Real Life Ksp Problems

1) Barium sulfate, $BaSO_4$, is used in medical imaging of the gastrointestinal tract because it is opaque to X rays. A barium sulfate solution, sometimes called a cocktail, is ingested by the patient, whose stomach and intestines can then be visualized via X-ray imaging. If a patient ingests 320 mL of a saturated barium sulfate solution, how much toxic Ba^{+2} ion has the patient consumed?

x x x

The solubility product , Ksp of barium sulfate is 1.1×10^{-10}.

$Ba^{2+}SO_4(s) \rightleftharpoons Ba^{2+}(aq) + SO_4^{2-}(aq)$

Express your answer numerically in grams. $(4.6 \times 10^{-4} g)$

$Ksp = [Ba^{2+}][SO_4^{2-}]$

$1.1 \times 10^{-10} = (x)(x)$

$X = 1.05 \times 10^{-5}$ mol/L $= x^2$

$1.05 \times 10^{-5} \frac{mol}{L} \times 0.32 L \times \frac{137.32 g}{1 mol} =$

2) There are some data that suggest that zinc lozenges can significantly shorten the duration of a cold. ~~If the solubility~~ of zinc acetate, is 43.0g/L, what is the solubility product Ksp of this compound? ~~(5.13 x 10^-2)~~ ✓

② $Zn(C_2H_3O_2)_2 \rightleftharpoons Zn^{2+} + 2C_2H_3O_2^-$

① $\frac{43.0 g}{1 L} \times \frac{1 mol}{183.39 g} = 0.234 \frac{mol}{L}$

$= .234 \frac{mol}{L}$ $0.468 \frac{mol}{L}$

$Zn^{2+}(C_2H_3O_2)_2^- = 183.g/mol$

65.39 $12 \times 2 \times 2 = 48$

③ $Ksp = [Zn^{2+}][C_2H_3O_2^-]^2$ $16 \times 2 \times 2 = 64$

$1 \times 3 \times 2 = 6$

$= (.234)(.468)^2$

$Ksp = 0.0513 = 5.13 \times 10^{-2}$

Mixing Problems with Ksp

In predicting the precipitation in reactions:

Knowing the solubility product of a salt, it is possible to predict **whether on mixing the solution of its ions, a precipitate will be formed or not. For precipitation to occur, its ionic product should exceed solubility product.** Therefore, to predict the precipitation reaction, we calculate the ionic product of the ions and find out whether it is greater than K_{sp} or not.

Thus:

If the Ion Product is greater than the Ksp value = precipitation occurs

If the Ion Product is less than the Ksp value = precipitation doe not occur

For example in order to precipitate barium sulfate from a solution of barium chloride at a concentration of 0.5 M, the precipitation is done by adding sulfuric acid in small amounts to the solution. Initially no precipitation occurs because the small amount of SO_4^{2-} is insufficient to make the ionic product, $[Ba^{2+}]\,[SO_4^{2-}]$ equal to solubility product of barium sulfate. When we have added sufficient amount of sulfuric acid is added so that the ionic product exceeds solubility product, barium sulfate would get precipitated.

1. The concentration of Ca^{++} in blood is 0.0025M. If an oxalate solution with oxalate ion concentration 1×10^{-7}M is added to it, state whether precipitation occurs or not. Solubility product of calcium oxalate = 2.3×10^{-9}.

$K_{trial} = [Ca^{2+}][C_2O_4^{2-}] = (.0025)(1 \times 10^{-7}) = 2.5 \times 10^{-10} < K_{sp}$

∴ no ppt

2. A solution is prepared by mixing equal volumes of 0.010 M $MgCl_2$, and 0.020 M MgC_2O_4 at 18°C. Would MgC_2O_4 precipitate out? K_{sp} of MgC_2O_4 at 18°C = 8.57×10^{-5}.

$K_{trial} > K_{sp}$ ∴ ppt

$MgCl_2 + MgC_2O_4 \rightarrow MgC_2O_4$

.010M, 1L + .020M, 1L

.020 mol/2L = .010M $[C_2O_4^{2-}]$

$K_{trial} = [Ca^{2+}][C_2O_4^{2-}] = (.015)(.010) = 1.5 \times 10^{-4}$

.010 mol/L × 1L = .010 mol Mg^{2+}

K_{trial} .020 mol/L × 1L = .020 mol Mg^{2+}

.030 mol Mg^{2+} / 2L = .015 mol/L = $[Mg^{2+}]$

Ksp Problems

1. The digestion of some foods, such as red meat, releases the urate ion C5H3N4O3- into the bloodstream. An excess of urate in the blood can result in the formation of sodium urate crystals in joints and tissues. This leads to a painful form of arthritis known as **gout.**

The equilibrium involved in the process is:

-12×5=60 14×4=56

Na C5H3N4O3(s) ←→ Na+(aq) + C5H3N4O3-(aq)

1×3=3 16×3=48

23

a) Use Le Chatelier's principle to explain why eliminating red meat from your diet can reduce the build-up of sodium urate in joints.

1) ↓ meat = ↓ urate ion conc
2) sys wants to ↑ the urate ion conc
3) sys shifts right to bring urate back up
4) am't of crystals ↓ (not conc.)

b) Gout can be caused by an error in nucleic acid metabolism that leads to a buildup of uric acid in body fluids, which is deposited as slightly soluble sodium urate (C5H3N4O3Na) in the soft tissues of joints. If the extracellular [Na+] is 0.16 M and the solubility in water of sodium urate is 0.066 g/100 mL, what is the minimum urate ion concentration (abbreviated [Ur -]) that will cause a deposit of sodium urate? (7.5×10^{-5} M [Ur-])

0.066g/100mL

Sodium urate(s) → sodium$^+_{(aq)}$ + urate$^-_{(aq)}$

$Ksp = [Na^+][Ur^-]$
$= (3.5 \times 10^{-3})(3.5 \times 10^{-3}) = 1.2 \times 10^{-5}$

$\frac{.066g}{100mL} \times \frac{1000mL}{1L} \times \frac{1mol}{190g} = 3.5 \times 10^{-3}\ \frac{mol}{L}$

$\frac{Ksp}{[Na^+]} = \frac{[Na^+][Ur^-]}{[Na^+]} = \frac{1.2 \times 10^{-5}}{.16 M} = 7.5 \times 10^{-5}$ M [Ur-]

2. **Kidney Stone Formation**

The supersaturation theory of kidney stone formation is based on the binding of salts, which occurs after a certain concentration is obtained. A compound's thermodynamic solubility product (Ksp) defines the saturation of a compound in a solution. The Ksp of a compound is equal to the product of a pure chemical in equilibrium between a solid and solvent in solution. **If the salt concentration is less than the Ksp, the compound remains in solution. However, if the salt concentration exceeds the Ksp, the compound precipitates.** Temperature and the pH of a solution also affect solubility. Calcium oxalate and calcium phosphate are the most frequently encountered compounds.

Urine is a complex mixture of many salts in solution. **When the concentration of ions that comprise these salts rises above their solubility product the urine is supersaturated and salt crystals (e.g. calcium oxalate) precipitate.** These precipitated crystals accumulate to form stones.

Although very small renal stones can pass unnoticed as **gravel** in urine, the passage of larger stones and even movement of stones within the urinary tract is the cause of the most excruciating pain a person is ever likely to experience. Such pain has afflicted man since antiquity, as evidence of renal stone disease has been found in an Egyptian **mummy** dating from 7000 BC.

a) Write the equation for the equilibrium of $CaC_2O_4(s)$ in water.

$$CaC_2O_4(s) \rightleftharpoons Ca^{+2}_{(aq)} + C_2O_4^{2-}{}_{(aq)}$$

5.2×10^{-8}

b) Given the Ksp of $CaC_2O_4(s)$ is 2.7×10^{-9}, will a precipitate (stone) form if 50.0 mL of 0.0050 M calcium chloride is mixed with 75.0 mL of sodium oxalate? at the same conc? (4.2×10^{-5} M)

$$0.0500\,L \times 0.0050\,\frac{mol}{L}\ CaCl_2(s) \rightleftharpoons Ca^{+2}_{aq} + 2Cl^-_{aq}$$

.00025 mol / .125 L

$$.0750\,L \times 0.42 \times 10^{-5}\,\frac{mol}{L}\ Na_2C_2O_4(s) \rightleftharpoons Na^+_{(aq)} + C_2O_4^{2-}{}_{(aq)}$$

3.2×10^{-6} mol / .125 L

$$K_{trial} = [Ca^{2+}][C_2O_4^{2-}]$$
$$= (.0020)(.000026)$$
$$= 5.2 \times 10^{-8}$$

yes a ppt forms = kidney stone forms