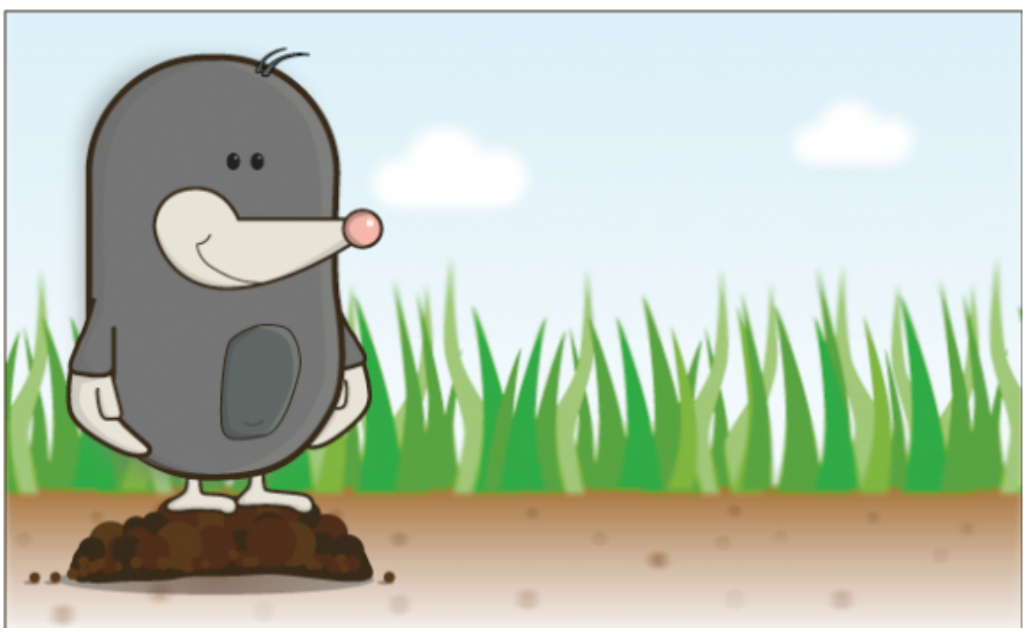
Chemistry B Moles Packet

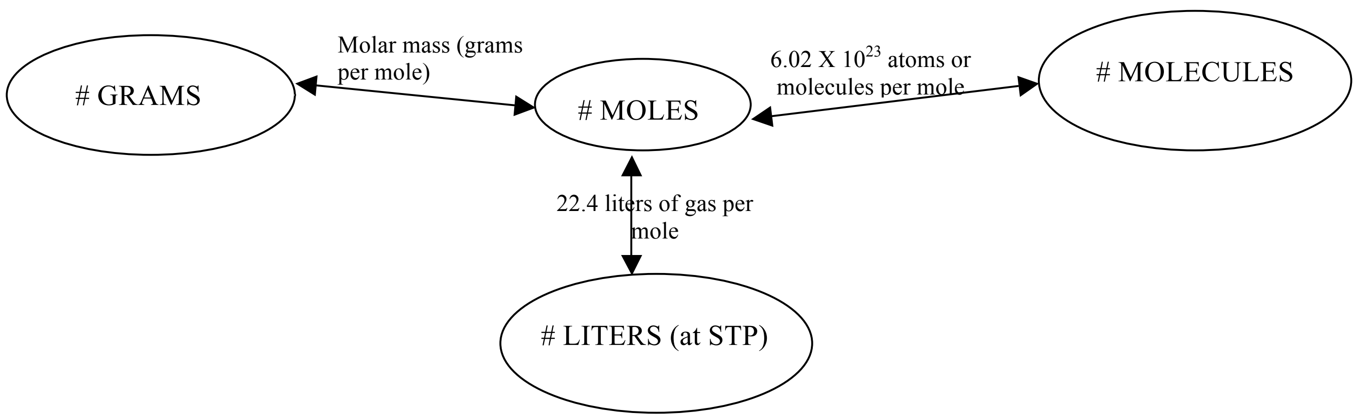


CHEMISTRY WORKSHEET # 1 MOLAR MASS

We are about to start on a unit of chemical calculations on **how we calculate the relationships between the amounts of reactants and the amounts of products.** For example, if we know the amount of reactants we have, we can use an organized, step-by-step approach to calculate how many products the chemical reaction will produce.

These problems involve numbers but no difficult mathematics. All you will ever have to do is add, multiply or divide. **You will be expected to have a functioning calculator with you for every chemistry class.** As we solve these problems we will apply the factor-label method you mastered early in the class, and we will frequently use scientific notation.

The only new concept we will introduce in this unit is the idea of a mole. **A mole is a quantity of matter that we use for conversion purposes.** We can convert from grams to moles, liters to moles (for gases), and atoms or molecules to moles. If you can convert any of these things to moles (and therefore moles to any of these things) we can convert grams to liters or molecules, liters to grams of molecules, and molecules to liters or grams.



Molar mass tells us the mass ("weight") of 1 mol of an atom or compound. In each case **we simply calculate the sum of the "weights" of the atoms in the formula to determine the weight of a mole. These weights can be found on the periodic table.**

EXAMPLE: Calculate the molar mass of a mole of iodine, I_2. Round to 2 decimal places.

2 I = 2 X (126.90) = **253.80 g I_2/mol**

EXAMPLE: Calculate the molar mass of a mole of aluminum sulfate, $Al_2(SO_4)_3$. Round to 2 decimal places.

2 Al = 2 X (26.98) = 53. 96
3 S = 3 X (32.07) = 64.14
+ 12 O = 12 X (16.00) = 192.00

$Al_2(SO_4)_3$ = **310.10 g $Al_2(SO_4)_3$ /mol**

CALCULATE THE MOLAR MASS FOR THE FOLLOWING COMPOUNDS OR DIATOMIC ELEMENTS. SET UP EACH PROBLEM AS SHOWN IN THE EXAMPLE ABOVE. INCLUDE UNITS (G/MOL)

1. water H_2O
2. calcium chloride $CaCl_2$
3. copper(II) sulfate $CuSO_4$
4. silver nitrate $AgNO_3$
5. sulfuric acid H_2SO_4
6. calcium phosphate $Ca_3(PO_4)_2$
7. sodium carbonate Na_2CO_3
8. ammonia NH_3
9. potassium chlorate $KClO_3$
10. lead(II) nitrate $Pb(NO_3)_2$
11. sodium oxalate $Na_2C_2O_4$
12. zinc chloride $ZnCl_2$
13. magnesium oxide MgO
14. antimony(III) chloride $SbCl_3$
15. nitrogen N_2
16. oxygen O_2

CHEMISTRY WORKSHEET # 2: THE MOLE AS A UNIT OF MASS

Now that you know how to find the mass of one mole of a substance (molar mass) you can easily find the mass of several moles or the mass of a fraction of a mole using the factor-label technique.

1 mol = a molar mass of an atom/molecule (g/mol)

EXAMPLE: What is the mass of 5.00 moles of water H_20?

STEP1: 2 H = 2 x(1.01) = 2.02
O = 1 x(16.00) = 16.00

H_20 = 18.02 g

STEP 2: ? grams H_20 = $\cancel{5.00 \text{ moles } H_20} \times \frac{18.02 \text{ g } H_20}{\cancel{1 \text{ mole } H_20}}$ = **90.10 g H_2O**

NOW YOU TRY ONE: What is the mass of 0.50 moles of calcium carbonate $CaCO_3$?

STEP 1: Ca =
C =
3O =

$CaCO_3$ =

STEP 2: ? g $CaCO_3$ =

USE A SEPARATE SHEET OF PAPER TO SOLVE THE FOLLOWING PROBLEMS. SHOW YOUR WORK. ROUND MOLAR MASSES TO TWO PLACES AFTER THE DECIMAL. ADD UNITS.

1. How many grams are there in 5.00 moles of lead Pb?
2. How many grams are there in 2.00 moles of sulfuric acid H_2SO_4?
3. How many grams are there in 0.250 moles of sodium hydroxide NaOH?
4. How many grams are there in 2.50 moles of potassium nitrate KNO_3?
5. How many grams are there in 10.0 moles of lithium carbonate Li_2CO_3?

#1-5: You are given the number of moles and asked to find the grams (mass)

MOLS → GRAMS

Now that you know how to find the mass of one mole of a substance you can easily find the number of moles there are in a given mass of the substance.

EXAMPLE: How many moles of calcium chloride are there in 333 grams of calcium chloride ($CaCl_2$)?

STEP 1: Ca = 1 x(40.08)= 40.0
2 Cl = 2 x(35.45)= 70.90
$CaCl_2$ = 110.98 g

STEP 2: ?moles $CaCl_2$ = $\cancel{333 \text{ grams } CaCl_2} \times \frac{1 \text{ mole } CaCl_2}{\cancel{110.98 \text{ g } CaCl_2}}$ = **3.00 mole $CaCl_2$**

USE THE SAME PAPER AS THE ABOVE PROBLEMS TO SOLVE THE FOLLOWING. SHOW YOUR WORK AND PUT UNITS ON EACH ANSWER!

6. How many moles of silver nitrate are there in 80.00 grams of silver nitrate $AgNO_3$?
7. How many moles of phosphoric acid are there in 658 grams of phosphoric acid H_3PO_4?
8. How many moles of tin (II) fluoride are there in 908 grams of tin (II) fluoride SnF_2?
9. How many moles of hydrogen peroxide are there in 1000.0 grams of hydrogen peroxide H_2O_2 ?
10. How many moles of magnesium chloride are there in 148 grams of magnesium chloride $MgCl_2$?

#6-10: You are given the grams (mass) and asked to find the number of mols

GRAMS → MOLS

CHEMISTRY WORKSHEET # 3 AVOGADRO'S NUMBER

One important property of a mole is that it means a definite number of "things" just like a dozen means a number of "things". While a dozen is only 12 particles a **mole is a much larger number—6.02 x 10^{23} particles.** Elements generally exist as the particles we call atoms. **A mole of carbon contains 6.02 x 10^{23} atoms of carbon.**

However, **we have learned about seven elements that exist as diatomic <u>molecules</u>—H_2, N_2, O_2, F_2, Cl_2, Br_2, and I_2. For these elements one mole is 6.02 x 10^{23} <u>molecules</u>. That is, 6.02 x 10^{23} molecules of hydrogen is one mole of hydrogen.** In the same way, **one mole of water contains 6.02 x 10^{23} molecules of water**.

In all of the above examples one mole of any substance contained the same number of particles. But remember, they all had different masses. The mass of one mole of each material was equal to the molar mass. This is the same idea as the mass of a dozen. A dozen eggs, a dozen bricks, a dozen dump trucks all contain twelve items but the mass of a dozen eggs is certainly much different than the mass of a dozen bricks which is much different from the mass of a dozen dump trucks!

The number **6.02 x 10^{23} is known as Avogadro's number** in honor of an Italian Professor of physics, Amadeo Avogadro, who did considerable work on the development of atomic theory and the mole concept in about 1810. Given this number we can calculate the number of atoms/molecules in a known number of moles or the number of moles in a given number of atoms/molecules.

1 mol = 6.02 x 10^{23} atoms/molecules (Avogadro's Number)

Problems #1-5 EXAMPLE: How many molecules of water are there in 3.00 moles of water?

$$? \text{ molecules } H_20 = 3.00 \cancel{\text{moles } H_20} \times \frac{6.02 \times 10^{23} \text{ molecules of } H_20}{1 \cancel{\text{mole } H_20}} = \mathbf{1.81 \times 10^{24} \text{ molecules } H_20}$$

Problems #6-10 EXAMPLE: How many moles of neon are there in 2.408 x 10^{24} atoms of neon?

$$? \text{ moles Ne} = 2.408 \times 10^{24} \cancel{\text{atoms}} \text{ Ne} \times \frac{1 \text{ mole Ne}}{6.02 \times 10^{23} \cancel{\text{atoms}} \text{ of Ne}} = \mathbf{4.00 \text{ moles Ne}}$$

USE A SEPARATE SHEET OF PAPER TO SET-UP AND SOLVE THE FOLLOWING PROBLEMS. If you do not know the formula, just write the name of the compound being discussed.

How many molecules are there in:

1. 2.00 moles of ammonia?
2. 0.50 moles chlorine?
3. 0.250 moles oxygen?
4. 4.00 moles of sulfur dioxide?
5. 2.50 moles of methane?

How many moles are there in:

6. 3.612 x 10^{24} molecules of phosgene?
7. 3.01 x 10^{23} molecules of freon?
8. 1.505 x 10^{24} molecules of sucrose?
9. 1.806 x 10^{24} molecules of bromine?
10. 3.01 x 10^{24} atoms of argon?

CHEMISTRY WORKSHEET # 4 MOLAR MASSES AND AVOGADRO'S NUMBER

Now that you know two definitions of a mole (a molar mass and an Avogadro's number of particles) you can combine these two definitions into one problem.

EXAMPLE: How many **molecules** are there in **90.1 grams** of water?

2 H = 2 x(1.01) = 2.02
O = 1 x (16.00) = 16.00
H_2O = 18.02 g

$$? \text{ molecules } H_2O = 90.1 \text{ g } \cancel{H_2O} \times \frac{1 \text{ mole } \cancel{H_2O}}{18.02 \text{ g } \cancel{H_2O}} \times \frac{6.02 \times 10^{23} \text{ molecules } H_2O}{1 \cancel{\text{ mole }} H_2O} = \mathbf{3.01 \times 10^{24} \text{ molecules } H_2O}$$

EXAMPLE: What is the mass, in **grams**, of **3.01 x 10^{23} molecules** of ammonia NH_3?

N = 1 x (14.01) = 14.01
3 H = 3 x (1.01) = 3.03
NH_3 = 17.04 g

$$? \text{ grams } NH_3 = 3.01 \times 10^{23} \cancel{\text{ molecules }} NH_3 \times \frac{1 \cancel{\text{ mole } NH_3}}{6.02 \times 10^{23} \cancel{\text{ molecules }} NH_3} \times \frac{17.04 \text{ g } NH_3}{1 \cancel{\text{ mole }} NH_3} = \mathbf{8.52 \text{ g } NH_3}$$

SOLVE THE FOLLOWING PROBLEMS ON A SEPARATE SHEET OF PAPER. YOU MUST SHOW ALL OF THE STEPS AND YOU MUST DO THE PROBLEM JUST AS ILLUSTRATED. INCLUDE UNITS!

1. How many **molecules** are there in **345 grams** of carbon dioxide CO_2?
2. What would be the mass, in **grams**, of 1.204 x 10^{24} molecules of sulfur dioxide SO_2?
3. How many **molecules** of sucrose are there in **454 grams** of sucrose $C_{12}H_{22}O_{11}$?
4. What would be the mass, in **grams**, of **1.806 x 10^{24} molecules** of carbon monoxide CO?
5. How many **molecules** of water are there in **8.050 x 10^3 grams** of water H_2O?
6. How many oxygen **molecules** are in a flask that contains **1.43 grams** of oxygen O_2?
7. What would be the mass, in **grams**, of **1.505 x 10^{23} molecules** of carbon disulfide CS_2?
8. How many **molecules** of hydrogen chloride HCl would there be in **100.00 grams** of this gas?
9. What would be the mass, in **grams**, of **2.408 x 10^{24} molecules** of tetraphosphorus decaoxide P_4O_{10}?

Extra Challenge:

10. How many hydrogen molecules are there in 1 ton of hydrogen H_2? (Hint: How many grams are there in 1 ton?)

CHEMISTRY WORKSHEET # 5 MOLE PROBLEMS—MOLAR VOLUME OF A GAS

We have learned two definitions of a mol, now we will learn a third. **A mole can also be a measure of volume when we are talking about gases**. AVOGADRO'S HYPOTHESIS SAYS THAT EQUAL VOLUMES OF GASES AT THE SAME TEMPERATURE AND PRESSURE CONTAIN EQUAL NUMBERS OF MOLECULES. Avogadro's statement makes sense and is possible because gases are mainly empty space—only about one thousandth of the space is actually filled with molecules. The molecules "fill" the remaining space by moving rapidly through it. So the difference in size between large molecules and small molecules is insignificant compared to the total volume the gas occupies. At **standard temperature and presssure (STP = O^{o}Celcius and 1.00 atm pressure) one mole of any gas will have a volume of 22.4 liters.** Once we know this we can convert from moles to liters or liters to moles for any gas at STP.

1 mol (of a gas) = 22.4 L (at STP)

EXAMPLE: What is the volume, in liters, of a 2.00 mole sample of methane (CH_4) at STP?

$$\# \text{ L } CH_4 = 2.00 \cancel{\text{ moles}} \; CH_4 \times \frac{22.4 \text{ L } CH_4}{1 \cancel{\text{ mole}} \; CH_4} = \mathbf{44.80 \text{ L } CH_4}$$

EXAMPLE: How many moles of ethane (C_2H_6) are there in 5.60 liters of ethane?

$$\# \text{ moles } C_2H_6 = 5.60 \cancel{\text{ L } C_2H_6} \times \frac{1 \text{ mole } C_2H_6}{22.4 \cancel{\text{ L } C_2H_6}} = \mathbf{0.25 \text{ mole } C_2H_6}$$

COMPLETE THE FOLLOWING PROBLEMS ON A SEPARATE SHEET OF PAPER USING THE SAME SET-UP AS SHOWN ABOVE. INCLUDE UNITS!

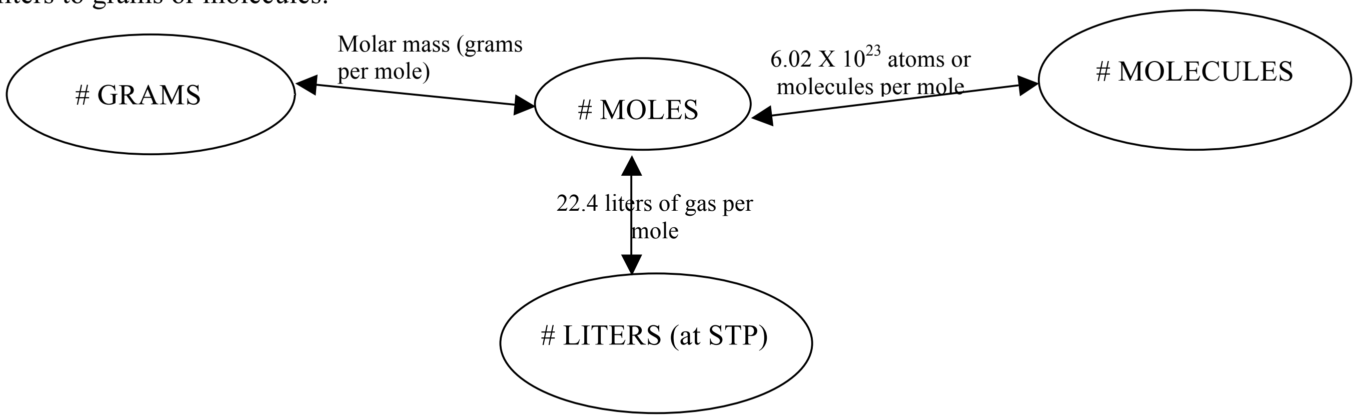
1. What is the volume, in liters, of 2.00 moles of hydrogen H_2 at STP?
2. What is the volume, in liters of 5.00 moles of oxygen O_2 occupy at STP?
3. What is the volume, in liters, of 0.250 moles of carbon monoxide CO at STP?
4. What is the volume, in liters, of a 3.00 mole sample of carbon dioxide CO_2 at STP?
5. How many moles of chlorine are there in a 67.2 liter sample of chlorine Cl_2 at STP?
6. A 44.8 liter sample of nitrogen at STP will contain how many moles of nitrogen N_2?
7. How many moles of ammonia are there in 405 liters of ammonia NH_3 at STP?
8. How many moles of neon Ne would you need to fill a 33.6 liter container at STP?
9. How many moles of argon Ar are there in 5.00×10^2 liters of argon at STP?
10. What is the volume, in liters, of 4.50 moles of fluorine F_2 at STP?

Extra Challenge

11. How many moles of nitrogen are there in a 16,500 mL sample of nitrogen N_2 at STP?

CHEMISTRY WORKSHEET # 6 MIXED MOLE PROBLEMS (GRAMS, MOLECULES, AND LITERS)

You now know three definitions of a mole: a molar mass (g/mol), 6.02×10^{23} atoms/molecules and, for a gas, 22.4 liters at STP. We can use this information to convert grams to molecules or liters, molecules to grams or liters, or liters to grams or molecules.



EXAMPLE 1: What would be the volume in liters of 40.36 grams of neon at STP?

$$\# \text{ liters Ne} = 40.36\ \cancel{\text{g Ne}} \times \frac{1\ \cancel{\text{mole Ne}}}{20.18\ \cancel{\text{g Ne}}} \times \frac{22.4\ \text{L Ne}}{1\ \cancel{\text{mole Ne}}} = \mathbf{44.80\ L\ Ne}$$

EXAMPLE 2: How many molecules would there be in 56 liters of carbon dioxide at STP?

$$\# \text{ molecules } CO_2 = 56.0\ \text{L}\ \cancel{CO_2} \times \frac{1\ \cancel{\text{mole}\ CO_2}}{22.4\ \text{L}\ \cancel{CO_2}} \times \frac{6.02 \times 10^{23}\ \text{molecules}\ CO_2}{1\ \cancel{\text{mole}\ CO_2}} = \mathbf{1.51 \times 10^{24}\ molecules\ CO_2}$$

SOLVE THE FOLLOWING PROBLEMS ON A SEPARATE SHEET OF PAPER.

- YOU MUST USE COMPLETE AND PROPER SET-UPS.
- SHOW THE MOLAR MASS CALCULATION WHENEVER THE PROBLEM REQUIRES YOU TO DO ONE. INCLUDE UNITS

1. What would be the volume, in **liters**, of **85.5 grams** of carbon monoxide CO at STP?

2. How many **molecules** would there be in **0.500 grams** of carbon disulfide CS_2?

3. What would be the mass, in **grams**, of **45.0 liters** of nitrogen N_2 at STP?

4. How many **molecules** of hydrogen H_2 are in a balloon full of hydrogen with a volume of **5.34 liters** at STP?

5. Your mommy buys you a helium He balloon at the circus. It has a volume of **4.00 liters** at STP. What mass of helium, expressed in **grams**, does this balloon contain?

6. How many **molecules** of ammonia would there be in **40.0 grams** of ammonia NH_3?

7. What would be the mass, in **grams**, of **3.50×10^{25} molecules** of chlorine Cl_2?

8. What volume, expressed in **liters,** would **50.0 grams** of fluorine F_2 occupy at STP?

9. How many **grams** of oxygen would there be in **1.00 liter** of oxygen O_2 at STP?

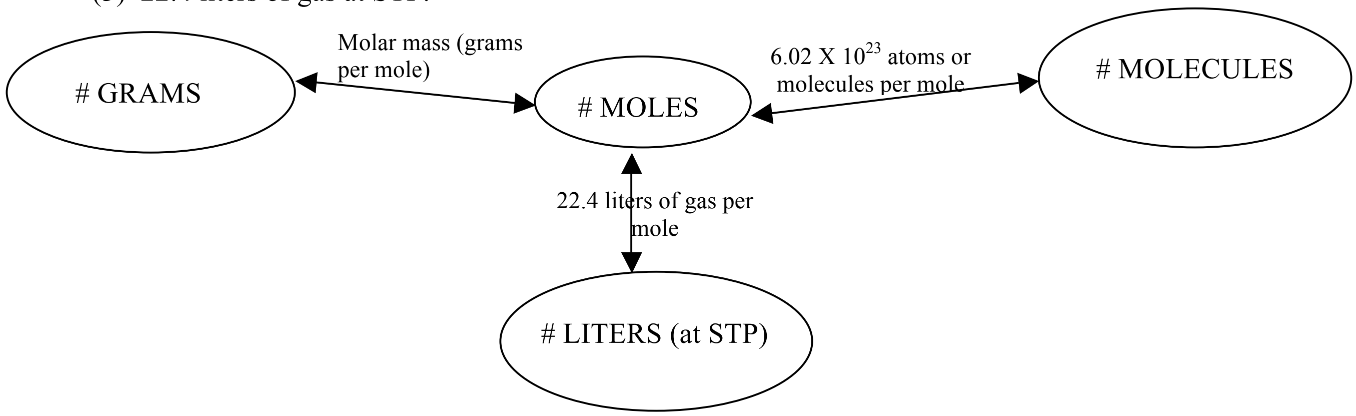
Extra Challenge:

10. How many molecules of water are there in 10 lbs of water?

CHEMISTRY WORKSHEET # 7: GENERAL REVIEW OF MOLE PROBLEMS

Now we have studied the idea of moles and learned three definitions of a mole:

(1) A molar mass (g/mol)
(2) 6.02×10^{23} atoms/molecules (Avogadro's Number)
(3) 22.4 liters of gas at STP.



Solve the following problems involving the mole concept. (If you are having difficulty go back and review mole worksheets 1-6.)

Problems 1-2: moles to grams AND grams to moles

1. How many grams are there in 11.8 moles of sodium hydroxide NaOH?

   Ans. 472 grams sodium hydroxide

2. How many moles are there in 215 grams of water H_2O?

   Ans. 11.9 moles water

Problems 3-4: moles to molecules AND molecules to moles

3. How many molecules are there in 3.85 moles of carbon tetrachloride CCl_4?

   Ans. 2.32×10^{24} molecules carbon tetrachloride

4. How many moles are there in 8.25×10^{26} molecules of methane CH_4?

   Ans. 1.37×10^{3} moles of methane

Problems 5-6: grams to moles to molecules AND molecules to moles to grams

5. How many molecules are there in 295 grams of ammonia NH_3?

   Ans. 1.04×10^{25} molecules of ammonia

6. How many grams are there in 8.95×10^{26} molecules of carbon disulfide CS_2?

   Ans. 1.13×10^{5} grams of carbon disulfide

Problems 7-8: moles to liters AND liters to moles

7. What would be the volume, in liters measured at STP, of 9.75 moles of carbon monoxide CO?
Ans. 2.18×10^2 liters of carbon monoxide

8. How many moles would there be in 5.25 liters of oxygen O_2 measured at STP?
Ans. 0.234 moles or 2.34×10^{-1} moles oxygen

Problems 9-10: grams to moles to liters AND liters to moles to grams

9. What is the volume, measured in liters at STP, of 285 grams of the gas acetylene, C_2H_2?
Ans. 245 liters of acetylene

10. How many grams are there in 512 liters (measured at STP) of propane, C_3H_8?
Ans. 1.01×10^3 grams of propane

Problems 11-12: molecules to moles to liters AND liters to moles to molecules

11. What would the volume be, measured in liters at STP, of 3.01×10^{25} molecules of fluorine F_2?
Ans. 1.12×10^3 liters of fluorine

12. How many molecules are there in 995 liters of sulfur dioxide SO_2 at STP?
Ans. 2.67×10^{25} molecules of sulfur dioxide

Problems 13-16: Mixed Problems- Think about what type of conversion you are doing!

13. How many molecules are there in 2270 g of table sugar, sucrose $C_{12}H_{22}O_{11}$.
Ans. 3.99×10^{24} molecules of sucrose

14. How many molecules would there be in 1.135×10^6 g of chlorine Cl_2?
Ans. 9.64×10^{27} molecules of chlorine

15. What would the mass be, in grams, of 348 liters of carbon dioxide CO_2 measured at STP?
Ans. 684 grams of carbon dioxide

16. How many molecules of nitrogen are there in 200 L of nitrogen N_2 measured at STP?