Unit 5 Packet: The Mole
WPHS Chemistry

Name Key

Mole-1

1. Describe/relate the size of the mole to an everyday object.

2. What is Avogadro's Number? 6.02×10^{23}

3. How many marbles are in a mole of marbles? 6.02×10^{23} marbles

4. How many mosquitoes are in a mole of mosquitoes? 6.02×10^{23} mosquitoes

Mole-2 Molar Mass

Find the molar mass of the following compounds: Show work and include units

1. CO_2 $12.0 + (16.0 \times 2) = \frac{44.0\text{g}}{1\text{mol}}$

2. Fe_2O_3 $(55.8 \times 2) + (16.0 \times 3) = \frac{159.6\text{g}}{1\text{mol}}$

3. $AgCl$ $(107.9 + 35.5) = \frac{143.4\text{g}}{1\text{mol}}$

4. $Ca_3(PO_4)_2$ $(40.1 \times 3) + (31.0 \times 2) + (8 \times 16.0) = \frac{310.3\text{g}}{1\text{mol}}$

5. $W_3(PO_3)_5$ $(183.8 \times 3) + (31.0 \times 5) + (15 \times 16.0) = \frac{946.4\text{g}}{1\text{mol}}$

6. $Fe(C_2H_3O_2)_2$
$55.8 + (4 \times 12.0) + (6 \times 1.0) + (4 \times 16.0)$
$\frac{173.8\text{g}}{1\text{mol}}$

7. Calcium Carbonate
$CaCO_3$
$40.1 + 12.0 + (3 \times 16.0) =$
$\frac{100.1\text{g}}{1\text{mol}}$

8. Lead IV Sulfate $Pb_2(SO_4)_2$
$207.2 + (32.1 \times 2) + (8 \times 16.0) = \frac{399.4\text{g}}{1\text{mol}}$

9. Lead IV Sulfite $Pb(SO_3)_2$
$207.2 + (32.1 \times 2) + (6 \times 16.0) = \frac{367.4\text{g}}{1\text{mol}}$

10. Lead IV Sulfide PbS_2
$207.2 + (32.1 \times 2) = \frac{271.4\text{g}}{1\text{mol}}$

11. Lead II sulfate $PbSO_4$
$207.2 + 32.1 + (4 \times 16.0) = \frac{303.3\text{g}}{1\text{mol}}$

12. Lead II Sulfite $PbSO_3$
$207.2 + 32.1 + (3 \times 16.0) = \frac{287.3\text{g}}{1\text{mol}}$

13. Lead II Sulfide PbS
$207.2 + 32.1 = 239.3\text{g/mol}$

14. Copper I Sulfide Cu_2S
$(63.5 \times 2) + 32.1 = \frac{159.1\text{g}}{1\text{mol}}$

15. Copper II Sulfite $CuSO_3$
$63.5 + 32.1 + (48) = \frac{143.6\text{g}}{1\text{mol}}$

Mole-3 Mole Conversions (one step)
Directions: Answer the following questions. Set-up all problems using the factor-label method of dimensional analysis and show all your work and units.

1. How many atoms are in 1.5 moles of neon?

$$1.5 \text{ mol Ne} \left| \frac{6.02\times10^{23} \text{ atoms Ne}}{1 \text{ mol Ne}} \right. = 9.03\times10^{23} \text{ atoms Ne} \Rightarrow \boxed{9.0\times10^{23} \text{ atoms Ne}}$$

2. How many moles of SF_6 are there in 4,595,000,000,000,000,000 molecules of SF_6?

$$4.595\times10^{18} \text{ molecules } SF_6 \left| \frac{1 \text{ mol } SF_6}{6.02\times10^{23} \text{ molecules } SF_6} \right. = \boxed{7.633\times10^{-6} \text{ mol } SF_6}$$

3. Calculate the number of moles in 5.45×10^{25} atoms of Zn

$$5.45\times10^{25} \text{ atoms Zn} \left| \frac{1 \text{ mol Zn}}{6.02\times10^{23} \text{ atoms Zn}} \right. = \boxed{90.5 \text{ mol Zn}}$$

1. What is the mass of 7.50 moles of sulfur dioxide (SO_2)? $(32.1 + (16.0\times2))$

$$7.50 \text{ mol } SO_2 \left| \frac{64.1 \text{ g } SO_2}{1 \text{ mol } SO_2} \right. = 480.75 \Rightarrow \boxed{481 \text{ g } SO_2}$$

2. How many moles are there in 250.0 grams of sodium phosphate (Na_3PO_4)? $(23.0\times3) + 31.0 + (16.0\times4)$

$$250.0 \text{ g } Na_3PO_4 \left| \frac{1 \text{ mol } Na_3PO_4}{164.0 \text{ g } Na_3PO_4} \right. = \boxed{1.524 \text{ mol } Na_3PO_4}$$

3. How many grams of potassium sulfate (K_2SO_4) are there in 25.3 moles? $(39.1\times2) + 32.1 + (16.0\times4) = 174.3$

$$25.3 \text{ mol } K_2SO_4 \left| \frac{174.3 \text{ g } K_2SO_4}{1 \text{ mol } K_2SO_4} \right. = 4409.79 \Rightarrow \boxed{4410 \text{ g } K_2SO_4}$$

4. Calculate the number of grams in 3.25-mol of $AgNO_3$ $107.9 + 14.0 + (16.0\times3) = 169.9$

$$3.25 \text{ mol } AgNO_3 \left| \frac{169.9 \text{ g } AgNO_3}{1 \text{ mol } AgNO_3} \right. = 552.175 \Rightarrow \boxed{552 \text{ grams } AgNO_3}$$

5. What is the volume of 0.38 moles of any gas at STP?

$$0.38 \text{ mol gas} \left| \frac{22.4 \text{ L gas}}{1 \text{ mol gas}} \right. = \boxed{8.5 \text{ L gas}}$$

6. Calculate the number of moles in 32.2-L of NH_3

$$32.2 \text{ L } NH_3 \left| \frac{1 \text{ mol } NH_3}{22.4 \text{ L } NH_3} \right. = 1.4375 \Rightarrow \boxed{1.44 \text{ mol } NH_3}$$

7. What is the mass of 51 liters of oxygen gas?

$$51 \text{ L } O_2 \text{ gas} \left| \frac{1 \text{ mol } O_2 \text{ gas}}{22.4 \text{ L } O_2 \text{ gas}} \right| \frac{32.0 \text{ g O}}{1 \text{ mol } O_2 \text{ gas}} = \boxed{73 \text{ grams } O_2}$$

Mole-4: Mole Conversions (two steps)
Directions: Answer the following questions. Set-up all problems using the factor-label method of dimensional analysis and show all your work and units.

8. What volume would be occupied by 9.45×10^{24} molecules of CO_2 gas at STP?

$$9.45\times10^{24}\ \text{molec. } CO_2 \left| \frac{1\ \text{mol } CO_2}{6.02\times10^{23}\ \text{molec. } CO_2} \right| \frac{22.4\text{L } CO_2}{1\ \text{mol } CO_2} = 351.607 \Rightarrow \boxed{352\text{L } CO_2}$$

9. How many calcium atoms would be in a 100 gram sample of calcium metal?

$$100\text{g Ca} \left| \frac{1\text{mol Ca}}{40.1\text{g Ca}} \right| \frac{6.02\times10^{23}\text{ atoms Ca}}{1\text{mol Ca}} = 1.501\times10^{24} \Rightarrow \boxed{2\times10^{24}\text{ atoms Ca}}$$

10. How many grams are in 5.6×10^{23} atoms of Zinc?

$$5.6\times10^{23}\text{ atoms Zn} \left| \frac{1\text{mol Zn}}{6.02\times10^{23}\text{ atoms Zn}} \right| \frac{65.4\text{g Zn}}{1\text{mol Zn}} = 60.837 \Rightarrow \boxed{61\text{g Zn}}$$

★ 11. Calculate the number of ~~molecules~~ formula units in 4.56-g of $Pb(NO_3)_2$

$207.2 + (2\times14.0) + (6\times16.0) = 331.2\text{ g}$

$$4.56\text{g } Pb(NO_3)_2 \left| \frac{1\text{mol } Pb(NO_3)_2}{331.2\text{g } Pb(NO_3)_2} \right| \frac{6.02\times10^{23}\text{ molecules } Pb(NO_3)_2}{1\text{mol } Pb(NO_3)_2} = 8.29\times10^{21} \Rightarrow \boxed{8.29\times10^{21}\text{ formula units } Pb(NO_3)_2}$$

12. Calculate the number of liters in 3.25-g of NH_3

$14.0 + (1.0\times3) = 17.0\text{g}$

$$3.25\text{g } NH_3 \left| \frac{1\text{ mol } NH_3}{17.0\text{g } NH_3} \right| \frac{22.4\text{L } NH_3}{1\text{ mol } NH_3} = 4.2823 \Rightarrow \boxed{4.28\text{L } NH_3}$$

13. Calculate the number of liters in 5.43×10^{25} molecules of H_2

$$5.43\times10^{25}\text{ molecules } H_2 \left| \frac{1\text{ mol } H_2}{6.02\times10^{23}\text{ molecules } H_2} \right| \frac{22.4\text{L } H_2}{1\text{mol } H_2} = 2020.47 \Rightarrow \boxed{2020\text{L } H_2}$$

14. Calculate the number of grams in 3.54-L of CO_2

$12 + (2\times16) = 44\text{g } CO_2$

$$3.54\text{L } CO_2 \left| \frac{1\text{mol } CO_2}{22.4\text{L } CO_2} \right| \frac{44.0\text{g } CO_2}{1\text{mol } CO_2} = 6.9537 \Rightarrow \boxed{6.95\text{g } CO_2}$$

15. Calculate the number of grams in 9.7×10^{22} molecules of CH_3CH_2OH

$$9.7\times10^{22}\text{ molecules } CH_3CH_2OH \left| \frac{1\text{mol } CH_3CH_2OH}{6.02\times10^{23}\text{ molecules } CH_3CH_2OH} \right| \frac{46.0\text{g}}{1\text{mol } CH_3CH_2OH} = 7.49 \Rightarrow \boxed{7.49\ CH_3CH_2OH}$$

$(2\times12) + (6\times1.0) + 16.0 = 46.0$

Mole-5 Percent Composition

1. Calculate the % composition of Li_2O. $(2 \times 6.9) + 16.0 = 29.8\ g\ Li_2O$

$\frac{13.8\ g\ Li}{29.8\ Li_2O} =$ 46.3% Lithium

$\frac{16.0\ g\ O}{29.8\ g\ Li_2O} =$ 53.7% Oxygen

2. What is the percentage composition of a carbon-oxygen compound, given that a 95.2 g sample of the compound contains 40.8 g of carbon and 54.4 g of oxygen?

mass = 95.2 g

$\frac{40.8\ g\ C}{95.2\ g} =$ 42.9% Carbon

$\frac{54.4\ g\ O}{95.2\ g} =$ 57.1% Oxygen

3. What is the percentage composition of N_2O_4? $(2 \times 14.0) + (4 \times 16.0) = 92.0$

28 N 64 O

$\frac{28.0\ g\ N}{92.0\ g\ N_2O_4} =$ 30.4% N

$\frac{64.0\ g\ O}{92.0\ g\ N_2O_4} =$ 69.6% O

4. What is the percentage composition of a compound made from 28 grams of nitrogen and 32 grams of oxygen? $28 + 32 = 60\ g$

$\frac{28\ g\ N}{60\ g} \times 100 =$ 46.6% Nitrogen

$\frac{32\ g\ O}{60\ g} \times 100 =$ 53.3% Oxygen

5. What is the percentage composition of a carbon-hydrogen-fluorine compound which contains 7.2 grams of carbon, 11.4 grams of fluorine, and 1.8 grams of hydrogen?

$7.2 + 11.4 + 1.8 = 20.4\text{g}$

$\frac{7.2\text{g C}}{20.4} \times 100 = 35.3\%\text{C}$ $\quad \frac{11.4\text{g F}}{20.4\text{g}} \times 100 = 55.9\%\text{ F}$ $\quad \frac{1.8\text{g H}}{20.4\text{g}} \times 100 = 8.8\%\text{ H}$

6. Find the percentage composition of Na_2SO_4?

$(23.0 \times 2) + 32.1 + (16.0 \times 4) = 142.1\text{g}$
(46) (64)

$\frac{46.0\text{g Na}}{142.1\text{g } Na_2SO_4} \times 100 = 32.4\%\text{ Na}$ $\quad \frac{32.1\text{g S}}{142.1\text{g } Na_2SO_4} \times 100 = 22.6\%\text{ S}$ $\quad \frac{64.0\text{g O}}{142.1\text{g } Na_2SO_4} \times 100 = 45.0\%\text{ O}$

7. If a compound is formed from 60.0 liters of nitrogen gas, N_2, (at STP) and 180 liters of hydrogen gas, H_2, (at STP), what is its percentage composition?

$\frac{60\text{L } N_2}{22.4\text{L } N_2} \left| \frac{1\text{mol } N_2}{1\text{mol } N_2} \right| \frac{28.0\text{g } N_2}{1\text{mol } N_2} = 75\text{g } N_2$

$75 + 16.1 = 91.1\text{g}$ / 1 mol compound

$\frac{75.0\text{g } N_2}{91.1\text{g compound}} \times 100 = 82.3\%\text{ } N_2$

$\frac{180\text{L } H_2}{22.4\text{L } H_2} \left| \frac{1\text{mol } H_2}{1\text{mol } H_2} \right| \frac{2.0\text{g } H_2}{1\text{mol } H_2} = 16.1\text{g } H_2$

$\frac{16.1\text{g } H_2}{91.1\text{g compound}} \times 100 = 17.7\%\text{ } H_2$

8. Find the percentage composition of a compound formed when 0.4 moles of potassium are reacted with 8.96 liters of O_2 gas and 2.41×10^{22} atoms of S.

$\frac{0.4\text{mol K}}{1\text{mol K}} \left| \frac{39.1\text{g K}}{1\text{mol K}} \right. = 15.64$ → $\frac{15.6}{29.7} \times 100 = 52.5\%\text{ K}$

$\frac{8.96\text{L } O_2}{22.4\text{L } O_2} \left| \frac{1\text{mol } O_2}{1\text{mol } O_2} \right| \frac{32\text{g } O_2}{1\text{mol } O_2} = 12.8\text{g } O_2$ → $\frac{12.8}{29.7} \times 100 = 43.1\%\text{ O}$

$\frac{2.41 \times 10^{22}\text{ atoms S}}{6.02 \times 10^{23}\text{ atoms S}} \left| \frac{1\text{mol S}}{1\text{mol S}} \right| \frac{32.1\text{g S}}{1\text{mol S}} = 1.285$ → $\frac{1.3}{29.7} \times 100 = 4.377 \sim 4.4\%\text{ S}$

$15.6 + 12.8 + 1.3 = 29.7\text{g}$ / 1 mol total

Mole-6: Empirical Formulas

1. Determine the **empirical** formula of a compound with 72.4% Fe and 27.6% Oxygen.

$72.4\text{g Fe} \left| \frac{1\text{mol Fe}}{55.8\text{g Fe}} \right. = \frac{1.297}{1.297} = 1 \times 3 = 3$

$27.6\text{g O} \left| \frac{1\text{mol}}{16.0\text{g O}} \right. = \frac{1.725}{1.297} = 1.3 \times 3 = 4$

Fe_3O_4

2. Determine the **empirical** formula of a compound with 65.2% Sc and 34.8% O

$65.2\text{g Sc} \left| \frac{1\text{mol Sc}}{45.0\text{g Sc}} \right. = \frac{1.45}{1.45} = 1 \times 2 = 2$

Sc_2O_3

$34.8\text{g O} \left| \frac{1\text{mol O}}{16.0\text{g O}} \right. = \frac{2.175}{1.45} = 1.5 \times 2 = 3$

3. Determine the **empirical** formula of a compound with 52.8% Sn, 12.4% Fe, 16% C and 18.8% N.

$52.8\text{g Sn} \left| \frac{1\text{mol Sn}}{118.7\text{g Sn}} \right. = \frac{.4448}{.2222} = 2$

$12.4\text{g Fe} \left| \frac{1\text{mol Fe}}{55.8\text{g Fe}} \right. = \frac{.2222}{.2222} = 1$

$16.0\text{g C} \left| \frac{1\text{mol}}{12.0\text{g}} \right. = \frac{1.333}{.2222} = 6$

$18.8\text{g N} \left| \frac{1\text{mol N}}{14.0\text{g}} \right. = \frac{1.34}{.2222} = 6$

$Sn_2FeC_6N_6$

4. Determine the **empirical formula** of a compound that contains 2.61-g of carbon, 0.65-g of hydrogen, and 1.74-g of oxygen

$2.61\text{g C} \left| \frac{1\text{mol C}}{12.0\text{g C}} \right. = \frac{.2175}{.10875} = 2$

C_2H_6O

$0.65\text{g H} \left| \frac{1\text{mol H}}{1.0\text{g H}} \right. = \frac{.65}{.10875} = 5.97 = 6$

$1.74\text{g O} \left| \frac{1\text{mol O}}{16.0\text{g O}} \right. = \frac{.10875}{.10875} = 1$

Mole-7 Molecular Formula

1. Determine the **molecular** formula for a compound that contains 12.2-g Nitrogen, 27.8-g Oxygen, and a molecular mass of 92.0 g/mol.

$12.2g\ N \mid \frac{1 mol N}{14.0g N} = \frac{.8714}{.8714} = 1$

$27.8g\ O \mid \frac{1 mol O}{16.0g O} = \frac{1.7375}{.8714} = 2$

EF NO_2 (46g) ×2 ⇒ MF N_2O_4 (92g)

2. Determine the **molecular** formula for a compound that contains 94.1% oxygen and 5.9% hydrogen and a molecular mass of 34 g/mol.

$94.1g\ O \mid \frac{1 mol O}{16.0g O} = \frac{5.88}{5.88} = 1$

$5.9g\ H \mid \frac{1 mol H}{1.0g H} = \frac{5.9}{5.88} = 1$

EF HO (17g / 1 mol) ⇒ MF H_2O_2 (34g / 1 mol)

3. Determine the **molecular** formula for a compound that contains 22.5% Na, 30.4% P and 47.1% O and a molar mass of 306 g/mol

$22.5g\ Na \mid \frac{1 mol Na}{23.0g Na} = \frac{.978}{.978} = 1$

$30.4g\ P \mid \frac{1 mol P}{31.0g P} = \frac{.9806}{.978} = 1$

$47.1g\ O \mid \frac{1 mol P}{16.0g} = \frac{2.94}{.978} = 3$

EF $NaPO_3$ (102g / 1 mol) ×3 ⇒ MF $Na_3(PO_3)_3$ (306g / 1 mol)

4. Determine the **molecular formula** of a compound that contains 76% iodine and 24% oxygen and has a molar mass of 334g/mol.

$76g\ I \mid \frac{1 mol I}{126.9g I} = \frac{.59}{.59} = 1 \times 2 = 2$

$24g\ O \mid \frac{1 mol O}{16.0g O} = \frac{1.5}{.59} = 2.5 \times 2 = 5$

EF=MF I_2O_5 (334g / 1 mol)

5. Determine the **molecular formula** of a compound that contains 48.6% carbon, 8.1% hydrogen, and 43.2% oxygen and has a molar mass of 296-g/mol.

$48.6\text{g C} \mid \frac{1\text{mol C}}{12.0\text{g C}} = \frac{4.05}{2.7} = 1.5 \times 2 = 3$

$8.1\text{g H} \mid \frac{1\text{mol H}}{1.0\text{g H}} = \frac{8.1}{2.7} = 3 \times 2 = 6$

$43.2\text{g O} \mid \frac{1\text{mol O}}{16.0\text{g O}} = \frac{2.7}{2.7} = 1 \times 2 = 2$

EF

$C_3H_6O_2 = 74\text{g/mol}$

X 4

$C_{12}H_{24}O_8$ = MF 296g/mol

6. Determine the **molecular formula** of a compound that contains 0.993-g nitrogen, 1.27-g carbon, 0.213-g hydrogen, 2.52-g chlorine and has a molar mass of 423-g/mol.

$0.993\text{g N} \mid \frac{1\text{mol N}}{14.0\text{g N}} = \frac{.07092}{.07092} = 1 \times 2 = 2$

$1.27\text{g C} \mid \frac{1\text{mol C}}{12.0\text{g C}} = \frac{.1058}{.07092} = 1.49 \times 2 = 3$

$0.213\text{g H} \mid \frac{1\text{mol H}}{1.0\text{g H}} = \frac{.213}{.07092} = 3 \times 2 = 6$

$2.52\text{g Cl} \mid \frac{1\text{mol}}{35.5\text{g Cl}} = \frac{.07098}{.07092} = 1 \times 2 = 2$

$EF = N_2C_3H_6Cl_2 = 141\text{g/mol}$

X 3

$MF = N_6C_9H_{18}Cl_6$

7. A sample of TNT, a common explosive is analyzed and found to contain 1.03-g of nitrogen, 0.220-g hydrogen, and 1.76-g of carbon. The molar mass is 123 g/mol. What is the **molecular formula?**

$1.03\text{g N} \mid \frac{1\text{mol N}}{14.0\text{g N}} = \frac{.07357}{.07357} = 1$

$0.220\text{g H} \mid \frac{1\text{mol H}}{1.0\text{g H}} = \frac{.22}{.07357} = 3$

$1.76\text{g C} \mid \frac{1\text{mol C}}{12.0\text{g C}} = .1466 = 2$

$EF = N_1H_3C_2 = 41\text{g/mol}$

X 3

$MF = N_3H_9C_6 = 123\text{g/mol}$

8. Azobenzene is an important intermediate in the manufacture of dyes. It contains 79.1% carbon, 5.55% hydrogen, and 15.4% nitrogen. It has a molar mass of 182-g/mol. What is the **molecular formula?**

$79.1\text{g C} \mid \frac{1\text{mol C}}{12.0\text{g C}} = \frac{6.59}{1.1} = 6$

$5.55\text{g H} \mid \frac{1\text{mol H}}{1.0\text{g H}} = \frac{5.55}{1.1} = 5.04$

$15.4\text{g N} \mid \frac{1\text{mol N}}{14.0\text{g N}} = \frac{1.1}{1.1} = 1$

$EF = C_6H_5N = 91\text{g/mol}$

X 2

$MF = C_{12}H_{10}N_2 = 182\text{g/mol}$