Name Key Mole Ratios and Stoichiometry

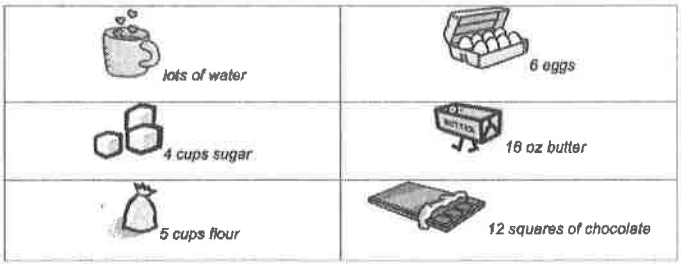
**Intro to Mole Ratios: Limiting Reagents (1-9 ©Pogil 2005-6)**

***Model***

A cake recipe calls for:

| | |
|---|---|
| *2 cups water* | *4 eggs* |
| *4 cups sugar* | *8 oz butter* |
| *4 cups flour* | *8 squares chocolate* |

Ingredients on hand:




1) According to the model, how much of each ingredient is necessary to make a cake?

| Water | Flour | Sugar | Eggs | Butter | Chocolate |
|---|---|---|---|---|---|
| 2 cups | 4 cups | 4 cups | 4 eggs | 8 oz | 8 squares |

2) If you follow the recipe, using only the ingredients on hand in the model, how much of each ingredient will be left over after you have prepared the cake?

| Water | Flour | Sugar | Eggs | Butter | Chocolate |
|---|---|---|---|---|---|
| unlimited | 1 cup flour | 0 cups | 2 eggs | 8 oz | 4 squares |

3) Which ingredients on hand were in excess of the quantities required for the recipe?
All But Sugar

4) Which ingredient on hand was completely consumed when making the cake?
Sugar

5) Which ingredient limits or prevents you from making a larger cake? Sugar

6) If only two eggs are available when a cake is being made, fill in the chart to indicate the quantity of each of the other ingredients will be used in order to maintain the same ratio between all of the components in the cake. Cut all ingredients in half.

Using units helps scale up numbers that are harder to deal with.

$2\text{eggs} \times \frac{2\text{cups water}}{4\text{eggs}} = 1\text{cup H}_2\text{O}$

$2\text{eggs} \times \frac{8\text{oz butter}}{4\text{eggs}} = 4\text{oz butter}$

| Water | Flour | Sugar | Eggs | Butter | Chocolate |
|---|---|---|---|---|---|
| 1 cup | 2 cups | 2 cups | 2 eggs | 4 oz | 4 squares |

7) Based on information presented in the model, what is meant by the term limiting reactant (ingredient or reagent)?

A limiting reactant is a chemical that limits how many products can be made.

8) You want to make 10 dozen standard-size cookies as specified by a recipe that requires 16 oz butter, 4 eggs, 3 cups flour and 4 cups sugar. When taking inventory of your supplies you find that you have 16 oz butter, 6 eggs, 3 cups of flour, and 3 cups of sugar.
   a. Which ingredient will limit the number of cookies you can make? Sugar
   b. How many standard-size cookies can you make? 90 cookies

Need 16oz butter 4 eggs 3 cups flour 4 cups sugar
Have 16oz butter 6 eggs 3 cups flour 3 cups sugar
Not enough

$3\text{ cups sugar} \times \frac{120\text{ cookies}}{4\text{ cups sugar}} =$

90 cookies

9) You have 100 bolts, 150 nuts and 150 washers. You assemble a nut/bolt/washer set using the following recipe or equation: 2 washers + 1 bolt + 1 nut = 1 set
   a. How many sets can you make from your supply? 75 sets
   b. Which is the limiting component? Washers

$100\text{ bolts} \times \frac{1\text{ set}}{1\text{ bolt}} = 100\text{ sets}$

$150\text{ washers} \times \frac{1\text{ set}}{2\text{ washers}} = 75\text{ sets}$

$150\text{ nuts} \times \frac{1\text{ set}}{1\text{ nut}} = 150\text{ sets}$

10) Hydrogen combines with oxygen to form water according to the following reaction:
$2H_2 + O_2 \rightarrow 2H_2O$
This means that two moles of hydrogen gas combines with one mole to produce two moles of water. Therefore, you always need twice as many moles of hydrogen as you do oxygen to crate water. This chemical equation is essentially a recipe for making water.
   a. If you had 2 moles of $O_2$ how much water could you make with an unlimited amount of hydrogen? 4mol $H_2O$
   b. How much hydrogen would you need in this case? 4mol $H_2$
   c. If you had 30 moles of $H_2$ and 20 moles of $O_2$, how much water could you make? 30mol $H_2O$
   d. Which substance is the limiting reagent? $H_2$
   e. If you had 0.32moles of $H_2$, how much water could it make and how much $O_2$ would you need? 0.16mol $O_2$ 0.32mol $H_2O$

a) $2\text{mol } O_2 \times \frac{2\text{mol } H_2O}{1\text{mol } O_2} = 4\text{mol } H_2O$

b) $4\text{mol } H_2O \times \frac{2\text{mol } H_2}{2\text{mol } H_2O} = 4\text{mol } H_2$

c) $30\text{mol } H_2 \times \frac{2\text{mol } H_2O}{2\text{mol } H_2} = 30\text{mol } H_2O$

$20\text{mol } O_2 \times \frac{2\text{mol } H_2O}{1\text{mol } O_2} = 40\text{mol } H_2O$

D) since you only have enough hydrogen to make 30 moles of $H_2O$ it is the limiting reagent. There will be 10moles of $O_2$ left over

e) $.32\text{mol } H_2 \times \frac{2\text{mol } H_2O}{2\text{mol } H_2} = 0.32\text{mol } H_2O$

$0.32\text{mol } H_2O \times \frac{1\text{mol } O_2}{2\text{mol } H_2O} = 0.16\text{mol } O_2$

**Mole Ratios: Solve showing work for 13 and 14!**

11) $N_2 + 3\ H_2 \rightarrow 2\ NH_3$, write the following molar ratios:

a. $N_2 / H_2$ a) $\frac{1 mol\ N_2}{3 mol\ H_2}$
b. $N_2 / NH_3$ b) $\frac{1 mol\ N_2}{2 mol\ NH_3}$
c. $H_2 / NH_3$ c) $\frac{3 mol\ H_2}{2 mol\ NH_3}$

12) Given the following equation: $8\ H_2 + S_8 \rightarrow 8\ H_2S$, write the following molar ratios:

d. $H_2 / H_2S$ d) $\frac{8 mol\ H_2}{8 mol\ H_2S}$
e. $H_2 / S_8$ e) $\frac{8 mol\ H_2}{1 mol\ S_8}$
f. $H_2S / S_8$ f) $\frac{8 mol\ H_2S}{1 mol\ S_8}$

13) Answer the following questions for this equation: $2\ H_2 + O_2 \rightarrow 2\ H_2O$

g. What is the $H_2 / H_2O$ molar ratio? $\frac{2 mol\ H_2}{2 mol\ H_2O}$
h. Suppose you had 20 moles of $H_2$ on hand and plenty of $O_2$, how many moles of $H_2O$ could you make? $20 mol\ H_2 \times \frac{2 mol\ H_2O}{2 mol\ H_2} = 20 mol\ H_2O$
i. What is the $O_2 / H_2O$ molar ratio? $\frac{1 mol\ O_2}{2 mol\ H_2O}$
j. Suppose you had 20 moles of $O_2$ and enough $H_2$, how many moles of $H_2O$ could you make? $20 mol\ O_2 \times \frac{2 mol\ H_2O}{1 mol\ O_2} = 40 mol$

14) $N_2 + 3\ H_2 \rightarrow 2\ NH_3$, for the following problems

k. If you used 1 mole of $N_2$, how many moles of $NH_3$ could be produced?
l. If 10 moles of $NH_3$ were produced, how many moles of $N_2$ would be required?
m. If 3.00 moles of $H_2$ were used, how many moles of $NH_3$ would be made?
n. d) If 0.600 moles of $NH_3$ were produced, how many moles of $H_2$ are required?

**Mole Ratios and Balancing. Balance each equation and solve showing work!**

$\_1\_ C_3H_8 + \_5\_ O_2 \rightarrow \_4\_ H_2O + \_3\_ CO_2$

15) How many moles of water will be produced if 1.2 mol of oxygen reacts with excess $C_3H_8$?

$1.2\,mol\,O_2 \times \frac{4\,mol\,H_2O}{5\,mol\,O_2} = 0.96\,mol\,H_2O$

$\_2\_ K + \_1\_ HgCl_2 \rightarrow \_1\_ Hg + \_2\_ KCl$

16) How many moles of potassium are needed to react with .633 moles of $HgCl_2$?

$.633\,mol\,HgCl_2 \times \frac{2\,mol\,K}{1\,mol\,HgCl_2} = 1.27\,mol\,K$

$\_3\_ Hf + \_2\_ N_2 \rightarrow \_1\_ Hf_3N_4$

17) How many moles of hafnium nitride are produced when 2.00 moles of nitrogen reacts with excess hafnium?

$2\,mol\,N_2 \times \frac{1\,mol\,Hf_3N_4}{2\,mol\,N_2} = 1\,mol\,Hf_3N_4$

$\_1\_ Pb(NO_3)_4 + \_4\_ NaI \rightarrow \_1\_ PbI_4 + \_4\_ NaNO_3$

18) How many moles of $PbI_4$ are produced when 11.7 moles of sodium nitrate are produced?

~~4 mole~~ $11.7\,moles\,NaNO_3 \times \frac{1\,mol\,PbI_4}{4\,mol\,NaNO_3} = 2.93\,mol\,PbI_4$

$\_1\_ Cl_2 + \_2\_ KI \rightarrow \_2\_ KCl + \_1\_ I_2$

19) How many moles of chlorine are need to produce .4789 moles of iodine?

$.4789\,mol\,I_2 \times \frac{1\,mol\,Cl_2}{1\,mol\,I_2} = .4789\,mol\,Cl_2$

$\_1\_ Ba(CN)_2 + \_1\_ H_2SO_4 \rightarrow \_1\_ BaSO_4 + \_2\_ HCN$

20) How many moles of barium cyanide are need to produce 12.0 moles of barium sulfate?

$12\,mol\,BaSO_4 \times \frac{1\,mol\,Ba(CN)_2}{1\,mol\,BaSO_4} = 12\,mol\,Ba(CN)_2$

1) Convert g → mol
2) use mol ratios
3) Convert mol → grams

**Mole Ratios with grams (two step). Solve showing your work.**

21) If 20.0 g of zinc react with excess hydrochloric acid ( $Zn + 2HCl \rightarrow H_2 + ZnCl_2$ )

a. Which is the limiting reagent? Zinc

b. how many moles of zinc chloride are produced? $20g\ Zn \times \frac{1mol\ Zn}{65.4g_{Zn}} = 0.306\ mol\ Zn$ (b)

c. how many grams of zinc chloride are produced?

(c) $.306mol\ ZnCl_2 \times \frac{136.3\ g\ ZnCl_2}{1mol\ ZnCl_2} = 41.7g\ ZnCl_2$ $0.306mol\ Zn \times \frac{1mol\ ZnCl_2}{1mol\ Zn} = 0.306mol\ ZnCl_2$

22) How many grams of chlorine gas must be reacted with excess sodium iodide if 10.0 g of sodium chloride is produced? $Cl_2 + 2NaI \rightarrow 2NaCl + I_2$

(1) $10g\ NaCl \times \frac{1mol\ NaCl}{58.45g\ NaCl} = 0.171mol\ NaCl$ (2) $0.171mol\ NaCl \times \frac{1mol\ Cl_2}{2mol\ NaCl} = 0.0855mol\ Cl_2$ $= 0.0855g\ Cl_2$

(3) $0.0855mol\ Cl_2 \times \frac{70.9g\ Cl_2}{1mol\ Cl_2} = 6.06g\ Cl_2$ ← Final Answer

23) How many grams of copper are required to replace 4.00 g of silver nitrate which is dissolved in water? $Cu + 2AgNO_3 \rightarrow 2Ag + Cu(NO_3)_2$

$4g\ AgNO_3 \times \frac{1mol\ AgNO_3}{169.9g\ AgNO_3} = 0.0235\ mol\ AgNO_3 \times \frac{1mol\ Cu}{2mol\ AgNO_3} = 0.0118\ mol\ Cu$

$0.0118\ mol\ Cu \times \frac{63.5g}{1mol\ Cu} = 0.747g\ Cu$ ← Final Answer

24) If excess sulfuric acid reacts with 30.0 g of sodium ~~chloride, how many grams of~~ hydrochloric acid are produced? $H_2SO_4 + 2NaCl \rightarrow Na_2SO_4 + 2HCl$

$30g\ NaCl \frac{1mol\ NaCl}{58.45g\ NaCl} = 0.513mol\ NaCl \times \frac{2mol\ HCl}{2mol\ NaCl} \rightarrow 0.513mol\ HCl \times \frac{36.45g\ HCl}{1mol\ HCl} = 18.7g\ HCl$

25) How many **moles** of hydrogen can be produced from 8.40 g of aluminum and excess sodium hydroxide? How many **grams**? $2Al + 6NaOH \rightarrow 2Na_3AlO_3 + 3H_2$

$8.40g\ Al \times \frac{1mol\ Al}{27g} = .311\ Mol\ Al \times \frac{3mol\ H_2}{2mol\ Al} = 0.467mol\ H_2$

$0.467mol\ H_2 \times \frac{2g\ H_2}{1mol\ H_2} = 0.933g\ H_2$

Need to write Balanced Equations first

↑ Come up with a double displacement reaction and solve it. It is really only soluble with column 1A elements

26) How many **moles** of calcium chloride would be necessary to prepare 94.0 g of calcium phosphate? Write a balance equation and solve.

$3\,CaCl_{2(aq)} + 2Na_3PO_{4(aq)} \rightarrow Ca_3(PO_4)_{2(s)} + 6NaCl$

$94g\,Ca_3(PO_4)_2 \times \frac{1mol}{310.2g} = 0.303mol\,Ca_3(PO_4)_2 \times \frac{3mol\,CaCl_2}{1mol\,Ca_3(PO_4)_2} = 0.909mol\,CaCl_2$

27) Calculate the number of grams of oxygen that could be produced by heating 9.70 g of potassium chlorate (decomposition)? $2KClO_3 \rightarrow 2KCl + 3O_2$

$2\,KClO_{3(s)} \rightarrow 2KCl_{(s)} + 3O_{2(g)}$

$9.70g\,KClO_3 \times \frac{1mol\,KClO_3}{122.55g\,KClO_3} = 0.0792mol\,KClO_3 \times \frac{3mol\,O_2}{2mol\,KClO_3} = 0.119mol\,O_2$

$0.119mol\,O_2 \times \frac{32g\,O_2}{1mol\,O_2} = 3.80g\,O_2$

28) An experimenter recovers 7.58 grams of sodium sulfate from the neutralization of sodium hydroxide by sulfuric acid. How many grams of sodium hydroxide reacted?

$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$ (acid base neutralization yields salt + water)

$7.58g\,Na_2SO_4 \times \frac{1mol\,Na_2SO_4}{142.04g\,Na_2SO_4} = 0.0533mol\,Na_2SO_4 \times \frac{2mol\,NaOH}{1mol\,Na_2SO_4} = 0.107mol\,NaOH \times \frac{40g\,NaOH}{1mol\,NaOH} = 4.27g\,NaOH$

29) Propane is combined with oxygen to give carbon dioxide and water. If 1.75 moles of propane are combined with 1.75 moles of oxygen, how many moles of water are formed? How many moles of which reactant are left over? Oxygen limits reaction

$1\,C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

$1.75mol\,O_2 \times \frac{4mol\,H_2O}{5mol\,O_2} = 1.4mol\,H_2O$

$1.75mol\,O_2 \times \frac{1mol\,C_3H_8}{5mol\,O_2} = 0.35mol\,C_3H_8\ Needed$

$1.75mol\,C_3H_8 - 0.35mol = 1.4mol\,C_3H_8\ remain$

30) How many grams of oxygen are required to burn 419g of propane ($C_3H_8$)?

$1C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

$419g\,C_3H_8 \times \frac{1mol\,C_3H_8}{44g\,C_3H_8} = 9.52mol\,C_3H_8 \times \frac{5mol\,O_2}{1mol\,C_3H_8} = 47.6mol\,O_2$

$47.6mol\,O_2 \times \frac{32g\,O_2}{1mol\,O_2} = 1523.6g\,O_2$ or $1.52kg\,O_2$

**Theoretical and Percent Yield: (% yield = (theoretical / actual) * 100)**

31) Given the following reaction: $2\ Al + 3\ Br_2 \rightarrow 2\ AlBr_3$

If 30.2 grams of aluminum are mixed with 30.2 grams of bromine,

a) Which chemical is the limiting reagent? Bromine

b) What is the theoretical yield of aluminum bromide? 33.6 g

c) If the actual yield of aluminum bromide was 33.6 grams, what was the percent yield? ≈ 100%

(a)

$30.2\ g\ Al \times \frac{1\ mol\ Al}{27\ g\ Al} = 1.12\ mol\ Al$

$30.2\ g\ Br_2 \times \frac{1\ mol\ Br_2}{159.8\ g\ Br_2} = 0.189\ mol\ Br_2$

Need 3 mol of $Br_2$ to 2 mol Al so it clearly limits the reaction

(b) $.189\ mol\ Br_2 \times \frac{2\ mol\ AlBr_3}{3\ mol\ Br_2} = 0.126\ mol\ AlBr_3$

$.126\ mol\ AlBr_3 \times \frac{266.7\ g}{1\ mol\ AlBr_3} = 33.6\ g\ AlBr_3$

(c) $\frac{33.6\ g\ AlBr_3}{33.6\ g\ AlBr_3} \times 100 = 100\%$ if you don't round you will get a number slightly over 100%.

32) Given the following reaction: $P_4 + 6\ F_2 \rightarrow 4\ PF_3$

If 40.2 grams of phosphorous are mixed with 2.85 moles of fluorine,

a) Which chemical is the limiting reagent? $P_4$

b) What is the theoretical yield of phosphorous fluoride? 114 g $PF_3$

c) If the percent yield was 89.2%, what was the actual yield? 127.8 g $PF_3$

(a)

$40.2\ g\ P_4 \times \frac{1\ mol\ P_4}{123.9\ g\ P_4} = .324\ mol\ P_4$

$2.85\ mol\ F_2 \times \frac{1\ mol\ P_4}{6\ mol\ F_2} = .475\ mol\ P_4$ Not enough $P_4$

(b) $.324\ mol\ P_4 \times \frac{4\ mol\ PF_3}{1\ mol\ P_4} = 1.296\ mol\ PF_3 \times \frac{87.97\ g\ PF_3}{1\ mol\ PF_3} = 114\ g\ PF_3$

c. $89.2\% = \frac{Actual}{theoretical} \times 100$ so $.892 = \frac{Actual}{114}$

$.892 = \frac{114}{Actual}$

127.8 g

33) A mixture of tetraphosphorous trisulfide and powdered glass is in the tip of strike-anywhere matches. If 34.0 grams of phosphorous is mixed with 29.0 grams of sulfur, how many grams of the compound can be formed? How much of which element will be left over? This compound is made using the following reaction:

$8P_4 + 3S_8 \rightarrow 8\ P_4S_3$

$34\ g\ P_4 \times \frac{1\ mol\ P_4}{123.9\ g\ P_4} = .274\ mol\ P_4 \times \frac{3\ mol\ S_8}{8\ mol\ P_4} = 0.103\ mol\ S_8$ needed

$29\ g\ S_8 \times \frac{1\ mol\ S_8}{256.5\ g\ S_8} = .113\ mol\ S_8 \times \frac{8\ mol\ P_4}{3\ mol\ S_8} = .301\ mol\ P_4$ needed

~~.103 mol~~ $.274\ mol\ P_4 \times \frac{8\ mol\ P_4S_3}{8\ mol\ P_4} = 0.274\ mol\ P_4S_3 \times \frac{220.1\ g\ P_4S_3}{1\ mol\ P_4S_3}$

60.3 g $P_4S_3$

So there isn't enough $P_4$ meaning it will be used up completely and limits the reaction

$.113\ mol\ S_8 - 0.103\ mol\ S_8 =$ 0.01 mol $S_8$ remaining