7.9: Equilibria of Other Reaction Classes (Exercises)

7.9.1: **Precipitation and Dissolution**

1. How do the concentrations of Ag^+ and CrO2−4CrO42− in a saturated solution above 1.0 g of solid Ag_2CrO_4 change when 100 g of solid Ag_2CrO_4 is added to the system? Explain.

Answer

There is no change. A solid has an activity of 1 whether there is a little or a lot.

2. How do the concentrations of Pb^{2+} and S^{2-} change when K_2S is added to a saturated solution of PbS?

3. What additional information do we need to answer the following question: How is the equilibrium of solid silver bromide with a saturated solution of its ions affected when the temperature is raised?

Answer

The solubility of silver bromide at the new temperature must be known. Normally the solubility increases and some of the solid silver bromide will dissolve.

4.Which of the following slightly soluble compounds has a solubility greater than that calculated from its solubility product because of hydrolysis of the anion present: $CoSO_3$, CuI, $PbCO_3$, $PbCl_2$, Tl_2S, $KClO_4$?

5. Which of the following slightly soluble compounds has a solubility greater than that calculated from its solubility product because of hydrolysis of the anion present: AgCl, $BaSO_4$, CaF_2, Hg_2I_2, $MnCO_3$, ZnS, PbS?

Answer

CaF_2, $MnCO_3$, and ZnS

6. Write the ionic equation for dissolution and the solubility product (K_{sp}) expression for each of the following slightly soluble ionic compounds:

1. $PbCl_2$
2. Ag_2S
3. $Sr_3(PO_4)_2$
4. $SrSO_4$

7. Write the ionic equation for the dissolution and the K_{sp} expression for each of the following slightly soluble ionic compounds:

a. LaF_3

b. $CaCO_3$

c. Ag_2SO_4

d. $Pb(OH)_2$

Answer

a. $LaF_3(s)\rightleftharpoons La^{3+}(aq)+3F^-(aq)$ $Ksp=[La^{3+}][F^-]^3$;

b. $CaCO_3(s)\rightleftharpoons Ca^{2+}(aq)+CO_3{}^{2-}(aq)$ $Ksp=[Ca^{2+}][CO_3{}^{2-}]$;

c. $Ag_2SO_4(s)\rightleftharpoons 2Ag^+(aq)+SO_4{}^{2-}(aq)$ $Ksp=[Ag^+]^2[SO_4{}^{2-}]$;

d. $Pb(OH)_2(s)\rightleftharpoons Pb^{2+}(aq)+2OH^-(aq)$ $Ksp=[Pb^{2+}][OH^-]^2$

8. The *Handbook of Chemistry and Physics* gives solubilities of the following compounds in grams per 100 mL of water. Because these compounds are only slightly soluble, assume that the volume does not change on dissolution and calculate the solubility product for each.

a. $BaSiF_6$, 0.026 g/100 mL (contains $SiF_6{}^{2-}$ ions)

b. $Ce(IO_3)_4$, 1.5×10^{-2} g/100 mL

c. $Gd_2(SO_4)_3$, 3.98 g/100 mL

d. $(NH_4)_2PtBr_6$, 0.59 g/100 mL (contains PtBr2−6PtBr62− ions)

9. The *Handbook of Chemistry and Physics* gives solubilities of the following compounds in grams per 100 mL of water. Because these compounds are only slightly soluble, assume that the volume does not change on dissolution and calculate the solubility product for each.

a. $BaSeO_4$, 0.0118 g/100 mL

b. $Ba(BrO_3)_2•H_2O$, 0.30 g/100 mL

c. $NH_4MgAsO_4•6H_2O$, 0.038 g/100 mL

d. $La_2(MoO_4)_3$, 0.00179 g/100 mL

Answer

a. 1.77×10^{-7}; b. 1.6×10^{-6}; c. 2.2×10^{-9}; d. 7.91×10^{-22}

10. Use solubility products and predict which of the following salts is the most soluble, in terms of moles per liter, in pure water: CaF_2, Hg_2Cl_2, PbI_2, or $Sn(OH)_2$.

11. Assuming that no equilibria other than dissolution are involved, calculate the molar solubility of each of the following from its solubility product:

a. $KHC_4H_4O_6$

b. PbI_2

c. $Ag_4[Fe(CN)_6]$, a salt containing the Fe(CN)−4Fe(CN)4− ion

d. Hg_2I_2

Answer

a. 2×10^{-2} *M*; b. 1.3×10^{-3} *M*; c. 2.27×10^{-9} *M*; d. 2.2×10^{-10} *M*

12. Assuming that no equilibria other than dissolution are involved, calculate the molar solubility of each of the following from its solubility product:

a. Ag_2SO_4

b. $PbBr_2$

c. AgI

d. $CaC_2O_4•H_2O$

13. Assuming that no equilibria other than dissolution are involved, calculate the concentration of all solute species in each of the following solutions of salts in contact with a solution containing a common ion. Show that changes in the initial concentrations of the common ions can be neglected.

a. AgCl(*s*) in 0.025 *M* NaCl

b. CaF_2(*s*) in 0.00133 *M* KF

c. Ag_2SO_4(*s*) in 0.500 L of a solution containing 19.50 g of K_2SO_4

d. $Zn(OH)_2$(*s*) in a solution buffered at a pH of 11.45

Answer

a. 7.2×10^{-9} *M* = $[Ag^+]$, $[Cl^-]$ = 0.025 *M*

Check: 7.2×10−9M0.025M×100%=2.9×10−5%7.2×10−9M0.025M×100%=2.9×10−5%, an insignificant change.

b. 2.2×10^{-5} *M* = $[Ca^{2+}]$, $[F^-]$ = 0.0013 *M*

Check: 2.25×10−5M0.00133M×100%=1.69%2.25×10−5M0.00133M×100%=1.69%. This value is less than 5% and can be ignored.

c. 0.2238 M = [SO2−4][SO42−]; [Ag^+] = 2.30×10^{-9} M

Check: 1.15×10−90.2238×100%=5.14×10−71.15×10−90.2238×100%=5.14×10−7; the condition is satisfied.

d. [OH^-] = 2.8×10^{-3} M; 5.7×10^{-12} M = [Zn^{2+}]

Check: 5.7×10−122.8×10−3×100%=2.0×10−7%5.7×10−122.8×10−3×100%=2.0×10−7%; x is less than 5% of [OH^-] and is, therefore, negligible.

14. Assuming that no equilibria other than dissolution are involved, calculate the concentration of all solute species in each of the following solutions of salts in contact with a solution containing a common ion. Show that changes in the initial concentrations of the common ions can be neglected.

a. $TlCl(s)$ in 1.250 M HCl

b. $PbI_2(s)$ in 0.0355 M CaI_2

c. $Ag_2CrO_4(s)$ in 0.225 L of a solution containing 0.856 g of K_2CrO_4

d. $Cd(OH)_2(s)$ in a solution buffered at a pH of 10.995

15. Assuming that no equilibria other than dissolution are involved, calculate the concentration of all solute species in each of the following solutions of salts in contact with a solution containing a common ion. Show that it is not appropriate to neglect the changes in the initial concentrations of the common ions.

a. $TlCl(s)$ in 0.025 M $TlNO_3$

b. $BaF_2(s)$ in 0.0313 M KF

c. MgC_2O_4 in 2.250 L of a solution containing 8.156 g of $Mg(NO_3)_2$

d. $Ca(OH)_2(s)$ in an unbuffered solution initially with a pH of 12.700

Answer

a. [Cl^-] = 7.6×10^{-3} M

Check: 7.6×10^{-3} / 0.025 × 100%=30%

This value is too large to drop x. Therefore solve by using the quadratic equation:

[Ti^+] = 3.1×10^{-2} M; [Cl^-] = 6.1×10^{-3}

b. [Ba^{2+}] = 1.7×10^{-3} M

Check: 1.7×10^{-3} / 0.0313×100%=5.5%

This value is too large to drop x, and the entire equation must be solved.

[Ba^{2+}] = 1.6×10^{-3} M; [F^-] = 0.0329 M;

c. $Mg(NO_3)_2$ = 0.02444 M

[$C_2O_4^{2-}$]=3.5×10^{-3}

Check: 3.5×10^{-3} / 0.02444 × 100%=14%

This value is greater than 5%, so the quadratic equation must be used:

[$C_2O_4^{2-}$]=3.5×10^{-3} M; [Mg^{2+}] = 0.0275 M;

d. [Ca^{2+}] = 2.8×10^{-3} M, [OH^-] = 0.053×10^{-2} M

16. Explain why the changes in concentrations of the common ions in the previous problem cannot be neglected.

Answer

The changes in concentration are greater than 5% and thus exceed the maximum value for disregarding the change.

17. Calculate the solubility of aluminum hydroxide, $Al(OH)_3$, in a solution buffered at pH 11.00.

18. Refer to Appendix J for solubility products for calcium salts. Determine which of the calcium salts listed is most soluble in moles per liter and which is most soluble in grams per liter.

Answer

$CaSO_4{\cdot}2H_2O$ is the most soluble Ca salt in mol/L, and it is also the most soluble Ca salt in g/L.

19. Most barium compounds are very poisonous; however, barium sulfate is often administered internally as an aid in the X-ray examination of the lower intestinal tract. This use of $BaSO_4$ is possible because of its low solubility. Calculate the molar solubility of $BaSO_4$ and the mass of barium present in 1.00 L of water saturated with $BaSO_4$.

20. Public Health Service standards for drinking water set a maximum of 250 mg/L (2.60×10^{-3} *M*) of SO_4^{2-} because of its cathartic action (it is a laxative). Does natural water that is saturated with $CaSO_4$ ("gyp" water) as a result or passing through soil containing gypsum, $CaSO_4{\bullet}2H_2O$, meet these standards? What is $[SO_4^{2-}]$ in such water?

Answer

4.9×10^{-3} *M* = $[SO_4^{2-}]$= $[Ca^{2+}]$; Since this concentration is higher than 2.60×10^{-3} *M*, "gyp" water does not meet the standards.

21. Perform the following calculations:

1. Calculate $[Ag^+]$ in a saturated aqueous solution of AgBr.
2. What will $[Ag^+]$ be when enough KBr has been added to make $[Br^-] = 0.050$ *M*?
3. What will $[Br^-]$ be when enough $AgNO_3$ has been added to make $[Ag^+] = 0.020$ *M*?

22. The solubility product of $CaSO_4{\bullet}2H_2O$ is 2.4×10^{-5}. What mass of this salt will dissolve in 1.0 L of 0.010 *M* SO_4^{2-}?

Answer

Mass ($CaSO_4{\bullet}2H_2O$) = 0.34 g/L

23. Assuming that no equilibria other than dissolution are involved, calculate the concentrations of ions in a saturated solution of each of the following (see Table E3 for solubility products).

a. TlCl

b. BaF_2

c. Ag_2CrO_4

d. $CaC_2O_4{\bullet}H_2O$

e. the mineral anglesite, $PbSO_4$

24. Assuming that no equilibria other than dissolution are involved, calculate the concentrations of ions in a saturated solution of each of the following (see Table E3 for solubility products).

a. AgI

b. Ag_2SO_4

c. $Mn(OH)_2$

d. $Sr(OH)_2{\bullet}8H_2O$

e. the mineral brucite, $Mg(OH)_2$

Answer

$[Ag^+] = [I^-] = 1.2 \times 10^{-8}$ *M*; $[Ag^+] = 2.86 \times 10^{-2}$ *M*, [SO2−4][SO42−] = 1.43×10^{-2} *M*; $[Mn^{2+}] = 2.2 \times 10^{-5}$ *M*, $[OH^-] = 4.5 \times 10^{-5}$ *M*; $[Sr^{2+}] = 4.3 \times 10^{-2}$ *M*, $[OH^-] = 8.6 \times 10^{-2}$ *M*; $[Mg^{2+}] = 1.6 \times 10^{-4}$ *M*, $[OH^-] = 3.1 \times 10^{-4}$ *M*.

25. The following concentrations are found in mixtures of ions in equilibrium with slightly soluble solids. From the concentrations given, calculate K_{sp} for each of the slightly soluble solids indicated:

1. AgBr: $[Ag^+] = 5.7 \times 10^{-7}$ *M*, $[Br^-] = 5.7 \times 10^{-7}$ *M*
2. $CaCO_3$: $[Ca^{2+}] = 5.3 \times 10^{-3}$ *M*, [CO 3 2−] = 9.0×10^{-7} *M*
3. PbF_2: $[Pb^{2+}] = 2.1 \times 10^{-3}$ *M*, $[F^-] = 4.2 \times 10^{-3}$ *M*
4. Ag_2CrO_4: $[Ag^+] = 5.3 \times 10^{-5}$ *M*, 3.2×10^{-3} *M*
5. InF_3: $[In^{3+}] = 2.3 \times 10^{-3}$ *M*, $[F^-] = 7.0 \times 10^{-3}$ *M*

26. The following concentrations are found in mixtures of ions in equilibrium with slightly soluble solids. From the concentrations given, calculate K_{sp} for each of the slightly soluble solids indicated:

1. TlCl: $[Tl^+] = 1.21 \times 10^{-2}$ *M*, $[Cl^-] = 1.2 \times 10^{-2}$ *M*
2. $Ce(IO_3)_4$: $[Ce^{4+}] = 1.8 \times 10^{-4}$ *M*, [IO−3][IO3−] = 2.6×10^{-13} *M*
3. $Gd_2(SO_4)_3$: $[Gd^{3+}] = 0.132$ *M*, [SO2−4][SO42−] = 0.198 *M*
4. Ag_2SO_4: $[Ag^+] = 2.40 \times 10^{-2}$ *M*, [SO2−4][SO42−] = 2.05×10^{-2} *M*
5. $BaSO_4$: $[Ba^{2+}] = 0.500$ *M*, [SO2−4][SO42−] = 2.16×10^{-10} *M*

Answer

2.0×10^{-4}; 5.1×10^{-17}; 1.35×10^{-4}; 1.18×10^{-5}; 1.08×10^{-10}

27. Which of the following compounds precipitates from a solution that has the concentrations indicated? (See Table E3 for K_{sp} values.)

1. $KClO_4$: $[K^+] = 0.01$ *M*, [ClO−4][ClO4−] = 0.01 *M*
2. K_2PtCl_6: $[K^+] = 0.01$ *M*, [PtCl2−6][PtCl62−] = 0.01 *M*
3. PbI_2: $[Pb^{2+}] = 0.003$ *M*, $[I^-] = 1.3 \times 10^{-3}$ *M*
4. Ag_2S: $[Ag^+] = 1 \times 10^{-10}$ *M*, $[S^{2-}] = 1 \times 10^{-13}$ *M*

28. Which of the following compounds precipitates from a solution that has the concentrations indicated? (See Table E3 for K_{sp} values.)

a. $CaCO_3$: $[Ca^{2+}] = 0.003$ *M*, [CO2−3][CO32−] = 0.003 *M*

b. $Co(OH)_2$: $[Co^{2+}] = 0.01$ *M*, $[OH^-] = 1 \times 10^{-7}$ *M*

c. $CaHPO_4$: $[Ca^{2+}] = 0.01$ *M*, [HPO2−4][HPO42−] = 2×10^{-6} *M*

d. $Pb_3(PO_4)_2$: $[Pb^{2+}] = 0.01$ *M*, [PO3−4][PO43−] = 1×10^{-13} *M*

Answer

a. $CaCO_3$ does precipitate; b. The compound does not precipitate; c. The compound does not precipitate; d. The compound precipitates.

29. Calculate the concentration of Tl^+ when TlCl just begins to precipitate from a solution that is 0.0250 *M* in Cl^-.

30. Calculate the concentration of sulfate ion when $BaSO_4$ just begins to precipitate from a solution that is 0.0758 *M* in Ba^{2+}.

Answer

1.42×10^{-9} M

31. Calculate the concentration of Sr^{2+} when SrF_2 starts to precipitate from a solution that is 0.0025 *M* in F^-.

32. Calculate the concentration of PO3−4PO43− when Ag_3PO_4 starts to precipitate from a solution that is 0.0125 *M* in Ag^+.

Answer

9.2×10^{-13} *M*

33. Calculate the concentration of F^- required to begin precipitation of CaF_2 in a solution that is 0.010 *M* in Ca^{2+}.

34. Calculate the concentration of Ag^+ required to begin precipitation of Ag_2CO_3 in a solution that is 2.50×10^{-6} *M* in CO2−3CO32−.

Answer

$[Ag^+] = 1.8 \times 10^{-3}$ *M*

35. What $[Ag^+]$ is required to reduce [CO2−3][CO32−] to 8.2×10^{-4} *M* by precipitation of Ag_2CO_3?

36. What $[F^-]$ is required to reduce $[Ca^{2+}]$ to 1.0×10^{-4} *M* by precipitation of CaF_2?

Answer

6.2×10^{-4} M

37. volume of 0.800 L of a 2×10^{-4}-*M* $Ba(NO_3)_2$ solution is added to 0.200 L of 5×10^{-4} *M* Li_2SO_4. Does $BaSO_4$ precipitate? Explain your answer.

38. Perform these calculations for nickel(II) carbonate.

1. With what volume of water must a precipitate containing $NiCO_3$ be washed to dissolve 0.100 g of this compound? Assume that the wash water becomes saturated with $NiCO_3$ ($K_{sp} = 1.36 \times 10^{-7}$).
2. If the $NiCO_3$ were a contaminant in a sample of $CoCO_3$ ($K_{sp} = 1.0 \times 10^{-12}$), what mass of $CoCO_3$ would have been lost? Keep in mind that both $NiCO_3$ and $CoCO_3$ dissolve in the same solution.

Answer

2.28 L; 7.3×10^{-7} g

39. Iron concentrations greater than 5.4×10^{-6} *M* in water used for laundry purposes can cause staining. What $[OH^-]$ is required to reduce $[Fe^{2+}]$ to this level by precipitation of $Fe(OH)_2$?

40. A solution is 0.010 *M* in both Cu^{2+} and Cd^{2+}. What percentage of Cd^{2+} remains in the solution when 99.9% of the Cu^{2+} has been precipitated as CuS by adding sulfide?

Answer

100% of it is dissolved

41. A solution is 0.15 *M* in both Pb^{2+} and Ag^+. If Cl^- is added to this solution, what is $[Ag^+]$ when $PbCl_2$ begins to precipitate?

42. What reagent might be used to separate the ions in each of the following mixtures, which are 0.1 *M* with respect to each ion? In some cases it may be necessary to control the pH. (Hint: Consider the K_{sp} values given in Appendix J.)

a. Hg2+2Hg22+ and Cu^{2+}

b. SO2−4SO42− and Cl^-

c. Hg^{2+} and Co^{2+}

d. Zn^{2+} and Sr^{2+}

e. Ba^{2+} and Mg^{2+}

f. CO2−3CO32− and OH^-

Answer

a. Hg2+2Hg22+ and Cu^{2+}: Add SO2−4SO42−.
b. SO2−4SO42− and Cl^-: Add Ba^{2+}.
c. Hg^{2+} and Co^{2+}: Add S^{2-}.
d. Zn^{2+} an Sr^{2+}: Add OH^- until $[OH^-] = 0.050$ *M*.
e. Ba^{2+} and Mg^{2+}: Add SO2−4SO42−
f. CO2−3CO32− and OH^-: Add Ba^{2+}.

43. A solution contains 1.0×10^{-5} mol of KBr and 0.10 mol of KCl per liter. $AgNO_3$ is gradually added to this solution. Which forms first, solid AgBr or solid AgCl?

44. A solution contains 1.0×10^{-2} mol of KI and 0.10 mol of KCl per liter. $AgNO_3$ is gradually added to this solution. Which forms first, solid AgI or solid AgCl?

Answer

AgI will precipitate first.

45. The calcium ions in human blood serum are necessary for coagulation. Potassium oxalate, $K_2C_2O_4$, is used as an anticoagulant when a blood sample is drawn for laboratory tests because it removes the calcium as a precipitate of $CaC_2O_4•H_2O$. It is necessary

to remove all but 1.0% of the Ca^{2+} in serum in order to prevent coagulation. If normal blood serum with a buffered pH of 7.40 contains 9.5 mg of Ca^{2+} per 100 mL of serum, what mass of $K_2C_2O_4$ is required to prevent the coagulation of a 10 mL blood sample that is 55% serum by volume? (All volumes are accurate to two significant figures. Note that the volume of serum in a 10-mL blood sample is 5.5 mL. Assume that the K_{sp} value for CaC_2O_4 in serum is the same as in water.)

46. About 50% of urinary calculi (kidney stones) consist of calcium phosphate, $Ca_3(PO_4)_2$. The normal mid range calcium content excreted in the urine is 0.10 g of Ca^{2+} per day. The normal mid range amount of urine passed may be taken as 1.4 L per day. What is the maximum concentration of phosphate ion that urine can contain before a calculus begins to form?

Answer

4×10^{-9} *M*

47. The pH of normal urine is 6.30, and the total phosphate concentration ([PO3−4][PO43−] + [HPO2−4][HPO42−] + [H2PO−4][H2PO4−] + [H_3PO_4]) is 0.020 *M*. What is the minimum concentration of Ca^{2+} necessary to induce kidney stone formation? (See Exercise for additional information.)

48. Magnesium metal (a component of alloys used in aircraft and a reducing agent used in the production of uranium, titanium, and other active metals) is isolated from sea water by the following sequence of reactions:

Mg2+(aq)+Ca(OH)2(aq)⟶Mg(OH)2(s)+Ca2+(aq)

Mg(OH)2(s)+2HCl(aq)⟶MgCl2(s)+2H2O(l)

MgCl2(l)→Mg(s)+Cl2(g) (electrolysis)

49. Sea water has a density of 1.026 g/cm^3 and contains 1272 parts per million of magnesium as Mg^{2+}(*aq*) by mass. What mass, in kilograms, of $Ca(OH)_2$ is required to precipitate 99.9% of the magnesium in 1.00×10^3 L of sea water?

Answer

3.99 kg

50. Hydrogen sulfide is bubbled into a solution that is 0.10 *M* in both Pb^{2+} and Fe^{2+} and 0.30 *M* in HCl. After the solution has come to equilibrium it is saturated with H_2S ([H_2S] = 0.10 *M*). What concentrations of Pb^{2+} and Fe^{2+} remain in the solution? For a saturated solution of H_2S we can use the equilibrium:

H2S(aq)+2H2O(l)⇌2H3O+(aq)+S2−(aq) K=1.0×10−26

(Hint: The [H3O+] changes as metal sulfides precipitate.)

51. Perform the following calculations involving concentrations of iodate ions:

1. The iodate ion concentration of a saturated solution of $La(IO_3)_3$ was found to be 3.1×10^{-3} mol/L. Find the K_{sp}.
2. Find the concentration of iodate ions in a saturated solution of $Cu(IO_3)_2$ ($K_{sp} = 7.4 \times 10^{-8}$).

Answer

3.1×10^{-11}; [Cu^{2+}] = 2.6×10^{-3}; [IO−3][IO3−] = 5.3×10^{-3}

52. Calculate the molar solubility of AgBr in 0.035 *M* NaBr ($K_{sp} = 5 \times 10^{-13}$).

53. How many grams of $Pb(OH)_2$ will dissolve in 500 mL of a 0.050-*M* $PbCl_2$ solution ($K_{sp} = 1.2 \times 10^{-15}$)?

Answer

1.8×10^{-5} g $Pb(OH)_2$

54. Use the simulation from the earlier Link to Learning to complete the following exercise:. Using 0.01 g CaF_2, give the K_{sp} values found in a 0.2-*M* solution of each of the salts. Discuss why the values change as you change soluble salts.

55. How many grams of Milk of Magnesia, $Mg(OH)_2$ (*s*) (58.3 g/mol), would be soluble in 200 mL of water. $K_{sp} = 7.1 \times 10^{-12}$. Include the ionic reaction and the expression for K_{sp} in your answer. ($K_w = 1 \times 10^{-14} = [H_3O^+][OH^-]$)

Answer

Mg(OH)2(s)⇌Mg2+2OH−

Ksp=[Mg2+][OH−]2

1.14×10^{-3} g $Mg(OH)_2$

56. Two hypothetical salts, LM_2 and LQ, have the same molar solubility in H_2O. If K_{sp} for LM_2 is 3.20×10^{-5}, what is the K_{sp} value for LQ?

57. Which of the following carbonates will form first? Which of the following will form last? Explain.

1. MgCO3Ksp=3.5×10−8
2. CaCO3Ksp=4.2×10−7
3. SrCO3Ksp=3.9×10−9
4. BaCO3Ksp=4.4×10−5
5. MnCO3Ksp=5.1×10−9

Answer

$SrCO_3$ will form first, since it has the smallest K_{sp} value it is the least soluble. $BaCO_3$ will be the last to precipitate, it has the largest K_{sp} value.

58. How many grams of $Zn(CN)_2(s)$ (117.44 g/mol) would be soluble in 100 mL of H_2O? Include the balanced reaction and the expression for K_{sp} in your answer. The K_{sp} value for $Zn(CN)_2(s)$ is 3.0×10^{-16}.

7.9.2: Lewis Acids and Bases

59. Under what circumstances, if any, does a sample of solid AgCl completely dissolve in pure water?

Answer

when the amount of solid is so small that a saturated solution is not produced

60. Explain why the addition of NH_3 or HNO_3 to a saturated solution of Ag_2CO_3 in contact with solid Ag_2CO_3 increases the solubility of the solid.

61. Calculate the cadmium ion concentration, $[Cd^{2+}]$, in a solution prepared by mixing 0.100 L of 0.0100 *M* $Cd(NO_3)_2$ with 1.150 L of 0.100 $NH_3(aq)$.

Answer

2.35×10^{-4} *M*

62. Explain why addition of NH_3 or HNO_3 to a saturated solution of $Cu(OH)_2$ in contact with solid $Cu(OH)_2$ increases the solubility of the solid.

Answer

Sometimes equilibria for complex ions are described in terms of dissociation constants, K_d. For the complex ion AlF3−6AlF63− the dissociation reaction is:

AlF3−6⇌Al3++6F−\)and$Kd=[Al3+][F-]6[AlF3-6]=2\times10-24(15.E.33)(15.E.33)AlF63-\rightleftharpoons Al3++6F-$and\(Kd=[Al3+][F−]6[AlF63−]=2×10−24

63. Calculate the value of the formation constant, K_f, for AlF3−6AlF63−.

Answer

5×10^{23}

64. Using the value of the formation constant for the complex ion Co(NH3)2+6Co(NH3)62+, calculate the dissociation constant.

65. Using the dissociation constant, $K_d = 7.8 \times 10^{-18}$, calculate the equilibrium concentrations of Cd^{2+} and CN^- in a 0.250-*M* solution of Cd(CN)2−4Cd(CN)42−.

Answer

This table has two main columns and three rows. The first row for the first column does not have a heading and then has the following in the first column: Initial concentration (M) and Equilibrium (M). The second column has the header, "[C d (C N) subscript 4 to the second power superscript negative sign] [C N superscript negative sign] [C d to the second power superscript positive sign]." Under the second column is a subgroup of two rows and three columns. The first column contains the following: 0.250 and 0.250 minus x. The second column contains the following: 0 and 4 x. The third column contains the following: 0 and x.

$[Cd^{2+}] = 9.5 \times 10^{-5}$ *M*; $[CN^{-}] = 3.8 \times 10^{-4}$ *M*

66. Using the dissociation constant, $K_d = 3.4 \times 10^{-15}$, calculate the equilibrium concentrations of Zn^{2+} and OH^{-} in a 0.0465-*M* solution of Zn(OH)2−4Zn(OH)42−.

67. Using the dissociation constant, $K_d = 2.2 \times 10^{-34}$, calculate the equilibrium concentrations of Co^{3+} and NH_3 in a 0.500-*M* solution of Co(NH3)3+6Co(NH3)63+.

Answer

$[Co^{3+}] = 3.0 \times 10^{-6}$ *M*; $[NH_3] = 1.8 \times 10^{-5}$ *M*

68. Using the dissociation constant, $K_d = 1 \times 10^{-44}$, calculate the equilibrium concentrations of Fe^{3+} and CN^{-} in a 0.333 M solution of Fe(CN)3−6Fe(CN)63−.

69. Calculate the mass of potassium cyanide ion that must be added to 100 mL of solution to dissolve 2.0×10^{-2} mol of silver cyanide, AgCN.

Answer

1.3 g

70. Calculate the minimum concentration of ammonia needed in 1.0 L of solution to dissolve 3.0×10^{-3} mol of silver bromide.

71. A roll of 35-mm black and white photographic film contains about 0.27 g of unexposed AgBr before developing. What mass of $Na_2S_2O_3{\bullet}5H_2O$ (sodium thiosulfate pentahydrate or hypo) in 1.0 L of developer is required to dissolve the AgBr as Ag(S2O3)3−2Ag(S2O3)23− ($K_f = 4.7 \times 10^{13}$)?

Answer

0.80 g

72. We have seen an introductory definition of an acid: An acid is a compound that reacts with water and increases the amount of hydronium ion present. In the chapter on acids and bases, we saw two more definitions of acids: a compound that donates a proton (a hydrogen ion, H^+) to another compound is called a Brønsted-Lowry acid, and a Lewis acid is any species that can accept a pair of electrons. Explain why the introductory definition is a macroscopic definition, while the Brønsted-Lowry definition and the Lewis definition are microscopic definitions.

73. Write the Lewis structures of the reactants and product of each of the following equations, and identify the Lewis acid and the Lewis base in each:

a. CO2+OH−⟶HCO3−

b. B(OH)3+OH−⟶B(OH)4−

c. I−+I2⟶I3−

d. AlCl3+Cl−⟶AlCl4− (use Al-Cl single bonds)

e. O2−+SO3⟶SO42−

Answer

(a)

This figure shows a chemical reaction modeled with structural formulas. On the left side is a structure with a central C atom. O atoms, each with two unshared electron pairs, are double bonded to the left and right sides of the C atom. Following a plus sign is another structure in brackets which has an O atom with three unshared electron dot pairs single bonded to an H atom on the right. Outside the brackets is superscript negative sign. Following a right pointing arrow is a structure in brackets that has a central C atom to which 3 O atoms are bonded. Above and slightly to the right, one of the O atoms is connected with a double bond. This O atom has two unshared electron pairs. The second O atom is single bonded below and slightly to the right. This O atom has three unshared electron pairs. The third O atom is bonded to the left of the C atom. This O atom has two unshared electron pairs and an H atom single bonded to its left. Outside the brackets to the right is a superscript negative symbol.

;

(b)

This figure shows a chemical reaction modeled with structural formulas. On the left side is a structure that has a central B atom to which 3 O atoms are bonded. The O atoms above and below slightly right of the B atom each have an H atom single bonded to the right. The third O atom is single bonded to the left side of the B atom. This O atom has an H atom single bonded to its left side. All O atoms in this structure have two unshared electron pairs. Following a plus sign is another structure which has an O atom single bonded to an H atom on its right. The O atom has three unshared electron pairs. The structure appears in brackets with a superscript negative sign. Following a right pointing arrow is a structure in brackets has a central B atom to which 4 O atoms are bonded. The O atoms above, below, and right of the B atom each hav an H atom single bonded to the right. The third O atom is single bonded to the left side of the B atom. This O atom has an H atom single bonded to its left side. All O atoms in this structure have two unshared electron pairs. Outside the brackets to the right is a superscript negative symbol.

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(c)

This figure illustrates a chemical reaction using structural formulas. On the left, two I atoms, each with 3 unshared electron pairs, are joined with a single bond. Following a plus sign is another structure which has an I atom with four pairs of electron dots and a superscript negative sign. Following a right pointing arrow is a structure in brackets that has three I atoms connected in a line with single bonds. The two end I atoms have three unshared electron dot pairs and the I atom at the center has two unshared electron pairs. Outside the brackets is a superscript negative sign.

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(d)

This figure illustrates a chemical reaction using structural formulas. On the left, an A l atom is positioned at the center of a structure and three Cl atoms are single bonded above, leftt, and below. Each C l atom has three pairs of electron dots. Following a plus sign is another structure which has an F atom is surrounded by four electron dot pairs and a superscript negative symbol. Following a right pointing arrow is a structure in brackets that has a central A l atom to which 4 C l atoms are connected with single bonds above, below, to the left, and to the right. Each C l atom in this structure has three pairs of electron dots. Outside the brackets is a superscript negative symbol.

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(e)

This figure illustrates a chemical reaction using structural formulas. On the left is a structure which has an S atom at the center. O atoms are single bonded above and below. These O atoms have three electron dot pairs each. To the right of the S atom is a double bonded O atom which has two pairs of electron dots. Following a plus sign is an O atom which is surrounded by four electron dot pairs and has a superscript 2 negative. Following a right pointing arrow is a structure in brackets that has a central S atom to which 4 O atoms are connected with single bonds above, below, to the left, and to the right. Each of the O atoms has three pairs of electron dots. Outside the brackets is a superscript 2 negative.

74. Write the Lewis structures of the reactants and product of each of the following equations, and identify the Lewis acid and the Lewis base in each:

1. $CS_2 + SH^- \longrightarrow HCS_3^-$
2. $BF_3 + F^- \longrightarrow BF_4^-$
3. $I^- + SnI_2 \longrightarrow SnI_3^-$
4. $Al(OH)_3 + OH^- \longrightarrow Al(OH)_4^-$
5. $F^- + SO_3 \longrightarrow SFO_3^-$

75. Using Lewis structures, write balanced equations for the following reactions:

a. $HCl(g) + PH_3(g) \longrightarrow HCl(g) + PH_3(g)$

b. $H_3O^+ + CH_3^- \longrightarrow H_3O^+ + CH_3$

c. $CaO + SO_3 \longrightarrow CaO + SO_3 \longrightarrow$

d. $NH_4^+ + C_2H_5O^- \longrightarrow NH_4^+ + C_2H_5O$

Answer

(a)

This figure represents a chemical reaction in two rows. The top row shows the reaction using chemical formulas. The second row uses structural formulas to represent the reaction. The first row contains the equation H C l (g) plus P H subscript 3 (g) right pointing arrow left bracket P H subscript 4 right bracket superscript plus plus left bracket C l with 4 pairs of electron dots right bracket superscript negative sign. The second row begins on the left with H left bracket C l with four unshared electron pairs right bracket plus a structure in brackets with a central P atom with H atoms single bonded at the left, above, and to the right. A single unshared electron pair is on the central P atom. Outside the brackets to the right is a superscript plus sign. Following a right pointing arrow is a structure in brackets with a central P atom with H atoms single bonded at the left, above, below, and to the right. Outside the brackets is a superscript plus sign. This structure is followed by a plus and a C l atom in brackets with four unshared electron pairs and a superscript negative sign.

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(b) $H_3O^+ + CH_3^- \longrightarrow CH_4 + H_2O$ $H_3O^+ + CH_3^- \longrightarrow CH_4 + H_2O$

This figure represents a chemical reaction using structural formulas. A structure is shown in brackets on the left which is composed of a central O atom with one unshared electron pair and three single bonded H atoms to the left, right, and above the atom. Outside the brackets to the right is a superscript plus sign. Following a plus sign, is another structure in brackets composed of a central C atom with one unshared electron pair and three single bonded H atoms to the left, right, and above the atom. Outside the brackets to the right is a superscript negative sign. Following a right pointing arrow is a structure with a central C atom with H atoms single bonded above, below, left and right. Following a plus sign is a structure with a central O atom with two unshared electron pairs and two H atoms connected with single bonds.

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(c) $CaO + SO_3 \longrightarrow CaSO_4$ $CaO + SO_3 \longrightarrow CaSO_4$

This figure represents a chemical reaction using structural formulas. On the left, C a superscript 2 plus is just left of bracket O with four unshared electron pairs right bracket superscript 2 negative plus a structure with a central S atom to which two O atoms are single bonded at the left and right, and a single O atom is double bonded above. The two single bonded O atoms each have three unshared electron pairs and the double bonded O atom has two unshared electron pairs. Following a right pointing arrow is C a superscript 2 plus just left of a structure in brackets with a central S atom which has 4 O atoms single bonded at the left, above, below, and to the right. Each of the O atoms has three unshared electron pairs. Outside the brackets to the right is a superscript two negative.

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(d) NH+4+C2H5O−⟶C2H5OH+NH3NH4++C2H5O−⟶C2H5OH+NH3

This figure represents a chemical reaction using structural formulas. A structure is shown in brackets on the left which is composed of a central N atom with four single bonded H atoms to the left, right, above, and below the atom. Outside the brackets to the right is a superscript plus sign. Following a plus sign, is another structure in brackets composed of a C atom with three single bonded H atoms above, below, and to the left. A second C atom is single bonded to the right. This C atom has H atoms single bonded above and below. To the right of the second C atom, an O atom is single bonded. This O atom has three unshared electron pairs. Outside the brackets to the right is a subperscript negative. Following a right pointing arrow is a structure composed of a C atom with three single bonded H atoms above, below, and to the left. A second C atom is single bonded to the right. This C atom has H atoms single bonded above and below. To the right of the second C atom, an O atom is single bonded. This O atom has two unshared electron pairs and an H atom single bonded to its right.

76. Calculate [HgCl42−] in a solution prepared by adding 0.0200 mol of NaCl to 0.250 L of a 0.100-*M* $HgCl_2$ solution.

77. In a titration of cyanide ion, 28.72 mL of 0.0100 *M* $AgNO_3$ is added before precipitation begins. [The reaction of Ag^+ with CN^- goes to completion, producing the Ag(CN)2− complex.] Precipitation of solid AgCN takes place when excess Ag^+ is added to the solution, above the amount needed to complete the formation of Ag(CN)2−. How many grams of NaCN were in the original sample?

Answer

0.0281 g

78. What are the concentrations of Ag^+, CN^-, and Ag(CN)−2Ag(CN)2− in a saturated solution of AgCN?

79. In dilute aqueous solution HF acts as a weak acid. However, pure liquid HF (boiling point = 19.5 °C) is a strong acid. In liquid HF, HNO_3 acts like a base and accepts protons. The acidity of liquid HF can be increased by adding one of several inorganic fluorides that are Lewis acids and accept F^- ion (for example, BF_3 or SbF_5). Write balanced chemical equations for the reaction of pure HNO_3 with pure HF and of pure HF with BF_3.

Answer

HNO3(l)+HF(l)⟶H2NO+3+F−HNO3(l)+HF(l)⟶H2NO3++F−; HF(l)+BF3(g)⟶H++BF4HF(l)+BF3(g)⟶H++BF4

80. The simplest amino acid is glycine, $H_2NCH_2CO_2H$. The common feature of amino acids is that they contain the functional groups: an amine group, $–NH_2$, and a carboxylic acid group, $–CO_2H$. An amino acid can function as either an acid or a base. For glycine, the acid strength of the carboxyl group is about the same as that of acetic acid, CH_3CO_2H, and the base strength of the amino group is slightly greater than that of ammonia, NH_3.

81. Write the Lewis structures of the ions that form when glycine is dissolved in 1 *M* HCl and in 1 *M* KOH.

82. Write the Lewis structure of glycine when this amino acid is dissolved in water. (Hint: Consider the relative base strengths of the $–NH_2$ and −CO−2−CO2− groups.)

83. Boric acid, H_3BO_3, is not a Brønsted-Lowry acid but a Lewis acid.

1. Write an equation for its reaction with water.
2. Predict the shape of the anion thus formed.
3. What is the hybridization on the boron consistent with the shape you have predicted?

Answer

H3BO3+H2O⟶H4BO−4+H+H3BO3+H2O⟶H4BO4−+H+; The electronic and molecular shapes are the same—both tetrahedral. The tetrahedral structure is consistent with sp^3 hybridization.

7.9.3: Multiple Equilibria

84. A saturated solution of a slightly soluble electrolyte in contact with some of the solid electrolyte is said to be a system in equilibrium. Explain. Why is such a system called a heterogeneous equilibrium?

85. Calculate the equilibrium concentration of Ni^{2+} in a 1.0-*M* solution $[Ni(NH_3)_6](NO_3)_2$.

Answer

0.014 *M*

86. Calculate the equilibrium concentration of Zn^{2+} in a 0.30-*M* solution of Zn(CN)42−.

87. Calculate the equilibrium concentration of Cu^{2+} in a solution initially with 0.050 *M* Cu^{2+} and 1.00 *M* NH_3.

Answer

1.0×10^{-13} *M*

88. Calculate the equilibrium concentration of Zn^{2+} in a solution initially with 0.150 *M* Zn^{2+} and 2.50 *M* CN^{-}.

89. Calculate the Fe^{3+} equilibrium concentration when 0.0888 mole of $K_3[Fe(CN)_6]$ is added to a solution with 0.0.00010 *M* CN^{-}.

Answer

9×10^{-22} *M*

90. Calculate the Co^{2+} equilibrium concentration when 0.100 mole of $[Co(NH_3)_6](NO_3)_2$ is added to a solution with 0.025 *M* NH_3. Assume the volume is 1.00 L.

91. The equilibrium constant for the reaction Hg2+(aq)+2Cl−(aq)⇌HgCl2(aq)Hg2+(aq)+2Cl−(aq)⇌HgCl2(aq) is 1.6×10^{13}. Is $HgCl_2$ a strong electrolyte or a weak electrolyte? What are the concentrations of Hg^{2+} and Cl^{-} in a 0.015-*M* solution of $HgCl_2$?

Answer

6.2×10^{-6} *M* = $[Hg^{2+}]$; 1.2×10^{-5} *M* = $[Cl^{-}]$; The substance is a weak electrolyte because very little of the initial 0.015 *M* $HgCl_2$ dissolved.

92. Calculate the molar solubility of $Sn(OH)_2$ in a buffer solution containing equal concentrations of NH_3 and NH4+.

93. Calculate the molar solubility of $Al(OH)_3$ in a buffer solution with 0.100 *M* NH_3 and 0.400 *M* NH4+.

Answer

$[OH^{-}] = 4.5 \times 10^{-5}$; $[Al^{3+}] = 2.1 \times 10^{-20}$ (molar solubility)

94. What is the molar solubility of CaF_2 in a 0.100-*M* solution of HF? K_a for HF = 7.2×10^{-4}.

95. What is the molar solubility of $BaSO_4$ in a 0.250-*M* solution of $NaHSO_4$? K_a for HSO4− = 1.2×10^{-2}.

Answer

[SO42−]=0.049M; $[Ba^{2+}] = 2.2 \times 10^{-9}$ (molar solubility)

96. What is the molar solubility of $Tl(OH)_3$ in a 0.10-*M* solution of NH_3?

97. What is the molar solubility of $Pb(OH)_2$ in a 0.138-*M* solution of CH_3NH_2?

Answer

$[OH^{-}] = 7.6 \times 10^{-3}$ *M*, $[Pb^{2+}] = 4.8 \times 10^{-12}$ (molar solubility)

98. A solution of 0.075 *M* $CoBr_2$ is saturated with H_2S ($[H_2S]$ = 0.10 *M*). What is the minimum pH at which CoS begins to precipitate?

CoS(s)⇌Co2+(aq)+S2−(aq)Ksp=4.5×10−27CoS(s)⇌Co2+(aq)+S2−(aq)Ksp=4.5×10−27

H2S(aq)+2H2O(l)⇌2H3O+(aq)+S2−(aq)K=1.0×10−26H2S(aq)+2H2O(l)⇌2H3O+(aq)+S2−(aq)K=1.0×10−26

99. A 0.125-*M* solution of $Mn(NO_3)_2$ is saturated with H_2S ($[H_2S]$ = 0.10 *M*). At what pH does MnS begin to precipitate?

MnS(s)⇌Mn2+(aq)+S2−(aq)Ksp=4.3×10−22MnS(s)⇌Mn2+(aq)+S2−(aq)Ksp=4.3×10−22

H2S(aq)+2H2O(l)⇌2H3O+(aq)+S2−(aq)K=1.0×10−26H2S(aq)+2H2O(l)⇌2H3O+(aq)+S2−(aq)K=1.0×10−26

Answer

3.27

100. Calculate the molar solubility of BaF_2 in a buffer solution containing 0.20 *M* HF and 0.20 *M* NaF.

101. Calculate the molar solubility of $CdCO_3$ in a buffer solution containing 0.115 *M* Na_2CO_3 and 0.120 *M* $NaHCO_3$

Answer

[CO32−]=0.115M; $[Cd^{2+}] = 3 \times 10^{-12}$ *M*

102. To a 0.10-M solution of $Pb(NO_3)_2$ is added enough HF(g) to make [HF] = 0.10 M.

1. Does PbF_2 precipitate from this solution? Show the calculations that support your conclusion.
2. What is the minimum pH at which PbF_2 precipitates?

Calculate the concentration of Cd^{2+} resulting from the dissolution of $CdCO_3$ in a solution that is 0.010 M in H_2CO_3.

Answer

1×10^{-5} M

103. Both AgCl and AgI dissolve in NH_3.

1. What mass of AgI dissolves in 1.0 L of 1.0 M NH_3?
2. What mass of AgCl dissolves in 1.0 L of 1.0 M NH_3?

104. Calculate the volume of 1.50 M CH_3CO_2H required to dissolve a precipitate composed of 350 mg each of $CaCO_3$, $SrCO_3$, and $BaCO_3$.

Answer

0.0102 L (10.2 mL)

105. Even though $Ca(OH)_2$ is an inexpensive base, its limited solubility restricts its use. What is the pH of a saturated solution of $Ca(OH)_2$?

106. What mass of NaCN must be added to 1 L of 0.010 M $Mg(NO_3)_2$ in order to produce the first trace of $Mg(OH)_2$?

Answer

5×10^{-3} g

107. Magnesium hydroxide and magnesium citrate function as mild laxatives when they reach the small intestine. Why do magnesium hydroxide and magnesium citrate, two very different substances, have the same effect in your small intestine. (Hint: The contents of the small intestine are basic.)

108. The following question is taken from a Chemistry Advanced Placement Examination and is used with the permission of the Educational Testing Service.

Solve the following problem:

MgF2(s)⇌Mg^{2+}(aq)+2F−(aq)

In a saturated solution of MgF_2 at 18 °C, the concentration of Mg^{2+} is 1.21×10^{-3} M. The equilibrium is represented by the preceding equation.

1. Write the expression for the solubility-product constant, K_{sp}, and calculate its value at 18 °C.
2. Calculate the equilibrium concentration of Mg^{2+} in 1.000 L of saturated MgF_2 solution at 18 °C to which 0.100 mol of solid KF has been added. The KF dissolves completely. Assume the volume change is negligible.
3. Predict whether a precipitate of MgF_2 will form when 100.0 mL of a 3.00×10^{-3}-M solution of $Mg(NO_3)_2$ is mixed with 200.0 mL of a 2.00×10^{-3}-M solution of NaF at 18 °C. Show the calculations to support your prediction.
4. At 27 °C the concentration of Mg^{2+} in a saturated solution of MgF_2 is 1.17×10^{-3} M. Is the dissolving of MgF_2 in water an endothermic or an exothermic process? Give an explanation to support your conclusion.

Answer

$K_{sp} = [Mg^{2+}][F^-]^2 = (1.21 \times 10^{-3})(2 \times 1.21 \times 10^{-3})^2 = 7.09 \times 10^{-9}$; 7.09×10^{-7} M

Determine the concentration of Mg^{2+} and F^- that will be present in the final volume. Compare the value of the ion product $[Mg^{2+}][F^-]^2$ with K_{sp}. If this value is larger than K_{sp}, precipitation will occur. 0.1000 L × 3.00×10^{-3} M $Mg(NO_3)_2$ = 0.3000 L × M $Mg(NO_3)_2$ M $Mg(NO_3)_2$ = 1.00×10^{-3} M 0.2000 L × 2.00×10^{-3} M NaF = 0.3000 L × M NaF M NaF = 1.33×10^{-3} M ion product = $(1.00 \times 10^{-3})(1.33 \times 10^{-3})^2 = 1.77 \times 10^{-9}$ This value is smaller than K_{sp}, so no precipitation will occur. MgF_2 is less soluble at 27 °C than at 18 °C. Because added heat acts like an added reagent, when it appears on the product side, the Le Chatelier's principle states that the equilibrium will shift to the reactants' side to counter the stress. Consequently, less reagent will dissolve. This situation is found in our case. Therefore, the reaction is exothermic.

109. Which of the following compounds, when dissolved in a 0.01-*M* solution of $HClO_4$, has a solubility greater than in pure water: CuCl, $CaCO_3$, MnS, $PbBr_2$, CaF_2? Explain your answer.

110. Which of the following compounds, when dissolved in a 0.01-*M* solution of $HClO_4$, has a solubility greater than in pure water: AgBr, BaF_2, $Ca_3(PO_4)_3$, ZnS, PbI_2? Explain your answer.

Answer

BaF_2, $Ca_3(PO_4)_2$, ZnS; each is a salt of a weak acid, and the [H3O+][H3O+] from perchloric acid reduces the equilibrium concentration of the anion, thereby increasing the concentration of the cations

111. What is the effect on the amount of solid $Mg(OH)_2$ that dissolves and the concentrations of Mg^{2+} and OH^- when each of the following are added to a mixture of solid $Mg(OH)_2$ and water at equilibrium?

1. $MgCl_2$
2. KOH
3. $HClO_4$
4. $NaNO_3$
5. $Mg(OH)_2$

112. What is the effect on the amount of $CaHPO_4$ that dissolves and the concentrations of Ca^{2+} and HPO−4HPO4− when each of the following are added to a mixture of solid $CaHPO_4$ and water at equilibrium?

- $CaCl_2$
- HCl
- $KClO_4$
- NaOH
- $CaHPO_4$

Answer

Effect on amount of solid $CaHPO_4$, $[Ca^{2+}]$, $[OH^-]$: increase, increase, decrease; decrease, increase, decrease; no effect, no effect, no effect; decrease, increase, decrease; increase, no effect, no effect

113. Identify all chemical species present in an aqueous solution of $Ca_3(PO_4)_2$ and list these species in decreasing order of their concentrations. (Hint: Remember that the PO43− ion is a weak base.

114. A volume of 50 mL of 1.8 *M* NH_3 is mixed with an equal volume of a solution containing 0.95 g of $MgCl_2$. What mass of NH_4Cl must be added to the resulting solution to prevent the precipitation of $Mg(OH)_2$?

Answer

7.1 g
