8.9: Exercises

8.3: Stoichiometry and the Molar Interpretation

1. What are all the conversion factors that can be constructed from the balanced chemical reaction: $2\ S(s) + 3\ O_2(g) \rightarrow 2\ SO_3(g)$?

Answer

$$\frac{2\ \text{mol S}}{3\ \text{mol O}_2};\ \frac{3\ \text{mol O}_2}{2\ \text{mol S}};\ \frac{1\ \text{mol S}}{1\ \text{mol SO}_3};\ \frac{1\ \text{mol SO}_3}{1\ \text{mol S}};\ \frac{3\ \text{mol O}_2}{2\ \text{mol SO}_3};\ \frac{2\ \text{mol SO}_3}{3\ \text{mol O}_2}$$

2. Construct the three independent conversion factors possible for these two reactions:
   a. $2\ H_2 + O_2 \rightarrow 2\ H_2O$
   b. $H_2 + O_2 \rightarrow H_2O_2$

   Why are the ratios between H_2 and O_2 different?

Answer

The conversion factors are different because the stoichiometries of the balanced chemical reactions are different.

8.4: Molar Ratios and Mole-to-Mole Conversions

3. Given the chemical equation: $Na(s) + H_2O(l) \rightarrow NaOH(aq) + H_2(g)$
   a. Balance the equation.
   b. How many moles of H_2 are produced when 332 moles of Na react?

Answer

a. $2\ Na(s) + 2\ H_2O(l) \rightarrow 2\ NaOH(aq) + H_2(g)$
b. 166 mol H_2

4. Given the chemical equation: $S(s) + O_2(g) \rightarrow SO_3(g)$
   a. Balance the equation.
   b. How many moles of O_2 are needed when 38 moles of S react?

Answer

a. $2\ S(s) + 3\ O_2(g) \rightarrow 2\ SO_3(g)$
b. 57 mol O_2

5. For the balanced chemical equation:

$$6\ H^+(aq) + 2\ MnO_4^-(aq) + 5\ H_2O_2(l) \rightarrow 2\ Mn^{2+}(aq) + 5\ O_2(g) + 8\ H_2O(l)$$

   how many moles of H_2O are produced when 75 moles of H_2O_2 react?

Answer

120 mol H_2O

6. For the balanced chemical reaction:

$$2\ C_6H_6(l) + 15\ O_2(g) \rightarrow 12\ CO_2(g) + 6\ H_2O(l)$$

how many moles of CO_2 are produced when 56 moles of C_6H_6 react?

Answer

3.4×10^2 mol CO_2

7. For the balanced chemical equation:

$$Fe_2O_3 + 3\ SO_3 \rightarrow Fe_2(SO_4)_3$$

suppose we need to make 145 moles of $Fe_2(SO_4)_3$. How many moles of SO_3 do we need?

Answer

435 mol SO_3

8. One way to make sulfur hexafluoride is to react thioformaldehyde, CH_2S, with elemental fluorine:

$$CH_2S + 6\ F_2 \rightarrow CF_4 + 2\ HF + SF_6$$

If 45.8 moles of SF_6 are needed, how many moles of F_2 are required?

Answer

275 mol F_2

9. For the balanced chemical equation:

$$3\ Cu(s) + 2\ NO_3^-(aq) + 8\ H^+(aq) \rightarrow 3\ Cu^{2+}(aq) + 4\ H_2O(l) + 2\ NO(g)$$

how many moles of Cu^{2+} are formed when 55.7 mol of H^+ are reacted?

Answer

20.9 mol Cu^{2+}

10. For the balanced chemical equation:

$$Al(s) + 3\ Ag^+(aq) \rightarrow Al^{3+}(aq) + 3\ Ag(s)$$

how many moles of Ag are produced when 0.661 mol of Al are reacted?

Answer

1.98 mol Ag

11. For the balanced chemical reaction:

$$4\ NH_3(g) + 5\ O_2(g) \rightarrow 4\ NO(g) + 6\ H_2O(l)$$

how many moles of H_2O are produced when 0.669 mol of NH_3 react?

Answer

1.00 mol H_2O

12. For the balanced chemical reaction:

$$4\ NaOH(aq) + 2\ S(s) + 3\ O_2(g) \rightarrow 2\ Na_2SO_4(aq) + 2\ H_2O(l)$$

how many moles of Na_2SO_4 are formed when 1.22 mol of O_2 react?

Answer

0.813 mol Na_2SO_4

13. For the balanced chemical reaction:

$$4\ KO_2(s) + 2\ CO_2(g) \rightarrow 2\ K_2CO_3(s) + 3\ O_2(g)$$

determine the number of moles of both products formed when 6.88 mol of KO_2 react.

Answer

3.44 mol K_2CO_3; 5.16 mol O_2

14. For the balanced chemical reaction

$$2\ AlCl_3 + 3\ H_2O \rightarrow Al_2O_3 + 6\ HCl$$

determine the number of moles of both products formed when 0.0552 mol of $AlCl_3$ react.

Answer

0.0276 mol Al_2O_3; 0.166 mol HCl

8.5: Mass-to-Mass Conversions

15. What mass of CO_2 is produced by the combustion of 1.00 mol of CH_4?

$$CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$$

Answer

44.0 g CO_2

16. What mass of H_2O is produced by the combustion of 1.00 mol of CH_4?

$$CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(l)$$

Answer

36.0 g H_2O

17. What mass of HgO is required to produce 0.692 mol of O_2?

$$2\ HgO(s) \rightarrow 2\ Hg(l) + O_2(g)$$

Answer

3.00×10^2 g HgO

18. What mass of $NaHCO_3$ is needed to produce 2.659 mol of CO_2?

$$2\ NaHCO3(s) \rightarrow Na_2CO3(s) + H_2O(l) + CO_2(g)$$

Answer

446.8 g $NaHCO_3$

19. How many moles of Al can be produced from 10.87 g of Ag?

$Al(NO_3)_3(aq) + 3\ Ag(s) \rightarrow Al(s) + 3\ AgNO_3(aq)$

Answer

0.03359 mol Al

20. How many moles of HCl can be produced from 0.226 g of $SOCl_2$?

$SOCl_2(l) + H_2O(l) \rightarrow SO_2(g) + 2\ HCl(g)$

Answer

3.80×10^{-3} mol HCl

21. How many moles of O_2 are needed to prepare 1.00 g of $Ca(NO_3)_2$?

$Ca(s) + N_2(g) + 3\ O_2(g) \rightarrow Ca(NO_3)_2(s)$

Answer

0.0183 mol O_2

22. How many moles of C_2H_5OH are needed to generate 106.7 g of H_2O?

$C_2H_5OH(l) + 3\ O_2(g) \rightarrow 2\ CO_2(g) + 3\ H_2O(l)$

Answer

1.974 mol C_2H_5OH

23. What mass of O_2 can be generated by the decomposition of 100.0 g of $NaClO_3$?

$2\ NaClO_3(s) \rightarrow 2\ NaCl(s) + 3\ O_2(g)$

Answer

45.10 g O_2

24. What mass of Li_2O is needed to react with 1,060 g of CO_2?

$Li_2O(aq) + CO_2(g) \rightarrow Li_2CO_3(aq)$

Answer

7.20×10^2 g Li_2O

25. What mass of Fe_2O_3 must be reacted to generate 324 g of Al_2O_3?

$Fe_2O_3(s) + 2\ Al(s) \rightarrow 2\ Fe(s) + Al_2O_3(s)$

Answer

507 g Fe_2O_3

26. What mass of Fe is generated when 100.0 g of Al are reacted?

$Fe_2O_3(s) + 2\ Al(s) \rightarrow 2\ Fe(s) + Al_2O_3(s)$

Answer

207.0 g Fe

27. What mass of MnO_2 is produced when 445 g of H_2O are reacted?

$H_2O(l) + 2\ MnO_4^-(aq) + Br^-(aq) \rightarrow BrO_3^-(aq) + 2\ MnO_2(s) + 2\ OH^-(aq)$

Answer

4290 g MnO_2

28. What mass of $PbSO_4$ is produced when 29.6 g of H_2SO_4 are reacted?

$Pb(s) + PbO_2(s) + 2\ H_2SO_4(aq) \rightarrow 2\ PbSO_4(s) + 2\ H_2O(l)$

Answer

91.5 g $PbSO_4$

29. If 83.9 g of ZnO are formed, what mass of Mn_2O_3 is formed with it?

$Zn(s) + 2\ MnO_2(s) \rightarrow ZnO(s) + Mn_2O_3(s)$

Answer

163 g Mn_2O_3

30. If 14.7 g of NO_2 are reacted, what mass of H_2O is reacted with it?

$3\ NO_2(g) + H_2O(l) \rightarrow 2\ HNO_3(aq) + NO(g)$

Answer

1.92 g H_2O

31. If 88.4 g of CH_2S are reacted, what mass of HF is produced?

$CH_2S + 6\ F_2 \rightarrow CF_4 + 2\ HF + SF_6$

Answer

76.7 g HF

32. If 100.0 g of Cl_2 are needed, what mass of NaOCl must be reacted?

$NaOCl + HCl \rightarrow NaOH + Cl_2$

Answer

105.0 g NaOCl

33. Calculate the mass of each product when 100.0 g of CuCl react according to the reaction

$$2\ CuCl(aq) \rightarrow CuCl_2(aq) + Cu(s)$$

What do you notice about the sum of the masses of the products? What concept is being illustrated here?

Answer

67.90 g $CuCl_2$; 32.10 g Cu; the sum is 100.0 g; this agrees with the Law of Conservation of Mass

34. Calculate the mass of each product when 500.0 g of $SnCl_2$ react according to the reaction

$$2\ SnCl_2(aq) \rightarrow SnCl_4(aq) + Sn(s)$$

What do you notice about the sum of the masses of the products? What concept is being illustrated here?

Answer

343.5 g $SnCl_4$; 156.5 g Sn; the sum is 500.0 g; this agrees with the Law of Conservation of Mass

35. Write the balanced equation and then determine the number of moles and the mass of chlorine, Cl_2, required to react with 10.0 g of sodium metal, Na, to produce sodium chloride, NaCl.

Answer

$2\ Na + Cl_2 \rightarrow 2\ NaCl$; 0.217 mol Cl_2; 15.4 g Cl_2

36. Write the balanced equation and then determine the number of moles and the mass of oxygen formed by the decomposition of 1.252 g of mercury(II) oxide.

Answer

$2\ HgO \rightarrow 2\ Hg + O_2$; 2.851×10^{-3} mol O_2; 0.09122 g O_2

37. Write the balanced equation and then determine the number of moles and the mass of sodium nitrate, $NaNO_3$, required to produce 128 g of oxygen. ($NaNO_2$ is the other product.)

Answer

$2\ NaNO_3 \rightarrow O_2 + 2\ NaNO_2$; 8.00 mol $NaNO_3$; 6.80×10^2 g $NaNO_3$

38. Write the balanced equation and then determine the number of moles and the mass of carbon dioxide formed by the combustion of 20.0 g of carbon in an excess of oxygen.

Answer

$C + O_2 \rightarrow CO_2$; 1.67 mol CO_2; 73.3 g CO_2

39. Write the balanced equation and then determine the number of moles and the mass of Mg required to react with 5.00 g of HCl and produce $MgCl_2$ and H_2.

Answer

$Mg + 2\ HCl \rightarrow MgCl_2 + H_2$; 0.0686 mol Mg; 1.67 g Mg

40. Write the balanced equation and then determine the number of moles and the mass of oxygen formed by the decomposition of 1.252 g of silver(I) oxide.

Answer

$2\ Ag_2O \rightarrow O_2 + 4\ Ag$; 2.902×10^{-3} mol O_2; 0.09285 g O_2

41. Write the balanced equation and then determine the number of moles and the mass of water formed by the combustion of 20.0 g of acetylene, C_2H_2, in an excess of oxygen.

Answer

$2\ C_2H_2 + 5\ O_2 \rightarrow 4\ CO_2 + 2\ H_2O$; 0.768 g H_2O; 13.8 g H_2O

42. Write the balanced equation and then determine the number of moles and the mass of barium peroxide, BaO_2, needed to produce 2.500 g of barium oxide, BaO (O_2 is the other product.)

Answer

$2\ BaO_2 \rightarrow 2\ BaO + O_2$; 0.01630 mol BaO_2; 2.761 g BaO_2

43. I_2 is produced by the reaction of 0.4235 mol of $CuCl_2$ according to the following equation: $2\ CuCl_2 + 4\ KI \rightarrow 2\ CuI + 4\ KCl + I_2$
    a. How many moles of I_2 are produced?
    b. What mass of I_2 is produced?

Answer

a. 0.2118 mol I_2
b. 53.74 g I_2

44. Silver is often extracted from ores as $K[Ag(CN)_2]$ and then recovered by the reaction: $2\ K[Ag(CN)_2] + Zn \rightarrow 2\ Ag + Zn(CN)_2 + 2\ KCN$
    a. How many moles of $Zn(CN)_2$ are produced by the reaction of 35.27 g of $K[Ag(CN)_2]$?
    b. What mass of $Zn(CN)_2$ is produced?

Answer

a. 0.08861 mol $Zn(CN)_2$
b. 10.41 g $Zn(CN)_2$

8.6: Limiting Reactants and Excess Reactants

45. Given the statement “20.0 g of methane is burned in excess oxygen,” is it obvious which reactant is the limiting reactant?

Answer

Yes. If oxygen is in excess, the methane must be the limiting reactant.

46. Given the statement “the metal is heated in the presence of excess hydrogen,” is it obvious which substance is the limiting reactant despite not specifying any quantity of reactant?

Answer

Yes. If the hydrogen is in excess, the metal must be the limiting reactant.

47. Acetylene (C_2H_2) is formed by reacting 7.08 g of C and 4.92 g of H_2.

$$2\ C(s) + H_2(g) \rightarrow C_2H_2(g)$$

What is the limiting reactant? How many grams of C_2H_2 are produced?

Answer

Limiting reactant = C; 7.67 g C_2H_2

48. Ethane (C_2H_6) is formed by reacting 7.08 g of C and 4.92 g of H_2.

$$2\ C(s) + 3\ H_2(g) \rightarrow C_2H_6(g)$$

What is the limiting reactant? How many grams of C_2H_6 are produced?

Answer

Limiting reactant = C; 8.86 g C_2H_6

49. If 35.6 g of P_4O_6 is reacted with 4.77 g of H_2O, what is the limiting reactant, and what mass of H_3PO_3 is produced?

$$P_4O_6(s) + 6\ H_2O(l) \rightarrow 4\ H_3PO_3(aq)$$

Answer

Limiting reactant = H_2O; 14.5 g H_3PO_3

50. If 377 g of NO_2 is reacted with 244 g of H_2O, what is the limiting reactant, and how many grams of HNO_3 and NO are produced?

$$3\ NO_2(g) + H_2O(l) \rightarrow 2\ HNO_3(aq) + NO(g)$$

Answer

Limiting reactant = NO_2; 344 g HNO_3 and 82.0 g NO

51. To form the precipitate $PbCl_2$, 2.88 g of NaCl and 7.21 g of $Pb(NO3)_2$ are mixed in solution. How much precipitate is formed? How much of which reactant is in excess?

$$2\ NaCl(aq) + Pb(NO_3)_2(aq) \rightarrow PbCl_2(s) + 2\ NaNO_3(aq)$$

Answer

6.06 g $PbCl_2$ formed; 0.34 g excess NaCl

52. In a neutralization reaction, 18.06 g of KOH are reacted with 13.43 g of HNO_3. What mass of H_2O is produced, and what mass of which reactant is in excess?

$$KOH(aq) + HNO_3(aq) \rightarrow KNO_3(aq) + H_2O(l)$$

Answer

3.839 g H_2O formed; 6.10 g excess KOH

53. What is the limiting reactant in a reaction that produces sodium chloride from 8 g of sodium and 8 g of diatomic chlorine?

$$2\ Na(s) + Cl_2(g) \rightarrow 2\ NaCl(s)$$

Answer

Cl_2

54. What is the limiting reactant when 30.0 g of propane, C_3H_8, is burned with 75.0 g of oxygen.

$$C_3H_8(g) + 5\ O_2(g) \rightarrow 3\ CO_2(g) + 4\ H_2O(g)$$

Answer

O_2

55. What is the limiting reactant when 0.50 g of Cr and 0.75 g of H_3PO_4 react according to the following chemical equation?

$$2\ Cr(s) + 2\ H_3PO_4(aq) \rightarrow 2\ CrPO_4(s) + 3\ H_2(g)$$

Answer

H_3PO_4

56. What is the limiting reactant when 1.50 g of lithium and 1.50 g of nitrogen combine to form lithium nitride, a component of advanced batteries, according to the following *unbalanced* equation?

$$Li + N_2 \rightarrow Li_3N$$

Answer

Li

8.7: Theoretical Yield and Percent Yield

57. What is the difference between the theoretical yield and the actual yield?

Answer

Theoretical yield is what you expect stoichiometrically from a chemical reaction; actual yield is what you actually get from a chemical reaction.

58. What is the difference between the actual yield and the percent yield?

Answer

Actual yield is the measured amount of product obtained from a chemical reaction; percent yield is the ratio of the actual yield to the amount predicted from stoichiometry.

59. A worker isolates 2.675 g of SiF_4 after reacting 2.339 g of SiO_2 with HF. What are the theoretical yield and the actual yield?

$$SiO_2(s) + 4\ HF(g) \rightarrow SiF_4(g) + 2\ H_2O(l)$$

Answer

Theoretical yield = 4.052 g; actual yield = 2.675 g

60. A worker synthesizes aspirin, $C_9H_8O_4$, according to this chemical equation. If 12.66 g of $C_7H_6O_3$ are reacted and 12.03 g of aspirin are isolated, what are the theoretical yield and the actual yield?

$$C_7H_6O_3 + C_4H_6O_3 \rightarrow C_9H_8O_4 + HC_2H_3O_2$$

Answer

Theoretical yield = 16.51 g; actual yield = 12.03 g

61. A chemist decomposes 1.006 g of $NaHCO_3$ and obtains 0.0334 g of Na_2CO_3. What are the theoretical yield and the actual yield?

$$2\ NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(l) + CO_2(g)$$

Answer

Theoretical yield = 0.6346 g; actual yield = 0.0334 g

62. A chemist combusts a 3.009 g sample of C_5H_{12} and obtains 3.774 g of H_2O. What are the theoretical yield and the actual yield?

$$C_5H_{12}(l) + 8\ O_2(g) \rightarrow 5\ CO_2(g) + 6\ H_2O(l)$$

Answer

Theoretical yield = 4.508 g; actual yield = 3.774 g

63. What is the percent yield in Exercise 59?

Answer

66.02%

64. What is the percent yield in Exercise 60?

Answer

72.86%

65. What is the percent yield in Exercise 61?

Answer

5.26%

66. What is the percent yield in Exercise 62?

Answer

83.72%

67. A student isolated 25 g of a compound following a procedure that would theoretically yield 81 g. What was his percent yield?

Answer

31%

68. A sample of 0.53 g of carbon dioxide was obtained by heating 1.31 g of calcium carbonate. What is the percent yield for this reaction?

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

Answer

91%

69. The phosphorus pentoxide used to produce phosphoric acid for cola soft drinks is prepared by burning phosphorus in oxygen.
    a. What is the limiting reactant when 0.200 mol of P_4 and 0.200 mol of O_2 react according to the reaction: $P_4 + 5\ O_2 \rightarrow P_4O_{10}$?
    b. Calculate the percent yield if 10.0 g of P_4O_{10} is isolated from the reaction.

Answer

a. O_2
b. 87.7%