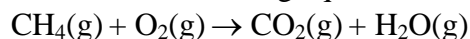


**Unit 4 Quantitative Relationships in Chemical Changes**  
**Solutions to Practice Problems**  
**Unit 4 Preparation**

**1. a)****Problem**

Balance the following equation and classify the reaction:

**What is Required?**

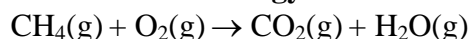
You must balance each equation to ensure that there is an equal number of each kind of atom on the reactant side and the product side for each equation. You must then classify each reaction.

**What is Given?**

The unbalanced equation is given.

**Plan Your Strategy**

Follow the rules for balancing equations and classifying reactions.

**Act on Your Strategy**

Compare the number of each type of atom on each side of the equation.

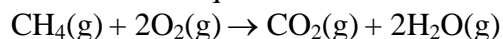
Reactants → Products

1C, 4H, 2O → 1C, 2H, 3O

Balance the H by putting a 2 in front of  $\text{H}_2\text{O}(\text{g})$ .

Balance the O by putting a 2 in front of  $\text{O}_2(\text{g})$ .

The balanced equation is



Since  $\text{CH}_4(\text{g})$  is a hydrocarbon and it reacts with  $\text{O}_2(\text{g})$  to form  $\text{CO}_2(\text{g})$  and  $\text{H}_2\text{O}(\text{g})$ , this is a hydrocarbon combustion reaction.

**1. b)****Problem**

Balance the following equation and classify the reaction:  $\text{P}_4(\text{s}) + \text{I}_2(\text{s}) \rightarrow \text{P}_2\text{I}_4(\text{s})$

**What is Required?**

You must balance each equation to ensure that there is an equal number of each kind of atom on the reactant side and the product side for each equation. You must then classify each reaction.

**What is Given?**

The unbalanced equation is given.

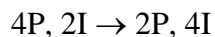
**Plan Your Strategy**

Follow the rules for balancing equations and classifying reactions.

**Act on Your Strategy**

Compare the number of each type of atom on each side of the equation.

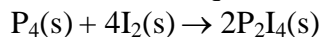
Reactants → Products



Balance the P by putting a 2 in front of  $\text{P}_2\text{I}_4(\text{s})$ .

Balance the I by putting a 4 in front of  $\text{I}_2(\text{s})$ .

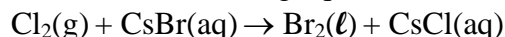
The balanced equation is



Since two elements combine to form a new compound, this is a formation or synthesis reaction.

**1. c)****Problem**

Balance the following equation and classify the reaction:

**What is Required?**

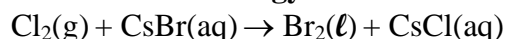
You must balance each equation to ensure that there is an equal number of each kind of atom on the reactant side and the product side for each equation. You must then classify each reaction.

**What is Given?**

The unbalanced equation is given.

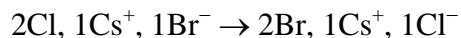
**Plan Your Strategy**

Follow the rules for balancing equations and classifying reactions.

**Act on Your Strategy**

Compare the number of each type of atom on each side of the equation.

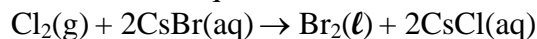
Reactants → Products



Balance the  $\text{Cl}^-$  by putting a 2 in front of  $\text{CsCl}(\text{aq})$ .

Balance the  $\text{Cs}^+$  and  $\text{Br}^-$  by putting a 2 in front of  $\text{CsBr}(\text{aq})$ .

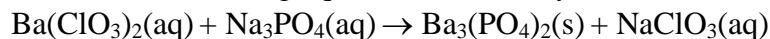
The balanced equation is



Since an element and a compound react to form a new element and a new compound, this is a single replacement reaction.

**1. d)****Problem**

Balance the following equation and classify the reaction:

**What is Required?**

You must balance each equation to ensure that there is an equal number of each kind of atom on the reactant side and the product side for each equation. You must then classify each reaction.

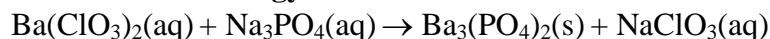
### What is Given?

The unbalanced equation is given.

### Plan Your Strategy

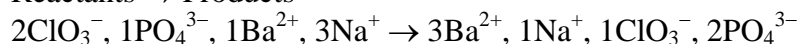
Follow the rules for balancing equations and classifying reactions.

### Act on Your Strategy



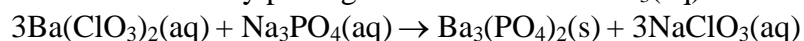
Compare the number of each type of atom and polyatomic ion on each side of the equation.

Reactants  $\rightarrow$  Products



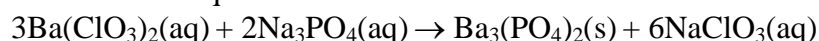
Balance the  $\text{Ba}^{2+}$  by putting a 3 in front of  $\text{Ba}(\text{ClO}_3)_2(\text{aq})$ .

Balance the  $\text{Na}^+$  by putting a 3 in front of  $\text{NaClO}_3(\text{aq})$ .



Balance the polyatomic ions by putting a 6 in front of  $\text{NaClO}_3(\text{aq})$  and a 2 in front of  $\text{Na}_3(\text{PO}_4)(\text{aq})$ . This also balances the  $\text{Na}^+$ .

The balanced equation is



Since there is an exchange of polyatomic ions between the two compounds, this is a double replacement reaction.

### 1. e)

#### Problem

Balance the following equation and classify the reaction:



### What is Required?

You must balance each equation to ensure that there is an equal number of each kind of atom on the reactant side and the product side for each equation. You must then classify each reaction.

### What is Given?

The unbalanced equation is given.

### Plan Your Strategy

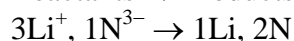
Follow the rules for balancing equations and classifying reactions.

### Act on Your Strategy



Compare the number of each type of atom on each side of the equation.

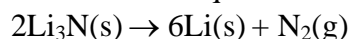
Reactants  $\rightarrow$  Products



Balance the  $\text{N}^{3-}$  by putting a 2 in front of  $\text{Li}_3\text{N}(\text{s})$ .

Balance the  $\text{Li}^+$  by putting a 6 in front of  $\text{Li}(\text{s})$ .

The balanced equation is



Since a compound breaks up into its elements, this is a decomposition reaction.

### 1. f)

#### Problem

Balance the following equation and classify the reaction:



#### What is Required?

You must balance each equation to ensure that there is an equal number of each kind of atom on the reactant side and the product side for each equation. You must then classify each reaction.

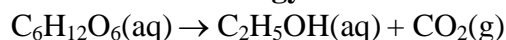
#### What is Given?

The unbalanced equation is given.

#### Plan Your Strategy

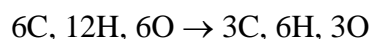
Follow the rules for balancing equations and classifying reactions.

#### Act on Your Strategy



Compare the number of each type of atom on each side of the equation.

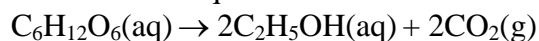
Reactants  $\rightarrow$  Products



Balance the C by putting a 2 in front of  $\text{C}_2\text{H}_5\text{OH}(\text{aq})$  and a 2 in front of  $\text{CO}_2(\text{g})$ .

The H and O are now also balanced.

The balanced equation is



Since one compound breaks up into two new compounds, this reaction may be classed as a decomposition. (This reaction is somewhat different from the other examples of decomposition. This reaction can be classified entirely differently as you will see later in this course.)

#### Check Your Solution

Question	Reactants	Products	Type of Reaction
1. a)	1C, 4H, 4O	1C, 4H, 4O	hydrocarbon + $\text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{g})$
1. b)	4P, 8I	4P, 8I	element + element $\rightarrow$ compound
1. c)	2Cl, $2\text{Cs}^+$ , $2\text{Br}^-$	$2\text{Cl}^-$ , $2\text{Cs}^+$ , 2Br	element + compound $\rightarrow$ new element + new compound
1. d)	$3\text{Ba}^{2+}$ , $6\text{ClO}_3^-$ , $6\text{Na}^+$ , $2\text{PO}_4^{3-}$	$3\text{Ba}^{2+}$ , $6\text{ClO}_3^-$ , $6\text{Na}^+$ , $2\text{PO}_4^{3-}$	compound A + compound B $\rightarrow$ compound C + compound D

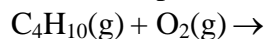
1. e)	$6\text{Li}^+, 2\text{N}^{3-}$	$6\text{Li}, 2\text{N}$	compound $\rightarrow$ 2 elements
1. f)	$6\text{C}, 12\text{H}, 6\text{O}$	$6\text{C}, 12\text{H}, 6\text{O}$	compound A $\rightarrow$ compound B + compound C

In each case, the number of atoms of each element are the same on both the reactant and the product side of the reaction. The type of reaction matches the format outlined in the textbook.

## 2. a)

### Problem

Predict the products for the following incomplete chemical equation. Then balance the equation:



### What is Required?

You must predict the products of each reaction and then balance the resulting equation.

### What is Given?

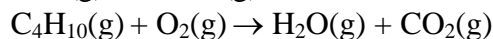
The chemical formulas of the reactants are given.

### Plan Your Strategy

Refer to the rules for classifying reactions to predict the products that will form in each example. Follow the rules for balancing equations to ensure that the same number of each kind of atom is on the reactant side and the product side of each equation.

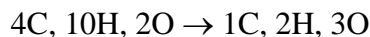
### Act on Your Strategy

$\text{C}_4\text{H}_{10}(\text{g})$  is a hydrocarbon. The products that form when complete combustion with  $\text{O}_2(\text{g})$  are  $\text{H}_2\text{O}(\text{g})$  and  $\text{CO}_2(\text{g})$ .



Compare the number of each type of atom on each side of the equation.

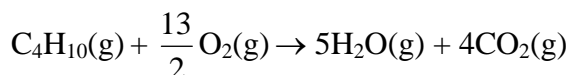
Reactants  $\rightarrow$  Products



Balance the C by putting a 4 in front of  $\text{CO}_2(\text{g})$ .

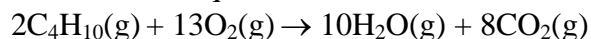
Balance the H by putting a 5 in front of  $\text{H}_2\text{O}(\text{g})$ .

Balance the O by putting  $\frac{13}{2}$  in front of  $\text{O}_2(\text{g})$ .



Multiply each coefficient by 2 to obtain whole number coefficients in front of each term in the equation.

The balanced equation is



## 2. b)

### Problem

Predict the products for the following incomplete chemical equations. Then balance the equations:

**What is Required?**

You must predict the products of each reaction and then balance the resulting equation.

**What is Given?**

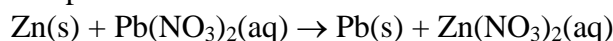
The chemical formulas of the reactants are given.

**Plan Your Strategy**

Refer to the rules for classifying reactions to predict the products that will form in each example. Follow the rules for balancing equations to ensure that the same number of each kind of atom is on the reactant side and the product side of each equation.

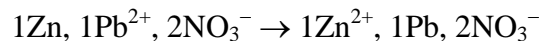
**Act on Your Strategy**

The reactants are an element and a compound. The products will be a new element and a new compound.

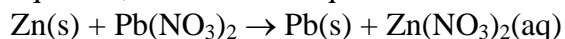


Compare the number of each type of atom and polyatomic ion on each side of the equation.

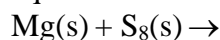
Reactants  $\rightarrow$  Products



Since there are the same number of each kind of atom and polyatomic ion on each side of the equation, the balanced equation is

**2. c)****Problem**

Predict the products for the following incomplete chemical equations. Then balance the equations:

**What is Required?**

You must predict the products of each reaction and then balance the resulting equation.

**What is Given?**

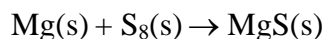
The chemical formulas of the reactants are given.

**Plan Your Strategy**

Refer to the rules for classifying reactions to predict the products that will form in each example. Follow the rules for balancing equations to ensure that the same number of each kind of atom is on the reactant side and the product side of each equation.

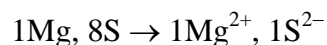
**Act on Your Strategy**

The reactants are two elements. The product will be a compound.



Compare the number of each type of atom on each side of the equation.

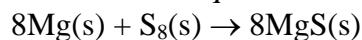
Reactants  $\rightarrow$  Products



Balance the  $\text{S}^{2-}$  by putting an 8 in front of  $\text{MgS}(\text{s})$ .

Balance the  $\text{Mg}^{2+}$  by putting an 8 in front of  $\text{Mg}(\text{s})$ .

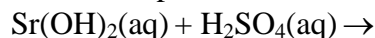
The balanced equation is



## 2. d)

### Problem

Predict the products for the following incomplete chemical equation. Then balance the equation:



### What is Required?

You must predict the products of each reaction and then balance the resulting equation.

### What is Given?

The chemical formulas of the reactants are given.

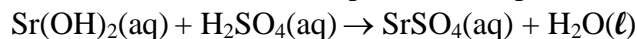
### Plan Your Strategy

Refer to the rules for classifying reactions to predict the products that will form in each example.

Follow the rules for balancing equations to ensure that the same number of each kind of atom is on the reactant side and the product side of each equation.

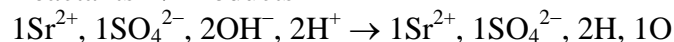
### Act on Your Strategy

The reactants are two compounds. The products will be two new compounds.



Compare the number of each type of atom and polyatomic ion on each side of the equation.

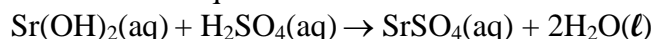
Reactants  $\rightarrow$  Products



Balance the  $\text{H}^+$  by putting a 2 in front of  $\text{H}_2\text{O}(\ell)$ .

This also balances the O.

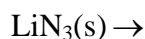
The balanced equation is



## 2. e)

### Problem

Predict the products for the following incomplete chemical equation. Then balance the equation:



### What is Required?

You must predict the products of each reaction and then balance the resulting equation.

### What is Given?

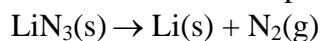
The chemical formulas of the reactants are given.

### Plan Your Strategy

Refer to the rules for classifying reactions to predict the products that will form in each example. Follow the rules for balancing equations to ensure that the same number of each kind of atom is on the reactant side and the product side of each equation.

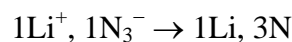
### Act on Your Strategy

The reactant is a compound. The products will be two elements.



Compare the number of each type of atom on each side of the equation.

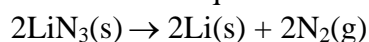
Reactants  $\rightarrow$  Products



Balance the N by putting a 3 in front of  $\text{N}_2(\text{g})$  and a 2 in front of  $\text{LiN}_3(\text{s})$ .

Balance the Na by putting a 2 in front of  $\text{Li}(\text{s})$ .

The balanced equation is



### Check Your Solution

Question	Reactants	Products	Type of Reaction
2. a)	8C, 20H, 26O	8C, 20H, 26O	hydrocarbon combustion
2. b)	1Zn, 1Pb <sup>2+</sup> , 2NO <sub>3</sub> <sup>-</sup>	1Zn <sup>2+</sup> , 1Pb, 2NO <sub>3</sub> <sup>-</sup>	single replacement
2. c)	8Mg, 8S	8Mg <sup>2+</sup> , 8S <sup>2-</sup>	formation or synthesis
2. d)	1Sr <sup>2+</sup> , 2OH <sup>-</sup> , 2H <sup>+</sup> 1SO <sub>4</sub> <sup>2-</sup> ,	1Sr <sup>2+</sup> , 1SO <sub>4</sub> <sup>2-</sup> , 4H, 2O	double replacement
2. e)	2Li <sup>+</sup> , 2N <sub>3</sub> <sup>-</sup>	2Li, 6N	decomposition

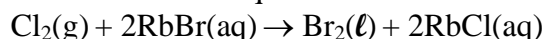
In each example, the same number of atoms of each kind of element appears on the reactant side and on the product side of the reaction. The equations are balanced. The type of reaction follows the format for classification of reactions found in the textbook.

## Chapter 7 Relationships in Chemical Reactions

### 1. a)

#### Problem

Write a net ionic equation for the following *balanced* single replacement reaction:



#### What is Required?

You must write the net ionic equation for each reaction.

#### What is Given?

A balanced equation is given.

#### Plan Your Strategy

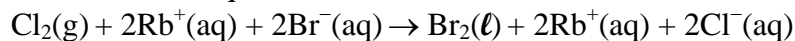
Rewrite each equation to show the dissociation of all ionic compounds of high solubility.

This is the total ionic equation. Identify and cancel the spectator ions. Write the net ionic equation.



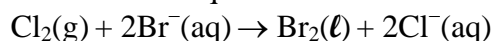
**Act on Your Strategy**

The total ionic equation is



The spectator ion is  $\text{Rb}^+(\text{aq})$ .

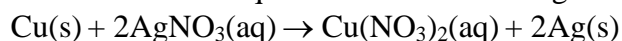
The net ionic equation is

**Check Your Solution**

The numbers of each kind of atom on the reactant side and the product side of each equation are the same. The equations are balanced. The total charges on the ions on each side of each equation are the same. There are no ions common to both sides of the equation. The net ionic equations are correct.

**1. b)****Problem**

Write a net ionic equation for the following *balanced* single replacement reaction:

**What is Required?**

You must write the net ionic equation for each reaction.

**What is Given?**

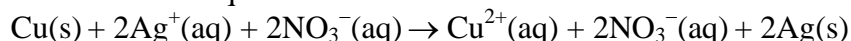
A balanced equation is given.

**Plan Your Strategy**

Rewrite each equation to show the dissociation of all ionic compounds of high solubility. This is the total ionic equation. Identify and cancel the spectator ions. Write the net ionic equation.

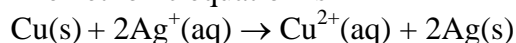
**Act on Your Strategy**

The total ionic equation is



The spectator ion is  $\text{NO}_3^-(\text{aq})$ .

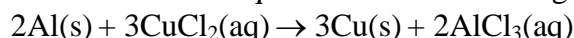
The net ionic equation is

**Check Your Solution**

The numbers of each kind of atom on the reactant side and the product side of each equation are the same. The equations are balanced. The total charges on the ions on each side of each equation are the same. There are no ions common to both sides of the equation. The net ionic equations are correct.

**1. c)****Problem**

Write a net ionic equation for the following *balanced* single replacement reaction:



**What is Required?**

You must write the net ionic equation for each reaction.

**What is Given?**

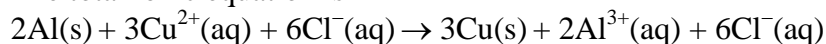
A balanced equation is given.

**Plan Your Strategy**

Rewrite each equation to show the dissociation of all ionic compounds of high solubility. This is the total ionic equation. Identify and cancel the spectator ions. Write the net ionic equation.

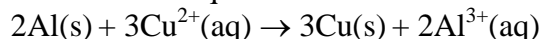
**Act on Your Strategy**

The total ionic equation is



The spectator ion is  $\text{Cl}^{-}(\text{aq})$ .

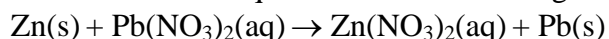
The net ionic equation is

**Check Your Solution**

The numbers of each kind of atom on the reactant side and the product side of each equation are the same. The equations are balanced. The total charges on the ions on each side of each equation are the same. There are no ions common to both sides of the equation. The net ionic equations are correct.

**1. d)****Problem**

Write a net ionic equation for the following *balanced* single replacement reaction:

**What is Required?**

You must write the net ionic equation for each reaction.

**What is Given?**

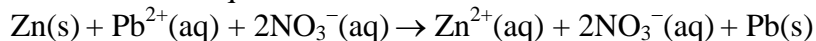
A balanced equation is given.

**Plan Your Strategy**

Rewrite each equation to show the dissociation of all ionic compounds of high solubility. This is the total ionic equation. Identify and cancel the spectator ions. Write the net ionic equation.

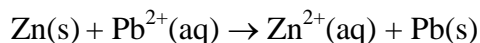
**Act on Your Strategy**

The total ionic equation is



The spectator ion is  $\text{NO}_3^{-}(\text{aq})$ .

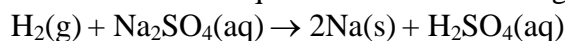
The net ionic equation is

**Check Your Solution**

The numbers of each kind of atom on the reactant side and the product side of each equation are the same. The equations are balanced. The total charges on the ions on each side of each equation are the same. There are no ions common to both sides of the equation. The net ionic equations are correct.

**1. e)****Problem**

Write a net ionic equation for the following *balanced* single replacement reaction:

**What is Required?**

You must write the net ionic equation for each reaction.

**What is Given?**

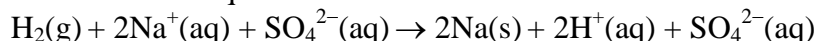
A balanced equation is given.

**Plan Your Strategy**

Rewrite each equation to show the dissociation of all ionic compounds of high solubility. This is the total ionic equation. Identify and cancel the spectator ions. Write the net ionic equation.

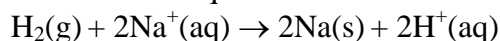
**Act on Your Strategy**

The total ionic equation is



The spectator ion is  $\text{SO}_4^{2-}(\text{aq})$ .

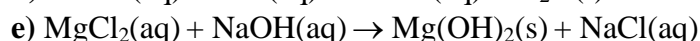
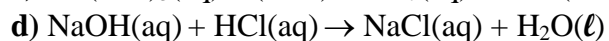
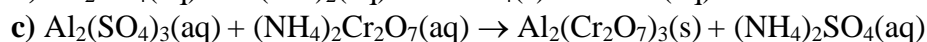
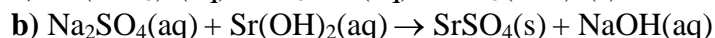
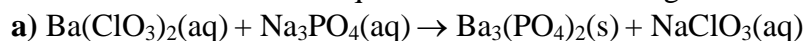
The net ionic equation is

**Check Your Solution**

The numbers of each kind of atom on the reactant side and the product side of each equation are the same. The equations are balanced. The total charges on the ions on each side of each equation are the same. There are no ions common to both sides of the equation. The net ionic equations are correct.

**2.****Problem**

Write balanced net ionic equations for the following *unbalanced* double-replacement reactions:



**What is Required?**

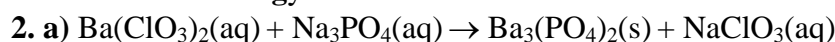
You must balance the skeleton equation and write the balanced net ionic equation for each reaction.

**What is Given?**

An unbalanced equation is given.

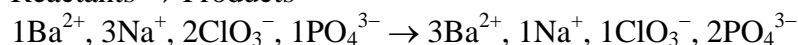
**Plan Your Strategy**

Balance the skeleton equation. This is the non-ionic equation. Rewrite each equation showing the dissociation of all ionic compounds of high solubility. This is the total ionic equation. Identify and cancel the spectator ions. Write the net ionic equation.

**Act on Your Strategy**

Compare the numbers of each type of atom and polyatomic ion on each side of the equation.

Reactants  $\rightarrow$  Products



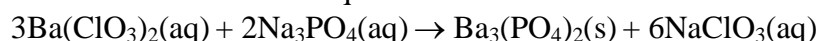
Balance the  $\text{PO}_4^{3-}(\text{aq})$  by putting a 2 in front of  $\text{Na}_3\text{PO}_4(\text{aq})$ .

Balance the  $\text{Ba}^{2+}(\text{aq})$  by putting a 3 in front of the  $\text{Ba}(\text{ClO}_3)_2(\text{aq})$ .

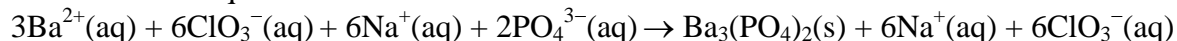
Balance the  $\text{ClO}_3^-(\text{aq})$  by putting a 6 in front of  $\text{NaClO}_3(\text{aq})$ .

The  $\text{Na}^+(\text{aq})$  is also balanced.

The balanced non-ionic equation is

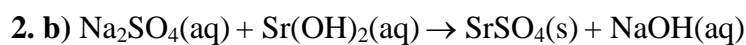
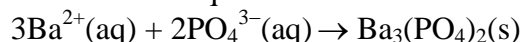


The total ionic equation is



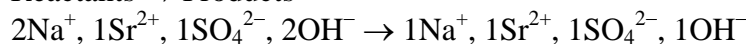
The spectator ions are  $\text{Na}^+(\text{aq})$  and  $\text{ClO}_3^-(\text{aq})$ .

The net ionic equation is



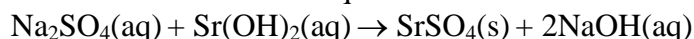
Compare the numbers of each type of atom and polyatomic ion on each side of the equation.

Reactants  $\rightarrow$  Products

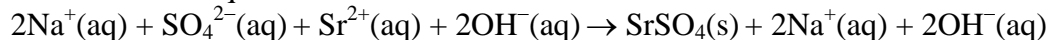


Balance the  $\text{Na}^+(\text{aq})$  and  $\text{OH}^-(\text{aq})$  by putting a 2 in front of  $\text{NaOH}(\text{aq})$ .

The balanced non-ionic equation is

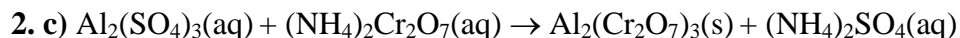
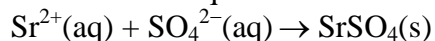


The total ionic equation is



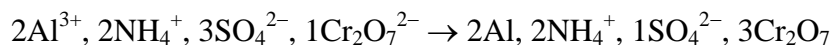
The spectator ions are  $\text{Na}^+(\text{aq})$  and  $\text{OH}^-(\text{aq})$ .

The net ionic equation is



Compare the numbers of each type of atom and polyatomic ion on each side of the equation.

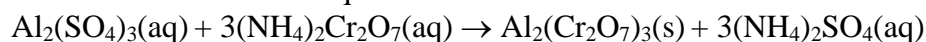
Reactants  $\rightarrow$  Products



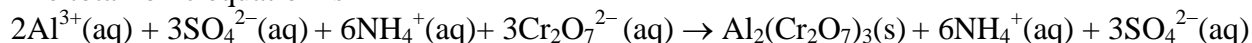
Balance the  $\text{Cr}_2\text{O}_7^{2-}(\text{aq})$  by putting a 3 in front of  $(\text{NH}_4)_2\text{Cr}_2\text{O}_7(\text{aq})$ .

Balance the  $\text{NH}_4^+(\text{aq})$  by putting a 3 in front of  $(\text{NH}_4)_2\text{SO}_4(\text{aq})$

The balanced non-ionic equation is

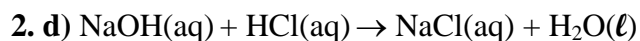
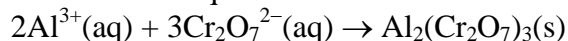


The total ionic equation is



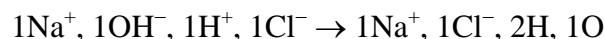
The spectator ions are  $\text{NH}_4^+(\text{aq})$  and  $\text{SO}_4^{2-}(\text{aq})$ .

The net ionic equation is



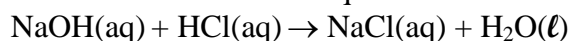
Compare the numbers of each type of atom and polyatomic ion on each side of the equation.

Reactants  $\rightarrow$  Products

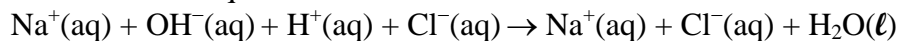


The same number of each kind of atom is on each side of the equation.

The balanced non-ionic equation is

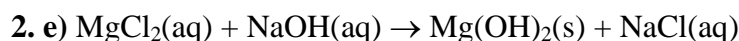
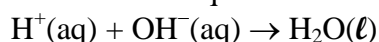


The total ionic equation is



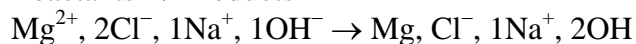
The spectator ions are  $\text{Na}^+(\text{aq})$  and  $\text{Cl}^-(\text{aq})$ .

The net ionic equation is



Compare the numbers of each type of atom and polyatomic ion on each side of the equation.

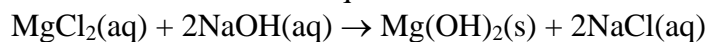
Reactants  $\rightarrow$  Products



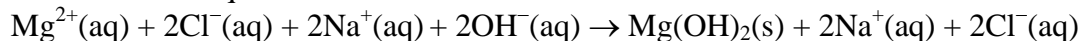
Balance the  $\text{OH}^-(\text{aq})$  by putting a 2 in front of  $\text{NaOH}(\text{aq})$ .

Balance the  $\text{Na}^+(\text{aq})$  by putting a 2 in front of  $\text{NaCl}(\text{aq})$

The balanced non-ionic equation is

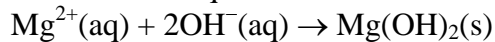


The total ionic equation is



The spectator ions are  $\text{Na}^+(\text{aq})$  and  $\text{Cl}^-(\text{aq})$ .

The net ionic equation is



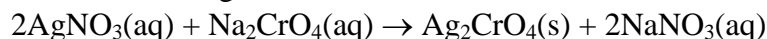
### Check Your Solution

The numbers of each kind of atom on the reactant side and the product side of each equation are the same. The equations are balanced. The total charges on the ions on each side of each equation are the same. There are no ions common to each side of the equation. The net ionic equations are correct.

### 3.

**Problem**

For the following reaction:



- Write the ratio of all the components.
- Write the mole ratio for silver nitrate,  $\text{AgNO}_3(\text{aq})$ , and silver chromate,  $\text{Ag}_2\text{CrO}_4(\text{s})$ .
- What amount (in mol) of  $\text{Ag}_2\text{CrO}_4(\text{s})$  would be produced from 0.5 mol of  $\text{AgNO}_3(\text{aq})$ ?

**What is Required**

- You must write the ratio of all the components.
- You must write the ratio for  $\text{AgNO}_3(\text{aq})$  and  $\text{Ag}_2\text{CrO}_4(\text{s})$ .
- You must calculate the amount of  $\text{Ag}_2\text{CrO}_4(\text{s})$  that would be produced from 0.5 mol  $\text{AgNO}_3(\text{aq})$ .

**What is Given**

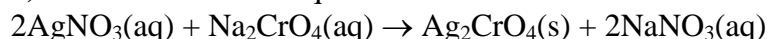
- & b) The balanced equation is given.
- The number of moles of  $\text{AgNO}_3(\text{aq})$  is 0.5 mol.

**Plan Your Strategy**

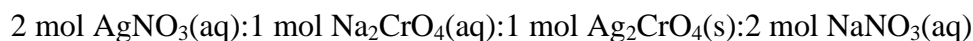
- The balanced equation gives the mole ratio of the components in the reaction.
- From the balanced equation, equate the given mole ratio of  $\text{AgNO}_3(\text{aq})$ : $\text{Ag}_2\text{CrO}_4(\text{s})$ .
- From the balanced equation, equate the given mole ratio of  $\text{AgNO}_3(\text{aq})$ : $\text{Ag}_2\text{CrO}_4(\text{s})$  to the number of moles given of  $\text{AgNO}_3(\text{aq})$  and solve for the number of moles of  $\text{Ag}_2\text{CrO}_4(\text{s})$ .

**Act on Your Strategy**

- From the balanced equation:



the mole ratio is



$$\text{b) } \frac{n(\text{AgNO}_3(\text{aq}))}{n(\text{Ag}_2\text{CrO}_4(\text{s}))} = \frac{2}{1}$$

$$\text{c) } \frac{0.5 \text{ mol AgNO}_3(\text{aq})}{n(\text{Ag}_2\text{CrO}_4(\text{s}))} = \frac{2}{1}$$

$$n(\text{Ag}_2\text{CrO}_4(\text{s})) = \frac{0.5 \text{ mol AgNO}_3(\text{aq})}{2} = 0.25 \text{ mol Ag}_2\text{CrO}_4(\text{s})$$

**Check Your Solution**

- The balanced equation represents the mole ratio between all of the components.

$$\text{b) The mole ratio } \frac{n(\text{AgNO}_3(\text{aq}))}{n(\text{Ag}_2\text{CrO}_4(\text{s}))} = \frac{2}{1}$$

c) The mole ratio  $\frac{n(\text{AgNO}_3(\text{aq}))}{n(\text{AgCrO}_4(\text{s}))} = \frac{0.5}{0.25} = \frac{2}{1}$

**4.****Problem**

For the following reaction:



- a) Write the ratio of all the components of the reaction.  
 b) What amount (in moles) of ammonia,  $\text{NH}_3(\text{g})$ , is required to prepare 1.30 mol of urea,  $\text{NH}_2\text{CONH}_2(\text{s})$ ?  
 c) What amount (in moles) of water is formed when 6.00 mol of carbon dioxide is consumed in the reaction?

**What is Required?**

- a) You must state the mole ratio of all the components in this reaction.  
 b) You must calculate the number of moles of ammonia needed to prepare 1.30 mol of urea.  
 c) You need to calculate the number of moles of water formed when 6.00 mol of  $\text{CO}_2(\text{g})$  react.

**What is Given?**

- a) The balanced equation is given.  
 b) The number of moles of  $\text{NH}_2\text{CONH}_2(\text{s})$  is 1.30 mol.  
 c) The number of moles of  $\text{CO}_2(\text{g})$  is 6.00 mol.

**Plan Your Strategy**

- a) The balanced equation gives the mole ratio of the components in the reaction.  
 b) From the balanced equation, equate the given mole ratio of  $\text{NH}_3(\text{g}):\text{NH}_2\text{CONH}_2(\text{s})$  to the ratio of number of moles given and solve for the number of moles of  $\text{NH}_3$ .  
 c) From the balanced equation, equate the given mole ratio of  $\text{H}_2\text{O}(\text{g}):\text{CO}_2(\text{g})$  to the ratio the of number of moles given and solve for the number of moles of  $\text{H}_2\text{O}(\text{g})$ .

**Act on Your Strategy**

- a) From the balanced equation:



the mole ratio is



b)  $\frac{n(\text{NH}_3(\text{g}))}{n(\text{NH}_2\text{CONH}_2(\text{s}))} = \frac{2}{1}$

$$n(\text{NH}_3(\text{g})) = \frac{2 \text{ mol NH}_3(\text{g}) \times 1.30 \text{ mol NH}_2\text{CONH}_2(\text{s})}{1 \text{ mol NH}_2\text{CONH}_2(\text{s})} = 2.60 \text{ mol NH}_3(\text{g})$$

c)  $\frac{n(\text{H}_2\text{O}(\text{g}))}{n(\text{CO}_2(\text{g}))} = \frac{1}{1}$

$$n(\text{H}_2\text{O}(\text{g})) = \frac{1 \text{ mol H}_2\text{O}(\text{g}) \times 6.0 \text{ mol CO}_2(\text{g})}{1 \text{ mol CO}_2(\text{g})} = 6.0 \text{ mol H}_2\text{O}(\text{g})$$

**Check Your Solution**

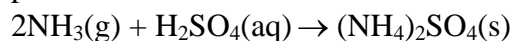
a) The balanced equation represents the mol ratio between all of the components.

b) The mole ratio  $\frac{n(\text{NH}_3(\text{g}))}{n(\text{NH}_2\text{CONH}_2(\text{s}))} = \frac{2.60}{1.30} = \frac{2}{1}$ .

c) The mole ratio  $\frac{n(\text{H}_2\text{O}(\text{g}))}{n(\text{CO}_2(\text{g}))} = \frac{6.0}{6.0} = \frac{1}{1}$ .

**5.****Problem**

The fertilizer ammonium sulfate,  $(\text{NH}_4)_2\text{SO}_4(\text{s})$ , is made at Sherrit International Corporation's plant in Fort Saskatchewan. The following chemical equation shows the reaction:



a) Write the ratio of all the components of the reaction.

b) What amount of ammonia is necessary to prepare 20 000 mol of ammonium sulfate?

c) What amount of ammonium sulfate fertilizer is formed when 3.28 mol of ammonia is consumed in the reaction?

**What is Required?**

a) You must state the mole ratio of all the components in this reaction.

b) You must calculate the number of moles of ammonia needed to prepare 20 000 mol of ammonium sulfate.

c) You need to calculate the number of moles of ammonium sulfate formed when 3.28 mol of  $\text{NH}_3(\text{g})$  is consumed.

**What is Given?**

a) The balanced equation is given.

b) The number of moles of  $(\text{NH}_4)_2\text{SO}_4(\text{s})$  is 20 000 mol.

c) The number of moles of  $\text{NH}_3(\text{g})$  is 3.28 mol.

**Plan Your Strategy**

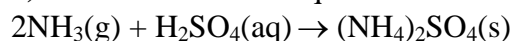
a) The balanced equation gives the mole ratio of the components in the reaction.

b) From the balanced equation, equate the given mole ratio of  $\text{NH}_3(\text{g}):(\text{NH}_4)_2\text{SO}_4(\text{s})$  to the ratio of number of moles given and solve for the number of moles of  $\text{NH}_3(\text{g})$ .

c) From the balanced equation, equate the given mole ratio of  $\text{NH}_3(\text{g}):(\text{NH}_4)_2\text{SO}_4(\text{s})$  to the ratio of number of moles given and solve for the number of moles of  $\text{NH}_3(\text{g})$ .

**Act on Your Strategy**

a) From the balanced equation:





the mole ratio is

2 mol NH<sub>3</sub>(g):1 mol H<sub>2</sub>SO<sub>4</sub>(aq):1 mol (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>(s)

$$\text{b) } \frac{n(\text{NH}_3(\text{g}))}{n((\text{NH}_4)_2\text{SO}_4(\text{s}))} = \frac{2}{1}$$

$$n(\text{NH}_3(\text{g})) = \frac{2 \text{ mol NH}_3(\text{g}) \times 20000 \text{ mol } (\text{NH}_4)_2\text{SO}_4(\text{s})}{1 \text{ mol } (\text{NH}_4)_2\text{SO}_4(\text{s})} = 40\,000 \text{ mol or } 40 \text{ kmol NH}_3(\text{g})$$

$$\text{c) } \frac{n(\text{NH}_3(\text{g}))}{n((\text{NH}_4)_2\text{SO}_4(\text{s}))} = \frac{2}{1}$$

$$n((\text{NH}_4)_2\text{SO}_4(\text{s})) = \frac{1 \text{ mol } (\text{NH}_4)_2\text{SO}_4(\text{s}) \times 3.28 \text{ mol NH}_3(\text{g})}{2 \text{ mol NH}_3(\text{g})} = 1.64 \text{ mol } (\text{NH}_4)_2\text{SO}_4(\text{s})$$

### Check Your Solution

a) The balanced equation represents the mole ratio between all of the components.

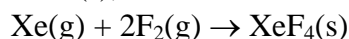
$$\text{b) The mole ratio } \frac{n(\text{NH}_3(\text{g}))}{n((\text{NH}_4)_2\text{SO}_4(\text{s}))} = \frac{40 \text{ kmol}}{20 \text{ kmol}} = \frac{2}{1}.$$

$$\text{c) The mole ratio } \frac{n(\text{NH}_3(\text{g}))}{n((\text{NH}_4)_2\text{SO}_4(\text{s}))} = \frac{3.28 \text{ mol}}{1.64 \text{ mol}} = \frac{2}{1}.$$

## 6.

### Problem

At 400 °C, xenon and fluorine react to produce colourless crystals of xenon tetrafluoride, XeF<sub>4</sub>(s), as shown below:



a) Write the ratio of all the components of the reaction.

b) What amount of F<sub>2</sub>(g) is necessary to prepare 2.35 mol of XeF<sub>4</sub>(s)?

c) What amount of F<sub>2</sub>(g) is required to react with 12.2 mmol of xenon?

(Note: 1 mol = 1000 mmol.)

### What is Required?

a) You must state the mole ratio of all the components in this reaction.

b) You must calculate the number of moles of F<sub>2</sub>(g) needed to prepare 2.35 mol of XeF<sub>4</sub>(s).

c) You need to calculate the number of moles of F<sub>2</sub>(g) needed to react with 12.2 mmol of xenon.

### What is Given?

a) The balanced equation is given.

b) The number of moles of XeF<sub>4</sub>(s) is 2.35 mol.

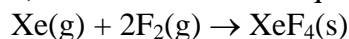
c) The number of moles of xenon is 12.2 mmol.

**Plan Your Strategy**

- a) The balanced equation gives the mole ratio of the components in the reaction.
- b) From the balanced equation, equate the given mole ratio of  $F_2(g):XeF_4(s)$  to the ratio of number of moles given and solve for the number of moles of  $F_2(g)$ .
- c) Convert 12.2 mmol to moles using the factor  $1000 \text{ mmol} = 1 \text{ mol}$ . From the balanced equation, equate the given mole ratio of  $F_2(g):Xe(g)$  to the ratio of number of moles given and solve for the number of moles of  $F_2(g)$ .

**Act on Your Strategy**

- a) From the balanced equation:



The mole ratio is 1 mol  $Xe(g):2 \text{ mol } F_2(g):1 \text{ XeF}_4(s)$ .

$$b) \frac{n(F_2(g))}{n(XeF_4(s))} = \frac{2}{1}$$

$$n(F_2(g)) = \frac{2 \text{ mol } F_2(g) \times 2.35 \text{ mol } XeF_4(s)}{1 \text{ mol } XeF_4(s)} = 4.70 \text{ mol } F_2(g)$$

$$c) 12.2 \text{ mmol } Xe(g) \times \frac{1 \text{ mol}}{1000 \text{ mmol}} = 0.0122 \text{ mol } Xe(g)$$

$$\frac{n(F_2(g))}{n(Xe(g))} = \frac{2}{1}$$

$$n(F_2(g)) = \frac{2 \text{ mol } F_2(g) \times 0.0122 \text{ mol } Xe(g)}{1 \text{ mol } Xe(g)} = 0.0244 \text{ mol or } 24.4 \text{ mmol } F_2(g)$$

**Check Your Solution**

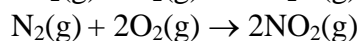
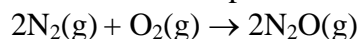
- a) The balanced equation represents the mole ratio between all of the components.

$$b) \text{ The mole ratio } \frac{n(F_2(g))}{n(Xe(g))} = \frac{4.70 \text{ mol}}{2.35 \text{ mol}} = \frac{2}{1}$$

$$c) \text{ The mole ratio } \frac{n(F_2(g))}{n(Xe(g))} = \frac{0.0244 \text{ mol}}{0.0122 \text{ mol}} = \frac{2}{1}$$

**7.****Problem**

A wide variety of formulas are possible from the reaction of nitrogen with oxygen. The equations below show two possible reactions:



- a) For each equation, write the ratio of all the components of the reaction.

- b) What amount of  $O_2(g)$  reacts with 0.0935 mol of nitrogen to form  $N_2O(g)$ ?  
 c) What amount of  $O_2(g)$  reacts with 93.5 mmol of nitrogen to form  $NO_2(g)$ ? (**Note:** 1 mol = 1000 mmol.)

### What is Required?

- a) You must state the mole ratio of all the components in each reaction.  
 b) You must calculate the number of moles of  $O_2(g)$  needed to react 0.0935 mol of  $N_2(g)$  to form  $N_2O(g)$ .  
 c) You must calculate the number of moles of  $O_2(g)$  needed to react 93.5 mmol of  $N_2(g)$  to form  $NO_2(g)$ .

### What is Given?

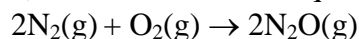
- a) The balanced equation is given.  
 b) The number of moles of  $N_2(g)$  is 0.0935 mol.  
 c) The number of millimoles of  $N_2(g)$  is 93.5 mmol.

### Plan Your Strategy

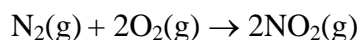
- a) The balanced equation gives the mole ratio of the components in each reaction.  
 b) From the balanced equation, equate the given mole ratio of  $O_2(g):N_2(g)$  to the ratio of number of moles given and solve for the number of moles of  $O_2(g)$ .  
 c) Convert 93.5 mmol to moles using the conversion factor 1 mol = 1000 mmol. From the balanced equation, equate the given mole ratio of  $O_2(g):N_2(g)$  to the ratio of number of moles given and solve for the number of moles of  $O_2(g)$ .

### Act on Your Strategy

- a) From the balanced equations:



The mole ratio is 2 mol  $N_2(g)$ :1 mol  $O_2(g)$ :2 mol  $N_2O(g)$



The mole ratio is 1 mol  $N_2(g)$ :2 mol  $O_2(g)$ :2 mol  $NO_2(g)$

$$\text{b) } \frac{n(O_2(g))}{n(N_2(g))} = \frac{1}{2}$$

$$n(O_2) = \frac{1 \text{ mol } O_2(g) \times 0.0935 \text{ mol } N_2(g)}{2 \text{ mol } N_2(g)} = 0.0468 \text{ mol } O_2(g)$$

$$\text{c) } 93.5 \text{ mmol } N_2(g) \times \frac{1 \text{ mol}}{1000 \text{ mmol}} = 0.0935 \text{ mol } N_2(g)$$

$$\frac{n(O_2(g))}{n(N_2(g))} = \frac{2}{1}$$

$$n(\text{O}_2(\text{g})) = \frac{2 \text{ mol O}_2(\text{g}) \times 0.0935 \text{ mol N}_2(\text{g})}{1 \text{ mol N}_2(\text{g})} = 0.187 \text{ mol or } 187 \text{ mmol O}_2(\text{g})$$

**Check Your Solution**

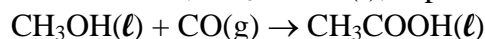
a) The balanced equation represents the mole ratio between all of the components.

b) The mole ratio  $\frac{n(\text{O}_2(\text{g}))}{n(\text{N}_2(\text{g}))} = \frac{0.0468 \text{ mol}}{0.0935 \text{ mol}} = \frac{1}{2}$ .

c) The mole ratio  $\frac{n(\text{O}_2(\text{g}))}{n(\text{N}_2(\text{g}))} = \frac{0.187 \text{ mol}}{0.0935 \text{ mol}} = \frac{2}{1}$ .

**8.****Problem**

Ethanoic acid,  $\text{CH}_3\text{COOH}(\ell)$ , is produced according to the following chemical equation:



Calculate the mass of ethanoic that would be produced by the reaction of  $6.0 \times 10^4$  g of  $\text{CO}(\text{g})$  with sufficient  $\text{CH}_3\text{OH}(\ell)$ .

**What is Required?**

You need to calculate the mass of  $\text{CH}_3\text{COOH}(\ell)$  that can be produced from the reaction of  $6.0 \times 10^4$  g of  $\text{CO}(\text{g})$  with methanol.

**What is Given?**

The balanced equation for the reaction and the mass of  $\text{CO}(\text{g})$  are given.

**Plan Your Strategy**

Determine the molar mass,  $M$ , of  $\text{CO}(\text{g})$ .

Calculate the number of moles,  $n$ , of  $\text{CO}(\text{g})$  using the equation  $n = \frac{m}{M}$ .

Use the mole ratio in the balanced equation to calculate the moles of  $\text{CH}_3\text{COOH}(\ell)$ .

Determine the molar mass,  $M$ , of  $\text{CH}_3\text{COOH}(\ell)$ .

Calculate the mass,  $m$ , of  $\text{CH}_3\text{COOH}(\ell)$  using the equation  $m = n \times M$ .

**Act on Your Strategy**

$$M_{\text{CO}(\text{g})} = 28.01 \frac{\text{g}}{\text{mol}}$$

$$n_{\text{CO}(\text{g})} = \frac{m}{M} = \frac{6.0 \times 10^4 \text{ g}}{28.01 \frac{\text{g}}{\text{mol}}} = 2.142 \times 10^3 \text{ mol}$$

From the balanced equation, the mole ratio  $\frac{n(\text{CO}(\text{g}))}{n(\text{CH}_3\text{COOH}(\ell))} = \frac{1}{1}$

$$2.142 \times 10^3 \text{ mol CO(g)} \times \frac{1 \text{ mol CH}_3\text{COOH(l)}}{1 \text{ mol CO(g)}} = 2.142 \times 10^3 \text{ mol CH}_3\text{COOH(l)}$$

$$M_{\text{CH}_3\text{COOH(l)}} = 60.06 \frac{\text{g}}{\text{mol}}$$

$$m_{\text{CH}_3\text{COOH(l)}} = n \times M = 2.142 \times 10^3 \text{ mol} \times 60.06 \frac{\text{g}}{\text{mol}} = 1.3 \times 10^5 \text{ g}$$

### Check Your Solution

The answer seems reasonable, has the correct units (g or kg) and the correct number of significant digits (2).

## 9.

### Problem

For the following chemical reaction:



Calculate the mass of sodium chloride that must react with water to provide 400 kg of sodium hydroxide.

### What is Required?

You must calculate the mass of NaCl(s) that is needed to produce 400 kg of NaOH(s).

### What is Given?

The balanced equation for the reaction and the mass of NaOH(s) are given.

### Plan Your Strategy

Determine the molar mass,  $M$ , of NaOH(s).

Convert the 400 kg of NaOH(s) to grams using the relationship  $1000 \text{ g} = 1 \text{ kg}$

Calculate the number of moles,  $n$ , of NaOH(s) using the equation  $n = \frac{m}{M}$ .

Use the mole ratio in the balanced equation to calculate the moles of NaCl(s).

Determine the molar mass,  $M$ , of NaCl(s).

Calculate the mass,  $m$ , of NaOH(s) using the equation  $m = n \times M$ .

### Act on Your Strategy

$$M_{\text{NaOH(s)}} = 40.00 \frac{\text{g}}{\text{mol}}$$

$$400 \text{ kg} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 4.0 \times 10^5 \text{ g}$$

$$n_{\text{NaOH(s)}} = \frac{m}{M} = \frac{4.0 \times 10^5 \text{ g}}{40.00 \frac{\text{g}}{\text{mol}}} = 1.00 \times 10^4 \text{ mol}$$

From the balanced equation, the mole ratio  $\frac{n(\text{NaOH(s)})}{n(\text{NaCl(s)})} = \frac{2}{2}$

$$1.00 \times 10^4 \text{ mol NaOH(s)} \times \frac{2 \text{ mol NaCl(s)}}{2 \text{ mol NaOH(s)}} = 1.00 \times 10^4 \text{ mol NaCl(s)}$$

$$M_{\text{NaCl(s)}} = 58.44 \frac{\text{g}}{\text{mol}}$$

$$m_{\text{NaCl(s)}} = n \times M = 1.0 \times 10^4 \text{ mol} \times 58.44 \frac{\text{g}}{\text{mol}} = 5.84 \times 10^5 \text{ g} = 5.84 \times 10^2 \text{ kg}$$

### Check Your Solution

The answer seems reasonable, has the correct units (g or kg) and the correct number of significant digits (3).

## 10.

### Problem

As an experiment, a student performed a single replacement reaction by dipping a strip of copper metal, Cu(s), into an aqueous solution of silver nitrate, AgNO<sub>3</sub>(aq), to produce silver, Ag(s).

- Write the balanced equation for this reaction.
- Calculate the mass of Ag(s) that would be produced if the copper strip had a mass of 1.00 g and was completely consumed in the reaction.

### What is Required?

- You must write the balanced equation for this reaction.
- You must calculate the mass of silver that is produced from the reaction of 1.00 g of copper metal with an aqueous solution of silver nitrate.

### What is Given?

- The reactants are copper metal and aqueous silver nitrate and a single replacement reaction occurs.
- The mass of copper is 1.00 g.

### Plan Your Strategy

- Write the balanced equation for the single replacement reaction that occurs between copper metal and aqueous silver nitrate.
- Determine the molar mass,  $M$ , of Cu(s).

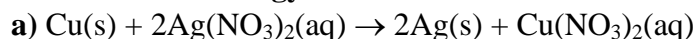
Calculate the number of moles,  $n$ , of Cu(s) using the equation  $n = \frac{m}{M}$ .

Use the mole ratio in the balanced equation to calculate the moles of Ag(s).

Determine the molar mass,  $M$ , of Ag(s).

Calculate the mass,  $m$ , of Ag(s) using the equation  $m = n \times M$ .

### Act on Your Strategy



$$\text{b) } M_{\text{Cu(s)}} = 63.55 \frac{\text{g}}{\text{mol}}$$

$$n_{\text{Cu(s)}} = \frac{m}{M} = \frac{1.00 \text{ g}}{63.55 \frac{\text{g}}{\text{mol}}} = 0.01574 \text{ mol}$$

From the balanced equation, the mole ratio  $\frac{n(\text{Ag(s)})}{n(\text{Cu(s)})} = \frac{2}{1}$

$$0.01574 \text{ mol Cu(s)} \times \frac{2 \text{ mol Ag(s)}}{1 \text{ mol Cu(s)}} = 0.03148 \text{ mol Ag(s)}$$

$$M_{\text{Ag(s)}} = 107.87 \frac{\text{g}}{\text{mol}}$$

$$m_{\text{Ag(s)}} = n \times M = 0.03148 \text{ mol} \times 107.87 \frac{\text{g}}{\text{mol}} = 3.39 \text{ g Ag(s)}$$

### Check Your Solution

The answer seems reasonable, has the correct units (g) and the correct number of significant digits (3).

## 11.

### Problem

At a cement plant in Edmonton, limestone,  $\text{CaCO}_3(\text{s})$ , decomposes into calcium oxide,  $\text{CaO}(\text{s})$  (lime), and carbon dioxide,  $\text{CO}_2(\text{g})$ , when it is heated to about  $900^\circ\text{C}$ . Calculate the mass of lime that would be produced by heating 200 g of limestone to  $900^\circ\text{C}$ .

### What is Required?

You must calculate the mass of  $\text{CaO}(\text{s})$  that is produced when 200 g of limestone,  $\text{CaCO}_3(\text{s})$ , decomposes.

### What is Given?

The names of the reactants and products are given and the mass of limestone is given.

### Plan Your Strategy

Write the balanced equation for the decomposition of  $\text{CaCO}_3(\text{s})$ .

Determine the molar mass,  $M$ , of  $\text{CaCO}_3(\text{s})$ .

Calculate the number of moles,  $n$ , of  $\text{CaCO}_3(\text{s})$  using the equation  $n = \frac{m}{M}$ .

Use the mole ratio in the balanced equation to calculate the moles of  $\text{CaO}(\text{s})$ .

Determine the molar mass,  $M$ , of  $\text{CaO}(\text{s})$ .

Calculate the mass,  $m$ , of  $\text{CaO}(\text{s})$  using the equation  $m = n \times M$ .

**Act on Your Strategy**

$$M_{\text{CaCO}_3(\text{s})} = 100.09 \frac{\text{g}}{\text{mol}}$$

$$n_{\text{CaCO}_3(\text{s})} = \frac{m}{M} = \frac{200 \text{ g}}{100.09 \frac{\text{g}}{\text{mol}}} = 1.998 \text{ mol}$$

From the balanced equation, the mole ratio  $\frac{n(\text{CaO}(\text{s}))}{n(\text{CaCO}_3(\text{s}))} = \frac{1}{1}$

$$1.998 \text{ mol CaCO}_3(\text{s}) \times \frac{1 \text{ mol CaO}(\text{s})}{1 \text{ mol CaCO}_3(\text{s})} = 1.998 \text{ mol CaO}(\text{s})$$

$$M_{\text{CaO}(\text{s})} = 56.08 \frac{\text{g}}{\text{mol}}$$

$$m_{\text{CaO}(\text{s})} = n \times M = 1.998 \text{ mol} \times 56.08 \frac{\text{g}}{\text{mol}} = 112 \text{ g CaO}(\text{s})$$

**Check Your Solution**

The answer seems reasonable, has the correct units (g) and the correct number of significant digits (3).

**12.****Problem**

What mass of magnesium oxide,  $\text{MgO}(\text{s})$ , would be produced by the reaction of 4.86 g of magnesium metal,  $\text{Mg}(\text{s})$ , in a copious supply of oxygen gas,  $\text{O}_2(\text{g})$ ?

**What is Required?**

You must calculate the mass of  $\text{MgO}(\text{s})$  that is produced when 4.86 g of magnesium metal,  $\text{Mg}(\text{s})$ , reacts with oxygen.

**What is Given?**

The reactants and products are given, and the mass of magnesium is given.

**Plan Your Strategy**

Write the balanced equation for the formation of  $\text{MgO}(\text{s})$ .

Determine the molar mass,  $M$ , of  $\text{Mg}(\text{s})$ .

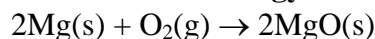
Calculate the number of moles,  $n$ , of  $\text{Mg}(\text{s})$  using the equation  $n = \frac{m}{M}$ .

Use the mole ratio in the balanced equation to calculate the moles of  $\text{MgO}(\text{s})$ .

Determine the molar mass,  $M$ , of  $\text{MgO}(\text{s})$ .

Calculate the mass,  $m$ , of  $\text{MgO}(\text{s})$  using the equation  $m = n \times M$ .



**Act on Your Strategy**

$$M \text{ Mg(s)} = 24.31 \frac{\text{g}}{\text{mol}}$$

$$n\text{Mg(s)} = \frac{m}{M} = \frac{4.86\text{g}}{24.31 \frac{\text{g}}{\text{mol}}} = 0.1999 \text{ mol}$$

From the balanced equation, the mole ratio  $\frac{n(\text{MgO(s)})}{n(\text{Mg(s)})} = \frac{1}{1}$

$$0.1999 \text{ mol Mg(s)} \times \frac{1 \text{ mol MgO(s)}}{1 \text{ mol Mg(s)}} = 0.1999 \text{ mol MgO(s)}$$

$$M\text{MgO(s)} = 40.31 \frac{\text{g}}{\text{mol}}$$

$$m\text{MgO(s)} = n \times M = 0.1999 \text{ mol} \times 40.31 \frac{\text{g}}{\text{mol}} = 8.06 \text{ g MgO(s)}$$

**Check Your Solution**

The answer seems reasonable, has the correct units (g) and the correct number of significant digits (3).

**13.****Problem**

Calculate the mass of liquid metal element produced by the decomposition of a 23.3 g mass of mercury(II) sulfide.

**What is Required?**

You must calculate the mass of Hg( $\ell$ ) that is produced when 23.3 g of mercury(II) sulfide(s) decomposes.

**What is Given?**

You know that mercury(II) sulfide decomposes into its elements, mercury and sulfur, and the mass of mercury(II) sulfide is 23.3 g.

**Plan Your Strategy**

Write the chemical formula for mercury(II) sulfide and the balanced equation for its decomposition.

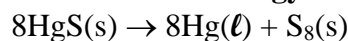
Determine the molar mass,  $M$ , of mercury(II) sulfide.

Calculate the number of moles,  $n$ , of mercury(II) sulfide using the equation  $n = \frac{m}{M}$ .

Use the mole ratio in the balanced equation to calculate the moles of mercury.

Determine the molar mass,  $M$ , of mercury.

Calculate the mass,  $m$ , of mercury using the equation  $m = n \times M$ .

**Act on Your Strategy**

$$M_{\text{HgS}(\text{s})} = 232.66 \frac{\text{g}}{\text{mol}}$$

$$n_{\text{HgS}(\text{s})} = \frac{m}{M} = \frac{23.3 \text{ g}}{232.66 \frac{\text{g}}{\text{mol}}} = 0.10015 \text{ mol}$$

From the balanced equation, the mole ratio  $\frac{n(\text{Hg}(\ell))}{n(\text{HgS}(\text{s}))} = \frac{8}{8}$

$$0.10015 \text{ mol HgS}(\text{s}) \times \frac{8 \text{ mol Hg}(\ell)}{8 \text{ mol HgS}(\text{s})} = 0.10015 \text{ mol Hg}(\ell)$$

$$M_{\text{Hg}(\ell)} = 200.59 \frac{\text{g}}{\text{mol}}$$

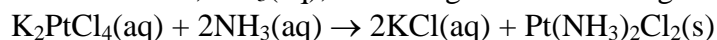
$$m_{\text{Hg}(\ell)} = n \times M = 0.10015 \text{ mol Hg}(\ell) \times 200.59 \frac{\text{g}}{\text{mol}} = 20.1 \text{ g Hg}(\ell)$$

**Check Your Solution**

The answer seems reasonable, has the correct units (g) and the correct number of significant digits (3).

**14.****Problem**

The compound cisplatin,  $\text{Pt}(\text{NH}_3)_2\text{Cl}_2(\text{s})$ , is commonly administered in combination with other chemotherapy drugs to treat cancers of the reproductive tracts, head, neck, bladder, esophagus, and lung. Cisplatin is prepared from potassium tetrachloroplatinate,  $\text{K}_2\text{PtCl}_4(\text{aq})$ , by reaction with ammonia,  $\text{NH}_3(\text{aq})$ , according to the following reaction:



What mass of cisplatin would result from the reaction of 55.8 g of  $\text{K}_2\text{PtCl}_4(\text{aq})$  in aqueous solution?

**What is Required?**

You must calculate the mass of cisplatin,  $\text{Pt}(\text{NH}_3)_2\text{Cl}_2(\text{s})$ , that is produced when 55.8 g of potassium tetrachloroplatinate,  $\text{K}_2\text{PtCl}_4(\text{aq})$ , react with ammonia,  $\text{NH}_3(\text{aq})$ .

**What is Given?**

The balanced equation for the reaction and the mass of  $\text{K}_2\text{PtCl}_4$  are given.

**Plan Your Strategy**

Determine the molar mass,  $M$ , of  $\text{K}_2\text{PtCl}_4$ .

Calculate the number of moles,  $n$ , of  $\text{K}_2\text{PtCl}_4$  using the equation  $n = \frac{m}{M}$ .

Use the mole ratio in the balanced equation to calculate the moles of  $\text{Pt}(\text{NH}_3)_2\text{Cl}_2$ .

Determine the molar mass,  $M$ , of  $\text{Pt}(\text{NH}_3)_2\text{Cl}_2(\text{s})$ .

Calculate the mass,  $m$ , of  $\text{Pt}(\text{NH}_3)_2\text{Cl}_2(\text{s})$  using the equation  $m = n \times M$ .

**Act on Your Strategy**

$$MK_2PtCl_4(aq) = 415.08 \frac{\text{g}}{\text{mol}}$$

$$nK_2PtCl_4(aq) = \frac{m}{M} = \frac{55.8\text{g}}{415.08 \frac{\text{g}}{\text{mol}}} = 0.1344 \text{ mol}$$

From the balanced equation, the mole ratio  $\frac{n(\text{Pt}(\text{NH}_3)_2\text{Cl}_2(s))}{n(\text{K}_2\text{PtCl}_4(aq))} = \frac{1}{1}$

$$0.1344 \text{ mol } K_2PtCl_4(aq) \times \frac{1 \text{ mol } \text{Pt}(\text{NH}_3)_2\text{Cl}_2(s)}{1 \text{ mol } K_2PtCl_4(aq)} = 0.1344 \text{ mol } \text{Pt}(\text{NH}_3)_2\text{Cl}_2(s)$$

$$MPt(\text{NH}_3)_2\text{Cl}_2(s) = 300.06 \frac{\text{g}}{\text{mol}}$$

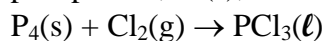
$$mPt(\text{NH}_3)_2\text{Cl}_2(s) = n \times M = 0.1344 \text{ mol } \text{Pt}(\text{NH}_3)_2\text{Cl}_2(s) \times 300.06 \frac{\text{g}}{\text{mol}} = 40.3 \text{ g } \text{Pt}(\text{NH}_3)_2\text{Cl}_2(s)$$

**Check Your Solution**

The answer seems reasonable, has the correct units (g), and the correct number of significant digits (3).

**15.****Problem**

The molecular compound phosphorus trichloride,  $\text{PCl}_3(\ell)$ , is a commercially important compound used in the manufacture of pesticides. It is prepared by the direct combination of phosphorus,  $\text{P}_4(s)$ , and chlorine,  $\text{Cl}_2(g)$ , according to the following *unbalanced* reaction equation:



What mass of  $\text{PCl}_3(\ell)$  forms when 323 g of  $\text{Cl}_2(g)$  reacts completely with  $\text{P}_4(s)$ ?

**What is Required?**

You must balance the equation for the reaction and calculate the mass of  $\text{PCl}_3(\ell)$  that can be produced when 323 g of chlorine gas,  $\text{Cl}_2(g)$ , react.

**What is Given?**

The unbalanced equation and the mass of chlorine are given.

**Plan Your Strategy**

Balance the equation.

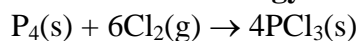
Determine the molar mass,  $M$ , of  $\text{Cl}_2(g)$ .

Calculate the number of moles,  $n$ , of  $\text{Cl}_2(g)$  using the equation  $n = \frac{m}{M}$ .

Use the mole ratio in the balanced equation to calculate the moles of  $\text{PCl}_3(\ell)$ .

Determine the molar mass,  $M$ , of  $\text{PCl}_3(\ell)$ .

Calculate the mass,  $m$ , of  $\text{PCl}_3(\ell)$  using the equation  $m = n \times M$ .

**Act on Your Strategy**

$$M_{\text{Cl}_2(\text{g})} = 70.9 \frac{\text{g}}{\text{mol}}$$

$$n_{\text{Cl}_2(\text{g})} = \frac{m}{M} = \frac{323 \text{ g}}{70.9 \frac{\text{g}}{\text{mol}}} = 4.556 \text{ mol}$$

From the balanced equation, the mole ratio  $\frac{n(\text{PCl}_3(\text{s}))}{n(\text{Cl}_2(\text{g}))} = \frac{4}{6}$

$$4.556 \text{ mol Cl}_2(\text{g}) \times \frac{4 \text{ mol PCl}_3(\text{s})}{6 \text{ mol Cl}_2(\text{g})} = 3.037 \text{ mol PCl}_3(\ell)$$

$$M_{\text{PCl}_3(\ell)} = 137.32 \frac{\text{g}}{\text{mol}}$$

$$m_{\text{PCl}_3(\ell)} = n \times M = 3.037 \text{ mol PCl}_3(\ell) \times 137.32 \frac{\text{g}}{\text{mol}} = 417 \text{ g PCl}_3(\ell)$$

**Check Your Solution**

The answer seems reasonable, has the correct units (g) and the correct number of significant digits (3).

**16.****Problem**

What minimum volume of  $0.50 \frac{\text{mol}}{\text{L}}$  aqueous magnesium chloride do you need to add to 60 mL of  $0.30 \frac{\text{mol}}{\text{L}}$  aqueous silver nitrate in order to remove all the chloride ions?

**What is Required?**

You must calculate the volume of  $\text{MgCl}_2(\text{aq})$  that will precipitate the  $\text{Cl}^-(\text{aq})$  from a given volume of  $0.30 \frac{\text{mol}}{\text{L}}$  silver nitrate solution.

**What is Given?**

$$c_{\text{MgCl}_2(\text{aq})} = 0.50 \frac{\text{mol}}{\text{L}}$$

$$c_{\text{AgNO}_3(\text{aq})} = 0.30 \frac{\text{mol}}{\text{L}}$$

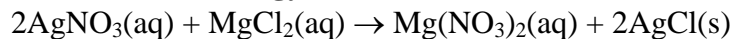
$$V_{\text{AgNO}_3(\text{aq})} = 60 \text{ mL} = 0.060 \text{ L}$$

**Plan Your Strategy**

Write the balanced non-ionic equation for the reaction. Use the equation  $n = c \times V$  to calculate the number of moles,  $n$ , of  $\text{AgNO}_3(\text{aq})$ . Use the mole ratio from the balanced equation to

calculate the number of moles of  $\text{MgCl}_2(\text{aq})$  that will react. Calculate the volume of  $\text{MgCl}_2(\text{aq})$  using the equation  $V = \frac{n}{c}$ .

### Act on Your Strategy



$$n\text{AgNO}_3(\text{aq}) = c \times V = 0.30 \frac{\text{mol}}{\text{L}} \times 0.060 \text{ L} = 0.018 \text{ mol}$$

$$n\text{MgCl}_2(\text{aq}) = 0.018 \text{ mol AgNO}_3(\text{aq}) \times \frac{1 \text{ mol MgCl}_2(\text{aq})}{2 \text{ mol AgNO}_3(\text{aq})} = 0.0090 \text{ mol}$$

$$V\text{MgCl}_2(\text{aq}) = \frac{n}{c} = \frac{0.0090 \text{ mol}}{0.50 \frac{\text{mol}}{\text{L}}} = 0.018 \text{ L} = 18 \text{ mL}$$

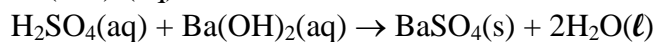
### Check Your Solution

The calculated volume of  $\text{MgCl}_2(\text{aq})$  is reasonable for the given information. The units (mL) and the number of significant digits (2) are correct.

## 17.

### Problem

Sulfuric acid,  $\text{H}_2\text{SO}_4(\text{aq})$ , can be neutralized by reacting it with aqueous barium hydroxide,  $\text{Ba}(\text{OH})_2(\text{aq})$ . The reaction is:



What volume of  $0.676 \frac{\text{mol}}{\text{L}} \text{H}_2\text{SO}_4(\text{aq})$  can be neutralized by  $22.7 \text{ mL}$  of  $0.385 \frac{\text{mol}}{\text{L}}$

$\text{Ba}(\text{OH})_2(\text{aq})$ ?

### What is Required?

You must calculate the volume of  $0.676 \frac{\text{mol}}{\text{L}} \text{H}_2\text{SO}_4(\text{aq})$  that will neutralize  $22.7 \text{ mL}$  of  $0.385$

$\frac{\text{mol}}{\text{L}} \text{Ba}(\text{OH})_2(\text{aq})$ ?

### What is Given?

$$c\text{H}_2\text{SO}_4(\text{aq}) = 0.676 \frac{\text{mol}}{\text{L}}$$

$$c\text{Ba}(\text{OH})_2(\text{aq}) = 0.385 \frac{\text{mol}}{\text{L}}$$

$$V\text{Ba}(\text{OH})_2(\text{aq}) = 22.7 \text{ mL} = 0.0227 \text{ L}$$

**Plan Your Strategy**

Use the equation  $n = c \times V$  to calculate the number of moles ( $n$ ) of  $\text{Ba}(\text{OH})_2(\text{aq})$ . Use the mole ratio from the balanced equation to calculate the number of moles of  $\text{H}_2\text{SO}_4(\text{aq})$  that will react.

Calculate the volume of  $\text{H}_2\text{SO}_4(\text{aq})$  using the equation  $V = \frac{n}{c}$ .

**Act on Your Strategy**

$$n_{\text{Ba}(\text{OH})_2(\text{aq})} = c \times V = 0.385 \frac{\text{mol}}{\text{L}} \times 0.0227 \text{ L} = 0.008740 \text{ mol}$$

$$n_{\text{H}_2\text{SO}_4(\text{aq})} = 0.008740 \text{ mol Ba}(\text{OH})_2(\text{aq}) \times \frac{1 \text{ mol H}_2\text{SO}_4(\text{aq})}{1 \text{ mol Ba}(\text{OH})_2(\text{aq})} = 0.008740 \text{ mol H}_2\text{SO}_4(\text{aq})$$

$$V_{\text{H}_2\text{SO}_4(\text{aq})} = \frac{n}{c} = \frac{0.008740 \text{ mol}}{0.676 \frac{\text{mol}}{\text{L}}} = 0.0129 \text{ L} = 12.9 \text{ mL}$$

**Check Your Solution**

The calculated volume of  $\text{H}_2\text{SO}_4(\text{aq})$  is reasonable for the given information. The units (mL) and the number of significant digits (3) are correct.

**18.****Problem**

When solutions of lead(II) nitrate and sodium iodide are mixed, a bright yellow precipitate appears.

a) Write the complete balanced equation for this double replacement reaction.

b) What volume of  $0.125 \frac{\text{mol}}{\text{L}} \text{NaI}(\text{aq})$  is necessary to precipitate all the aqueous lead(II) ions in

25.0 mL of  $0.100 \frac{\text{mol}}{\text{L}} \text{Pb}(\text{NO}_3)_2(\text{aq})$ ?

c) What mass of precipitate is formed in this reaction?

(Hint: Use  $m_{\text{given}} = n_{\text{given}} \times M_{\text{given}}$ )

**What is Required?**

a) You must write the complete balanced equation for the double replacement reaction between aqueous solutions of sodium iodide and lead(II) nitrate.

b) You must calculate the volume of  $0.125 \frac{\text{mol}}{\text{L}} \text{NaI}(\text{aq})$  that will react with 25.0 mL of  $0.100$

$\frac{\text{mol}}{\text{L}} \text{Pb}(\text{NO}_3)_2(\text{aq})$ .

c) You must calculate the mass of precipitate that forms in this reaction.

**What is Given?**

$$c_{\text{NaI}(\text{aq})} = 0.125 \frac{\text{mol}}{\text{L}}$$

$$c_{\text{Pb(NO}_3)_2(\text{aq})} = 0.100 \frac{\text{mol}}{\text{L}}$$

$$V_{\text{Pb(NO}_3)_2(\text{aq})} = 25.0 \text{ mL} = 0.0250 \text{ L}$$

### Plan Your Strategy

a) Write the balanced non-ionic equation for the reaction.

b) Use the equation  $n = c \times V$  to calculate the number of moles,  $n$ , of  $\text{Pb(NO}_3)_2(\text{aq})$ . Use the mole ratio from the balanced equation to calculate the number of moles of  $\text{NaI}(\text{aq})$  that will react.

Calculate the volume of  $\text{NaI}(\text{aq})$  using the equation  $V = \frac{n}{c}$ .

c) Determine the molar mass,  $M$ , of  $\text{PbI}_2(\text{s})$ .

Use the mole ratio from the balanced equation to determine the number of moles of  $\text{PbI}_2(\text{s})$ .

Calculate the mass of  $\text{PbI}_2(\text{s})$  using the equation  $m = n \times M$

### Act on Your Strategy

a)  $2 \text{ NaI}(\text{aq}) + \text{Pb(NO}_3)_2(\text{aq}) \rightarrow 2 \text{ NaNO}_3(\text{aq}) + \text{PbI}_2(\text{s})$

b) The precipitate is lead(II) iodide ( $\text{PbI}_2$ ).

$$n_{\text{Pb(NO}_3)_2(\text{aq})} = c \times V = 0.100 \frac{\text{mol}}{\text{L}} \times 0.0250 \text{ L} = 0.00250 \text{ mol}$$

$$n_{\text{NaI}(\text{aq})} = 0.00250 \text{ mol Pb(NO}_3)_2(\text{aq}) \times \frac{2 \text{ mol NaI}(\text{aq})}{1 \text{ mol Pb(NO}_3)_2(\text{aq})} = 0.00500 \text{ mol NaI}(\text{aq})$$

$$V_{\text{NaI}(\text{aq})} = \frac{n}{c} = \frac{0.00500 \text{ mol}}{0.125 \frac{\text{mol}}{\text{L}}} = 0.0400 \text{ L} = 40.0 \text{ mL}$$

$$\text{c) } n_{\text{PbI}_2(\text{s})} = 0.00250 \text{ mol Pb(NO}_3)_2(\text{aq}) \times \frac{1 \text{ mol PbI}_2(\text{s})}{1 \text{ mol Pb(NO}_3)_2(\text{aq})} = 0.00250 \text{ mol}$$

$$M(\text{PbI}_2) = 461.00 \frac{\text{g}}{\text{mol}}$$

$$m(\text{PbI}_2) = n \times M = 0.00250 \text{ mol} \times 461.00 \frac{\text{g}}{\text{mol}} = 1.15 \text{ g}$$

### Check Your Solution

b) The calculated volume of  $\text{NaI}(\text{aq})$  is reasonable for the given information. The units (mL) and the number of significant digits (3) are correct.

c) The unit for mass is correct (g) and the number of significant digits is correct (3).

## 19.

### Problem

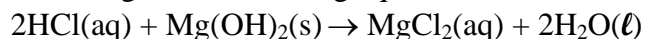
The cells lining your stomach secrete hydrochloric acid, with a typical concentration of  $0.030 \frac{\text{mol}}{\text{L}}$   $\text{HCl}(\text{aq})$ . Antacid tablets are used to help relieve the pain of heartburn, caused by excess

stomach acid irritating the lining of the esophagus just above your stomach. One Brand X antacid tablet contains 500 mg of  $\text{CaCO}_3(\text{s})$  and 110 mg of  $\text{Mg(OH)}_2(\text{s})$ .

**a)** Calculate the volume of stomach acid neutralized by the  $\text{CaCO}_3(\text{s})$  in one Brand X antacid tablet according to the following equation:



**b)** Calculate the volume of stomach acid neutralized by the  $\text{Mg}(\text{OH})_2(\text{s})$  in one Brand X tablet according to the following equation:



**c)** What total volume of stomach acid is neutralized by one Brand X antacid tablet?

### What is Required?

**a)** You must calculate the volume of stomach acid that can be neutralized by the  $\text{CaCO}_3(\text{s})$  in an antacid tablet.

**b)** You must calculate the volume of stomach acid that can be neutralized by the  $\text{Mg}(\text{OH})_2(\text{s})$  in an antacid tablet.

**c)** You must calculate the total volume of stomach acid that can be neutralized by an antacid tablet.

### What is Given?

**a)** The balanced equation is given.

$$m(\text{CaCO}_3(\text{s})) = 500 \text{ mg}$$

$$c(\text{HCl}(\text{aq})) = 0.030 \frac{\text{mol}}{\text{L}}$$

**b)** The balanced equation is given.

$$m(\text{Mg}(\text{OH})_2(\text{s})) = 110 \text{ mg}$$

### Plan Your Strategy

**a)** Determine the molar mass,  $M$ , of  $\text{CaCO}_3(\text{s})$ . Change the 500 mg to grams (1000 mg = 1 g) and calculate the number of moles of  $\text{CaCO}_3(\text{s})$  using the equation  $n = \frac{m}{M}$ .

Use the mole ratio from the balanced equation to calculate the number of moles of  $\text{HCl}(\text{aq})$  that will react with the calculated number of moles of  $\text{CaCO}_3(\text{s})$ . Calculate the volume of  $\text{HCl}(\text{aq})$

that will contain this number of moles of  $\text{HCl}(\text{aq})$  using the equation  $V = \frac{n}{c}$ .

**b)** Determine the molar mass,  $M$ , of  $\text{Mg}(\text{OH})_2(\text{s})$ . Change the 110 mg to grams (1000 mg = 1 g) and calculate the number of moles of  $\text{Mg}(\text{OH})_2(\text{s})$  using the equation  $n = \frac{m}{M}$ .

Use the mole ratio from the balanced equation to calculate the number of moles of  $\text{HCl}(\text{aq})$  that will react with the calculated number of moles of  $\text{Mg}(\text{OH})_2(\text{s})$ . Calculate the volume of  $\text{HCl}(\text{aq})$

that will contain this number of moles of  $\text{HCl}(\text{aq})$  using the equation  $V = \frac{n}{c}$ .

**c)** Add together the answers from parts **a)** & **b)**.

### Act on Your Strategy

**a)**  $M(\text{CaCO}_3) = 100.09 \frac{\text{g}}{\text{mol}}$



$$n\text{CaCO}_3(\text{s}) = \frac{0.500\text{g}}{100.09\frac{\text{g}}{\text{mol}}} = 0.004996\text{ mol}$$

$$n\text{HCl}(\text{aq}) = 0.004996\text{ mol CaCO}_3(\text{s}) \times \frac{2\text{ mol HCl}(\text{aq})}{1\text{ mol CaCO}_3(\text{s})} = 0.009992\text{ mol}$$

$$V\text{HCl}(\text{aq}) = \frac{n}{c} = \frac{0.009992\text{ mol}}{0.030\frac{\text{mol}}{\text{L}}} = 0.33\text{ L}$$

$$\text{c) } M(\text{Mg}(\text{OH})_2) = 58.33\frac{\text{g}}{\text{mol}}$$

$$n\text{Mg}(\text{OH})_2(\text{s}) = \frac{0.110\text{g}}{58.33\text{g/mol}} = 0.001886\text{ mol}$$

$$n\text{HCl}(\text{aq}) = 0.001886\text{ mol CaCO}_3(\text{s}) \times \frac{2\text{ mol HCl}(\text{aq})}{1\text{ mol Mg}(\text{OH})_2(\text{s})} = 0.003772\text{ mol}$$

$$V\text{HCl}(\text{aq}) = \frac{n}{c} = \frac{0.003772\text{ mol}}{0.030\text{ mol/L}} = 0.13\text{ L}$$

$$\text{c) } V\text{HCl}(\text{aq}) = 0.33\text{ L} + 0.13\text{ L} = 0.46\text{ L}$$

### Check Your Solution

The answers seem reasonable for the given data. The units are correct (L) and the answers have the correct number of significant digits (2).

## 20.

### Problem

For the reaction  $2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{H}_2\text{O}(\text{g})$

- What is the mole ratio of oxygen gas to water vapour?
- What is the volume ratio of hydrogen gas to water vapour?
- Calculate the volume of  $\text{H}_2\text{O}(\text{g})$  produced if 20 L of hydrogen gas reacts with the appropriate amount of oxygen.

### What is Required?

- You must write the mole ratio of  $\text{O}_2(\text{g})$  to  $\text{H}_2\text{O}(\text{g})$ .
- You must write the volume ratio of  $\text{H}_2(\text{g})$  to  $\text{H}_2\text{O}(\text{g})$ .
- You must calculate the volume of  $\text{H}_2\text{O}(\text{g})$  produced from 20 L of  $\text{H}_2(\text{g})$ .

### What is Given?

- & b) The balanced equation is given and all gases are at the same temperature and pressure.
- $V(\text{H}_2(\text{g})) = 20\text{ L}$

### Plan Your Strategy

- & b) Since all the gases are at the same temperature and pressure, the law of combining volumes can be applied.
- Using the mole ratio of  $\text{H}_2(\text{g})$  to  $\text{H}_2\text{O}(\text{g})$ , calculate the volume of  $\text{H}_2\text{O}(\text{g})$ .

**Act on Your Strategy**

$$\text{a) } \frac{n(\text{O}_2(\text{g}))}{n(\text{H}_2\text{O}(\text{g}))} = \frac{1 \text{ mol}}{2 \text{ mol}}$$

$$\text{b) } \frac{V(\text{H}_2(\text{g}))}{V(\text{H}_2\text{O}(\text{g}))} = \frac{2 \text{ L}}{2 \text{ L}}$$

$$\text{c) } \frac{V(\text{H}_2(\text{g}))}{V(\text{H}_2\text{O}(\text{g}))} = \frac{2 \text{ L}}{2 \text{ L}}$$

$$V(\text{H}_2\text{O}(\text{g})) = V(\text{H}_2(\text{g})) \times \frac{2 \text{ L}}{2 \text{ L}} = 20 \text{ L H}_2(\text{g}) \times \frac{2 \text{ L}}{2 \text{ L}} = 20 \text{ L H}_2\text{O}(\text{g})$$

**Check Your Solution**

The answers are consistent with the law of combining volumes and have the correct number of significant digits (2).

**21.****Problem**

Suppose that 12.0 L of nitrogen gas reacts with excess hydrogen gas to make ammonia gas, all at the same temperature and pressure. What volume of ammonia is expected from this reaction?

**What is Required?**

You must determine the volume of ammonia produced in a reaction between hydrogen gas and nitrogen gas.

**What is Given?**

The volume of nitrogen gas is given. Hydrogen gas is in excess.

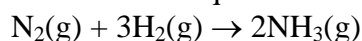
$$V(\text{N}_2(\text{g})) = 12.0 \text{ L}$$

**Plan Your Strategy**

Since all of the gases are at the same temperature and pressure, the law of combining volumes can be applied. Write the balanced equation for this reaction.

**Act on Your Strategy**

The balanced equation is



$$\frac{V(\text{NH}_3(\text{g}))}{V(\text{N}_2(\text{g}))} = \frac{2 \text{ L}}{1 \text{ L}}$$

$$V(\text{NH}_3(\text{g})) = V(\text{N}_2(\text{g})) \times \frac{2 \text{ L}}{1 \text{ L}} = 12.0 \text{ L N}_2(\text{g}) \times \frac{2 \text{ L}}{1 \text{ L}} = 24.0 \text{ L}$$

**Check Your Solution**

The answer is consistent with the law of combining volumes and has the correct number of significant digits (3).

**22.****Problem**

If 15 L of methane gas burns in a hot water heater, what volume of oxygen gas at the same temperature and pressure is required for the methane to undergo complete combustion?

**What is Required?**

You must calculate the volume of oxygen gas required to burn 15 L of methane.

**What is Given?**

$$V(\text{CH}_4(\text{g})) = 15 \text{ L}$$

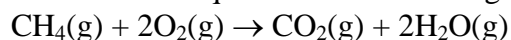
All the gases are at the same temperature and pressure.

**Plan Your Strategy**

Since all of the gases are at the same temperature and pressure, the law of combining volumes can be applied. Write the balanced equation for the complete combustion of methane,  $\text{CH}_4(\text{g})$ , to produce  $\text{CO}_2(\text{g})$  and  $\text{H}_2\text{O}(\text{g})$ .

**Act on Your Strategy**

The balanced equation for the burning of methane is



$$\frac{n(\text{O}_2(\text{g}))}{n(\text{CH}_4(\text{g}))} = \frac{V(\text{O}_2(\text{g}))}{V(\text{CH}_4(\text{g}))} = \frac{2}{1}$$

$$V(\text{O}_2(\text{g})) = V(\text{CH}_4(\text{g})) \times \frac{n(\text{O}_2(\text{g}))}{n(\text{CH}_4(\text{g}))} = 15 \text{ L CH}_4(\text{g}) \times \frac{2 \text{ mol O}_2(\text{g})}{1 \text{ mol CH}_4(\text{g})} = 30 \text{ L}$$

**Check Your Solution**

The volume ratio is the same as the molar ratio and the answer has the correct number of significant digits (2).

**23.****Problem**

In the gas phase, 2.0 L of element A reacts with 1.0 L of element B to make 1.0 L of compound C. All the gases are at the same temperature and pressure.

- Write a balanced chemical equation for this reaction
- Each molecule of element A is actually made of two A atoms—it is really  $\text{A}_2(\text{g})$ . Each molecule of element B is actually made of two B atoms—it is really  $\text{B}_2(\text{g})$ . What is the formula of compound C in terms of A and B atoms?

**What is Required?**

- You must write the balanced equation for this reaction.
- You must predict the chemical formula for the compound C.

**What is Given?**

The ratio by volume in which element A, element B, and compound C are present are given.

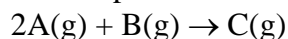
**Plan Your Strategy**

- a) Since all of the gases are at the same temperature and pressure, the law of combining volumes can be applied. The given ratio by volume will be the same as the molar ratio.
- b) For conservation of atoms in the reaction, compound C must have four moles of A atoms and two moles of B atoms.

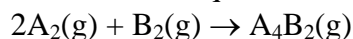
**Act on Your Strategy**

$$\text{a) } \frac{V(\text{A(g)})}{V(\text{B(g)})} = \frac{2\text{ L}}{1\text{ L}} = \frac{n(\text{A(g)})}{n(\text{B(g)})} = \frac{2\text{ mol}}{1\text{ mol}}$$

Based upon this information, the balanced equation is



- b) If elements A and B are diatomic, their chemical formulas are  $\text{A}_2(\text{g})$  and  $\text{B}_2(\text{g})$  respectively. To have conservation of atoms, the chemical formula for compound C will be  $\text{A}_4\text{B}_2(\text{g})$ . The balanced equation should then be

**Check Your Solution**

The answers are consistent with the law of combining volumes.

**24.****Problem**

- a) What is the volume of 2.0 mol of chlorine gas at 75 kPa and 27 °C?
- b) What amount, in moles, of an unknown gas occupies 3.2 L at 16.6 kPa and 127 °C?
- c) What amount, in moles, of  $\text{C}_2\text{F}_6(\text{g})$  occupies 12.5 mL at 600 mmHg pressure and -23 °C? (Note that 760 mmHg pressure is equivalent to 1 atm, or 101.325 kPa.)

**What is Required?**

- a) You must calculate the volume of 2.0 mol of chlorine gas at 75 kPa and 27°C.
- b) You must calculate the number of moles of an unknown gas that occupy 3.2 L at 16.6 kPa and 127 °C.
- c) You must calculate the number of moles of  $\text{C}_2\text{F}_6(\text{g})$  that occupy 12.5 mL at 600 mmHg pressure and -23°C.

**What is Given?**

a)  $n(\text{Cl}_2) = 2.0\text{ mol}$

$$P = 75\text{ kPa}$$

$$t = 27\text{ }^\circ\text{C}$$

b)  $V = 3.2\text{ L}$

$$P = 16.6\text{ kPa}$$

$$t = 127\text{ }^\circ\text{C}$$

c)  $V(\text{C}_2\text{F}_6) = 12.5\text{ mL} = 0.0125\text{ L}$

$$P = 600\text{ mmHg}$$

$$t = -23\text{ }^\circ\text{C}$$

**Plan Your Strategy**

$$T(\text{Kelvin}) = t(\text{Celsius}) + 273.15$$

Use the ideal gas law,  $PV = nRT$ , where  $R = \frac{8.314 \text{ kPa} \cdot \text{L}}{\text{mol} \cdot \text{K}}$ , to solve for the unknown quantity.

### Act on Your Strategy

a)  $T = 27 \text{ }^\circ\text{C} + 273.15 = 300.15 \text{ K}$

$$V = \frac{nRT}{P} = \frac{2.0 \text{ mol} \times \frac{8.314 \text{ kPa} \cdot \text{L}}{\text{mol} \cdot \text{K}} \times 300.15 \text{ K}}{75 \text{ kPa}} = 67 \text{ L}$$

b)  $T = 127 \text{ }^\circ\text{C} + 273.15 = 400.15 \text{ K}$

$$n = \frac{PV}{RT} = \frac{16.6 \text{ kPa} \times 3.2 \text{ L}}{\frac{8.314 \text{ kPa} \cdot \text{L}}{\text{mol} \cdot \text{K}} \times 400.15 \text{ K}} = 0.016 \text{ mol}$$

c)  $T = -23 \text{ }^\circ\text{C} + 273.15 = 250.15 \text{ K}$

$$P = 600 \text{ mmHg} \times \frac{101.325 \text{ kPa}}{760 \text{ mmHg}} = 79.99 \text{ kPa}$$

$$n = \frac{PV}{RT} = \frac{79.99 \text{ kPa} \times 0.0125 \text{ L}}{\frac{8.314 \text{ kPa} \cdot \text{L}}{\text{mol} \cdot \text{K}} \times 250.15 \text{ K}} = 4.8 \times 10^{-4} \text{ mol}$$

### Check Your Solution

The answers are reasonable for the given data, have the correct units and the correct number of significant digits (2).

## 25.

### Problem

Oxygen gas and magnesium react to form 2.43 g of magnesium oxide. What volume of oxygen gas at 94.9 kPa and 25.0 °C would be consumed to produce this mass of MgO(s)?

### What is Required?

You must calculate the volume of oxygen gas that is required to react with magnesium to produce 2.43 g of magnesium oxide.

### What is Given?

The names of the reactants and product are given.

$$m(\text{MgO}) = 2.43 \text{ g}$$

$$t = 25.0 \text{ }^\circ\text{C}$$

$$P = 94.9 \text{ kPa}$$

### Plan Your Strategy

Write the balanced equation for the reaction.

Determine the molar mass,  $M$ , of MgO(s) and convert the mass of MgO(s) to moles using the

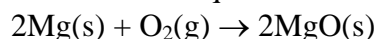
equation  $n = \frac{m}{M}$ . Use the mole ratio from the balanced equation to calculate the number of moles of O<sub>2</sub>(g).

Use the relationship  $T(\text{Kelvin}) = t(\text{Celsius}) + 273.15$  to convert the Celsius temperature to Kelvin.

Use the ideal gas law,  $PV = nRT$ , where  $R = \frac{8.314 \text{ kPa} \cdot \text{L}}{\text{mol} \cdot \text{K}}$  to solve for the volume of  $\text{O}_2(\text{g})$ .

### Act on Your Strategy

The balanced equation is



$$M(\text{MgO}(\text{s})) = 40.31 \frac{\text{g}}{\text{mol}}$$

$$n\text{MgO}(\text{s}) = \frac{2.43 \text{ g}}{40.31 \frac{\text{g}}{\text{mol}}} = 0.06028 \text{ mol}$$

$$n\text{O}_2(\text{g}) = 0.06028 \text{ mol MgO}(\text{s}) \times \frac{1 \text{ mol O}_2(\text{g})}{2 \text{ mol MgO}(\text{s})} = 0.03014 \text{ mol}$$

$$T(\text{Kelvin}) = 25.0 \text{ }^\circ\text{C} + 273.15 = 298.15 \text{ K}$$

$$V = \frac{nRT}{P} = \frac{0.03014 \text{ mol} \times \frac{8.314 \text{ kPa} \cdot \text{L}}{\text{mol} \cdot \text{K}} \times 298.15 \text{ K}}{94.9 \text{ kPa}} = 0.787 \text{ L}$$

### Check Your Solution

The answer is reasonable for the given data, has the correct units (L), and the correct number of significant digits (3).

## 26.

### Problem

A 3070 kg load of coal is 90% carbon by mass. The coal burns to produce carbon dioxide. What volume of carbon dioxide gas is produced at 100 kPa and 25 °C, once it has cooled? (**Hint:** Use the percentage given to determine how much carbon undergoes combustion.)

### What is Required?

You must calculate the volume of carbon dioxide produced from the burning of coal that is 90% carbon.

### What is Given?

$m(\text{coal}) = 3070 \text{ kg}$  and is 90% carbon

$P = 100 \text{ kPa}$

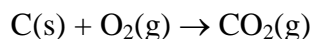
$t = 25^\circ\text{C}$

### Plan Your Strategy

Determine the mass of carbon in the coal, in grams. Write the balanced equation for the reaction and use the mole ratio to determine the number of moles of  $\text{CO}_2(\text{g})$  that is produced. Convert the Celsius temperature to Kelvin and use the ideal gas law to calculate the volume of  $\text{CO}_2(\text{g})$  at the given temperature and pressure.

**Act on Your Strategy**

$$m_{\text{carbon}} = 90\% \times 3070 \text{ kg} = 2763 \text{ kg} = 2.76 \times 10^6 \text{ g}$$



$$M_{\text{C(s)}} = 12.01 \frac{\text{g}}{\text{mol}}$$

$$n_{\text{C(s)}} = \frac{2.76 \times 10^6 \text{ g}}{12.01 \frac{\text{g}}{\text{mol}}} = 2.30 \times 10^5 \text{ mol}$$

$$n_{\text{CO}_2\text{(g)}} = 2.30 \times 10^5 \text{ mol C(s)} \times \frac{1 \text{ mol C(s)}}{1 \text{ mol CO}_2\text{(g)}} = 2.30 \times 10^5 \text{ mol}$$

$$T \text{ (Kelvin)} = 25.0 \text{ }^\circ\text{C} + 273.15 \text{ K} = 298.15 \text{ K}$$

$$V = \frac{nRT}{P} = \frac{2.30 \times 10^5 \text{ mol} \times \frac{8.314 \text{ kPa} \cdot \text{L}}{\text{mol} \cdot \text{K}} \times 298.15 \text{ K}}{100 \text{ kPa}} = 5.7 \times 10^6 \text{ L}$$

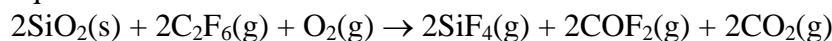
**Check Your Solution**

The answer has the correct units (L) and the correct number of significant digits (2).

27.

**Problem**

In the semiconductor industry, perfluoroethylene,  $\text{C}_2\text{F}_6\text{(g)}$ , is used to remove silicon dioxide,  $\text{SiO}_2\text{(s)}$ , from apparatus as silicon tetrafluoride,  $\text{SiF}_4\text{(g)}$ , according to the following chemical equation:



What mass of  $\text{SiO}_2\text{(s)}$  reacts with 1.270 L of  $\text{C}_2\text{F}_6\text{(g)}$  at a pressure of 0.200 kPa and a temperature of  $400 \text{ }^\circ\text{C}$ ?

**What is Required?**

You must calculate the mass of  $\text{SiO}_2\text{(s)}$  that reacts with 1.270 L of  $\text{C}_2\text{F}_6\text{(g)}$  at a pressure of 0.200 kPa and a temperature of  $400 \text{ }^\circ\text{C}$ .

**What is Given?**

The balanced equation is given.

$$V(\text{C}_2\text{F}_6\text{(g)}) = 1.270 \text{ L}$$

$$P = 0.200 \text{ kPa}$$

$$t = 400 \text{ }^\circ\text{C}$$

**Plan Your Strategy**

Convert the Celsius temperature to Kelvin and use the ideal gas equation to calculate the number of moles of  $\text{C}_2\text{F}_6\text{(g)}$ . Use the mole ratio in the balanced equation to determine the number of moles of  $\text{SiO}_2\text{(s)}$  that react. Determine the molar mass of  $\text{SiO}_2\text{(s)}$  and change the number of moles to grams using the equation  $m = n \times M$ .

**Act on Your Strategy**

$$T \text{ (Kelvin)} = 400 \text{ }^\circ\text{C} + 273.15 = 673.15 \text{ K}$$

$$n_{\text{C}_2\text{F}_6(\text{g})} = \frac{PV}{RT} = \frac{0.200 \text{ kPa} \times 1.270 \text{ L}}{\frac{8.314 \text{ kPa} \cdot \text{L}}{\text{mol} \cdot \text{K}} \times 673.15 \text{ K}} = 4.538 \times 10^{-5} \text{ mol}$$

$$n_{\text{SiO}_2(\text{s})} = 4.538 \times 10^{-5} \text{ mol C}_2\text{F}_6(\text{g}) \times \frac{2 \text{ mol SiO}_2(\text{s})}{2 \text{ mol C}_2\text{F}_6(\text{g})} = 4.538 \times 10^{-5} \text{ mol}$$

$$M(\text{SiO}_2(\text{s})) = 60.09 \frac{\text{g}}{\text{mol}}$$

$$m_{\text{SiO}_2(\text{s})} = 4.538 \times 10^{-5} \text{ mol SiO}_2(\text{s}) \times 60.09 \frac{\text{g}}{\text{mol}} = 2.73 \times 10^{-3} \text{ g SiO}_2(\text{s})$$

**Check Your Solution**

The answer has the correct units (g) and the correct number of significant digits (3).