BALANCING EQUATIONS

Balance the equations: (a) $Ag_2O \rightarrow Ag + O_2$,

(b) $Zn + HCl \rightarrow ZnCl_2 + H_2$, (c) $NaOH + H_2SO_4 \rightarrow Na_2SO_4 + H_2O$.

Balance the following by filling in missing species and proper coefficient: (a) $NaOH + \underline{\hspace{1cm}} \rightarrow NaHSO_4 + HOH$,

(b) $PCl_3 + \underline{\hspace{0.5cm}}HOH \rightarrow \underline{\hspace{1cm}} + 3HCl$, (c) $CH_4 + \underline{\hspace{1cm}} \rightarrow CCl_4 + 4HCl$.

CALCULATIONS USING CHEMICAL ARITHMETIC

Verify that the following data confirm the law of equivalent proportions: Nitrogen and oxygen react with hydrogen to form ammonia and water, respectively. 4.66 g of nitrogen is required for every gram of hydrogen in ammonia, and 8 g of oxygen for every gram of hydrogen in water. Nitrogen plus oxygen yields NO. Here, 14 g of nitrogen is required for every 16 g of oxygen.

In a chemical reaction requiring two atoms of phosphorus for five atoms of oxygen, how many grams of oxygen are required by 3.10 g of phosphorus?

Two atoms of scandium are to combine with three atoms of oxygen. If you start with 1 gram of scandium, how much oxygen is required? Scandium has an atomic weight of 44.96 g/mole. The at. wt. of oxygen is 15.999 g/mole.

A metal has an atomic weight of 24. When it reacts with a non-metal of atomic weight 80, it does so in a ratio of 1 atom to 2 atoms, respectively. With this information, how many grams of non-metal will combine with 33.3 g of metal. If 1 g of metal is reacted with 5 g of non-metal, find the amount of product produced.
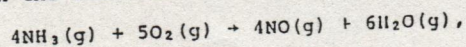
WEIGHT-WEIGHT PROBLEMS

Upon the addition of heat to an unknown amount of $KClO_3$, .96 g of oxygen was liberated. How much $KClO_3$ was present?

Given the balanced equation

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g),$$

how many grams of NH_3 will be required to react with 80 g of O_2?

In the commercial preparation of hydrogen chloride gas, what weight of HCl in grams may be obtained by heating 234 g. of NaCl with excess H_2SO_4?

The balanced equation for the reaction is

$$2NaCl + H_2SO_4 \rightarrow Na_2SO_4 + 2HCl$$

Molecular weights: NaCl = 58.5, HCl = 36.5.

A chemist decides to react 2 g of VO (vanadium oxide) with 5.75 g of Fe_2O_3 to produce V_2O_5 and FeO. How many grams of V_2O_5 can be obtained?

Determine the weights of CO_2 and H_2O produced on burning 104 g. of C_2H_2. Molecular weights are CO_2 = 44 and H_2O = 18. The equation for the reaction is

$$2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O$$
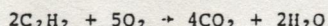
Silver bromide, AgBr, used in photography, may be prepared from $AgNO_3$ and NaBr. Calculate the weight of each required for producing 93.3 lb of AgBr. (1 lb = 454 g.)

What weight of sulfur must combine with aluminum to form 600 lbs (272.4 kg) of aluminum sulfide?

Heating of $NaNO_3$ decomposed it to $NaNO_2$ and O_2. How much $NaNO_3$ would you have to decompose to produce 1.50 g of O_2?

Baking powder consists of a mixture of cream of tartar (potassium hydrogen tartrate, $KHC_4H_4O_6$, molecular weight = 188 g/mole) and baking soda (sodium bicarbonate, $NaHCO_3$, molecular weight = 84 g/mole). These two components react according to the equation

$$KHC_4H_4O_6 + NaHCO_3 \rightarrow KNaC_4H_4O_6 + H_2O + CO_2.$$
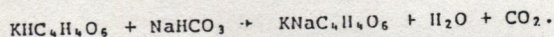
How much baking soda must be added to 8.0 g of cream of tartar for both materials to react completely?

Some solid CaO in a test tube picks up water vapor from the surroundings to change completely to $Ca(OH)_2(s)$. An observed total initial weight (CaO + test tube) of 10.860 g goes eventually to 11.149 g. What is the weight of the test tube?

"Hard" water contains small amounts of the salts calcium bicarbonate $(Ca(HCO_3)_2)$ and calcium sulfate $(CaSO_4$, molecular weight = 136 g/mole). These react with soap before it has a chance to lather, which is responsible for its cleansing ability. $Ca(HCO_3)_2$ is removed by boiling to form insoluble $CaCO_3$. $CaSO_4$ is removed by reaction with washing soda $(Na_2CO_3$, molecular weight = 106 g/mole) according to the following equation:

$$CaSO_4 + Na_2CO_3 \rightarrow CaCO_3 + Na_2SO_4.$$

If the rivers surrounding New York City have a $CaSO_4$ concentration of 1.8×10^{-3} g/liter, how much Na_2CO_3 is required to "soften" (remove $CaSO_4$) the water consumed by the city in one day (about 6.8×10^9 liters)?

How many pounds of air (which is 23.19% O_2 and 75.46% N_2 by weight) would be needed to burn a pound of gasoline by a reaction whereby C_8H_{18} reacts with O_2 to form CO_2 and H_2O?
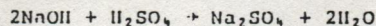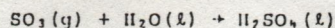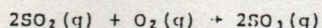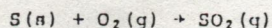
A lunar module used Aerozine 50 as fuel and nitrogen
tetroxide (N_2O_4, molecular weight = 92.0 g/mole) as
oxidizer. Aerozine 50 consists of 50 % by weight of
hydrazine (N_2H_4, molecular weight = 32.0 g/mole) and 50 %
by weight of unsymmetrical dimethylhydrazine (($CH_3)_2N_2H_2$,
molecular weight = 60.0 g/mole). The chief exhaust
product was water (H_2O, molecular weight = 18.0 g/mole).
Two of the reactions that led to the formation of water
are the following:

$$2N_2H_4 + N_2O_4 \rightarrow 3N_2 + 4H_2O$$

$$(CH_3)_2N_2H_2 + 2N_2O_4 \rightarrow 2CO_2 + 3N_2 + 4H_2O.$$

If we assume that these reactions were the only ones in
which water was formed, how much water was produced by
the ascent of the lunar module if 2200 kg of Aerozine 50
were consumed in the process?

It has been found that the following sequence can be
used to prepare sodium sulfate, Na_2SO_4:

$$S(s) + O_2(g) \rightarrow SO_2(g)$$

$$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$$

$$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(l)$$

$$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$$

If you performed this sequence of reactions, how many moles
of Na_2SO_4 could possibly be produced if you start with
1 mole of sulfur? How many moles are possible with 4.5 g
of water?

When 4.90 g of $KClO_3$ was heated, it showed a weight loss
of 0.384 g. Find the percent of the original $KClO_3$ that
had decomposed.

An impure sample of aluminum sulfate, $Al_2(SO_4)_3$, is
analyzed by forming a precipitate of insoluble barium
sulfate, $BaSO_4$, by reacting aluminum sulfate with an
excess of $BaCl_2$ (to insure complete precipitation).
After washing and drying, 2.000 g of $BaSO_4$ was obtained.
If the original sample weighed 1.000 g, what was the
per cent of aluminum sulfate in the sample?

A silicious rock contains the mineral ZnS. To analyze for
Zn, a sample of the rock is pulverized and treated with
HCl to dissolve the ZnS (silicious matter is insoluable).
Zinc is precipitated from solution by the addition of
potassium ferrocyanide $K_4Fe(CN)_6$. After filtering, the
precipitate is dried and weighed. The reactions which
occur are

$$ZnS + 2HCl \rightarrow ZnCl_2 + H_2S$$

$$2ZnCl_2 + K_4Fe(CN)_6 \rightarrow Zn_2Fe(CN)_6 + 4 KCl$$

If a 2 gram sample of rock yields 0.969 gram of $Zn_2Fe(CN)_6$,
what is the percentage of Zn in the sample? Atomic weight
Zn = 65.4, molecular weight $Zn_2Fe(CN)_6$ = 342.6.

Clay contains 30 % Al_2O_3, 55 % SiO_2, and 15 % H_2O. What
weight of limestone is required per ton of clay to carry
out the following chemical change?

$$6CaCO_3 + Al_2O_3 + SiO_2 \rightarrow 3CaO \cdot Al_2O_3 + 3CaO \cdot SiO_2 + 6CO_2.$$
(limestone)
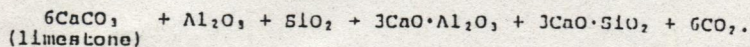
A chemist has a mixture of $KClO_3$, $KHCO_3$, K_2CO_3, and KCl. She heats 1,000 g of this mixture and notices that the following gases evolve: 18 g of water (H_2O), 132 g of CO_2, and 40 g of O_2 according to the following reactions:

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

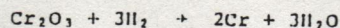$$2KHCO_3 \rightarrow K_2O + H_2O + 2CO_2$$

$$K_2CO_3 \rightarrow K_2O + CO_2$$
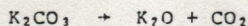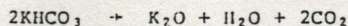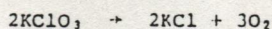
The KCl is inert under these conditions. Assuming complete decomposition, determine the composition of the original mixture.

REACTIONS WITH LIMITING REAGENTS

Chromic oxide (Cr_2O_3) may be reduced with hydrogen according to the equation

$$Cr_2O_3 + 3H_2 \rightarrow 2Cr + 3H_2O$$

(a) What weight of hydrogen would be required to reduce 7.6 g of Cr_2O_3? (b) For each mole of metallic chromium prepared, how many moles of hydrogen will be required? (c) What weight of metallic chromium can be prepared from one ton of Cr_2O_3? 1 lb = 454 g.
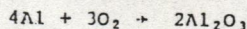
When 10.0 g of silicon dust, Si, is exploded with 100.0 g of oxygen, O_2, forming silicon dioxide, SiO_2, how many grams of O_2 remain uncombined? The reaction equation is

$$Si + O_2 \rightarrow SiO_2.$$

How many moles of Al_2O_3 can be formed when a mixture of 0.36 moles of aluminum and 0.36 moles of oxygen is ignited? Which substance and how much of it is in excess of that required?
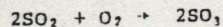
$$4Al + 3O_2 \rightarrow 2Al_2O_3$$

Suppose the change $HC_2O_4^- + Cl_2 \rightarrow CO_3^{2-} + Cl^-$ is to be carried out in basic solution. Starting with 0.10 mole of OH^-, 0.10 mole of $HC_2O_4^-$, and 0.05 mole of Cl_2, how many moles of Cl^- would be expected to be in the final solution?

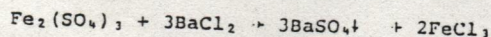What is the maximum weight of SO_3 that could be made from 25.0 g of SO_2 and 6.00 g of O_2 by the following reaction?

$$2SO_2 + O_2 \rightarrow 2SO_3$$

A chemist reacts ferric sulfate with barium chloride and obtains barium sulfate and ferric chloride. He writes the following balanced equation to express this reaction:

$$Fe_2(SO_4)_3 + 3BaCl_2 \rightarrow 3BaSO_4\downarrow + 2FeCl_3$$

(A) How much $BaCl_2$ should be used to react with 10 grams of $Fe_2(SO_4)_3$? (B) How much $Fe_2(SO_4)_3$ will be necessary to produce 100 g of $BaSO_4$? (C) From a mixture of 50 g of $Fe_2(SO_4)_3$ and 100 g of $BaCl_2$, how much $FeCl_3$ can be produced?
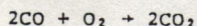
Through several successive reactions, a chemist uses carbon, CaO, HCl and H_2O to produce $C_6H_4Cl_2$. Assuming an efficiency of 65 %, how much $C_6H_4Cl_2$ can be produced from 500 grams of carbon? Assume that 1/3 of the carbon is lost as 3 moles CO.

VOLUME-VOLUME PROBLEMS

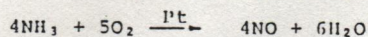Calculate the volume of O_2 necessary to burn 50 liters of CO completely. The balanced reaction is:

$$2CO + O_2 \rightarrow 2CO_2$$

Also, calculate the volume of CO_2 formed.

In the Ostwald process for the commercial preparation of nitric acid, ammonia gas is burned in oxygen in the presence of a Pt catalyst. The balanced equation is:

$$4NH_3 + 5O_2 \xrightarrow{\text{Pt}} 4NO + 6H_2O$$

What volume of O_2 and what volume of NO is formed in the combustion of 500 liters of NH_3. All gases are under the same conditions of temperature and pressure.

Calculate the volume of oxygen necessary to burn completely 100 cubic feet (1 cubic foot = 28.316 liters) of butane gas according to the equation

$$2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O$$

WEIGHT-VOLUME PROBLEMS

Glucose-1-phosphate, essential to the metabolism of carbohydrates in humans, has a molecular weight of ___ g/mole and a density of about 1.5 g/cm^3. What is the volume occupied by one molecule of glucose-1-phosphate?
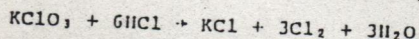
What is the mass of 1 liter of carbon monoxide (CO) at standard temperature and pressure (STP).

What is the weight of 1,000 cubic feet of air at STP?

Chlorine may be prepared by the action of $KClO_3$ on HCl, and the reaction may be represented by the equation:

$$KClO_3 + 6HCl \rightarrow KCl + 3Cl_2 + 3H_2O$$

Calculate the weight of $KClO_3$ which would be required to produce 1.0 liter of Cl_2 gas at STP. R = .082 liter-atm/mole-°K.

Lithium oxide (Li_2O, molecular weight = 30 g/mole) reacts with water (H_2O, molecular weight = 18 g/mole, density = 1.0 g/cm^3) to produce lithium hydroxide (LiOH) according to the following reaction:

$$Li_2O + H_2O \rightarrow 2LiOH.$$
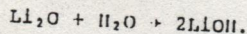
What mass of Li_2O is required to completely react with 24 liters of H_2O?

What volume of hydrogen at STP is produced as sulfuric acid acts on 120 g. of metallic calcium. Equation for the reaction is

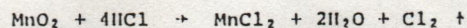$$Ca + H_2SO_4 \rightarrow CaSO_4 + H_2$$

The executioner in charge of the lethal gas chamber at the state penitentiary adds excess dilute H_2SO_4 to 196 g (about ½ lb) of NaCN. What volume of HCN gas is formed at STP?

A chemist decides to prepare some chlorine gas by the following reaction:

$$MnO_2 + 4HCl \rightarrow MnCl_2 + 2H_2O + Cl_2 \uparrow$$

If he uses 100 g of MnO_2, what is the maximum volume of chlorine gas that can be obtained at standard temperature and pressure (STP)?

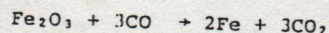What volume of ammonia at STP can be obtained when steam is passed over 4000 g of calcium cyanamide? The balanced reaction is

$$CaCN_2 + 3H_2O \rightarrow 2NH_3 + CaCO_3$$

(Molecular weight of $CaCN_2$ = 80, MW of NH_3 = 17.)

Iron (III) oxide is reacted with carbon monoxide in a blast furnace to produce iron. The balanced reaction is:

$$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$$

What volume of CO at STP is required to completely use up 31.94 kg of iron oxide? (MW of Fe_2O_3 = 159.7, MW of CO = 28.)

How many liters of phosphine (PH_3) gas at STP could be made from 30 g of calcium by use of the following sequence of reactions:

$$3Ca + 2P \rightarrow Ca_3P_2$$

$$Ca_3P_2 + 6HCl \rightarrow 2PH_3 + 3CaCl_2$$
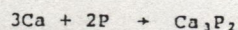
(Molecular weights: Ca = 40, PH_3 = 34.)

Nitroglycerin ($C_3H_5(NO_3)_3$) explodes according to the following reaction:

$$4C_3H_5(NO_3)_3(\ell) \rightarrow 12CO_2(g) + 6N_2(g) + O_2(g) + 10H_2O(g),$$
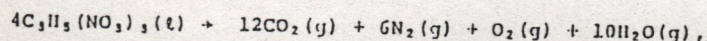
producing only gaseous products. What is the total volume of gaseous products produced at standard temperature and pressure (STP) when 454 g of nitroglycerin explodes? The molecular weight of nitroglycerin is 227 g/mole.

A chemist performs the following reaction:

$$2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g).$$
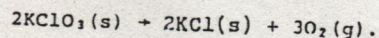
He collects the O_2 gas by water displacement at 20°C. He observes a pressure of 753 mm Hg. Assuming the pressure of water vapor is 17.5 mm Hg at 20°C and he started with 1.28 g of potassium chlorate ($KClO_3$), what volume of gas is produced? (R = .0821 ℓ-atm/mole °K.)