Name _____

Class _____ Date _____

The Mole

A. Molar Mass

The mass of a mole of a substance is equal to the total mass, in grams, of the moles of atoms that make it up. This total mass, or mass of 6.02×10^{23} formula units of a substance, is called molar mass, and is usually expressed in grams.

1. Complete each of the accompanying charts, filling in the items listed and determine the molar mass, in g, of each substance.

AMMONIA, NH_3			
NAME OF COMPONENT ATOM	MASS OF 1 MOLE OF SINGLE COMPONENT ATOM	NUMBER OF THAT KIND OF ATOM IN MOLECULE	TOTAL MASS OF THE MOLES OF THAT KIND OF ATOM IN 1 MOLE OF THE COMPOUND
nitrogen	14.0g	1	14.0g
hydrogen	1.0g	3	3.0g

Molar mass = 17.0g

GLUCOSE, $C_6H_{12}O_6$			
NAME OF COMPONENT ATOM	MASS OF 1 MOLE OF SINGLE COMPONENT ATOM	NUMBER OF THAT KIND OF ATOM IN MOLECULE	TOTAL MASS OF THE MOLES OF THAT KIND OF ATOM IN 1 MOLE OF THE COMPOUND
Carbon	12.0g	6	72.0g
hydrogen	1.0g	12	12.0g
oxygen	16.0g	8	96.0g

Molar mass = 180.0g

SULFURIC ACID, H_2SO_4			
NAME OF COMPONENT ATOM	MASS OF 1 MOLE OF SINGLE COMPONENT ATOM	NUMBER OF THAT KIND OF ATOM IN MOLECULE	TOTAL MASS OF THE MOLES OF THAT KIND OF ATOM IN 1 MOLE OF THE COMPOUND
hydrogen	1.0g	2	2.0g
sulfur	32.1g	1	32.1g
oxygen	16.0g	4	64.0g

Molar mass = 98.1g

SODIUM BICARBONATE, $NaHCO_3$			
NAME OF COMPONENT ATOM	MASS OF 1 MOLE OF SINGLE COMPONENT ATOM	NUMBER OF THAT KIND OF ATOM IN MOLECULE	TOTAL MASS OF THE MOLES OF THAT KIND OF ATOM IN 1 MOLE OF THE COMPOUND
sodium	23.0 g	1	23.0 g
hydrogen	1.0 g	1	1.0 g
carbon	12.0 g	1	12.0 g
oxygen	16.0 g	3	48.0 g

Molar mass = 84.0 g

2. Complete the chart below and answer the questions that follow it.

SUBSTANCE	FORMULA	MOLAR MASS
methane (marsh gas)	CH_4	16.0 g
hydrochloric acid	HCl	36.5 g
benzene	C_6H_6	78.0 g
oxygen gas	O_2	32.0 g
ozone	O_3	48.0 g
ethanol	C_2H_5OH	46.0 g
sodium hydroxide	NaOH	40.0 g
acetylene	C_2H_2	26.0 g

a. How many particles of methane are found in 16.0 grams of the gas? 6.02×10^{23}

In 32 grams of the gas? $2 \times 6.02 \times 10^{23} = 1.204 \times 10^{24}$

b. How many atoms of carbon are found in one mole of methane gas? 6.02×10^{23}

$4 \times 6.02 \times 10^{23} = 2.408 \times 10^{24}$

How many atoms of hydrogen are found in the same sample? _____

$2 \times 6.02 \times 10^{23} = 1.204 \times 10^{24}$

c. How many atoms of oxygen are found in one mole of oxygen gas? _____

$3 \times 6.02 \times 10^{23} = 1.806 \times 10^{24}$

How many atoms of oxygen are found in one mole of ozone? _____

d. How many moles of acetylene are found in 130 grams of the gas? $\frac{130\ g}{26.0\ g/mol} = 5.00\ mol$

How many particles of acetylene are present? $5 \times 6.02 \times 10^{23} = 3.01 \times 10^{24}$

e. What is the mass, in grams, of 3.01×10^{23} formula units of benzene?

$\frac{3.01 \times 10^{23}\ \text{formula units}}{6.02 \times 10^{23}\ \text{formula units/mol}} = 0.500\ mol$; $0.500\ mol \times 78.0\ g/mol = 39.0\ g$

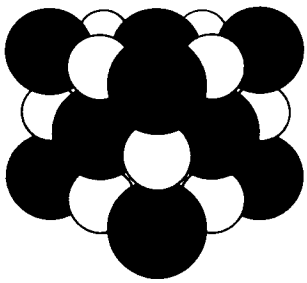
f. What is the mass, in grams, of 6.02×10^{25} formula units of sodium hydroxide?

$\frac{6.02 \times 10^{25}\ \text{formula units}}{6.02 \times 10^{23}\ \text{formula units/mol}} = 1.00 \times 10^{2}\ mol$; $1.00 \times 10^{2}\ mol \times 40.0\ g/mol = 4.00 \times 10^{3}\ g$

3. Fill in the table with the molecular formula and molar mass of each of the following elementary gases, which exist as molecules composed of two atoms.

ELEMENT	MOLECULAR FORMULA	MOLAR MASS
astatine	At_2	420 g
bromine	Br_2	159.8 g
chlorine	Cl_2	71.0 g
fluorine	F_2	38.0 g
hydrogen	H_2	2.0 g
iodine	I_2	253.8 g
nitrogen	N_2	28.0 g
oxygen	O_2	32.0 g

4. The diagram illustrates the ion arrangement found in the salt potassium bromide. Examine the illustration and answer the following questions.



Bromide ions

Potassium ions

a. What is the ratio of bromide ions to potassium ions in this salt? 1:1

b. What is the formula unit of this salt?

KBr

c. Calculate, in grams to the nearest whole number, the molar mass of this salt.

119 g

d. How many moles of this salt are present in 238 grams?

$\frac{238\ g}{119\ g/mol} = 2.00\ mol$

e. How many bromide ions are present in 238 grams?

$2.00\ mol \times 6.02 \times 10^{23}\ \frac{bromide\ ions}{mol} = 1.20 \times 10^{24}\ bromide\ ions$

f. How many moles of potassium bromide are present in 1.19 grams of this salt?

$\frac{1.19\ g}{119\ g/mol} = 0.0100\ mol$

g. How many potassium ions are present in the 1.19 grams?

$0.0100\ mol \times 6.02 \times 10^{23}\ \frac{potassium\ ions}{mol} = 6.02 \times 10^{21}\ potassium\ ions$

h. How many moles of potassium bromide are present in 595 grams of this salt?

$\frac{595\ g}{119\ g/mol} = 5.00\ mol$

i. What is the total number of ions present in the 595 grams?

$5.00\ mol \times \frac{2.00 \times 6.02 \times 10^{23}\ ions}{mol} = 6.02 \times 10^{24}\ ions$

B. Mole Calculations

One mole of a molecular substance contains 6.02×10^{23} molecules. Given a sample with a certain mass, it is possible to calculate the number of moles in the sample by dividing the mass of the sample by the molar mass. The number of molecules can then be calculated by multiplying 6.02×10^{23}.

Fill into the table the molar mass for each of the following substances. Next, calculate the number of moles and molecules present in the given sample mass and fill these quantities into the table. Use the blank space below for your calculations.

SUBSTANCE	FORMULA	MOLAR MASS	MASS OF GIVEN SAMPLE	NUMBER OF MOLES	NUMBER OF MOLECULES
bromine	Br_2	159.8 g	40.0 g	0.250 mol	1.51×10^{23}
carbon dioxide	CO_2	44.0 g	17.6 g	0.400 mol	2.41×10^{23}
nitrogen	N_2	28.0 g	154.0 g	5.50 mol	3.31×10^{24}
water	H_2O	18.0 g	360.0 g	20.0 mol	1.20×10^{25}
helium	He	4.0 g	0.10 g	0.025 mol	1.5×10^{22}
sucrose	$C_{12}H_{22}O_{11}$	342.0 g	684.0 g	2.000 mol	1.204×10^{24}
sulfur trioxide	SO_3	80.1 g	2.0 g	0.25 mol	1.5×10^{3}
hydrogen peroxide	H_2O_2	34.0 g	510.0 g	15.0 mol	9.03×10^{24}

C. Empirical Formulas

The empirical formula of a substance indicates the simplest whole number ratios of the different kinds of atoms that make up the substance. The empirical formula of a substance with the molecular formula N_2O_4, for example, is NO_2.

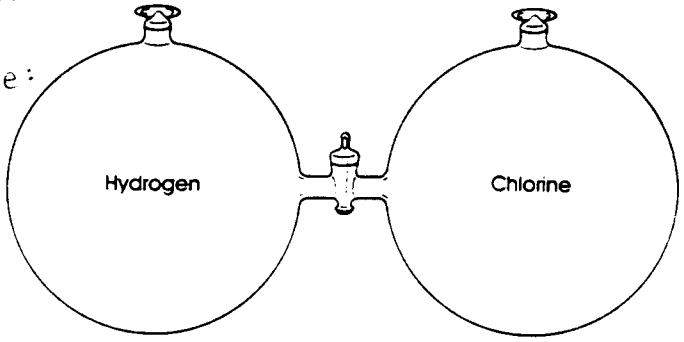
1. Fill in the table with the empirical formula for each of the following hydrogen-carbon compounds.

COMPOUND	MOLECULAR FORMULA	EMPIRICAL FORMULA
methane	CH_4	CH_4
benzene	C_6H_6	CH
ethane	C_2H_6	CH_3
ethylene (ethene)	C_2H_4	CH_2
octane	C_8H_{18}	C_4H_9
acetylene (ethyne)	C_2H_2	CH
naphthalene	$C_{10}H_8$	C_5H_4
cyclohexane	C_6H_{12}	CH_2

Which of the above compounds have the same empirical formulas?

benzene and acetylene: CH

ethylene and cyclohexane: CH_2



2. The apparatus shown above contains two isolated volumes of reactant gases. The chamber on the left contains 5.5 grams of hydrogen gas, and the chamber on the right contains an unknown quantity of chlorine gas. When the valve between the chambers is opened, the gases react to form hydrogen chloride. When the reaction is complete, the contents of the entire apparatus is analyzed. It is shown to contain 199.5 grams of product gas. (There is no detectable unreacted hydrogen or chlorine gas in the apparatus at the end of the reaction.)

Answer the following questions. Show your work.

a. What is the mass of chlorine in the product gas?

199.5g - 5.5g = 194.0 g

b. How many moles of chlorine atoms are in the product?

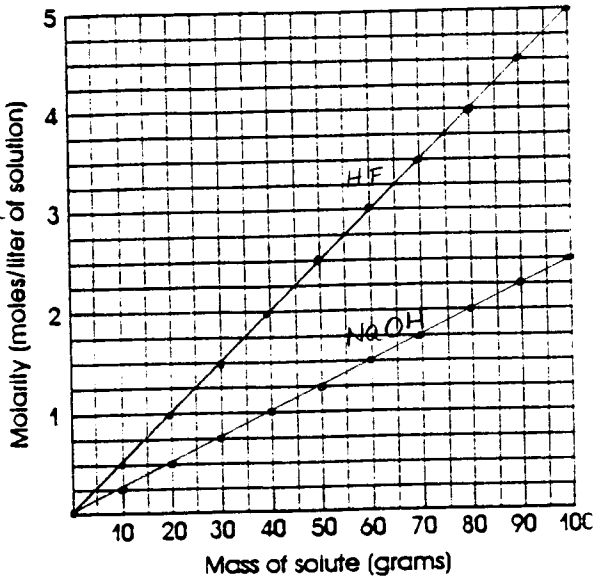
$\frac{194.0\ g}{35.5\ g/mol} = 5.47\ mol$

c. How many moles of hydrogen atoms are in the product?

$\frac{5.50\ g}{1.0\ g/mol} = 5.50\ mol$

d. What is the empirical formula of hydrogen chloride?

$\frac{5.50\ mol\ H}{5.47\ mol\ Cl} \sim \frac{1\ mol\ H}{1\ mol\ Cl}$; formula: HCl



D. Molarity

The molarity (M) of a solution is defined as the number of moles of dissolved substance per liter of solution. This quantity can be calculated by dividing grams of dissolved substance by molar mass, and then dividing the result by the volume of the solution.

Complete the following table by carrying out the appropriate calculations. Then using these results, construct a graph of molarity versus mass of solute. Make use of the grid on the next page for this purpose.

SODIUM HYDROXIDE, NaOH MOLAR MASS = 40 g		
MASS OF NaOH	MOLES OF NaOH	MOLARITY PRODUCED BY DISSOLVING THIS QUANTITY IN SUFFICIENT WATER TO MAKE 1 L OF SOLUTION
10 g	0.250	0.25 M
20 g	0.500	0.50 M
30 g	0.750	0.75 M
40 g	1.00	1.0 M
50 g	1.25	1.3 1
60 g	1.50	1.5 M
70 g	1.75	1.8 M
80 g	2.00	2.0 M
90 g	2.25	2.3 M
100 g	2.50	2.5 M

HYDROGEN FLUORIDE, HF MOLAR MASS = 20 g		
MASS OF HF	MOLES OF HF	MOLARITY PRODUCED BY DISSOLVING THIS QUANTITY IN SUFFICIENT WATER TO MAKE 1 L OF SOLUTION
10 g	0.500	0.50M
20 g	1.00	1.0 M
30 g	1.50	1.5 M
40 g	2.00	2.0 M
50 g	2.50	2.5 M
60 g	3.00	3.0 M
70 g	3.50	3.5 M
80 g	4.00	4.0 M
90 g	4.50	4.5 M
100 g	5.00	5.0 M