Chemistry

Stoichiometry Packet

Chemistry: Form WS5.5.2A

Name ______________________

CHEMICAL REACTIONS

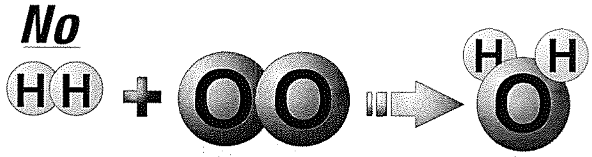
Date ____________ Period _____

Balancing Equations

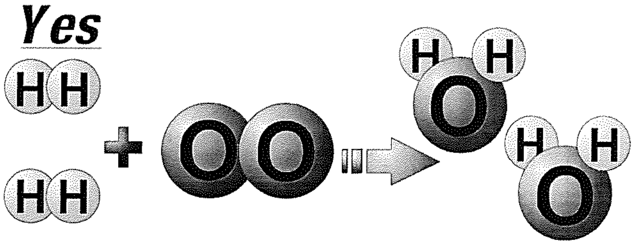
During a chemical change, there is no change in mass. A properly written chemical equation shows this. The equation below is not properly written. It does not show conservation of mass.

$$H_2 + O_2 \rightarrow H_2O$$
$$2 + 32 \neq 18$$

No



Yes



$$2H_2 + O_2 \rightarrow 2H_2O$$
$$2(2) + 32 = 2(18)$$

The reason the equation doesn't work is simple. There are two atoms of oxygen in the reactants, but only one in the product. If two molecules of hydrogen react with a molecule of oxygen to form two molecules of water, there are no atoms missing and mass is conserved. The number of molecules is shown with a number to the left of the formula known as a coefficient. A coefficient behaves like a multiplier. It's not necessary to check the mass to get a properly written equation. Counting atoms is sufficient. When the equation for the formation of water is written properly, $2H_2 + O_2 \rightarrow 2H_2O$, there are 4 hydrogen atoms and two oxygen atoms on both sides of the equation and the mass of the reactants is the same as the mass of the products. Making the number of atoms equal on both sides of the equation is all that is needed. The process is called balancing.

Balance the equations below by writing the correct coefficient in the space before each formula. Coefficient "1" need not be written.

1. ____ H_2 + ____ Cl_2 → ____ HCl
2. ____ $Ca(NO_3)_2$ + ____ H_2SO_4 → ____ $CaSO_4$ + ____ HNO_3
3. ____ Fe + ____ Cl_2 → ____ $FeCl_3$
4. ____ Fe + ____ O_2 → ____ Fe_2O_3
5. ____ Zn + ____ HCl → ____ $ZnCl_2$ + ____ H_2
6. ____ Cu + ____ $AgCH_3COO$ → ____ $Cu(CH_3COO)_2$ + ____ Ag
7. ____ H_2SO_4 + ____ $NaOH$ → ____ Na_2SO_4 + ____ H_2O
8. ____ N_2 + ____ H_2 → ____ NH_3
9. ____ CH_4 + ____ O_2 → ____ CO_2 + ____ H_2O
10. ____ S + ____ O_2 → ____ SO_3

Balancing Equations Race

1) ___ C_3H_8 + ___ O_2 → ___ CO_2 + ___ H_2O

2) ___ Al + ___ Fe_3N_2 → ___ AlN + ___ Fe

3) ___ Na + ___ Cl_2 → ___ NaCl

4) ___ H_2O_2 → ___ H_2O + ___ O_2

5) ___ $C_6H_{12}O_6$ + ___ O_2 → ___ H_2O + ___ CO_2

6) ___ H_2O + ___ CO_2 → ___ C_7H_8 + ___ O_2

7) ___ $NaClO_3$ → ___ NaCl + ___ O_2

8) ___ $(NH_4)_3PO_4$ + ___ $Pb(NO_3)_4$ → ___ $Pb_3(PO_4)_4$ + ___ NH_4NO_3

9) ___ BF_3 + ___ Li_2SO_3 → ___ $B_2(SO_3)_3$ + ___ LiF

10) ___ C_7H_{17} + ___ O_2 → ___ CO_2 + ___ H_2O

11) ___ $CaCO_3$ + ___ H_3PO_4 → ___ $Ca_3(PO_4)_2$ + ___ H_2CO_3

12) ___ Ag_2S → ___ Ag + ___ S_8

13) ___ KBr + ___ $Fe(OH)_3$ → ___ KOH + ___ $FeBr_3$

14) ___ KNO_3 + ___ H_2CO_3 → ___ K_2CO_3 + ___ HNO_3

15) ___ $Pb(OH)_4$ + ___ Cu_2O → ___ PbO_2 + ___ CuOH

16) ___ $Cr(NO_2)_2$ + ___ $(NH_4)_2SO_4$ → ___ $CrSO_4$ + ___ NH_4NO_2

17) ___ KOH + ___ $Co_3(PO_4)_2$ → ___ K_3PO_4 + ___ $Co(OH)_2$

18) ___ $Sn(NO_2)_4$ + ___ Pt_3N_4 → ___ Sn_3N_4 + ___ $Pt(NO_2)_4$

19) ___ B_2Br_6 + ___ HNO_3 → ___ $B(NO_3)_3$ + ___ HBr

20) ___ ZnS + ___ AlP → ___ Zn_3P_2 + ___ Al_2S_3

Name: ______________________________ **Date:** __________

Balancing Equations

Balance the following chemical equations.

1. ____ Fe + ____ H_2S0_4 $\longrightarrow$ ____ $Fe_2(SO_4)_3$ + ____ H_2

2. ____ C_2H_6 + ____ O_2 $\longrightarrow$ ____ H_2O + ____ CO_2

3. ____ KOH + ____ H_3PO_4 $\longrightarrow$ ____ K_3PO_4 + ____ H_2O

4. ____ SnO_2 + ____ H_2 $\longrightarrow$ ____ Sn + ____ H_2O

5. ____ NH_3 + ____ O_2 $\longrightarrow$ ____ NO + ____ H_2O

6. ____ KNO_3 + ____ H_2CO_3 $\longrightarrow$ ____ K_2CO_3 + ____ HNO_3

7. ____ B_2Br_6 + ____ HNO_3 $\longrightarrow$ ____ $B(NO_3)_3$ + ____ HBr

8. ____ BF_3 + ____ Li_2SO_3 $\longrightarrow$ ____ $B_2(SO_3)_3$ + ____ LiF

9. ____ $(NH_4)_3PO_4$ + ____ $Pb(NO_3)_4$ $\longrightarrow$ ____ $Pb_3(PO_4)_4$ + ____ NH_4NO_3

10. ____ $SeCl_6$ + ____ O_2 $\longrightarrow$ ____ SeO_2 + ____ Cl_2

Name: ______________________________ **Date:** ____________

Balancing Equations

Balance the following chemical equations.

1. ___ CH_4 + ___ O_2 → ___ CO_2 + ___ H_2O

2. ___ Na^+ + ___ Cl^- → ___ NaCl

3. ___ Al + ___ O_2 → ___ Al_2O_3

4. ___ N_2^+ + ___ H_2 → ___ NH_3

5. ___ CO(g) + ___ H_2(g) → ___ C_8H_{18}(l) + ___ H_2O

6. ___ FeO_3(s) + ___ CO(g) → ___ Fe(l) + ___ CO_2(g)

7. ___ H_2SO_4 + ___ $Pb(OH)_4$ → ___ $Pb(SO_4)_2$ + ___ H_2O

8. ___ Al + ___ HCl → ___ $AlCl_3$ + ___ H_2

9. ___ $Ca_3(PO_4)_2$ + ___ H_2SO_4 → ___ $CaSO_4$ + ___ $Ca(H_2PO_4)_2$

10. ___ H_3PO_4 + ___ HCl → ___ PCl_5 + ___ H_2O

Name: ______________________________ **Date:** ____________

Balancing Equations

Balance the following chemical equations.

1. ____ $SiCl_4(l)$ + ____ $H_2O(l)$ $\longrightarrow$ ____ $SiO_2(s)$ + ____ $HCl(aq)$

2. ____ As + ____ $NaOH$ $\longrightarrow$ ____ Na_3AsO_3 + ____ H_2

3. ____ Au_2S_3 + ____ H_2 $\longrightarrow$ ____ Au + ____ H_2S

4. ____ V_2O_5 + ____ HCl $\longrightarrow$ ____ $VOCl_3$ + ____ H_2O

5. ____ $Hg(OH)_2$ + ____ H_3PO_4 $\longrightarrow$ ____ $Hg_3(PO_4)_2$ + ____ H_2O

6. ____ SiO_2 + ____ HF $\longrightarrow$ ____ SiF_4 + ____ H_2O

7. ____ Zn + ____ HCl $\longrightarrow$ ____ $ZnCl_2$ + ____ H_2

8. ____ $HClO_4$ + ____ P_4O_{10} $\longrightarrow$ ____ H_3PO_4 + ____ Cl_2O_7

9. ____ $N_2(g)$ + ____ $O_2(g)$ + ____ H_2O $\longrightarrow$ ____ $HNO_3(aq)$

10. ____ NH_4NO_3 $\longrightarrow$ ____ N_2 + ____ O_2 + ____ H_2O

WORD EQUATIONS

Name ______________________

Write the word equations below as chemical equations and balance.

1. zinc + lead (II) nitrate yield zinc nitrate + lead

2. aluminum bromide + chlorine yield aluminum chloride + bromine

3. sodium phosphate + calcium chloride yield calcium phosphate + sodium chloride

4. potassium chlorate when heated yields potassium chloride + oxygen gas

5. aluminum + hydrochloric acid yield aluminum chloride + hydrogen gas

6. calcium hydroxide + phosphoric acid yield calcium phosphate + water

7. copper + sulfuric acid yield copper (II) sulfate + water + sulfur dioxide

8. hydrogen + nitrogen monoxide yield water + nitrogen

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Word Equations

Write the word equations below as chemical equations and balance:

1) Zinc and lead (II) nitrate react to form zinc nitrate and lead.

2) Aluminum bromide and chlorine gas react to form aluminum chloride and bromine gas.

3) Sodium phosphate and calcium chloride react to form calcium phosphate and sodium chloride.

4) Potassium metal and chlorine gas combine to form potassium chloride.

5) Aluminum and hydrochloric acid react to form aluminum chloride and hydrogen gas.

6) Calcium hydroxide and phosphoric acid react to form calcium phosphate and water.

7) Copper and sulfuric acid react to form copper (II) sulfate and water and sulfur dioxide.

8) Hydrogen gas and nitrogen monoxide react to form water and nitrogen gas.

NAME:________________________ DATE:____________________

To React or Not To React!

Introduction:

A **chemical reaction** is a process that leads to the transformation of one set of chemical substances to another. Classically, chemical reactions encompass changes that strictly involve the motion of electrons in the forming and breaking of chemical bonds, although the general concept of a chemical reaction, in particular the notion of a chemical equation, is applicable to transformations of elementary particles, as well as nuclear reactions.

A chemical equation is a way to describe what goes on in a chemical reaction, the actual change in a material. Chemical equations are written with the symbols of materials to include elements, ionic or covalent compounds, aqueous solutions, ions, or particles. There is an arrow pointing to the right that indicates the action of the reaction. The materials to the left of the arrow are the *reactants*, or materials that are going to react. The materials to the right of the arrow are the *products*, or materials that have been produced by the reaction. The *Law of Conservation of Mass* states that in a chemical reaction no mass is lost or gained. The Law of Conservation of Mass applies to individual types of atom. One could say that for any element, there is no loss or gain of that element in a chemical reaction.

There are so many chemical reactions that it is helpful to classify them into 5 general types which include the following:

SYNTHESIS REACTION

In a synthesis reaction two or more simple substances combine to form a more complex substance. Two or more reactants yielding one product is another way to identify a synthesis reaction.

A general chemical equation for a synthesis reaction looks like:

$$A + B \rightarrow AB$$

DECOMPOSITION REACTION

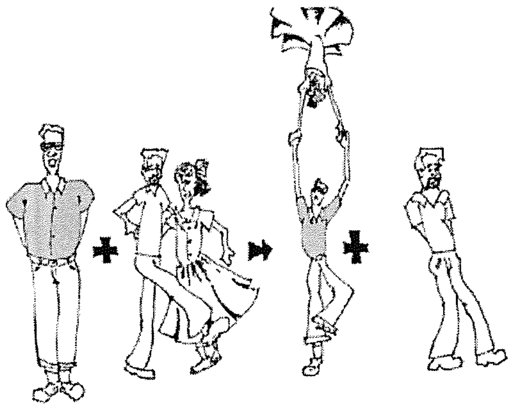
In a decomposition reaction a more complex substance breaks down into its more simple parts. One reactant yields 2 or more products. Basically, synthesis and decomposition reactions are opposites.

$$AB \rightarrow A + B$$

SINGLE REPLACEMENT REACTION

In a single replacement reaction a single uncombined element replaces another in a compound. Two reactants yield two products.

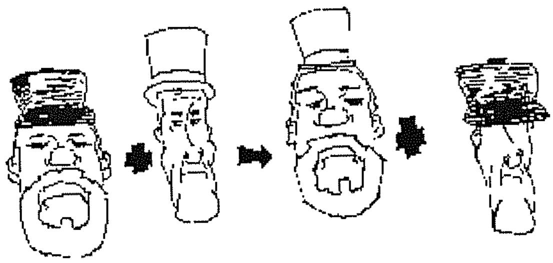
$$A + BC \rightarrow AC + B$$



DOUBLE REPLACEMENT REACTION

In a double replacement reaction parts of two compounds switch places to form two new compounds. Two reactants yield two products. For example when silver nitrate combines with sodium chloride, two new compounds--silver chloride and sodium nitrate are formed because the sodium and silver switched places. The chemical equation for this double replacement reaction looks like:

$$AB + CD \rightarrow AD + CB$$



COMBUSTION

A combustion reaction is when oxygen combines with another compound to form water and carbon dioxide. These reactions are exothermic, meaning they produce heat. An example of this kind of reaction is the burning of methane:

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

Problems:

Chemical reactions, also called chemical changes, are not limited to happening in a chemistry lab. Here are some examples of chemical reactions with the corresponding chemical equations. Complete, Identify and balance the type of chemical reaction.

1) A silver spoon tarnishes. The silver reacts with sulfur in the air to make silver sulfide, the black material we call tarnish.

$Ag + S \longrightarrow Ag_2S$ ______________

2) An iron bar rusts. The iron reacts with oxygen in the air to make rust.

$Fe + O_2 \longrightarrow Fe_2O_3$ ______________ Product name: ____________

3) Propane in a gas grill burns. Propane combines with oxygen in the air to make carbon dioxide and water vapor.

$C_3H_8 + O_2 \longrightarrow CO_2 + H_2O$ ______________

4) An antacid (calcium hydroxide) neutralizes stomach acid (hydrochloric acid).

$Ca(OH)_2 + HCl \longrightarrow CaCl_2 + H_2O$ ______________

5) Glucose (simple sugar) ferments to ethyl alcohol and carbon dioxide. The sugar in grapes or from grain ferments with yeast to make the alcohol and carbon dioxide. The carbon dioxide is the gas that bubbles out of beer or Champaign.

$C_6H_{12}O_6 \longrightarrow C_2H_5OH + CO_2$ ______________

6) $NaOH + KNO_3 \rightarrow$ _______ + _______ ______________

7) $Fe + NaBr$ --> _______ + _______ ______________

4) $CaSO_4 + Mg(OH)_2$ --> _______ + _______ ______________

5) $NH_4OH + HBr$ --> $H_2O + NH_4Br$ ______________

6) $Pb + O_2$ --> PbO_2 ______________

7) Na_2CO_3 --> $Na_2O + CO_2$ ______________

8) $HNO_3 \rightarrow N_2O_5 + H_2O$ ______________

9) $CaCl_2 + K_2CO_3 \rightarrow$ ______ + ______ ____________

11) $Cl_2 + KI \rightarrow$ ______ + ______ ____________

12) $Fe_2O_3 + C \rightarrow CO_2 + Fe$ ____________

13) $P + Cl_2 \rightarrow PCl_3$ ____________

14) $H_2O_2 \rightarrow H_2O + O_2$ ____________

15) $C_6H_6 + O_2 \rightarrow$ ______ + ______ ____________

Questions:

Based your answers to questions 1 and 2 on the following equation:

$$K + S_8 \rightarrow K_2S$$

1) What type of reaction?
(1) Synthesis
(2) Decomposition
(3) Combustion
(4) Single Replacement

2) In terms of the number of atoms describe how this reaction obeys the law of conservation of mass.

3) In terms of elements describe how a chemical reaction differs from a nuclear reaction.

Reflection:

In your own words describe each type of reaction.

Synthesis

Decomposition

Single Replacement

Double Replacement

Six Types of Chemical Reaction Worksheet

Balance the following reactions and indicate which of the six types of chemical reaction are being represented:

1) ____ $NaBr$ + ____ $Ca(OH)_2 \rightarrow$ ___ $CaBr_2$ + ____ $NaOH$

Type of reaction: ______________________

2) ____ NH_3+ ____ $H_2SO_4 \rightarrow$ ____ $(NH_4)_2SO_4$

Type of reaction: ______________________

3) ____ C_5H_9O + ____ $O_2 \rightarrow$ ____ CO_2 + ____ H_2O

Type of reaction: ______________________

4) ____ Pb + ____ $H_3PO_4 \rightarrow$ ____ H_2 + ____ $Pb_3(PO_4)_2$

Type of reaction: ______________________

5) ____ Li_3N + ____ $NH_4NO_3 \rightarrow$ ___ $LiNO_3$ + ___ $(NH_4)_3N$

Type of reaction: ______________________

6) ____ HBr + ___ $Al(OH)_3 \rightarrow$ ___ H_2O + ___ $AlBr_3$

Type of reaction: ______________________

7) What's the main difference between a double displacement reaction and an acid-base reaction?

8) Combustion reactions always result in the formation of water. What other types of chemical reaction may result in the formation of water? Write examples of these reactions on the opposite side of this paper.

Predicting Reaction Products

Balance the equations and predict the products for the following reactions:

1) ____ Na + ____ $FeBr_3 \rightarrow$

2) ____ $NaOH$ + ____ $H_2SO_4 \rightarrow$

3) ____ $C_2H_4O_2$ + ____ $O_2 \rightarrow$

4) ____ NH_3 + ____ $H_2O \rightarrow$

5) ____ $PbSO_4$ + ____ $AgNO_3 \rightarrow$

6) ____ $PBr_3 \rightarrow$

7) ____ HBr + ____ $Fe \rightarrow$

8) ____ $KMnO_4$ + ____ $ZnCl_2 \rightarrow$

9) ____ MnO_2 + ____ $Sn(OH)_4 \rightarrow$

10) ____ O_2 + ____ $C_5H_{12}O_2 \rightarrow$

11) ____ $H_2O_2 \rightarrow$

12) ____ $PtCl_4$ + ____ $Cl_2 \rightarrow$

Double Displacement Reactions

Indicate which of the following double displacement reactions will go to completion, and circle what the product of the reaction will be (if any). You may want to consult a list of K_{sp} values to solve these problems.

1) ___ NaOH + ___ $CaBr_2$ →

Will this reaction occur? _____

2) ___ $Pb(NO_3)_2$ + ___ HCl →

Will this reaction occur? _____

3) ___ Na_2CO_3 + ___ KF →

Will this reaction occur? _____

4) ___ $AgNO_3$ + ___ $CuSO_4$ →

Will this reaction occur? _____

5) ___ AgF + ___ $NiCl_2$ →

Will this reaction occur? _____

6) Devise a method for making silver chromate, given any two other ionic compounds. Write the equation here:

7) On the opposite side of this page, indicate how much of each reagent you would require to make 100 grams of silver chromate.

Reaction Products Worksheet

For each of the following reactions, determine what the products of each reaction will be. When you have predicted the products, balance the equation and use a table of solubility products to determine which of the products (if any) will precipitate. Assume all reactions take place in water.

1) ____ $Ca(OH)_2$ + ____ $HF \rightarrow$

2) ____ $Pb(NO_3)_2$ + ____ $K_2CrO_4 \rightarrow$

3) ____ $NaC_2H_3O_2$ + ____ $H_2SO_4 \rightarrow$

4) ____ $Cu(OH)_2$ + ____ $H_3PO_4 \rightarrow$

5) ____ $AgNO_3$ + ____ $Na_2CO_3 \rightarrow$

6) ____ Zn + ____ $H_2CO_3 \rightarrow$

7) ____ $Pb(OH)_2$ + ____ $Hg_2S \rightarrow$

Worksheet: Writing Equations

Write equations for the following reactions:

1) The reaction of ammonia with iodine to form nitrogen triiodide (NI_3) and hydrogen gas.

2) The combustion of propane (C_3H_8).

3) The incomplete combustion of propane to form CO and water.

4) The reaction of nitric acid with potassium hydroxide.

5) The reaction of copper (II) oxide with hydrogen to form copper metal and water.

6) The reaction of iron metal with oxygen to form iron (III) oxide.

7) The complete combustion of 2,2-dimethylpropane (C_4H_{10}) in oxygen.

8) The reaction of $AlBr_3$ with $Mg(OH)_2$

9) The decomposition of hydrogen peroxide to form water and oxygen.

10) The reaction of ammonia with sulfuric acid.

Name ____________________ Class______ Date__________

Activity 3-11
Practice Drill: Chemical Equations

Complete and balance the following equations for chemical reactions. In the space at the right of each equation, identify the category of reaction. Use:

SYN—synthesis
DEC—decomposition
SR—single replacement

1. ___$Al(s)$ + ___$Br_2(g)$ → ______ 1. ______
2. ___$O_2(g)$ + ______ → ___$Fe_2O_3(s)$ 2. ______
3. ___$Zn(s)$ + ___$HCl(aq)$ → ______ + ______ 3. ______
4. ___Mg + ___H_3PO_4 → ______ + ______ 4. ______
5. ___$NH_4OH(aq)$ → ___$NH_3(g)$ + ______ 5. ______
6. ___$Al_2O_3(s)$ → ___$Al(s)$ + ______ 6. ______
7. ___$KClO_3(s)$ → ___$O_2(g)$ + ______ 7. ______
8. ___$K(s)$ + ___$HOH(l)$ → ______ + ___$KOH(aq)$ 8. ______
9. ___$Ba(s)$ + ______ → ___$Ba_3N_2(s)$ 9. ______
10. ___$Cu(s)$ + ______ → ___$Cu_2S(s)$ 10. ______

Complete and balance the following equations for chemical reactions.

11. ___$AlI_3(aq)$ + ___$HgCl_2(aq)$ → ______ + ______
12. ___$FeCl_3(aq)$ + ___$H_3PO_4(aq)$ → ______ + ______
13. ___$SnCl_4(aq)$ + ______ → ___$NH_4Cl(aq)$ + ___$SnS_2(s)$
14. ___$CaBr_2(aq)$ + ___$KOH(aq)$ → ______ + ______
15. ___$AgNO_3(aq)$ + ______ → ___$Ag_3PO_4(s)$ + ___$KNO_3(aq)$
16. ______ + ___$Ba(OH)_2(aq)$ → ___$Al(OH)_3(s)$ + ___$BaCl_2(aq)$
17. ___$Ca(C_2H_3O_2)_2(aq)$ + ______ → ___$CaCO_3(s)$ + ___$NaC_2H_3O_2(aq)$
18. ___ $Na_3PO_4(aq)$ + ___ $ZnSO_4\ (aq)$ → ______ + ______
19. ___$Ba(ClO_3)_2(aq)$ + ___$Na_2S(aq)$ → ______ + ______
20. ______ + ___$AlCl_3(aq)$ → ___$KCl(aq)$ + ___$Al_2(CrO_4)_3(s)$
21. ___$(NH_4)_2CO_3(aq)$ + ___$NaOH(aq)$ → ______ + ___$NH_3(g)$ + ______
22. ___$K_2SO_3(aq)$ + ___$HNO_3(aq)$ → ______ + ______ + ___$H_2O(l)$
23. ______ + ___$HNO_3(aq)$ → ___$Ca(NO_3)_2(aq)$ + ___ $H_2O(l)$
24. ___$Hg_2(NO_3)_2(aq)$ + ______(aq) → ___ $Hg_2I_2(s)$ + ___$NaNO_3(aq)$

To which category do all these reactions belong? ____________________

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Write balanced chemical equations for each of the following double replacement reactions.

25. calcium iodide + sulfuric acid →

26. manganese sulfide + lead (IV) chloride →

27. potassium hydroxide + iron (III) chloride →

28. zinc bromide + sodium carbonate →

29. calcium hydroxide + mercuric chloride →

30. barium carbonate + sulfuric acid →

31. potassium hydroxide + ammonium sulfate →

32. sodium sulfite + hydrogen chloride →

A Voyage through Equations

After working on this worksheet, you should be able to do the following:

1) Given an equation, you should be able to tell what kind of reaction it is.
2) Predict the products of a reaction when given the reactants.

Section 1: Identify the type of reaction

For the following reactions, indicate whether the following are examples of synthesis, decomposition, combustion, single displacement, double displacement, or acid-base reactions:

1) $Na_3PO_4 + 3\ KOH \rightarrow 3\ NaOH + K_3PO_4$ ______________________
2) $MgCl_2 + Li_2CO_3 \rightarrow MgCO_3 + 2\ LiCl$ ______________________
3) $C_6H_{12} + 9\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$ ______________________
4) $Pb + FeSO_4 \rightarrow PbSO_4 + Fe$ ______________________
5) $CaCO_3 \rightarrow CaO + CO_2$ ______________________
6) $P_4 + 3\ O_2 \rightarrow 2\ P_2O_3$ ______________________
7) $2\ RbNO_3 + BeF_2 \rightarrow Be(NO_3)_2 + 2\ RbF$ ______________________
8) $2\ AgNO_3 + Cu \rightarrow Cu(NO_3)_2 + 2\ Ag$ ______________________
9) $C_3H_6O + 4\ O_2 \rightarrow 3\ CO_2 + 3\ H_2O$ ______________________
10) $2\ C_5H_5 + Fe \rightarrow Fe(C_5H_5)_2$ ______________________
11) $SeCl_6 + O_2 \rightarrow SeO_2 + 3Cl_2$ ______________________
12) $2\ MgI_2 + Mn(SO_3)_2 \rightarrow 2\ MgSO_3 + MnI_4$ ______________________
13) $O_3 \rightarrow O^{\cdot} + O_2$ ______________________
14) $2\ NO_2 \rightarrow 2\ O_2 + N_2$______________________

Section 2: Practicing equation balancing

Before you can write a balanced equation for a problem which asks you to predict the products of a reaction, you need to know how to balance an equation. Because some of you may not fully remember how to balance an equation, here are some practice problems:

1) __ C_6H_6 + __ $O_2 \rightarrow$ __ H_2O + __ CO_2

2) __ NaI + __ $Pb(SO_4)_2 \rightarrow$ __ PbI_4 + __ Na_2SO_4

3) __ NH_3 + __ $O_2 \rightarrow$ __ NO + __ H_2O

4) __ $Fe(OH)_3 \rightarrow$ __ Fe_2O_3 + __ H_2O

5) __ HNO_3 + __ $Mg(OH)_2 \rightarrow$ __ H_2O + __ $Mg(NO_3)_2$

6) __ H_3PO_4 + __ NaBr $\rightarrow$ __ HBr + __ Na_3PO_4

7) __ C + __ $H_2 \rightarrow$ __ C_3H_8

8) __ CaO + __ $MnI_4 \rightarrow$ __ MnO_2 + __ CaI_2

9) __ Fe_2O_3 + __ $H_2O \rightarrow$ __ $Fe(OH)_3$

10) __ C_2H_2 + __ $H_2 \rightarrow$ __ C_2H_6

11) __ VF_5 + __ HI $\rightarrow$ __ V_2I_{10} + __ HF

12) __ OsO_4 + __ $PtCl_4 \rightarrow$ __ PtO_2 + __ $OsCl_8$

13) __ CF_4 + __ $Br_2 \rightarrow$ __ CBr_4 + __ F_2

14) __ Hg_2I_2 + __ $O_2 \rightarrow$ __ Hg_2O + __ I_2

15) __ $Y(NO_3)_2$ + __ $GaPO_4 \rightarrow$ __ YPO_4 + __ $Ga(NO_3)_2$

Section 3: Predicting the products of chemical reactions

Predict the products of the following reactions:

1) __ Ag + __ $CuSO_4$ →

Type:______________________________

2) __ NaI + __ $CaCl_2$ →

Type:______________________________

3) __ O_2 + __ H_2 →

Type:______________________________

4) __ HNO_3 + __ $Mn(OH)_2$ →

Type:______________________________

5) __ $AgNO_2$ + __ $BaSO_4$ →

Type:______________________________

6) __ HCN + __ $CuSO_4$ →

Type:______________________________

7) __ H_2O + __ AgI →

Type:______________________________

8) __ HNO_3 + __ $Fe(OH)_3$ →

Type:______________________________

9) __ LiBr + __ $Co(SO_3)_2$ →

Type:______________________________

10) __ $LiNO_3$ + __ Ag →

Type:______________________________

11) __ N_2 + __ O_2 →

Type:______________________________

12) __ H_2CO_3 →

Type:______________________________

13) __ $AlCl_3$ + __ Cs →

Type:______________________________

14) __ $Al(NO_3)_3$ + __ Ga →

Type:______________________________

15) __ H_2SO_4 + __ NH_4OH →

Type:______________________________

16) __ CH_3COOH + __ O_2 →

Type:______________________________

17) __ C_4H_8 + __ O_2 →

Type:______________________________

18) __ KCl + __ $Mg(OH)_2$ →

Type:______________________________

19) __ Zn + __ $Au(NO_2)_2$ →

Type:______________________________

20) __ KOH + __ H_2SO_4 →

Type:______________________________

21) __ BaS + __ $PtCl_2$ →

Type:______________________________

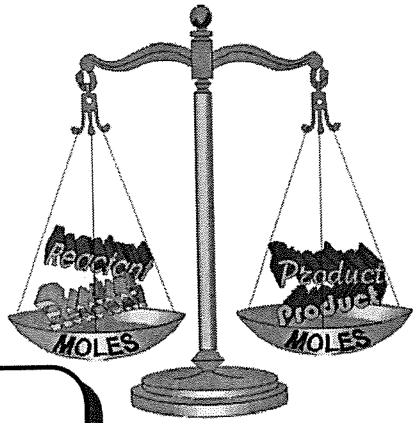
22) __ Na_2O →

Type:______________________________

Name ______________________

Date ______________ Period ____

Stochiometric Relationships



Calculations based on quantitative relationships in a balanced chemical equation are called stoichiometry. Stoichiometric calculations are based on several assumptions. It is assumed that the reaction has no side reactions, the reaction goes to completion, and the reactants are completely consumed. One type of problem that can be solved stoichiometrically is based on the mole ratios of a balanced equation. A sample problem is shown below.

Sample Problem

How many moles of oxygen are consumed when 0.6 moles of hydrogen burns to produce water?

Step 1: Write a balanced equation and determine the mole ratios from the equation

Step 2: Identify the known and the unknown

Step 3: Set up a proportion and solve for the unknown

	$2\,H_2(g)$	$+\ O_2(g)$	$\rightarrow 2\,H_2O$
mole ratio	2	1	2
moles	known 0.6	unknown x	

- $\dfrac{2}{0.6mol} = \dfrac{1}{x}$
- $2x = 0.6mol$
- $x = 0.3mol$

Answer the questions below using the procedure described in the sample problem above.

1. How many moles of oxygen will be produced from the decomposition of 3 moles of $KClO_3$?

   $\_\_KClO_3 \rightarrow \_\_KCl + \_\_O_2$

2. How many moles of Zn will be needed to completely react with 0.4 moles of HCl?

   $\_\_Zn + \_\_HCl \rightarrow \_\_ZnCl_2 + \_\_H_2$

3. How many moles of oxygen will be needed to completely oxidize 4 moles of CH_4?

$$\_CH_4 + \quad \_O_2 \rightarrow \quad \_CO_2 + \quad \_H_2O$$

4. How many moles of hydrogen will be needed to react with 2 moles of nitrogen according to the following?

$$\_N_2 + \quad \_H_2 \rightarrow \quad \_NH_3$$

5. Using the above reaction how many moles of NH_3 will be formed if 18 moles of H_2 is used?

6. How many moles of sulfur will be needed to oxidize 3 moles of zinc to zinc sulfide?

$$\_Zn + \quad \_S \rightarrow \quad \_ZnS$$

7. How many moles of silver chloride will be produced if 2 moles of silver is allowed to react with an unlimited amount of chlorine?

$$\_Ag^+ + \quad \_Cl^- \rightarrow \quad \_AgCl(s)$$

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Mass/Mass Problems

With a balanced equation, a *Periodic Table*, and some knowledge of chemistry, you can figure out how much of any product will form from a given amount of reactant. Consider the following problem:

How much oxygen is needed to produce 27.0 g of water by burning hydrogen?

Step 1: Write a balanced equation
$2H_2 + O_2 \rightarrow 2H_2O$

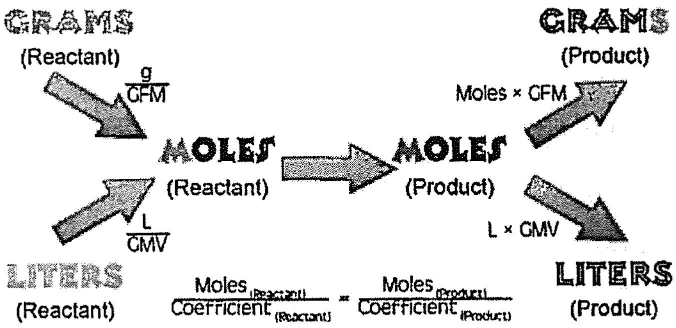
Step 2: Calculate the GFM of the known and unknown.

O_2: O = 16 × 2 = 32

H_2O: H = 1 × 2 = 2; O = 16 × 1 = 16; total 18

Step 3: Apply the factor label method

$$27g_{H_2O} \times \frac{1\,mol_{H_2O}}{18g_{H_2O}} \times \frac{1\,mol_{O_2}}{2\,mol_{H_2O}} \times \frac{32g_{O_2}}{1\,mol_{O_2}} = 24g_{O_2}$$



You will notice that, in applying the factor label method, you are first converting grams of the known to moles, then moles of the known to moles of the unknown using a proportion from the coefficients of the balanced equation, and, finally, moles of the unknown to grams as shown above. You can use the equations above instead of using the factor label method.

Calculate the amount of material asked for in each of the following. A balanced equation is provided:

1. How many grams of oxygen will be produced from the decomposition of 244 grams of $KClO_3$?

$$2KClO_3 \rightarrow 2KCl + 3O_2$$

2. How many grams of Zn will be needed to completely react with 72 g of HCl?

$$Zn + 2\,HCl \rightarrow ZnCl_2 + H_2$$

3. How many moles of oxygen will be needed to completely oxidize 64 g CH_4?

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

4. How many grams of hydrogen will be needed to react with 56 g of nitrogen according to the following?

$$N_2 + 3H_2 \rightarrow 2NH_3$$

5. Using the above reaction how many grams of NH_3 will be formed if 36 grams of H_2 is used?

6. How many grams of sulfur will be needed to oxidize 195 grams of zinc to zinc sulfide?

$$Zn + S \rightarrow ZnS$$

7. How many grams of silver chloride will be produced if 216 grams of silver is allowed to react with an unlimited amount of chlorine?

$$Ag^{+} + Cl^{-} \rightarrow AgCl(s)$$

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Activity 3-12

Mole and Mass Relations in Chemical Reactions

Mole ratios

In the laboratory or in commercial processes, the chemist or engineer must often find the quantity of one or more products that can be obtained from a given quantity of reactants. In order to solve any problem related to a chemical reaction, we must start with a balanced chemical equation. In this reaction

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

one mole of methane (CH_4) and two moles of oxygen react to produce one mole of carbon dioxide and two moles of water. Thus, the reaction can be restated as

$$\left(\text{one mole}\right) CH_4(g) \text{ reacts with } \left(\text{two moles}\right) O_2(g) \text{ to yield } \left(\text{one mole}\right) CO_2(g) \text{ and } \left(\text{two moles}\right) H_2O(g)$$

A balanced chemical equation can be used to obtain mole ratios for any two substances taking part in the reaction. For example, the ratio of CH_4 to O_2 in the above reaction is

$$\frac{1 \text{ mole } CH_4}{2 \text{ moles } O_2}$$

1. For the above reaction, write the mole ratios of:

   a. CH_4 to CO_2 ____________

   b. O_2 to CO_2 ____________

   c. CH_4 to H_2O ____________

   d. O_2 to H_2O ____________

Mass-mass problems

Mole ratios in reactions are used in solving problems that deal with mass-mass relations.

Sample Problem 1 In the reaction

$$4Fe + 3O_2 \rightarrow 2Fe_2O_3$$

84.9 grams of Fe reacts. What mass of O_2 will react?

Solution

$$84.9 \text{ g Fe} \times \frac{1 \text{ mole Fe}}{55.8 \text{ g Fe}} \times \frac{3 \text{ moles } O_2}{4 \text{ moles Fe}} \times \frac{32.0 \text{ g } O_2}{1 \text{ mole } O_2} = 36.5 \text{ g } O_2$$

Sample Problem 2 In the reaction above, what mass of Fe is required to produce 11.7 grams of Fe_2O_3?

Solution

$$11.7 \text{ g } Fe_2O_3 \times \frac{1 \text{ mole } Fe_2O_3}{160 \text{ g } Fe_2O_3} \times \frac{4 \text{ moles Fe}}{2 \text{ moles } Fe_2O_3} \times \frac{55.8 \text{ g Fe}}{1 \text{ mole Fe}} = 8.16 \text{ g Fe}$$

Practice problems

Solve each of the following problems. In the space below each problem, show a labeled setup. Do any necessary arithmetic on scrap paper. Write your answer in the space at the right.

1. In the reaction

$$2KClO_3 \rightarrow 2KCl + 3O_2$$

8.20 g $KClO_3$ reacts. Calculate the following:

a. the mass of KCl produced — 1. a. ______

b. the mass of O_2 produced — b. ______

2. In the reaction

$$P_4 + 5O_2 \rightarrow P_4O_{10}$$

7.75 g P_4 reacts. Calculate the following:

a. the mass of P_4O_{10} produced — 2. a. ______

b. the mass of O_2 that reacts — b. ______

3. In the reaction

$$C_5H_{12} + 8O_2 \rightarrow 5CO_2 + 6H_2O$$

109 g C_5H_{12} reacts. Calculate the following:

a. the mass of O_2 that reacts — 3. a. ______

b. the mass of CO_2 produced — b. ______

c. the mass of H_2O produced — c. ______

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4. In the reaction $Al_2(SO_4)_3 + 6NaOH \rightarrow 2Al(OH)_3 + 3Na_2SO_4$

22.7 g NaOH reacts. Calculate the following:

a. the mass of $Al_2(SO_4)_3$ that reacts — 4. a. ______

b. the mass of $Al(OH)_3$ produced — b. ______

c. the mass of Na_2SO_4 produced — c. ______

5. In the reaction $3Cu + 8HNO_3 \rightarrow 3Cu(NO_3)_2 + 2NO + 4H_2O$

11.3 g NO is produced. Calculate the following:

a. the mass of Cu that reacts — 5. a. ______

b. the mass of HNO_3 that reacts — b. ______

c. the mass of $Cu(NO_3)_2$ produced — c. ______

d. the mass of H_2O produced — d. ______

For 6-10, write your own balanced equation as the first step in solving the problem.

6. When butane, C_4H_{10}, burns in oxygen, the products are carbon dioxide and water. What mass of carbon dioxide will be produced when 4.42 kg of butane is burned in excess oxygen? — 6. ______

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7. Sodium oxide reacts with water to produce sodium hydroxide. What mass of sodium oxide must be used to produce 275 grams of sodium hydroxide?

7.____________

8. Aluminum reacts with hydrochloric acid to produce aluminum chloride and hydrogen gas. What mass of hydrochloric acid reacts when 87.7 grams of aluminum dissolves in excess hydrochloric acid?

8.____________

9. When a solution of barium chloride is mixed with a solution of sodium phosphate, a precipitate of barium phosphate is produced. The amount of barium chloride present in a given barium chloride solution is 62.9 grams. If this solution is added to a solution containing excess sodium phosphate, what mass of barium phosphate will be produced?

9.____________

10. When magnesium burns in pure nitrogen gas, magnesium nitride is formed. What mass of magnesium must be provided in order to produce 1.19 grams of magnesium nitride?

10.____________

Name ______________

STOICHIOMETRY: MIXED PROBLEMS

1. $N_2 + 3H_2 \rightarrow 2NH_3$
   What volume of NH_3 at STP is produced if 25.0 g of N_2 is reacted with an excess of H_2?

   ____

2. $2KClO_3 \rightarrow 2KCl + 3O_2$
   If 5.0 g of $KClO_3$ is decomposed, what volume of O_2 is produced at STP?

   ____

3. How many grams of KCl are produced in Problem 2?

   ____

4. $Zn + 2HCl \rightarrow ZnCl_2 + H_2$
   What volume of hydrogen at STP is produced when 2.5 g of zinc react with an excess of hydrochloric acid?

   ____

5. $H_2SO_4 + 2NaOH \rightarrow H_2O + Na_2SO_4$
   How many molecules of water are produced if 2.0 g of sodium sulfate are produced in the above reaction?

   ____

6. $2AlCl_3 \rightarrow 2Al + 3Cl_2$
   If 10.0 g of aluminum chloride are decomposed, how many molecules of Cl_2 are produced?

   ____

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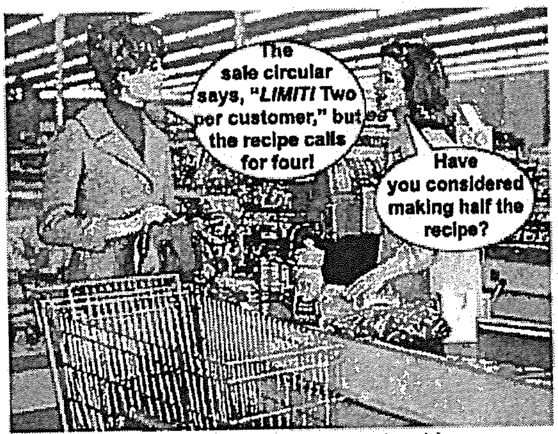
Limiting Reactants



Limiting reactants in the *real* world.

You drop a piece of zinc into a beaker of hydrochloric acid. It begins to bubble furiously, but eventually it stops. You drop another piece of zinc into the acid. The bubbling begins anew, but again it stops. This time, you add more hydrochloric acid. Nothing happens. Obviously, each time the reaction stopped it was because you ran out of zinc. There was always plenty of hydrochloric acid. In fact, there was an excess of the acid. Zinc, on the other hand, was a limiting reactant. The reactant that is consumed first limits the amount of product that is produced, and is called a limiting reactant. The balanced equation predicts the amounts of reactants needed to completely consume each other (stoichiometric quantities). If any of the reactants is in excess, the other(s) is (are) limiting reactants.

In stoichiometry problems where the amount of only one of the reactants is given, it is assumed either that there are stoichiometric amounts of all the reactants and products, or, at the very least, that all of the reactant for which the amount is specified is consumed because it is the limiting reactant. For problems in which the amount of more than one reactant is specified, you need to consider that there may be a limiting reactant. If there is a limiting reactant, you need to know which one it is and use it for your calculations, because excess, unconsumed reactants do NOT produce any product.

To identify the limiting reactant: [1] Write a balanced equation; [2] Calculate the number of moles of each of the reactants present; and [3] Divide the number of moles of each reactant by its stoichiometric coefficient. The smallest number corresponds to the limiting reactant. Once the limiting reactant is identified, stoichiometry problems are done as usual using the amount of the limiting reactant.

Sample Problem

How much ammonia is formed from 25.0 kg of nitrogen and 5.00 kg of hydrogen? How much material is unreacted?

Step 1: Write the balanced equation

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

Step 2: Calculate the number of moles of each of the reactants present.

$$\left(25.0kg_{N_2}\right)\left(\frac{1000g}{1kg}\right)\left(\frac{1mol_{N_2}}{28.0g_{N_2}}\right) = 8.93\times10^2\,mol_{N_2} \qquad \left(5.00kg_{H_2}\right)\left(\frac{1000g}{1kg}\right)\left(\frac{1mol_{H_2}}{2.02g_{H_2}}\right) = 2.48\times10^3\,mol_{H_2}$$

Step 3: Divide the number of moles of each reactant by its stoichiometric coefficient. The smallest number corresponds to the limiting reactant.

$$\frac{8.93\times10^2\,mol_{N_2}}{1} = 8.93\times10^2\,mol_{N_2} \qquad \frac{2.48\times10^3\,mol_{H_2}}{3} = 8.25\times10^2\,mol_{H_2}$$

H_2 is limiting

Step 4: Use the limiting reactant to complete the calculation.

$$\left(2.48\times10^3\,mol_{H_2}\right)\left(\frac{2mol_{NH_3}}{3mol_{H_2}}\right)\left(\frac{17.0g_{NH_3}}{1mol_{NH_3}}\right)\left(\frac{1kg}{1000g}\right) = 28.1kg_{NH_3}$$

Step 5: Calculate the amount of unreacted material by calculating the stoichiometric amount that reacted and subtracting it from the initial amount.

$$\left(2.48\times10^3\,mol_{H_2}\right)\left(\frac{1mol_{N_2}}{3mol_{H_2}}\right)\left(\frac{28.0g_{N_2}}{1mol_{N_2}}\right)\left(\frac{1kg}{1000g}\right) = 23.1kg_{N_2}$$

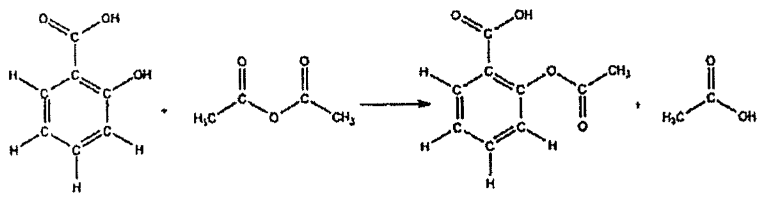
$$25.0kg_{N_2} - 23.1kg_{N_2} = 1.9kg_{N_2}$$

(CONTINUED ON THE NEXT PAGE)

Answer the questions below based on the preceding example. (*NOTE*: Equations provided may not be balanced.)

1. How much pure iron can be extracted from 250. kg of iron III oxide when it reacts with 148 kg of carbon monoxide? What is in excess, and by how much? [$Fe_2O_3 + CO \rightarrow Fe + CO_2$]

2. Salicylic acid ($C_7H_6O_3$) reacts with acetic anhydride ($C_4H_6O_3$) to form aspirin ($C_9H_8O_4$) and acetic acid ($C_2H_4O_2$). How much aspirin forms from 25.0 g of salicylic acid and 25.0 g of acetic anhydride? What is in excess, and by how much?
   [$C_7H_6O_3 + C_4H_6O_3 \rightarrow C_9H_8O_4 + C_2H_4O_2$].



3. How much copper will precipitate when 10.0 g of granular zinc are added to solution containing 16.0 g of aqueous copper II sulfate? What is in excess, and by how much? [$Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$]

STOICHIOMETRY: LIMITING REAGENT

Name ______________

1. $N_2 + 3H_2 \rightarrow 2NH_3$
   How many grams of NH_3 can be produced from the reaction of 28 g of N_2 and 25 g of H_2?

   ____

2. How much of the excess reagent in Problem 1 is left over?

   ____

3. $Mg + 2HCl \rightarrow MgCl_2 + H_2$
   What volume of hydrogen at STP is produced from the reaction of 50.0 g of Mg and the equivalent of 75 g of HCl?

   ____

4. How much of the excess reagent in Problem 3 is left over?

   ____

5. $3AgNO_3 + Na_3PO_4 \rightarrow Ag_3PO_4 + 3NaNO_3$
   Silver nitrate and sodium phosphate are reacted in equal amounts of 200. g each. How many grams of silver phosphate are produced?

   ____

6. How much of the excess reagent in Problem 5 is left?

   ____

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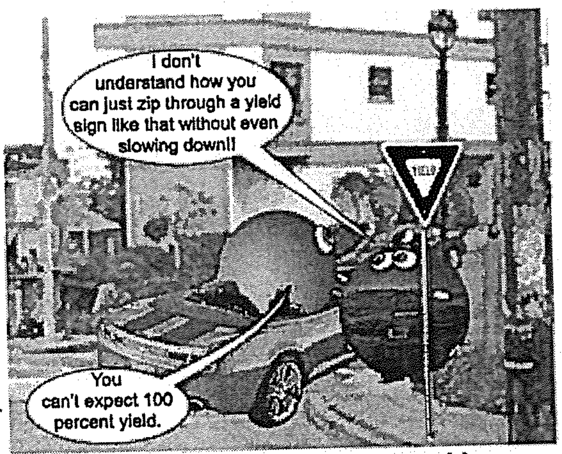
Percent Yield

You are making chocolate chip cookies. The recipe calls for two eggs to make 2½ dozen cookies. You have only one egg. There is no choice but to make half a recipe. The next problem is that your oven doesn't heat evenly, so the cookies towards the back are always better done than the ones in front. You pop them into the oven and hope for the best. In the end, the three cookies in the back row are burnt beyond recognition, but the rest are good. By scaling back the recipe, you could have theoretically anticipated having 15 cookies, but you only have 12 that are edible. Your yield is only 80 percent of what you anticipated. The same thing happens in chemistry.

Chocolate Chip Cookies
(makes 2½ dozen cookies)

3 cups flour
1¼ teaspoons salt
1 teaspoon baking soda
¼ teaspoon baking powder
¾ cup unsalted butter
1 cup dark brown sugar
½ cup white sugar
1 tablespoon vanilla extract
2 eggs
2 tablespoons corn syrup
1 tablespoon half-and-half
2 cups chocolate chips



Why atoms make notoriously poor drivers.

In chemical reactions, the actual yield is usually less than the theoretical yield due to side reactions and other complications. The theoretical yield is the amount of product formed when the limiting reactant is completely consumed. It is the maximum amount of product that can be produced. The actual yield is often expressed as a percentage of the theoretical yield called the percent yield.

$$\textit{percent yield} = \frac{\textit{actual yield}}{\textit{theoretical yield}} \times 100$$

<u>Sample Problem</u>

If 68.5 kg of CO reacts with 8.60 kg of H_2 to produce 35.7 kg of CH_3OH, what is the percent yield?

Step 1: Write a balanced equation.

$2H_2(g) + CO(g) \rightarrow CH_3OH(\ell)$

Step 2: Identify the limiting reactant

$$\left(8.60 kg_{H_2}\right)\left(\frac{1000 g}{1 kg}\right)\left(\frac{1 mol_{H_2}}{2.02 g_{H_2}}\right) = 4.26 \times 10^3 mol_{H_2} \qquad \frac{4.26 \times 10^3 mol_{H_2}}{2} = 2.13 \times 10^3 mol_{H_2}$$

$$\left(68.5 kg_{CO}\right)\left(\frac{1000 g}{1 kg}\right)\left(\frac{1 mol_{CO}}{28.0 g_{CO}}\right) = 2.45 \times 10^3 mol_{CO} \qquad \frac{2.45 \times 10^3 mol_{CO}}{1} = 2.45 \times 10^3 mol_{CO}$$

H_2 *is limiting*

Step 3: Use the limiting reactant to complete the calculation of the theoretical yield

$$\left(4.26 \times 10^3 mol_{H_2}\right)\left(\frac{1 mol_{CH_3OH}}{2 mol_{H_2}}\right)\left(\frac{32.04 g_{CH_3OH}}{1 mol_{CH_3OH}}\right)\left(\frac{1 kg}{1000 g}\right) = 68.2 kg_{CH_3OH}$$

Step 4: Calculate the percent yield

$$\frac{35.7 kg_{CH_3OH}}{68.2 kg_{CH_3OH}} \times 100 = 52.3\%$$

(CONTINUED ON THE NEXT PAGE)

Calculate the percent yield in each of the problems below. (*NOTE*: Equations may not be balanced.)

1. 3.25×10^3 kg of iron III oxide are treated in a blast furnace with 1.50×10^3 kg of carbon monoxide to form 1.30×10^3 kg of pure iron. [$Fe_2O_3 + CO \rightarrow Fe + CO_2$]. What is the percent yield?

2. 6.16×10^2 kg of nitrogen are reacted with 1.75×10^2 kg hydrogen under conditions of high temperature and pressure in the presence of a catalyst to produce 1.12×10^2 kg ammonia. [$N_2 + H_2 \rightarrow NH_3$] What is the percent yield?

3. The explosive, ammonium nitrate, is produced by reacting ammonia with nitric acid (HNO_3). [$NH_3 + HNO_3 \rightarrow NH_4NO_3$] If 475 kg of ammonia are reacted with 1,060 kg of nitric acid to produce 1150 kg of ammonium nitrate, what is the percent yield?