

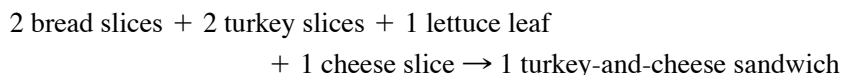
**CHEMFILE MINI-GUIDE TO PROBLEM SOLVING**

## *Stoichiometry*

So far in your chemistry course, you have learned that chemists count quantities of elements and compounds in terms of moles and that they relate moles of a substance to mass by using the molar mass. In addition, you have learned to write chemical equations so that they represent the rearrangements of atoms that take place during chemical reactions, and you have learned to balance these equations. In this chapter you will be able to put these separate skills together to accomplish one of the most important tasks of chemistry — using chemical equations to make predictions about the quantities of substances that react or are given off as products and relating those quantities to one another. This process of relating quantities of reactants and products in a chemical reaction to one another is called *stoichiometry*.

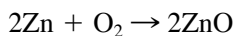
First, look at an analogy.

Suppose you need to make several sandwiches to take on a picnic with friends. You decide to make turkey-and-cheese sandwiches using the following “equation:”

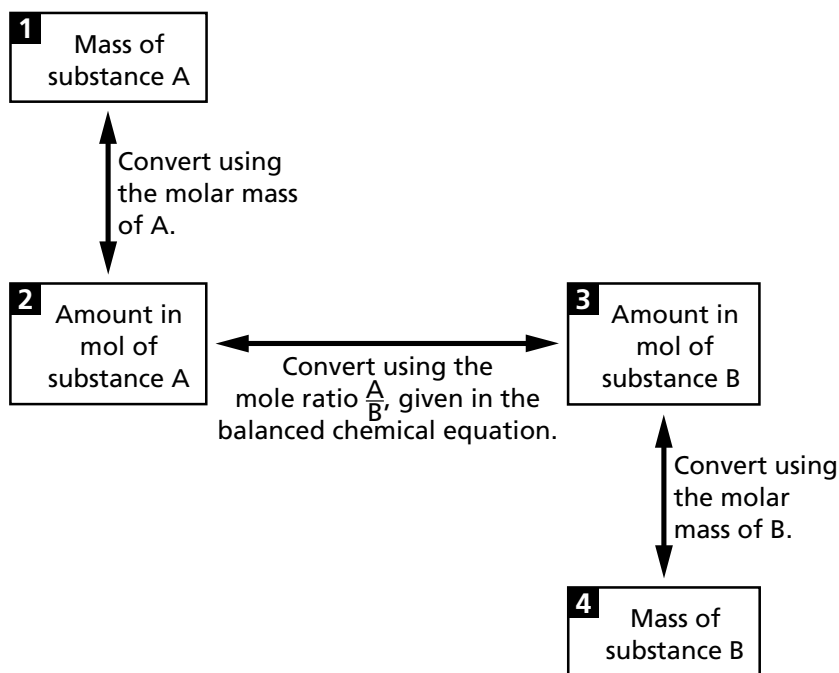


This equation shows that you need those ingredients in a ratio of 2:2:1:1, respectively. You can use this equation to predict that you would need 30 turkey slices to make 15 sandwiches or 6 cheese slices to go with 12 turkey slices.

Zinc reacts with oxygen according to the following balanced chemical equation:



Like the sandwich recipe, this equation can be viewed as a “recipe” for zinc oxide. It tells you that reacting two zinc atoms with a molecule of oxygen will produce two formula units of zinc oxide. Can you predict how many zinc oxide units could be formed from 500 zinc atoms? Could you determine how many moles of oxygen molecules it would take to react with 4 mol of zinc atoms? What if you had 22 g of zinc and wanted to know how many grams of ZnO could be made from it? Keep in mind that the chemical equation relates amounts, not masses, of products and reactants. The problems in this chapter will show you how to solve problems of this kind.

**CHEMFILE MINI-GUIDE TO PROBLEM SOLVING****General Plan for Solving Stoichiometry Problems****SAMPLE PROBLEM 1**

Ammonia is made industrially by reacting nitrogen and hydrogen under pressure, at high temperature, and in the presence of a catalyst. The equation is  $\text{N}_2(g) + 3\text{H}_2(g) \rightarrow 2\text{NH}_3(g)$ . If 4.0 mol of  $\text{H}_2$  react, how many moles of  $\text{NH}_3$  will be produced?

**SOLUTION****1. ANALYZE**

- *What is given in the problem?* the balanced equation, and the amount of  $\text{H}_2$  in moles
- *What are you asked to find?* the amount of  $\text{NH}_3$  produced in moles

Organization of data is extremely important in dealing with stoichiometry problems. You will find that it is most helpful to make data tables such as the following one.

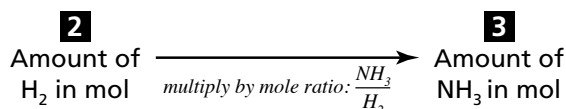
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Items	Data	
Substance	H <sub>2</sub>	NH <sub>3</sub>
Coefficient in balanced equation	3	2
Molar mass	NA*	NA
Amount	4.0 mol	? mol
Mass of substance	NA	NA

\* NA means not applicable to the problem

**2. PLAN**

- What steps are needed to calculate the amount of NH<sub>3</sub> that can be produced from 4.0 mol H<sub>2</sub>?  
Multiply by the mole ratio of NH<sub>3</sub> to H<sub>2</sub> determined from the coefficients of the balanced equation.



$$\text{given mol H}_2 \times \frac{\text{mole ratio } 2 \text{ mol NH}_3}{3 \text{ mol H}_2} = \text{mol NH}_3$$

**3. COMPUTE**

$$4.0 \text{ mol H}_2 \times \frac{2 \text{ mol NH}_3}{3 \text{ mol H}_2} = 2.7 \text{ mol NH}_3$$

**4. EVALUATE**

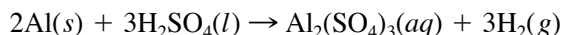
- Are the units correct? Yes; the answer has the correct units of moles NH<sub>3</sub>.
- Is the number of significant figures correct? Yes; two significant figures is correct because data were given to two significant figures.
- Is the answer reasonable? Yes; the answer is 2/3 of 4.0.

**PRACTICE**

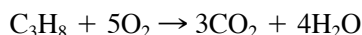
- How many moles of sodium will react with water to produce 4.0 mol of hydrogen in the following reaction?  
 $2\text{Na}(s) + 2\text{H}_2\text{O}(l) \rightarrow 2\text{NaOH}(aq) + \text{H}_2(g)$     *ans:* 8.0 mol Na
- How many moles of lithium chloride will be formed by the reaction of chlorine with 0.046 mol of lithium bromide in the following reaction?  
 $2\text{LiBr}(aq) + \text{Cl}_2(g) \rightarrow 2\text{LiCl}(aq) + \text{Br}_2(l)$     *ans:* 0.046 mol LiCl

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3. Aluminum will react with sulfuric acid in the following reaction.



- a. How many moles of  $\text{H}_2\text{SO}_4$  will react with 18 mol Al? *ans:* 27 mol  $\text{H}_2\text{SO}_4$
- b. How many moles of each product will be produced? *ans:* 27 mol  $\text{H}_2$   
9 mol  $\text{Al}_2(\text{SO}_4)_3$
4. Propane burns in excess oxygen according to the following reaction.



- a. How many moles each of  $\text{CO}_2$  and  $\text{H}_2\text{O}$  are formed from 3.85 mol of propane? *ans:* 11.6 mol  $\text{CO}_2$   
15.4 mol  $\text{H}_2\text{O}$
- b. If 0.647 mol of oxygen are used in the burning of propane, how many moles each of  $\text{CO}_2$  and  $\text{H}_2\text{O}$  are produced? How many moles of  $\text{C}_3\text{H}_8$  are consumed? *ans:* 0.388 mol  $\text{CO}_2$   
0.518 mol  $\text{H}_2\text{O}$   
0.129 mol  $\text{C}_3\text{H}_8$

**SAMPLE PROBLEM 2**

Potassium chlorate is sometimes decomposed in the laboratory to generate oxygen. The reaction is  $2\text{KClO}_3(s) \rightarrow 2\text{KCl}(s) + 3\text{O}_2(g)$ . What mass of  $\text{KClO}_3$  do you need to produce 0.50 mol  $\text{O}_2$ ?

**SOLUTION****1. ANALYZE**

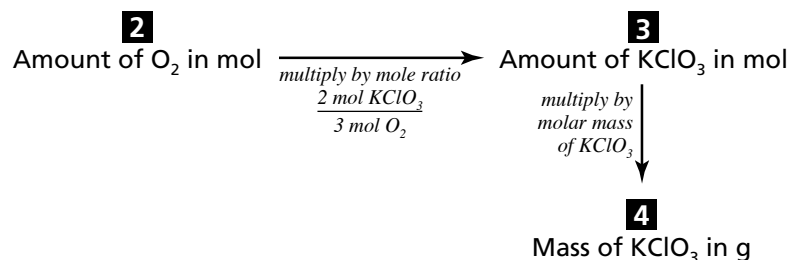
- What is given in the problem? the amount of oxygen in moles
- What are you asked to find? the mass of potassium chlorate

Items	Data	
Substance	$\text{KClO}_3$	$\text{O}_2$
Coefficient in balanced equation	2	3
Molar mass*	122.55 g/mol	NA
Amount	? mol	0.50 mol
Mass	? g	NA

\* determined from the periodic table

**2. PLAN**

- What steps are needed to calculate the mass of  $\text{KClO}_3$  needed to produce 0.50 mol  $\text{O}_2$ ? Use the mole ratio to convert amount of  $\text{O}_2$  to amount of  $\text{KClO}_3$ . Then convert amount of  $\text{KClO}_3$  to mass of  $\text{KClO}_3$ .

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$$\text{given mol O}_2 \times \frac{\text{mole ratio } 2 \text{ mol KClO}_3}{3 \text{ mol O}_2} \times \frac{\text{molar mass KClO}_3}{1 \text{ mol KClO}_3} = \text{g KClO}_3$$

**3. COMPUTE**

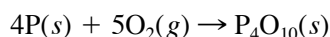
$$0.50 \text{ mol O}_2 \times \frac{2 \text{ mol KClO}_3}{3 \text{ mol O}_2} \times \frac{122.55 \text{ g KClO}_3}{1 \text{ mol KClO}_3} = 41 \text{ g KClO}_3$$

**4. EVALUATE**

- *Are the units correct?* Yes; units canceled to give grams of KClO<sub>3</sub>.
- *Is the number of significant figures correct?* Yes; two significant figures is correct.
- *Is the answer reasonable?* Yes; 41 g is about 1/3 of the molar mass of KClO<sub>3</sub>, and  $0.5 \times 2/3 = 1/3$ .

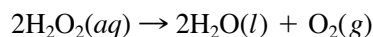
**PRACTICE**

1. Phosphorus burns in air to produce a phosphorus oxide in the following reaction:



- a. What mass of phosphorus will be needed to produce 3.25 mol of P<sub>4</sub>O<sub>10</sub>? ans: 403 g P
- b. If 0.489 mol of phosphorus burns, what mass of oxygen is used? What mass of P<sub>4</sub>O<sub>10</sub> is produced? ans: 19.6 g O<sub>2</sub>  
15.4 g P<sub>2</sub>O<sub>4</sub>

2. Hydrogen peroxide breaks down, releasing oxygen, in the following reaction:



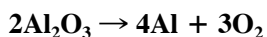
- a. What mass of oxygen is produced when 1.840 mol of H<sub>2</sub>O<sub>2</sub> decompose? ans: 29.44 g O<sub>2</sub>

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- b. What mass of water is produced when  
5.0 mol  $O_2$  is produced by this reaction? *ans:* 180 g  $H_2O$

**SAMPLE PROBLEM 3**

How many moles of aluminum will be produced from 30.0 kg  $Al_2O_3$  in the following reaction?

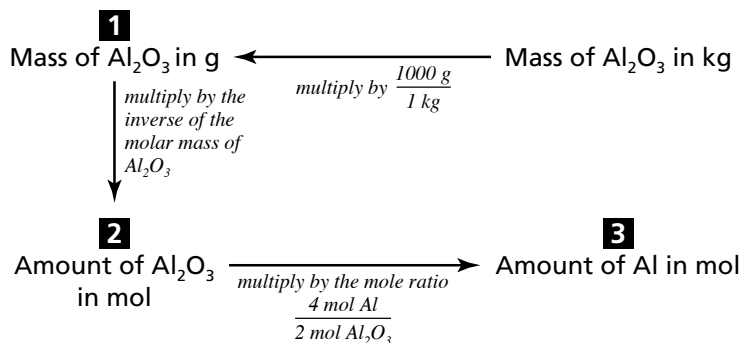
**SOLUTION****1. ANALYZE**

- What is given in the problem? the mass of aluminum oxide
- What are you asked to find? the amount of aluminum produced

Items	Data	
Substance	$Al_2O_3$	Al
Coefficient in balanced equation	2	4
Molar mass	101.96 g/mol	NA
Amount	? mol	? mol
Mass	30.0 kg	NA

**2. PLAN**

- What steps are needed to calculate the amount of Al produced from 30.0 kg of  $Al_2O_3$ ?  
The molar mass of  $Al_2O_3$  can be used to convert to moles  $Al_2O_3$ . The mole ratio of Al :  $Al_2O_3$  from the coefficients in the equation will convert to moles Al from moles  $Al_2O_3$ .



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$$\text{kg Al}_2\text{O}_3 \times \frac{1000 \text{ g}}{\text{kg}} \times \frac{\frac{1}{\text{molar mass Al}_2\text{O}_3}}{1 \text{ mol Al}_2\text{O}_3} \times \frac{\text{mole ratio}}{2 \text{ mol Al}_2\text{O}_3} = \text{mol Al}$$

**3. COMPUTE**

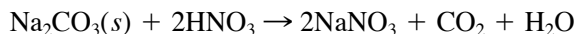
$$30.0 \text{ kg Al}_2\text{O}_3 \times \frac{1000 \text{ g}}{\text{kg}} \times \frac{1 \text{ mol Al}_2\text{O}_3}{101.96 \text{ g Al}_2\text{O}_3} \times \frac{4 \text{ mol Al}}{2 \text{ mol Al}_2\text{O}_3} = 588 \text{ mol Al}$$

**4. EVALUATE**

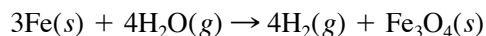
- *Are the units correct?* Yes; units canceled to give moles of Al.
- *Is the number of significant figures correct?* Yes; three significant figures is correct.
- *Is the answer reasonable?* Yes; the molar mass of  $\text{Al}_2\text{O}_3$  is about 100, so 30 kg of  $\text{Al}_2\text{O}_3$  is about 300 mol. The mole ratio of Al: $\text{Al}_2\text{O}_3$  is 2:1, so the answer should be about 600 mol Al.

**PRACTICE**

1. Sodium carbonate reacts with nitric acid according to the following equation.



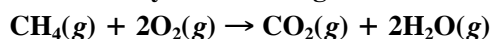
- a. How many moles of  $\text{Na}_2\text{CO}_3$  are required to produce 100.0 g of  $\text{NaNO}_3$ ? ans: 0.5882 mol  $\text{Na}_2\text{CO}_3$
- b. If 7.50 g of  $\text{Na}_2\text{CO}_3$  reacts, how many moles of  $\text{CO}_2$  are produced? ans: 0.0708 mol  $\text{CO}_2$
2. Hydrogen is generated by passing hot steam over iron, which oxidizes to form  $\text{Fe}_3\text{O}_4$ , in the following equation.



- a. If 625 g of  $\text{Fe}_3\text{O}_4$  is produced in the reaction, how many moles of hydrogen are produced at the same time? ans: 10.8 mol  $\text{H}_2$
- b. How many moles of iron would be needed to generate 27 g of hydrogen? ans: 10. mol Fe

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Methane burns in air by the following reaction:



What mass of water is produced by burning 500. g of methane?

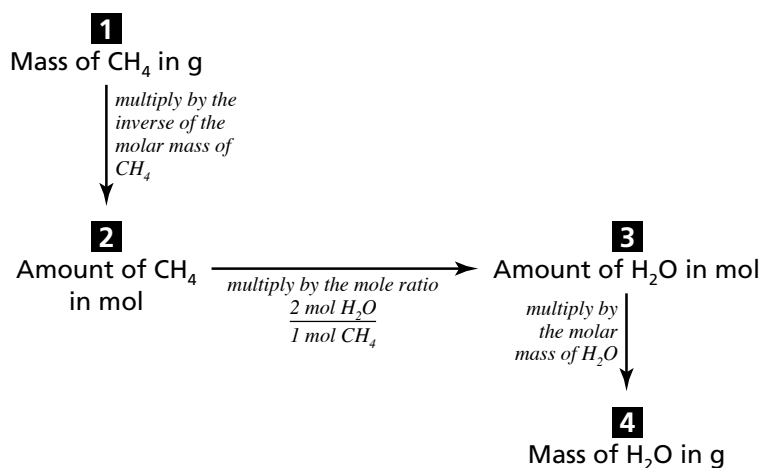
**SOLUTION****1. ANALYZE**

- What is given in the problem? the mass of methane in grams
- What are you asked to find? the mass of water produced

Items	Data	
Substance	CH <sub>4</sub>	H <sub>2</sub> O
Coefficient in balanced equation	1	2
Molar mass	16.05 g/mol	18.02 g/mol
Amount	? mol	? mol
Mass	500. g	? g

**2. PLAN**

- What steps are needed to calculate the mass of H<sub>2</sub>O produced from the burning of 500. g of CH<sub>4</sub>?  
Convert grams of CH<sub>4</sub> to moles CH<sub>4</sub> by using the molar mass of CH<sub>4</sub>. Use the mole ratio from the balanced equation to determine moles H<sub>2</sub>O from moles CH<sub>4</sub>. Use the molar mass of H<sub>2</sub>O to calculate grams H<sub>2</sub>O.





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$$\text{g CH}_4 \times \frac{\frac{1}{\text{molar mass CH}_4}}{16.05 \text{ g CH}_4} \times \frac{\text{mole ratio}}{2 \text{ mol H}_2\text{O}} \times \frac{\text{molar mass H}_2\text{O}}{18.02 \text{ g H}_2\text{O}} = \text{g H}_2\text{O}$$

**3. COMPUTE**

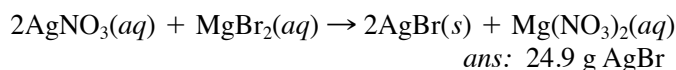
$$500. \text{ g CH}_4 \times \frac{1 \text{ mol CH}_4}{16.05 \text{ g CH}_4} \times \frac{2 \text{ mol H}_2\text{O}}{1 \text{ mol CH}_4} \times \frac{18.02 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 1.12 \times 10^3 \text{ g H}_2\text{O}$$

**4. EVALUATE**

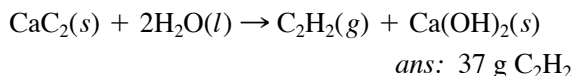
- *Are the units correct?* Yes; mass of H<sub>2</sub>O was required, and units canceled to give grams H<sub>2</sub>O.
- *Is the number of significant figures correct?* Yes; three significant figures is correct because the mass of CH<sub>4</sub> was given to three significant figures.
- *Is the answer reasonable?* Yes; CH<sub>4</sub> and H<sub>2</sub>O have similar molar masses, and twice as many moles of H<sub>2</sub>O are produced as moles CH<sub>4</sub> burned. So, you would expect to get a little more than 1000 g of H<sub>2</sub>O.

**PRACTICE**

1. Calculate the mass of silver bromide produced from 22.5 g of silver nitrate in the following reaction:



2. What mass of acetylene, C<sub>2</sub>H<sub>2</sub>, will be produced from the reaction of 90. g of calcium carbide, CaC<sub>2</sub>, with water in the following reaction?



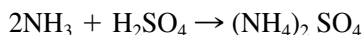
3. Chlorine gas can be produced in the laboratory by adding concentrated hydrochloric acid to manganese(IV) oxide in the following reaction:



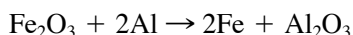
- a. Calculate the mass of MnO<sub>2</sub> needed to produce 25.0 g of Cl<sub>2</sub>. ans: 30.7 g MnO<sub>2</sub>
- b. What mass of MnCl<sub>2</sub> is produced when 0.091 g of Cl<sub>2</sub> is generated? ans: 0.16 g MnCl<sub>2</sub>

**CHEMFILE MINI-GUIDE TO PROBLEM SOLVING****ADDITIONAL PROBLEMS**

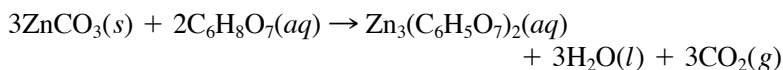
1. How many moles of ammonium sulfate can be made from the reaction of 30.0 mol of  $\text{NH}_3$  with  $\text{H}_2\text{SO}_4$  according to the following equation:



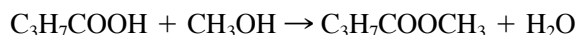
2. In a very violent reaction called a thermite reaction, aluminum metal reacts with iron(III) oxide to form iron metal and aluminum oxide according to the following equation:



- What mass of Al will react with 150 g of  $\text{Fe}_2\text{O}_3$ ?
  - If 0.905 mol  $\text{Al}_2\text{O}_3$  is produced in the reaction, what mass of Fe is produced?
  - How many moles of  $\text{Fe}_2\text{O}_3$  will react with 99.0 g of Al?
3. As you saw in Sample Problem 1, the reaction  $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightarrow 2\text{NH}_3(\text{g})$  is used to produce ammonia commercially. If 1.40 g of  $\text{N}_2$  are used in the reaction, how many grams of  $\text{H}_2$  will be needed?
4. What mass of sulfuric acid,  $\text{H}_2\text{SO}_4$ , is required to react with 1.27 g of potassium hydroxide, KOH? The products of this reaction are potassium sulfate and water.
5. Ammonium hydrogen phosphate,  $(\text{NH}_4)_2\text{HPO}_4$ , a common fertilizer; is made from reacting phosphoric acid,  $\text{H}_3\text{PO}_4$ , with ammonia.
- Write the equation for this reaction.
  - If 10.00 g of ammonia react, how many moles of fertilizer will be produced?
  - What mass of ammonia will react with 2800 kg of  $\text{H}_3\text{PO}_4$ ?
6. The following reaction shows the synthesis of zinc citrate, a ingredient in toothpaste, from zinc carbonate and citric acid.



- How many moles of  $\text{ZnCO}_3$  and  $\text{C}_6\text{H}_8\text{O}_7$  are required to produce 30.0 mol of  $\text{Zn}_3(\text{C}_6\text{H}_5\text{O}_7)_2$ ?
  - What quantities, in kilograms, of  $\text{H}_2\text{O}$  and  $\text{CO}_2$  are produced by the reaction of 500. mol of citric acid?
7. Methyl butanoate, an oily substance with a strong fruity fragrance can be made by reacting butanoic acid with methanol according to the following equation:



- What mass of methyl butanoate is produced from the reaction of 52.5 g of butanoic acid?

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- b. In order to purify methyl butanoate, water must be removed. What mass of water is produced from the reaction of 5800. g of methanol?
8. Ammonium nitrate decomposes to yield nitrogen gas, water, and oxygen gas in the following reaction:
- $$2\text{NH}_4\text{NO}_3 \rightarrow 2\text{N}_2 + \text{O}_2 + 4\text{H}_2\text{O}$$
- a. How many moles of nitrogen gas are produced when 36.0 g of  $\text{NH}_4\text{NO}_3$  reacts?
- b. If 7.35 mol of  $\text{H}_2\text{O}$  are produced in this reaction, what mass of  $\text{NH}_4\text{NO}_3$  reacted?
9. Lead(II) nitrate reacts with potassium iodide to produce lead(II) iodide and potassium nitrate. If 1.23 mg of lead nitrate are consumed, what is the mass of the potassium nitrate produced?
10. A car battery produces electrical energy with the following chemical reaction:
- $$\text{Pb}(s) + \text{PbO}_2(s) + 2\text{H}_2\text{SO}_4(aq) \rightarrow 2\text{PbSO}_4(s) + 2\text{H}_2\text{O}(l)$$
- If the battery loses 0.34 kg of lead in this reaction, how many moles of lead(II) sulfate are produced?
11. In a space shuttle, the  $\text{CO}_2$  that the crew exhales is removed from the air by a reaction within canisters of lithium hydroxide. On average, each astronaut exhales about 20.0 mol of  $\text{CO}_2$  daily. What mass of water will be produced when this amount reacts with  $\text{LiOH}$ ? The other product of the reaction is  $\text{Li}_2\text{CO}_3$ .
12. Water is sometimes removed from the products of a reaction by placing them in a closed container with excess  $\text{P}_4\text{O}_{10}$ . Water is absorbed by the following reaction:
- $$\text{P}_4\text{O}_{10} + 6\text{H}_2\text{O} \rightarrow 4\text{H}_3\text{PO}_4$$
- a. What mass of water can be absorbed by  $1.00 \times 10^2$  g of  $\text{P}_4\text{O}_{10}$ ?
- b. If the  $\text{P}_4\text{O}_{10}$  in the container absorbs 0.614 mol of water, what mass of  $\text{H}_3\text{PO}_4$  is produced?
- c. If the mass of the container of  $\text{P}_4\text{O}_{10}$  increases from 56.64 g to 63.70 g, how many moles of water are absorbed?
13. Ethanol,  $\text{C}_2\text{H}_5\text{OH}$ , is considered a clean fuel because it burns in oxygen to produce carbon dioxide and water with few trace pollutants. If 95.0 g of  $\text{H}_2\text{O}$  are produced during the combustion of ethanol, how many grams of ethanol were present at the beginning of the reaction?

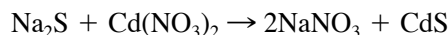
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14. Sulfur dioxide is one of the major contributors to acid rain. Sulfur dioxide can react with oxygen and water in the atmosphere to form sulfuric acid, as shown in the following equation:



If 50.0 g of sulfur dioxide from pollutants reacts with water and oxygen found in the air, how many grams of sulfuric acid can be produced? How many grams of oxygen are used in the process?

15. When heated, sodium bicarbonate,  $\text{NaHCO}_3$ , decomposes into sodium carbonate,  $\text{Na}_2\text{CO}_3$ , water, and carbon dioxide. If 5.00 g of  $\text{NaHCO}_3$  decomposes, what is the mass of the carbon dioxide produced?
16. A reaction between hydrazine,  $\text{N}_2\text{H}_4$ , and dinitrogen tetroxide,  $\text{N}_2\text{O}_4$ , has been used to launch rockets into space. The reaction produces nitrogen gas and water vapor.
- Write a balanced chemical equation for this reaction.
  - What is the mole ratio of  $\text{N}_2\text{O}_4$  to  $\text{N}_2$ ?
  - How many moles of  $\text{N}_2$  will be produced if 20 000 mol of  $\text{N}_2\text{H}_4$  are used by a rocket?
  - How many grams of  $\text{H}_2\text{O}$  are made when 450. kg of  $\text{N}_2\text{O}_4$  are consumed?
17. Joseph Priestley is credited with the discovery of oxygen. He produced  $\text{O}_2$  by heating mercury(II) oxide,  $\text{HgO}$ , to decompose it into its elements. How many moles of oxygen could Priestley have produced if he had decomposed 517.84 g of mercury oxide?
18. Iron(III) chloride,  $\text{FeCl}_3$ , can be made by the reaction of iron with chlorine gas. How much iron, in grams, will be needed to completely react with 58.0 g of  $\text{Cl}_2$ ?
19. Sodium sulfide and cadmium nitrate undergo a double-replacement reaction as shown by the following equation:



What is the mass, in milligrams, of cadmium sulfide that can be made from 5.00 mg of sodium sulfide?

20. Potassium permanganate and glycerin react explosively according to the following equation:



- How many moles of carbon dioxide can be produced from 4.44 mol of  $\text{KMnO}_4$ ?
- If 5.21 g of  $\text{H}_2\text{O}$  are produced, how many moles of glycerin,  $\text{C}_3\text{H}_5(\text{OH})_3$ , were used?

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- c. If 3.39 mol of potassium carbonate are made, how many grams of manganese(III) oxide are also made?
- d. How many grams of glycerin will be needed to react with 50.0 g of  $\text{KMnO}_4$ ? How many grams of  $\text{CO}_2$  will be produced in the same reaction?
21. Calcium carbonate found in limestone and marble reacts with hydrochloric acid to form calcium chloride, carbon dioxide, and water according to the following equation:
- $$\text{CaCO}_3(s) + 2\text{HCl}(aq) \rightarrow \text{CaCl}_2(aq) + \text{CO}_2(g) + \text{H}_2\text{O}(l)$$
- a. What mass of HCl will be needed to produce  $5.00 \times 10^3$  kg of  $\text{CaCl}_2$ ?
- b. What mass of  $\text{CO}_2$  could be produced from the reaction of 750 g of  $\text{CaCO}_3$ ?
22. The fuel used to power the booster rockets on the space shuttle is a mixture of aluminum metal and ammonium perchlorate. The following balanced equation represents the reaction of these two ingredients:
- $$3\text{Al}(s) + 3\text{NH}_4\text{ClO}_4(s) \rightarrow \text{Al}_2\text{O}_3(s) + \text{AlCl}_3(g) + 3\text{NO}(g) + 6\text{H}_2\text{O}(g)$$
- a. If  $1.50 \times 10^5$  g of Al react, what mass of  $\text{NH}_4\text{ClO}_4$ , in grams, is required?
- b. If aluminum reacts with 620 kg of  $\text{NH}_4\text{ClO}_4$ , what mass of nitrogen monoxide is produced?
23. Phosphoric acid is typically produced by the action of sulfuric acid on rock that has a high content of calcium phosphate according to the following equation:
- $$3\text{H}_2\text{SO}_4 + \text{Ca}_3(\text{PO}_4)_2 + 6\text{H}_2\text{O} \rightarrow 3[\text{CaSO}_4 \cdot 2\text{H}_2\text{O}] + 2\text{H}_3\text{PO}_4$$
- a. If  $2.50 \times 10^5$  kg of  $\text{H}_2\text{SO}_4$  react, how many moles of  $\text{H}_3\text{PO}_4$  can be made?
- b. What mass of calcium sulfate dihydrate is produced by the reaction of 400. kg of calcium phosphate?
- c. If the rock being used contains 78.8%  $\text{Ca}_3(\text{PO}_4)_2$ , how many metric tons of  $\text{H}_3\text{PO}_4$  can be produced from 68 metric tons of rock?
24. Rusting of iron occurs in the presence of moisture according to the following equation:
- $$4\text{Fe}(s) + 3\text{O}_2(g) \rightarrow 2\text{Fe}_2\text{O}_3(s)$$
- Suppose that 3.19% of a heap of steel scrap with a mass of 1650 kg rusts in a year. What mass will the heap have after one year of rusting?