

***Fundamentals of Analytical Chemistry 10th edition
Skoog Solutions Manual***

SKU: 9780357450390-SOLUTIONS

Student Solution Manual

Student Solution Manual: Skoog et al., *Fundamentals of Analytical Chemistry*, 10e,
© 2022, 978-0-357-45055-0, Chapter 2: Calculations Used in Analytical Chemistry

Some of the answers below may differ in format but have the same value as your result. Please check with your instructor if a specific format is desired.

Chapter 2

2-1. Define

Answers:

(a) molar mass.

The molar mass is the mass in grams of one mole of a chemical species.

(c) millimolar mass.

The *millimolar mass* is the mass in grams of one millimole of a chemical species.

2-3. Give two examples of units derived from the fundamental base SI units.

Solution:

$$\text{The liter: } 1 \text{ L} = \frac{1000 \text{ mL}}{1 \text{ L}} \times \frac{1 \text{ cm}^3}{\text{mL}} \times \left(\frac{\text{m}}{100 \text{ cm}} \right)^3 = 10^{-3} \text{ m}^3$$

$$\text{Molar concentration: } 1 \text{ M} = \frac{1 \text{ mol}}{\text{L}} \times \frac{\text{L}}{10^{-3} \text{ m}^3} = \frac{1 \text{ mol}}{10^{-3} \text{ m}^3}$$

2-4. Simplify the following quantities using a unit with an appropriate prefix:

Solutions:

(a) $5.8 \times 10^8 \text{ Hz}$.

$$5.8 \times 10^8 \text{ Hz} \times \frac{\text{MHz}}{10^6 \text{ Hz}} = 580 \text{ MHz}$$

(c) $9.31 \times 10^7 \mu\text{mol}$.

$$9.31 \times 10^7 \mu\text{mol} \times \frac{\text{mol}}{10^6 \mu\text{mol}} = 93.1 \text{ mol}$$

(e) $3.96 \times 10^6 \text{ nm}$.

$$3.96 \times 10^6 \text{ nm} \times \frac{\text{mm}}{10^6 \text{ nm}} = 3.96 \text{ mm}$$

2-5. Why is 1 g no longer exactly 1 mole of unified atomic mass units?

Answer:

The dalton is defined as 1/12 the mass of a neutral ^{12}C atom. With the redefinition of SI base units in 2019, the definition of the dalton remained the same. However, the definition of the mole and the kilogram changed in such a way that the molar mass unit is no longer exactly 1 g/mol.

2-7. Find the number of Na^+ ions in 2.75 g of Na_3PO_4 ?

Solution:

$$2.75 \text{ g Na}_3\text{PO}_4 \times \frac{1 \text{ mol Na}_3\text{PO}_4}{163.94 \text{ g}} \times \frac{3 \text{ mol Na}^+}{\text{mol Na}_3\text{PO}_4} \times \frac{6.022 \times 10^{23} \text{ Na}^+}{\text{mol Na}^+} = 3.03 \times 10^{22} \text{ Na}^+$$

2-9. Find the amount of the indicated element (in moles) in

Solutions:

(a) 5.32 g of B_2O_3 .

$$5.32 \text{ g B}_2\text{O}_3 \times \frac{2 \text{ mol B}}{\text{mol B}_2\text{O}_3} \times \frac{\text{mol B}_2\text{O}_3}{69.62 \text{ g B}_2\text{O}_3} = 0.153 \text{ mol B}$$

(b) 195.7 mg of $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$.

$$195.7 \text{ mg Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O} \times \frac{\text{g}}{1000 \text{ mg}} \times \frac{7 \text{ mol O}}{\text{mol Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}} \times \frac{\text{mol Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}}{381.37 \text{ g}} = 3.59 \times 10^{-3} \text{ mol O} = 3.59 \text{ mmol}$$

(c) 4.96 g of Mn_3O_4 .

$$4.96 \text{ g Mn}_3\text{O}_4 \times \frac{\text{mol Mn}_3\text{O}_4}{228.81 \text{ g Mn}_3\text{O}_4} \times \frac{3 \text{ mol Mn}}{\text{mol Mn}_3\text{O}_4} = 6.50 \times 10^{-2} \text{ mol Mn}$$

(d) 333 mg of CaC_2O_4 .

$$333 \text{ mg CaC}_2\text{O}_4 \times \frac{\text{g}}{1000 \text{ mg}} \times \frac{\text{mol CaC}_2\text{O}_4}{128.10 \text{ g CaC}_2\text{O}_4} \times \frac{2 \text{ mol C}}{\text{mol CaC}_2\text{O}_4} = 5.20 \times 10^{-3} \text{ mol C} = 5.20 \text{ mmol}$$

2-11. Find the number of millimoles of solute in

Solutions:

(a) 2.00 L of 0.0449 M_{KMnO_4} .

$$\frac{0.0449 \text{ mol KMnO}_4}{\text{L}} \times \frac{1000 \text{ mmol}}{\text{mol}} \times 2.00 \text{ L} = 89.8 \text{ mmol KMnO}_4$$

- (b) 750 mL of 5.35×10^{-3} M KSCN.

$$\frac{5.35 \times 10^{-3} \text{ M KSCN}}{\text{L}} \times \frac{1000 \text{ mmol}}{\text{mol}} \times \frac{\text{L}}{1000 \text{ mL}} \times 750 \text{ mL} = 4.01 \text{ mmol KSCN}$$

- (c) 3.50 L of a solution that contains 6.23 ppm of CuSO_4 .

$$\frac{6.23 \text{ mg CuSO}_4}{\text{L}} \times \frac{\text{g}}{1000 \text{ mg}} \times \frac{\text{mol CuSO}_4}{159.61 \text{ g CuSO}_4} \times \frac{1000 \text{ mmol}}{\text{mol}} \times 3.50 \text{ L} = 0.137 \text{ mmol CuSO}_4$$

- (d) 250 mL of 0.414 mM KCl.

$$\frac{0.414 \text{ mmol KCl}}{\text{L}} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times 250 \text{ mL} = 0.104 \text{ mmol KCl}$$

- 2-13.** What is the mass in milligrams of

Solutions:

- (a) 0.367 mol of HNO_3 ?

$$0.367 \text{ mol HNO}_3 \times \frac{63.01 \text{ g HNO}_3}{\text{mol HNO}_3} \times \frac{1000 \text{ mg}}{\text{g}} = 2.31 \times 10^4 \text{ mg HNO}_3$$

- (b) 245 mmol of MgO?

$$245 \text{ mmol MgO} \times \frac{\text{mol}}{1000 \text{ mmol}} \times \frac{40.30 \text{ g MgO}}{\text{mol MgO}} \times \frac{1000 \text{ mg}}{\text{g}} = 9.87 \times 10^3 \text{ mg MgO}$$

- (c) 12.5 mol of NH_4NO_3 ?

$$12.5 \text{ mol NH}_4\text{NO}_3 \times \frac{80.04 \text{ g NH}_4\text{NO}_3}{\text{mol NH}_4\text{NO}_3} \times \frac{1000 \text{ mg}}{\text{g}} = 1.00 \times 10^6 \text{ mg NH}_4\text{NO}_3$$

- (d) 4.95 mol of $(\text{NH}_4)_2\text{e}(\text{NO}_3)_6$ (548.23 g/mol)?

$$4.95 \text{ mol } (\text{NH}_4)_2\text{Ce}(\text{NO}_3)_6 \times \frac{548.23 \text{ g } (\text{NH}_4)_2\text{Ce}(\text{NO}_3)_6}{\text{mol } (\text{NH}_4)_2\text{Ce}(\text{NO}_3)_6} \times \frac{1000 \text{ mg}}{\text{g}} \\ = 2.71 \times 10^6 \text{ mg } (\text{NH}_4)_2\text{Ce}(\text{NO}_3)_6$$

- 2-15.** What is the mass in milligrams of solute in

Solutions:

- (a) 16.0 mL of 0.350 M sucrose (342 g/mol)?

$$\frac{0.350 \text{ mol sucrose}}{\text{L}} \times \frac{\text{L}}{1000 \text{ mL}} \times \frac{342 \text{ g sucrose}}{\text{mol sucrose}} \times \frac{1000 \text{ mg}}{\text{g}} \\ \times 16.0 \text{ mL} = 1.92 \times 10^3 \text{ mg sucrose}$$

- (b) 1.92 L of $3.76 \times 10^{-3} \text{ M H}_2\text{O}_2$?

$$\frac{3.76 \times 10^{-3} \text{ mol H}_2\text{O}_2}{\text{L}} \times \frac{34.02 \text{ g H}_2\text{O}_2}{\text{mol H}_2\text{O}_2} \times \frac{1000 \text{ mg}}{\text{g}} \times 1.92 \text{ L} = 246 \text{ mg H}_2\text{O}_2$$

- 2-16.** What is the mass in grams of solute in

Solutions:

- (a) 250 mL of 0.264 M H_2O_2 ?

$$\frac{0.264 \text{ mol H}_2\text{O}_2}{\text{L}} \times \frac{\text{L}}{1000 \text{ mL}} \times \frac{34.02 \text{ g H}_2\text{O}_2}{\text{mol H}_2\text{O}_2} \times 250 \text{ mL} = 2.25 \text{ g H}_2\text{O}_2$$

- (b) 37.0 mL of $5.75 \times 10^{-4} \text{ M}$ benzoic acid (122 g/mol)?

$$\begin{aligned} &\frac{5.75 \times 10^{-4} \text{ mol benzoic acid}}{\text{L}} \times \frac{\text{L}}{1000 \text{ mL}} \times \frac{122 \text{ g benzoic acid}}{\text{mol benzoic acid}} \\ &\times 37.0 \text{ mL} = 2.60 \times 10^{-3} \text{ g benzoic acid} \end{aligned}$$

- 2-17.** Calculate the p-value for each of the listed ions in the following:

Solutions:

- (a) Na^+ , Cl^- , and OH^- in a solution that is 0.0635 M in NaCl and 0.0403 M in NaOH.

$$\text{pNa} = -\log(0.0635 + 0.0403) = -\log(0.1038) = 0.9838$$

$$\text{pCl} = -\log(0.0635) = 1.197$$

$$\text{pOH} = -\log(0.0403) = 1.395$$

- (c) H^+ , Cl^- , and Zn^{2+} in a solution that is 0.400 M in HCl and 0.100 M in ZnCl_2 .

$$\text{pH} = -\log(0.400) = 0.398$$

$$\text{pCl} = -\log(0.400 + 2 \times 0.100) = -\log(0.600) = 0.222$$

$$\text{pZn} = -\log(0.100) = 1.00$$

- (e) K^+ , OH^- , and $\text{Fe}(\text{CN})_6^{4-}$ in a solution that is $1.62 \times 10^{-7} \text{ M}$ in $\text{K}_4\text{Fe}(\text{CN})_6$ and $5.12 \times 10^{-7} \text{ M}$ in KOH.

$$\text{pK} = -\log(4 \times 1.62 \times 10^{-7} + 5.12 \times 10^{-7}) = -\log(1.16 \times 10^{-6}) = 5.94$$

$$\text{pOH} = -\log(5.12 \times 10^{-7}) = 6.291$$

$$\text{pFe}(\text{CN})_6 = -\log(1.62 \times 10^{-7}) = 6.790$$

2-18. Calculate the molar H_3O^+ ion concentration of a solution that has a pH of

Solutions:

(a) 3.73.

$$\text{pH} = 3.73, \log[\text{H}_3\text{O}^+] = -3.73, [\text{H}_3\text{O}^+] = 1.9 \times 10^{-4} \text{ M}$$

as in part (a)

(c) 0.59.

$$[\text{H}_3\text{O}^+] = 0.26 \text{ M}$$

(e) 7.62.

$$[\text{H}_3\text{O}^+] = 2.4 \times 10^{-8} \text{ M}$$

(g) -0.76.

$$[\text{H}_3\text{O}^+] = 5.8 \text{ M}$$

2-19. Calculate the p-functions for each ion in a solution that is

Solutions:

(a) 0.0200 M in NaBr.

$$\text{pNa} = \text{pBr} = -\log(0.0200) = 1.699$$

(c) $4.5 \times 10^{-3} \text{ M}$ in $\text{Ba}(\text{OH})_2$.

$$\text{pBa} = -\log(4.5 \times 10^{-3}) = 2.35; \text{pOH} = -\log(2 \times 4.5 \times 10^{-3}) = 2.05$$

(e) $7.2 \times 10^{-3} \text{ M}$ in CaCl_2 and $8.2 \times 10^{-3} \text{ M}$ in BaCl_2 .

$$\text{pCa} = -\log(7.2 \times 10^{-3}) = 2.14; \text{pBa} = -\log(8.2 \times 10^{-3}) = 2.09$$

$$\text{pCl} = -\log(2 \times 7.2 \times 10^{-3} + 2 \times 8.2 \times 10^{-3}) = -\log(0.0308) = 1.51$$

2-20. Convert the following p-functions to molar concentrations:

Solutions:

(a) $\text{pH} = 1.102$.

$$\text{pH} = 1.102; \log[\text{H}_3\text{O}^+] = -1.102; [\text{H}_3\text{O}^+] = 0.0791 \text{ M}$$

(c) $\text{pBr} = 7.77$.

$$\text{pBr} = 7.77; \log[\text{Br}^-] = -7.77; [\text{Br}^-] = 1.70 \times 10^{-8} \text{ M}$$

(e) $\text{pLi} = 12.35$.

$$\text{pLi} = 12.35; \log[\text{Li}^+] = -12.35; [\text{Li}^+] = 4.5 \times 10^{-13} \text{ M}$$

(g) $\text{pMn} = 0.135$.

$$\text{pMn} = 0.135; \log[\text{Mn}^{2+}] = -0.135; [\text{Mn}^{2+}] = 0.733 \text{ M}$$

- 2-21.** Seawater contains an average of 1.08×10^3 ppm of Na^+ and 270 ppm of SO_4^{2-} . Calculate

Solutions:

- (a) the molar concentrations of Na^+ and SO_4^{2-} given that the average density of seawater is 1.02 g/mL.

$$1.08 \times 10^3 \text{ ppm Na}^+ \times \frac{1}{10^6 \text{ ppm}} \times \frac{1.02 \text{ g}}{\text{mL}} \times \frac{1000 \text{ mL}}{\text{L}} \times \frac{\text{mol Na}^+}{22.99 \text{ g}} = 4.79 \times 10^{-2} \text{ M Na}^+$$

$$270 \text{ ppm SO}_4^{2-} \times \frac{1}{10^6 \text{ ppm}} \times \frac{1.02 \text{ g}}{\text{mL}} \times \frac{1000 \text{ mL}}{\text{L}} \times \frac{\text{mol SO}_4^{2-}}{96.06 \text{ g}} = 2.87 \times 10^{-3} \text{ M SO}_4^{2-}$$

- (b) the pNa and pSO_4 for seawater.

$$\text{pNa} = -\log(4.79 \times 10^{-2}) = 1.320$$

$$\text{pSO}_4 = -\log(2.87 \times 10^{-3}) = 2.543$$

- 2-23.** A solution was prepared by dissolving 5.76 g of $\text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}$ (277.85 g/mol) in sufficient water to give 2.000 L. Calculate

Solutions:

- (a) the molar analytical concentration of $\text{KCl} \cdot \text{MgCl}_2$ in this solution.

$$\frac{5.76 \text{ g KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}}{2.00 \text{ L}} \times \frac{\text{mol KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}}{277.85 \text{ g}} = 1.04 \times 10^{-2} \text{ M KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}$$

- (b) the molar concentration of Mg^{2+} .

There is 1 mole of Mg^{2+} per mole of $\text{KCl} \cdot \text{MgCl}_2$, so the molar concentration of Mg^{2+} is the same as the molar concentration of $\text{KCl} \cdot \text{MgCl}_2$ or $1.04 \times 10^{-2} \text{ M}$.

- (c) the molar concentration of Cl^- .

$$1.04 \times 10^{-2} \text{ M KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O} \times \frac{3 \text{ mol Cl}^-}{\text{mol KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}} = 3.12 \times 10^{-2} \text{ M Cl}^-$$

- (d) the weight/volume percentage of $\text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}$.

$$\frac{5.76 \text{ g KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}}{2.00 \text{ L}} \times \frac{\text{L}}{1000 \text{ mL}} \times 100\% = 0.288\% \text{ (w/v)}$$

- (e) the number of millimoles of Cl^- in 25.0 mL of this solution.

$$\frac{3.12 \times 10^{-2} \text{ mol Cl}^-}{\text{L}} \times \frac{\text{L}}{1000 \text{ mL}} \times \frac{1000 \text{ mmol}}{\text{mol}} \times 25 \text{ mL} = 7.8 \times 10^{-1} \text{ mmol Cl}^-$$

(f) ppm K^+ .

$$1.04 \times 10^{-2} \text{ M KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O} \times \frac{1 \text{ mol } K^+}{1 \text{ mol KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}} \times \frac{39.10 \text{ g } K^+}{\text{mol } K^+} \times \frac{1000 \text{ mg}}{\text{g}} \\ = \frac{407 \text{ mg}}{\text{L}} = 407 \text{ ppm } K^+$$

(g) pMg for the solution.

$$\text{pMg} = -\log(1.04 \times 10^{-2}) = 1.983$$

(h) pCl for the solution.

$$\text{pCl} = -\log(3.12 \times 10^{-2}) = 1.506$$

2-25. A 5.85% (w/w) $\text{Fe}(\text{NO}_3)_3$ (241.86 g/mol) solution has a density of 1.059 g/mL. Calculate

Solutions:

(a) the molar analytical concentration of $\text{Fe}(\text{NO}_3)_3$ in this solution.

$$5.85\% \text{ Fe}(\text{NO}_3)_3 = \frac{5.85 \text{ g Fe}(\text{NO}_3)_3}{\text{g solution}} \times \frac{1}{100} \times \frac{1.059 \text{ g}}{\text{mL}} \times \frac{1000 \text{ mL}}{\text{L}} \times \frac{\text{mol Fe}(\text{NO}_3)_3}{241.86 \text{ g}} \\ = 2.56 \times 10^{-1} \text{ M Fe}(\text{NO}_3)_3 = 0.256 \text{ M}$$

(b) the molar NO_3^- concentration in the solution.

$$2.56 \times 10^{-1} \text{ M Fe}(\text{NO}_3)_3 = \frac{2.56 \times 10^{-1} \text{ mol Fe}(\text{NO}_3)_3}{\text{L}} \times \frac{3 \text{ mol NO}_3^-}{\text{mol Fe}(\text{NO}_3)_3} = 7.68 \times 10^{-1} \text{ M NO}_3^-$$

(c) the mass in grams of $\text{Fe}(\text{NO}_3)_3$ contained in each liter of this solution.

$$\frac{2.56 \times 10^{-1} \text{ mol Fe}(\text{NO}_3)_3}{\text{L}} \times \frac{241.86 \text{ g Fe}(\text{NO}_3)_3}{\text{mol}} \times \text{L} = 6.20 \times 10^1 \text{ g Fe}(\text{NO}_3)_3 = 62.0 \text{ g}$$

2-27. Describe the preparation of

Solutions:

(a) 500 mL of 5.25% (w/v) aqueous ethanol ($\text{C}_2\text{H}_5\text{OH}$, 46.1 g/mol).

$$\frac{5.25 \text{ g C}_2\text{H}_5\text{OH}}{\text{mL soln}} \times \frac{1}{100} \times 500 \text{ mL soln} = 26.3 \text{ g C}_2\text{H}_5\text{OH}$$

Weigh 26.3 g ethanol and add enough water to give a final volume of 500 mL.

(b) 500 g of 5.25% (w/w) aqueous ethanol.

$$5.25\% \text{ (w/w) C}_2\text{H}_5\text{OH} = \frac{5.25 \text{ g C}_2\text{H}_5\text{OH}}{\text{g soln}} \times \frac{1}{100} \times 500 \text{ g soln} = 2.63 \times 10^1 \text{ g C}_2\text{H}_5\text{OH}$$

$$500 \text{ g soln} = 26.3 \text{ g C}_2\text{H}_5\text{OH} + x \text{ g water}$$

$$x \text{ g water} = 500 \text{ g soln} - 26.3 \text{ g C}_2\text{H}_5\text{OH} = 473.7 \text{ g water}$$

Mix 26.3 g ethanol with 473.7 g water.

- (c) 500 mL of 5.25% (v/v) aqueous ethanol.

$$5.25\% \text{ (v/v) C}_2\text{H}_5\text{OH} = \frac{5.25 \text{ mL C}_2\text{H}_5\text{OH}}{100 \text{ mL soln}}$$

$$\frac{5.25 \text{ mL C}_2\text{H}_5\text{OH}}{100 \text{ mL soln}} \times 500 \text{ mL soln} = 26.3 \text{ mL C}_2\text{H}_5\text{OH}$$

Dilute 26.3 mL ethanol with enough water to give a final volume of 500 mL.

- 2-29. Describe the preparation of 500 mL of 3.00 M H_3PO_4 from the commercial reagent that is 86% H_3PO_4 (w/w) and has a specific gravity of 1.71.

Solution:

$$\frac{3.00 \text{ mol H}_3\text{PO}_4}{\text{L}} \times \frac{\text{L}}{1000 \text{ mL}} \times 500 \text{ mL} = 1.50 \text{ mol H}_3\text{PO}_4$$

$$\frac{86 \text{ g H}_3\text{PO}_4}{\text{g reagent}} \times \frac{1}{100} \times \frac{1.71 \text{ g reagent}}{\text{g water}} \times \frac{\text{g water}}{\text{mL}} \times \frac{1000 \text{ mL}}{\text{L}} \times \frac{\text{mol H}_3\text{PO}_4}{98.0 \text{ g}} = \frac{1.50 \times 10^1 \text{ mol H}_3\text{PO}_4}{\text{L}}$$

$$\begin{aligned} \text{volume 86\% (w/w) H}_3\text{PO}_4 \text{ required} &= 1.50 \text{ mol H}_3\text{PO}_4 \times \frac{\text{L}}{1.50 \times 10^1 \text{ mol H}_3\text{PO}_4} \\ &= 1.00 \times 10^{-1} \text{ L} \end{aligned}$$

Dilute 100 mL to 500 mL with water.

- 2-31. Describe the preparation of

Solutions:

- (a) 500 mL of 0.1000 M AgNO_3 from the solid reagent.

$$\begin{aligned} 0.1000 \text{ M AgNO}_3 &= \frac{0.1000 \text{ mol AgNO}_3}{\text{L}} \\ &= \frac{0.1000 \text{ mol AgNO}_3}{\text{L}} \times \frac{169.87 \text{ g AgNO}_3}{\text{mol}} \times \frac{\text{L}}{1000 \text{ mL}} \times 500 \text{ mL} \\ &= 8.49 \text{ g AgNO}_3 \end{aligned}$$

Dissolve 8.49 g AgNO_3 in enough water to give a final volume of 500 mL.

- (b) 1.00 L of 0.1000 M HCl , starting with a 6.00 M solution of the reagent.

$$\frac{0.1000 \text{ mol HCl}}{\text{L}} \times 1 \text{ L} = 0.1000 \text{ mol HCl}$$

$$0.1000 \text{ mol HCl} \times \frac{\text{L}}{6.00 \text{ mol HCl}} = 1.67 \times 10^{-2} \text{ L HCl}$$

Take 167 mL of the 6.00 M HCl and dilute to 1.00 L using water.

- (c) 250 mL of a solution that is 0.0810 M in K^+ , starting with solid $K_4Fe(CN)_6$.

$$\frac{0.0810 \text{ mol } K^+}{L} \times \frac{L}{1000 \text{ mL}} \times 250 \text{ mL} = 2.025 \times 10^{-2} \text{ mol } K^+$$

$$2.025 \times 10^{-2} \text{ mol } K^+ \times \frac{\text{mol } K_4Fe(CN)_6}{4 \text{ mol } K^+} \times \frac{368.35 \text{ g } K_4Fe(CN)_6}{\text{mol}} = 1.86 \text{ g } K_4Fe(CN)_6$$

Dissolve 1.86 g $K_4Fe(CN)_6$ in enough water to give a final volume of 250 mL.

- (d) 500 mL of 3.00% (w/v) aqueous $BaCl_2$ from a 0.400 M $BaCl_2$ solution.

$$\frac{3.00 \text{ g } BaCl_2}{\text{mL soln}} \times \frac{1}{100} \times 500 \text{ mL} = 1.5 \times 10^1 \text{ g } BaCl_2$$

$$1.5 \times 10^1 \text{ g } BaCl_2 \times \frac{\text{mol } BaCl_2}{208.23 \text{ g}} \times \frac{L}{0.400 \text{ mol } BaCl_2} = 1.80 \times 10^{-1} \text{ L}$$

Take 180 mL of the 0.400 M $BaCl_2$ solution and dilute to 500 mL using water.

- (e) 2.00 L of 0.120 M $HClO_4$ from the commercial reagent [71.0% $HClO_4$ (w/w), sp gr 1.67].

$$\frac{0.120 \text{ mol } HClO_4}{L} \times 2.00 \text{ L} = 0.240 \text{ mol } HClO_4$$

$$\frac{71 \text{ g } HClO_4}{100 \text{ g reagent}} \times \frac{1.67 \text{ g reagent}}{\text{g water}} \times \frac{\text{g water}}{\text{mL}} \times \frac{1000 \text{ mL}}{L} \times \frac{\text{mol } HClO_4}{100.46 \text{ g}} = \frac{1.18 \times 10^1 \text{ mol } HClO_4}{L}$$

$$\text{volume 71\% (w/w) } HClO_4 \text{ required} = 0.240 \text{ mol } HClO_4 = \frac{L}{1.18 \times 10^1 \text{ mol } HClO_4} \\ = 2.03 \times 10^{-2} \text{ L}$$

Take 20.3 mL of the concentrated reagent and dilute to 2.00 L using water.

- (f) 1.00 L of a solution that is 60.0 ppm in Na^+ , starting with solid Na_2SO_4 .

$$60 \text{ ppm } Na^+ = \frac{60 \text{ mg } Na^+}{L \text{ soln}}$$

$$\frac{60 \text{ mg } Na^+}{L \text{ soln}} \times 1.00 \text{ L} = 60 \text{ mg } Na^+$$

$$60 \text{ mg } Na^+ \times \frac{\text{g}}{1000 \text{ mg}} \times \frac{\text{mol } Na^+}{22.99 \text{ g}} = 2.61 \times 10^{-3} \text{ mol } Na^+$$

$$2.61 \times 10^{-3} \text{ mol } Na^+ \times \frac{\text{mol } Na_2SO_4}{2 \text{ mol } Na^+} \times \frac{142.04 \text{ g } Na_2SO_4}{\text{mol}} = 0.19 \text{ g } Na_2SO_4$$

Dissolve 0.19 g Na_2SO_4 in enough water to give a final volume of 1.00 L.

- 2-33.** What mass of solid $\text{La}(\text{IO}_3)_3$ (663.6 g/mol) is formed when 50.0 mL of 0.250 M La^{3+} is mixed with 75.0 mL of 0.302 M IO_3^- ?

Solution:

$$\frac{0.250 \text{ mol } \text{La}^{3+}}{\text{L}} \times \frac{\text{L}}{1000 \text{ mL}} \times 50.0 \text{ mL} = 1.25 \times 10^{-2} \text{ mol } \text{La}^{3+}$$

$$0.302 \text{ M } \text{IO}_3^- = \frac{0.302 \text{ mol } \text{IO}_3^-}{\text{L}} \times \frac{\text{L}}{1000 \text{ mL}} \times 75.0 \text{ mL} = 2.27 \times 10^{-2} \text{ mol } \text{IO}_3^-$$

Because each mole of $\text{La}(\text{IO}_3)_3$ requires three moles IO_3^- , IO_3^- is the limiting reagent. Thus,

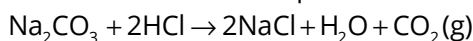
$$2.27 \times 10^{-2} \text{ mol } \text{IO}_3^- \times \frac{\text{mol } \text{La}(\text{IO}_3)_3}{3 \text{ mol } \text{IO}_3^-} \times \frac{663.6 \text{ g } \text{La}(\text{IO}_3)_3}{\text{mol}} = 5.01 \text{ g } \text{La}(\text{IO}_3)_3 \text{ formed}$$

- 2-35.** Exactly 0.118 g of pure Na_2CO_3 is dissolved in 100.0 mL of 0.0731 M HCl.

Solutions:

- (a)** What mass in grams of CO_2 is evolved?

A balanced chemical equation can be written as:



$$0.1180 \text{ g } \text{Na}_2\text{CO}_3 \times \frac{\text{mol } \text{Na}_2\text{CO}_3}{105.99 \text{ g}} = 1.113 \times 10^{-3} \text{ mol } \text{Na}_2\text{CO}_3$$

$$\frac{0.0731 \text{ mol } \text{HCl}}{\text{L}} \times \frac{\text{L}}{1000 \text{ mL}} \times 100.0 \text{ mL} = 7.31 \times 10^{-3} \text{ mol } \text{HCl}$$

Because one mole of CO_2 is evolved for every mole Na_2CO_3 reacted, Na_2CO_3 is the limiting reagent. Thus,

$$1.113 \times 10^{-3} \text{ mol } \text{Na}_2\text{CO}_3 \times \frac{\text{mol } \text{CO}_2}{\text{mol } \text{Na}_2\text{CO}_3} \times \frac{44.00 \text{ g } \text{CO}_2}{\text{mol}} = 4.897 \times 10^{-2} \text{ g } \text{CO}_2 \text{ evolved}$$

- (b)** What is the molar concentration of the excess reactant (HCl or Na_2CO_3)?

$$\text{amnt HCl left} = 7.31 \times 10^{-3} \text{ mol} - (2 \times 1.113 \times 10^{-3} \text{ mol}) = 5.08 \times 10^{-3} \text{ mol}$$

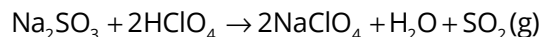
$$\frac{5.08 \times 10^{-3} \text{ mol } \text{HCl}}{100.0 \text{ mL}} \times \frac{1000 \text{ mL}}{\text{L}} = 5.08 \times 10^{-2} \text{ M HCl}$$

- 2-37.** Exactly 75.00 mL of a 0.3132 M solution of Na_2SO_3 is treated with 150.0 mL of 0.4025 M HClO_4 and boiled to remove the SO_2 formed.

Solutions:

- (a)** What is the mass in grams of SO_2 that is evolved?

A balanced chemical equation can be written as:



$$0.3132 \text{ M Na}_2\text{SO}_3 = \frac{0.3132 \text{ mol Na}_2\text{SO}_3}{\text{L}} \times \frac{\text{L}}{1000 \text{ mL}} \times 75 \text{ mL} = 2.3 \times 10^{-2} \text{ mol Na}_2\text{SO}_3$$

$$\begin{aligned} 0.4025 \text{ M HClO}_4 &= \frac{0.4025 \text{ mol HClO}_4}{\text{L}} \times \frac{\text{L}}{1000 \text{ mL}} \times 150.0 \text{ mL} \\ &= 6.038 \times 10^{-2} \text{ mol HClO}_4 \end{aligned}$$

Because one mole SO_2 is evolved per mole Na_2SO_3 , Na_2SO_3 is the limiting reagent. Thus,

$$2.3 \times 10^{-2} \text{ mol Na}_2\text{SO}_3 \times \frac{\text{mol SO}_2}{\text{mol Na}_2\text{SO}_3} \times \frac{64.06 \text{ g SO}_2}{\text{mol}} = 1.5 \text{ g SO}_2 \text{ evolved}$$

- (b) What is the concentration of the unreacted reagent (Na_2SO_3 or HClO_4) after the reaction is complete?

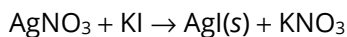
$$\text{mol HClO}_4 \text{ unreacted} = 6.038 \times 10^{-2} \text{ mol} - (2 \times 2.3 \times 10^{-2}) = 1.4 \times 10^{-2} \text{ mol}$$

$$\frac{1.4 \times 10^{-2} \text{ mol HClO}_4}{225 \text{ mL}} \times \frac{1000 \text{ mL}}{\text{L}} = 6.4 \times 10^{-2} \text{ M HClO}_4 = 0.064 \text{ M}$$

- 2-39.** What volume of 0.01000 M AgNO_3 is required to precipitate all of the I^- in 150 mL of a solution that contains 22.50 ppt KI?

Solution:

A balanced chemical equation can be written as:



$$22.50 \text{ ppt KI} \times \frac{1}{10^3 \text{ ppt}} \times \frac{\text{g}}{\text{mL}} \times 150 \text{ mL} \times \frac{\text{mol KI}}{166.0 \text{ g}} = 2.03 \times 10^{-2} \text{ mol KI}$$

$$2.03 \times 10^{-2} \text{ mol KI} \times \frac{\text{mol AgNO}_3}{\text{mol KI}} \times \frac{\text{L}}{0.0100 \text{ mol AgNO}_3} = 2.03 \text{ L AgNO}_3$$

2.03 L of 0.0100 M AgNO_3 would be required to precipitate I^- as AgI.

Solution and Answer Guide

Solution and Answer Guide: Skoog et al., *Fundamentals of Analytical Chemistry*, 10e,
© 2022, 978-0-357-45039-0, Chapter 2: Calculations Used in Analytical Chemistry

Chapter 2

2-1. Define

Answers:

***(a)** molar mass.

The molar mass is the mass in grams of one mole of a chemical species.

(b) millimole.

The *millimole* is an amount of a chemical species, such as an atom, an ion, a molecule or an electron. There are

$$6.02 \times 10^{23} \frac{\text{particles}}{\text{mole}} \times 10^{-3} \frac{\text{mole}}{\text{millimole}} = 6.02 \times 10^{20} \frac{\text{particles}}{\text{millimole}}$$

***(c)** millimolar mass.

The *millimolar mass* is the mass in grams of one millimole of a chemical species.

(d) parts per billion.

Parts per billion, c_{ppb} , is a term expressing the concentration of dilute solutions.

Thus,

$$c_{\text{ppb}} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 10^9 \text{ ppb}$$

The units of mass in the numerator and the denominator must be the same.

2-2. What is the difference between molar species concentration and molar analytical concentration?

Answer:

The molar species concentration is number of moles of that species contained in one liter of solution. The molar analytical concentration is the total number of moles of a solute in 1 liter of the solution, regardless of the solute's chemical state.

*Answers and solutions are provided in the Student Solutions Manual for questions and problems marked with an asterisk.

- *2-3.** Give two examples of units derived from the fundamental base SI units.

Solution:

$$\text{The liter: } 1 \text{ L} = \frac{1000 \text{ mL}}{1 \text{ L}} \times \frac{1 \text{ cm}^3}{\text{mL}} \times \left(\frac{\text{m}}{100 \text{ cm}} \right)^3 = 10^{-3} \text{ m}^3$$

$$\text{Molar concentration: } 1 \text{ M} = \frac{1 \text{ mol}}{\text{L}} \times \frac{\text{L}}{10^{-3} \text{ m}^3} = \frac{1 \text{ mol}}{10^{-3} \text{ m}^3}$$

- 2-4.** Simplify the following quantities using a unit with an appropriate prefix:

Solutions:

***(a)** $5.8 \times 10^8 \text{ Hz}$.

$$5.8 \times 10^8 \text{ Hz} \times \frac{\text{MHz}}{10^6 \text{ Hz}} = 580 \text{ MHz}$$

(b) $4.37 \times 10^{-7} \text{ g}$

$$4.37 \times 10^{-7} \text{ g} \times \frac{10^9 \text{ ng}}{\text{g}} = 437 \text{ ng}$$

***(c)** $9.31 \times 10^7 \mu\text{mol}$.

$$9.31 \times 10^7 \mu\text{mol} \times \frac{\text{mol}}{10^6 \mu\text{mol}} = 93.1 \text{ mol}$$

(d) $8.3 \times 10^{10} \text{ s}$.

$$8.3 \times 10^{10} \text{ s} \times \frac{\text{Gs}}{10^9 \text{ s}} = 83 \text{ Gs}$$

***(e)** $3.96 \times 10^6 \text{ nm}$.

$$3.96 \times 10^6 \text{ nm} \times \frac{\text{mm}}{10^6 \text{ nm}} = 3.96 \text{ mm}$$

(f) $53,000 \text{ g}$.

$$53,000 \text{ g} \times \frac{\text{kg}}{1000 \text{ g}} = 53 \text{ kg}$$

- *2-5.** Why is 1 g no longer exactly 1 mole of unified atomic mass units?

Answer:

The dalton is defined as 1/12 the mass of a neutral ^{12}C atom. With the redefinition of SI base units in 2019, the definition of the dalton remained the same. However, the definition of the mole and the kilogram changed in such a way that the molar mass unit is no longer exactly 1 g/mol.

- 2-6.** How did the definition of the mole change with the 2019 redefinition of SI base units?

Answer:

Avogadro's constant is now an exact number, $6.02214076 \times 10^{23}$. One mole contains exactly that number of elementary entities, atoms, molecules, ions electrons, etc. In the earlier definition one mole was the mass in grams of Avogadro's number of entities.

- *2-7.** Find the number of Na^+ ions in 2.75 g of Na_3PO_4 ?

Solution:

$$2.75 \text{ g Na}_3\text{PO}_4 \times \frac{1 \text{ mol Na}_3\text{PO}_4}{163.94 \text{ g}} \times \frac{3 \text{ mol Na}^+}{\text{mol Na}_3\text{PO}_4} \times \frac{6.022 \times 10^{23} \text{ Na}^+}{\text{mol Na}^+} = 3.03 \times 10^{22} \text{ Na}^+$$

- 2-8.** Find the number of K^+ ions in 1.43 mol of K_2HPO_4 ?

Solution:

$$1.43 \text{ mol K}_2\text{HPO}_4 \times \frac{2 \text{ mol K}^+}{\text{mol K}_2\text{HPO}_4} \times \frac{6.022 \times 10^{23} \text{ K}^+}{\text{mol K}^+} = 1.72 \times 10^{24} \text{ K}^+$$

- *2-9.** Find the amount of the indicated element (in moles) in

Solutions:

- (a)** 5.32 g of B_2O_3 .

$$5.32 \text{ g B}_2\text{O}_3 \times \frac{2 \text{ mol B}}{\text{mol B}_2\text{O}_3} \times \frac{\text{mol B}_2\text{O}_3}{69.62 \text{ g B}_2\text{O}_3} = 0.153 \text{ mol B}$$

- (b)** 195.7 mg of $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$.

$$195.7 \text{ mg Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O} \times \frac{\text{g}}{1000 \text{ mg}} \times \frac{7 \text{ mol O}}{\text{mol Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}} \times \frac{\text{mol Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}}{381.37 \text{ g}} = 3.59 \times 10^{-3} \text{ mol O} = 3.59 \text{ mmol}$$

- (c)** 4.96 g of Mn_3O_4 .

$$4.96 \text{ g Mn}_3\text{O}_4 \times \frac{\text{mol Mn}_3\text{O}_4}{228.81 \text{ g Mn}_3\text{O}_4} \times \frac{3 \text{ mol Mn}}{\text{mol Mn}_3\text{O}_4} = 6.50 \times 10^{-2} \text{ mol Mn}$$

- (d)** 333 mg of CaC_2O_4 .

$$333 \text{ mg CaC}_2\text{O}_4 \times \frac{\text{g}}{1000 \text{ mg}} \times \frac{\text{mol CaC}_2\text{O}_4}{128.10 \text{ g CaC}_2\text{O}_4} \times \frac{2 \text{ mol C}}{\text{mol CaC}_2\text{O}_4} = 5.20 \times 10^{-3} \text{ mol C} \\ = 5.20 \text{ mmol}$$

2-10. Find the amount in millimoles of the indicated species in

Solutions:

(a) 12.92 g of NaHCO_3 .

$$12.92 \text{ g NaHCO}_3 \times \frac{\text{mol NaHCO}_3}{84.01 \text{ g NaHCO}_3} \times \frac{1000 \text{ mmol}}{\text{mol}} \times \frac{3 \text{ mol O}}{\text{mol NaHCO}_3} = 461.4 \text{ mmol O}$$

(b) 57 mg of MgNH_4PO_4 .

$$57 \text{ mg MgNH}_4\text{PO}_4 \times \frac{\text{g}}{1000 \text{ mg}} \times \frac{\text{mol MgNH}_4\text{PO}_4}{137.32 \text{ g MgNH}_4\text{PO}_4} \times \frac{1000 \text{ mmol}}{\text{mol}} \times \frac{1 \text{ mol Mg}}{\text{mol MgNH}_4\text{PO}_4} = 0.42 \text{ mmol Mg}$$

(c) 850 mg of P_2O_5 .

$$850 \text{ mg P}_2\text{O}_5 \times \frac{\text{g}}{1000 \text{ mg}} \times \frac{\text{mol P}_2\text{O}_5}{141.94 \text{ g P}_2\text{O}_5} \times \frac{1000 \text{ mmol}}{\text{mol}} \times \frac{2 \text{ mol P}}{\text{mol P}_2\text{O}_5} = 11.98 \text{ mmol P}$$

(d) 40.0 g of CO_2 .

$$40.0 \text{ g CO}_2 \times \frac{\text{mol CO}_2}{44.01 \text{ g CO}_2} \times \frac{1000 \text{ mmol}}{\text{mol}} \times \frac{1 \text{ mol C}}{\text{mol CO}_2} = 909 \text{ mmol C}$$

***2-11.** Find the number of millimoles of solute in

Solutions:

(a) 2.00 L of 0.0449 M KMnO_4 .

$$\frac{0.0449 \text{ mol KMnO}_4}{\text{L}} \times \frac{1000 \text{ mmol}}{\text{mol}} \times 2.00 \text{ L} = 89.8 \text{ mmol KMnO}_4$$

(b) 750 mL of 5.35×10^{-3} M KSCN .

$$\frac{5.35 \times 10^{-3} \text{ M KSCN}}{\text{L}} \times \frac{1000 \text{ mmol}}{\text{mol}} \times \frac{\text{L}}{1000 \text{ mL}} \times 750 \text{ mL} = 4.01 \text{ mmol KSCN}$$

(c) 3.50 L of a solution that contains 6.23 ppm of CuSO_4 .

$$\frac{6.23 \text{ mg CuSO}_4}{\text{L}} \times \frac{\text{g}}{1000 \text{ mg}} \times \frac{\text{mol CuSO}_4}{159.61 \text{ g CuSO}_4} \times \frac{1000 \text{ mmol}}{\text{mol}} \times 3.50 \text{ L} = 0.137 \text{ mmol CuSO}_4$$

(d) 250 mL of 0.414 mM KCl .

$$\frac{0.414 \text{ mmol KCl}}{\text{L}} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times 250 \text{ mL} = 0.104 \text{ mmol KCl}$$

2-12. Find the number of millimoles of solute in

Solutions:

(a) 386 mL of 0.210 M HClO_4 .

$$\frac{0.210 \text{ mol HClO}_4}{\text{L}} \times \frac{1000 \text{ mmol}}{\text{mol}} \times \frac{\text{L}}{1000 \text{ mL}} \times 386 \text{ mL} = 81.1 \text{ mmol HClO}_4$$

(b) 25.0 L of 8.05×10^{-3} M K_2CrO_4 .

$$\frac{8.05 \times 10^{-3} \text{ mol K}_2\text{CrO}_4}{\text{L}} \times \frac{1000 \text{ mmol}}{\text{mol}} \times 25.0 \text{ L} = 201 \text{ mmol K}_2\text{CrO}_4$$

(c) 4.50 L of an aqueous solution that contains 6.95 ppm of AgNO_3 .

$$\frac{6.95 \text{ mg AgNO}_3}{\text{L}} \times \frac{\text{g}}{1000 \text{ mg}} \times \frac{\text{mol AgNO}_3}{169.87 \text{ g AgNO}_3} \times \frac{1000 \text{ mmol}}{\text{mol}} \times 4.50 \text{ L} = 0.184 \text{ mmol AgNO}_3$$

(d) 537 mL of 0.0200 M KOH.

$$\frac{0.0200 \text{ mol KOH}}{\text{L}} \times \frac{1000 \text{ mmol}}{\text{mol}} \times \frac{\text{L}}{1000 \text{ mL}} \times 537 \text{ mL} = 10.7 \text{ mmol KOH}$$

***2-13.** What is the mass in milligrams of

Solutions:

(a) 0.367 mol of HNO_3 ?

$$0.367 \text{ mol HNO}_3 \times \frac{63.01 \text{ g HNO}_3}{\text{mol HNO}_3} \times \frac{1000 \text{ mg}}{\text{g}} = 2.31 \times 10^4 \text{ mg HNO}_3$$

(b) 245 mmol of MgO?

$$245 \text{ mmol MgO} \times \frac{\text{mol}}{1000 \text{ mmol}} \times \frac{40.30 \text{ g MgO}}{\text{mol MgO}} \times \frac{1000 \text{ mg}}{\text{g}} = 9.87 \times 10^3 \text{ mg MgO}$$

(c) 12.5 mol of NH_4NO_3 ?

$$12.5 \text{ mol NH}_4\text{NO}_3 \times \frac{80.04 \text{ g NH}_4\text{NO}_3}{\text{mol NH}_4\text{NO}_3} \times \frac{1000 \text{ mg}}{\text{g}} = 1.00 \times 10^6 \text{ mg NH}_4\text{NO}_3$$

(d) 4.95 mol of $(\text{NH}_4)_2\text{Ce}(\text{NO}_3)_6$ (548.23 g/mol)?

$$4.95 \text{ mol } (\text{NH}_4)_2\text{Ce}(\text{NO}_3)_6 \times \frac{548.23 \text{ g } (\text{NH}_4)_2\text{Ce}(\text{NO}_3)_6}{\text{mol } (\text{NH}_4)_2\text{Ce}(\text{NO}_3)_6} \times \frac{1000 \text{ mg}}{\text{g}} \\ = 2.71 \times 10^6 \text{ mg } (\text{NH}_4)_2\text{Ce}(\text{NO}_3)_6$$

2-14. What is the mass in grams of

Solutions:

(a) 2.25 mol of KBr?

$$2.25 \text{ mol KBr} \times \frac{119.0 \text{ g KBr}}{\text{mol KBr}} = 268 \text{ g KBr}$$

(b) 15.5 mmol of PbO?

$$15.5 \text{ mmol PbO} \times \frac{\text{mol}}{1000 \text{ mmol}} \times \frac{223.20 \text{ g PbO}}{\text{mol PbO}} = 3.46 \text{ g PbO}$$

(c) 5.04 mol of CaSO_4 ?

$$5.04 \text{ mol CaSO}_4 \times \frac{136.13 \text{ g CaSO}_4}{\text{mol CaSO}_4} = 686 \text{ g CaSO}_4$$

(d) 10.9 mmol of $\text{Fe}(\text{NH}_4)_2(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$?

$$10.9 \text{ mmol Fe}(\text{NH}_4)_2(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O} \times \frac{\text{mol}}{1000 \text{ mmol}} \times \frac{392.13 \text{ g Fe}(\text{NH}_4)_2(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}}{\text{mol Fe}(\text{NH}_4)_2(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}} \\ = 4.27 \text{ g Fe}(\text{NH}_4)_2(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$$

2-15. What is the mass in milligrams of solute in

Solutions:

***(a)** 16.0 mL of 0.350 M sucrose (342 g/mol)?

$$\frac{0.350 \text{ mol sucrose}}{\text{L}} \times \frac{\text{L}}{1000 \text{ mL}} \times \frac{342 \text{ g sucrose}}{\text{mol sucrose}} \times \frac{1000 \text{ mg}}{\text{g}} \\ \times 16.0 \text{ mL} = 1.92 \times 10^3 \text{ mg sucrose}$$

***(b)** 1.92 L of $3.76 \times 10^{-3} \text{ M H}_2\text{O}_2$?

$$\frac{3.76 \times 10^{-3} \text{ mol H}_2\text{O}_2}{\text{L}} \times \frac{34.02 \text{ g H}_2\text{O}_2}{\text{mol H}_2\text{O}_2} \times \frac{1000 \text{ mg}}{\text{g}} \times 1.92 \text{ L} = 246 \text{ mg H}_2\text{O}_2$$

(c) 356 mL of a solution that contains 2.96 ppm of $\text{Pb}(\text{NO}_3)_2$?

$$\frac{2.96 \text{ mg Pb}(\text{NO}_3)_2}{\text{L}} \times \frac{\text{L}}{1000 \text{ mL}} \times 356 \text{ mL} = 1.05 \text{ mg Pb}(\text{NO}_3)_2$$

(d) 5.75 mL of 0.0819 M KNO_3 ?

$$\frac{0.0819 \text{ mol KNO}_3}{\text{L}} \times \frac{101.10 \text{ g KNO}_3}{\text{mol}} \times \frac{1000 \text{ mg}}{\text{g}} \times \frac{\text{L}}{1000 \text{ mL}} \times 5.75 \text{ mL} = 47.6 \text{ mg KNO}_3$$

2-16. What is the mass in grams of solute in

Solutions:

***(a)** 250 mL of 0.264 M H_2O_2 ?

$$\frac{0.264 \text{ mol } \text{H}_2\text{O}_2}{\text{L}} \times \frac{\text{L}}{1000 \text{ mL}} \times \frac{34.02 \text{ g } \text{H}_2\text{O}_2}{\text{mol } \text{H}_2\text{O}_2} \times 250 \text{ mL} = 2.25 \text{ g } \text{H}_2\text{O}_2$$

***(b)** 37.0 mL of 5.75×10^{-4} M benzoic acid (122 g/mol)?

$$\frac{5.75 \times 10^{-4} \text{ mol benzoic acid}}{\text{L}} \times \frac{\text{L}}{1000 \text{ mL}} \times \frac{122 \text{ g benzoic acid}}{\text{mol benzoic acid}} \times 37.0 \text{ mL} = 2.60 \times 10^{-3} \text{ g benzoic acid}$$

(c) 2.50 L of a solution that contains 37.2 ppm of SnCl_2 ?

$$\frac{37.2 \text{ mg } \text{SnCl}_2}{\text{L}} \times \frac{\text{g}}{1000 \text{ mg}} \times 2.50 \text{ L} = 0.093 \text{ g } \text{SnCl}_2$$

(d) 11.7 mL of 0.0225 M KBrO_3 ?

$$\frac{0.0225 \text{ mol } \text{KBrO}_3}{\text{L}} \times \frac{\text{L}}{1000 \text{ mL}} \times \frac{167 \text{ g } \text{KBrO}_3}{\text{mol } \text{KBrO}_3} \times 11.7 \text{ mL} = 4.40 \times 10^{-2} \text{ g } \text{KBrO}_3$$

2-17. Calculate the p-value for each of the listed ions in the following:

Solutions:

***(a)** Na^+ , Cl^- , and OH^- in a solution that is 0.0635 M in NaCl and 0.0403 M in NaOH.

$$\text{pNa} = -\log(0.0635 + 0.0403) = -\log(0.1038) = 0.9838$$

$$\text{pCl} = -\log(0.0635) = 1.197$$

$$\text{pOH} = -\log(0.0403) = 1.395$$

(b) Ba^{2+} , Mn^{2+} , and Cl^- in a solution that is 4.65×10^{-3} M in BaCl_2 and 2.54 M in MnCl_2 .

$$\text{pBa} = -\log(4.65 \times 10^{-3}) = 2.333$$

$$\text{pMn} = -\log(2.54) = -0.405$$

$$\text{pCl} = -\log(2 \times 4.65 \times 10^{-3} + 2 \times 2.54) = -\log(5.089) = -0.707$$

***(c)** H^+ , Cl^- , and Zn^{2+} in a solution that is 0.400 M in HCl and 0.100 M in ZnCl_2 .

$$\text{pH} = -\log(0.400) = 0.398$$

$$\text{pCl} = -\log(0.400 + 2 \times 0.100) = -\log(0.600) = 0.222$$

$$\text{pZn} = -\log(0.100) = 1.00$$

- (d) Cu^{2+} , Zn^{2+} , and NO_3^- in a solution that is $5.78 \times 10^{-2} \text{ M}$ in $\text{Cu}(\text{NO}_3)_2$ and 0.204 M in $\text{Zn}(\text{NO}_3)_2$.

$$\text{pCu} = -\log(5.78 \times 10^{-2}) = 1.238$$

$$\text{pZn} = -\log(0.204) = 0.690$$

$$\text{pNO}_3 = -\log(2 \times 0.0578 + 2 \times 0.204) = -\log(0.5236) = 0.281$$

- *(e) K^+ , OH^- , and $\text{Fe}(\text{CN})_6^{4-}$ in a solution that is $1.62 \times 10^{-7} \text{ M}$ in $\text{K}_4\text{Fe}(\text{CN})_6$ and $5.12 \times 10^{-7} \text{ M}$ in KOH .

$$\text{pK} = -\log(4 \times 1.62 \times 10^{-7} + 5.12 \times 10^{-7}) = -\log(1.16 \times 10^{-6}) = 5.94$$

$$\text{pOH} = -\log(5.12 \times 10^{-7}) = 6.291$$

$$\text{pFe}(\text{CN})_6 = -\log(1.62 \times 10^{-7}) = 6.790$$

- (f) H^+ , Ba^{2+} , and ClO_4^- in a solution that is $2.35 \times 10^{-4} \text{ M}$ in $\text{Ba}(\text{ClO}_4)_2$ and $4.75 \times 10^{-4} \text{ M}$ in HClO_4 .

$$\text{pH} = -\log(4.75 \times 10^{-4}) = 3.32$$

$$\text{pBa} = -\log(2.35 \times 10^{-4}) = 3.63$$

$$\text{pClO}_4 = -\log(2 \times 2.35 \times 10^{-4} + 4.75 \times 10^{-4}) = -\log(9.45 \times 10^{-4}) = 3.02$$

2-18. Calculate the molar H_3O^+ ion concentration of a solution that has a pH of

Solutions:

- *(a) 3.73.

$$\text{pH} = 3.73, \log[\text{H}_3\text{O}^+] = -3.73, [\text{H}_3\text{O}^+] = 1.9 \times 10^{-4} \text{ M}$$

as in part (a)

- (b) 3.28.

$$[\text{H}_3\text{O}^+] = 5.3 \times 10^{-4} \text{ M}$$

- *(c) 0.59.

$$[\text{H}_3\text{O}^+] = 0.26 \text{ M}$$

- (d) 11.29.

$$[\text{H}_3\text{O}^+] = 5.1 \times 10^{-12} \text{ M}$$

- *(e) 7.62.

$$[\text{H}_3\text{O}^+] = 2.4 \times 10^{-8} \text{ M}$$

(f) 5.19.

$$[\text{H}_3\text{O}^+] = 6.5 \times 10^{-6} \text{ M}$$

*(g) -0.76.

$$[\text{H}_3\text{O}^+] = 5.8 \text{ M}$$

(h) -0.42.

$$[\text{H}_3\text{O}^+] = 2.6 \text{ M}$$

2-19. Calculate the p-functions for each ion in a solution that is

Solutions:

*(a) 0.0200 M in NaBr.

$$\text{pNa} = \text{pBr} = -\log(0.0200) = 1.699$$

(b) 0.0300 M in BaBr_2 .

$$\text{pBa} = -\log(0.0300) = 1.523; \text{pBr} = -\log(2 \times 0.0300) = 1.222$$

*(c) $4.5 \times 10^{-3} \text{ M}$ in $\text{Ba}(\text{OH})_2$.

$$\text{pBa} = -\log(4.5 \times 10^{-3}) = 2.35; \text{pOH} = -\log(2 \times 4.5 \times 10^{-3}) = 2.05$$

(d) 0.020 M in HCl and 0.010 M in NaCl.

$$\text{pH} = -\log(0.020) = 1.70; \text{pNa} = -\log(0.010) = 2.00$$

$$\text{pCl} = -\log(0.020 + 0.010) = -\log(0.030) = 1.52$$

*(e) $7.2 \times 10^{-3} \text{ M}$ in CaCl_2 and $8.2 \times 10^{-3} \text{ M}$ in BaCl_2 .

$$\text{pCa} = -\log(7.2 \times 10^{-3}) = 2.14; \text{pBa} = -\log(8.2 \times 10^{-3}) = 2.09$$

$$\text{pCl} = -\log(2 \times 7.2 \times 10^{-3} + 2 \times 8.2 \times 10^{-3}) = -\log(0.0308) = 1.51$$

(f) $2.8 \times 10^{-8} \text{ M}$ in $\text{Zn}(\text{NO}_3)_2$ and $6.6 \times 10^{-7} \text{ M}$ $\text{Cd}(\text{NO}_3)_2$.

$$\text{pZn} = -\log(2.8 \times 10^{-8}) = 7.55; \text{pCd} = -\log(6.6 \times 10^{-7}) = 6.18$$

$$\text{pNO}_3 = -\log(2 \times 2.8 \times 10^{-8} + 2 \times 6.6 \times 10^{-7}) = 5.86$$

2-20. Convert the following p-functions to molar concentrations:

Solutions:

*(a) $\text{pH} = 1.102$.

$$\text{pH} = 1.102; \log[\text{H}_3\text{O}^+] = -1.102; [\text{H}_3\text{O}^+] = 0.0791 \text{ M}$$

(b) $\text{pOH} = 0.0057$.

$$\text{pOH} = 0.0057; \log[\text{OH}^-] = -0.0057; [\text{OH}^-] = 0.99 \text{ M}$$

*(c) $\text{pBr} = 7.77$.

$$\text{pBr} = 7.77; \log[\text{Br}^-] = -7.77; [\text{Br}^-] = 1.70 \times 10^{-8} \text{ M}$$

(d) $\text{pCa} = -0.221$.

$$\text{pCa} = -0.221; \log[\text{Ca}^{2+}] = 0.221; [\text{Ca}^{2+}] = 1.66 \text{ M}$$

*(e) $\text{pLi} = 12.35$.

$$\text{pLi} = 12.35; \log[\text{Li}^+] = -12.35; [\text{Li}^+] = 4.5 \times 10^{-13} \text{ M}$$

(f) $\text{pNO}_3 = 0.054$.

$$\text{pNO}_3 = 0.054; \log[\text{NO}_3^-] = -0.054; [\text{NO}_3^-] = 0.88 \text{ M}$$

*(g) $\text{pMn} = 0.135$.

$$\text{pMn} = 0.135; \log[\text{Mn}^{2+}] = -0.135; [\text{Mn}^{2+}] = 0.733 \text{ M}$$

(h) $\text{pCl} = 8.92$.

$$\text{pCl} = 8.92; \log[\text{Cl}^-] = -8.92; [\text{Cl}^-] = 1.20 \times 10^{-9} \text{ M}$$

***2-21.** Seawater contains an average of 1.08×10^3 ppm of Na^+ and 270 ppm of SO_4^{2-} . Calculate

Solutions:

(a) the molar concentrations of Na^+ and SO_4^{2-} given that the average density of seawater is 1.02 g/mL.

$$1.08 \times 10^3 \text{ ppm Na}^+ \times \frac{1}{10^6 \text{ ppm}} \times \frac{1.02 \text{ g}}{\text{mL}} \times \frac{1000 \text{ mL}}{\text{L}} \times \frac{\text{mol Na}^+}{22.99 \text{ g}} = 4.79 \times 10^{-2} \text{ M Na}^+$$

$$270 \text{ ppm SO}_4^{2-} \times \frac{1}{10^6 \text{ ppm}} \times \frac{1.02 \text{ g}}{\text{mL}} \times \frac{1000 \text{ mL}}{\text{L}} \times \frac{\text{mol SO}_4^{2-}}{96.06 \text{ g}} = 2.87 \times 10^{-3} \text{ M SO}_4^{2-}$$

(b) the pNa and pSO_4 for seawater.

$$\text{pNa} = -\log(4.79 \times 10^{-2}) = 1.320$$

$$\text{pSO}_4 = -\log(2.87 \times 10^{-3}) = 2.543$$

- 2-22.** Average human blood contains 300 nmoles of hemoglobin(Hb) per liter of plasma and 2.2 mmol per liter of whole blood. Calculate

Solutions:

- (a) the molar concentration in each of these media.

$$300 \text{ nmol/L} = 300 \times 10^{-9} \text{ mol/L or } 300 \text{ nM in plasma}$$

$$2.2 \text{ mmol/L} = 2.2 \times 10^{-3} \text{ mol/L or } 2.2 \text{ mM in whole blood}$$

- (b) pHb in plasma in human serum.

$$\text{pHb in plasma} = -\log(300 \times 10^{-9}) = 6.52$$

$$\text{pHb in blood} = -\log(2.2 \times 10^{-3}) = 2.66$$

- *2-23.** A solution was prepared by dissolving 5.76 g of $\text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}$ (277.85 g/mol) in sufficient water to give 2.000 L. Calculate

Solutions:

- (a) the molar analytical concentration of $\text{KCl} \cdot \text{MgCl}_2$ in this solution.

$$\frac{5.76 \text{ g } \text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}}{2.00 \text{ L}} \times \frac{\text{mol } \text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}}{277.85 \text{ g}} = 1.04 \times 10^{-2} \text{ M } \text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}$$

- (b) the molar concentration of Mg^{2+} .

There is 1 mole of Mg^{2+} per mole of $\text{KCl} \cdot \text{MgCl}_2$, so the molar concentration of Mg^{2+} is the same as the molar concentration of $\text{KCl} \cdot \text{MgCl}_2$ or $1.04 \times 10^{-2} \text{ M}$.

- (c) the molar concentration of Cl^- .

$$1.04 \times 10^{-2} \text{ M } \text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O} \times \frac{3 \text{ mol } \text{Cl}^-}{\text{mol } \text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}} = 3.12 \times 10^{-2} \text{ M } \text{Cl}^-$$

- (d) the weight/volume percentage of $\text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}$.

$$\frac{5.76 \text{ g } \text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}}{2.00 \text{ L}} \times \frac{\text{L}}{1000 \text{ mL}} \times 100\% = 0.288\% \text{ (w/v)}$$

- (e) the number of millimoles of Cl^- in 25.0 mL of this solution.

$$\frac{3.12 \times 10^{-2} \text{ mol } \text{Cl}^-}{\text{L}} \times \frac{\text{L}}{1000 \text{ mL}} \times \frac{1000 \text{ mmol}}{\text{mol}} \times 25 \text{ mL} = 7.8 \times 10^{-1} \text{ mmol } \text{Cl}^-$$

- (f) ppm K^+ .

$$1.04 \times 10^{-2} \text{ M } \text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O} \times \frac{1 \text{ mol } \text{K}^+}{1 \text{ mol } \text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}} \times \frac{39.10 \text{ g } \text{K}^+}{\text{mol } \text{K}^+} \times \frac{1000 \text{ mg}}{\text{g}}$$

$$= \frac{407 \text{ mg}}{\text{L}} = 407 \text{ ppm } \text{K}^+$$

(g) pMg for the solution.

$$\text{pMg} = -\log(1.04 \times 10^{-2}) = 1.983$$

(h) pCl for the solution.

$$\text{pCl} = -\log(3.12 \times 10^{-2}) = 1.506$$

2-24. A solution was prepared by dissolving 875 mg of $\text{K}_3\text{Fe}(\text{CN})_6$ (329.2 g/mol) in sufficient water to give 750 mL. Calculate

Solutions:

(a) the molar analytical concentration of $\text{K}_3\text{Fe}(\text{CN})_6$.

$$\frac{875 \text{ mg } \text{K}_3\text{Fe}(\text{CN})_6}{750 \text{ mL}} = \frac{875 \text{ g } \text{K}_3\text{Fe}(\text{CN})_6}{750 \text{ L}} \times \frac{\text{mol } \text{K}_3\text{Fe}(\text{CN})_6}{329.2 \text{ g}} = 3.54 \times 10^{-3} \text{ M } \text{K}_3\text{Fe}(\text{CN})_6$$

(b) the molar concentration of K^+ .

$$3.54 \times 10^{-3} \text{ M } \text{K}_3\text{Fe}(\text{CN})_6 \times \frac{3 \text{ mol } \text{K}^+}{\text{mol } \text{K}_3\text{Fe}(\text{CN})_6} = 1.06 \times 10^{-2} \text{ M } \text{K}^+$$

(c) the molar concentration of $\text{Fe}(\text{CN})_6^{3-}$.

$$3.54 \times 10^{-3} \text{ M } \text{K}_3\text{Fe}(\text{CN})_6 \times \frac{\text{mol } \text{Fe}(\text{CN})_6^{3-}}{\text{mol } \text{K}_3\text{Fe}(\text{CN})_6} = 3.54 \times 10^{-3} \text{ M } \text{Fe}(\text{CN})_6^{3-}$$

(d) the weight/volume percentage of $\text{K}_3\text{Fe}(\text{CN})_6$.

$$\frac{875 \text{ mg } \text{K}_3\text{Fe}(\text{CN})_6}{750 \text{ mL}} \times \frac{\text{g}}{1000 \text{ mg}} \times 100\% = 0.117\% \text{ (w/v)}$$

(e) the number of millimoles of K^+ in 50.0 mL of this solution.

$$\frac{1.06 \times 10^{-2} \text{ mol } \text{K}^+}{\text{L}} \times \frac{\text{L}}{1000 \text{ mL}} \times \frac{1000 \text{ mmol } \text{K}^+}{\text{mol } \text{K}^+} \times 50 \text{ mL} = 5.3 \times 10^{-2} \text{ mmol } \text{K}^+$$

(f) the concentration of $\text{Fe}(\text{CN})_6^{3-}$ in ppm.

$$\begin{aligned} & \frac{3.54 \times 10^{-3} \text{ mol } \text{K}_3\text{Fe}(\text{CN})_6}{\text{L}} \times \frac{\text{mol } \text{Fe}(\text{CN})_6^{3-}}{\text{mol } \text{K}_3\text{Fe}(\text{CN})_6} \times \frac{211.95 \text{ g } \text{Fe}(\text{CN})_6^{3-}}{\text{mol } \text{Fe}(\text{CN})_6^{3-}} \\ & \times \frac{1000 \text{ mg}}{\text{g}} = \frac{750 \text{ mg}}{\text{L}} \text{ Fe}(\text{CN})_6^{3-} = 750 \text{ ppm } \text{Fe}(\text{CN})_6^{3-} \end{aligned}$$

(g) pK for the solution.

$$\text{pK} = -\log(1.06 \times 10^{-2}) = 1.975$$

(h) $\text{pFe}(\text{CN})_6$ for the solution.

$$\text{pFe}(\text{CN})_6 = -\log(3.54 \times 10^{-3}) = 2.451$$

***2-25.** A 5.85% (w/w) $\text{Fe}(\text{NO}_3)_3$ (241.86 g/mol) solution has a density of 1.059 g/mL. Calculate

Solutions:

(a) the molar analytical concentration of $\text{Fe}(\text{NO}_3)_3$ in this solution.

$$\begin{aligned} 5.85\% \text{ Fe}(\text{NO}_3)_3 &= \frac{5.85 \text{ g Fe}(\text{NO}_3)_3}{\text{g solution}} \times \frac{1}{100} \times \frac{1.059 \text{ g}}{\text{mL}} \times \frac{1000 \text{ mL}}{\text{L}} \times \frac{\text{mol Fe}(\text{NO}_3)_3}{241.86 \text{ g}} \\ &= 2.56 \times 10^{-1} \text{ M Fe}(\text{NO}_3)_3 = 0.256 \text{ M} \end{aligned}$$

(b) the molar NO_3^- concentration in the solution.

$$2.56 \times 10^{-1} \text{ M Fe}(\text{NO}_3)_3 = \frac{2.56 \times 10^{-1} \text{ mol Fe}(\text{NO}_3)_3}{\text{L}} \times \frac{3 \text{ mol NO}_3^-}{\text{mol Fe}(\text{NO}_3)_3} = 7.68 \times 10^{-1} \text{ M NO}_3^-$$

(c) the mass in grams of $\text{Fe}(\text{NO}_3)_3$ contained in each liter of this solution.

$$\frac{2.56 \times 10^{-1} \text{ mol Fe}(\text{NO}_3)_3}{\text{L}} \times \frac{241.86 \text{ g Fe}(\text{NO}_3)_3}{\text{mol}} \times \text{L} = 6.20 \times 10^1 \text{ g Fe}(\text{NO}_3)_3 = 62.0 \text{ g}$$

2-26. A 11.4% (w/w) NiCl_2 (129.61 g/mol) solution has a density of 1.149 g/mL. Calculate

Solutions:

(a) the molar concentration of NiCl_2 in this solution.

$$11.4\% \text{ NiCl}_2 = \frac{11.4 \text{ g NiCl}_2}{\text{g solution}} \times \frac{1}{100} \times \frac{1.149 \text{ g}}{\text{mL}} \times \frac{1000 \text{ mL}}{\text{L}} \times \frac{\text{mol NiCl}_2}{129.61 \text{ g}} = 1.01 \text{ M NiCl}_2$$

(b) the molar Cl^- concentration of the solution.

$$1.01 \text{ M NiCl}_2 = \frac{1.01 \text{ mol NiCl}_2}{\text{L}} \times \frac{2 \text{ mol Cl}^-}{\text{mol NiCl}_2} = 2.02 \text{ M Cl}^-$$

(c) the mass in grams of NiCl_2 contained in each liter of this solution.

$$\frac{1.01 \text{ mol NiCl}_2}{\text{L}} \times \frac{129.61 \text{ g NiCl}_2}{\text{mol}} \times \text{L} = 131 \text{ g NiCl}_2$$

***2-27.** Describe the preparation of

Solutions:

(a) 500 mL of 5.25% (w/v) aqueous ethanol ($\text{C}_2\text{H}_5\text{OH}$, 46.1 g/mol).

$$\frac{5.25 \text{ g C}_2\text{H}_5\text{OH}}{\text{mL soln}} \times \frac{1}{100} \times 500 \text{ mL soln} = 26.3 \text{ g C}_2\text{H}_5\text{OH}$$

Weigh 26.3 g ethanol and add enough water to give a final volume of 500 mL.

(b) 500 g of 5.25% (w/w) aqueous ethanol.

$$5.25\% \text{ (w/w) C}_2\text{H}_5\text{OH} = \frac{5.25 \text{ g C}_2\text{H}_5\text{OH}}{\text{g soln}} \times \frac{1}{100} \times 500 \text{ g soln} = 2.63 \times 10^1 \text{ g C}_2\text{H}_5\text{OH}$$

$$500 \text{ g soln} = 26.3 \text{ g C}_2\text{H}_5\text{OH} + x \text{ g water}$$

$$x \text{ g water} = 500 \text{ g soln} - 26.3 \text{ g C}_2\text{H}_5\text{OH} = 473.7 \text{ g water}$$

Mix 26.3 g ethanol with 473.7 g water.

(c) 500 mL of 5.25% (v/v) aqueous ethanol.

$$5.25\% \text{ (v/v) C}_2\text{H}_5\text{OH} = \frac{5.25 \text{ mL C}_2\text{H}_5\text{OH}}{100 \text{ mL soln}}$$

$$\frac{5.25 \text{ mL C}_2\text{H}_5\text{OH}}{100 \text{ mL soln}} \times 500 \text{ mL soln} = 26.3 \text{ mL C}_2\text{H}_5\text{OH}$$

Dilute 26.3 mL ethanol with enough water to give a final volume of 500 mL.

2-28. Describe the preparation of

Solutions:

(a) 1.50 L of 21.0% (w/v) aqueous glycerol ($\text{C}_3\text{H}_8\text{O}_3$, 92.1 g/mol).

$$\frac{21.0 \text{ g C}_3\text{H}_8\text{O}_3}{\text{mL soln}} \times \frac{1}{100} \times \frac{1000 \text{ mL}}{\text{L}} \times 1.50 \text{ L soln} = 3.15 \times 10^2 \text{ g C}_3\text{H}_8\text{O}_3$$

Weigh 315 g glycerol and add enough water to give a final volume of 1.50 L.

(b) 1.50 kg of 21.0% (w/w) aqueous glycerol.

$$21.0\% \text{ (w/w) C}_3\text{H}_8\text{O}_3 = \frac{21.0 \text{ g C}_3\text{H}_8\text{O}_3}{\text{g soln}} \times \frac{1}{100} \times \frac{1000 \text{ g}}{\text{kg}} \times 1.50 \text{ kg soln} = 3.15 \times 10^2 \text{ g C}_3\text{H}_8\text{O}_3$$

$$1.50 \text{ kg soln} = 0.315 \text{ kg C}_3\text{H}_8\text{O}_3 + x \text{ kg water}$$

$$x \text{ kg water} = 1.50 \text{ kg soln} - 0.315 \text{ kg C}_3\text{H}_8\text{O}_3 = 1.185 \text{ kg water}$$

Mix 315 g glycerol with 1.185 kg water.

- (c) 1.50 L of 21.0% (v/v) aqueous glycerol.

$$21.0\% \text{ (v/v) } \text{C}_3\text{H}_8\text{O}_3 = \frac{21.0 \text{ mL } \text{C}_3\text{H}_8\text{O}_3}{\text{mL soln}} \times \frac{1}{100} \times \frac{1000 \text{ mL}}{\text{L}} \times 1.50 \text{ L soln} = 3.15 \times 10^2 \text{ mL } \text{C}_3\text{H}_8\text{O}_3$$

Dilute 315 mL glycerol with enough water to give a final volume of 1.50 L.

- *2-29.** Describe the preparation of 500 mL of 3.00 M H_3PO_4 from the commercial reagent that is 86% H_3PO_4 (w/w) and has a specific gravity of 1.71.

Solution:

$$\frac{3.00 \text{ mol } \text{H}_3\text{PO}_4}{\text{L}} \times \frac{\text{L}}{1000 \text{ mL}} \times 500 \text{ mL} = 1.50 \text{ mol } \text{H}_3\text{PO}_4$$

$$\frac{86 \text{ g } \text{H}_3\text{PO}_4}{\text{g reagent}} \times \frac{1}{100} \times \frac{1.71 \text{ g reagent}}{\text{g water}} \times \frac{\text{g water}}{\text{mL}} \times \frac{1000 \text{ mL}}{\text{L}} \times \frac{\text{mol } \text{H}_3\text{PO}_4}{98.0 \text{ g}} = \frac{1.50 \times 10^1 \text{ mol } \text{H}_3\text{PO}_4}{\text{L}}$$

$$\begin{aligned} \text{volume } 86\% \text{ (w/w) } \text{H}_3\text{PO}_4 \text{ required} &= 1.50 \text{ mol } \text{H}_3\text{PO}_4 \times \frac{\text{L}}{1.50 \times 10^1 \text{ mol } \text{H}_3\text{PO}_4} \\ &= 1.00 \times 10^{-1} \text{ L} \end{aligned}$$

Dilute 100 mL to 500 mL with water.

- 2-30.** Describe the preparation of 750 mL of 3.00 M HNO_3 from the commercial reagent that is 70.5% HNO_3 (w/w) and has a specific gravity of 1.42.

Solution:

$$\frac{3.00 \text{ mol } \text{HNO}_3}{\text{L}} \times \frac{\text{L}}{1000 \text{ mL}} \times 750 \text{ mL} = 2.25 \text{ mol } \text{HNO}_3$$

$$\frac{70.5 \text{ g } \text{HNO}_3}{\text{g reagent}} \times \frac{1}{100} \times \frac{1.42 \text{ g reagent}}{\text{g water}} \times \frac{\text{g water}}{\text{mL}} \times \frac{1000 \text{ mL}}{\text{L}} \times \frac{\text{mol } \text{HNO}_3}{63.0 \text{ g}} = \frac{15.9 \text{ mol } \text{HNO}_3}{\text{L}}$$

Volume HNO_3 required = 0.142 L

Dilute 142 mL of the commercial reagent to 750 mL using water.

- *2-31.** Describe the preparation of

Solutions:

- (a) 500 mL of 0.1000 M AgNO_3 from the solid reagent.

$$\begin{aligned} 0.1000 \text{ M } \text{AgNO}_3 &= \frac{0.1000 \text{ mol } \text{AgNO}_3}{\text{L}} \\ &= \frac{0.1000 \text{ mol } \text{AgNO}_3}{\text{L}} \times \frac{169.87 \text{ g } \text{AgNO}_3}{\text{mol}} \times \frac{\text{L}}{1000 \text{ mL}} \times 500 \text{ mL} \\ &= 8.49 \text{ g } \text{AgNO}_3 \end{aligned}$$

Dissolve 8.49 g AgNO_3 in enough water to give a final volume of 500 mL.

- (b) 1.00 L of 0.1000 M HCl, starting with a 6.00 M solution of the reagent.

$$\frac{0.1000 \text{ mol HCl}}{\text{L}} \times 1 \text{ L} = 0.1000 \text{ mol HCl}$$

$$0.1000 \text{ mol HCl} \times \frac{\text{L}}{6.00 \text{ mol HCl}} = 1.67 \times 10^{-2} \text{ L HCl}$$

Take 167 mL of the 6.00 M HCl and dilute to 1.00 L using water.

- (c) 250 mL of a solution that is 0.0810 M in K^+ , starting with solid $\text{K}_4\text{Fe}(\text{CN})_6$.

$$\frac{0.0810 \text{ mol K}^+}{\text{L}} \times \frac{\text{L}}{1000 \text{ mL}} \times 250 \text{ mL} = 2.025 \times 10^{-2} \text{ mol K}^+$$

$$2.025 \times 10^{-2} \text{ mol K}^+ \times \frac{\text{mol K}_4\text{Fe}(\text{CN})_6}{4 \text{ mol K}^+} \times \frac{368.35 \text{ g K}_4\text{Fe}(\text{CN})_6}{\text{mol}} = 1.86 \text{ g K}_4\text{Fe}(\text{CN})_6$$

Dissolve 1.86 g $\text{K}_4\text{Fe}(\text{CN})_6$ in enough water to give a final volume of 250 mL.

- (d) 500 mL of 3.00% (w/v) aqueous BaCl_2 from a 0.400 M BaCl_2 solution.

$$\frac{3.00 \text{ g BaCl}_2}{\text{mL soln}} \times \frac{1}{100} \times 500 \text{ mL} = 1.5 \times 10^1 \text{ g BaCl}_2$$

$$1.5 \times 10^1 \text{ g BaCl}_2 \times \frac{\text{mol BaCl}_2}{208.23 \text{ g}} \times \frac{\text{L}}{0.400 \text{ mol BaCl}_2} = 1.80 \times 10^{-1} \text{ L}$$

Take 180 mL of the 0.400 M BaCl_2 solution and dilute to 500 mL using water.

- (e) 2.00 L of 0.120 M HClO_4 from the commercial reagent [71.0% HClO_4 (w/w), sp gr 1.67].

$$\frac{0.120 \text{ mol HClO}_4}{\text{L}} \times 2.00 \text{ L} = 0.240 \text{ mol HClO}_4$$

$$\frac{71 \text{ g HClO}_4}{100 \text{ g reagent}} \times \frac{1.67 \text{ g reagent}}{\text{g water}} \times \frac{\text{g water}}{\text{mL}} \times \frac{1000 \text{ mL}}{\text{L}} \times \frac{\text{mol HClO}_4}{100.46 \text{ g}} = \frac{1.18 \times 10^1 \text{ mol HClO}_4}{\text{L}}$$

$$\text{volume 71\% (w/w) HClO}_4 \text{ required} = 0.240 \text{ mol HClO}_4 = \frac{\text{L}}{1.18 \times 10^1 \text{ mol HClO}_4} \\ = 2.03 \times 10^{-2} \text{ L}$$

Take 20.3 mL of the concentrated reagent and dilute to 2.00 L using water.

- (f) 1.00 L of a solution that is 60.0 ppm in Na^+ , starting with solid Na_2SO_4 .

$$60 \text{ ppm Na}^+ = \frac{60 \text{ mg Na}^+}{\text{L soln}}$$

$$\frac{60 \text{ mg Na}^+}{\text{L soln}} \times 1.00 \text{ L} = 60 \text{ mg Na}^+$$

$$60 \text{ mg Na}^+ \times \frac{\text{g}}{1000 \text{ mg}} \times \frac{\text{mol Na}^+}{22.99 \text{ g}} = 2.61 \times 10^{-3} \text{ mol Na}^+$$

$$2.61 \times 10^{-3} \text{ mol Na}^+ \times \frac{\text{mol Na}_2\text{SO}_4}{2 \text{ mol Na}^+} \times \frac{142.04 \text{ g Na}_2\text{SO}_4}{\text{mol}} = 0.19 \text{ g Na}_2\text{SO}_4$$

Dissolve 0.19 g Na_2SO_4 in enough water to give a final volume of 1.00 L.

2-32. Describe the preparation of

Solutions:

- (a)** 2.50 L of 0.0250 M KMnO_4 from the solid reagent.

$$\frac{0.0250 \text{ mol KMnO}_4}{\text{L}} \times 2.50 \text{ L} \times \frac{158.03 \text{ g KMnO}_4}{\text{mol}} = 9.877 \text{ g KMnO}_4$$

Dissolve 9.9 g KMnO_4 in enough water to give a final volume of 2.50 L.

- (b)** 4.00 L of 0.250 M HClO_4 , starting with an 8.00 M solution of the reagent.

$$\frac{0.250 \text{ mol HClO}_4}{\text{L}} \times 4.00 \text{ L} = 1.00 \text{ mol HClO}_4$$

$$1.00 \text{ mol HClO}_4 \times \frac{\text{L}}{8.00 \text{ mol reagent}} = 1.25 \times 10^{-1} \text{ L reagent}$$

Take 125 mL of the 8.00 M reagent and dilute a final of volume of 4.00 L using water.

- (c)** 500 mL of a solution that is 0.0200 M in I^- , starting with MgI_2 .

$$\frac{0.0200 \text{ mol I}^-}{\text{L}} \times \frac{\text{L}}{1000 \text{ mL}} \times 500 \text{ mL} = 1.00 \times 10^{-2} \text{ mol I}^-$$

$$1.00 \times 10^{-2} \text{ mol I}^- \times \frac{\text{mol MgI}_2}{2 \text{ mol I}^-} \times \frac{278.11 \text{ g MgI}_2}{\text{mol}} = 1.39 \text{ g MgI}_2$$

Dissolve 1.39 g MgI_2 in enough water to give a final volume of 500 mL.

- (d)** 200 mL of 1.00% (w/v) aqueous CuSO_4 from a 0.365 M CuSO_4 solution.

$$1.00\% \text{ (w/v) CuSO}_4 = \frac{1.00 \text{ g CuSO}_4}{100 \text{ mL soln}}$$

$$\frac{1.00 \text{ g CuSO}_4}{100 \text{ mL soln}} \times 200 \text{ mL} = 2.00 \text{ g CuSO}_4$$

$$2.00 \text{ g CuSO}_4 \times \frac{\text{mol CuSO}_4}{159.60 \text{ g}} \times \frac{\text{L}}{0.365 \text{ mol CuSO}_4} = 3.43 \times 10^{-2} \text{ L}$$

Take 34.3 mL of the 0.365 M CuSO_4 and dilute to a final volume of 200 mL using water.

- (e) 1.50 L of 0.300 M NaOH from the concentrated commercial reagent [50% NaOH (w/w), sp gr 1.525].

$$\frac{0.300 \text{ mol NaOH}}{\text{L}} \times 1.50 \text{ L} = 0.450 \text{ mol NaOH}$$

$$50\% \text{ (w/w) NaOH} = \frac{50 \text{ g NaOH}}{100 \text{ g reagent}}$$

$$\begin{aligned} \frac{50 \text{ g NaOH}}{100 \text{ g reagent}} \times \frac{1.525 \text{ g reagent}}{\text{g water}} \times \frac{\text{g water}}{\text{mL}} \times \frac{1000 \text{ mL}}{\text{L}} \times \frac{\text{mol NaOH}}{40.00 \text{ g}} \\ = \frac{1.9 \times 10^1 \text{ mol NaOH}}{\text{L}} \end{aligned}$$

$$\begin{aligned} \text{volume } 50\% \text{ (w/w) NaOH required} &= 0.450 \text{ mol NaOH} \times \frac{\text{L}}{1.9 \times 10^1 \text{ mol NaOH}} \\ &= 2.4 \times 10^{-2} \text{ L} \end{aligned}$$

Take 24 mL of the concentrated reagent and dilute to a final volume of 1.50 L using water.

- (f) 1.50 L of a solution that is 15.0 ppm in K^+ , starting with solid $\text{K}_4\text{Fe}(\text{CN})_6$.

$$15.0 \text{ ppm K}^+ = \frac{15 \text{ mg K}^+}{\text{L soln}}$$

$$\frac{15 \text{ mg K}^+}{\text{L soln}} \times 1.50 \text{ L} = 2.25 \times 10^1 \text{ mg K}^+$$

$$2.25 \times 10^1 \text{ mg K}^+ \times \frac{\text{g}}{1000 \text{ mg}} \times \frac{\text{mol K}^+}{39.10 \text{ g}} = 5.75 \times 10^{-4} \text{ mol K}^+$$

$$5.75 \times 10^{-4} \text{ mol K}^+ \times \frac{\text{mol K}_4\text{Fe}(\text{CN})_6}{4 \text{ mol K}^+} \times \frac{368.35 \text{ g K}_4\text{Fe}(\text{CN})_6}{\text{mol}} = 5.30 \times 10^{-2} \text{ g K}_4\text{Fe}(\text{CN})_6$$

Dissolve 53.0 mg $\text{K}_4\text{Fe}(\text{CN})_6$ in enough water to give a final volume of 1.50 L.

- *2-33.** What mass of solid $\text{La}(\text{IO}_3)_3$ (663.6 g/mol) is formed when 50.0 mL of 0.250 M La^{3+} is mixed with 75.0 mL of 0.302 M IO_3^- ?

Solution:

$$\frac{0.250 \text{ mol La}^{3+}}{\text{L}} \times \frac{\text{L}}{1000 \text{ mL}} \times 50.0 \text{ mL} = 1.25 \times 10^{-2} \text{ mol La}^{3+}$$

$$0.302 \text{ M IO}_3^- = \frac{0.302 \text{ mol IO}_3^-}{\text{L}} \times \frac{\text{L}}{1000 \text{ mL}} \times 75.0 \text{ mL} = 2.27 \times 10^{-2} \text{ mol IO}_3^-$$

Because each mole of $\text{La}(\text{IO}_3)_3$ requires three moles IO_3^- , IO_3^- is the limiting reagent. Thus,

$$2.27 \times 10^{-2} \text{ mol IO}_3^- \times \frac{\text{mol La}(\text{IO}_3)_3}{3 \text{ mol IO}_3^-} \times \frac{663.6 \text{ g La}(\text{IO}_3)_3}{\text{mol}} = 5.01 \text{ g La}(\text{IO}_3)_3 \text{ formed}$$

- 2-34.** What mass of solid PbCl_2 (278.10 g/mol) is formed when 200 mL of 0.125 M Pb^{2+} is mixed with 400 mL of 0.175 M Cl^- ?

Solution:

$$\frac{0.125 \text{ mol Pb}^{2+}}{\text{L}} \times \frac{\text{L}}{1000 \text{ mL}} \times 200 \text{ mL} = 2.50 \times 10^{-2} \text{ mol Pb}^{2+}$$

$$\frac{0.175 \text{ mol Cl}^-}{\text{L}} \times \frac{\text{L}}{1000 \text{ mL}} \times 400 \text{ mL} = 7.00 \times 10^{-2} \text{ mol Cl}^-$$

Because each mole of PbCl_2 requires two moles Cl^- , Pb^{2+} is the limiting reagent. Thus,

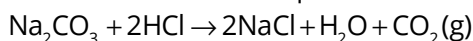
$$2.50 \times 10^{-2} \text{ mol Pb}^{2+} \times \frac{\text{mol PbCl}_2}{\text{mol Pb}^{2+}} \times \frac{278.10 \text{ g PbCl}_2}{\text{mol}} = 6.95 \text{ g PbCl}_2 \text{ formed}$$

- *2-35.** Exactly 0.118 g of pure Na_2CO_3 is dissolved in 100.0 mL of 0.0731 M HCl.

Solutions:

- (a)** What mass in grams of CO_2 is evolved?

A balanced chemical equation can be written as:



$$0.1180 \text{ g Na}_2\text{CO}_3 \times \frac{\text{mol Na}_2\text{CO}_3}{105.99 \text{ g}} = 1.113 \times 10^{-3} \text{ mol Na}_2\text{CO}_3$$

$$\frac{0.0731 \text{ mol HCl}}{\text{L}} \times \frac{\text{L}}{1000 \text{ mL}} \times 100.0 \text{ mL} = 7.31 \times 10^{-3} \text{ mol HCl}$$

Because one mole of CO_2 is evolved for every mole Na_2CO_3 reacted, Na_2CO_3 is the limiting reagent. Thus,

$$1.113 \times 10^{-3} \text{ mol Na}_2\text{CO}_3 \times \frac{\text{mol CO}_2}{\text{mol Na}_2\text{CO}_3} \times \frac{44.00 \text{ g CO}_2}{\text{mol}} = 4.897 \times 10^{-2} \text{ g CO}_2 \text{ evolved}$$

- (b)** What is the molar concentration of the excess reactant (HCl or Na_2CO_3)?

$$\text{amnt HCl left} = 7.31 \times 10^{-3} \text{ mol} - (2 \times 1.113 \times 10^{-3} \text{ mol}) = 5.08 \times 10^{-3} \text{ mol}$$

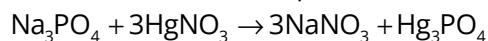
$$\frac{5.08 \times 10^{-3} \text{ mol HCl}}{100.0 \text{ mL}} \times \frac{1000 \text{ mL}}{\text{L}} = 5.08 \times 10^{-2} \text{ M HCl}$$

- 2-36.** Exactly 25.0 mL of a 0.3757 M solution of Na_3PO_4 is mixed with 100.00 mL of 0.5151 M HgNO_3 .

Solutions:

- (a)** What mass of solid Hg_3PO_4 is formed?

A balanced chemical equation can be written as



$$\frac{0.3757 \text{ mol Na}_3\text{PO}_4}{\text{L}} \times \frac{\text{L}}{1000 \text{ mL}} \times 25.0 \text{ mL} = 9.39 \times 10^{-3} \text{ mol Na}_3\text{PO}_4$$

$$\frac{0.5151 \text{ mol HgNO}_3}{\text{L}} \times \frac{\text{L}}{1000 \text{ mL}} \times 100.0 \text{ mL} = 5.151 \times 10^{-2} \text{ mol HgNO}_3$$

The limiting reagent is Na_3PO_4 . Thus,

$$9.39 \times 10^{-3} \text{ mol Na}_3\text{PO}_4 \times \frac{\text{mol Hg}_3\text{PO}_4}{\text{mol Na}_3\text{PO}_4} \times \frac{696.74 \text{ g Hg}_3\text{PO}_4}{\text{mol}} = 6.54 \text{ g Hg}_3\text{PO}_4 \text{ formed}$$

- (b) What is the molar concentration of the unreacted species (Na_3PO_4 or HgNO_3) after the reaction is complete?

$$\text{mol HgNO}_3 \text{ unreacted} = 5.151 \times 10^{-2} \text{ mol} - (3 \times 9.39 \times 10^{-3} \text{ mol}) = 2.33 \times 10^{-2} \text{ mol}$$

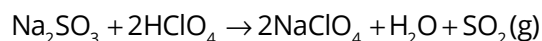
$$\frac{2.33 \times 10^{-2} \text{ mol HgNO}_3}{125.0 \text{ mL}} \times \frac{1000 \text{ mL}}{\text{L}} = 1.87 \times 10^{-1} \text{ M HgNO}_3$$

- *2-37.** Exactly 75.00 mL of a 0.3132 M solution of Na_2SO_3 is treated with 150.0 mL of 0.4025 M HClO_4 and boiled to remove the SO_2 formed.

Solution:

- (a) What is the mass in grams of SO_2 that is evolved?

A balanced chemical equation can be written as:



$$0.3132 \text{ M Na}_2\text{SO}_3 = \frac{0.3132 \text{ mol Na}_2\text{SO}_3}{\text{L}} \times \frac{\text{L}}{1000 \text{ mL}} \times 75 \text{ mL} = 2.3 \times 10^{-2} \text{ mol Na}_2\text{SO}_3$$

$$\begin{aligned} 0.4025 \text{ M HClO}_4 &= \frac{0.4025 \text{ mol HClO}_4}{\text{L}} \times \frac{\text{L}}{1000 \text{ mL}} \times 150.0 \text{ mL} \\ &= 6.038 \times 10^{-2} \text{ mol HClO}_4 \end{aligned}$$

Because one mole SO_2 is evolved per mole Na_2SO_3 , Na_2SO_3 is the limiting reagent. Thus,

$$2.3 \times 10^{-2} \text{ mol Na}_2\text{SO}_3 \times \frac{\text{mol SO}_2}{\text{mol Na}_2\text{SO}_3} \times \frac{64.06 \text{ g SO}_2}{\text{mol}} = 1.5 \text{ g SO}_2 \text{ evolved}$$

- (b) What is the concentration of the unreacted reagent (Na_2SO_3 or HClO_4) after the reaction is complete?

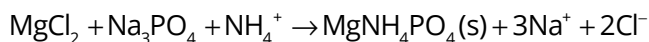
$$\text{mol HClO}_4 \text{ unreacted} = 6.038 \times 10^{-2} \text{ mol} - (2 \times 2.3 \times 10^{-2}) = 1.4 \times 10^{-2} \text{ mol}$$

$$\frac{1.4 \times 10^{-2} \text{ mol HClO}_4}{225 \text{ mL}} \times \frac{1000 \text{ mL}}{\text{L}} = 6.4 \times 10^{-2} \text{ M HClO}_4 = 0.064 \text{ M}$$

- 2-38.** What mass of MgNH_4PO_4 precipitates when 200.0 mL of a 1.000% (w/v) solution of MgCl_2 is treated with 40.0 mL of 0.1753 M Na_3PO_4 and an excess of NH_4^+ ? What is the molar concentration of the excess reagent (Na_3PO_4 or MgCl_2) after the precipitation is complete?

Solution:

A balanced chemical equation can be written as:



$$\frac{1.000 \text{ g MgCl}_2}{100 \text{ mL}} \times 200.0 \text{ mL} \times \frac{\text{mol MgCl}_2}{95.21 \text{ g}} = 2.101 \times 10^{-2} \text{ mol MgCl}_2$$

$$\frac{0.1753 \text{ mol Na}_3\text{PO}_4}{\text{L}} \times \frac{\text{L}}{1000 \text{ mL}} \times 40.0 \text{ mL} = 7.01 \times 10^{-3} \text{ mol Na}_3\text{PO}_4$$

Na_3PO_4 is the limiting reagent. Thus,

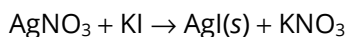
$$\text{amt MgCl}_2 \text{ unreacted} = (2.101 \times 10^{-2} - 7.01 \times 10^{-3}) = 1.40 \times 10^{-2} \text{ mol}$$

$$\frac{1.40 \times 10^{-2} \text{ mol MgCl}_2}{240.0 \text{ mL}} \times \frac{1000 \text{ mL}}{\text{L}} = 5.83 \times 10^{-2} \text{ M MgCl}_2$$

- *2-39.** What volume of 0.01000 M AgNO_3 is required to precipitate all of the I^- in 150 mL of a solution that contains 22.50 ppt KI?

Solution:

A balanced chemical equation can be written as:



$$22.50 \text{ ppt KI} \times \frac{1}{10^3 \text{ ppt}} \times \frac{\text{g}}{\text{mL}} \times 150 \text{ mL} \times \frac{\text{mol KI}}{166.0 \text{ g}} = 2.03 \times 10^{-2} \text{ mol KI}$$

$$2.03 \times 10^{-2} \text{ mol KI} \times \frac{\text{mol AgNO}_3}{\text{mol KI}} \times \frac{\text{L}}{0.0100 \text{ mol AgNO}_3} = 2.03 \text{ L AgNO}_3$$

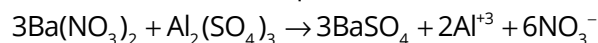
2.03 L of 0.0100 M AgNO_3 would be required to precipitate I^- as AgI.

- 2-40.** Exactly 750.0 mL of a solution that contains 500.0 ppm of $\text{Ba}(\text{NO}_3)_2$ is mixed with 200.0 mL of a solution that was 0.04100 M in $\text{Al}_2(\text{SO}_4)_3$.

Solutions:

- (a)** What mass of solid BaSO_4 is formed?

A balanced chemical equation can be written as



$$500 \text{ ppm Ba}(\text{NO}_3)_2 \times \frac{1}{10^6 \text{ ppm}} \times \frac{\text{g}}{\text{mL}} \times 750.0 \text{ mL} \times \frac{\text{mol Ba}(\text{NO}_3)_2}{261.34 \text{ g}} = 1.43 \times 10^{-3} \text{ mol Ba}(\text{NO}_3)_2$$

For $\text{Al}_2(\text{SO}_4)_3$

$$\frac{0.0410 \text{ mol Al}_2(\text{SO}_4)_3}{\text{L}} \times \frac{\text{L}}{1000 \text{ mL}} \times 200.0 \text{ mL} = 8.20 \times 10^{-3} \text{ mol Al}_2(\text{SO}_4)_3$$

$\text{Ba}(\text{NO}_3)_2$ is the limiting reagent. Thus,

$$1.43 \times 10^{-3} \text{ mol Ba}(\text{NO}_3)_2 \times \frac{3 \text{ mol BaSO}_4}{3 \text{ mol Ba}(\text{NO}_3)_2} \times \frac{233.39 \text{ g BaSO}_4}{\text{mol}} = 3.34 \times 10^{-1} \text{ g BaSO}_4 \text{ formed}$$

- (b)** What is the molar concentration of the unreacted reagent [$\text{Al}_2(\text{SO}_4)_3$ or $\text{Ba}(\text{NO}_3)_2$]?

Since 3 moles of $\text{Ba}(\text{NO}_3)_2$ react with 1 mole of $\text{Al}_2(\text{SO}_4)_3$,

$$\text{amt Al}_2(\text{SO}_4)_3 \text{ unreacted} = 8.20 \times 10^{-3} \text{ mol} - (1/3 \times 1.43 \times 10^{-3} \text{ mol}) = 7.72 \times 10^{-3} \text{ mol}$$

$$\frac{7.72 \times 10^{-3} \text{ mol Al}_2(\text{SO}_4)_3}{950.0 \text{ mL}} \times \frac{1000 \text{ mL}}{\text{L}} = 8.13 \times 10^{-3} \text{ M Al}_2(\text{SO}_4)_3$$