Chemistry 12

Solubility Equilibrium Review Package

Name: Key
Date:
Block:

I. Multiple Choice

1. Which one of the following would form an ionic solution when dissolved in water?

A. I_2 C. $Ca(NO_3)_2$
B. CH_3OH D. $C_{12}H_{22}O_{11}$

soluble in water (pg. 4 databooklet)

~~2. In a saturated solution of $Zn(OH)_2$, the $[Zn^{2+}]$ is:~~

~~A. less than 0.10 M~~ ~~C. more than 0.10 M, but less than 1.0 M~~
~~B. more than 10.0 M~~ ~~D. more than 1.0 M, but less than 10.0 M~~

3. The **complete** ionic equation for the reaction between $MgCl_2$ and $AgNO_3$ is

A. $Ag^+_{(aq)} + Cl^-_{(aq)} \rightarrow AgCl_{(s)}$
B. $2AgNO_{3(aq)} + MgCl_{2(aq)} \rightarrow 2AgCl_{(s)} + Mg(NO_3)_{2(aq)}$
C. $2Ag^+_{(aq)} + Mg^{2+}_{(aq)} + 2NO_3^-{}_{(aq)} + 2Cl^-_{(aq)} \rightarrow MgCl_{2(s)} + 2Ag^+_{(aq)} + 2NO_3^-{}_{(aq)}$
D. $2Ag^+_{(aq)} + Mg^{2+}_{(aq)} + 2NO_3^-{}_{(aq)} + 2Cl^-_{(aq)} \rightarrow 2AgCl_{(s)} + Mg^{2+}_{(aq)} + 2NO_3^-{}_{(aq)}$

4. Which of the following would precipitate out both Ca^{2+} and Mg^{2+}?

A. S^{2-} C. SO_4^{2-}
B. PO_4^{3-} D. CH_3COO^-

low solubility

5. The $[SO_4^{2-}]$ in a saturated solution of $PbSO_4$ is:

A. 1.2×10^{-16} M C. 1.1×10^{-8}M
B. 5.0×10^{-9}M D. 1.3×10^{-4}M

$PbSO_4 \rightleftharpoons \underset{s}{Pb^{2+}} + \underset{s}{SO_4^{2-}}$

$K_{sp} = 1.8 \cdot 10^{-8} = s^2$

$1.3 \cdot 10^{-4} = s = [SO_4^{2-}]$

6. Which one of the following salts is soluble?

alkali ion

A. $BaSO_4$ B. $CaCO_3$ C. K_3PO_4 D. $Fe(OH)_2$

7. The compound Ag_2S has a solubility of 1.3×10^{-4} M at 25°C. The K_{sp} for this compound is:

A. 2.2×10^{-12} C. 1.7×10^{-8}
B. 8.8×10^{-12} D. 3.4×10^{-8}

$\underset{s}{Ag_2S} \rightleftharpoons \underset{2s}{2Ag^+} + \underset{s}{S^{2-}}$

$K_{sp} = (2s)^2(s)$
$= 4s^3$
$= 4(1.3 \cdot 10^{-4})^3$
$= 8.8 \cdot 10^{-12}$

8. Which of the following could be used to express solubility?

A. mol B. M/s C. g/mL D. mL/min

9. When 100.0 mL of a saturated solution of BaF_2 is heated and all the water is evaporated, 3.6×10^{-4} mol of solute remains. The solubility of BaF_2 is:

A. 1.9×10^{-10} M B. 1.3×10^{-5} M C. 3.6×10^{-4} M D. 3.6×10^{-3} M

$\frac{3.6 \cdot 10^{-4}\,\text{mol}}{0.100\,\text{L}}$

10. A solution contains both 0.2M Mg^{2+} and 0.2M Sr^{2+}. These ions can be removed separately through precipitation by adding equal volumes of 0.2M solutions of:

A. OH-, and then S^{2+}
B. Cl-, and then OH-
C. CO_3^{2-} and then SO_3^{2-}
D. SO_4^{2-} and then PO_4^{2-}

11. Consider the following equilibrium:

$$CaSO_{4(s)} \leftrightharpoons Ca^{2+}{}_{(aq)} + SO_4^{2-}{}_{(aq)}$$

Which of the following would shift the above equilibrium to the left?

A. adding $CaSO_{4(s)}$ no shift
B. adding $MgSO_{4(s)}$ ←
C. removing some $Ca^{2+}{}_{(aq)}$ →
D. removing some $SO_4^{2-}{}_{(aq)}$ →

12. Calculate the solubility of CaC_2O_4.

A. 2.3×10^{-9}M
B. 1.2×10^{-5} M
C. 4.8×10^{-5}M
D. 8.3×10^{-4}M

$$\underset{s}{CaC_2O_4} \rightleftharpoons \underset{s}{Ca^{2+}} + \underset{s}{C_2O_4^{2-}}$$
$K_{sp} = 2.3 \cdot 10^{-9} = s^2$
$4.8 \cdot 10^{-5} M = s = [CaC_2O_4]$

13. How many moles of dissolved solute are present in 100.0mL of a saturated $SrCO_3$ solution?

② $\frac{2.4 \cdot 10^{-5} mol}{L} \times \frac{0.100 L}{1} =$

① $\underset{s}{SrCO_3} \rightleftharpoons \underset{s}{Sr^{2+}} + \underset{s}{CO_3^{2-}}$
$K_{sp} = 5.6 \cdot 10^{-10} = s^2$
$2.4 \cdot 10^{-5} M = s = [SrCO_3]$

A. 5.6×10^{-11} mol
B. 2.4×10^{-6} mol
C. 2.4×10^{-5} mol
D. 2.4×10^{-4} mol

14. What happens when equal volumes of 0.2M $AgNO_3$ and 0.2M NaCl are combined?

$AgCl_{(s)}$ $K_{sp} = 1.8 \cdot 10^{-10}$

A. A precipitate forms because the trial ion product > K_{sp}
B. A precipitate forms because the trial ion product < K_{sp}
C. No precipitate forms because the trial ion product > K_{sp}
D. No precipitate forms because the trial ion product < K_{sp}

$TIP = [Ag^+][Cl^-]$
$= (0.2)(0.2)$
$= 4.0 \cdot 10^{-2}$
$TIP > K_{sp}$

15. Determine the maximum $[Na_2CO_3]$ that can exist in 1.0L of 0.0010M $Ba(NO_3)_2$ without forming a precipitate.

$BaCO_{3(s)}$ $K_{sp} = 2.6 \cdot 10^{-9} = [Ba^{2+}][CO_3^{2-}]$

A. 2.6×10^{-12} M
B. 2.6×10^{-9} M
C. 2.6×10^{-6} M
D. 5.1×10^{-5} M

$2.6 \cdot 10^{-9} = (0.0010)[CO_3^{2-}]$
$2.6 \cdot 10^{-6} M = [CO_3^{2-}]$

16. When a student mixes equal volumes of 0.20 M Na_2S and 0.20 M $Sr(OH)_2$,

A. no precipitate forms.
B. a precipitate of only SrS forms.
C. a precipitate of only NaOH forms.
D. precipitates of both NaOH and SrS form.

Both SrS & NaOH are soluble

17. A student wishes to identify an unknown cation in a solution. A precipitate does not form with the addition of SO_4^{2-}, but does form with the addition of S^{2-}. Which of the following is the unknown cation?

A. Ag^+ B. Mg^{2+} C. Ca^{2+} D. Cu^{2+}

18. The solubility of MnS is 4.8×10^{-7}M, at 25^{0}C. The K_{sp} value is

A. 2.3×10^{-13} B. 4.8×10^{-7} C. 9.6×10^{-7} D. 6.9×10^{-4}

$K_{sp} = [Mn^{2+}][S^{2-}]$
$= (4.8 \cdot 10^{-7})(4.8 \cdot 10^{-7}) = 2.3 \cdot 10^{-13}$

$[Ba(NO_3)_2] = \frac{0.050\,mol}{0.200\,L}$
$= 0.25\,M$

19. A 200.0mL solution contains 0.050 mol of $Ba(NO_3)_2$. The $[NO_3^-]$ is:

$Ba(NO_3)_2 \rightleftharpoons Ba^{2+} + 2NO_3^-$
0.25M → 0.50M
1:2

A. 0.050 M
B. 0.10 M
C. 0.25M
D. 0.50 M

20. Consider the following solubility equilibrium:

$$MgCO_{3(s)} \rightleftharpoons Mg^{2+}{}_{(aq)} + CO_3^{2-}{}_{(aq)}$$

The addition of which of the following substances would decrease the solubility of $MgCO_3$?

A. H_2O
B. NaCl
C. NaOH
D. Na_2CO_3

21. In a solubility equilibrium, the:

A. rate of dissolving equals the rate of crystallization.
B. neither dissolving nor crystallization are occurring.
C. concentration of solute and solvent are always equal.
D. mass of dissolved solute is greater than the mass of the solution.

22. Which of the following solutions would have $[Fe^{3+}]$= 0.020M?

A. 0.40 L of 0.050M $Fe(NO_3)_3$
B. 0.80 L of 0.020M $Fe_2(SO_4)_3$
C. 0.50 L of 0.040M $FeC_6H_5O_7$
D. 0.50L of 0.010M $Fe_2(C_2O_4)_3$

$Fe_2(C_2O_4)_3 \rightleftharpoons 2Fe^{3+} + 3C_2O_4^{2-}$
0.010M → 0.020M
1:2

23. Which of the following substances has the lowest solubility?

A. BaS
B. CuS
C. FeS
D. ZnS

smallest Ksp

24. The complete ionic equation for the reaction between MgS and $Sr(OH)_2$ is:

A. $MgS_{(aq)} + Sr(OH)_{2(aq)} \rightarrow Mg(OH)_{2(s)} + SrS_{(s)}$
B. $MgS_{(aq)} + Sr(OH)_{2(aq)} \rightarrow Mg(OH)_{2(s)} + SrS_{(aq)}$
C. $Mg^{2+}{}_{(aq)} + S^{2-}{}_{(aq)} + Sr^{2+}{}_{(aq)} + 2OH^-{}_{(aq)} \rightarrow Mg^{2+}{}_{(aq)} + 2OH^-{}_{(aq)} + SrS_{(s)}$
D. $Mg^{2+}{}_{(aq)} + S^{2-}{}_{(aq)} + Sr^{2+}{}_{(aq)} + 2OH^-{}_{(aq)} \rightarrow Mg(OH)_{2(s)} + Sr^{2+}{}_{(aq)} + S^{2-}{}_{(aq)}$

25. Consider the following equilibrium:

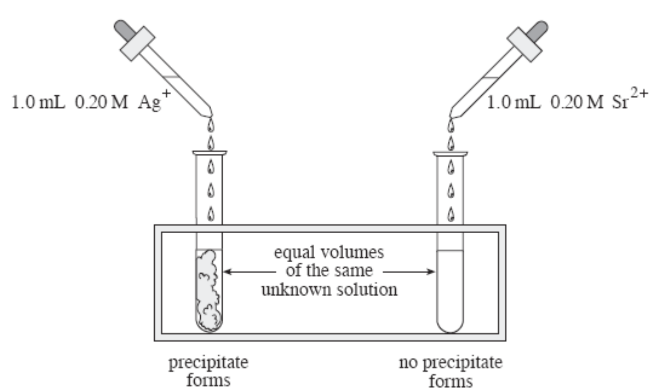
$$Fe(OH)_{2(s)} \rightleftharpoons Fe^{2+}{}_{(aq)} + 2OH^-{}_{(aq)}$$

Which of the following will cause the equilibrium to shift to the right?

A. adding KOH
B. adding Na_2S
C. adding $Fe(OH)_2$
D. adding $Fe(NO_3)_2$

$FeS_{(s)}$ ppt

26. Consider the following experiment:



The unknown solution could contain

A. 0.20M OH-
B. 0.20M NO_3^{-1}
C. 0.20M PO_4^{3-}
D. 0.20M SO_4^{2-}

$K_{sp} = 5.0 \cdot 10^{-9} = s^2$
$7.1 \cdot 10^{-5} M = s$

27. A compound has a solubility of 7.1×10^{-5}M at 25^0C. The compound is:
A. CuS B. AgBr C. $CaCO_3$ D. $CaSO_4$

28. In a saturated solution of KNO_3, the rate of crystallization is:
A. equal to zero.
B. equal to the rate of dissolving.
C. less than the rate of dissolving.
D. greater than the rate of dissolving.

29. At a certain temperature, the solubility of BaF_2 is 7. 4 x 10^{-3} M. The K_{sp} of BaF_2 is:
A. 1.6 x 10^{-6} B. 5.5 x 10^{-5} C. 1.1 x 10^{-4} D. 7. 4 x10^{-3}

$K_{sp} = [Ba^{2+}][F]^2$
$= (s)(2s)^2$
$= 4s^3$
$= 4(7.4 \cdot 10^{-3})^3$

30. What is the maximum $[Sr^{2+}]$ that can exist in a solution of 0.10 M Na_2SO_4 ?
A. 3. 4 x10^{-7} M
B. 3. 4 x 10^{-6} M
C. 1. 7 x 10^{-6} M
D. 5.8 x 10^{-4} M

$SrSO_4$ $K_{sp} = 3.4 \cdot 10^{-7}$
$3.4 \cdot 10^{-7} = [Sr^{2+}](0.10)$

31. A student could precipitate silver chloride from a saturated solution of silver chloride by adding
A. water.
B. sodium iodide.
C. sodium nitrate.
D. sodium chloride.

32. When equal volumes of 0.20M $SrBr_2$ and 0.20M $AgNO_3$ are combined,
A. no precipitate forms.
B. a precipitate of only AgBr forms.
C. a precipitate of only $Sr(NO_3)_2$ forms.
D. precipitates of both AgBr and Sr $(NO_3)_2$ form.

AgBr $K_{sp} = 5.4 \cdot 10^{-13}$

TIP > K_{sp}

33. Consider the following solubility equilibrium:

$$PbCl_{2(s)} \leftrightharpoons Pb^{2+}_{(aq)} + 2Cl^-_{(aq)}$$

A student adds NaCl to a saturated solution of $PbCl_2$. When equilibrium is reestablished, how have the concentrations changed from the original equilibrium?
A. $[Pb^{2+}]$ and [Cl-] both increased.
B. $[Pb^{2+}]$ and [Cl-] both decreased.
C. $[Pb^{2+}]$ decreased and [Cl-] increased.
D. $[Pb^{2+}]$ increased and [Cl-] decreased

34. Solid Ag_2CrO_4 is added to water to form a saturated solution. The K_{sp} value can be calculated by

A. $K_{sp} = [CrO_4^{2-}]^2$

B. $K_{sp} = [CrO_4^{2-}]^3$

C. $K_{sp} = \frac{[CrO_4^{2-}]^3}{2}$

D. $K_{sp} = 4[CrO_4^{2-}]^3$

$$\underset{}{Ag_2CrO_4} \rightleftharpoons \underset{2s}{2Ag^+} + \underset{s}{CrO_4^{2-}}$$

$K_{sp} = (2s)^2(s)$
$= 4s^3$

II. Short Answer:

1. A chemistry stockroom contains a bottle of 12.0 M HCl. A teacher needs to make up 800.0 mL of a 3.0 M solution of HCl. What volume of the stock solution (12.0 M) does the teacher need to use?

$$C_1V_1 = C_2V_2$$
$$(12.0\,M)(V_1) = (3.0\,M)(800.0\,mL)$$
$$V_1 = \boxed{200.0\,mL}$$

2. A student has 600.0 mL of a 0.30 M solution of HNO_3. How much water must she add in order to make it a 0.15 M solution?

$$C_1V_1 = C_2V_2$$
$$(0.30\,M)(600.0\,mL) = (0.15\,M)(V_2)$$
$$V_2 = 1200.\,mL$$
$$V_2 - V_1 = \text{mL of water to add}$$
$$1200 - 600.0 = \boxed{600.0\,mL \text{ must be added}}$$

3. An aqueous solution of $Pb(NO_3)_2$ is mixed with an aqueous solution of KBr and a precipitate forms.

   a. Write a balanced formula equation for this reaction. (Include all subscripts.)

$$Pb(NO_3)_{2(aq)} + 2KBr_{(aq)} \rightleftharpoons PbBr_{2(s)} + 2KNO_{3(aq)}$$

   b. Write a balanced total ionic equation for this reaction. (Include all subscripts.)

$$Pb^{2+}_{(aq)} + 2NO_3^-{}_{(aq)} + 2K^+_{(aq)} + 2Br^-_{(aq)} \rightleftharpoons PbBr_{2(s)} + 2K^+_{(aq)} + 2NO_3^-{}_{(aq)}$$

   c. Write a balanced net ionic equation for this reaction. (Include all subscripts.)

$$Pb^{2+}_{(aq)} + 2Br^-_{(aq)} \rightleftharpoons PbBr_{2(s)}$$

4. Devise a procedure to separate the ions Ba^{2+}, Mg^{2+}, Ag^+

One possibility:

① Add $NaCl_{(aq)}$ → $AgCl_{(s)}$ ppt; Ba^{2+}, Mg^{2+} remain

② Add $Na_2SO_{4(aq)}$ → $BaSO_{4(s)}$ ppt; Mg^{2+} remains

③ Add $NaOH_{(aq)}$ → $Mg(OH)_{2(s)}$ ppt

5. Calculate the molar solubility of the following solutions:

a. $BaCO_3$

$$BaCO_3 \rightleftharpoons \underset{s}{Ba^{2+}} + \underset{s}{CO_3^{2-}}$$

$$K_{sp} = \sqrt{2.6 \cdot 10^{-9}} = \sqrt{s^2}$$

$$s = \boxed{5.1 \cdot 10^{-5} M}$$

b. $Mg(OH)_2$

$$Mg(OH)_2 \rightleftharpoons \underset{s}{Mg^{2+}} + \underset{2s}{2OH^-}$$

$$K_{sp} = 5.6 \cdot 10^{-12} = 4s^3$$

$$s = \sqrt[3]{\frac{5.6 \cdot 10^{-12}}{4}} = \boxed{1.1 \cdot 10^{-4} M}$$

6. Will a precipitate form if 100 mL of 1.0×10^{-3} M $Pb(NO_3)_2$ solution is added to 100.0 mL of 2.0×10^{-3} M $MgSO_4$ solution? Show all calculations and include the Trial Ksp.

$$Pb(NO_3)_{2(aq)} + MgSO_{4(aq)} \rightleftharpoons Mg(NO_3)_{2(aq)} + PbSO_{4(s)}$$

$[Pb(NO_3)_2]$

$$C_1V_1 = C_2V_2$$

$$(1.0 \cdot 10^{-3})(100.0) = C_2(200.0)$$

$$C_2 = 5.0 \cdot 10^{-4} M = [Pb^{2+}]$$

$[MgSO_4]$

$$C_1V_1 = C_2V_2$$

$$(2.0 \cdot 10^{-3})(100.0) = C_2(200.0)$$

$$C_2 = 1.0 \cdot 10^{-3} M = [SO_4^{2-}]$$

$$PbSO_4 \rightleftharpoons Pb^{2+} + SO_4^{2-}$$

$$TIP = [Pb^{2+}][SO_4^{2-}]$$

$$= (5.0 \cdot 10^{-4})(1.0 \cdot 10^{-3})$$

$$= 5.0 \cdot 10^{-7}$$

Actual Ksp $= 1.8 \cdot 10^{-8}$

$\boxed{\text{TIP} > K_{sp}}$ ppt will form