SECTION 1

Mastering Concepts

36. Mole ratios are determined by the coefficients in a balanced equation. If the equation is not balanced, the relationship between reactants and products cannot be determined.

37. Relationships among particles, moles, and mass for all reactants and products.

38. Mole ratios allow for the conversion from moles of one substance in a balanced chemical equation to moles of another substance in the same equation.

39. Mols/moles A

40. The coefficients in the balanced chemical equation show the numbers of representative particles involved in a reaction. Subscripts give the numbers of different kinds of atoms within a molecule or formula unit.

41. The mass of the reactants will always equal the mass of the products.

42. 1 mol (NH₄)₂Cr₂O₇ → 1 mol N₂ and inverse; 1 mol (NH₄)₂Cr₂O₇ → 1 mol Cr₂O₃ and inverse; 1 mol (NH₄)₂Cr₂O₇ → 4 mol H₂O and inverse

43. 2 M/N → M₂ + N₂; 1 mol N₂ + 2 mol M/N, 1 mol N₂/1 mol M, 2 mol M/N + 1 mol N₂, 2 mol M/N + 2 mol N₂, 1 mol M/N + 1 mol N₂, 1 mol M/N + 2 mol M/N

Mastering Problems

44. 4 atoms Al + 3 molecules O₂ → 2 formula units Al₂O₃; 4 mol Al + 3 mol O₂ → 2 mol Al₂O₃; 107.93 g Al + 95.99 g O₂ → 203.92 g Al₂O₃

45. 1 formula unit SnO₂ + 2 atoms C → 1 atom Sn + 2 molecules CO; 1 mol SnO₂ + 2 mol C → 1 mol Sn + 2 mol CO; 150.71 g SnO₂ + 24.02 g C → 118.71 g Sn + 56.02 g CO

46. Cu(s) + 4HNO₃(aq) → Cu(NO₃)₂(aq) + 2NO₂(g) + 2H₂O(l); answers may include 1 mol Cu + 4 mol HNO₃ and inverse, 1 mol Cu + 1 mol Cu(NO₃)₂ and inverse, 1 mol Cu + 2 mol NO₂ and inverse, 1 mol Cu + 2 mol H₂O and inverse, 1 mol Cu + 2 mol NO and inverse, 1 mol Cu + 2 mol H₂O and inverse, 4 mol HNO₃/1 mol Cu(NO₃)₂ and inverse, 1 mol HNO₃/2 mol Cu(NO₃)₂ and inverse, 1 mol HNO₃/2 mol Cu(NO₃)₂ and inverse, 1 mol Cu(NO₃)₂/2 mol NO₂ and inverse, 1 mol Cu(NO₃)₂/2 mol H₂O and inverse, 2 mol NO₂/2 mol H₂O and inverse

47. a. When hydrochloric acid solution reacts with nitric acid, lead(II) chloride precipitates and solution of nitric acid is produced.
   Write the balanced chemical equation for the reaction.
   b. Write the balanced chemical equation for the reaction.
   c. Interpret the equation in terms of molecules, atoms, and mass.
   d. When aluminum is mixed with iron(III) oxide and large quantities of heat, what is the product of the reaction? What are the mole ratios of Fe to Al, Fe₂O₃ to Al, and Al₂O₃ to Al? What is the mole ratio of Fe to Al?

48. Solid silicon dioxide, silicon tetrachloride, and hydrofluoric acid react to produce silicon tetrachloride and water.
   a. Write the balanced chemical equation for this reaction.
   b. Write the balanced chemical equation for this reaction.

50. Chromes
   a. The most important commercial use of chromium is to produce chrome (Cr₂O₃). One method used to extract chromium from chromium ore involves the reaction with coke (carbon) to produce ferrochrome (FeCr₂).
   b. What is the mole ratio of Cr₂O₃ to FeCr₂?

51. Air Pollution
   a. The pollutant SO₂ is removed from air in a reaction that also involves calcium carbonate. The products of this reaction are calcium carbonate dioxide and water. Determine the mole ratio of SO₂ to CaCO₃.
   b. Two substances, W and X, react to form the products, Y and Z. Table 2 shows the mole ratios of the reactants and products involved in the reaction. Use the data to determine the coefficients that balance the equation W + X → Y + Z.

52. Antacids
   a. Magnesium hydroxide is an impure form of antacid. Antacid react with hydrochloric acid in the stomach to relieve indigestion.
   b. Write the reactions of Mg(OH)₂ with HCl.
   c. Write the reactions of Mg(OH)₂ with HCl.

53. Antacids
   a. Balance the reaction of Mg(OH)₂ with HCl.
   b. Write the reactions of Mg(OH)₂ with HCl.
   c. Write the reactions of Mg(OH)₂ with HCl.

54. a. 2HCl(aq) + Pb(NO₃)₂(aq) → PbCl₂(s) + 2HNO₃(aq)
   b. 2 molecules HCl + 1 formula unit Pb(NO₃)₂ → 1 formula unit PbCl₂ + 2 molecules HNO₃;
   c. 2 mol HCl + 1 mol Pb(NO₃)₂ → 1 mol PbCl₂ + 2 mol HNO₃;
   d. 72.9 g HCl + 331.2 g Pb(NO₃)₂ → 278.1 g PbCl₂ + 126.0 g HNO₃

55. a. 2FeCl₃ + 3H₂O → Fe₂O₃ + 6HCl
   b. 2 mol FeCl₃ + 3 mol H₂O → Fe₂O₃ + 6 mol HCl

56. a. 2Mg + O₂ → 2MgO
   b. 2 mol Mg + 1 mol O₂ → 2 mol MgO

57. 1 mol BaCO₃ + 1 mol HCl → BaCl₂ + CO₂ + H₂O

58. a. 2H₂ + O₂ → 2H₂O
   b. 2 mol H₂ + 1 mol O₂ → 2 mol H₂O

59. a. 2H₂O₂ → 2H₂O + O₂
   b. 2 mol H₂O₂ → 2 mol H₂O + 1 mol O₂

60. a. 2H₂ + O₂ → 2H₂O
   b. 2 mol H₂ + 1 mol O₂ → 2 mol H₂O

61. a. 2H₂O + O₂ → 2H₂O₂
   b. 2 mol H₂O + 1 mol O₂ → 2 mol H₂O₂

62. a. 2H₂ + O₂ → 2H₂O
   b. 2 mol H₂ + 1 mol O₂ → 2 mol H₂O

63. a. 2H₂O + O₂ → 2H₂O₂
   b. 2 mol H₂O + 1 mol O₂ → 2 mol H₂O₂

64. a. 2H₂ + O₂ → 2H₂O
   b. 2 mol H₂ + 1 mol O₂ → 2 mol H₂O

65. a. 2H₂O + O₂ → 2H₂O₂
   b. 2 mol H₂O + 1 mol O₂ → 2 mol H₂O₂

66. a. 2H₂ + O₂ → 2H₂O
   b. 2 mol H₂ + 1 mol O₂ → 2 mol H₂O

67. a. 2H₂O + O₂ → 2H₂O₂
   b. 2 mol H₂O + 1 mol O₂ → 2 mol H₂O₂

68. a. 2H₂ + O₂ → 2H₂O
   b. 2 mol H₂ + 1 mol O₂ → 2 mol H₂O

69. a. 2H₂O + O₂ → 2H₂O₂
   b. 2 mol H₂O + 1 mol O₂ → 2 mol H₂O₂

70. a. 2H₂ + O₂ → 2H₂O
   b. 2 mol H₂ + 1 mol O₂ → 2 mol H₂O
63. Esterification The process in which an organic acid and an alcohol react to form an ester and water is known as esterification. Ethyl butanoate (C₆H₄COOC₂H₅), an ester, is formed when the alcohol ethanol (C₂H₅OH) and butanoic acid (C₄H₈O₂) are heated in the presence of sulfuric acid.

\[
\text{C}_2\text{H}_5\text{OH}(l) + \text{C}_4\text{H}_8\text{O}_2(\ell) \rightarrow \text{C}_6\text{H}_{12}\text{O}_4(\ell) + \text{H}_2\text{O}(l)
\]

Determine the mass of ethyl butanoate produced if 4.50 mol of ethanol is used.

64. Greenhouse Gas Carbon dioxide is a greenhouse gas that is linked to global warming. It is released into the atmosphere through the combustion of octane (C₈H₁₈) in gasoline. Write the balanced chemical equation for the combustion of octane and calculate the mass of carbon dioxide needed to release 4.50 mol of CO₂.

65. A solution of potassium chromate reacts with a solution of lead(II) nitrate to produce a yellow precipitate of lead(II) chromate and a solution of potassium nitrate.

a. Write the balanced chemical equation.

b. Starting with 0.250 mol of potassium chromate, determine the mass of lead chromate formed.

66. Rocket Fuel The exothermic reaction between liquid hydrazine (N₂H₄) and liquid hydrogen peroxide (H₂O₂) is used to fuel rockets. The products of this reaction are nitrogen gas and water.

a. Write the balanced chemical equation.

b. How much hydrazine, in grams, is needed to produce 10.0 g of nitrogen gas?

67. Chloroform (CHCl₃), an important solvent, is produced by a reaction between methylene chloride and chlorine.

\[
\text{CH}_2\text{Cl}_2(g) + \text{Cl}_2(g) \rightarrow \text{CHCl}_3(g) + \text{HCl}(g)
\]

How much CH₃Cl, in grams, is needed to produce 50.0 g of CHCl₃?

68. Oxygen Production The Russian Space Agency uses potassium superoxide (KO₂) for the chemical oxygen generators in their space suits.

\[
4\text{KO}_2 + 2\text{H}_2\text{O} + 4\text{CO}_2 \rightarrow 4\text{KClO}_3 + 3\text{O}_2
\]

Complete Table 3.

<table>
<thead>
<tr>
<th>Reagent</th>
<th>Volume (mL)</th>
<th>Mass (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KO₂</td>
<td>100</td>
<td>15.0</td>
</tr>
<tr>
<td>H₂O</td>
<td>50</td>
<td>7.0</td>
</tr>
<tr>
<td>CO₂</td>
<td>200</td>
<td>50.0</td>
</tr>
</tbody>
</table>

69. Gasohol is a mixture of ethanol and gasoline. Balance the equation and determine the mass of CO₂ produced from the combustion of 10.00 g of ethanol.

\[
\text{C}_2\text{H}_5\text{OH}(l) + \text{O}_2(g) \rightarrow \text{CO}_2(g) + \text{H}_2\text{O}(g)
\]

Mastering Problems

60. C₂H₄O₂ → 2C₂H₂O + 2CO₂; 390.0 g of C₂H₂O₂

61. 5.00 mol of C₈H₁₈

62. 0.010 g of Na₂CO₃

63. 57.3 g of C₈H₁₈

64. 2C₂H₂O + 2H₂O(l) → 10(CO₂(g) + 18g H₂O(l))

71.4 g of Na₂CO₃

65. a. H₃CrO₄(aq) + Pb(NO₃)₂(aq) → PbCrO₄(s) + 2KNO₃(aq)

b. 80.8 g of PbCrO₄

66. a. N₂H₄(ℓ) + 2H₂O(l) → N₂(ℓ) + 4H₂(ℓ)

b. 3.20 × 10⁻⁴ g of N₂H₄

67. 6.72 g of CH₄

68. mass KO₂ = 1100 g, mass H₂O = 140 g, mass CO₂ = 7.0 × 10⁻² g, mass K₃CO₃ = 1600 g

69. C₆H₈O₄(ℓ) + 3O₂(ℓ) → 2CO₂(g) + 3H₂O(l); 191.0 g CO₂

SECTION 2

Mastering Concepts

54. Write a balanced chemical equation for the reaction.

55. The balanced equation provides the relationship between reactants and products, and the coefficients in the equation are used to write mole ratios relating reactants and products.

56. Stoichiometry is based on the law of conservation of mass. The calculations are used to determine the mass of reactants and products. Once found, the sum of reactants will equal the sum of products, verifying the law of conservation of mass.

57. Molar mass is a conversion factor for converting moles of a given substance to grams or for converting moles of a given substance to moles.

58. You must have the balanced chemical equation and know the quantity of one substance in the reaction other than the product you are determining.

59. a. 0.10 g Na₂CO₃, 0.40 g H₂O → 0.80 g NaHCO₃

b. Student sketches should show the formation of six water molecules (H₂O) and six sulfur atoms (S).

Mastering Problems

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69. C₆H₈O₄(ℓ) + 3O₂(ℓ) → 2CO₂(g) + 3H₂O(l); 191.0 g CO₂
70. Car Battery  Car batteries use lead, lead(IV) oxide, and a sulfuric acid solution to produce an electric current. The products of the reaction are lead(II) sulfate in solution and water.
   a. Write the balanced equation for the reaction.
   b. Determine the mass of lead(II) sulfate produced when 25.0 g of lead reacts with an excess of lead(IV) oxide and sulfuric acid.
   c. Determine the mass of gold in the ore.
   d. Determine the mass of gold in the ore.
   e. Determine the mass of gold in the ore.

71. To extract gold from the ore, the ore is treated with sodium cyanide solution in the presence of oxygen and water.
   a. Determine the mass of gold that can be extracted if 25.0 g of sodium cyanide is used.
   b. If the mass of the ore from which the gold was extracted is 150.0 g, what percentage of the ore is gold?

72. Film  Photographic film contains silver bromide in gelatin. Once exposed, some of the silver bromide decomposes, producing fine grains of silver. The unexposed silver bromide is removed by treating the film with sodium thiosulfate, soluble sodium silver thiosulfate (Na₂Ag(S₂O₃)₂) is produced.
   a. Write the balanced equation for the reaction.
   b. Determine the mass of Na₂Ag(S₂O₃)₂ produced if 0.275 g of AgBr is removed.

SECTION 3

Mastering Concepts

73. The actual mole ratio of reactants from the chemical equation is compared to the mole ratio determined from the given quantities. The limiting reactant is the reactant that produces the lowest number of moles of product. Mass does not determine the limiting reactant but the number of moles.

75. a. 3M₁ + N₁ → 2M₂N₂
    b. 6 moles of element M (in the form of 3 moles of M₁) and 6 moles of element N (likewise, 3 moles of N₂)
    c. 2 moles of M₂N₂ form with 2 moles of N₂, unreacted (4 total moles of element N)
    d. M₁ is the limiting reactant and N₂ is the excess reactant.

Mastering Problems

76. Hydrogen is limiting; ethylene is the excess reactant. One mol of ethylene is left over.
77. 4.0 mol Fe(OH)₃
78. 10.0 mol CsXeF₇
79. 1120 g Fe
80. Cl₂ is the limiting reactant; phosphorus is in excess.
81. a. MnO₂ is the limiting reactant.
    b. 17.1 g Zn(OH)₂
82. 2Li(s) + Br₂(l) → 2LiBr(s)
    a. Br₂
    b. 27.1 g LiBr
    c. Li, 22.8 g

75. Figure 12 uses squares to represent Element M and circles to represent Element N.
   a. Write the balanced equation for the reaction.
   b. If each square represents 1 mol of M and each circle represents 1 mol of N, how many moles of M and N were present at the start of the reaction?
   c. How many moles of product form? How many moles of Element M and Element N are unreacted?
   d. Identify the limiting reactant and the excess reactant.

SECTION 2

Mastering Problems

76. The reaction between ethyne (C₂H₂) and hydrogen (H₂) is illustrated in Figure 13. The product is excess reactant. Explain.

77. Nickel-Iron Battery  In 1901, Thomas Edison invented the nickel-iron battery. The following reaction takes place in the battery.
   Fe(s) + 2Ni(OH)₂(s) + 2H₂O(l) → Fe(OH)₃(s) + 2Ni(OH)₂(s)
   How many mol of Fe(OH)₃ is produced when 5.0 g of Fe and 8.0 mol of Ni(OH)₂ react?

78. One of the few xenon compounds that form is xenon heptahalide (CsXeF₇⁻). How many moles of CsXeF₇ can be produced from the reaction of 12.7 g of cesium fluoride with 10.0 mol of xenon heptahalide.
   CsF(s) + XeF₆(s) → CsXeF₇⁻

79. Iron Production  Iron is obtained commercially by reaction of hematite (Fe₂O₃) with carbon monoxide. How many grams of iron is produced when 30.0 mol of hematite reacts with 30.0 mol of carbon monoxide.
   Fe₂O₃(s) + 3CO(g) → 2Fe(s) + 3CO₂(g)

80. The reaction of chlorine gas with solid phosphorus produces solid phosphorus pentachloride. What is the limiting reactant of chlorine react 23.0 g of P₄, which reactant is in excess?

81. Alkaline Battery  An alkaline battery produces electrical energy according to this equation.
   Zn(s) + 2MnO₂(s) + H₂O(l) → Zn(OH)₂(s) + MnO₂(s)
   a. Determine the limiting reactant if 25.0 g of Zn is used.
   b. Determine the mass of Zn(OH)₂ produced.

82. Lithium reacts spontaneously with bromine to form lithium bromide. Write the balanced chemical equation for the reaction. If 25.0 g of lithium and 25.0 g of bromine are present at the beginning of the reaction determine.
   a. the limiting reactant.
   b. the mass of lithium bromide produced.
   c. the excess reactant and the excess mass.