Sample Problems

1. 288 tricycles
   1 seat/bike = 288 seats;
   3 wheels/bike → 3 x 288 bikes = 864 wheels
   2 pedals/bike → 2 x 288 bikes = 576 pedals

2. Answers will vary but should include the correct number of "parts" to make the product.

FIGURE 12.2 10 molecules NH_3

3. 2 molecules H_2 + 1 molecule $O_2 \rightarrow$ 2 molecules H_2O

2 mol H_2 + 1 mol $O_2 \rightarrow$ 2 mol H_2O

44.8 L H_2 + 22.4 L $O_2 \rightarrow$ 44.8 L H_2O

4. C_2H_4 (g) + $3O_2$ (g) → $2CO_2$ (g) + $2H_2O$(g)

   1 mol + 3 mol → 2 mol + 2 mol

   22.4 L/mol + 3(22.4 L/mol) → 2(22.4 L/mol) + 2(22.4 L/mol)

   28 g/mol + 3 (32 g/mol) → 2(44 g/mol) + 2(18 g/mol)

   124 g → 124 g

Lesson Check Answers

5. as a basis to calculate how much reactant is needed or product is formed in a reaction

6. numbers of atoms, molecules, or moles; mass; and volumes

7. Both a balanced equation and a recipe give quantitative information about the starting and end materials.

8. mass and atoms

9. 2 atoms K + 2 molecules $H_2O \rightarrow$ 2 formula units KOH + 1 molecule H_2

2 mol K + 2 mol $H_2O \rightarrow$ 2 mol KOH + 1 mol H_2

78.2 g K + 36.0 g $H_2O \rightarrow$ 112.2 g KOH + 2.0 g H_2

10. $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$

46.0 g C_2H_5OH + 96.0 g $O_2 \rightarrow$ 88.0 g CO_2 + 54.0 g H_2O

142.0 g reactants → 142.0 g products

Sample Problems

11. a. $\frac{4 \text{ mol Al}}{3 \text{ mol } O_2}$ $\frac{3 \text{ mol } O_2}{4 \text{ mol Al}}$ $\frac{4 \text{ mol Al}}{2 \text{ mol } Al_2O_3}$

$\frac{2 \text{ mol } Al_2O_3}{4 \text{ mol Al}}$ $\frac{3 \text{ mol } O_2}{2 \text{ mol } Al_2O_3}$ $\frac{2 \text{ mol } Al_2O_3}{3 \text{ mol } O_2}$

11b. ? / 4 mol Al = 3.7 mol / 2 mol Al_2O_3 → 7.4 mol Al

12a. ? / 3 mol O_2 = 14.8 mol / 4 mol Al → 11.1 mol O_2

12b. ? / 2 mol Al_2O_3 = 0.78 mol / 3 mol O_2 → 0.52 mol Al_2O_3

FIGURE 12.4 No; the given could be a product.

13. 5.00 g CaC_2 x 1 mol / 64.1 g = 0.078 mol CaC_2
1:1 mol ratio $CaC_2 : C_2H_2$
0.078 mol C_2H_2 x 26.0 g / mol = 2.03 g C_2H_2

14. 49.0 g H_2O x 1 mol / 18.0 g = 2.72 mol H_2O
1:2 mol ratio $CaC_2 : H_2O$
2.72 mol / 2 = 1.36 mol CaC_2

Figure 12.5 6.02×10^{23} representative molecules / 1 mol

15. 6.54 g $KClO_3$ x 1 mol / 122.6 g = 0.0533 mol KCO_3
2:3 mol ratio $KClO_3 : O_2$
0.0533 mol / 2 mol = X mol / 3 mol → 0.0800 mol O_2
0.0800 mol O_2 x 6.02×10^{23} molecules/mol = 4.82×10^{22} molecules

16. 5.00×10^{22} molecules NO x 1 mol / 6.02×10^{23} molecules = 0.083 mol NO
3:1 mol ratio NO_2 : NO
0.083 mol NO x 3 mol NO_2 = 0.249 mol NO_2
0.249 mol NO_2 x 46.0 g/mol = 11.5 g NO_2

17. 3.86 L CO x 1 mol / 22.4 L = 0.172 mol CO
2:1 mol ratio CO : O_2
0.172 mol CO / 2 mol = 0.086 mol O_2 x 22.4 L/mol = 1.93 L O_2

18. $0.42\ L\ H_2 \times 1\ mol / 22.4\ L = 0.0187\ mol\ H_2$
$6:4$ mol ratio $H_2 : PH_3$
$0.0187\ mol\ CO / 6\ mol\ H_2 = ? / 4\ mol\ PH_3 = 0.125\ mol\ PH_3$
$0.125\ mol\ PH_3 \times 22.4\ L/mol = 0.28\ L\ PH_3$

19. $27.9\ ml \times 1\ L / 10^3\ ml = 0.0279\ L$
$0.0279\ L\ H_2 \times 1\ mol / 22.4\ L = 1.25 \times 10^{-3}\ mol\ O_2$
$3:2$ mol ratio $O_2 : SO_2$
$1.25 \times 10^{-3}\ mol / 3\ mol\ O_2 = ? / 2\ mol\ SO_2 = 8.33 \times 10^{-4}\ mol\ SO_2$
$8.33 \times 10^{-4}\ mol\ SO_2 \times 22.4\ L/mol = 0.0186\ L\ SO_2$
$0.0186\ mL\ SO_2 \times 1\ L / 10^3\ ml = 18.6\ ml$

20. $0.38\ L\ SO_2 \times 1\ mol / 22.4\ L = 1.70 \times 10^{-3}\ mol\ SO_2$
$1:2$ mol ratio $CO_2 : SO_2$
$1.70 \times 10^{-3}\ mol\ SO_2 / 2\ mol\ CO_2 = 8.48 \times 10^{-4}\ mol\ CO_2$
$8.48 \times 10^{-4}\ mol\ CO_2 \times 22.4\ L/mol = 0.190\ L\ CO_2$
$0.190\ L\ CO_2 \times 10^1\ dl / 1\ L = 1.9\ dl\ CO_2$

Lesson Check Answers

21. Mole ratios are written using the coefficients from a balanced chemical equation. They are used to relate moles of reactants and products in stoichiometric calculations.

22. Convert the given quantity to moles; use the mole ratio from the equations to find the moles of the wanted; convert moles of wanted to the desired unit.

23. **a.** 176 g CO_2, 36.0 g H_2O **b.** 2.46 mol H_2O

24. $\frac{2\ mol\ C_3H_7OH}{9\ mol\ O_2}$ $\frac{2\ mol\ C_3H_7OH}{6\ mol\ CO_2}$ $\frac{2\ mol\ C_3H_7OH}{8\ mol\ H_2O}$ $\frac{9\ mol\ O_2}{6\ mol\ CO_2}$ $\frac{9\ mol\ O_2}{8\ mol\ H_2O}$ $\frac{6\ mol\ CO_2}{8\ mol\ H_2O}$

$\frac{9\ mol\ O_2}{2\ mol\ C_3H_7OH}$ $\frac{6\ mol\ CO_2}{2\ mol\ C_3H_7OH}$ $\frac{8\ mol\ H_2O}{2\ mol\ C_3H_7OH}$ $\frac{6\ mol\ CO_2}{9\ mol\ O_2}$ $\frac{8\ mol\ H_2O}{9\ mol\ O_2}$ $\frac{8\ mol\ H_2O}{6\ mol\ CO_2}$

25. A chemical reaction's mole ratios are derived from the relationships between coefficients in a balanced chemical equation.

Sample Problems

26. 1:3 mol ratio C_2H_2 : O_2
2.70 mol C_2H_2 x 3 mol O_2 = 8.1 mol O_2 are needed to react with C_2H_2, but you only have 6.30 mol O_2. Therefore, O_2 is the limiting reagent.

27. 5.00 g Mg x 1 mol / 24.3 g = 0.206 mol Mg available to react
6.00 g HCl x 1 mol / 36.5 g = 0.164 mol HCl available to react
1:2 mol ratio Mg : HCl
0.206 mol Mg x 2 mol HCl = 0.412 HCl are needed to react with Mg, but you only have 0.164 mol HCl. Therefore, HCl is the limiting reagent.

28a. 1:2 mol ratio C_2H_4 : O_2
2.70 mol C_2H_2 x 2 mol O_2 = 5.40 mol O_2 are needed to react with C_2H_4
Since you have 6.30 mol O_2 (extra amount), C_2H_4 is the limiting reagent.

28b. Use the limiting reagent to calculate the amount of product
1:2 mol ratio C_2H_4 : H_2O
2.70 mol C_2H_2 x 2 mol H_2O = 5.40 mol H_2O are produced
5.40 mol H_2O x 18 g/mol = 97.2 g H_2O

29. 2:5 mol ratio C_2H_2 : O_2
2.40 mol C_2H_2 / 2 mol C_2H_2 = ? / 5 mol O_2 = 6 mol O_2 are needed to react with C_2H_2. Since you have 7.40 mol O_2 (extra amount), C_2H_2 is the limiting reagent.
2:2 mol ratio C_2H_2 : H_2O
2.40 mol C_2H_2 = 2.40 mol H_2O are produced
2.40 mol H_2O x 18 g/mol = 43.2 g H_2O

30. Theoretical yield assumes that all the reactants react completely to produce as much product as possible.
84.8 g Fe_2O_3 x 1 mol / 159.6 g = 0.531 mol Fe_2O_3
1:2 mol ratio Fe_2O_3 : Fe
0.531 mol Fe_2O_3 x 2 mol Fe = 1.063 mol Fe
1.063 mol Fe x 55.8 g/mol = 59.3 g Fe

31. You need the balanced chemical reaction first:
$Cu + 2AgNO_3 \rightarrow Cu(NO_3)_2 + 2Ag$
Theoretical yield assumes that all the reactants react completely to produce as much product as possible.
5.00 g Cu x 1 mol / 63.5 g = 0.0787 mol Cu
1:2 mol ratio Cu : Ag
0.0787 mol Cu x 2 mol Ag = 0.1575 mol Ag
0.1575 mol Ag x 107.9 g/mol = 17.0 g Ag

32. You must determine the theoretical yield based on the balanced chemical reaction: $SiO_{2(s)} + 3C_{(s)} \rightarrow SiC_{(s)} + 2CO_{(g)}$
50.0 g $SiO_{2(s)}$ x 1 mol / 60.1 g = 0.832 mol $SiO_{2(s)}$
Since there is an excess of carbon, we use as the $SiO_{2(s)}$ limiting reactant.
1:1 mol ratio $SiO_{2(s)}$: $SiC_{(s)}$
0.832 mol $SiC_{(s)}$ x 40.1 g/mol = 33.4 g → theoretical yield
27.9 g / 33.4 g x 100% = 83.5% yield

33. You must determine the theoretical yield based on the balanced chemical reaction: $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$
Find Moles based on Actual:
H_2 15.0 g x 1 mol/2.00 g = 7.50 mol
N_2 15.0 g x 1 mol/28.0 g = 0.536 mol
Mol ratio of $N_2(g)$: $3H_2(g)$ = 1:3, meaning that nitrogen is the limiting reactant (0.536 mol/1 mol = X/3 mol = 1.61 mol $3H_2(g)$ is needed, but we have much more than that available.
Mol ratio of $N_2(g)$: $NH_3(g)$ = 1:2
… 0.536 mol/1 mol = X/2 mol = 1.07 mol $NH_3(g)$
1.07 mol $NH_3(g)$ x 17.0 g/mol = 18.2 g → theoretical yield
10.5 g / 18.2 g x 100% = 57.7% yield

Lesson Check Answers

34. In a chemical reaction, an insufficient quantity of any of the reactants will limit the amount of product that forms.

35. The efficiency of a reaction carried out in a laboratory can be measured by calculating the percent yield.

36. A limiting reagent is a reagent that determines how much product can be formed in a reaction. An excess reagent is a reactant that is not completely used up in a reaction.

37. 26.7 g SO_3

38. 70.5%