1. The Arithmetic of Equations
   a. Interpret each chemical equation in terms of interacting particles.
      \[ 2\text{KCl}(s) \rightarrow 2\text{KCl}(s) + 3\text{O}_2(g) \]
      \[ 4\text{NH}_3(g) + 6\text{NO}_2(g) \rightarrow 5\text{N}_2(g) + 6\text{H}_2\text{O}(g) \]
      \[ 4\text{K}(s) + 3\text{O}_2(g) \rightarrow 2\text{K}_2\text{O}(s) \]

   b. Interpret each equation in Problem 36 in terms of interacting numbers of moles of reactants and products.

   c. Calculate and compare the mass of the reactants with the mass of the products for each equation in Problem 36. Show that each balanced equation obeys the law of conservation of mass.

2. Chemical Calculations
   Explain the term mole ratio in your own words. When would you use this term?

   a. Carbon disulfide is an important industrial solvent. It is prepared by the reaction of coke with sulfur dioxide.
      \[ 5\text{C}(s) + 2\text{SO}_2(g) \rightarrow \text{CS}_2(l) + 4\text{CO}(g) \]

   b. How many moles of CS₂ form when 2.7 mol C react?

   c. How many moles of carbon are needed to react with 5.44 mol SO₂?

   d. How many moles of carbon monoxide form at the same time that 0.246 mol CS₂ forms?

   e. How many mol SO₂ are required to make 118 mol CS₂?

   f. Methanol (CH₃OH) is used in the production of many chemicals. Methanol is made by reacting carbon monoxide and hydrogen at high temperature and pressure.
      \[ \text{CO}(g) + 2\text{H}_2(g) \rightarrow \text{CH}_3\text{OH}(g) \]

   g. How many moles of each reactant are needed to produce 3.80 x 10³ g CH₃OH?

   h. Calculate the number of grams of each reactant needed to produce 4.00 mol CH₃OH.

   i. How many grams of hydrogen are necessary to react with 2.85 mol CO?

   j. The reaction of fluorspar with ammonia produces dinitrogen tetrafluoride and hydrogen fluoride.
      \[ 5\text{F}_2(g) + 2\text{NH}_3(g) \rightarrow \text{N}_2\text{F}_4(g) + 6\text{HF}(g) \]

   k. If you have 66.6 g NH₃, how many grams of F₂ are required for complete reaction?

   l. How many grams of NH₃ are required to produce 4.65 g HF?

   m. How many grams of N₂F₄ can be produced from 225 g F₂?

43. What information about a chemical reaction is derived from the coefficients in a balanced equation?

44. Lithium nitride reacts with water to form ammonia and aqueous lithium hydroxide.

   \[ \text{Li}_3\text{N}(s) + 3\text{H}_2\text{O}(l) \rightarrow \text{NH}_3(g) + 3\text{LiOH}(aq) \]

   a. What mass of water is needed to react with 32.9 g Li₃N?

   b. When the above reaction takes place, how many molecules of NH₃ are produced?

   c. Calculate the number of grams of Li₃N that must be added to an excess of water to produce 15.0 L NH₃ (at STP).

45. Limiting Reagent and Percent Yield

46. What is the significance of the limiting reagent in a reaction? What happens to the amount of any reagent that is present in an excess?

47. In a reaction chamber, 3.0 mol of aluminum is mixed with 5.3 mol Cl₂ and reacts. The reaction is described by the following balanced chemical equation.

   \[ 2\text{Al} + 3\text{Cl}_2 \rightarrow 2\text{AlCl}_3 \]

   a. Identify the limiting reagent for the reaction.

   b. Calculate the number of moles of product formed.

   c. Calculate the number of moles of excess reagent remaining after the reaction.

48. Heating an ore of antimony (Sb₂S₅) in the presence of iron gives the element antimony and iron(II) sulfide.

   \[ \text{Sb}_2\text{S}_5(s) + 3\text{Fe}(s) \rightarrow 2\text{Sb}(s) + 3\text{FeS}(s) \]

   When 15.0 g Sb₂S₅ reacts with an excess of Fe, 9.84 g Sb is produced. What is the percent yield of this reaction?

Reviewing Content

36. a. Two formula units KClO₃ decompose to form two formula units KCl and three molecules O₂.

b. Four molecules NH₃ react with six molecules NO to form five molecules N₂ and six molecules H₂O.

c. Four atoms K react with one molecule O₂ to form two formula units K₂O.

37. a. Two mol KClO₃ decompose to form two mol KCl and three mol O₂.

b. Four mol NH₃ react with six mol NO to form five mol N₂ and six mol H₂O.

c. Four mol K react with one mol O₂ to form two mol K₂O.

38. a. 245.2 g b. 248.0 g c. 188.4 g

   All obey the law of conservation of mass.

39. Acceptable answers include the idea of writing a ratio using the coefficients of two substances from a balanced equation as the number of moles of each substance reacting being formed.

40. a. 0.54 mol b. 13.6 mol c. 0.984 mol d. 236 mol

41. a. 11.3 mol CO, 22.5 mol H₂ b. 112 g CO, 16.0 g H₂ c. 11.4 g H₂

42. a. 372 g F₂ b. 132 g NH₃ c. 123 g N₂F₄

43. The coefficients indicate the relative number of moles (or particles) of reactants and products.

44. a. 51.2 g H₂O b. 5.71 x 10²³ molecules NH₃ c. 23.2 g Li₃N

45. The amount of the limiting reagent determines the maximum amount of product that can be formed. Excess reagent is only partially consumed in the reaction.

46. To identify the limiting reagent, express quantities of reactants and products; compare the mole ratio from the balanced equation.

47. a. Al b. 3.0 mol AlCl₃ c. 0.8 mol Cl₂

48. 91.5%
49. Calcium carbonate reacts with phosphoric acid to produce calcium phosphate, carbon dioxide, and water.
\[3\text{CaCO}_3(s) + 2\text{H}_3\text{PO}_4(aq) \rightarrow 3\text{Ca}_3(\text{PO}_4)_2(aq) + 3\text{CO}_2(g) + 3\text{H}_2\text{O}(l)\]
   a. How many grams of phosphoric acid react with excess calcium carbonate to produce 3.74 g \(\text{Ca}_3(\text{PO}_4)_2\)?
   b. Calculate the number of grams of CO\(_2\) formed when 0.773 g H\(_2\)O is produced.

50. Nitric acid and zinc react to form zinc nitrate, ammonium nitrate, and water.
\[4\text{Zn}(s) + 10\text{HNO}_3(aq) \rightarrow 4\text{Zn(NO}_3)_2(aq) + 2\text{NH}_4\text{NO}_3(aq) + 3\text{H}_2\text{O}(l)\]
   a. How many atoms of zinc react with 1.49 g H\(_2\)O?
   b. Calculate the number of grams of zinc that must react with an excess of H\(_2\)O to form 29.1 g NH\(_4\)NO\(_3\).

51. Hydrazine (\(\text{N}_2\text{H}_4\)) is used as rocket fuel. It reacts with oxygen to form nitrogen and water.
\[\text{N}_2\text{H}_4(l) + 2\text{O}_2(g) \rightarrow \text{N}_2(g) + 2\text{H}_2\text{O}(g)\]
   a. How many liters of \(\text{N}_2\) (at STP) form when 1.0 kg \(\text{H}_2\text{O}\) reacts with 1.0 kg \(\text{O}_2\)?
   b. How many grams of the excess reagent remain after the reaction?

52. When 50.0 g of silicon dioxide is heated with an excess of carbon, 32.2 g of silicon carbide is produced.
\[\text{SiO}_2(s) + 3\text{C}(s) \rightarrow \text{SiC}(s) + 2\text{CO}(g)\]
   a. What is the percent yield of this reaction?
   b. How many grams of CO gas are made?

53. If the reaction below proceeds with a 96.8% yield, how many kilograms of CaSO\(_4\) are formed when 5.24 kg SO\(_2\) reacts with an excess of CaCO\(_3\) and O\(_2\)?
\[2\text{CaCO}_3(s) + 2\text{SO}_2(g) + \text{O}_2(g) \rightarrow 2\text{CaSO}_4(s) + 2\text{CO}_2(g)\]

54. Ammonium nitrate will decompose explosively at high temperatures to form nitrogen, oxygen, and water vapor.
\[2\text{NH}_4\text{NO}_3(s) \rightarrow 2\text{N}_2(g) + 4\text{H}_2\text{O}(g) + \text{O}_2(g)\]
   What is the total number of liters of gas formed when 228 g NH\(_4\)NO\(_3\) is decomposed? (Assume STP)

55. In an experiment, varying masses of sodium metal are reacted with a fixed initial mass of chlorine gas. The amounts of sodium used and the amounts of sodium chloride formed are shown on the following graph.

![Graph showing mass of NaCl produced vs mass of Na used]

   a. Explain the general shape of the graph.
   b. Estimate the amount of chlorine gas used in this experiment at the point where the curve becomes horizontal.

56. The manufacture of compound \(F\) requires five separate chemical reactions. The initial reactant compound \(A\), is converted to compound \(B\), compound \(B\) is converted to compound \(C\), and so forth. The diagram below summarizes the step-wise manufacture of compound \(F\), including the percent yield for each step. Provide the missing quantities or missing percent yields. Assume the reactant and product in each step react in a one-to-one mole ratio.