×10^{-4} mol L^{-1}, so $Q = 1.0 \times 10^{-8}$, which is greater than $Ks = 1.8 \times 10^{-10}$: yes, a precipitate forms.

6. Write the equation for the equilibrium in a saturated solution, and the Ks expression.
   $Zn(OH)_2(s) \rightleftharpoons Zn^{2+}(aq) + 2OH^-(aq)$; $Ks = [Zn^{2+}][OH^-]^2$ (Achieved).

7. Calculate the solubility of $Zn(OH)_2$ in pure water.
   $Ks = 4s^3$, so $s = \sqrt[3]{(3.0 \times 10^{-17} \div 4)} = \sqrt[3]{(7.5 \times 10^{-18})} = 1.96 \times 10^{-6}$ mol L^{-1} (Merit).

8. Calculate its solubility in a solution of pH 12.00, and explain the difference.
   $[OH^-] = 1.0 \times 10^{-2}$ mol L^{-1}, so $s = 3.0 \times 10^{-17} \div (1.0 \times 10^{-2})^2 = 3.0 \times 10^{-13}$ mol L^{-1}. The added OH^- is a common ion: it shifts the equilibrium to the left, so far less dissolves (Merit for the value with the reason).

9. When concentrated NaOH is added a little at a time, a white precipitate forms and then dissolves. Explain.
   At first, OH^- raises Q above Ks, so $Zn(OH)_2$ precipitates. With excess OH^-, the complex ion forms, $Zn^{2+} + 4OH^- \rightarrow [Zn(OH)_4]^{2-}$, which removes Zn^{2+}; Q falls below Ks, the equilibrium shifts to the right, and the precipitate dissolves (Excellence).

10. 10.0 mL of 2.0×10^{-4} mol L^{-1} $ZnSO_4$ is mixed with 10.0 mL of NaOH of pH 9.00. Will a precipitate form?
    After mixing, $[Zn^{2+}] = 1.0 \times 10^{-4}$ and $[OH^-] = 1.0 \times 10^{-5} \div 2 = 5.0 \times 10^{-6}$ mol L^{-1}, so $Q = 1.0 \times 10^{-4} \times (5.0 \times 10^{-6})^2 = 2.5 \times 10^{-15}$. Q is greater than $Ks = 3.0 \times 10^{-17}$, so a precipitate forms (Excellence for the full calculation with dilution).

11. Correct this statement: "For PbI_2, $Ks = s \times 2s = 2s^2$."
    The iodide concentration is 2s and it is squared: $Ks = s \times (2s)^2 = 4s^3$.

12. Correct this statement: "Ag_2CrO_4 has a smaller Ks than AgCl, so it must be less soluble."
    Ks values compare solubility only for solids of the same type; work out s for each.

13. Correct this statement: "Adding NaCl to saturated AgCl lowers Ks."
    Only temperature changes Ks; the common ion lowers the solubility, s.

14. Correct this statement: "Q is worked out from the concentrations of the two solutions before they are mixed."
    Mixing dilutes both, so find each ion's concentration in the total volume first.