

Solved Problems

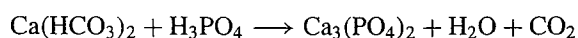
INTRODUCTION

- 8.1. How many oxygen atoms are there in each of the following, perhaps part of a balanced chemical equation?
(a) 7 H₂O, (b) 4 Ba(NO₃)₂, (c) 2 CuSO₄·5H₂O, and (d) 4 VO(ClO₃)₂.

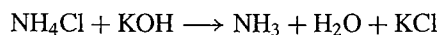
BALANCING SIMPLE EQUATIONS

- 8.2. Balance the following equation: $C + Cu_2O \xrightarrow{\text{heat}} CO + Cu$

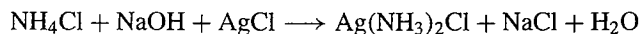
- 8.3. Balance the following equation:



- 8.4. Balance the following equation:



- 8.5. Balance the following equation



- 8.6. Balance the following chemical equations:

- (a) $NCl_3 + H_2O \longrightarrow HClO + NH_3$
- (b) $NaOH + H_3PO_4 \longrightarrow Na_2HPO_4 + H_2O$
- (c) $Al + HCl \longrightarrow AlCl_3 + H_2$
- (d) $HCl + Mg \longrightarrow MgCl_2 + H_2$
- (e) $SrCO_3 + HClO_4 \longrightarrow Sr(ClO_4)_2 + CO_2 + H_2O$
- (f) $KC_2H_3O_2 + HBr \longrightarrow KBr + HC_2H_3O_2$
- (g) $Ba(OH)_2 + H_3PO_4 \longrightarrow BaHPO_4 + H_2O$
- (h) $HCl + Na_3PO_4 \longrightarrow NaCl + NaH_2PO_4$

8.7. Write balanced equations for each of the following reactions:

- (a) Sodium plus oxygen yields sodium peroxide.
- (b) Mercury(II) oxide, when heated, yields mercury and oxygen.
- (c) Carbon plus oxygen yields carbon monoxide.
- (d) Sulfur plus oxygen yields sulfur dioxide.
- (e) Propane (C_3H_8) plus oxygen yields carbon dioxide plus water.
- (f) Ethane (C_2H_6) plus oxygen yields carbon monoxide plus water.
- (g) Ethylene (C_2H_4) plus oxygen yields carbon dioxide plus water.

8.8. Write balanced chemical equations for the following reactions:

- (a) Sodium plus fluorine yields sodium fluoride.
- (b) Potassium chlorate, when heated, yields potassium chloride plus oxygen.
- (c) Zinc plus copper(II) nitrate yields zinc nitrate plus copper.
- (d) Magnesium hydrogen carbonate plus heat yields magnesium carbonate plus carbon dioxide plus water.
- (e) Magnesium hydrogen carbonate plus hydrobromic acid yields magnesium bromide plus carbon dioxide plus water.
- (f) Lead(II) acetate plus sodium chromate yields lead(II) chromate plus sodium acetate.

8.9. Balance the following equation: $Ba(ClO_4)_2 + Na_2SO_4 \rightarrow BaSO_4 + NaClO_4$

8.10. Write balanced chemical equations for the following reactions:

- (a) Phosphorus pentachloride plus water yields phosphoric acid plus hydrogen chloride.
- (b) Sodium hydroxide plus sulfuric acid yields sodium hydrogen sulfate plus water.
- (c) Ethane, C_2H_6 , plus oxygen yields carbon dioxide plus water.
- (d) Octane, C_8H_{18} , plus oxygen yields carbon monoxide plus water.

- (e) Copper(II) chloride plus hydrosulfuric acid yields copper(II) sulfide plus hydrochloric acid.
- (f) Barium hydroxide plus chloric acid yields barium chlorate plus water.
- (g) Copper(II) sulfate plus water yields copper(II) sulfate pentahydrate.
- (h) Copper(II) chloride plus sodium iodide yields copper(I) iodide plus iodine plus sodium chloride.

8.11. Balance the following equation: $\text{Cr} + \text{CrCl}_3 \longrightarrow \text{CrCl}_2$

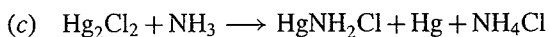
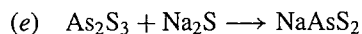
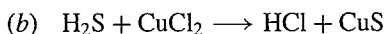
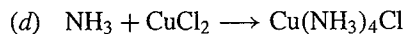
8.12. Write balanced chemical equations for the following reactions: (a) Hydrogen chloride is produced by the reaction of hydrogen and chlorine. (b) Hydrogen combines with chlorine to yield hydrogen chloride. (c) Chlorine reacts with hydrogen to give hydrogen chloride.

8.13. Write balanced chemical equations for the following reactions: (a) Hydrogen fluoride is produced by the reaction of hydrochloric acid and sodium fluoride. (b) Hydrochloric acid combines with sodium fluoride to yield hydrogen fluoride. (c) Sodium fluoride reacts with hydrochloric acid to give hydrofluoric acid.

8.14. Balance the following chemical equations:

- (a) $\text{Na}_2\text{CO}_3 + \text{HClO}_3 \longrightarrow \text{NaClO}_3 + \text{CO}_2 + \text{H}_2\text{O}$
- (b) $\text{Ca}(\text{HCO}_3)_2 + \text{HCl} \longrightarrow \text{CaCl}_2 + \text{CO}_2 + \text{H}_2\text{O}$
- (c) $\text{BiCl}_3 + \text{H}_2\text{O} \longrightarrow \text{BiOCl} + \text{HCl}$
- (d) $\text{H}_2\text{S} + \text{O}_2 \longrightarrow \text{H}_2\text{O} + \text{SO}_2$
- (e) $\text{Cu}_2\text{S} + \text{O}_2 \longrightarrow \text{Cu} + \text{SO}_2$
- (f) $\text{NH}_3 + \text{O}_2 \longrightarrow \text{NO} + \text{H}_2\text{O}$
- (g) $\text{H}_2\text{O}_2 \longrightarrow \text{H}_2\text{O} + \text{O}_2$

8.15. Balance the following chemical equations:



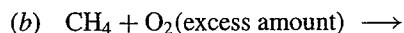
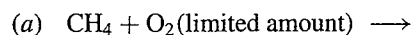
8.16. Why is the catalyst not merely placed on both sides of the arrow, since it comes out of the reaction with the same composition as it started with?

PREDICTING THE PRODUCTS OF A REACTION

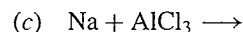
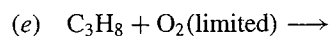
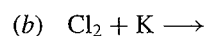
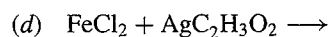
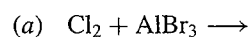
8.17. In the list of reactivities of metals, Table 8-1, are all alkali metals more reactive than all alkaline earth metals, or are all elements of both groups of metals more active than any other metals?

8.18. (a) What type of reaction requires knowledge of reactivities of elements? (b) What type requires knowledge of solubility properties of compounds?

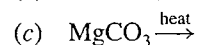
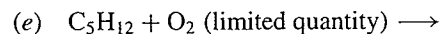
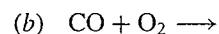
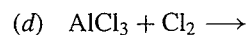
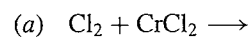
8.19. Complete and balance the following equations:



8.20. What type of chemical reaction is represented by each of the following? Complete and balance the equation for each.



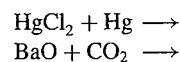
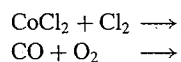
8.21. What type of chemical reaction is represented by each of the following? Complete and balance the equation for each.



- 8.22. Which of the following is soluble in water, CuCl or CuCl_2 ?
- 8.23. Complete and balance an equation for the reaction of excess HCl and Na_3PO_4 .
- 8.24. Is F_2 soluble in water?

Supplementary Problems

- 8.25. What is the difference between dissolving and reacting?
- 8.26. How can you tell that the following are combination reactions rather than replacement or double-replacement reactions.



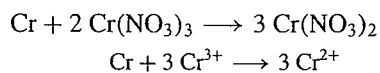
- 8.27. State why the equation of Problem 8.2 is unusual.
- 8.28. Complete and balance each of the following. If no reaction occurs, write "NR."
- | | |
|--|--|
| (a) $\text{SO}_2 + \text{H}_2\text{O} \longrightarrow$ | (l) $\text{C} + \text{O}_2 \text{ (excess)} \longrightarrow$ |
| (b) $\text{BaO} + \text{H}_2\text{O} \longrightarrow$ | (m) $\text{KOH} + \text{HNO}_3 \longrightarrow$ |
| (c) $\text{Al} + \text{O}_2 \longrightarrow$ | (n) $\text{HClO}_3 + \text{ZnO} \longrightarrow$ |
| (d) $\text{Na} + \text{S} \longrightarrow$ | (o) $\text{BaCl}_2 + \text{Na}_2\text{SO}_4 \longrightarrow$ |
| (e) $\text{MgO} + \text{CO}_2 \longrightarrow$ | (p) $\text{AgNO}_3 + \text{KCl} \longrightarrow$ |
| (f) $\text{Al} + \text{Br}_2 \longrightarrow$ | (q) $\text{NaOH} + \text{H}_2\text{SO}_4 \longrightarrow$ |
| (g) $\text{Ag} + \text{ZnCl}_2 \longrightarrow$ | (r) $\text{Ba}(\text{OH})_2 + \text{HClO}_2 \longrightarrow$ |
| (h) $\text{Cl}_2 + \text{KBr} \longrightarrow$ | (s) $\text{C} + \text{O}_2 \text{ (limited)} \longrightarrow$ |
| (i) $\text{BaSO}_4 + \text{NaCl} \longrightarrow$ | (t) $\text{C}_5\text{H}_{10} + \text{O}_2 \text{ (excess)} \longrightarrow$ |
| (j) $\text{NaCl}(l) \xrightarrow{\text{electricity}}$ | (u) $\text{C}_5\text{H}_{10} + \text{O}_2 \text{ (limited)} \longrightarrow$ |
| (k) $\text{KCl} + \text{HNO}_3 \longrightarrow$ | (v) $\text{C}_5\text{H}_{10}\text{O} + \text{O}_2 \text{ (excess)} \longrightarrow$ |
| | (w) $\text{C}_5\text{H}_{10}\text{O} + \text{O}_2 \text{ (limited)} \longrightarrow$ |

Solved Problems

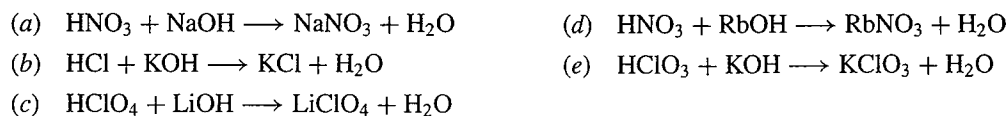
WRITING NET IONIC EQUATIONS

- 9.1. How many types of ions are generally found in any ionic compound?
- 9.2. Which of the following compounds are ionic? Which are soluble? Which would be written as separate ions in an ionic equation as written for the first equation in this section? Write the species as they would appear in an ionic equation. (a) CuCl , (b) $\text{NH}_4\text{C}_2\text{H}_3\text{O}_2$, (c) Hg_2Cl_2 , (d) CoCl_2 , (e) Na_3PO_4 , and (f) $\text{CH}_3\text{OH}(\text{aq})$.
- 9.3. Write the formulas for the ions present in each of the following compounds: (a) NaClO_4 , (b) BaCl_2 , (c) KClO , (d) $\text{Ba}(\text{NO}_3)_2$, (e) LiClO_3 , (f) $(\text{NH}_4)_3\text{PO}_4$, (g) $\text{Co}_3(\text{PO}_3)_2$, (h) $\text{AgCl}(\text{s})$, and (i) $\text{Mg}(\text{HCO}_3)_2$.
- 9.4. Write a net ionic equation for the equation in each of the following parts:
- (a) $\text{NH}_4\text{I} + \text{AgClO}_3 \longrightarrow \text{AgI}(\text{s}) + \text{NH}_4\text{ClO}_3$
(b) $\text{H}_2\text{SO}_4 + \text{BaCl}_2 \longrightarrow \text{BaSO}_4 + 2 \text{HCl}$
- 9.5. Write a net ionic equation for the equation in each of the following parts:
- (a) $\text{HNO}_3 + \text{NaHCO}_3 \longrightarrow \text{NaNO}_3 + \text{CO}_2 + \text{H}_2\text{O}$
(b) $\text{NaOH} + \text{NH}_4\text{ClO}_3 \longrightarrow \text{NH}_3 + \text{H}_2\text{O} + \text{NaClO}_3$
(c) $\text{HC}_2\text{H}_3\text{O}_2 + \text{KOH} \longrightarrow \text{KC}_2\text{H}_3\text{O}_2 + \text{H}_2\text{O}$
(d) $\text{Ba}(\text{OH})_2(\text{aq}) + 2 \text{HI} \longrightarrow \text{BaI}_2 + 2 \text{H}_2\text{O}$
- 9.6. Given that BaCO_3 is insoluble in water and that NH_3 and H_2O are covalent compounds, write net ionic equations for the following processes:
- (a) $\text{NH}_4\text{Cl} + \text{NaOH} \longrightarrow \text{NH}_3 + \text{H}_2\text{O} + \text{NaCl}$
(b) $\text{BaCl}_2 + \text{Li}_2\text{CO}_3 \longrightarrow \text{BaCO}_3 + 2 \text{LiCl}$

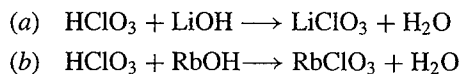
9.7. Write a net ionic equation for the following overall equation:



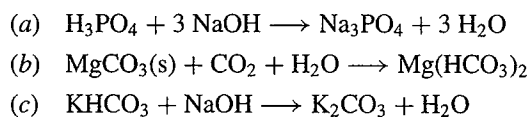
9.8. Write a net ionic equation for each of the following overall equations:



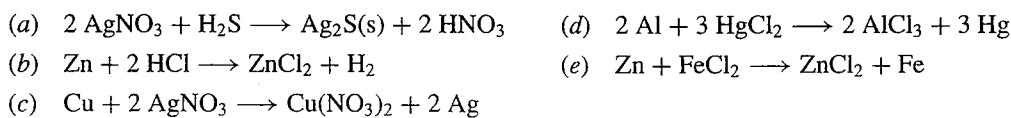
9.9. Write a net ionic equation for each of the following overall equations:



9.10. Write a net ionic equation for each of the following overall equations:



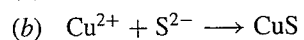
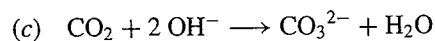
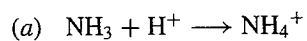
9.11. Write a net ionic equation for each of the following overall equations:



9.12. Write six more equations that can be represented by the net ionic equation of Example 9.1. Use the same reactants that are used in the equations in Example 9.1

9.13. A student used H_3PO_4 to prepare a test solution that was supposed to contain phosphate ions. Criticize this choice.

9.14. Write one or more complete equations for each of the following net ionic equations:



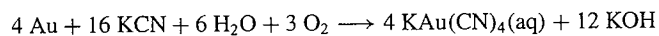
9.15. What chemical would you use to prepare a solution to be used for a test requiring the presence of Ca^{2+} ions?

9.16. What chemical would you use to prepare a solution to be used for a test requiring the presence of Br^- ions?

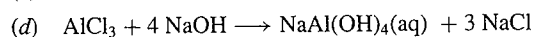
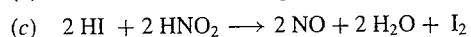
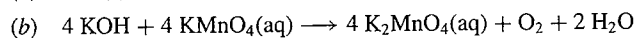
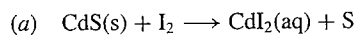
9.17. What chemical would you use to prepare a solution to be used for a test requiring the presence of SO_4^{2-} ions?

Supplementary Problems

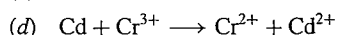
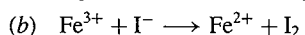
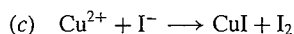
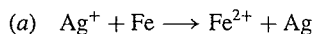
9.18. Write a net equation for the following overall equation:



9.19. Write a net ionic equation for each of the following equations:

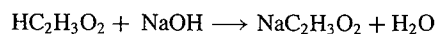


9.20. Balance the following net ionic equations:



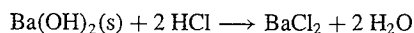
9.21. Try to write a complete equation corresponding to the unbalanced and the balanced net ionic equations of the prior problem. What do you find?

9.22. Would the following reaction yield 56 kJ of heat per mole of water formed, as the reactions in Example 9.4 do? Explain.

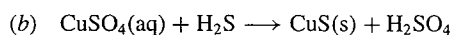
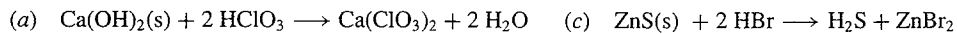


9.23. Per mole of water formed, how much heat is generated by the reaction of Example 9.5?

9.24. Would 56 kJ per mole of water formed be generated by the following reaction? Compare your answer with that of the prior problem.



9.25. Write a net ionic equation for each of the following overall equations:



9.26. Write 12 more equations represented by the net ionic equation given in Example 9.4, using only the reactants used in that example.

- 9.27. Indicate how you could choose different compounds to enable you to write 100 additional equations in response to Problem 9.12.

EXAMPLE 10.20. What rise in temperature will occur if 24.5 kJ of heat is added to 175 g of a dilute aqueous solution of sodium chloride [$c = 4.10 \text{ J/g}\cdot^\circ\text{C}$] (a) by heating with a bunsen burner and (b) by means of a chemical reaction?

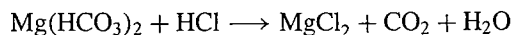
EXAMPLE 10.21. Calculate the heat of reaction per mole of water formed if 0.0500 mol of HCl and 0.0500 mol of NaOH are added to 15.0 g of water, all at 18.0°C . The solution formed is heated from 18.0°C to 54.3°C . The specific heat of the solution is $4.10 \text{ J/(g}\cdot^\circ\text{C)}$.

Solved Problems

MOLE-TO-MOLE CALCULATIONS

- 10.1.** Can the balanced chemical equation dictate to a chemist how much of each reactant to place in a reaction vessel?
- 10.2.** How many factor labels can be used corresponding to each of the following balanced equations?
- (a) $2 \text{ K} + \text{Cl}_2 \longrightarrow 2 \text{ KCl}$
- (b) $\text{NCl}_3 + 3 \text{ H}_2\text{O} \longrightarrow 3 \text{ HOCl} + \text{NH}_3$
- 10.3.** Which of the factors of Problem 10.2a would be used to convert (a) the number of moles of Cl_2 to the number of moles of KCl, (b) K to Cl_2 , and (c) Cl_2 to K?
- 10.4.** How many moles of AlCl_3 can be prepared from 7.5 mol Cl_2 and sufficient Al?
- 10.5.** How many moles of H_2O will react with 2.25 mol PCl_5 to form HCl and H_3PO_4 ?

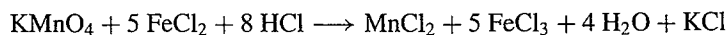
- 10.6. Balance the following equation. Calculate the number of moles of CO_2 that can be prepared by the reaction of 2.50 mol of $\text{Mg}(\text{HCO}_3)_2$.



- 10.7. (a) How many moles of CaCl_2 can be prepared by the reaction of 2.50 mol HCl with excess $\text{Ca}(\text{OH})_2$?
(b) How many moles of NaCl can be prepared by the reaction of 2.50 mol HCl with excess NaOH ?

- 10.8. How many moles of H_2O are prepared along with 0.750 mol Na_3PO_4 in a reaction of NaOH and H_3PO_4 ?

- 10.9. Consider the following equation:



How many moles of FeCl_3 will be produced by the reaction of 0.968 mol of HCl ?

CALCULATIONS INVOLVING OTHER QUANTITIES

- 10.10. Figure 10-2 is a combination of which two earlier figures?
- 10.11. Which earlier sections must be understood before mass-to-mass conversions can be studied profitably?
- 10.12. In a stoichiometry problem, (a) if the mass of a reactant is given, what conversions (if any) should be made? (b) If a number of molecules is given, what conversions (if any) should be made? (c) If a number of moles is given, what conversions (if any) should be made?
- 10.13. Phosphoric acid reacts with sodium hydroxide to produce sodium phosphate and water. (a) Write a balanced chemical equation for the reaction. (b) Determine the number of moles of phosphoric acid in 50.0 g of the acid. (c) How many moles of sodium phosphate will be produced by the reaction of this

number of moles of phosphoric acid? (d) How many grams of sodium phosphate will be produced? (e) How many moles of sodium hydroxide will it take to react with this quantity of phosphoric acid? (f) How many grams of sodium hydroxide will be used up?

10.14. (a) Write the balanced chemical equation for the reaction of sodium with chlorine. (b) How many moles of Cl_2 are there in 7.650 g chlorine? (c) How many moles of NaCl will that number of moles of chlorine produce? (d) What mass of NaCl is that number of moles of NaCl ?

10.15. How many formula units of sodium hydroxide, along with H_2SO_4 , does it take to make 7.50×10^{22} formula units of Na_2SO_4 ?

10.16. How many grams of barium hydroxide will be used up in the reaction with hydrogen chloride (hydrochloric acid) to produce 16.70 g of barium chloride plus some water?

10.17. Draw a figure like Fig. 10-2 for Problem 10.15.

10.18. (a) What reactant may be treated with phosphoric acid to produce 6.00 mol of potassium hydrogen phosphate (plus some water)? (b) How many moles of phosphoric acid will it take? (c) How many moles of the other reactant are required? (d) How many grams?

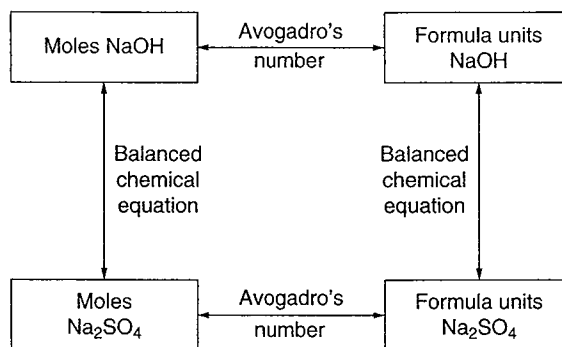
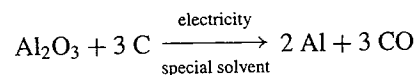


Fig. 10-4. Conversion of formula units of a reactant to formula units of a product

- 10.19. Determine the number of grams of hydrochloric acid that will just react with 20.0 g of calcium carbonate to produce carbon dioxide, water, and calcium chloride.
- 10.20. How many grams of Hg_2Cl_2 can be prepared from 15.0 mL of mercury (density 13.6 g/mL)?
- 10.21. How many grams of methyl alcohol, CH_3OH , can be obtained in an industrial process from 5.00 metric tons (5.00×10^6 g) of CO plus hydrogen gas? To calculate the answer: (a) Write a balanced chemical equation for the process. (b) Calculate the number of moles of CO in 5.00×10^6 g CO. (c) Calculate the number of moles of CH_3OH obtainable from that number of moles of CO. (d) Calculate the number of grams of CH_3OH obtainable.
- 10.22. Determine the number of grams of barium hydroxide it would take to neutralize (just react completely, with none left over) 14.7 g of phosphoric acid.

10.23. Calculate the number of moles of NaOH required to remove the SO₂ from 3.50 metric tons (3.50×10^6 g) of atmosphere if the SO₂ is 0.10% by mass. (Na₂SO₃ and water are the products.)

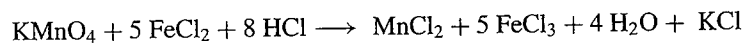
10.24. Calculate the number of moles of Al₂O₃ needed to prepare 4.00×10^6 g of Al metal in the Hall process:



10.25. How much AgCl can be prepared with 50.0 g CaCl₂ and excess AgNO₃?

10.26. In chemistry recitation, a student hears (incorrectly) the instructor say, "Hydrogen chloride reacts with Ba(OH)₂" when the instructor has actually said, "Hydrogen fluoride reacts with Ba(OH)₂." The instructor then asked how much product is formed. The student answers the question correctly. Which section, 10.1 or 10.2, were they discussing? Explain.

10.27. Consider the equation



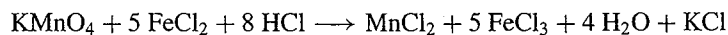
How many grams of FeCl₃ will be produced by the reaction of 2.72 g of KMnO₄?

10.28. How many grams of NaCl can be produced from 7.650 g chlorine?

10.29. How much KClO₃ must be decomposed thermally to produce 14.6 g O₂?

LIMITING QUANTITIES

- 10.30. How many sandwiches, each containing 1 slice of salami and 2 slices of bread, can you make with 42 slices of bread and 25 slices of salami?
- 10.31. How can you recognize a limiting-quantities problem?
- 10.32. How much sulfur dioxide is produced by the reaction of 5.00 g S and all the oxygen in the atmosphere of the earth?
- 10.33. (a) The price of pistachio nuts is \$5.00 per pound. If a grocer has 17 lb for sale and a buyer has \$45.00 to buy nuts with, what is the maximum number of pounds that can be sold? (b) Consider the reaction

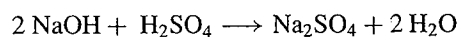


If 45.0 mol of FeCl_2 and 17.0 mol of KMnO_4 are mixed with excess HCl, how many moles of MnCl_2 can be formed?

- 10.34. In each of the following cases, determine which reactant is present in excess, and tell how many moles in excess it is.

Equation	Moles Present
(a) $2 \text{Na} + \text{Cl}_2 \longrightarrow 2 \text{NaCl}$	1.20 mol Na, 0.400 mol Cl_2
(b) $\text{P}_4\text{O}_{10} + 6 \text{H}_2\text{O} \longrightarrow 4 \text{H}_3\text{PO}_4$	0.25 mol P_4O_{10} , 1.5 mol H_2O
(c) $\text{HNO}_3 + \text{NaOH} \longrightarrow \text{NaNO}_3 + \text{H}_2\text{O}$	0.90 mol acid, 0.85 mol base
(d) $\text{Ca}(\text{HCO}_3)_2 + 2 \text{HCl} \longrightarrow \text{CaCl}_2 + 2 \text{CO}_2 + 2 \text{H}_2\text{O}$	2.5 mol HCl, 1.0 mol $\text{Ca}(\text{HCO}_3)_2$
(e) $\text{H}_3\text{PO}_4 + 3 \text{NaOH} \longrightarrow \text{Na}_3\text{PO}_4 + 3 \text{H}_2\text{O}$	0.70 mol acid, 2.2 mol NaOH

10.35. For the following reaction,



- (a) How many moles of NaOH would react with 0.250 mol H_2SO_4 ? How many moles of Na_2SO_4 would be produced?
- (b) If 0.250 mol of H_2SO_4 and 0.750 mol NaOH were mixed, how much NaOH would react?
- (c) If 24.5 g H_2SO_4 and 30.0 g NaOH were mixed, how many grams of Na_2SO_4 would be produced?

10.36. For the reaction



a chemist added 2.55 mol of HCl and a certain quantity of Na_3PO_4 to a reaction vessel, which produced 0.750 mol H_3PO_4 . Which one of the reactants was in excess?

10.37. (a) How many moles of Cl_2 will react with 1.22 mol Na to produce NaCl? (b) If 0.880 mol Cl_2 is treated with 1.22 mol Na, how much Cl_2 will react? (c) What is the limiting quantity in this problem?

10.38. What mass of CO_2 can be produced by the complete combustion of 2.00 kg of octane, C_8H_{18} , a major component of gasoline, in 8.00 kg of oxygen?

10.39. If you were treating two chemicals, one very cheap and one expensive, to produce a product, which chemical would you use in excess, if one had to be in excess?

CALCULATIONS BASED ON NET IONIC EQUATIONS

10.40. What mass of each of the following silver salts would be required to react completely with a solution containing 35.5 g of chloride ion to form (insoluble) silver chloride? (a) AgNO_3 , (b) Ag_2SO_4 , and (c) $\text{AgC}_2\text{H}_3\text{O}_2$.

HEAT CAPACITY AND HEAT OF REACTION

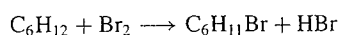
10.41. The student political science society decides to take a trip to Washington, D.C. The hostel rate is \$20 per student each night. How much will it cost for 23 students to stay for three nights?

10.42. A system is initially at 15°C . What will be the final temperature if the system (a) is warmed 35°C and (b) is warmed to 35°C ? (c) What is the difference between final temperature and temperature change?

- 10.43. How much heat is required to raise 43.2 g of iron from 20.0°C to 35.1°C? [$c = 0.447 \text{ J/(g}\cdot\text{°C)}$]
- 10.44. Calculate the heat produced by incomplete combustion of carbon, producing 45.7 g of CO according to the following equation:
- $$2 \text{ C} + \text{O}_2 \longrightarrow 2 \text{ CO} + 220 \text{ kJ}$$
- 10.45. Calculate the temperature change produced by the addition of 225 J of heat to 15.3 g of water.
- 10.46. Calculate the final temperature t_f if 225 J of energy is added to 15.3 g of water at 19.0°C.
- 10.47. Calculate the specific heat of a 125 g metal bar which rose in temperature from 18.0°C to 33.0°C on addition of 2.37 kJ of heat.

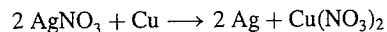
Supplementary Problems

- 10.48. Read each of the other supplementary problems and state which ones are limiting-quantities problems.
- 10.49. Calculate the number of grams of methyl alcohol, CH_3OH , obtainable in an industrial process from 5.00 metric tons ($5.00 \times 10^6 \text{ g}$) of CO plus hydrogen gas.
- 10.50. Make up your own stoichiometry problem, using the equation
- $$\text{CaCl}_2 + 2 \text{ AgNO}_3 \longrightarrow \text{Ca(NO}_3)_2 + 2 \text{ AgCl}$$
- 10.51. What percentage of 50.0 g of KClO_3 must be decomposed thermally to produce 14.6 g O_2 ?
- 10.52. Percent yield is defined as 100 times the amount of a product actually prepared during a reaction divided by the amount theoretically possible to be prepared according to the balanced chemical equation. (Some reactions are slow, and sometimes not enough time is allowed for their completion; some reactions are accompanied by side reactions which consume a portion of the reactants; some reactions never get to completion.) If 5.00 g $\text{C}_6\text{H}_{11}\text{Br}$ is prepared by treating 5.00 g C_6H_{12} with excess Br_2 , what is the percent yield? The equation is



- 10.53. In a certain experiment, 225 g of ethane, C_2H_6 , is burned. (a) Write a balanced chemical equation for the combustion of ethane to produce CO_2 and water. (b) Determine the number of moles of ethane in 225 g of ethane. (c) Determine the number of moles of CO_2 produced by the combustion of that number of moles of ethane. (d) Determine the mass of CO_2 that can be produced by the combustion of 225 g of ethane.
- 10.54. Determine the number of kilograms of SO_3 produced by treating excess SO_2 with 50.0 g of oxygen.
- 10.55. How many grams of K_2CO_3 will be produced by thermal decomposition of 4.00 g $KHCO_3$?
- 10.56. What is the difference in mass between reactions involving 2.25 g Cl^- and 2.25 g $NaCl$?
- 10.57. How many moles of H_2 can be prepared by treating 5.00 g Na with 2.80 g H_2O ? *Caution:* This reaction is very energetic and can even cause an explosion.
- 10.58. How many grams of $NaCl$ can be prepared by treating 18.9 g $BaCl_2$ with 14.8 g Na_2SO_4 ?

- 10.59. If 4.00 g Cu is treated with 15.0 g AgNO₃, how many grams of Ag metal can be prepared?



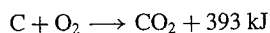
- 10.60. What, if any, is the difference between the following three exam questions?

How much NaCl is produced by treating 10.00 g NaOH with excess HCl?

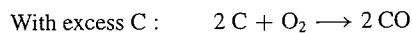
How much NaCl is produced by treating 10.00 g NaOH with sufficient HCl?

How much NaCl is produced by treating 10.00 g NaOH with HCl?

- 10.61. What mass of water can be heated from 20.0°C to 45.0°C by the combustion of 4.00 g of carbon to carbon dioxide?



- 10.62. Some pairs of substances undergo different reactions if one or the other is in excess. For example,



Does this fact make the limiting-quantities calculations in the text untrue for such pairs?

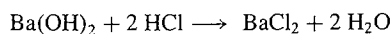
- 10.63. A manufacturer produces impure ammonium phosphate as a fertilizer. Treatment of 56.0 g of product with excess NaOH produces 18.3 g NH₃. What percentage of the fertilizer is pure (NH₄)₃PO₄? (Assume that any impurity contains no ammonium compound.)

- 10.64. (a) When 5.00 g NaOH reacts with 5.00 g HCl, how much NaCl is produced? (b) When 6.00 g NaOH reacts with 5.00 g HCl, how much NaCl is produced?

- 10.65. Calculate the number of moles of each solute in the final solution after 1.75 mol of aqueous BaCl₂ and 2.70 mol of aqueous AgNO₃ are mixed.

- 10.66. Calculate the number of moles of each ion in the final solution after 1.75 mol of aqueous BaCl₂ and 2.70 mol of aqueous AgNO₃ are mixed.

- 10.67. Consider the reaction



If exactly 20.0 g of Ba(OH)₂ reacts according to this equation, do you know how much Ba(OH)₂ was added to the HCl? Do you know how much HCl was added to the Ba(OH)₂? Explain.

- 10.68. Redo Problem 10.18 without bothering to solve for intermediate answers.

- 10.69. Determine the number of grams of SO₃ produced by treating excess SO₂ with 50.0 g of oxygen.

- 10.70.** A sample of a hydrocarbon (a compound of carbon and hydrogen only) is burned, and 1.10 g CO_2 and 0.450 g H_2O are produced. What is the empirical formula of the hydrocarbon?
- 10.71.** How many moles of each substance are present in solution after 0.100 mol of NaOH is added to 0.200 mol of $\text{HC}_2\text{H}_3\text{O}_2$?
- 10.72.** Combine Figs. 7-5 and 10-4 to show all the conversions learned so far.

EXAMPLE 11.15. (a) Calculate the concentration of Zn^{2+} produced when excess solid zinc is treated with 100.0 mL of 6.000 *M* HCl. Assume no change in volume. (b) Repeat the problem with solid aluminum.

Solved Problems

INTRODUCTION

- 11.1. Which, if either, has more sugar in it, (a) a half cup of tea with one lump of sugar or (b) a whole cup of tea with two lumps of sugar?
- 11.2. Which, if either, of the following tastes sweeter, (a) a half cup of tea with one lump of sugar or (b) a whole cup of tea with two lumps of sugar?

MOLARITY CALCULATIONS

- 11.3. Calculate the molarity of each of the following solutions: (a) 4.00 mol solute in 2.50 L of solution, (b) 0.200 mol solute in 0.240 L of solution, (c) 0.0500 mol solute in 25.0 mL of solution, and (d) 0.240 mol solute in 750.0 mL of solution.
- 11.4. Calculate the number of moles of solute in each of the following solutions: (a) 1.50 L of 0.800 *M* solution, (b) 1.66 L of 0.150 *M* solution, (c) 45.0 mL of 0.600 *M* solution, and (d) 25.0 mL of 2.00 *M* solution.

- 11.5. How can you make 2.25 L of 4.00 *M* sugar solution?
- 11.6. Calculate the volume of 1.75 *M* solution required to contain 4.20 mol of solute.
- 11.7. A 10.0-mL solution contains 2.40 mmol of solute. What is its molarity?
- 11.8. How many moles of solute are present in 29.4 mL of 0.606 *M* solution?
- 11.9. Calculate the number of milliliters of 1.25 *M* solution required to contain 0.622 mol of solute.
- 11.10. What volume of 1.45 *M* NaCl solution contains 71.3 g NaCl?
- 11.11. What is the concentration of a solution prepared by dissolving 22.2 g NaCl in sufficient water to make 86.9 mL of solution?
- 11.12. How many grams of NaCl are present in 72.1 mL of 1.03 *M* NaCl?
- 11.13. Calculate the volume of 0.900 *M* solution required to contain 1.84 mol of solute.
- 11.14. How many milligrams of NaOH are present in 35.0 mL of 2.18 *M* NaOH?

- 11.15.** What is the concentration of a solution prepared by diluting 3.0 L of 2.5 *M* solution to 8.0 L with water?
- 11.16.** What is the concentration of a solution prepared by diluting 0.500 L of 1.80 *M* solution to 1.50 L with solvent?
- 11.17.** What is the concentration of a solution prepared by diluting 0.500 L of 1.80 *M* solution with 1.50 L of solvent?
- 11.18.** What is the concentration of a solution prepared by diluting 25.0 mL of 3.00 *M* solution to 60.0 mL?
- 11.19.** What concentration of salt is obtained by mixing 20.0 mL of 3.0 *M* salt solution with 30.0 mL of 2.0 *M* salt solution?

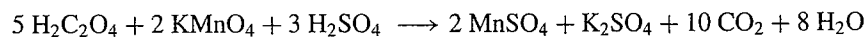
- 11.20. What concentration of salt is obtained by mixing 20.0 mL of 3.0 *M* salt solution with 30.0 mL of 2.0 *M* salt solution and diluting with water to 100.0 mL?
- 11.21. Calculate the concentration of sugar in a solution prepared by mixing 3.0 L of 2.0 *M* sugar with 2.5 L of 1.0 *M* salt.

TITRATION

- 11.22. (a) A solid acid containing one hydrogen atom per molecule is titrated with 1.000 *M* NaOH. If 27.21 mL of base is used in the titration, how many moles of base is present? (b) How many moles of acid? (c) If the mass of the acid was 3.494 g, what is the molar mass of the acid?
- 11.23. A 25.00-mL sample of 1.000 *M* HCl is titrated with 31.72 mL of NaOH. What is the concentration of the base?
- 11.24. A 25.00-mL sample of 2.000 *M* H₂SO₄ is titrated with 16.54 mL of NaOH until both hydrogen atoms of each molecule of the acid are just neutralized. What is the concentration of the base?

STOICHIOMETRY IN SOLUTION

11.25. What mass of $\text{H}_2\text{C}_2\text{O}_4$ can react with 35.0 mL of 1.50 *M* KMnO_4 according to the following equation?



11.26. Calculate the number of grams of BaSO_4 that can be prepared by treating 35.0 mL of 0.479 *M* BaCl_2 with excess Na_2SO_4 .

11.27. When 20.0 mL of 1.71 *M* AgNO_3 is added to 35.0 mL of 0.444 *M* CuCl_2 , how many grams of AgCl will be produced?

11.28. What concentration of NaCl will be produced when 1.00 L of 1.11 *M* HCl and 250 mL of 4.05 *M* NaOH are mixed? Assume that the volume of the final solution is the sum of the two initial volumes.

Supplementary Problems

11.29. Describe in detail how you would prepare 250.0 mL of 4.000 *M* NaCl solution.

- 11.30. What is the percent by mass of NaCl in 1.60 *M* NaCl solution? Assume that the solution has a density of 1.06 g/mL.
- 11.31. Which boxes of the conversion diagram (page 348) indicate the method of converting volumes of solutions to moles of reactants and/or products and vice versa?