Unit 7

The Mole

Chemistry Assignments and Objectives

EQ: Why does "Root Kill" turn from blue to white when heated?

Lesson 1 – Learning Targets

1. Define Avogadro's number.
2. Convert moles to number of particles.
3. Calculate molar mass.
4. Convert mass of a compound to moles and vice versa.
5. Convert moles to volume of a gas and vice versa.
6. Convert into or out of moles as part of a solution concentration problem.

Lesson 1 – Homework Problems

1. Make the following conversions:
   a. 1.51 x 10^{15} atoms Si to mol Si $1.51\times10^{15}\,\text{atoms} \times \frac{1\,\text{mole}}{6.022\times10^{23}\,\text{atoms}} = 2.51\times10^{-9}\,\text{mol Si}$

   b. 4.25 x 10^{-2} mol H_2SO_4 to molecules H_2SO_4 $4.25\times10^{-2}\,\text{mol} \times \frac{6.022\times10^{23}\,\text{molecules}}{1\,\text{mol}} = 2.56\times10^{22}\,\text{molecules } H_2SO_4$

   c. 8.95 x 10^{25} molecules CCl_4 to mol CCl_4 $8.95\times10^{25}\,\text{molecules} \times \frac{1\,\text{mole}}{6.022\times10^{23}\,\text{molecules}} = 1.49\times10^{2}\,\text{mole } CCl_4$

   d. 5.90 mol Ca to atoms Ca $5.90\,\text{mol Ca} \times \frac{6.022\times10^{23}\,\text{atoms}}{1\,\text{mol}} = 3.55\times10^{24}\,\text{atoms Ca}$

   e. 3.50 mol Li to g Li $3.50\,\text{mol} \times \frac{6.941\,\text{g}}{1\,\text{mol}} = 24.3\,\text{g Li}$

   f. 7.65 g Co to mol Co $7.65\,\text{g Co} \times \frac{1\,\text{mol Co}}{58.93\,\text{g}} = 0.130\,\text{mol Co}$

   g. 5.62 g Kr to mol Kr $5.62\,\text{g Kr} \times \frac{1\,\text{mol Kr}}{83.80\,\text{g}} = 0.0671\,\text{g Kr}$

2. Determine the molar mass of the following:
   a. Nitric acid (HNO_3) $63.018\ \frac{\text{g}}{\text{mol}}$

   b. Ammonium nitrate (NH_4NO_3) $80.052\ \frac{\text{g}}{\text{mol}}$

   c. Zinc oxide (ZnO) $81.39\ \frac{\text{g}}{\text{mol}}$

3. Propane, C_3H_8, is a gas commonly used as a home fuel for cooking and heating. Calculate the volume that 0.540 mol of propane occupies at STP.

$0.540\,mol \times \frac{22.4\,L}{1\,mol} = 12.1\,L$

4. Carbon monoxide, CO, is a product of incomplete combustion of fuels. Find the volume that 42 g of CO gas occupies at STP.

$42g \times \frac{1\,mol}{28.01g} \times \frac{22.4\,L}{1\,mol} = 34\,L$

5. 500.0 mL of an aqueous solution of calcium chloride has 33.93 grams of solute dissolved in it. What is the concentration of the solution?

$33.93g \times \frac{1\,mol}{110.98g} = .305\,mol$ $\quad M = \frac{.3057\,mol}{.500L} = .6115\,\frac{mol}{L}$

6. A 1.5 M solution of sodium fluoride has 60.10 grams of solute dissolved in it. What is the volume of the solution?

$L \cdot M = mol$ & $\frac{mol}{M} = L$ $\quad L = \frac{mol}{M} = \frac{1.431\,mol}{1.5\,\frac{mol}{L}} = 0.95L$

$60.10g \times \frac{1\,mol}{41.99g} = 1.431\,mol$

7. 350.0 mL of a 0.80 M solution has how many grams of potassium permanganate dissolved in it?

$L \cdot M = mol$ & $mol = L \cdot M$

$= (.3500L)(0.80\,\frac{mol}{L}) = 0.28\,mol \times \frac{158.04g}{1\,mol} = 44g\ KMnO_4$

Lesson 2 – Learning Targets

1. Explain what is meant by the percent composition of a compound.
2. Determine the empirical and molecular formulas for a compound from mass percent and actual mass data.

Lesson 2 – Homework Problems

1. Express the composition of each of the following as the mass percent of its elements (percent composition):
   a. Sucrose ($C_{12}H_{22}O_{11}$) 342.296

   $\frac{144.12}{342.296} \times 100 = 42.10\%\ C$ $\quad \frac{22.176}{342.296} \times 100 = 6.48\%\ H$

   $\frac{176}{342.296} \times 100 = 51.42\%\ O$

   b. Magnetite (Fe_3O_4)

   $\frac{167.55}{231.55} \times 100 = 72.36\%\ Fe$ $\quad \frac{64}{231.55} \times 100 = 27.64\%\ O$

   c. Aluminum sulfate ($Al_2(SO_4)_3$)

   $\frac{53.96}{342.17} \times 100 = 15.77\%\ Al$ $\quad \frac{96.21}{342.17} \times 100 = 28.12\%\ S$ $\quad \frac{192}{342.17} \times 100 = 56.11\%\ O$

2. Determine the empirical formula for each of the following compounds:
   a. Ethylene (C_2H_4) CH_2

   b. Ascorbic acid ($C_6H_8O_6$) $C_3H_4O_3$

c. Naphthalene ($C_{10}H_8$) C_5H_4

3. Monosodium glutamate (MSG) is sometimes added to food to enhance flavor. Analysis determined this compound to be 35.5% C, 4.77% H, 8.29% N, 13.6% Na and 37.9% O. what is the empirical formula for MSG?

8.29g N x 1mol / 14.0g = .5917 mol N

35.5g C x 1mol / 12.01g = 2.956 mol C

4.77g H x 1mol / 1.008g = 4.732 mol H

13.6g Na x 1mol / 22.99g = .5916 mol Na

37.9g O x 1mol / 16g = 2.369 mol O

$NaC_5H_8O_4$

4. Determine the molecular formula for ibuprofen, a common headache remedy. Analysis of ibuprofen yields a molecular mass of 206 g/mol and a percent composition of 75.7% C, 8.80% H and 15.5% O.

75.7g C x 1mol / 12.01g = 6.30 mol C / .969

8.80 g H x 1mol / 1.008g = 8.73 mol H / .969

15.5g O x 1mol / 16g = 0.969 mol O / .969

divide by smallest

6.5 mol C x 2 = 13 C

9 mol H x 2 = 18 H

1 mol O x 2 = 2 O

adds up to 206 g/mol

empirical + molecular match! Happens sometimes. $C_{13}H_{18}O_2$

Lesson 3 – Learning Targets

1. Explain what a hydrate is and how to name hydrates.
2. Determine the formula for a hydrate from laboratory data.

Lesson 3 – Homework Problems

1.Determine the mass percent of anhydrous sodium carbonate (Na_2CO_3) and water in sodium carbonate decahydrate ($Na_2CO_3 \cdot 10\ H_2O$).

$\frac{105.99}{180+105.99} \times 100 = \frac{105.99}{285.99} \times 100 = 37.1\%\ Na_2CO_3$

$\frac{180}{285.99} \times 100 = 62.9\%\ H_2O$

2. What is the formula and name of a hydrate that is 85.3% barium chloride and 14.7% water?

85.3g $BaCl_2$ x 1mol $BaCl_2$ / 208.23g = 0.4096 mol $BaCl_2$ / .4096

14.7g H_2O x 1mol / 18.02g = 0.816 mol H_2O / .4096

$BaCl_2 \cdot 2H_2O$

Unit 7 Review

Mole Relationships

Find the molar mass of the compounds. Show all of your work.

1. N_2 28.02 g/mol ⇒ 2(14.01) write
2. $Ba(NO_3)_2$ 261.35 g/mol ⇒ 137.33 + 2(14.01) + 6(16)
3. $(NH_4)_3PO_4$ 149.096 g/mol ⇒ 3(14.01) + 12(1.008) + 30.97 + 4(16)

4. $NaHCO_3$ 84.008 g/mol ⇒ work: $22.99 + 1.008 + 12.01 + 3(16)$
5. H_2O 18.018 g/mol ⇒ $2(1.008) + 16$

Mole Conversions Practice

Answer the following questions. Show all your work!

1. Find the volume of 2.5 moles of C_2H_6 gas at STP.

$$2.5\,mol \times \frac{22.4\,L}{1\,mol} = 56\,L$$

2. Find the number of moles present in 1.5×10^{23} molecules of C_2H_6.

$$1.5 \times 10^{23}\,molecules \times \frac{1\,mol}{6.022 \times 10^{23}\,molecules} = 0.25\,mol$$

3. Find the mass of 4.0 moles of CO_2.

$$4.0\,mol \times \frac{44.01\,g}{1\,mol} = 180\,g \quad (sig.\ fig.\ !)$$

4. How many atoms of nitrogen (N) are there in 2.18 moles of nitrogen (N_2)?

$$2.18\,mol\,N_2 \times \frac{2\,mol\,N}{1\,mol\,N_2} \times \frac{6.022 \times 10^{23}\,atoms}{1\,mol} = 2.63 \times 10^{24}\,atoms$$

5. How many moles are there in 0.335 L of argon gas (Ar) at STP?

$$0.335\,L \times \frac{1\,mol}{22.4\,L} = 0.0150\,mol$$

6. Find the mass of 1.2×10^{24} molecules of H_2S.

$$1.2 \times 10^{24}\,molecules \times \frac{1\,mol}{6.022 \times 10^{23}\,molecules} \times \frac{34.086\,g}{1\,mol} = 68\,g$$

7. What is the mass of 67.2 L of CO at STP?

$$67.2\,L \times \frac{1\,mol}{22.4\,L} \times \frac{28.01\,g}{1\,mol} = 84.0\,g$$

8. How many molecules are in 8.0 g of methane (CH_4)?

$$8.0\,g \times \frac{1\,mol}{12.042\,g} \times \frac{6.022 \times 10^{23}\,molecules}{1\,mol} = 3.0 \times 10^{23}\,molecules$$

9. How many molecules are in 33.6 L of carbon dioxide at STP?

$$33.6\,L \times \frac{1\,mol}{22.4\,L} \times \frac{6.022 \times 10^{23}\,molecules}{1\,mol} = 9.03 \times 10^{23}\,molecules$$

Solution applications:

10. 650.0 mL of an aqueous solution of sodium chloride has 14.78 grams of solute dissolved in it. What is the concentration of the solution?

$$14.78\,g \times \frac{1\,mol}{58.44\,g} = 0.25325\,mol \qquad \frac{0.25325\,mol}{0.650\,L} = 0.3896\,M \text{ or } 0.3896\,\frac{mol}{L}$$

11. A 2.3 M solution of ammonium nitrate has 50.49 grams of solute dissolved in it. What is the volume of the solution? NH_4NO_3

$$50.49\,g \times \frac{1\,mol}{80.052\,g} = 0.6307\,mol \qquad L_M = \frac{mol_x}{M} = \frac{0.6307\,mol}{2.3\,M} = 0.27\,L$$

12. 250.0 mL of a 0.60 M solution has how many grams of lithium chloride dissolved in it?

$$L_M = \frac{mol_x}{L} = (0.2500\,L)\left(0.60\,\frac{mol}{L}\right) = 0.15\,mol \times \frac{42.391\,g}{1\,mol} = 6.4\,g$$

Empirical Formulas Practice

Divide by smallest

Directions: Find the empirical formula and name for each of the following.

1. A compound is 24.7% Calcium, 1.2% Hydrogen, 14.8% Carbon, and 59.3% Oxygen. Write the empirical formula and name the compound.

$24.7\text{g Ca} \times \frac{1\text{mol}}{40.08\text{g}} = 0.616\text{ mol Ca}$ → 1 mol Ca

$1.2\text{g H} \times \frac{1\text{mol}}{1.008\text{g}} = 1.19\text{ mol H}$ → 2 mol H

$14.8\text{g C} \times \frac{1\text{mol}}{12.01\text{g}} = 1.23\text{ mol C}$ → 2 mol C

$59.3\text{g O} \times \frac{1\text{mol}}{16.00\text{g}} = 3.71\text{ mol O}$ → 6 mol O

$CaH_2C_2O_6$

$Ca(HCO_3)_2$

2. In an experiment, it was found that 11.775 g of Sn combined with 3.180 g of O. Write the empirical formula and name the compound that is formed.

$11.775\text{g Sn} \times \frac{1\text{mol Sn}}{118.71\text{g}} = 0.0992\text{ mol Sn}$

$3.180\text{g O} \times \frac{1\text{mol O}}{16\text{g}} = 0.199\text{ mol O}$

SnO_2

tin (IV) oxide

3. A compound is 19.3% Na, 26.9% S, and 53.8% O. Its formula mass is 238 g. What is its molecular formula?

$19.3\text{g Na} \times \frac{1\text{mol}}{22.99\text{g}} = .839\text{ mol Na}$

$26.9\text{g S} \times \frac{1\text{mol}}{32.07\text{g}} = .839\text{ mol S}$

$53.8\text{g O} \times \frac{1\text{mol}}{16\text{g}} = 3.363\text{ mol O}$

$NaSO_4$ ← empirical

$119 \times 2 = 238$

molecular → $Na_2S_2O_8$

Hydrates Practice

1) Name the following hydrates:

a. $Na_3PO_4 \cdot 7\,H_2O$ sodium phosphate heptahydrate

b. $CaSO_4 \cdot 2\,H_2O$ calcium sulfate dihydrate

c. $Mn(NO_3)_2 \cdot 4\,H_2O$ manganese (II) nitrate tetrahydrate

2) Write the formulas of the following hydrates:

a. magnesium nitrate hexahydrate $Mg(NO_3)_2 \cdot 6H_2O$

b. iron (II) sulfate heptahydrate $FeSO_4 \cdot 7H_2O$

c. tin (II) chloride dihydrate $SnCl_2 \cdot 2H_2O$

3) What is the formula of a hydrate that is 86.7% Mo_2S_5 and 13.3% H_2O?

$86.7\text{g} \times \frac{1\text{mol}}{352.23\text{g}} = 0.246\text{ mol } Mo_2S_5$

$13.3\text{g} \times \frac{1\text{mol}}{18.018\text{g}} = 0.738\text{ mol } H_2O$

answers on next page

formula of hydrate = $Mo_2S_5 \cdot 3H_2O$ name of hydrate = molybdenum(V) sulfide trihydrate

4) During lab, 1.62 g of $CoCl_2 \cdot H_2O$ were heated. After heating, only 0.88 g of $CoCl_2$ remained.
What was the formula of the original hydrate?

$.88\,g\ CoCl_2 \times \frac{1\,mol}{129.83\,g} = .00678\ mol\ CoCl_2$ $\quad 0.74\,g\ H_2O \times \frac{1\,mol}{18.015\,g} = 0.0411\ mol$

formula of hydrate = $CoCl_2 \cdot 6H_2O$ name of hydrate = cobalt(II) chloride hexahydrate

5) Determine the percent of WATER in $K_2S \cdot 5\ H_2O$. (check answer by seeing if percents add to 100%)

name of hydrate = potassium sulfide pentahydrate

mass of K_2S = 110.27 g
mass of H_2O = 90.09 g

$$\%\ K_2S = \frac{110.27\,g}{200.36\,g} \times 100 = 55.0\%$$

$$\%\ water = \frac{90.09\,g}{200.36\,g} \times 100 = 45.0\%$$