Introduction to Stoichiometry

Name: **KEY**

General Chemistry

Date:____________________ Hour_______

Chemistry is the study of matter and the changes that matter undergoes. In the last unit we studied chemical reactions and you were able to predict the products and write balanced chemical equations for a variety of chemical changes. In this unit we will use balanced chemical equations and dimensional analysis (unit conversions) to calculate the amount of a product produced in a chemical reaction. The calculation of chemical quantities is referred to as **stoichiometry**.

Case 1: The woodworker's shop.

A woodworker is tasked with assembling kitchen tables according to the following equation:

1 tabletop (TT) + 4 legs (L) → 1 kitchen table (KT) or

TT + 4L → KT

In this "reaction" the tabletop and legs serve as the "reactants" and the kitchen table serves the "product".

1. Consider each situation below as it relates to the woodworker's "reaction".

	TT Consumed	L Consumed	KT Produced	Ratio TT:L:KT (reduced)
If the woodworker performed this reaction once, how many of each substance would be consumed or produced?	**1**	**4**	**1**	**1:4:1**
If this reaction occurred one hundred times, how many of each substance would be consumed or produced?	**100**	**400**	**100**	**1:4:1**
If the reaction occurred 734 times, how many of each substance would be consumed or produced?	**734**	**2936**	**734**	**1:4:1**
If the reaction occurred 6.02×10^{23} times, how many of each substance would be consumed or produced?	**6.02×10^{23}**	**2.41×10^{24}**	**6.02×10^{23}**	**1:4:1**
If the reaction occurred 400 ***dozen*** times, how many ***dozen*** of each substance would be consumed or produced?	**400 dozen**	**1600 dozen**	**400 dozen**	**1:4:1**
If the reaction occurred 2 ***moles*** times, how many ***moles*** of each substance would be consumed or produced?	**2 moles**	**8 moles**	**2 moles**	**1:4:1**

2. Several ratios are developed to describe the woodworker's reaction. Put a box around the ratio(s) that are correct.

$\frac{25\ TT}{25\ KT}$ $\frac{8\ dozen\ KT}{32\ dozen\ L}$ $\frac{4\ moles\ L}{4\ moles\ KT}$ $\frac{29\ dozen\ TT}{116\ dozen\ L}$ $\frac{1 \times 10^6\ KT}{1 \times 10^6\ TT}$

CORRECT **CORRECT** **INCORRECT** **CORRECT** **CORRECT**

16 mole L

Suppose the woodworker had 20 tabletops and 20 legs. How many kitchen tables could the woodworker make? Would there be any material left over or "in excess"? If so, how much?

They could make 5 kitchen tables with 15 tabletops left over "in excess".

4. The woodworker receives a shipment of tables and legs from his supplier. This shipment contains 3,000 ***grams*** of tabletops and 29,000 ***grams*** of legs. Can you determine how many kitchen tables he can produce? If not, what other information would you need?

No. Need to know the mass of 1 table top and 1 leg.

Case 2: The chemist's laboratory.

Ammonia (NH_3) is colorless gas with a characteristic pungent smell. Ammonia is used in many cleaning products and as a building block for several pharmaceuticals. Ammonia can be produced as shown below.

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

5. Complete the table below.

	N_2 Consumed	H_2 Consumed	NH_3 Produced	Ratio N_2:H_2:NH_3 (reduced)
How many ***moles*** of each substance would be consumed or produced in the previous situation?	**1**	**3**	**2**	**1:3:2**
If this reaction occurred 250 times, how many molecules would be consumed or produced?	**250**	**750**	**500**	**1:3:2**
If this reaction occurred 6.02×10^{23} times, how many moles would be consumed or produced?	**6.02×10^{23}**	**1.81×10^{24}**	**1.20×10^{24}**	**1:3:2**

6. Several ratios are developed to describe the synthesis of ammonia. Put a box around the ratio(s) that are correct.

$\frac{15\ N_2\ molecules}{30\ NH_3\ molecules}$ $\frac{2\ dozen\ H_2\ molecules}{1\ dozen\ N_2\ molecules}$ $\frac{12\ moles\ NH_3\ molecules}{18\ moles\ H_2\ molecules}$ $\frac{9 \times 10^{40}\ H_2\ molecules}{3 \times 10^{40}\ N_2\ molecules}$

CORRECT **INCORRECT** **CORRECT** **CORRECT**

3 dozen molecules H_2

7. The chemist is tasked with producing 28 moles of NH_3. The chemist uses the balanced equation on Page 2 to calculate the moles of H_2 needed to react with all of the NH_3:

$$28\ moles\ NH_3\left(\frac{3\ moles\ H_2}{2\ moles\ NH_3}\right) = \ 42\ moles\ H_2$$

Use the spaces below to calculate the moles of N_2 that the chemist needs.

$$28\ moles\ NH_3\left(\frac{1\ mole\ N_2}{2\ moles\ NH_3}\right) = \ 14\ moles\ N_2$$

8. One way that the chemist organizes a stoichiometry problem is through a BCA table. Before the reaction, the chemist is given 3 moles of N_2 molecules and 9 moles of H_2 molecules. The BCA table that corresponds to this situation is:

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

	N_2	H_2	NH_3
B (**B**efore the chemical reaction)	3 moles	9 moles	0 moles
C (**C**hemistry!)	-3 moles	-9 moles	+6 moles
A (**A**fter the chemical reaction)	0 moles	0 moles	6 moles

a. Why is there a negative sign in the "C" line for N_2 and H_2?
A negative sign is used when a reactant is consumed.

b. A positive sign in the "C" line for NH_3?
A positive sign is used when a product is produced.

c. Why did the NH_3 increase by 6 moles while the N_2 only decreased by 3 moles?
The ratio of the reaction states that for every 2 moles of NH_3 produced 1 mole of N_2 is consumed. Thus, when N_2 decreases by 3 moles NH_3 increases by 6 moles.

d. Why did the H_2 decrease by 9 moles while the N_2 only decreased by 3 moles?

The ratio of the reaction states that for every 1 mole of N_2 consumed 3 mole of H_2 is consumed. Thus, when H_2 decreases by 9 moles H_2 increases by 3 moles.

9. In a different scenario, the chemist is asked to produce aluminum oxide according to the balanced equation below. Before the reaction, the chemist is given 20 moles of Al and 15 moles of O_2. VIDEO WALKTHROUGH

$$4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$$

The BCA table that corresponds to this situation is:

	Al	O_2	Al_2O_3
B (**B**efore the chemical reaction)	20 moles	15 moles	0 moles
C (**C**hemistry!)	-20 moles	**-15 moles**	**+10 moles**
A (**A**fter the chemical reaction)	0 moles	**0 moles**	**10 moles**

a. Calculate the moles of O_2 that will be consumed in this reaction. Place this answer in the "C" line for O_2.

$$|\frac{20\ moles\ Al}{}||\frac{3\ moles\ O_2}{4\ moles\ Al}| = 15\ moles\ O_2$$

b. Calculate the moles of Al_2O_3 that will be produced in this reaction. Place this answer in the "C" line for Al_2O_3.

$$|\frac{20\ moles\ Al}{}||\frac{2\ moles\ Al_2O_3}{4\ moles\ Al}| = 10\ moles\ Al_2O_3$$

c. Calculate the moles of O_2 and Al_2O_3 that will remain after the reaction. Place these answers in the appropriate "A" lines.

Oftentimes, one of the reactants is "in excess". A reactant that is in excess is not consumed completely and remains unreacted after the reaction has completed. For example, if a chemist were given 20 moles of Al and 1,000 moles of O_2 the BCA table would be:

	Al	O_2	Al_2O_3
B (**B**efore the chemical reaction)	20 moles	1,000 moles or "EXCESS"	0 moles
C (**C**hemistry!)	-20 moles	-15 moles	+10 moles
A (**A**fter the chemical reaction)	0 moles	985 moles or "EXCESS – 15 moles"	10 moles

If the chemist wishes to produce more Al_2O_3 they would have to add more Al to react with the excess O_2. In this case the Al is called the "limiting reactant".

Let's Practice!

Read the directions for each of the following questions. Be sure to show your work anytime you are doing dimensional analysis! Also, don't forget to round your answers according to the rules of significant figures!

$$2H_2S(g) + 3O_2(g) \rightarrow 2SO_2(g) + 2H_2O(g)$$

10. Consider the mole ratios below. Circle the ratios that are correct. **Correct the ratios** that are not correct.
[VIDEO WALKTHROUGH]

$\frac{2 \text{ moles } H_2S}{3 \text{ moles } O_2}$	$\frac{3 \text{ moles } O_2}{2 \text{ moles } SO_2}$	$\frac{2 \text{ moles } H_2O}{2 \text{ moles } O_2}$	$\frac{2 \text{ moles } H_2S}{2 \text{ moles } O_2}$	$\frac{2 \text{ moles } SO_2}{1 \text{ moles } O_2}$
Correct	**Correct**	**Incorrect**	**Incorrect**	**Incorrect**
		3 moles O_2	**3 moles O_2**	**3 moles O_2**

The single replacement reaction between solid copper and aqueous silver (I) nitrate is shown below.

$$Cu(s) + 2AgNO_3(aq) \rightarrow 2Ag(s) + Cu(NO_3)_2(aq)$$

11. Consider the ratios below. Circle the ratios that are correct. **Correct the ratios** that are not correct.
[VIDEO WALKTHROUGH]

$\frac{1 \text{ Cu atom}}{2 \text{ Ag atoms}}$ $\frac{1 \text{ Cu atom}}{1\ Cu(NO_3)_2 \text{ f. unit}}$ $\frac{1 \text{ mole Cu}}{2 \text{ moles Ag}}$ $\frac{1 \text{ f. unit } AgNO_3}{1 \text{ Ag atom}}$ $\frac{2 \text{ moles } AgNO_3}{1 \text{ mole } Cu(NO_3)_2}$

All are correct

12. Barium carbonate decomposes according to the balanced equation below. Calculate the moles of carbon dioxide gas and solid barium oxide produced when 2.54 moles of solid barium carbonate decomposes. Complete the BCA table below.
[VIDEO WALK THROUGH]

$$BaCO_3(s) \rightarrow BaO(s) + CO_2(g)$$

	$BaCO_3$	BaO	CO_2
B (**B**efore the chemical reaction)	**2.54 moles**	**0.0 moles**	**0.0 moles**
C (**C**hemistry!)	**-2.54 moles**	**+2.54 moles**	**+2.54 moles**
A (**A**fter the chemical reaction)	**0.0 moles**	**2.54 moles**	**2.54 moles**

Note that when 2.54 moles of $BaCO_3$ decomposes 2.54 moles of BaO and 2.54 moles of CO_2 are produced as the mole ratios are 1:1:1. For example,

$$\left|\frac{2.54 \text{ moles } BaCO_3}{}\right|\left|\frac{1 \text{ mole BaO}}{1 \text{ mole } BaCO_3}\right| = 2.54 \text{ moles } BaCO_3$$

13. Calculate the moles of hydrogen gas and the moles of aluminum nitrate produced when 15.45 moles of solid aluminum reacts completely with *excess* aqueous nitric acid.
VIDEO WALK THROUGH

$$2Al(s) + 6HNO_3(aq) \rightarrow 2Al(NO_3)_3(aq) + 3H_2(g)$$

	Al	HNO_3	$Al(NO_3)_3$	H_2
B (**B**efore the chemical reaction)	**15.45 mole**	EXCESS	**0.0 mole**	**0.0 mole**
C (**C**hemistry!)	**-15.45 mole**	**-46.35 mole**	**+15.45 mole**	**+23.18 mole**
A (**A**fter the chemical reaction)	**0.0 mole**	**EXCESS**	**15.45 mole**	**23.18 mole**

$$\frac{15.45 \text{ moles Al}}{} \left| \frac{6 \text{ moles } HNO_3}{2 \text{ moles Al}} \right| = 46.35 \text{ moles } HNO_3$$

$$\frac{15.45 \text{ mole Al}}{} \left| \frac{2 \text{ mole } Al(NO_3)_3}{2 \text{ mole Al}} \right| = 15.45 \text{ mole } Al(NO_3)_3$$

$$\frac{15.45 \text{ mole Al}}{} \left| \frac{3 \text{ mole } H_2}{2 \text{ mole Al}} \right| = 23.18 \text{ mole } H_2$$

14. Dicarbon hexahydride gas incompletely combusts to produce carbon monoxide gas and water gas. 6.77 moles of dicarbon hexahydride react with *excess* oxygen gas. Calculate the moles of carbon monoxide gas and the moles of water gas that are produced.
VIDEO WALK THROUGH

$$2C_2H_6(g) + 5O_2(g) \rightarrow 4CO(g) + 6H_2O(g)$$

	C_2H_6	O_2	CO	H_2O
B (**B**efore the chemical reaction)	**6.77 mole**	EXCESS	**0.0 mole**	**0.0 mole**
C (**C**hemistry!)	**-6.77 mole**	**-16.9 mole**	**+13.5 mole**	**+20.3 mole**
A (**A**fter the chemical reaction)	**0.0 mole**	**EXCESS**	**13.5 mole**	**20.3 mole**

$$\frac{6.77 \text{ mole } C_2H_6}{} \left| \frac{5 \text{ mole } O_2}{2 \text{ mole } C_2H_6} \right| = 16.9 \text{ mole } O_2$$

$$\frac{6.77 \text{ mole } C_2H_6}{} \left| \frac{4 \text{ mole CO}}{2 \text{ mole } C_2H_6} \right| = 13.5 \text{ mole CO}$$

$$\frac{6.77 \text{ mole } C_2H_6}{} \left| \frac{6 \text{ mole } H_2O}{2 \text{ mole } C_2H_6} \right| = 20.3 \text{ mole } H_2O$$

15. Solid aluminum carbonate is decomposed and 7.58 moles of solid aluminum oxide are produced. Calculate the moles of carbon dioxide gas that were also produced.
VIDEO WALK THROUGH

$$Al_2(CO_3)_3(s) \rightarrow Al_2O_3(s) + 3CO_2(g)$$

$$\frac{7.58 \text{ mole } Al_2O_3}{} \left| \frac{3 \text{ mole } CO_2}{1 \text{ mole } Al_2O_3} \right| = 22.7 \text{ mole } CO_2$$