THE MOLE AND AVOGADRO'S NUMBER

Name _____

One mole of a substance contains Avogadro's Number (6.02×10^{23}) of molecules.

How many molecules are in the quantities below?

1. 2.0 moles $\times \frac{6.02 \times 10^{23} \text{ molecules}}{1 \text{ mol}}$ $= 1.204 \times 10^{24}$ molecules

2. 1.5 moles $\times \frac{6.02 \times 10^{23} \text{ molecules}}{1 \text{ moles}} = 9.03 \times 10^{23}$ molecules.

3. 0.75 mole $\times \frac{6.02 \times 10^{23} \text{ molecules}}{1 \text{ mole}} = 4.52 \times 10^{23}$ molec.

4. 15 moles $\times \frac{6.02 \times 10^{23} \text{ molecules}}{1 \text{ mole}} = 9.03 \times 10^{24}$ molecules

5. 0.35 mole

How many moles are in the number of molecules below?

1. 6.02×10^{23} molecules $\times \frac{1 \text{ mole}}{6.02 \times 10^{23} \text{ molecules}} = 1$ mole

2. $1.204 \times 10^{24} \times \frac{1 \text{ mol}}{6.02 \times 10^{23} \text{ molecules}} = 2$ moles

3. 1.5×10^{20} molecules $\times \frac{1 \text{ mol}}{6.02 \times 10^{23} \text{ molecules}} = 2.49 \times 10^{-4}$ moles

4. 3.4×10^{26} molecules $\times \frac{1 \text{ mol}}{6.02 \times 10^{23} \text{ molecules}} = 564.8$ moles

5. 7.5×10^{19} molecules $\times \frac{1 \text{ moles}}{6.02 \times 10^{23} \text{ molecules}} = 0.000125$ moles

MOLES AND MASS

Name _____

Determine the number of moles in each of the quantities below.

1. 25 g of NaCl $\times \frac{1 \text{ mol}}{58.4425 \text{ g}} =$ 0.428 mole

2. 125 g of H_2SO_4 $\times \frac{1 \text{ mol}}{98.0784 \text{ g}}$ 1.274 mole

3. 100. g of $KMnO_4$ $\times \frac{1 \text{ mole}}{158.0339 \text{ g}}$ 0.633 mole

4. 74 g of KCl $\times \frac{1 \text{ mol}}{74.551 \text{ g}}$ 0.993 mol

5. 35 g of $CuSO_4 \cdot 5H_2O$ $\times \frac{1 \text{ mol}}{249.6846 \text{ g}}$ 0.140 mol

Determine the number of grams in each of the quantities below.

1. 2.5 moles of NaCl $\times \frac{58.4425 \text{ g NaCl}}{1 \text{ mol}}$ 146.11 g

2. 0.50 moles of H_2SO_4 $\times \frac{98.0784 \text{ g } H_2SO_4}{1 \text{ mol}}$ 49.04 g

3. 1.70 moles of $KMnO_4$ $\times \frac{158.0339 \text{ g}}{1 \text{ mol}}$ 268.66 g

4. 0.25 moles of KCl $\times \frac{74.551 \text{ g}}{1 \text{ mol}}$ 18.64 g

5. 3.2 moles of $CuSO_4 \cdot 5H_2O$ $\times \frac{249.6846 \text{ g}}{1 \text{ mol}}$ 798.99 g

THE MOLE AND VOLUME

Name _____

For gases at STP (273 K and 1 atm pressure), one mole occupies a volume of 22.4 L. What volume will the following quantities of gases occupy at STP?

1. 1.00 mole of H_2 $\times \frac{22.4\ L}{1\ mol}$ 22.4 L H_2

2. 3.20 moles of O_2 $\times \frac{22.4\ L}{1\ mol}$ 71.68 L O_2

3. 0.750 mole of N_2 $\times \frac{22.4\ L}{1\ mol}$ 16.8 L N_2

4. 1.75 moles of CO_2 $\times \frac{22.4\ L}{1\ mol}$ 39.2 L CO_2

5. 0.50 mole of NH_3 $\times \frac{22.4\ L}{1\ mol}$ 11.2 L NH_3

6. 5.0 g of H_2 $\times \frac{1\ mol}{2.0158\ g} \times \frac{22.4\ L}{1\ mol}$ = 55.56 L H_2

7. 100. g of O_2 $\times \frac{1\ mol}{31.9988\ g} \times \frac{22.4\ L}{1\ mol}$ = 70.00 L O_2

8. 28.0 g of N_2 $\times \frac{1\ mol}{28.0134\ g} \times \frac{22.4\ L}{1\ mol}$ = 22.39 L N_2

9. 60. g of CO_2 $\times \frac{1\ mol}{44.0098\ g} \times \frac{22.4\ L}{1\ mol}$ = 30.54 L CO_2

10. 10. g of NH_3 $\times \frac{1\ mol}{17.0304\ g} \times \frac{22.4\ L}{1\ mol}$ = 13.15 L NH_3

MIXED MOLE PROBLEMS

Name _____

Solve the following problems.

1. How many grams are there in 1.5×10^{25} molecules of CO_2?

2. What volume would the CO_2 in Problem 1 occupy at STP?

3. A sample of NH_3 gas occupies 75.0 liters at STP. How many molecules is this?

4. What is the mass of the sample of NH_3 in Problem 3?

5. How many atoms are there in 1.3×10^{22} molecules of NO_2?

6. A 5.0 g sample of O_2 is in a container at STP. What volume is the container?

7. How many molecules of O_2 are in the container in Problem 6? How many atoms of oxygen?

MOLARITY (M)

Name _____

$$\text{Molarity} = \frac{\text{moles of solute}}{\text{liter of solution}}$$

Solve the problems below.

1. What is the molarity of a solution in which 58 g of NaCl are dissolved in 1.0 L of solution?

$58\text{ g NaCl} \times \frac{1\text{ mol}}{58.4425\text{ g}} = 0.992\text{ mol}$

$M = \frac{\text{mol}}{V_L} = \frac{0.992\text{ mol}}{1.0\text{ L}}$

0.992 M

2. What is the molarity of a solution in which 10.0 g of $AgNO_3$ is dissolved in 500. mL of solution?

$10.0\text{ g } AgNO_3 \times \frac{1\text{ mol}}{169.8749\text{ g}} = 0.0589\text{ mol}$

$M = \frac{\text{mol}}{V_L} = \frac{0.0589\text{ mol}}{0.500\text{ L}}$

0.118 M

3. How many grams of KNO_3 should be used to prepare 2.00 L of a 0.500 M solution?

$\text{moles} = M \times V_L$

$= (0.500\text{ M})(2.0\text{ L})$

$= 1.0\text{ moles } KNO_3 \times \frac{101.1032\text{ g}}{1\text{ mol}}$

101.10 g KNO_3

4. To what volume should 5.0 g of KCl be diluted in order to prepare a 0.25 M solution?

$5.0\text{ g KCl} \times \frac{1\text{ mol}}{74.551\text{ g}} = 0.0671\text{ mol}$

$M = \frac{\text{mol}}{V_L}$

$V_L = \frac{\text{mol}}{M} = \frac{0.0671\text{ mol}}{0.25\text{ M}} = 0.268$

0.268 L

5. How many grams of $CuSO_4 \cdot 5H_2O$ are needed to prepare 100. mL of a 0.10 M solution?

$\text{mol} = M \times V_L$

$= (0.10\text{ M})(0.100\text{ L})$

$= 0.010\text{ mol } CuSO_4 \cdot 5H_2O \times \frac{249.6849\text{ g}}{1\text{ mol}}$

2.497 g

Name ______________

MOLARITY BY DILUTION

Acids are usually acquired from chemical supply houses in concentrated form. These acids are diluted to the desired concentration by adding water. Since moles of acid before dilution = moles of acid after dilution, and moles of acid = M x V then, $M_1 \times V_1 = M_2 \times V_2$. Solve the following problems.

1. How much concentrated 18 M sulfuric acid is needed to prepare 250 mL of a 6.0 M solution? $M_cV_c = M_dV_d$

   $V_c = \frac{(6.0M)(0.250L)}{18M}$

   0.0833 L (83 mL)

2. How much concentrated 12 M hydrochloric acid is needed to prepare 100 mL of a 2.0 M solution?

   $V_c = \frac{M_dV_d}{M_c} = \frac{(2.0M)(0.100L)}{12M}$

   0.0167 L (16.7 mL)

3. To what volume should 25 mL of 15 M nitric acid be diluted to prepare a 3.0 M solution?

   $V_d = \frac{M_cV_c}{M_d}$

   $= \frac{(15.0M)(0.025L)}{3.0M}$

   0.125 L (125 mL)

4. To how much water should 50. mL of 12 M hydrochloric acid be added to produce a 4.0 M solution?

   $V_d = \frac{M_cV_c}{M_d} = \frac{(12M)(0.050L)}{4.0M}$ ~~$V_d = 0.150L$~~

   water = 0.150L - 0.050L

   0.100 L (100 mL)

5. To how much water should 100. mL of 18 M sulfuric acid be added to prepare a 1.5 M solution?

   $V_d = \frac{M_cV_c}{M_d}$ $V_d = \frac{(18M)(0.100L)}{1.5M}$ $V_d = 1.2L$

   water = $V_d - V_c$

   1.1 L (1100 mL)

PERCENTAGE COMPOUNDS

Name _____

Determine the percentage composition of each of the compounds below.

1. $KMnO_4$ ⟶ 158.0339

K = 24.7%
Mn = 34.8%
O = 40.5%

$K = \frac{39.0983}{158.0339} \times 100 = 24.7\%$

$Mn = \frac{54.938}{158.0339} \times 100 = 34.8\%$

$O = \frac{4(15.9994)}{158.0339} \times 100 = 40.5\%$

2. HCl ⟶ 36.4606 g/mol

H = 2.8%
Cl = 97.2%

$H = \frac{1.0079}{36.4606} \times 100$

$Cl = \frac{35.4527}{36.4606} \times 100$

3. $Mg(NO_3)_2$

Mg = 16.4%
N = 18.9%
O = _____

$Mg = \frac{24.305}{148.3148} \times 100$

$N = \frac{2(14.0067)}{148.3148} \times 100$

$O = \frac{6(15.9994)}{148.3148} \times 100$

4. $(NH_4)_3PO_4$ ⟶ 149.0863

N = 28.2%
H = 8.1%
P = 20.8%
O = 42.9%

$N = \frac{3(14.0067)}{149.0863} \times 100$

$H = \frac{12(1.0079)}{149.0863} \times 100$

$P = \frac{30.9738}{149.0863} \times 100$

$O = \frac{4(15.9994)}{149.0863} \times 100$

5. $Al_2(SO_4)_3$ ⟶ 342.086 g/mol

Al = 15.8%
S = 28.1%
O = 56.1%

$Al = \frac{2(26.9815)}{342.086} \times 100$

$S = \frac{3(32.065)}{342.086} \times 100$

$O = \frac{12(15.9994)}{342.086}$

Solve the following problems.

6. How many grams of oxygen can be produced from the decomposition of 100. g of $KClO_3$? _____

7. How much iron can be recovered from 25.0 g of Fe_2O_3? _____

8. How much silver can be produced from 125 g of Ag_2S? _____

DETERMINING EMPIRICAL FORMULAS

Name _____

What is the empirical formula (lowest whole number ratio) of the compounds below?

1. 75% carbon, 25% hydrogen 75 g C ; 25 g H

75 g C $\times \frac{1 \text{ mol}}{12.011 \text{ g}} = 6.24428 \text{ mol C}$

25 g H $\times \frac{1 \text{ mol}}{1.0079 \text{ g}} = 24.8040 \text{ mol H}$

[C] $\frac{6.24... \text{ mol C}}{6.24... \text{ mol C}} = 1$

[H] $\frac{24.8... \text{ mol H}}{6.24... \text{ mol C}} = 4$ CH_4

2. 52.7% potassium, 47.3% chlorine

52.7 g K $\times \frac{1 \text{ mol}}{39.0983 \text{ g}} = 1.34788 \text{ mol K}$

47.3 g Cl $\times \frac{1 \text{ mol}}{35.4527 \text{ g}} = 1.33417 \text{ mol Cl}$

[K] $\frac{1.347... \text{ mol K}}{1.33... \text{ mol Cl}} = 1.01$

[Cl] $\frac{1.33... \text{ mol Cl}}{1.33... \text{ mol Cl}} =$ KCl

3. 22.1% aluminum, 25.4% phosphorus, 52.5% oxygen

22.1 g Al $\times \frac{1 \text{ mol}}{26.9815 \text{ g}} = 0.815373 \text{ mol Al}$

25.4 g P $\times \frac{1 \text{ mol}}{30.9738 \text{ g}} = 0.82005 \text{ mol P}$

52.5 g O $\times \frac{1 \text{ mol}}{15.9994 \text{ g}} = 3.28137 \text{ mol O}$

[Al] $\frac{0.815... \text{ mol Al}}{0.815... \text{ mol Al}} = 1$

[P] $\frac{0.820... \text{ mol P}}{0.815... \text{ mol Al}} = 1.005$

[O] $\frac{3.28... \text{ mol O}}{0.815... \text{ mol Al}} = 4.02$ $AlPO_4$

4. 13% magnesium, 87% bromine

13 g Mg $\times \frac{1 \text{ mol}}{24.305 \text{ g}} = 0.53487 \text{ mol Mg}$

87 g Br $\times \frac{1 \text{ mol}}{79.904 \text{ g}} = 1.0888 \text{ mol Br}$

[Mg] $\frac{0.53... \text{ mol Mg}}{0.53... \text{ mol Mg}} = 1$

[Br] $\frac{1.08... \text{ mol Br}}{0.53... \text{ mol Mg}} = 2.03$ $MgBr_2$

5. 32.4% sodium, 22.5% sulfur, 45.1% oxygen

32.4 g Na $\times \frac{1 \text{ mol}}{22.98989 \text{ g}} = 1.40932 \text{ mol Na}$

22.5 g S $\times \frac{1 \text{ mol}}{32.065 \text{ g}} = 0.701 6997 \text{ mol S}$

45.1 g O $\times \frac{1 \text{ mol}}{15.9994 \text{ g}} = 2.818856 \text{ mol O}$

[Na] $\frac{1.40... \text{ mol Na}}{0.70... \text{ mol S}} = 2.009$

[S] $\frac{0.701... \text{ mol S}}{0.701... \text{ mol S}} = 1$

[O] $\frac{2.81... \text{ mol O}}{0.701... \text{ mol S}} = 4.01$ Na_2SO_4

6. 25.3% copper, 12.9% sulfur, 25.7% oxygen, 36.1% water

25.3 g Cu $\times \frac{1 \text{ mol}}{63.546 \text{ g}} = 0.398137 \text{ mol Cu}$

12.9 g S $\times \frac{1 \text{ mol}}{32.065 \text{ g}} = 0.40231 \text{ mol S}$

25.7 g O $\times \frac{1 \text{ mol}}{15.9994} = 1.60631 \text{ mol O}$

36.1 g H_2O $\times \frac{1 \text{ mol}}{18.0152 \text{ g}} = 2.00386$ H_2O

[Cu] $\frac{0.39 \text{ mol}}{0.39 \text{ mol}}$ [O] $\frac{1.6 \text{ mol}}{0.39 \text{ mol}}$

[S] $\frac{0.40 \text{ mol}}{0.39 \text{ mol}}$ [H_2O] $\frac{2.00 \text{ mol}}{0.39}$ $CuSO_4 \cdot 5H_2O$

DETERMINING MOLECULAR FORMULAS (TRUE FORMULAS)

Name _____

Solve the problems below.

1. The empirical formula of a compound is NO_2. Its molecular mass is 92 g/mol. What is its molecular formula? $NO_2 \rightarrow 46.0055$ g/mol

$$T.F. = \frac{M.T.F.}{M.E.F.}$$

$$= \frac{92 \text{ g/mol}}{46.0055 \text{ g/mol}} \simeq 2$$

N_2O_4

2. The empirical formula of a compound is CH_2. Its molecular mass is 70 g/mol. What is its molecular formula? $\rightarrow 14.0268$

$$T.F. = \frac{M.T.F.}{M.E.F.}$$

$$= \frac{70. \text{ g/mol}}{14.0268 \text{ g/mol}} \simeq 5$$

C_5H_{10}

3. A compound is found to be 40.0% carbon, 6.7% hydrogen and 53.5% oxygen. Its molecular mass is 60. g/mol. What is its molecular formula?

$40.0 \text{ g C} \times \frac{1 \text{ mol}}{12.011 \text{ g}} = 3.3303 \text{ mol C}$

$6.7 \text{ g H} \times \frac{1 \text{ mol}}{1.0079 \text{ g}} = 6.6475 \text{ mol H}$

$53.5 \text{ g O} \times \frac{1 \text{ mol}}{15.9994 \text{ g}} = 3.34388 \text{ mol O}$

C: $\frac{3.3.. \text{ mol}}{3.3... \text{ mol}} = 1$

H: $\frac{6.64.. \text{ mol}}{3.3... \text{ mol}} = 2$

O: $\frac{3.3... \text{ mol}}{3.3... \text{ mol}} = 1$

$CH_2O \rightarrow 30.0262$

$T.F. = \frac{60}{30.0262} \simeq 2$

$C_2H_4O_2$

4. A compound is 64.9% carbon, 13.5% hydrogen and 21.6% oxygen. Its molecular mass is 74 g/mol. What is its molecular formula? $EF \rightarrow C_4H_{10}O \rightarrow 74.1224$

$$T.F. = \frac{M.T.F}{M.E.F.}$$

$$= \frac{74}{74.1224} \simeq 1$$

$C_4H_{10}O$

5. A compound is 54.5% carbon, 9.1% hydrogen and 36.4% oxygen. Its molecular mass is 88 g/mol. What is its molecular formula? $E.F. = C_2H_4O \rightarrow 44.053$

$$T.F. = \frac{M.T.F.}{M.E.F.}$$

$$= \frac{88}{44.053} \simeq 2$$

$C_4H_8O_2$

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