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:
$CH_4(g) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$

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
$CH_4(g) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$
Compare the number of each type of atom on each side of the equation.
Reactants $\rightarrow$ Products
1C, 4H, 2O $\rightarrow$ 1C, 2H, 3O
Balance the H by putting a 2 in front of $H_2O(g)$.
Balance the O by putting a 2 in front of $O_2(g)$.
The balanced equation is
$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$

Since $CH_4(g)$ is a hydrocarbon and it reacts with $O_2(g)$ to form $CO_2(g)$ and $H_2O(g)$, this is a hydrocarbon combustion reaction.

1. b)
Problem
Balance the following equation and classify the reaction: $P_4(s) + I_2(s) \rightarrow P_2I_4(s)$

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
4P, 2I → 2P, 4I
Balance the P by putting a 2 in front of P_2I_4(s).
Balance the I by putting a 4 in front of I_2(s).
The balanced equation is
$P_4(s) + 4I_2(s) \rightarrow 2P_2I_4(s)$

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:
$Cl_2(g) + CsBr(aq) \rightarrow Br_2(\ell) + CsCl(aq)$

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
$Cl_2(g) + CsBr(aq) \rightarrow Br_2(\ell) + CsCl(aq)$
Compare the number of each type of atom on each side of the equation.
Reactants → Products
2Cl, $1Cs^+$, $1Br^-$ → 2Br, $1Cs^+$, $1Cl^-$
Balance the Cl^- by putting a 2 in front of CsCl(aq).
Balance the Cs^+ and Br^- by putting a 2 in front of CsBr(aq).
The balanced equation is
$Cl_2(g) + 2CsBr(aq) \rightarrow Br_2(\ell) + 2CsCl(aq)$

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:
$Ba(ClO_3)_2(aq) + Na_3PO_4(aq) \rightarrow Ba_3(PO_4)_2(s) + NaClO_3(aq)$

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
$Ba(ClO_3)_2(aq) + Na_3PO_4(aq) \rightarrow Ba_3(PO_4)_2(s) + NaClO_3(aq)$
Compare the number of each type of atom and polyatomic ion on each side of the equation.
Reactants $\rightarrow$ Products
$2ClO_3^-$, $1PO_4^{3-}$, $1Ba^{2+}$, $3Na^+$ $\rightarrow$ $3Ba^{2+}$, $1Na^+$, $1ClO_3^-$, $2PO_4^{3-}$
Balance the Ba^{2+} by putting a 3 in front of $Ba(ClO_3)_2(aq)$.
Balance the Na^+ by putting a 3 in front of $NaClO_3(aq)$.
$3Ba(ClO_3)_2(aq) + Na_3PO_4(aq) \rightarrow Ba_3(PO_4)_2(s) + 3NaClO_3(aq)$

Balance the polyatomic ions by putting a 6 in front of $NaClO_3(aq)$ and a 2 in front of $Na_3(PO_4)(aq)$. This also balances the Na^+.
The balanced equation is
$3Ba(ClO_3)_2(aq) + 2Na_3PO_4(aq) \rightarrow Ba_3(PO_4)_2(s) + 6NaClO_3(aq)$

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:
$Li_3N(s) \rightarrow Li(s) + N_2(g)$

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
$Li_3N(s) \rightarrow Li(s) + N_2(g)$
Compare the number of each type of atom on each side of the equation.
Reactants $\rightarrow$ Products
$3Li^+$, $1N^{3-}$ $\rightarrow$ 1Li, 2N

Balance the N^{3-} by putting a 2 in front of $Li_3N(s)$.
Balance the Li^+ by putting a 6 in front of Li(s).
The balanced equation is
$2Li_3N(s) \rightarrow 6Li(s) + N_2(g)$

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

1. f)
Problem
Balance the following equation and classify the reaction:
$C_6H_{12}O_6(aq) \rightarrow C_2H_5OH(aq) + CO_2(g)$

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
$C_6H_{12}O_6(aq) \rightarrow C_2H_5OH(aq) + CO_2(g)$
Compare the number of each type of atom on each side of the equation.
Reactants $\rightarrow$ Products
6C, 12H, 6O $\rightarrow$ 3C, 6H, 3O
Balance the C by putting a 2 in front of $C_2H_5OH(aq)$ and a 2 in front of $CO_2(g)$.
The H and O are now also balanced.
The balanced equation is
$C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$

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 + $O_2(g) \rightarrow CO_2(g)$ + $H_2O(g)$
1. b)	4P, 8I	4P, 8I	element + element $\rightarrow$ compound
1. c)	2Cl, $2Cs^+$, $2Br^-$	$2Cl^-$, $2Cs^+$, 2Br	element + compound $\rightarrow$ new element + new compound
1. d)	$3Ba^{2+}$, $6ClO_3^-$, $6Na^+$, $2PO_4^{3-}$	$3Ba^{2+}$, $6ClO_3^-$, $6Na^+$, $2PO_4^{3-}$	compound A + compound B $\rightarrow$ compound C + compound D

1. e)	$6Li^{+}$, $2N^{3-}$	6Li, 2N	compound → 2 elements
1. f)	6C, 12H, 6O	6C, 12H, 6O	compound A → 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:
$C_4H_{10}(g) + O_2(g) \rightarrow$

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
$C_4H_{10}(g)$ is a hydrocarbon. The products that form when complete combustion with $O_2(g)$ are $H_2O(g)$ and $CO_2(g)$.
$C_4H_{10}(g) + O_2(g) \rightarrow H_2O(g) + CO_2(g)$
Compare the number of each type of atom on each side of the equation.
Reactants → Products
4C, 10H, 2O → 1C, 2H, 3O
Balance the C by putting a 4 in front of $CO_2(g)$.
Balance the H by putting a 5 in front of $H_2O(g)$.
Balance the O by putting $\frac{13}{2}$ in front of $O_2(g)$.

$$C_4H_{10}(g) + \frac{13}{2}O_2(g) \rightarrow 5H_2O(g) + 4CO_2(g)$$

Multiply each coefficient by 2 to obtain whole number coefficients in front of each term in the equation.
The balanced equation is
$2C_4H_{10}(g) + 13O_2(g) \rightarrow 10H_2O(g) + 8CO_2(g)$

2. b)
Problem
Predict the products for the following incomplete chemical equations. Then balance the equations:

$Zn(s) + Pb(NO_3)_2(aq) \rightarrow$

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.
$Zn(s) + Pb(NO_3)_2(aq) \rightarrow Pb(s) + Zn(NO_3)_2(aq)$
Compare the number of each type of atom and polyatomic ion on each side of the equation.
Reactants $\rightarrow$ Products
$1Zn, 1Pb^{2+}, 2NO_3^{-} \rightarrow 1Zn^{2+}, 1Pb, 2NO_3^{-}$
Since there are the same number of each kind of atom and polyatomic ion on each side of the equation, the balanced equation is
$Zn(s) + Pb(NO_3)_2 \rightarrow Pb(s) + Zn(NO_3)_2(aq)$

2. c)
Problem
Predict the products for the following incomplete chemical equations. Then balance the equations:
$Mg(s) + S_8(s) \rightarrow$

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.
$Mg(s) + S_8(s) \rightarrow MgS(s)$
Compare the number of each type of atom on each side of the equation.
Reactants $\rightarrow$ Products

1Mg, 8S $\rightarrow$ 1Mg^{2+}, 1S^{2-}
Balance the S^{2-} by putting an 8 in front of MgS(s).
Balance the Mg^{2+} by putting an 8 in front of Mg(s).
The balanced equation is
$8Mg(s) + S_8(s) \rightarrow 8MgS(s)$

2. d)
Problem
Predict the products for the following incomplete chemical equation. Then balance the equation:
$Sr(OH)_2(aq) + H_2SO_4(aq) \rightarrow$

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.
$Sr(OH)_2(aq) + H_2SO_4(aq) \rightarrow SrSO_4(aq) + H_2O(\ell)$
Compare the number of each type of atom and polyatomic ion on each side of the equation.
Reactants $\rightarrow$ Products
1Sr^{2+}, 1SO_4^{2-}, 2OH^-, 2H^+ $\rightarrow$ 1Sr^{2+}, 1SO_4^{2-}, 2H, 1O
Balance the H^+ by putting a 2 in front of $H_2O(\ell)$.
This also balances the O.
The balanced equation is
$Sr(OH)_2(aq) + H_2SO_4(aq) \rightarrow SrSO_4(aq) + 2H_2O(\ell)$

2. e)
Problem
Predict the products for the following incomplete chemical equation. Then balance the equation:
$LiN_3(s) \rightarrow$

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.
$LiN_3(s) \rightarrow Li(s) + N_2(g)$
Compare the number of each type of atom on each side of the equation.
Reactants $\rightarrow$ Products
$1Li^+, 1N_3^- \rightarrow 1Li, 3N$
Balance the N by putting a 3 in front of $N_2(g)$ and a 2 in front of $LiN_3(s)$.
Balance the Na by putting a 2 in front of Li(s).
The balanced equation is
$2LiN_3(s) \rightarrow 2Li(s) + 2N_2(g)$

Check Your Solution

Question	Reactants	Products	Type of Reaction
2. a)	8C, 20H, 26O	8C, 20H, 26O	hydrocarbon combustion
2. b)	$1Zn, 1Pb^{2+}, 2NO_3^-$	$1Zn^{2+}, 1Pb, 2NO_3^-$	single replacement
2. c)	8Mg, 8S	$8Mg^{2+}, 8S^{2-}$	formation or synthesis
2. d)	$1Sr^{2+}, 2OH^-, 2H^+$ $1SO_4^{2-}$,	$1Sr^{2+}, 1SO_4^{2-}$, 4H, 2O	double replacement
2. e)	$2Li^+, 2N_3^-$	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:
$Cl_2(g) + 2RbBr(aq) \rightarrow Br_2(\ell) + 2RbCl(aq)$

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
$Cl_2(g) + 2Rb^+(aq) + 2Br^-(aq) \rightarrow Br_2(\ell) + 2Rb^+(aq) + 2Cl^-(aq)$
The spectator ion is $Rb^+(aq)$.
The net ionic equation is
$Cl_2(g) + 2Br^-(aq) \rightarrow Br_2(\ell) + 2Cl^-(aq)$

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:
$Cu(s) + 2AgNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + 2Ag(s)$

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
$Cu(s) + 2Ag^+(aq) + 2NO_3^-(aq) \rightarrow Cu^{2+}(aq) + 2NO_3^-(aq) + 2Ag(s)$
The spectator ion is $NO_3^-(aq)$.
The net ionic equation is
$Cu(s) + 2Ag^+(aq) \rightarrow Cu^{2+}(aq) + 2Ag(s)$

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:
$2Al(s) + 3CuCl_2(aq) \rightarrow 3Cu(s) + 2AlCl_3(aq)$

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
$2Al(s) + 3Cu^{2+}(aq) + 6Cl^{-}(aq) \rightarrow 3Cu(s) + 2Al^{3+}(aq) + 6Cl^{-}(aq)$
The spectator ion is $Cl^{-}(aq)$.
The net ionic equation is
$2Al(s) + 3Cu^{2+}(aq) \rightarrow 3Cu(s) + 2Al^{3+}(aq)$

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:
$Zn(s) + Pb(NO_3)_2(aq) \rightarrow Zn(NO_3)_2(aq) + Pb(s)$

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
$Zn(s) + Pb^{2+}(aq) + 2NO_3^{-}(aq) \rightarrow Zn^{2+}(aq) + 2NO_3^{-}(aq) + Pb(s)$
The spectator ion is $NO_3^{-}(aq)$.
The net ionic equation is

$Zn(s) + Pb^{2+}(aq) \rightarrow Zn^{2+}(aq) + Pb(s)$

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:
$H_2(g) + Na_2SO_4(aq) \rightarrow 2Na(s) + H_2SO_4(aq)$

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
$H_2(g) + 2Na^+(aq) + SO_4^{2-}(aq) \rightarrow 2Na(s) + 2H^+(aq) + SO_4^{2-}(aq)$
The spectator ion is $SO_4^{2-}(aq)$.
The net ionic equation is
$H_2(g) + 2Na^+(aq) \rightarrow 2Na(s) + 2H^+(aq)$

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:
a) $Ba(ClO_3)_2(aq) + Na_3PO_4(aq) \rightarrow Ba_3(PO_4)_2(s) + NaClO_3(aq)$
b) $Na_2SO_4(aq) + Sr(OH)_2(aq) \rightarrow SrSO_4(s) + NaOH(aq)$
c) $Al_2(SO_4)_3(aq) + (NH_4)_2Cr_2O_7(aq) \rightarrow Al_2(Cr_2O_7)_3(s) + (NH_4)_2SO_4(aq)$
d) $NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(\ell)$
e) $MgCl_2(aq) + NaOH(aq) \rightarrow Mg(OH)_2(s) + NaCl(aq)$

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
2. a) $Ba(ClO_3)_2(aq) + Na_3PO_4(aq) \rightarrow Ba_3(PO_4)_2(s) + NaClO_3(aq)$
Compare the numbers of each type of atom and polyatomic ion on each side of the equation.
Reactants $\rightarrow$ Products
$1Ba^{2+}$, $3Na^{+}$, $2ClO_3^{-}$, $1PO_4^{3-} \rightarrow 3Ba^{2+}$, $1Na^{+}$, $1ClO_3^{-}$, $2PO_4^{3-}$
Balance the $PO_4^{3-}(aq)$ by putting a 2 in front of $Na_3PO_4(aq)$.
Balance the $Ba^{2+}(aq)$ by putting a 3 in front of the $Ba(ClO_3)_2(aq)$.
Balance the $ClO_3^{-}(aq)$ by putting a 6 in front of $NaClO_3(aq)$.
The $Na^{+}(aq)$ is also balanced.
The balanced non-ionic equation is
$3Ba(ClO_3)_2(aq) + 2Na_3PO_4(aq) \rightarrow Ba_3(PO_4)_2(s) + 6NaClO_3(aq)$
The total ionic equation is
$3Ba^{2+}(aq) + 6ClO_3^{-}(aq) + 6Na^{+}(aq) + 2PO_4^{3-}(aq) \rightarrow Ba_3(PO_4)_2(s) + 6Na^{+}(aq) + 6ClO_3^{-}(aq)$
The spectator ions are $Na^{+}(aq)$ and $ClO_3^{-}(aq)$.
The net ionic equation is
$3Ba^{2+}(aq) + 2PO_4^{3-}(aq) \rightarrow Ba_3(PO_4)_2(s)$

2. b) $Na_2SO_4(aq) + Sr(OH)_2(aq) \rightarrow SrSO_4(s) + NaOH(aq)$
Compare the numbers of each type of atom and polyatomic ion on each side of the equation.
Reactants $\rightarrow$ Products
$2Na^{+}$, $1Sr^{2+}$, $1SO_4^{2-}$, $2OH^{-} \rightarrow 1Na^{+}$, $1Sr^{2+}$, $1SO_4^{2-}$, $1OH^{-}$
Balance the $Na^{+}(aq)$ and $OH^{-}(aq)$ by putting a 2 in front of $NaOH(aq)$.
The balanced non-ionic equation is
$Na_2SO_4(aq) + Sr(OH)_2(aq) \rightarrow SrSO_4(s) + 2NaOH(aq)$
The total ionic equation is
$2Na^{+}(aq) + SO_4^{2-}(aq) + Sr^{2+}(aq) + 2OH^{-}(aq) \rightarrow SrSO_4(s) + 2Na^{+}(aq) + 2OH^{-}(aq)$
The spectator ions are $Na^{+}(aq)$ and $OH^{-}(aq)$.
The net ionic equation is
$Sr^{2+}(aq) + SO_4^{2-}(aq) \rightarrow SrSO_4(s)$

2. c) $Al_2(SO_4)_3(aq) + (NH_4)_2Cr_2O_7(aq) \rightarrow Al_2(Cr_2O_7)_3(s) + (NH_4)_2SO_4(aq)$
Compare the numbers of each type of atom and polyatomic ion on each side of the equation.
Reactants $\rightarrow$ Products

$2Al^{3+}$, $2NH_4^+$, $3SO_4^{2-}$, $1Cr_2O_7^{2-}$ → 2Al, $2NH_4^+$, $1SO_4^{2-}$, $3Cr_2O_7$
Balance the $Cr_2O_7^{2-}$(aq) by putting a 3 in front of $(NH_4)_2Cr_2O_7$(aq).
Balance the NH_4^+(aq) by putting a 3 in front of $(NH_4)_2SO_4$(aq)
The balanced non-ionic equation is
$Al_2(SO_4)_3(aq) + 3(NH_4)_2Cr_2O_7(aq) \rightarrow Al_2(Cr_2O_7)_3(s) + 3(NH_4)_2SO_4(aq)$
The total ionic equation is
$2Al^{3+}(aq) + 3SO_4^{2-}(aq) + 6NH_4^+(aq) + 3Cr_2O_7^{2-}(aq) \rightarrow Al_2(Cr_2O_7)_3(s) + 6NH_4^+(aq) + 3SO_4^{2-}(aq)$
The spectator ions are NH_4^+(aq) and SO_4^{2-}(aq).
The net ionic equation is
$2Al^{3+}(aq) + 3Cr_2O_7^{2-}(aq) \rightarrow Al_2(Cr_2O_7)_3(s)$

2. d) $NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(\ell)$
Compare the numbers of each type of atom and polyatomic ion on each side of the equation.
Reactants → Products
$1Na^+$, $1OH^-$, $1H^+$, $1Cl^-$ → $1Na^+$, $1Cl^-$, 2H, 1O
The same number of each kind of atom is on each side of the equation.
The balanced non-ionic equation is
$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(\ell)$
The total ionic equation is
$Na^+(aq) + OH^-(aq) + H^+(aq) + Cl^-(aq) \rightarrow Na^+(aq) + Cl^-(aq) + H_2O(\ell)$
The spectator ions are Na^+(aq) and Cl^-(aq).
The net ionic equation is
$H^+(aq) + OH^-(aq) \rightarrow H_2O(\ell)$

2. e) $MgCl_2(aq) + NaOH(aq) \rightarrow Mg(OH)_2(s) + NaCl(aq)$
Compare the numbers of each type of atom and polyatomic ion on each side of the equation.
Reactants → Products
Mg^{2+}, $2Cl^-$, $1Na^+$, $1OH^-$ → Mg, Cl^-, $1Na^+$, 2OH
Balance the OH^-(aq) by putting a 2 in front of NaOH(aq).
Balance the Na^+(aq) by putting a 2 in front of NaCl(aq)
The balanced non-ionic equation is
$MgCl_2(aq) + 2NaOH(aq) \rightarrow Mg(OH)_2(s) + 2NaCl(aq)$
The total ionic equation is
$Mg^{2+}(aq) + 2Cl^-(aq) + 2Na^+(aq) + 2OH^-(aq) \rightarrow Mg(OH)_2(s) + 2Na^+(aq) + 2Cl^-(aq)$
The spectator ions are Na^+(aq) and Cl^-(aq).
The net ionic equation is
$Mg^{2+}(aq) + 2OH^-(aq) \rightarrow Mg(OH)_2(s)$

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:
$2AgNO_3(aq) + Na_2CrO_4(aq) \rightarrow Ag_2CrO_4(s) + 2NaNO_3(aq)$
a) Write the ratio of all the components.
b) Write the mole ratio for silver nitrate, $AgNO_3(aq)$, and silver chromate, $Ag_2CrO_4(s)$.
c) What amount (in mol) of $Ag_2CrO_4(s)$ would be produced from 0.5 mol of $AgNO_3(aq)$?

What is Required
a) You must write the ratio of all the components.
b) You must write the ratio for $AgNO_3(aq)$ and $Ag_2CrO_4(s)$.
c) You must calculate the amount of $Ag_2CrO_4(s)$ that would be produced from 0.5 mol $AgNO_3(aq)$.

What is Given
a) & **b)** The balanced equation is given.
c) The number of moles of $AgNO_3(aq)$ is 0.5 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 $AgNO_3(aq):Ag_2CrO_4(s)$.
c) From the balanced equation, equate the given mole ratio of $AgNO_3(aq):Ag_2CrO_4(s)$ to the number of moles given of $AgNO_3(aq)$ and solve for the number of moles of $Ag_2CrO_4(s)$.

Act on Your Strategy
a) From the balanced equation:
$2AgNO_3(aq) + Na_2CrO_4(aq) \rightarrow Ag_2CrO_4(s) + 2NaNO_3(aq)$
the mole ratio is
2 mol $AgNO_3(aq)$:1 mol $Na_2CrO_4(aq)$:1 mol $Ag_2CrO_4(s)$:2 mol $NaNO_3(aq)$

b) $\frac{n(AgNO_3(aq))}{n(Ag_2CrO_4(s))} = \frac{2}{1}$

c) $\frac{0.5\,mol\,(AgNO_3(aq))}{n(Ag_2CrO_4(s))} = \frac{2}{1}$

$$n(Ag_2CrO_4(s)) = \frac{0.5\,mol\,AgNO_3(aq)}{2} = 0.25\,mol\,Ag_2CrO_4(s)$$

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

b) The mole ratio $\frac{n(AgNO_3(aq))}{n(Ag_2CrO_4(s))} = \frac{2}{1}$

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:
$2NH_3(g) + CO_2(g) \rightarrow NH_2CONH_2(s) + H_2O(g)$
a) Write the ratio of all the components of the reaction.
b) What amount (in moles) of ammonia, $NH_3(g)$, is required to prepare 1.30 mol of urea, $NH_2CONH_2(s)$?
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 $CO_2(g)$ react.

What is Given?
a) The balanced equation is given.
b) The number of moles of $NH_2CONH_2(s)$ is 1.30 mol.
c) The number of moles of $CO_2(g)$ 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 $NH_3(g)$:$NH_2CONH_2(s)$ to the ratio of number of moles given and solve for the number of moles of NH_3.
c) From the balanced equation, equate the given mole ratio of $H_2O(g)$:$CO_2(g)$ to the ratio the of number of moles given and solve for the number of moles of $H_2O(g)$.

Act on Your Strategy
a) From the balanced equation:
$2NH_3(g) + CO_2(g) \rightarrow NH_2CONH_2(s) + H_2O(g)$
the mole ratio is
2 mol $NH_3(g)$:1 mol $CO_2(g)$:1 mol $NH_2CONH_2(s)$:1 mol $H_2O(g)$

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

$n(H_2O(g)) = \frac{1 \text{mol } H_20(g) \times 6.0 \text{mol } CO_2(g)}{1 \text{mol } CO_2(g)}$ = 6.0 mol $H_2O(g)$

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

b) The mole ratio $\frac{n(NH_3(g))}{n(NH_2CONH_2(s))} = \frac{2.60}{1.30} = \frac{2}{1}$.

c) The mole ratio $\frac{n(H_2O(g))}{n(CO_2(g))} = \frac{6.0}{6.0} = \frac{1}{1}$.

5.
Problem
The fertilizer ammonium sulfate, $(NH_4)_2SO_4(s)$, is made at Sherrit International Corporation's plant in Fort Saskatchewan. The following chemical equation shows the reaction:
$2NH_3(g) + H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(s)$
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 $NH_3(g)$ is consumed.

What is Given?
a) The balanced equation is given.
b) The number of moles of $(NH_4)_2SO_4(s)$ is 20 000 mol.
c) The number of moles of $NH_3(g)$ 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 $NH_3(g)$:$(NH_4)_2SO_4(s)$ to the ratio of number of moles given and solve for the number of moles of $NH_3(g)$.
c) From the balanced equation, equate the given mole ratio of $NH_3(g)$:$(NH_4)_2SO_4(s)$ to the ratio of number of moles given and solve for the number of moles of $NH_3(g)$.

Act on Your Strategy
a) From the balanced equation:
$2NH_3(g) + H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(s)$

the mole ratio is
2 mol NH_3(g):1 mol H_2SO_4(aq):1 mol $(NH_4)_2SO_4$(s)

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

$n(\text{NH}_3(\text{g})) = \dfrac{2\,\text{mol}\,\text{NH}_3(\text{g}) \times 20\,000\,\text{mol}\,(\text{NH}_4)_2\text{SO}_4(\text{s})}{1\,\text{mol}\,(\text{NH}_4)_2\text{SO}_4(\text{s})}$ = 40 000 mol or 40 kmol NH_3(g)

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

$n((\text{NH}_4)_2\text{SO}_4(\text{s})) = \dfrac{1\,\text{mol}\,(\text{NH}_4)_2\text{SO}_4(\text{s}) \times 3.28\,\text{mol}\,\text{NH}_3(\text{g})}{2\,\text{mol}\,\text{NH}_3(\text{g})}$ = 1.64 mol $(NH_4)_2SO_4$(s)

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

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

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

6.
Problem
At 400 ^{o}C, xenon and fluorine react to produce colourless crystals of xenon tetrafluoride, XeF_4(s), as shown below:
Xe(g) + $2F_2$(g) $\rightarrow$ XeF_4(s)
a) Write the ratio of all the components of the reaction.
b) What amount of F_2(g) is necessary to prepare 2.35 mol of XeF_4(s)?
c) What amount of F_2(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_2(g) needed to prepare 2.35 mol of XeF_4(s).
c) You need to calculate the number of moles of F_2(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_4 (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 mmol = 1 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:
$Xe(g) + 2F_2(g) \rightarrow XeF_4(s)$
The mole ratio is 1 mol Xe(g):2 mol $F_2(g)$:1 $XeF_4(s)$.

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

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

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

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

$n(F_2(g)) = \dfrac{2\,mol\,F_2(g) \times 0.0122\,mol\,Xe(g)}{1\,mol\,Xe(g)} = 0.0224\text{ mol or }24.4\text{ mmol }F_2(g)$

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

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

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

7.
Problem
A wide variety of formulas are possible from the reaction of nitrogen with oxygen. The equations below show two possible reactions:
$2N_2(g) + O_2(g) \rightarrow 2N_2O(g)$
$N_2(g) + 2O_2(g) \rightarrow 2NO_2(g)$
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:
$2N_2(g) + O_2(g) \rightarrow 2N_2O(g)$
The mole ratio is 2 mol $N_2(g)$:1 mol $O_2(g)$:2 mol $N_2O(g)$
$N_2(g) + 2O_2(g) \rightarrow 2NO_2(g)$
The mole ratio is 1 mol $N_2(g)$:2 mol $O_2(g)$:2 mol $NO_2(g)$

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

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

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

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

$n(O_2(g)) = \frac{2\,\text{mol}\,O_2(g) \times 0.0935\,\text{mol}\,N_2(g)}{1\,\text{mol}\,N_2(g)}$ = 0.187 mol or 187 mmol $O_2(g)$

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

b) The mole ratio $\frac{n(O_2(g))}{n(N_2(g))} = \frac{0.0468\,\text{mol}}{0.0935\,\text{mol}} = \frac{1}{2}$.

c) The mole ratio $\frac{n(O_2(g))}{n(N_2(g))} = \frac{0.187\,\text{mol}}{0.0935\,\text{mol}} = \frac{2}{1}$.

8.
Problem
Ethanoic acid, $CH_3COOH(\ell)$, is produced according to the following chemical equation:
$CH_3OH(\ell) + CO(g) \rightarrow CH_3COOH(\ell)$
Calculate the mass of ethanoic that would be produced by the reaction of 6.0×10^4 g of CO(g) with sufficient $CH_3OH(\ell)$.

What is Required?
You need to calculate the mass of $CH_3COOH(\ell)$ that can be produced from the reaction of 6.0×10^4 g of CO(g) with methanol.

What is Given?
The balanced equation for the reaction and the mass of CO(g) are given.

Plan Your Strategy
Determine the molar mass, *M*, of CO(g).
Calculate the number of moles, *n*, of CO(g) using the equation $n = \frac{m}{M}$.
Use the mole ratio in the balanced equation to calculate the moles of $CH_3COOH(\ell)$.
Determine the molar mass, *M*, of $CH_3COOH(\ell)$.
Calculate the mass, *m*, of $CH_3COOH(\ell)$ using the equation $m = n \times M$.

Act on Your Strategy
$M\text{CO(g)} = 28.01\ \frac{\text{g}}{\text{mol}}$

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

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

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

$$M\text{CH}_3\text{COOH}(\ell) = 60.06 \ \frac{\text{g}}{\text{mol}}$$

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

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:
$2NaCl(aq) + 2H_2O(\ell) \rightarrow 2NaOH(aq) + Cl_2(g) + H_2(g)$
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 g = 1 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 $\frac{n(\text{NaOH(s)})}{n(\text{NaCl(s)})} = \frac{2}{2}$

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

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

mNaCl(s) = $n \times M = 1.0 \times 10^4$ mol $\times$ 58.44 $\frac{\text{g}}{\text{mol}}$ = 5.84×10^5 g = 5.84×10^2 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, $AgNO_3$(aq), to produce silver, Ag(s).

a) Write the balanced equation for this reaction.

b) 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?

a) You must write the balanced equation for this reaction.

b) 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?

a) The reactants are copper metal and aqueous silver nitrate and a single replacement reaction occurs.

b) The mass of copper is 1.00 g.

Plan Your Strategy

a) Write the balanced equation for the single replacement reaction that occurs between copper metal and aqueous silver nitrate.

b) 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

a) Cu(s) + $2Ag(NO_3)_2$(aq) $\rightarrow$ 2Ag(s) + $Cu(NO_3)_2$(aq)

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

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

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

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

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

mAg(s) = $n \times M$ = 0.03148 mol × 107.87 $\frac{\text{g}}{\text{mol}}$ = 3.39 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, $CaCO_3$(s), decomposes into calcium oxide, CaO(s) (lime), and carbon dioxide, CO_2(g), when it is heated to about 900 ^{o}C. Calculate the mass of lime that would be produced by heating 200 g of limestone to 900 ^{o}C.

What is Required?
You must calculate the mass of CaO(s) that is produced when 200 g of limestone, $CaCO_3$(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 $CaCO_3$(s).
Determine the molar mass, M, of $CaCO_3$(s).
Calculate the number of moles, n, of $CaCO_3$(s) using the equation $n = \frac{m}{M}$.
Use the mole ratio in the balanced equation to calculate the moles of CaO(s).
Determine the molar mass, M, of CaO(s).
Calculate the mass, m, of CaO(s) using the equation $m = n \times M$.

Act on Your Strategy
$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

$M CaCO_3(s) = 100.09 \ \frac{g}{mol}$

$n CaCO_3(s) = \frac{m}{M} = \frac{200 \text{ g}}{100.09 \frac{g}{mol}} = 1.998 \text{ mol}$

From the balanced equation, the mole ratio $\frac{n(CaO(s))}{n(CaCO_3(s))} = \frac{1}{1}$

$1.998 \text{ mol } CaCO_3(s) \times \frac{1 \text{ mol } CaO(s)}{1 \text{ mol } CaCO_3(s)} = 1.998 \text{ mol } CaO(s)$

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

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

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, MgO(s), would be produced by the reaction of 4.86 g of magnesium metal, Mg(s), in a copious supply of oxygen gas, $O_2(g)$?

What is Required?
You must calculate the mass of MgO(s) that is produced when 4.86 g of magnesium metal, Mg(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 MgO(s).
Determine the molar mass, M, of Mg(s).
Calculate the number of moles, n, of Mg(s) using the equation $n = \frac{m}{M}$.
Use the mole ratio in the balanced equation to calculate the moles of MgO(s).
Determine the molar mass, M, of MgO(s).
Calculate the mass, m, of MgO(s) using the equation $m = n \times M$.

Act on Your Strategy

$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$

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

nMg(s) = $\frac{m}{M} = \frac{4.86\,g}{24.31\frac{g}{mol}}$ = 0.1999 mol

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

0.1999 mol Mg(s) × $\frac{1\,mol\,MgO(s)}{1\,mol\,Mg(s)}$ = 0.1999 mol MgO(s)

MMgO(s) = 40.31 $\frac{g}{mol}$

mMgO(s) = $n \times M$ = 0.1999 mol × 40.31 $\frac{g}{mol}$ = 8.06 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(ℓ) 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

$8HgS(s) \rightarrow 8Hg(\ell) + S_8(s)$

MHgS(s) = $232.66 \ \frac{g}{mol}$

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

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

0.10015 mol HgS(s) × $\frac{8\,mol\,Hg(\ell)}{8\,mol\,HgS(s)}$ = 0.10015 mol Hg(ℓ)

MHg(ℓ) = $200.59 \ \frac{g}{mol}$

mHg(ℓ) = $n \times M$ = 0.10015 mol Hg(ℓ) × $200.59 \ \frac{g}{mol}$ = 20.1g Hg(ℓ)

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, $Pt(NH_3)_2Cl_2(s)$, 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, $K_2PtCl_4(aq)$, by reaction with ammonia, $NH_3(aq)$, according to the following reaction:

$K_2PtCl_4(aq) + 2NH_3(aq) \rightarrow 2KCl(aq) + Pt(NH_3)_2Cl_2(s)$

What mass of cisplatin would result from the reaction of 55.8 g of $K_2PtCl_4(aq)$ in aqueous solution?

What is Required?

You must calculate the mass of cisplatin, $Pt(NH_3)_2Cl_2(s)$, that is produced when 55.8 g of potassium tetrachloroplatinate, $K_2PtCl_4(aq)$, react with ammonia, $NH_3(aq)$.

What is Given?

The balanced equation for the reaction and the mass of K_2PtCl_4 are given.

Plan Your Strategy

Determine the molar mass, M, of K_2PtCl_4.

Calculate the number of moles, n, of K_2PtCl_4 using the equation $n = \frac{m}{M}$.

Use the mole ratio in the balanced equation to calculate the moles of $Pt(NH_3)_2Cl_2$.

Determine the molar mass, M, of $Pt(NH_3)_2Cl_2(s)$.

Calculate the mass, m, of $Pt(NH_3)_2Cl_2(s)$ using the equation $m = n \times M$.

Act on Your Strategy

$M\text{K}_2\text{PtCl}_4\text{(aq)} = 415.08\ \frac{\text{g}}{\text{mol}}$

$n\text{K}_2\text{PtCl}_4\text{(aq)} = \frac{m}{M} = \frac{55.8\text{ g}}{415.08\ \frac{\text{g}}{\text{mol}}} = 0.1344\text{ mol}$

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

$0.1344\text{ mol K}_2\text{PtCl}_4\text{(aq)} \times \frac{1\text{ mol Pt(NH}_3)_2\text{Cl}_2\text{(s)}}{1\text{ mol K}_2\text{PtCl}_4\text{(aq)}} = 0.1344\text{ mol Pt(NH}_3)_2\text{Cl}_2\text{(s)}$

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

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

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, P_4(s), and chlorine, Cl_2(g), according to the following *unbalanced* reaction equation:

$\text{P}_4\text{(s)} + \text{Cl}_2\text{(g)} \rightarrow \text{PCl}_3(\ell)$

What mass of $\text{PCl}_3(\ell)$ forms when 323 g of Cl_2(g) reacts completely with 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, 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 Cl_2(g).

Calculate the number of moles, n, of 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

$P_4(s) + 6Cl_2(g) \rightarrow 4PCl_3(s)$

$M Cl_2(g) = 70.9\ \frac{g}{mol}$

$n Cl_2(g) = \frac{m}{M} = \frac{323 g}{70.9 \frac{g}{mol}} = 4.556\ mol$

From the balanced equation, the mole ratio $\frac{n(PCl_3(s))}{n(Cl_2(g))} = \frac{4}{6}$

$4.556\ mol\ Cl_2(g) \times \frac{4\ mol\ PCl_3(s)}{6\ mol\ Cl_2(g)} = 3.037\ mol\ PCl_3\ (\ell)$

$M PCl_3(\ell) = 137.32\ \frac{g}{mol}$

$m PCl_3(\ell) = n \times M = 3.037\ mol\ PCl_3(\ell) \times 137.32\ \frac{g}{mol} = 417\ g\ PCl_3(\ell)$

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

What is Required?

You must calculate the volume of $MgCl_2(aq)$ that will precipitate the $Cl^-(aq)$ from a given volume of $0.30\ \frac{mol}{L}$ silver nitrate solution.

What is Given?

$c MgCl_2(aq) = 0.50\ \frac{mol}{L}$

$c AgNO_3(aq) = 0.30\ \frac{mol}{L}$

$V AgNO_3(aq) = 60\ mL = 0.060\ L$

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 $AgNO_3(aq)$. Use the mole ratio from the balanced equation to calculate the number of moles of $MgCl_2(aq)$ that will react. Calculate the volume of $MgCl_2(aq)$ using the equation $V = \frac{n}{c}$.

Act on Your Strategy

$2AgNO_3(aq) + MgCl_2(aq) \rightarrow Mg(NO_3)_2(aq) + 2AgCl(s)$

$n AgNO_3(aq) = c \times V = 0.30\ \frac{\text{mol}}{\text{L}} \times 0.060\ \text{L} = 0.018\ \text{mol}$

$n MgCl_2(aq) = 0.018\ \text{mol}\ AgNO_3(aq) \times \frac{1\,\text{mol}\ MgCl_2(aq)}{2\,\text{mol}\ AgNO_3(aq)} = 0.0090\ \text{mol}$

$V MgCl_2(aq) = \frac{n}{c} = \frac{0.0090\,\text{mol}}{0.50\,\frac{\text{mol}}{\text{L}}} = 0.018\ \text{L} = 18\ \text{mL}$

Check Your Solution

The calculated volume of $MgCl_2(aq)$ is reasonable for the given information. The units (mL) and the number of significant digits (2) are correct.

17.

Problem

Sulfuric acid, $H_2SO_4(aq)$, can be neutralized by reacting it with aqueous barium hydroxide, $Ba(OH)_2(aq)$. The reaction is:

$H_2SO_4(aq) + Ba(OH)_2(aq) \rightarrow BaSO_4(s) + 2H_2O(\ell)$

What volume of 0.676 $\frac{\text{mol}}{\text{L}}$ $H_2SO_4(aq)$ can be neutralized by 22.7 mL of 0.385 $\frac{\text{mol}}{\text{L}}$ $Ba(OH)_2(aq)$?

What is Required?

You must calculate the volume of 0.676 $\frac{\text{mol}}{\text{L}}$ $H_2SO_4(aq)$ that will neutralize 22.7 mL of 0.385 $\frac{\text{mol}}{\text{L}}$ $Ba(OH)_2(aq)$?

What is Given?

$c H_2SO_4(aq) = 0.676\ \frac{\text{mol}}{\text{L}}$

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

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

Plan Your Strategy
Use the equation $n = c \times V$ to calculate the number of moles (n) of $Ba(OH)_2(aq)$. Use the mole ratio from the balanced equation to calculate the number of moles of $H_2SO_4(aq)$ that will react. Calculate the volume of $H_2SO_4(aq)$ using the equation $V = \frac{n}{c}$.

Act on Your Strategy

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

$n H_2SO_4(aq) = 0.008740\text{ mol } Ba(OH)_2(aq) \times \frac{1\text{ mol } H_2SO_4(aq)}{1\text{ mol } Ba(OH)_2(aq)} = 0.008740\text{ mol } H_2SO_4(aq)$

$V H_2SO_4(aq) = \frac{n}{c} = \frac{0.008740\text{ mol}}{0.676 \frac{\text{mol}}{\text{L}}} = 0.0129\text{ L} = 12.9\text{ mL}$

Check Your Solution
The calculated volume of $H_2SO_4(aq)$ 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 $\frac{\text{mol}}{\text{L}}$ NaI(aq) is necessary to precipitate all the aqueous lead(II) ions in 25.0 mL of 0.100 $\frac{\text{mol}}{\text{L}}$ $Pb(NO_3)_2(aq)$?
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 $\frac{\text{mol}}{\text{L}}$ NaI(aq) that will react with 25.0 mL of 0.100 $\frac{\text{mol}}{\text{L}}$ $Pb(NO_3)_2(aq)$.
c) You must calculate the mass of precipitate that forms in this reaction.

What is Given?

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

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

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

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 $Pb(NO_3)_2$(aq). Use the mole ratio from the balanced equation to calculate the number of moles of NaI(aq) that will react.

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

c) Determine the molar mass, M, of PbI_2(s).

Use the mole ratio from the balanced equation to determine the number of moles of PbI_2(s).

Calculate the mass of PbI_2(s) using the equation $m = n \times M$

Act on Your Strategy

a) 2 NaI(aq) + $Pb(NO_3)_2$(aq) → $2NaNO_3$(aq) + PbI_2(s)

b) The precipitate is lead(II) iodide (PbI_2).

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

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

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

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 NaI(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 $\frac{\text{mol}}{\text{L}}$ HCl(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 $CaCO_3$(s) and 110 mg of $Mg(OH)_2$(s).

a) Calculate the volume of stomach acid neutralized by the $CaCO_3(s)$ in one Brand X antacid tablet according to the following equation:
$2HCl(aq) + CaCO_3(s) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(\ell)$
b) Calculate the volume of stomach acid neutralized by the $Mg(OH)_2(s)$ in one Brand X tablet according to the following equation:
$2HCl(aq) + Mg(OH)_2(s) \rightarrow MgCl_2(aq) + 2H_2O(\ell)$
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 $CaCO_3(s)$ in an antacid tablet.
b) You must calculate the volume of stomach acid that can be neutralized by the $Mg(OH)_2(s)$ 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.
$m(CaCO_3(s)) = 500$ mg
$c(HCl(aq)) = 0.030 \frac{\text{mol}}{\text{L}}$
b) The balanced equation is given.
$m(Mg(OH)_2(s)) = 110$ mg

Plan Your Strategy
a) Determine the molar mass, M, of $CaCO_3(s)$. Change the 500 mg to grams (1000 mg = 1 g) and calculate the number of moles of $CaCO_3(s)$ using the equation $n = \frac{m}{M}$.
Use the mole ratio from the balanced equation to calculate the number of moles of HCl(aq) that will react with the calculated number of moles of $CaCO_3(s)$. Calculate the volume of HCl(aq) that will contain this number of moles of HCl(aq) using the equation $V = \frac{n}{c}$.
b) Determine the molar mass, M, of $Mg(OH)_2(s)$. Change the 110 mg to grams (1000 mg = 1 g) and calculate the number of moles of $Mg(OH)_2(s)$ using the equation $n = \frac{m}{M}$.
Use the mole ratio from the balanced equation to calculate the number of moles of HCl(aq) that will react with the calculated number of moles of $Mg(OH)_2(s)$. Calculate the volume of HCl(aq) that will contain this number of moles of HCl(aq) using the equation $V = \frac{n}{c}$.
c) Add together the answers from parts **a)** & **b)**.

Act on Your Strategy
a) $M(CaCO_3) = 100.09 \frac{\text{g}}{\text{mol}}$

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

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

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

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

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

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

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

c) VHCl(aq) = 0.33 L + 0.13 L = 0.46 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 $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$

a) What is the mole ratio of oxygen gas to water vapour?

b) What is the volume ratio of hydrogen gas to water vapour?

c) Calculate the volume of H_2O(g) produced if 20 L of hydrogen gas reacts with the appropriate amount of oxygen.

What is Required?

a) You must write the mole ratio of O_2(g) to H_2O(g).

b) You must write the volume ratio of H_2(g) to H_2O(g).

c) You must calculate the volume of H_2O(g) produced from 20 L of H_2(g).

What is Given?

a) & **b)** The balanced equation is given and all gases are at the same temperature and pressure.

c) $V(H_2(g))$ = 20 L

Plan Your Strategy

a) & **b)** Since all the gases are at the same temperature and pressure, the law of combining volumes can be applied.

c) Using the mole ratio of H_2(g) to H_2O(g), calculate the volume of H_2O(g).

Act on Your Strategy

a) $\frac{n(O_2(g))}{n(H_2O(g))} = \frac{1\,mol}{2\,mol}$

b) $\frac{V(H_2(g))}{V(H_2O(g))} = \frac{2\,L}{2\,L}$

c) $\frac{V(H_2(g))}{V(H_2O(g))} = \frac{2\,L}{2\,L}$

$V(H_2O(g)) = V(H_2(g)) \times \frac{2\,L}{2\,L} = 20\text{ L } H_2(g) \times \frac{2\,L}{2\,L} = 20\text{ L } H_2O(g)$

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.

$V(N_2(g)) = 12.0\text{ L}$

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

$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

$\frac{V(NH_3(g))}{V(N_2(g))} = \frac{2\,L}{1\,L}$

$V(NH_3(g)) = V(N_2(g)) \times \frac{2\,L}{1\,L} = 12.0\text{ L } N_2(g) \times \frac{2\,L}{1\,L} = 24.0\text{ L}$

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?

$V(CH_4(g)) = 15$ 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, $CH_4(g)$, to produce $CO_2(g)$ and $H_2O(g)$.

Act on Your Strategy

The balanced equation for the burning of methane is

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

$$\frac{n(O_2(g))}{n(CH_4(g))} = \frac{V(O_2(g))}{V(CH_4(g))} = \frac{2}{1}$$

$$V(O_2(g)) = V(CH_4(g)) \times \frac{n(O_2(g))}{n(CH_4(g))} = 15\text{ L } CH_4(g) \times \frac{2\text{ mol } O_2(g)}{1\text{ mol } CH_4(g)} = 30\text{ L}$$

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.

a) Write a balanced chemical equation for this reaction

b) Each molecule of element A is actually made of two A atoms—it is really $A_2(g)$. Each molecule of element B is actually made of two B atoms—it is really $B_2(g)$. What is the formula of compound C in terms of A and B atoms?

What is Required?

a) You must write the balanced equation for this reaction.

b) 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
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
$2A(g) + B(g) \rightarrow C(g)$
b) If elements A and B are diatomic, their chemical formulas are $A_2(g)$ and $B_2(g)$ respectively. To have conservation of atoms, the chemical formula for compound C will be $A_4B_2(g)$.
The balanced equation should then be
$2A_2(g) + B_2(g) \rightarrow A_4B_2(g)$

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 ºC?
b) What amount, in moles, of an unknown gas occupies 3.2 L at 16.6 kPa and 127 ºC?
c) What amount, in moles, of $C_2F_6(g)$ occupies 12.5 mL at 600 mmHg pressure and –23 ºC? (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 27ºC.
b) You must calculate the number of moles of an unknown gas that occupy 3.2 L at 16.6 kPa and 127 ºC.
c) You must calculate the number of moles of $C_2F_6(g)$ that occupy 12.5 mL at 600 mmHg pressure and –23ºC.

What is Given?
a) $n(Cl_2) = 2.0$ mol
$P = 75$ kPa
$t = 27$ ºC
b) $V = 3.2$ L
$P = 16.6$ kPa
$t = 127$ ºC
c) $V(C_2F_6) = 12.5$ mL $= 0.0125$ L
$P = 600$ mmHg
$t = -23\ ^{o}$C

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

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

Act on Your Strategy

a) T = 27 ºC + 273.15 = 300.15 K

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

b) T = 127 ºC + 273.15 = 400.15 K

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

c) T = –23 ºC + 273.15 = 250.15 K

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

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

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 ºC 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(MgO) = 2.43 g

t = 25.0 ºC

P = 94.9 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_2(g).

Use the relationship T(Kelvin) = t(Celsius) + 273.15 to convert the Celsius temperature to Kelvin.

Use the ideal gas law, $PV = nRT$, where R = $\frac{8.314\ \text{kPa} \bullet \text{L}}{\text{mol} \bullet \text{K}}$ to solve for the volume of O_2(g).

Act on Your Strategy
The balanced equation is
$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$

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

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

$nO_2(g) = 0.06028\ \text{mol MgO(s)} \times \frac{1\ \text{mol}\ O_2(g)}{2\ \text{mol MgO(s)}} = 0.03014\ \text{mol}$

T (Kelvin) = 25.0 ºC + 273.15 = 298.15 K

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

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 ºC, 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(coal) = 3070 kg and is 90% carbon
P = 100 kPa
$t = 25^{o}$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 CO_2(g) that is produced. Convert the Celsius temperature to Kelvin and use the ideal gas law to calculate the volume of CO_2(g) at the given temperature and pressure.

Act on Your Strategy

$m$carbon = 90% × 3070 kg = 2763 kg = 2.76×10^6 g

$C(s) + O_2(g) \rightarrow CO_2(g)$

$MC(s) = 12.01\ \frac{g}{mol}$

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

$nCO_2(g) = 2.30 \times 10^5\ mol\ C(s) \times \frac{1\,mol\,C(s)}{1\,mol\,CO_2(g)} = 2.30 \times 10^5\ mol$

T (Kelvin) = 25.0 ºC + 273.15 K = 298.15 K

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

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, $C_2F_6(g)$, is used to remove silicon dioxide, $SiO_2(s)$, from apparatus as silicon tetrafluoride, $SiF_4(g)$, according to the following chemical equation:

$2SiO_2(s) + 2C_2F_6(g) + O_2(g) \rightarrow 2SiF_4(g) + 2COF_2(g) + 2CO_2(g)$

What mass of $SiO_2(s)$ reacts with 1.270 L of $C_2F_6(g)$ at a pressure of 0.200 kPa and a temperature of 400 ºC?

What is Required?

You must calculate the mass of $SiO_2(s)$ that reacts with 1.270 L of $C_2F_6(g)$ at a pressure of 0.200 kPa and a temperature of 400 ºC.

What is Given?

The balanced equation is given.

$V(C_2F_6(g)) = 1.270$ L

$P = 0.200$ kPa

$t = 400^oC$

Plan Your Strategy

Convert the Celsius temperature to Kelvin and use the ideal gas equation to calculate the number of moles of $C_2F_6(g)$. Use the mole ratio in the balanced equation to determine the number of moles of $SiO_2(s)$ that react. Determine the molar mass of $SiO_2(s)$ and change the number of moles to grams using the equation $m = n \times M$.

Act on Your Strategy

T (Kelvin) = 400 ^{o}C + 273.15 = 673.15K

$$nC_2F_6(g) = \frac{PV}{RT} = \frac{0.200\,\text{kPa} \times 1.270\,\text{L}}{\frac{8.314\,\text{kPa} \bullet \text{L}}{\text{mol} \bullet \text{K}} \times 673.15\,\text{K}} = 4.538 \times 10^{-5}\ \text{mol}$$

$$nSiO_2(s) = 4.538 \times 10^{-5}\ \text{mol}\ C_2F_6(g) \times \frac{2\,\text{mol}\,SiO_2(s)}{2\,\text{mol}\,C_2F_6(g)} = 4.538 \times 10^{-5}\ \text{mol}$$

$$M(SiO_2(s)) = 60.09\ \frac{\text{g}}{\text{mol}}$$

$$mSiO_2(s) = 4.538 \times 10^{-5}\ \text{mol}\ SiO_2(s) \times 60.09\ \frac{\text{g}}{\text{mol}} = 2.73 \times 10^{-3}\ \text{g}\ SiO_2(s)$$

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