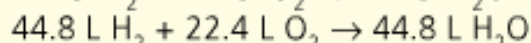
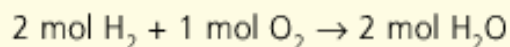
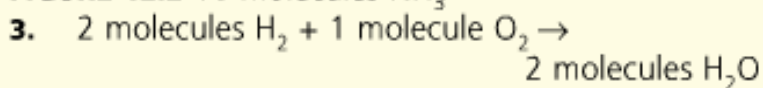


## Sample Problems

- 288 tricycles  
1 seat/bike = 288 seats;  
3 wheels/bike  $\rightarrow$  3 x 288 bikes = 864 wheels  
2 pedals/bike  $\rightarrow$  2 x 288 bikes = 576 pedals

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

**FIGURE 12.2** 10 molecules  $\text{NH}_3$

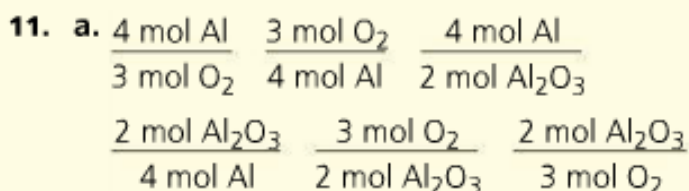


- $\text{C}_2\text{H}_4(\text{g}) + 3\text{O}_2(\text{g}) \rightarrow 2\text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{g})$   
 1 mol + 3 mol  $\rightarrow$  2 mol + 2 mol  
 $22.4 \text{ L/mol} + 3(22.4 \text{ L/mol}) \rightarrow 2(22.4 \text{ L/mol}) + 2(22.4 \text{ L/mol})$   
 $28 \text{ g/mol} + 3(32 \text{ g/mol}) \rightarrow 2(44 \text{ g/mol}) + 2(18 \text{ g/mol})$   
 $124 \text{ g} \rightarrow 124 \text{ g}$

## Lesson Check Answers

- as a basis to calculate how much reactant is needed or product is formed in a reaction
- numbers of atoms, molecules, or moles; mass; and volumes
- Both a balanced equation and a recipe give quantitative information about the starting and end materials.
- mass and atoms
- $2 \text{ atoms K} + 2 \text{ molecules } \text{H}_2\text{O} \rightarrow 2 \text{ formula units KOH} + 1 \text{ molecule } \text{H}_2$   
 $2 \text{ mol K} + 2 \text{ mol } \text{H}_2\text{O} \rightarrow 2 \text{ mol KOH} + 1 \text{ mol } \text{H}_2$   
 $78.2 \text{ g K} + 36.0 \text{ g } \text{H}_2\text{O} \rightarrow 112.2 \text{ g KOH} + 2.0 \text{ g } \text{H}_2$
- $\text{C}_2\text{H}_5\text{OH} + 3\text{O}_2 \rightarrow 2\text{CO}_2 + 3\text{H}_2\text{O}$   
 $46.0 \text{ g } \text{C}_2\text{H}_5\text{OH} + 96.0 \text{ g } \text{O}_2 \rightarrow 88.0 \text{ g } \text{CO}_2 + 54.0 \text{ g } \text{H}_2\text{O}$   
 $142.0 \text{ g reactants} \rightarrow 142.0 \text{ g products}$

## Sample Problems



$$11\text{b. } ? / 4 \text{ mol Al} = 3.7 \text{ mol} / 2 \text{ mol Al}_2\text{O}_3 \rightarrow 7.4 \text{ mol Al}$$

$$12\text{a. } ? / 3 \text{ mol O}_2 = 14.8 \text{ mol} / 4 \text{ mol Al} \rightarrow 11.1 \text{ mol O}_2$$

$$12\text{b. } ? / 2 \text{ mol Al}_2\text{O}_3 = 0.78 \text{ mol} / 3 \text{ mol O}_2 \rightarrow 0.52 \text{ mol Al}_2\text{O}_3$$

**FIGURE 12.4** No; the given could be a product.

$$13. \quad 5.00 \text{ g CaC}_2 \times 1 \text{ mol} / 64.1 \text{ g} = 0.078 \text{ mol CaC}_2$$

1:1 mol ratio  $\text{CaC}_2 : \text{C}_2\text{H}_2$

$$0.078 \text{ mol C}_2\text{H}_2 \times 26.0 \text{ g/mol} = 2.03 \text{ g C}_2\text{H}_2$$

$$14. \quad 49.0 \text{ g H}_2\text{O} \times 1 \text{ mol} / 18.0 \text{ g} = 2.72 \text{ mol H}_2\text{O}$$

1:2 mol ratio  $\text{CaC}_2 : \text{H}_2\text{O}$

$$2.72 \text{ mol} / 2 = 1.36 \text{ mol CaC}_2$$

**Figure 12.5**  $6.02 \times 10^{23}$  representative molecules / 1 mol

$$15. \quad 6.54 \text{ g KClO}_3 \times 1 \text{ mol} / 122.6 \text{ g} = 0.0533 \text{ mol KClO}_3$$

2:3 mol ratio  $\text{KClO}_3 : \text{O}_2$

$$0.0533 \text{ mol} / 2 \text{ mol} = X \text{ mol} / 3 \text{ mol} \rightarrow 0.0800 \text{ mol O}_2$$

$$0.0800 \text{ mol O}_2 \times 6.02 \times 10^{23} \text{ molecules/mol} = 4.82 \times 10^{22} \text{ molecules}$$

$$16. \quad 5.00 \times 10^{22} \text{ molecules NO} \times 1 \text{ mol} / 6.02 \times 10^{23} \text{ molecules} = 0.083 \text{ mol NO}$$

3:1 mol ratio  $\text{NO}_2 : \text{NO}$

$$0.083 \text{ mol NO} \times 3 \text{ mol NO}_2 = 0.249 \text{ mol NO}_2$$

$$0.249 \text{ mol NO}_2 \times 46.0 \text{ g/mol} = 11.5 \text{ g NO}_2$$

$$17. \quad 3.86 \text{ L CO} \times 1 \text{ mol} / 22.4 \text{ L} = 0.172 \text{ mol CO}$$

2:1 mol ratio  $\text{CO} : \text{O}_2$

$$0.172 \text{ mol CO} / 2 \text{ mol} = 0.086 \text{ mol O}_2 \times 22.4 \text{ L/mol} = 1.93 \text{ L O}_2$$

18.  $0.42 \text{ L H}_2 \times 1 \text{ mol} / 22.4 \text{ L} = 0.0187 \text{ mol H}_2$   
 6:4 mol ratio  $\text{H}_2 : \text{PH}_3$   
 $0.0187 \text{ mol CO} / 6 \text{ mol H}_2 = ? / 4 \text{ mol PH}_3 = 0.125 \text{ mol PH}_3$   
 $0.125 \text{ mol PH}_3 \times 22.4 \text{ L/mol} = 0.28 \text{ L PH}_3$
19.  $27.9 \text{ ml} \times 1 \text{ L} / 10^3 \text{ ml} = 0.0279 \text{ L}$   
 $0.0279 \text{ L H}_2 \times 1 \text{ mol} / 22.4 \text{ L} = 1.25 \times 10^{-3} \text{ mol O}_2$   
 3:2 mol ratio  $\text{O}_2 : \text{SO}_2$   
 $1.25 \times 10^{-3} \text{ mol} / 3 \text{ mol O}_2 = ? / 2 \text{ mol SO}_2 = 8.33 \times 10^{-4} \text{ mol SO}_2$   
 $8.33 \times 10^{-4} \text{ mol SO}_2 \times 22.4 \text{ L/mol} = 0.0186 \text{ L SO}_2$   
 $0.0186 \text{ mL SO}_2 \times 1 \text{ L} / 10^3 \text{ ml} = 18.6 \text{ ml}$
20.  $0.38 \text{ L SO}_2 \times 1 \text{ mol} / 22.4 \text{ L} = 1.70 \times 10^{-3} \text{ mol SO}_2$   
 1:2 mol ratio  $\text{CO}_2 : \text{SO}_2$   
 $1.70 \times 10^{-3} \text{ mol SO}_2 / 2 \text{ mol CO}_2 = 8.48 \times 10^{-4} \text{ mol CO}_2$   
 $8.48 \times 10^{-4} \text{ mol CO}_2 \times 22.4 \text{ L/mol} = 0.190 \text{ L CO}_2$   
 $0.190 \text{ L CO}_2 \times 10^1 \text{ dl} / 1 \text{ L} = 1.9 \text{ dl CO}_2$

### 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  $\text{CO}_2$ , 36.0 g  $\text{H}_2\text{O}$     **b.** 2.46 mol  $\text{H}_2\text{O}$
24.  $\frac{2 \text{ mol C}_3\text{H}_7\text{OH}}{9 \text{ mol O}_2} \frac{2 \text{ mol C}_3\text{H}_7\text{OH}}{6 \text{ mol CO}_2} \frac{2 \text{ mol C}_3\text{H}_7\text{OH}}{8 \text{ mol H}_2\text{O}} \frac{9 \text{ mol O}_2}{6 \text{ mol CO}_2} \frac{9 \text{ mol O}_2}{8 \text{ mol H}_2\text{O}} \frac{6 \text{ mol CO}_2}{8 \text{ mol H}_2\text{O}}$   
 $\frac{9 \text{ mol O}_2}{2 \text{ mol C}_3\text{H}_7\text{OH}} \frac{6 \text{ mol CO}_2}{2 \text{ mol C}_3\text{H}_7\text{OH}} \frac{8 \text{ mol H}_2\text{O}}{2 \text{ mol C}_3\text{H}_7\text{OH}} \frac{6 \text{ mol CO}_2}{9 \text{ mol O}_2} \frac{8 \text{ mol H}_2\text{O}}{9 \text{ mol O}_2} \frac{8 \text{ mol H}_2\text{O}}{6 \text{ mol CO}_2}$
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  $C_2H_2 : O_2$   
 $2.70 \text{ mol } C_2H_2 \times 3 \text{ mol } O_2 = 8.1 \text{ mol } O_2$  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.  $5.00 \text{ g Mg} \times 1 \text{ mol} / 24.3 \text{ g} = 0.206 \text{ mol Mg}$  available to react  
 $6.00 \text{ g HCl} \times 1 \text{ mol} / 36.5 \text{ g} = 0.164 \text{ mol HCl}$  available to react  
1:2 mol ratio  $Mg : HCl$   
 $0.206 \text{ mol Mg} \times 2 \text{ mol HCl} = 0.412 \text{ mol HCl}$  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  $C_2H_4 : O_2$   
 $2.70 \text{ mol } C_2H_4 \times 2 \text{ mol } O_2 = 5.40 \text{ mol } O_2$  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  $C_2H_4 : H_2O$   
 $2.70 \text{ mol } C_2H_4 \times 2 \text{ mol } H_2O = 5.40 \text{ mol } H_2O$  are produced  
 $5.40 \text{ mol } H_2O \times 18 \text{ g/mol} = 97.2 \text{ g } H_2O$
29. 2:5 mol ratio  $C_2H_2 : O_2$   
 $2.40 \text{ mol } C_2H_2 / 2 \text{ mol } C_2H_2 = ? / 5 \text{ mol } O_2 = 6 \text{ mol } O_2$  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  $C_2H_2 : H_2O$   
 $2.40 \text{ mol } C_2H_2 = 2.40 \text{ mol } H_2O$  are produced  
 $2.40 \text{ mol } H_2O \times 18 \text{ g/mol} = 43.2 \text{ g } H_2O$
30. Theoretical yield assumes that all the reactants react completely to produce  
as much product as possible.  
 $84.8 \text{ g } Fe_2O_3 \times 1 \text{ mol} / 159.6 \text{ g} = 0.531 \text{ mol } Fe_2O_3$   
1:2 mol ratio  $Fe_2O_3 : Fe$   
 $0.531 \text{ mol } Fe_2O_3 \times 2 \text{ mol Fe} = 1.063 \text{ mol Fe}$   
 $1.063 \text{ mol Fe} \times 55.8 \text{ g/mol} = 59.3 \text{ g Fe}$

31. You need the balanced chemical reaction first:  
 $\text{Cu} + 2\text{AgNO}_3 \rightarrow \text{Cu}(\text{NO}_3)_2 + 2\text{Ag}$   
Theoretical yield assumes that all the reactants react completely to produce as much product as possible.  
 $5.00 \text{ g Cu} \times 1 \text{ mol} / 63.5 \text{ g} = 0.0787 \text{ mol Cu}$   
1:2 mol ratio Cu : Ag  
 $0.0787 \text{ mol Cu} \times 2 \text{ mol Ag} = 0.1575 \text{ mol Ag}$   
 $0.1575 \text{ mol Ag} \times 107.9 \text{ g/mol} = 17.0 \text{ g Ag}$
32. You must determine the theoretical yield based on the balanced chemical reaction:  $\text{SiO}_{2(s)} + 3\text{C}_{(s)} \rightarrow \text{SiC}_{(s)} + 2\text{CO}_{(g)}$   
 $50.0 \text{ g SiO}_{2(s)} \times 1 \text{ mol} / 60.1 \text{ g} = 0.832 \text{ mol SiO}_{2(s)}$   
Since there is an excess of carbon, we use as the  $\text{SiO}_{2(s)}$  limiting reactant.  
1:1 mol ratio  $\text{SiO}_{2(s)} : \text{SiC}_{(s)}$   
 $0.832 \text{ mol SiC}_{(s)} \times 40.1 \text{ g/mol} = 33.4 \text{ g} \rightarrow$  theoretical yield  
 $27.9 \text{ g} / 33.4 \text{ g} \times 100\% = 83.5\% \text{ yield}$
33. You must determine the theoretical yield based on the balanced chemical reaction:  $\text{N}_2(g) + 3\text{H}_2(g) \rightarrow 2\text{NH}_3(g)$   
Find Moles based on Actual:  
 $\text{H}_2 \quad 15.0 \text{ g} \times 1 \text{ mol} / 2.00 \text{ g} = 7.50 \text{ mol}$   
 $\text{N}_2 \quad 15.0 \text{ g} \times 1 \text{ mol} / 28.0 \text{ g} = 0.536 \text{ mol}$   
Mol ratio of  $\text{N}_2(g) : 3\text{H}_2(g) = 1:3$ , meaning that nitrogen is the limiting reactant ( $0.536 \text{ mol} / 1 \text{ mol} = X / 3 \text{ mol} = 1.61 \text{ mol } 3\text{H}_2(g)$  is needed, but we have much more than that available.  
Mol ratio of  $\text{N}_2(g) : \text{NH}_3(g) = 1:2$   
...  $0.536 \text{ mol} / 1 \text{ mol} = X / 2 \text{ mol} = 1.07 \text{ mol NH}_3(g)$   
 $1.07 \text{ mol NH}_3(g) \times 17.0 \text{ g/mol} = 18.2 \text{ g} \rightarrow$  theoretical yield  
 $10.5 \text{ g} / 18.2 \text{ g} \times 100\% = 57.7\% \text{ yield}$

**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  $\text{SO}_3$
- 38.** 70.5%