# Chemistry 12 - Solubility Equilibrium Answer Key

1. D
2. A
3. B
4. C
5. a) add solute to solvent until no more solute dissolves

b) $Be_3(PO_4)_2(s) \leftrightarrows 3Be^{2+}(aq) + 2PO_4^{3-}(aq)$

6. D
7. C
8. A
9. B
10. A
11. C
12. C
13. D
14. A
15. B
16. D
17. D
18. A
19. B
20. D
21. B
22. B
23. D
24. B
25. D
26. B
27. B
28. C
29. B
30. D
31. B
32. D
33. C
34. A
35. A
36. A
37. D
38. B
39. B
40. D
41. D
42. C
43. D
44. D
45. D
46. C
47. C
48. B
49. B
50. A
51. D
52. B
53. D
54. C
55. D
56. B
57. B
58. See answer
59. See answer
60. A
61. A
62. A
63. D
64. A
65. D
66. D
67. See answer
68. See answer
69. See answer
70. See answer
71. A
72. B
73. A
74. B
75. B
76. B
77. A
78. B
79. A
80. A
81. A
82. B
83. C
84. B
85. D
86. A
87. B
88. B
89. B

90. D
91. A
92. D
93. A
94. B
95. B
96. B
97. A
98. B
99. B
100. A
101. A
102. C
103. A
104. D
105. D
106. A
107. A
108. Ksp = $1.4 \times 10^{-7}$
109. Ksp = $3.9 \times 10^{-13}$
110. D
111. C
112. D
113. C
114. A
115. B
116. C
117. A
118. A
119. D
120. C
121. B
122. 0.11g/L
123. 0.041g/L
124. $[IO_3^-] = 0.0052M$
125. D
126. D
127. D
128. A
129. A
130. B
131. Ksp(T) = $6.9 \times 10^{-8}$, Ksp(T)<Ksp = no ppt.
132. Ksp(T) = $1.1 \times 10^{-10}$, Ksp(T)< Ksp = no ppt.
133. Ksp(T) = $7.0 \times 10^{-10}$, Ksp(T)>Ksp = ppt.
134. C
135. C
136. A
137. D
138. A
139. A
140. D
141. C
142. $[CO_3^{2-}] = 0.0068M$
143. $[CO_3^{2-}] = 8.5 \times 10^{-6}M$
144. mass NaI = $4.9 \times 10^{-9}$g
145. mass NaCl = $2.6 \times 10^{-7}$g
146. mass $BaCl_2$ = 0.13g
147. A
148. B
149. A
150. B
151. C
152. A
153. C
154. C
155. B
156. D
157. C
158. D
159. B
160. D
161. A
162. C
163. C
164. Ksp = $1.20 \times 10^{-5}$
165. See answer
166. See answer
167. Ksp(T) = $7.4 \times 10^{-9}$, Ksp(T)>Ksp = ppt.
168. Mass NaCl = 0.51g
169. C
170. C

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# Prescribed Learning Outcomes - Chemistry 12

## Solubility Section

### G: Solubility Equilibria (Concept of Solubility)

G1: Classify solutions as ionic or molecular given the formula of the solute
G2: Describe the conditions necessary to form a saturated solution
G3: Describe solubility as the concentration of a substance in a saturated solution
G4: Use appropriate units to represent the solubility of substances in aqueous solutions
G5: Measure the solubility of a compound in aqueous solution
G6: Describe the equilibrium that exists in a saturated solution
G7: Write a net ionic equation that describes a saturated solution
G8: Calculate the concentration of the positive and negative ions given the concentration of a solute in an aqueous solution

### H: Solubility Equilibria (Solubility and Precipitation)

H1: Describe a compound as having high or low solubility relative to 0.1 M by using a solubility chart
H2: Use a solubiltiy chart to predict if a precipitate will form when two solutions are mixed, and identify the precipitate
H3: Write a formula equation, complete ionic equation, and net ionic equation that represents a precipitation reaction
H4: Use a solubility chart to predict if ions can be separated from solution through precipitation, and outline the process
H5: Predict qualitative changes in the solubility equilibrium upon the addition of a common ion
H6: Identify an unknown ion through experimentation involving a qualitative analysis scheme
H7: Devise a procedure by which the contaminating ions in hard or polluted water can be removed

### I: Solubility Equilibria (Quantitative Aspects)

I1: Describe the $K_{sp}$ expression as a specialized $K_{eq}$ expression
I2: Write a $K_{sp}$ expression for a solubility equilibrium
I3: Calculate the $K_{sp}$ for AB and $AB_2$ type compounds when given the solubility of a compound
I4: Calculate the solubility of AB and $AB_2$ type compounds from the $K_{sp}$
I5: Predict the formation of a precipitate by comparing the trial ion product to the $K_{sp}$ value using specific data
I6: Calculate the maximum concentration of one ion given the $K_{sp}$ and the concentration of the other ion
I7: Demonstrate and describe a method for determining the concentration of a specific ion

## G1 - Classify solutions as ionic or molecular given the formula of the solute

1. Which of the following will dissolve to form a molecular solution?
   A. $H_2SO_4$ B. $AgNO_3$ C. $Ca(OH)_2$ D. $C_6H_{12}O_6$

2. Which of the following is both ionic and most soluble?
   A. RbOH B. $CH_3OH$ C. $Ca(OH)_2$ D. $Fe(OH)_3$

## G2- Describe the conditions necessary to form a saturated solution

3. In every solubility equilibrium, the rate of dissolving is
   A. equal to zero
   B. equal to the rate of crystallization
   C. less than the rate of crystallization
   D. greater than the rate of crystallization

4. Given a saturated solution of $Ca(OH)_2$, which of the following statements is always true?
   A. The $[Ca^{+2}]$ is twice that of $[OH^-]$
   B. The $OH^-$ precipitates half as fast as the $Ca^{+2}$
   C. The rate of crystallization equals the rate of dissolving
   D. The rate of dissolving is greater than the rate of crystallization

5. a. How would a saturated solution be prepared at room temperature?

   b. Write a chemical equation to illustrate the equilibrium that exists in a saturated solution of $Be_3(PO_4)_2$.

## G3 - Describe solubility as the concentration of a substance in a saturated solution

6. Which of the following does not define solubility?
   A. the concentration of solute in a saturated solution.
   B. the moles of solute dissolved in a given volume of solution
   C. the maximum mass of solute that can dissolve in a given volume of solution
   D. the minimum moles of solute needed to produce one litre of saturated solution

7. Which of the following will dissolve in water to produce a molecular solution?
   A. $CaCl_2$ B. NaOH C. $CH_3OH$ D. $Sr(OH)_2$



## G4 - Use appropriate units to represent the solubility of substances in aqueous solutions

8. Which of the following could be used to express solubility?
   A. mol/mL B. M/s C. g/min D. mL/mol

9. Which of the following would best describe the solubility of a solute?
   A. litres per gram B. moles per litre C. grams per mole D. moles per second

10. The following data was collected to determine the solubility of a substance:

| | |
|---|---|
| Mass of solute dissolved | 5.00 g |
| Volume of solvent | 250.0 mL |
| Molar mass of solute | 100.0 g/mol |
| Molar mass of solvent | 20.0 g/mol |

    Which of the following best describes its solubility?
    A. $2.00 \times 10^{-2}$ g/mL
    B. $5.00 \times 10^{-2}$ mol
    C. 0.250 mol
    D. 1.00 mol/L

11. Which of the following is commonly used to describe the solubility of a solute?
    A. mass of solute / moles of solute
    B. moles of solute / mass of solute
    C. mass of solute / volume of solution
    D. mass of solution / volume of solute

## G5 - Measure the solubility of a compound in aqueous solution

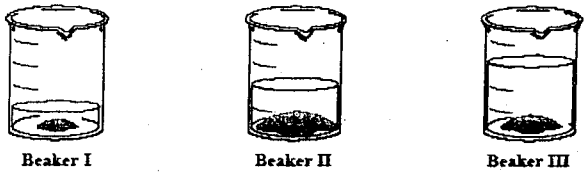
12. Which of the following could be used to express solubility?
    A. mol B. M/s C. g/mL D. mL/min

13. When 100.0 mL of a saturated solution of $BaF_2$ is heated and all the water is evaporated. $1.753 \times 10^{-2}$ grams of solute remains. The solubility of $BaF_2$ is
    A. $1.753 \times 10^{-2}$ M B. $1.753 \times 10^{-5}$ M C. $1.000 \times 10^{-4}$ M D. $1.000 \times 10^{-3}$ M

## G6 - Describe the equilibrium that exists in a saturated solution

14. Consider the following diagram:

The following three beakers each contain different volumes of a saturated solution of $PbI_2$ and different masses of solid $PbI_2$ :




What is the relationship for the $[Pb^{2+}]$ in the solution in the three beakers?

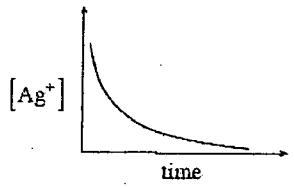
A. I = II = III
B. I > II > III
C. I < III < II
D. II < III < I

15. Consider the following equilibrium:

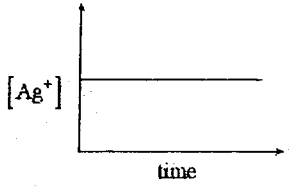
$$AgCl_{(s)} \leftrightarrows Ag^{+}_{(aq)} + Cl^{-}_{(aq)}$$

Which of the following graphs best describes the $[Ag^{+}_{(aq)}]$ after equilibrium has been established?

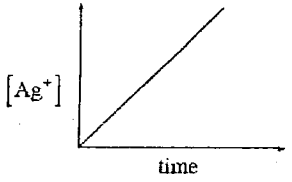
A.



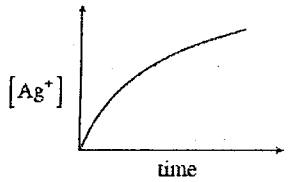

B.




C.




D.





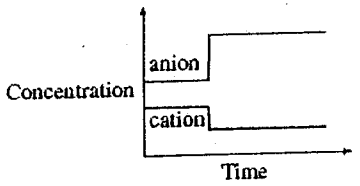



16. The equation that describes the solubility equilibrium of $Ca(HCO_3)_{2(s)}$ is

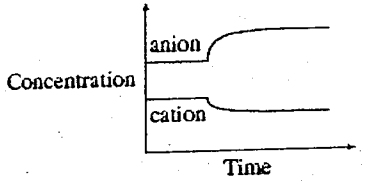
A. $Ca(HCO_3)_{2(s)} \leftrightarrows Ca^{+2}_{(aq)} + 2H^{+}_{(aq)} + 2CO_3^{2-}{}_{(aq)}$
B. $Ca(HCO_3)_{2(s)} + H_2O_{(l)} \leftrightarrows Ca(OH)_{2\,(aq)} + 2CO_{2\,(g)}$
C. $Ca(HCO_3)_{2(s)} \leftrightarrows CaO_{(s)} + H_2O_{(l)} + 2CO_{2\,(g)}$
D. $Ca(HCO_3)_{2(s)} \leftrightarrows Ca^{+2}_{(aq)} + 2HCO_3^{-}{}_{(aq)}$

17. A saturated solution is prepared by dissolving a salt in water. Which of the following graphs could represent the ion concentrations as the temperature is increased?

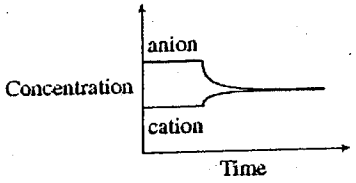
A.



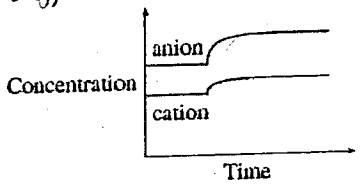

B.




C.




D. heat + $NaCl_{(s)} \rightleftarrows Na^{+}_{(aq)} + Cl^{-}_{(aq)}$




## G7 - Write a formula, complete and net ionic equation that describes a saturated solution

18. Which net ionic equation best describes the reaction that exists in a solution prepared by mixing equal volumes of 0.20 M $Ca(NO_3)_2$ and 0.20 M $Na_2CO_3$?

A. $Ca^{+2}_{(aq)} + CO_3^{-2}{}_{(aq)} \leftrightarrows CaCO_{3\,(s)}$
B. $Na^{+}_{(aq)} + NO_3^{-}{}_{(aq)} \leftrightarrows NaNO_{3\,(s)}$
C. $Ca(NO_3)_{2\,(aq)} + Na_2CO_{3\,(aq)} \leftrightarrows 2NaNO_{3\,(s)} + CaCO_{3\,(s)}$
D. $Ca(NO_3)_{2\,(aq)} + Na_2CO_{3\,(aq)} \leftrightarrows 2\,NaNO_{3\,(aq)} + CaCO_{3\,(s)}$

## G8 - Calculate the concentration of the positive and negative ions given the concentration of a solute in an aqueous solution

19. The ion concentrations in 3.00 L of a 0.250 M $Al_2(SO_4)_3$ are

| | $[Al^{+3}]$ | $[SO_4^{-2}]$ |
|---|---|---|
| A. | 0.250 M | 0.250 M |
| B. | 0.500 M | 0.750 M |
| C. | 1.50 M | 2.25 M |
| D. | 0.750 M | 0.750 M |

20. Which of the following solutions would have $[Fe^{+3}] = 0.020$ M?
   A. 0.40 L of a 0.050 M $Fe(NO_3)_3$ solution
   B. 0.80 L of a 0.020 M $Fe_2(SO_4)_3$ solution
   C. 0.50 L of a 0.040 M $FeC_6H_5O_7$ solution
   D. 0.50 L of a 0.010 M $Fe_2(C_2O_4)_3$ solution

21. In a saturated solution of $Ag_2C_2O_4$ the $[Ag^+] = 2.2 \times 10^{-4}$ M. What is the solubility of $Ag_2C_2O_4$ in this solution?
   A. $5.2 \times 10^{-12}$ M  B. $1.1 \times 10^{-4}$ M  C. $2.2 \times 10^{-4}$ M  D. $4.4 \times 10^{-4}$ M

22. The solubility of $SrCO_3$ is $2.4 \times 10^{-5}$ M. How many moles of dissolved solute are present in 100.0 mL of saturated $SrCO_3$ solution?
   A. $5.6 \times 10^{-10}$ mol  B. $2.4 \times 10^{-6}$ mole  C. $2.4 \times 10^{-5}$ mol  D. $2.4 \times 10^{-4}$ mol

23. What are the ion concentrations in 2.5 L of a 0.30 M $CuCl_2$?

| | $[Cu^{+2}]$ | $[Cl^-]$ |
|---|---|---|
| A. | 0.75 M | 1.5 M |
| B. | 1.5 M | 0.75 M |
| C. | 0.15 M | 0.30 M |
| D. | 0.30 M | 0.60 M |

24. A 3.0 L solution of $BaCl_2$ has a chloride ion concentration of 0.20 M. The barium ion concentration in this solution is
   A. 0.067 M  B. 0.10 M  C. 0.20 M  D. 0.60 M

25. What is the $[OH^-]$ in 250 mL of a 0.20 M $Sr(OH)_2$ ?
   A. 0.050 M  B. 0.10 M  C. 0.20 M  D. 0.40 M

26. What is the concentration of the ions in 3.0 L of 0.50 M $Fe_2(SO_4)_3$?

| | $[Fe^{+3}]$ | $[SO_4^{-2}]$ |
|---|---|---|
| A. | 0.33M | 0.50M |
| B. | 1.0 M | 1.5 M |
| C. | 1.5 M | 1.5 M |
| D. | 3.0 M | 4.5 M |





27. What is the concentration of the ions in 3.0 L of 0.50 M $AgClO_3$?

| | $[Ag^+]$ | $[ClO_3^-]$ |
|---|---|---|
| A. | 0.17M | 0.17M |
| B. | 0.50 M | 0.50 M |
| C. | 0.50 M | 1.5 M |
| D. | 1.5 M | 4.5 M |

28. What is the [Cl-] when 1.50 grams of NaCl is dissolved in enough water to make 100.0 mL of solution?
   A. 0.150 M  B. 15.0 M  C. 0.256 M  D. 0.390 M

**H1 - Describe a compound as having high or low solubility relative to 0.1 M by using a solubility chart**

29. Which of the following has the lowest solubility?
   A. CaS  B. CuS  C. FeS  D. MgS

30. Which of the following compounds could be used to prepare a solution with a $[S^{-2}]$ greater than 0.1 M?
   A. ZnS  B. PbS  C. $Ag_2S$  D. $Rb_2S$

31. Which of the following compounds could be used to prepare a solution with a $[S^{-2}]$ greater than 0.1 M?
   A. CuS  B. CaS  C. $Ag_2S$  D. $Fe_2S_3$

32. Which of the following compounds could be used to prepare a solution with a $[SO_3^{-2}]$ greater than 0.1 M?
   A. $CuSO_3$  B. $CaSO_3$  C. $Ag_2SO_3$  D. $H_2SO_3$

33. Which compound will have the lowest solubility?
   A. $Fe(OH)_2$  B. $CaSO_4$  C. $AgIO_3$  D. $Fe(NO_3)_3$

34. Which of the following would form a saturated solution when 0.100 mol of the solid solute is added to 100.0 mL of water?
   A. $BaCO_3$  B. $FeSO_4$  C. NaCN  D. $Pb(NO_3)_2$

35. Which compound will have the greatest solubility in water?
   A. $CuCl_2$  B. $BaCO_3$  C. $CaSO_4$  D. AgCl

**H2 - Use a solubility chart to predict if a precipitate will form when two solutions are mixed, and identify the precipitate**

36. When equal volumes of 0.2 M solutions are mixed, which of the following combinations will form a single precipitate?
A. CaS and $Sr(OH)_2$
B. $H_2SO_4$ and $MgCl_2$
C. $(NH_4)_2SO_4$ and $K_2CO_3$
D. $H_2SO_3$ and $NaCH_3COO$

37. When equal volumes of 0.2 M solutions are mixed, which of the following combinations will form a single precipitate?
A. $Na_2S$ and RbOH
B. $ZnSO_4$ and $MgCl_2$
C. $(NH_4)_2SO_4$ and $K_2CO_3$
D. $H_2SO_3$ and $Fe(CH_3COO)_3$

38. When equal volumes of 0.2 M solutions are mixed, which of the following combinations will form a single precipitate?
A. BaS and NaI
B. $CuSO_4$ and $CaCl_2$
C. $Rb_2SO_4$ and $K_2CO_3$
D. $H_2SO_4$ and $Fe(CH_3COO)_3$

39. A solution contains 0.2 M $Zn^{+2}$ and 0.2 M $Sr^{+2}$. An equal volume of a second solution was added, forming a precipitate with the $Zn^{+2}$ but not the $Sr^{+2}$. What was present in the second solution?
A. 0.2 M $Cl^-$ B. 0.2 M $OH^-$ C. 0.2 M $SO_4^{2-}$ D. 0.2 M $SO_3^{-2}$

40. A solution contains 0.2 M $Pb^{+2}$ and 0.2 M $Sr^{+2}$. An equal volume of a second solution was added, forming a precipitate with the $Pb^{+2}$ but not the $Sr^{+2}$. What was present in the second solution?
A. 0.2 M $NO_3^-$ B. 0.2 M $PO_4^{-3}$ C. 0.2 M $SO_4^{2-}$ D. 0.2 M $S^{-2}$

41. A solution contains 0.2 M $Cu^{+2}$ and 0.2 M $Sr^{+2}$. An equal volume of a second solution was added, forming a precipitate with the $Cu^{+2}$ but not the $Sr^{+2}$. What was present in the second solution?
A. 0.2 M $Cl^-$ B. 0.2 M $NO_3^-$ C. 0.2 M $SO_4^{2-}$ D. 0.2 M $S^{-2}$

42. Which of the following would be true when equal volumes of 0.2 M $(NH_4)_2SO_4$ and 0.2 M BaS are combined?
A. no precipitate forms
B. a precipitate of $(NH_4)_2S$ forms
C. a precipitate of $BaSO_4$ forms
D. precipitates of both $(NH_4)_2S$ and $BaSO_4$ form

43. Which of the following would be true when equal volumes of 0.2 M CaS and 0.2 M $Fe_2(SO_4)_3$ are combined?
A. no precipitate forms
B. a precipitate of $Fe_2S_3$ forms
C. a precipitate of $CaSO_4$ forms
D. precipitates of both $Fe_2S_3$ and $CaSO_4$ form



44. Which of the following would be true when equal volumes of 0.2 M $Sr(OH)_2$ and 0.2 M $Fe_2(SO_4)_3$ are combined?
A. no precipitate forms
B. a precipitate of $Fe(OH)_3$ forms
C. a precipitate of $SrSO_4$ forms
D. precipitates of both $Fe(OH)_3$ and $SrSO_4$ form

45. What happens when 10.0 mL of 0.2 M $Sr(OH)_2$ is added to 10.0 mL of 0.2 M $CuSO_4$?
A. No precipitate forms
B. A precipitate of $Cu(OH)_2$ forms
C. A precipiate of $SrSO_4$ forms
D. Precipitates of $Cu(OH)_2$ and $SrSO_4$ form

46. What happens when 10.0 mL of 0.2 M $Sr(OH)_2$ is added to 10.0 mL of 0.2 M $Rb_2SO_4$?
A. No precipitate forms
B. A precipitate of RbOH forms
C. A precipiate of $SrSO_4$ forms
D. Precipitates of RbOH and $SrSO_4$ form

47. Which of the following will **not** form a precipitate when mixed with an equal amount of 0.2 M $AgNO_3$?
A. 0.2 M NaOH B. 0.2 M NaBr C. 0.2 M $NaNO_3$ D. 0.2 M $NaBrO_3$

48. Which of the following will **not** form a precipitate when mixed with an equal amount of 0.2 M $Ca(NO_3)_2$?
A. 0.2 M NaOH B. 0.2 M NaBr C. 0.2 M $Na_2SO_3$ D. 0.2 M $Na_2CO_3$

49. Which of the following will **not** form a precipitate when mixed with an equal amount of 0.2 M $Fe(NO_3)_3$?
A. 0.2 M NaOH B. 0.2 M $Na_2SO_4$ C. 0.2 M $Na_2SO_3$ D. 0.2 M $Na_2CO_3$

50. Which of the following will **not** form a precipitate when mixed with an equal amount of 0.2 M $Cu(NO_3)_2$?
A. 0.2 M NaCl B. 0.2 M $Na_2S$ C. 0.2 M $Na_2SO_3$ D. 0.2 M $Na_2CO_3$

51. What will happen when equal volumes of 0.20 M $(NH_4)_2S$ and 0.20 M $Sr(OH)_2$ are mixed?
A. SrS precipitates.
B. $NH_4OH$ presipitates
C. Both SrS and $NH_4OH$ precipitate
D. No precipitate forms

52. What happens when equal volumes of 0.2 M $BaCl_2$ and $CuSO_4$ are mixed?
    A. Only $CuCl_2$ precipitates
    B. Only $BaSO_4$ precipitates
    C. Both $CuCl_2$ and $BaSO_4$ precipitate
    D. No precipitate forms

## H3 - Write a formula equation, complete ionic equation and net ionic equation that represents a precipitation reaction

53. What is the net ionic equation for the reaction that occurs when equal volumes of 0.20 M BaS and 0.20 M $Fe_2(SO_4)_3$ are mixed?
    A. $3Ba^{+2}_{(aq)} + 3SO_4^{-2}{}_{(aq)} \Rightarrow 3BaSO_{4\,(s)}$
    B. $2Fe^{+3}_{(aq)} + 3S^{-2}_{(aq)} \Rightarrow Fe_2S_{3\,(s)}$
    C. $3BaS_{(aq)} + Fe_2(SO_4)_{3\,(aq)} \Rightarrow 3BaSO_{4\,(s)} + Fe_2S_{3\,(s)}$
    D. $3Ba^{+2}_{(aq)} + 3SO_4^{-2}{}_{(aq)} + 2Fe^{+3}_{(aq)} + 3S^{-2}_{(aq)} \Rightarrow 3BaSO_{4\,(s)} + Fe_2S_{3\,(s)}$

54. What is the formula equation for the reaction that occurs when equal volumes of 0.20 M BaS and 0.20 M $Fe_2(SO_4)_3$ are mixed?
    A. $3Ba^{+2}_{(aq)} + 3SO_4^{-2}{}_{(aq)} \Rightarrow 3BaSO_{4\,(s)}$
    B. $2Fe^{+3}_{(aq)} + 3S^{-2}_{(aq)} \Rightarrow Fe_2S_{3\,(s)}$
    C. $3BaS_{(aq)} + Fe_2(SO_4)_{3\,(aq)} \Rightarrow 3BaSO_{4\,(s)} + Fe_2S_{3\,(s)}$
    D. $3Ba^{+2}_{(aq)} + 3SO_4^{-2}{}_{(aq)} + 2Fe^{+3}_{(aq)} + 3S^{-2}_{(aq)} \Rightarrow 3BaSO_{4\,(s)} + Fe_2S_{3\,(s)}$

55. What is the complete ionic equation for the reaction that occurs when equal volumes of 0.20 M $Ba(NO_3)_2$ and 0.20 M $Na_2SO_4$ are mixed?
    A. $Ba^{+2}_{(aq)} + SO_4^{-2}{}_{(aq)} \Rightarrow BaSO_{4\,(s)}$
    B. $2Na^{+}_{(aq)} + 2NO_3^{-}{}_{(aq)} \Rightarrow 2NaNO_{3\,(s)}$
    C. $Ba(NO_3)_{2\,(aq)} + 2Na_2SO_{4\,(aq)} \Rightarrow BaSO_{4\,(s)} + 2NaNO_{3\,(aq)}$
    D. $Ba^{+2}_{(aq)} + SO_4^{-2}{}_{(aq)} + 2Na^{+}_{(aq)} + 2NO_3^{-}{}_{(aq)} \Rightarrow BaSO_{4\,(s)} + 2Na^{+}_{(aq)} + 2NO_3^{-}{}_{(aq)}$

56. What is the net ionic equation for the reaction that occurs when equal volumes of 0.20 M $K_3PO_4$ and 0.20 M $ZnCl_2$ are mixed together?
    A. $K^{+}_{(aq)} + Cl^{-}_{(aq)} \rightarrow KCl_{(s)}$
    B. $3Zn^{+2}_{(aq)} + 2PO_4^{-3}{}_{(aq)} \rightarrow Zn_3(PO_4)_{2\,(s)}$
    C. $2\,K_3PO_{4\,(aq)} + 3ZnCl_{2\,(aq)} \rightarrow Zn_3(PO_4)_{2\,(s)} + 6\,KCl_{(aq)}$
    D. $2\,K_3PO_{4\,(aq)} + 3ZnCl_{2\,(aq)} \rightarrow Zn_3(PO_4)_{2\,(aq)} + 6\,KCl_{(s)}$



57. Which of the following best represents the formula reaction resulting from the mixing of equal volumes of 0.2 M $Ca(NO_3)_2$ and 0.2 M NaOH?
    A. $Ca^{+2}_{(aq)} + 2\,OH^{-}_{(aq)} \rightarrow Ca(OH)_{2\,(s)}$
    B. $Ca(NO_3)_{2(aq)} + 2\,NaOH_{(aq)} \rightarrow Ca(OH)_{2\,(s)} + 2NaNO_{3\,(aq)}$
    C. $Ca^{+2}_{(aq)} + 2NO_3^{-}{}_{(aq)} + 2Na^{+}_{(aq)} + 2OH^{-}_{(aq)} \rightarrow Ca(OH)_{2\,(s)} + 2Na^{+}_{(aq)} + 2NO_3^{-}{}_{(aq)}$
    D. $Ca^{+2}_{(aq)} + 2NO_3^{-}{}_{(aq)} + 2Na^{+}_{(aq)} + 2OH^{-}_{(aq)} \rightarrow Ca(OH)_{2\,(s)} + 2NaNO_{3\,(aq)}$

58. When equal volumes of 0.20 M BaS and 0.20 M $FeCl_3$ are mixed, a precipitate forms.
    a. Write the formula equation for the above reaction.
    b. Write the complete ionic equation for the above reaction.
    c. Write the net ionic equation for the above reaction.

59. When equal volumes of 0.20 M SrS and 0.20 M $Fe_2(SO_4)_3$ are mixed, a precipitate forms.
    a. Write the formula equation for the above reaction.
    b. Write the complete ionic equation for the above reaction.
    c. Write the net ionic equation for the above reaction.

## H4 - Use a solubility chart to predict if ions can be separated from solution through precipitation, and outline the process

60. A solution contains both $Ag^+$ and $Mg^{+2}$ ions. During selective precipitation, these ions are removed one at a time by adding
A. $I^-$ followed by $OH^-$
B. $OH^-$ followed by $S^{-2}$
C. $SO_4^{-2}$ followed by $Cl^-$
D. $NO_3^-$ followed by $PO_4^{-3}$

61. A solution contains both $Pb^{+2}$ and $Mg^{+2}$ ions. During selective precipitation, these ions are removed one at a time by adding
A. $Cl^-$ followed by $PO_4^{-3}$
B. $OH^-$ followed by $S^{-2}$
C. $SO_4^{-2}$ followed by $Cl^-$
D. $S^{-2}$ followed by $SO_4^{-2}$

62. A solution contains both 0.2 M $Mg^{+2}$ $_{(aq)}$ and 0.2 M $Sr^{+2}$ $_{(aq)}$. These ions can be removed separately through precipitation by adding equal volumes of 0.2 M solutions of
A. $OH^-$ and then $SO_4^{-2}$
B. $Cl^-$ and then $OH^-$
C. $CO_3^{-2}$ and then $SO_4^{-2}$
D. $SO_4^{-2}$ and then $S^{-2}$

63. Using the solubility table, determine which of the following ions could **not** be used to separate $S^{-2}$ from $SO_4^{-2}$ by precipitation.
A. $Ca^{+2}$ B. $Zn^{+2}$ C. $Cu^{+2}$ D. $NH_4^+$

64. Using the solubility table, determine which of the following ions could **not** be used to separate $OH^{-1}$ from $SO_4^{-2}$ by precipitation.
A. $Ba^{+2}$ B. $Zn^{+2}$ C. $Cu^{+2}$ D. $Sr^{+2}$

65. Using the solubility table, determine which of the following ions could be used to separate $OH^{-1}$ from $SO_3^{-2}$ by precipitation.
A. $Ba^{+2}$ B. $Zn^{+2}$ C. $Cu^{+2}$ D. $Sr^{+2}$

66. A solution is prepared containing both 0.2 M $S^{2-}$ and 0.2 M $PO_4^{3-}$ ions. An equal volume of a second solution is added in order to precipitate only one of these two anions. The second solution must contain which of the following?
A. 0.2 M $Cs^+$ B. 0.2 M $Zn^{+2}$ C. 0.2 M $Pb^{+2}$ D. 0.2 $Sr^{+2}$



67. A solution is found to contain $NaBr_{(aq)}$, $K_2SO_{4\,(aq)}$ and $Li_2SO_{3\,(aq)}$ in solution. Devise a procedure by which each of the anions in the solution can be removed, one at a time. The solutions that are available to use are:

$Ca(NO_3)_2$ $NH_4NO_3$ $AgNO_3$ $Mg(NO_3)_2$

1. First you would add _____. The precipitate formed would be _____ Filter out the precipitate.
2. To the remaining solution add _____. The precipitate formed would be _____. Filter out the precipitate.
3. To the remaining solution add _____. The precipitate formed would be _____. FIlter out the precipitate.

68. A solution is found to contain $Ca(NO_3)_{2\,(aq)}$, $AgNO_{3\,(aq)}$, $Fe(NO_3)_{3\,(aq)}$ in solution. Devise a procedure by which each of the cations in the solution can be removed, one at a time. The solutions that are available to use are:

NaI $KNO_3$ $Li_2SO_4$ KOH

1. First you would add _____. The precipitate formed would be _____ Filter out the precipitate.
2. To the remaining solution add _____. The precipitate formed would be _____. Filter out the precipitate.
3. To the remaining solution add _____. The precipitate formed would be _____. FIlter out the precipitate.

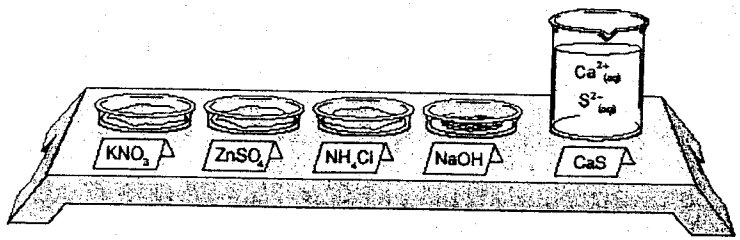
69. A solution is found to contain $CuSO_{4\,(aq)}$ in solution. Devise a procedure by which each of the cations in the solution can be removed, one at a time. The solutions that are available to use are:

$BaI_2$ CaS $Pb(NO_3)_4$ $NH_4Cl$

1. First you would add _____. The precipitate formed would be _____ Filter out the precipitate.
2. To the remaining solution add _____. The precipitate formed would be _____. Filter out the precipitate.

Consider the following:

70.




a. Fill in the blanks below that would separate the $Ca^{+2}$ ions from the $S^{-2}$ ions using the solids samples. Indicate which sample you would add first, and the precipitate that would form. Indicate which sample you would add second and the precipitate that would form then.

First, add _____. The precipitate formed would be _____

Second, add _____. The precipitate formed would be _____

b. Write the net ionic equations for one of the precipitation reactions in part (a)

## H5 - Predict qualitative changes in the solubility equilibrium upon the addition of a common ion

71. Which of the following could dissolve a precipitate of $CaC_2O_4$ in a saturated solution of $CaC_2O_4$?

A. NaOH B. $CaC_2O_4$ C. $H_2C_2O_4$ D. $Ca(NO_3)_2$

72. Consider the following equilibrium:

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

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 $Fe(NO_3)_2$





73. Consider the following equilibrium:

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

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

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

74. Consider the following equilibrium:

$$AgIO_{3\,(s)} \leftrightarrows Ag^+{}_{(aq)} + IO_3^-{}_{(aq)}$$

A few crystals of $NaIO_3$ are added to the above equilibrium. When equilibrium is re-established, how do the new ion concentrations compare with the original equilibrium concentrations?

| | $[Ag^+]$ | $[IO_3^-]$ |
|---|---|---|
| A. | decreased | decreased |
| B. | decreased | increased |
| C. | increased | increased |
| D. | increased | decreased |

75. Consider the following equilibrium:

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

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

A. adding $CaSO_{4(s)}$ B. adding $MgSO_{4(s)}$
C. removing some $Ca^{+2}{}_{(aq)}$ D. removing some $SO_4^{-2}{}_{(aq)}$

76. Which of the following is true when solid $Cu(NO_3)_2$ is added to a saturated solution of CuS and equilibrium is reestablished?

A. $[S^{-2}]$ increases B. $[Cu^{+2}]$ increases
C. $[S^{-2}]$ does not change D. $[Cu^{+2}]$ does not change

77. Which of the following is true when solid NaOH is added to a saturated solution of CuS and equilibrium is reestablished?

A. $[S^{-2}]$ increases B. $[Cu^{+2}]$ increases
C. $[S^{-2}]$ does not change D. $[Cu^{+2}]$ does not change

78. Solid NaI is added to a saturated AgCl solution. How have $[Ag^+]$ and $[Cl^-]$ changed when equilibrium has been reestablished?

| | $[Ag^+]$ | $[Cl^-]$ |
|---|---|---|
| A. | increased | decreased |
| B. | decreased | increased |
| C. | increased | increased |
| D. | stayed the same | stayed the same |

79. Consider the following equilibrium:

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

When $Ba(NO_3)_2$ is added to this solution, which of the following will occur in regards to the equilibrium and $[Ca^{2+}]$?

| | Equilibrium | $[Ca^{2+}]$ |
|---|---|---|
| A. | shifts right | increases |
| B. | shifts right | decreases |
| C. | shifts left | increases |
| D. | shifts left | decreases |

80. Consider the following equilibrium:

$$\text{energy} + AgCl_{(s)} \leftrightarrows Ag^+{}_{(aq)} + Cl^-{}_{(aq)}$$

Addition of which of the following will increase the solubility of AgCl?

A. heat B. HCl C. $AgNO_3$ D. a catalyst

81. Consider the following equilibrium:

$$\text{energy} + AgCl_{(s)} \leftrightarrows Ag^+{}_{(aq)} + Cl^-{}_{(aq)}$$

Addition of which of the following will increase the solubility of AgCl?

A. NaBr B. HCl
C. $AgNO_3$ D. decrease the volume

82. In which of the following would $PbCl_{2(s)}$ be the **least** soluble?

A. 1 M HCl B. 1 M $BaCl_2$ C. 1 M $K_2SO_4$ D. 1 M $Pb(NO_3)_2$

83. What will be the effect of adding some solid $AgNO_3$ to a saturated solution of AgCl?

A. The $AgNO_3$ will not dissolve.
B. More AgCl will dissolve.
C. More AgCl will be produced.
D. The $AgNO_3$ will not affect the AgCl equilibrium.



84. What will be the effect of adding some solid $K_2SO_4$ to a saturated solution of AgCl?

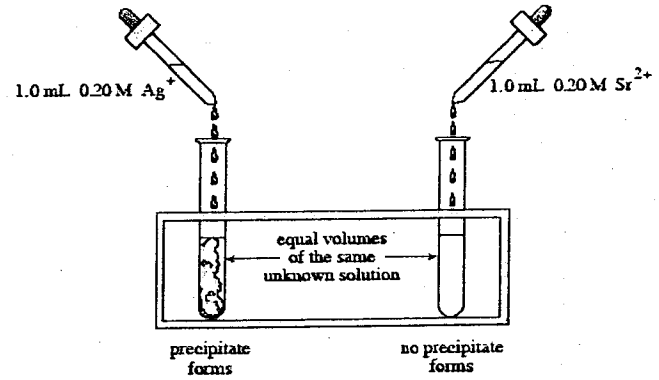
A. The $K_2SO_4$ will not dissolve.
B. More AgCl will dissolve.
C. More AgCl will be produced.
D. The $K_2SO_4$ will not affect the AgCl equilibrium.

85. What will be the effect of adding some solid $Cu(NO_3)_2$ to a saturated solution of AgCl?

A. The $Cu(NO_3)_2$ will not dissolve.
B. More AgCl will dissolve.
C. More AgCl will be produced.
D. The $Cu(NO_3)_2$ will not affect the AgCl equilibrium.

## H6 - Identify an unknown ion through experimentation involving a qualitative analysis scheme

86. Consider the following:

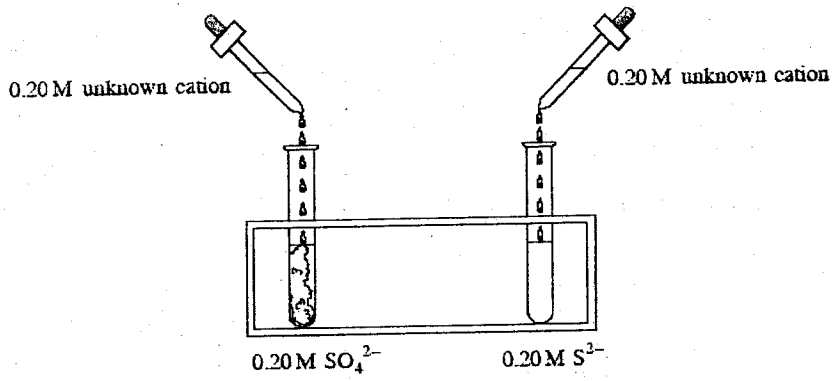



Which of the following could be the unknown solution?

A. 0.20 M KOH B. 0.20 M $NaNO_3$ C. 0.20 M $K_3PO_4$ D. 0.20 M $Na_2SO_4$

87.

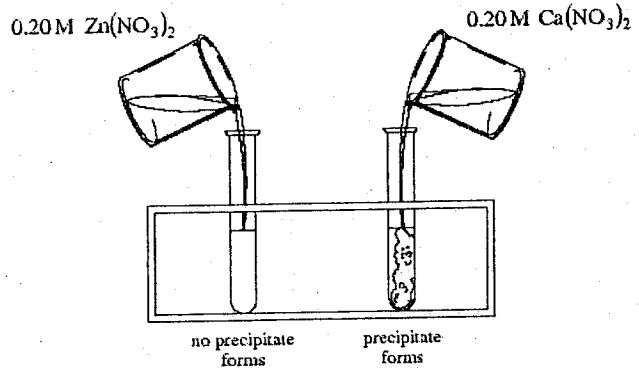
A precipitate forms when a 0.20 M solution containing an unknown cation is added to $SO_4^{2-}$, but not when an equal volume is added to $S^{2-}$. **(2 marks)**




The unknown cation is

A. $Pb^{+2}$ B. $Ba^{+2}$ C. $Zn^{+2}$ D. $Mg^{+2}$

When 10.0 mL of 0.20 M $Zn(NO_3)_2$ is added to a 10.0 mL sample of 0.20 M unknown solution, no precipitate forms. When the same volume of 0.20 M $Ca(NO_3)_2$ is added to a separate 10.0 mL sample of the unknown solution, a precipitate does form. **(2 marks)**




88.

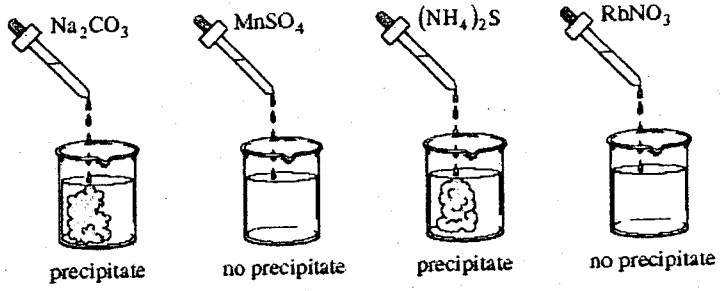
The unknown solution could be

A. $Na_2CO_3$ B. $Na_2SO_4$ C. KOH D. $K_2S$





An experiment is conducted to identify an unknown cation that is present in each of four beakers.




89.

Which of the following is the unknown cation?

A. $Ag^{+1}$ B. $Fe^{+3}$ C. $Ba^{+2}$ D. $Be^{+2}$

## H7 - Devise a procedure by which the contaminating ions in hard orpulluted water can be removed

90. Which of the following could be added to a sample of hard water to remove both 0.2 M $Ca^{+2}$ and 0.2 M $Mg^{+2}$?

A. 0.2 M $NO_3^-$ B. 0.2 M $I^-$ C. 0.2 M $S^{-2}$ D. 0.2 M $SO_3^{-2}$

91. Which anion would be most effective in removing the cations responsible for hard water?

A. $SO_3^{-2}$ B. $Cl^-$ C. $S^{-2}$ D. $SO_4^{-2}$

## I1 - Describe the $K_{sp}$ expression as a specialized $K_{eq}$ expression

92. For a saturated solution, the $K_{sp}$ expression does not contain any solid solute term. What is the reason for this?

A. The solid solute is a product.
B. The solid solute is a reactant.
C. The solid solute continues to change in amount.
D. The solid solute does not change in concentration.

## I2 - Write a Ksp expression for a solubility equilibrium

93. The Ksp expression for a saturated solution of $Mg(OH)_2$ is

A. $K_{sp} = [Mg^{+2}][OH^-]^2$

B. $K_{sp} = [Mg^{+2}][2OH^-]^2$

C. $K_{sp} = \dfrac{[Mg^{+2}][OH^-]^2}{[Mg(OH)_2]}$

D. $K_{sp} = [Mg^{+2}][2OH^-]$

94. The $K_{sp}$ expression for a saturated solution of $Ba_3(AsO_4)_2$ would be

A. $Ksp = \dfrac{[Ba^{+2}]^3\ [AsO_4^{-3}]^2}{Ba_3(AsO_4)_2}$

B. $Ksp = [Ba^{+2}]^3\ [AsO_4^{-3}]^2$

C. $Ksp = [3Ba^{+2}]^3\ [2AsO_4^{-3}]^2$

D. $Ksp = [3Ba^{+2}]\ [2AsO_4^{-3}]$

95. The $K_{sp}$ expression for a saturated solution of $Ag_2SO_3$ is

A. $K_{sp} = [2Ag^+][SO_3^{-2}]$

B. $K_{sp} = [Ag^+]^2[SO_3^{-2}]$

C. $K_{sp} = [2Ag^+]^2[SO_3^{-2}]$

D. $K_{sp} = [Ag_2^{+2}][SO_3^{-2}]$

96. Which of the following expressions represents $[Fe^{+3}]$ in a saturated $Fe(OH)_3$ solution?

A. $[Fe^{+3}] = \dfrac{Ksp}{3[OH^-]}$

B. $[Fe^{+3}] = \dfrac{Ksp}{[OH^-]^3}$

C. $[Fe^{+3}] = \dfrac{Ksp}{\sqrt[3]{[OH^-]}}$

D. $[Fe^{+3}] = Ksp \times [OH^-]^3$

97. Given the equilibrium reaction:

$$2NaNO_{3\,(aq)} + Ag_2S_{(s)} \leftrightarrows 2\,AgNO_{3\,(aq)} + Na_2S_{(aq)}$$

Which $K_{sp}$ expression best describes the net ionic reaction?

A. $K_{sp} = [Ag^+]^2\,[S^{-2}]$

B. $K_{sp} = \dfrac{1}{[Ag^+]^2\,[S^{-2}]}$

C. $K_{sp} = \dfrac{[Ag^+]\,[S^{-2}]}{[Ag_2S]}$

D. $K_{sp} = \dfrac{[AgNO_3]^2\,[Na_2S]}{[NaNO_3]^2}$

98. Which of the following is the $K_{sp}$ expression for barium phosphate?

A. $K_{sp} = [Ba^{+2}][PO_4^{-3}]$

B. $K_{sp} = [Ba^{+2}]^3[PO_4^{-3}]^2$

C. $K_{sp} = [3Ba^{+2}][2PO_4^{-3}]$

D. $K_{sp} = [3Ba^{+2}]^3[2PO_4^{-3}]^2$



99. What is the $K_{sp}$ expression for the precipitate formed when solutions of $Fe(NO_3)_3$ and $Sr(OH)_2$ are mixed?

A. $K_{sp} = [Sr^{+2}][OH^-]^2$

B. $K_{sp} = [Fe^{+3}][OH^-]^3$

C. $K_{sp} = [Sr^{+2}][NO_3^-]^2$

D. $K_{sp} = [Fe^{+3}][3OH^-]^3$

100. Which relationship can be used to determine the [Ba+2] in a saturated solution of barium phosphate?

A. $[Ba^{2+}] = \sqrt[3]{\dfrac{K_{sp}}{[PO_4^{3-}]^2}}$

B. $[Ba^{2+}] = \dfrac{K_{sp}}{\sqrt[3]{[PO_4^{3-}]}}$

C. $[Ba^{2+}] = \dfrac{K_{sp}}{[PO_4^{3-}]}$

D. $[Ba^{2+}] = \sqrt[3]{K_{sp}[PO_4^{3-}]^2}$

## I3 - Calculate the $K_{sp}$ for AB, $A_2B$ and $AB_2$ type compounds when given the solubility of a compound.

101. The solubility of CdS is $2.8 \times 10^{-14}$ M. The value of Ksp is

A. $7.8 \times 10^{-28}$ B. $2.8 \times 10^{-14}$ C. $1.7 \times 10^{-7}$ D. $5.6 \times 10^{-14}$

102. In a saturated solution of $Ag_2C_2O_4$ the $[Ag^+] = 2.2 \times 10^{-4}$ M. What is the $K_{sp}$ of $Ag_2C_2O_4$ in this solution?

A. $4.3 \times 10^{-11}$ B. $1.1 \times 10^{-4}$ C. $5.3 \times 10^{-12}$ D. $4.8 \times 10^{-8}$

103. The solubility of $CdCO_3$ is $2.5 \times 10^{-6}$ M. Calculate the $K_{sp}$ value for $CdCO_3$.

A. $6.3 \times 10^{-12}$ B. $2.5 \times 10^{-6}$ C. $5.0 \times 10^{-6}$ D. $1.6 \times 10^{-3}$

104. What is the value of $K_{sp}$ for $Zn(OH)_2$ if the solubility of $Zn(OH)_2$ is equal to $4.2 \times 10^{-6}$M?

A. $1.0 \times 10^{-2}$ B. $4.0 \times 10^{-3}$ C. $1.8 \times 10^{-11}$ D. $3.0 \times 10^{-16}$

105. What is the value of $K_{sp}$ for $Cr(OH)_2$ if the solubility of $Cr(OH)_2$ is equal to $7.5 \times 10^{-3}$M?

A. 0.12 B. $8.7 \times 10^{-2}$ C. $5.6 \times 10^{-5}$ D. $1.7 \times 10^{-6}$

106. The solubility of $ZnCO_3$ is $6.4 \times 10^{-9}$ M What is the value of $K_{sp}$ for $ZnCO_3$?

A. $4.1 \times 10^{-17}$ B. $6.4 \times 10^{-9}$ C. $1.3 \times 10^{-8}$ D. $8.0 \times 10^{-5}$

107. The solubility of $Mg(OH)_2$ is found to be $1.2 \times 10^{-4}$ M. What is its $K_{sp}$?

A. $6.9 \times 10^{-12}$ B. $1.7 \times 10^{-12}$ C. $1.4 \times 10^{-8}$ D. 1.2 x 10-4

108. A saturated solution of nickel carbonate, $NiCO_3$, contains 0.090 g in 2.0 L of solution. Calculate the $K_{sp}$ for $NiCO_3$.

109. After a 50.0 mL sample of a saturated solution of $Ag_2SO_4$ was heated to dryness, $7.2 \times 10^{-4}$ g of solid $Ag_2SO_4$ remained. What is the value of $K_{sp}$ for $Ag_2SO_4$

## I4 - Calculate the solubility of AB, $A_2B$ and $AB_2$ type compounds from their $K_{sp}$

110. How many moles of solute are dissolved in 200.0 mL of a saturated solution of FeS?
A. $1.2 \times 10^{-19}$ moles B. $3.9 \times 10^{-9}$ moles C. $7.7 \times 10^{-10}$ moles D. $1.5 \times 10^{-10}$ moles



111. Consider the following saturated solutions:

$CuSO_4$, $BaSO_4$, $CaSO_4$

the order of cation concentration, from highest to lowest is
A. $[Ba^{+2}] > [Ca^{+2}] > [Cu^{+2}]$
B. $[Ca^{+2}] > [Cu^{+2}] > [Ba^{+2}]$
C. $[Cu^{+2}] > [Ca^{+2}] > [Ba^{+2}]$
D. $[Cu^{+2}] > [Ba^{+2}] > [Ca^{+2}]$

112. Calculate the solubility of $PbSO_4$
A. $3.2 \times 10^{-16}$ M B. $1.8 \times 10^{-8}$ M C. $3.6 \times 10^{-8}$ M D. $1.3 \times 10^{-4}$ M

113. Calculate the solubility of $CaC_2O_4$.
A. $2.3 \times 10^{-9}$ M B. $1.2 \times 10^{-5}$ M C. $4.8 \times 10^{-5}$ M D. $8.3 \times 10^{-4}$ M

114. Calculate the solubility of $CaC_2O_4$ in grams per L
A. $6.2 \times 10^{-3}$ g/L B. $2.9 \times 10^{-7}$ g/L C. $4.8 \times 10^{-5}$ g/L D. $1.1 \times 10^{-1}$ g/L

115. How many moles of dissolved solute are present in 100.0 mL of a saturated $SrCO_3$ solution?
A. $5.6 \times 10^{-11}$ mol B. $2.4 \times 10^{-6}$ mol C. $2.4 \times 10^{-5}$ mol D. $2.3 \times 10^{-4}$ mol

116. Which of the following saturated solutions will have the lowest $[S^{-2}]$?
A. BaS B. CaS C. CuS D. ZnS

117. Which of the following saturated solutions will have the lowest $[IO_3^{-1}]$?
A. $Pb(IO_3)_2$ B. $AgIO_3$ C. $NaIO_3$ D. $Cu(IO_3)_2$

118. Which of the following saturated solutions will have the lowest $[CO_3^{-2}]$?
A. $Ag_2CO_3$ B. $BaCO_3$ C. $SrCO_3$ D. $CaCO_3$

119. What is the solubility of $SrF_2$?
A. $6.6 \times 10^{-5}$ M B. $1.8 \times 10^{-17}$ M C. $4.3 \times 10^{-9}$ M D. $1.0 \times 10^{-3}$ M

120. How many moles of $Pb^{2+}$ are there in 500.0 mL of a saturated solution of $PbSO_4$.
A. $3.2 \times 10^{-16}$ B. $9.0 \times 10^{-9}$ C. $6.7 \times 10^{-5}$ D. $1.3 \times 10^{-4}$

121. Which of the following compounds is the least soluble in water?
A. $CuI_2$ B. $PbI_2$ C. $PbCl_2$ D. CsI

122. Calculate the solubility of $SrSO_4$ in grams per litre.

123. Calculate the solubility of $PbSO_4$ in grams per litre.

124. Calculate the iodate ion concentration in a saturated copper(II) iodate solution.

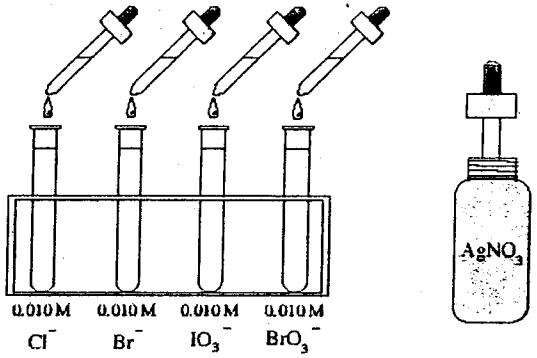




## I5 - Predict the formation of a precipitate by comparing the trial ion product to the $K_{sp}$ value using specific data

125.

Consider the following 10.0 mL solutions:




Equal moles of $AgNO_3$ are added to each solution. It is observed that a precipitate forms in all but one solution. Which solution does not form a precipitate?

A. $Cl^-$ B. $Br^-$ C. $IO_3^-$ D. $BrO_3^-$

126. 15.0 mL of a 0.020 M $AgNO_3$ is added to 35.0 mL of a 0.0040 M $KBrO_3$. Will a precipitate form?

A. A precipitate will form because the Trial $K_{sp} > K_{sp}$.
B. A precipitate will not form because the Trial $K_{sp} > K_{sp}$.
C. A precipitate will form because the Trial $K_{sp} < K_{sp}$.
D. A precipitate will not form because the Trial $K_{sp} < K_{sp}$.

127. 25.0 mL of a 0.020 M $Ca(NO_3)_2$ is added to 75.0 mL of a 0.0030 M $K_2SO_4$. Will a precipitate form?

A. A precipitate will form because the Trial $K_{sp} > K_{sp}$.
B. A precipitate will not form because the Trial $K_{sp} > K_{sp}$.
C. A precipitate will form because the Trial $K_{sp} < K_{sp}$.
D. A precipitate will not form because the Trial $K_{sp} < K_{sp}$.

128. What happens when equal volumes of 0.2 M BaS and 0.2 M $Sr(OH)_2$ are combined?

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

129. What happens when equal volumes of 0.2 M BaS and 0.2 M $CuSO_4$ are combined?

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

130. Two salt solutions were mixed and a Trial $K_{sp}$ was calculated to be $2.0 \times 10^{-9}$. The Ksp value is $1.0 \times 10^{-10}$. From this information, which of the following is a true statement?

| | $K_{sp}$ comparison | Outcome |
|---|---|---|
| A. | Trial $K_{sp} < K_{sp}$ | precipitate forms |
| B. | Trial $K_{sp} > K_{sp}$ | precipitate forms |
| C. | Trial $K_{sp} < K_{sp}$ | no precipitate forms |
| D. | Trial $K_{sp} > K_{sp}$ | no precipitate forms |

131. 25.0 mL of a 0.0012 M $NaIO_3$ solution is added to 75.0 mL of a 0.0016 M $Cu(NO_3)_2$ solution. Will a precipitate form? Support your answer with calculations.





132. 25.0 mL of a 0.0012 M $Mg(IO_3)_2$ solution is added to 75.0 mL of a 0.0016 M $CuSO_4$ solution. Will a precipitate form? Support your answer with calculations.

133. 25.0 mL of a 0.0024 M $KIO_3$ solution is added to 35 mL of a 0.0012 M $Pb(NO_3)_2$ solution. Will a precipitate form? Support your answer with calculations.

## I6 - Calculate the maximum concentration of one ion given the Ksp and the concentration of the other ion

134. What is the maximum $[Ag^+]$ that can exist in a solution of 0.010 M $NaIO_3$?

A. $3.2 \times 10^{-10}$ M  B. $3.2 \times 10^{-8}$ M  C. $3.2 \times 10^{-6}$ M  D. $1.8 \times 10^{-4}$ M

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

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

136. What is the maximum number of moles of $Cl^-$ that can exist in 500.0 mL of 2.0 M $AgNO_3$?

A. $4.5 \times 10^{-11}$ B. $9.0 \times 10^{-11}$ C. $1.8 \times 10^{-8}$ D. $1.8 \times 10^{-9}$

137. Which of the following ions would have the highest concentration in 0.1 M $CO_3^{-2}$?

A. $Ba^{+2}$ B. $Ca^{+2}$ C. $Sr^{+2}$ D. $Mg^{+2}$

138. Which of the following ions would have the highest concentration in 0.1 M $Ag^+$?

A. $CO_3^{-2}$ B. $CrO_4^{-2}$ C. $Cl^-$ D. $Br^-$

139. Which of the following ions could be used in the lowest concentration to remove $Ag^+$ ions from a polluted water sample?

A. $I^-$ B. $Br^-$ C. $BrO_3^-$ D. $CO_3^{-2}$

140. Which of the following ions could be used in the lowest concentration to remove $Pb^{+2}$ ions from a polluted water sample?

A. $I^-$ B. $Br^-$ C. $Cl^-$ D. $SO_4^{-2}$

141. What is the maximum [$Pb^{+2}$] possible in a 0.10 M NaCl solution?

A. $1.2 \times 10^{-5}$ M
B. $6.0 \times 10^{-5}$ M
C. $1.2 \times 10^{-3}$ M
D. $3.0 \times 10^{-3}$ M

142. Calculate the maximum [$CO_3^{-2}$] that can exist in a 0.0010 M $Mg(NO_3)_2$



143. Calculate the maximum [$CO_3^{-2}$] that can exist in a 0.0010 M $AgNO_3$

144. Calculate the mass of NaI necessary to begin precipitation of $Cu^+$ from a 250.0 mL sample of 0.010 M $CuNO_3$.

145. Calculate the mass of NaCl necessary to begin precipitation of $Ag^+$ from a 250.0 mL sample of 0.010 M $AgNO_3$.

146. Calculate the maximum mass of $BaCl_2(s)$ that can be added to 250 mL of 0.50 M $Pb(NO_3)_2$ **without** forming a precipitate of $PbCl_2$.

## I7 - Demonstrate and describe a method for determining the concentration of a specific ion

## I8 - Review

147. The solubility of $NiCO_3$ is $4.4 \times 10^{-2}$ g/L. Determine the $K_{sp}$ value for $NiCO_3$.

A. $1.4 \times 10^{-7}$ B. $3.7 \times 10^{-4}$ C. $1.9 \times 10^{-3}$ D. $2.1 \times 10^{-1}$





148. When equal volumes of 0.2 M solutions are mixed, which of the following combinations will form a single precipitate?

A. BaS and NaI
B. $CuSO_4$ and $CaCl_2$
C. $ZnSO_4$ and SrS
D. $(NH_4)_2SO_4$ and $Al(CH_3COO)_3$

149. In a solubility equilibrium, the

A. rate of dissolving equals the rate of crystallization
B. concentration of anion and cation are always equal
C. concentration of solute and solvent are equal
D. Ksp = solubility

150. Consider the following equilibrium:

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

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 $NaNO_3$

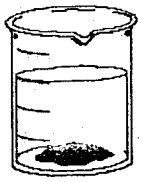
151. A compound has a solubility of $7.1 \times 10^{-5}$ M at 25°C. The compound is

A. CuS B. AgBr C. $CaCO_3$ D. $CaSO_4$

The following three beakers each contain different volumes of a saturated solution of $PbI_2$ and different masses of solid $PbI_2$ :

**Beaker I**

**Beaker II**



**Beaker III**

What is the relationship for the $[Pb^{2+}]$ in the solution in the three beakers?

152.

A. I = II = III
B. I > II > III
C. II > I > III
D. III > II > I

153. At 25°C, what is the $[Cl^-]$ in a saturated solution of $PbCl_2$?

A. $1.4 \times 10^{-2}$ M  B. $2.3 \times 10^{-2}$ M  C. $2.9 \times 10^{-2}$ M  D. $4.6 \times 10^{-2}$ M

154. What is the formula equation for the reaction that occurs when equal volumes of 0.20 M $K_3PO_4$ and 0.20 M $ZnCl_2$ are mixed together?

A. $K^+_{(aq)} + Cl^-_{(aq)} \rightarrow KCl_{(s)}$

B. $3Zn^{+2}_{(aq)} + 2PO_4^{-3}{}_{(aq)} \rightarrow Zn_3(PO_4)_{2\,(s)}$

C. $2\,K_3PO_{4\,(aq)} + 3ZnCl_{2\,(aq)} \rightarrow Zn_3(PO_4)_{2\,(s)} + 6\,KCl_{(aq)}$

D. $2\,K_3PO_{4\,(aq)} + 3ZnCl_{2\,(aq)} \rightarrow Zn_3(PO_4)_{2\,(aq)} + 6\,KCl_{(s)}$

155. The solubility of $CaF_2$ is $3.3 \times 10^{-4}$ M. Determine the $K_{sp}$ for $CaF_2$.

A. $3.6 \times 10^{-11}$  B. $1.4 \times 10^{-10}$  C. $1.1 \times 10^{-7}$  D. $3.3 \times 10^{-4}$

156. Solid $BaSO_4$ is added to water to prepare a saturated solution. Which of the following is true for this equilibrium?

A. solubility = $1.1 \times 10^{-10}$ M

B. trial $K_{sp}$ is less than $K_{sp}$

C. $[BaSO_4] = [Ba^{+2}]^2$

D. the rate of dissolving = rate of crystallization

157. Which of the following saturated solutions will have the lowest $[S^{-2}]$?

A. SrS  B. FeS  C. CuS  D. $Na_2S$

158. What is the value of $K_{sp}$ for $AgClO_2$ if the solubility of $AgClO_2$ is equal to $1.8 \times 10^{-6}$M?

A. $3.6 \times 10^{-6}$  B. $2.3 \times 10^{-17}$  C. $1.3 \times 10^{-3}$  D. $3.2 \times 10^{-12}$

159. A solution is prepared containing both 0.2 M $SO_4^{2-}$ and 0.2 M $PO_4^{3-}$ ions. An equal volume of a second solution is added in order to precipitate only one of these two anions. The second solution must contain which of the following?

A. 0.2 M $Cs^+$  B. 0.2 M $Zn^{+2}$  C. 0.2 M $Pb^{+2}$  D. 0.2 $Sr^{+2}$

160. Consider the following equilibrium:

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

When $Ca(NO_3)_2$ is added to this solution, which of the following will occur in regards to the equilibrium and $[SO_4^{2-}]$

| | Equilibrium | $[SO_4^{2-}]$ |
|---|---|---|
| A. | shifts right | increases |
| B. | shifts right | decreases |
| C. | shifts left | increases |
| D. | shifts left | decreases |

161. Which of the following compounds is the least soluble in water?

A. CuI  B. BeS  C. CsOH  D. $AgBrO_3$



162. An equal number of moles of $Na_2CO_3$ is added to four different 10.0 mL testtubes.

| Sample 1 | Sample 2 | Sample 3 | Sample 4 |
|---|---|---|---|
| 0.50 M $Ba^{2+}_{(aq)}$ | 0.50 M $Ca^{2+}_{(aq)}$ | 0.50 M $Mg^{2+}_{(aq)}$ | 0.50 M $Sr^{2+}_{(aq)}$ |

A precipitate forms in only one of the samples. Identify the cation which is present in the precipitate.

A. $Ca^{+2}$  B. $Ba^{+2}$  C. $Sr^{+2}$  D. $Mg^{+2}$

163. Which of the following best represents the complete ionic reaction resulting from the mixing of equal volumes of 0.2 M $Ca(NO_3)_2$ and 0.2 M NaOH?

A. $Ca^{+2}_{(aq)} + 2\,OH^-_{(aq)} \rightarrow Ca(OH)_{2\,(s)}$

B. $Ca(NO_3)_{2\,(aq)} + 2\,NaOH_{(aq)} \rightarrow Ca(OH)_{2\,(s)} + 2NaNO_{3\,(aq)}$

C. $Ca^{+2}_{(aq)} + 2NO_3^-{}_{(aq)} + 2Na^+_{(aq)} + 2OH^-_{(aq)} \rightarrow Ca(OH)_{2\,(s)} + 2Na^+_{(aq)} + 2NO_3^-{}_{(aq)}$

D. $Ca^{+2}_{(aq)} + 2NO_3^-{}_{(aq)} + 2Na^+_{(aq)} + 2OH^-_{(aq)} \rightarrow Ca(OH)_{2\,(s)} + 2NaNO_{3\,(aq)}$

164. A 30.00 mL sample of a saturated solution of $Ag_2SO_4$ was heated in an evaporating dish until all the water was evaporated. The following data were recorded:

| | |
|---|---|
| Mass of solution and evaporating dish | 62.260 g |
| Mass of evaporating dish | 32.125 g |
| Mass of evaporating dish and solid $Ag_2SO_4$ | 32.260 g |

Calculate the $K_{sp}$ value for the $Ag_2SO_4$

165. A solution of $(NH_4)_2SO_{3\,(aq)}$ is mixed with a solution of $CaCl_{2\,(aq)}$.

a. Write the formula equation for the reaction.

b. Write the complete ionic equation for the reaction.

c. Write the net ionic equation for the reaction.

b. Explain what happens when some $CaS_{(s)}$ is added to the contents.

166. A solution is found to contain $ZnSO_{4\,(aq)}$ in solution. Devise a procedure by which each of the ions in the solution can be removed, one at a time. The solutions that are available to use are:

$Sr(OH)_2$ BaS $NH_4Cl$ $Pb(NO_3)_2$ $FeI_3$

1. First you would add _____. The precipitate formed would be _____ Filter out the precipitate.

2. To the remaining solution add _____. The precipitate formed would be _____. Filter out the precipitate.





167. 25.0 mL of a $4.5 \times 10^{-3}$ M NaF solution is added to 35.0 mL of a $3.6 \times 10^{-3}$ M $Sr(NO_3)_2$ solution. Will a precipitate form?

168. Calculate the mass of NaCl necessary to begin precipitation of $Pb^{+2}$ from a 250.0 mL sample of 0.010 M $Pb(NO_3)_2$.

169. Which of the solutes below can form an ionic solution with the highest conductivity?
A. $Ag_2SO_4$
B. $CH_3OH$
C. $NH_4NO_3$
D. $HNO_2$

170. Which of the solutes below can form an ionic solution with the highest conductivity?
A. PbS B. $CH_3Cl$ C. $NaNO_3$ D. $CH_3COOH$