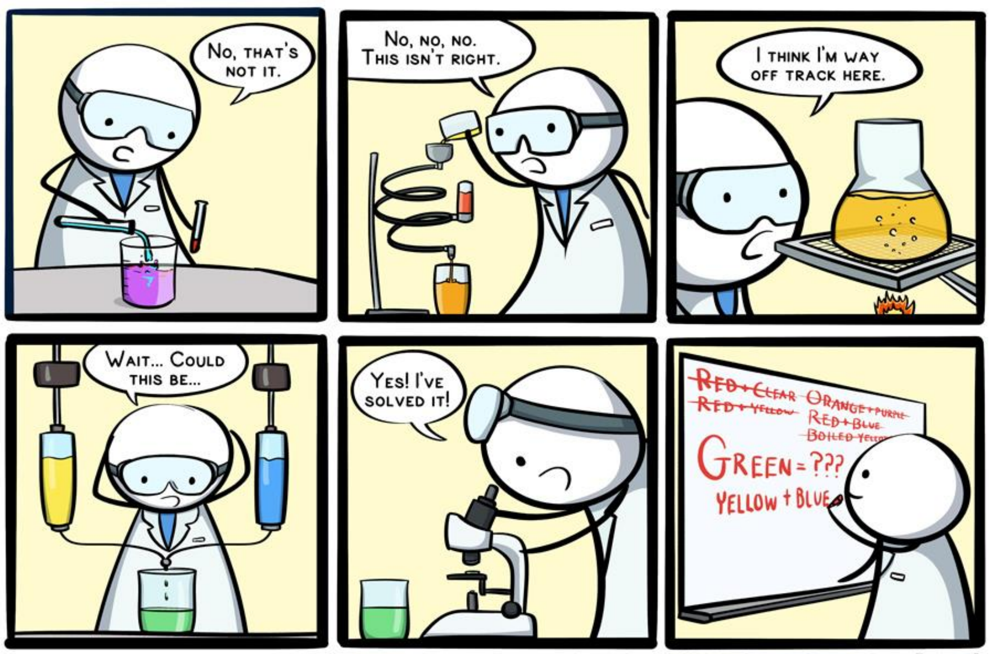
CHEMISTRY 30S

The Alchemist's Cookbook

UNIT 2 – CHEMICAL REACTIONS



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NAME:______________________________________

It is expected that the activities in this book are completed as they are performed in class. This book will be collected at the end of the unit and a mark will be given.

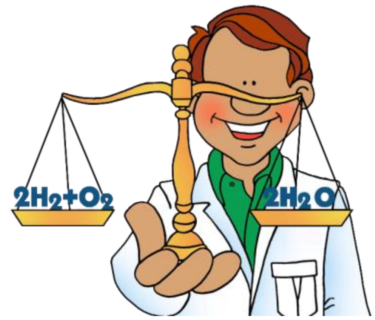
LET'S GET STARTED!

By the end of this unit, should be able to:

- ✓ Write balanced formula equations for a variety of types of chemical reactions, including predicting the products.
- ✓ Interpret a balanced equation in terms of mole/volume of gas ratios.
- ✓ Solve stoichiometric problems involving moles and mass, given the reactants and products in a balanced chemical reaction.
- ✓ Use the molar volume of a gas as a conversion factor in stoichiometric problems
- ✓ Determine % yield of a chemical reaction from the actual and theoretical yield.
- ✓ Identify the limiting reactant and calculate the mass of a product, given the reaction equation and reactant data.
- ✓ Perform an experiment to determine the percent yield of a chemical reaction

ACTIVITY #1 – DON'T LOSE YOUR BALANCE!

5-steps to success: USE PENCIL WHEN BALANCING CHEMICAL EQUATIONS



1. **Underline** the name of each substance in the chemical equation
2. Draw **ionic pictures** for each substance and write the proper **formula** under each substance's name.
3. Add symbols + and → where appropriate to link the substances involved in the reaction.
4. Place **underlines** in front of all chemical formulas to act as placeholders for coefficients (e.g. ___ KCl)
5. Balance the equation using **coefficients** so that all atoms are accounted for.

TRY SOME:

1. Aluminum reacts with hydrogen chloride to produce hydrogen gas and aluminum chloride

Word Equation: Pictures:			

Formula Equation:

2. Sodium carbonate reacts with zinc chloride to form sodium chloride and zinc carbonate. *Note: there are four separate salts here—you should draw a picture for* EACH *of the four salts!*

___ Na_2CO_3 (aq) + ___ ____________ → ___ __________ + ___ ____________

3. Dissolved **silver nitrate** reacts with dissolved **magnesium chromate** to form **silver chromate** and **magnesium nitrate**.

___ $AgNO_3$ **(aq)** + ___ ____________ → ___ __________ + ___ ____________

4. Aluminum bromide reacts with potassium hydroxide to form aluminum hydroxide and potassium bromide.

5. Iron(II) chloride reacts with sodium phosphate to form sodium chloride and iron(II) phosphate.

ACTIVITY #2 – CHEMICAL EQUATION PRACTICE

For each of the following, balance the equation by putting coefficients in front of each reactant and/or product, and circle the correct reaction type.

Types	Pattern	Example
Double **R**eplacement	$XY + AB \rightarrow XB + AY$	$2AgNO_3 + K_2CrO_4 \rightarrow Ag_2CrO_4 + 2KNO_3$
Single **R**eplacement	$XY + A \rightarrow AY + X$	$Zn + 2HCl \rightarrow H_2 + ZnCl_2$
Synthesis	$X + Y \rightarrow XY$	$2H_2 + O_2 \rightarrow 2H_2O$
Decomposition	$AB \rightarrow A + B$	$H_2CO_3 \rightarrow H_2O + CO_2$
Combustion	$C_xH_y + O_2 \rightarrow CO_2 + H_2O$	$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

	Chemical Equation	Type of Reaction
(a)	…Al (s) + … Br_2 (ℓ) → … $AlBr_3$ (s)	C | D | DR | SR | S
(b)	…C_3H_7OH (ℓ) + …O_2 (g) →…CO_2 (g) + … H_2O (ℓ)	C | D | DR | SR | S
(c)	…C_3H_6O (g) + …O_2 (g) →…CO_2 (g) + … H_2O (ℓ)	C | D | DR | SR | S
(d)	…Ca (s) + …HCl (aq) → …$CaCl_2$ (aq) + …H_2 (g)	C | D | DR | SR | S
(e)	…$CaBr_2$ (aq) + …Na_2CO_3 (s) → …$CaCO_3$ (s) + …NaBr (aq)	C | D | DR | SR | S
(f)	…$(NH_4)_2CO_3$ (s) → …NH_3 (g) + …CO_2 (g) + …H_2O (ℓ)	C | D | DR | SR | S
(g)	…Cu_2O (s) → …Cu (s) + O_2 (g)	C | D | DR | SR | S

ACTIVITY #3 – BE A CHEMICAL REACTION PSYCHIC!

The accompanying YouTube video was created by a friend of mine and demonstrates 16 chemical reactions. For this activity, you'll look at the **first 13 reactions**. For each reaction, you will need to classify the reaction type (synthesis, decomposition, single replacement, double replacement, or hydrocarbon combustion), write the word equation, the balanced formula equation, and provided evidence of a chemical reaction. Be sure to listen to the narration as it provides hints as to what the products of the reaction might be!

SCAN ME

	Chemical Equation	Type of Reaction
(1)	**Yellow sulfur (octasulfur) combined with copper metal** Octasulfur + copper →	C | D | DR | SR | S
(2)	**Solutions of copper(II) nitrate and sodium phosphate are mixed** Sodium phosphate + copper(II) nitrate →	C | D | DR | SR | S
(3)	**Bromine (dissolved in water) is mixed with a solution of sodium chloride** Bromine + sodium chloride →	C | D | DR | SR | S
(4)	**Silver nitrate and sodium phosphate solutions are mixed together** Silver nitrate + sodium phosphate →	C | D | DR | SR | S

	Chemical Equation	Type of Reaction
(5)	**Magnesium metal reacts with the oxygen in the air through combustion** Magnesium + oxygen →	C | D | DR | SR | S
(6)	**A piece of copper wire is placed in a solution of silver nitrate** Copper + silver nitrate →	C | D | DR | SR | S
(7)	**Iron(III) nitrate solution is mixed with sodium hydroxide solution** Iron(III) nitrate + sodium hydroxide →	C | D | DR | SR | S
(8)	**Cyclohexane (C_6H_6) reacts with the oxygen in the air through combustion** Cyclohexane + oxygen →	C | D | DR | SR | S
(9)	**A piece of potassium metal is placed in water** Potassium + water →	C | D | DR | SR | S

	Chemical Equation	Type of Reaction
(10)	**Ammonium carbonate is heated and decomposed** Ammonium carbonate →	C | D | DR | SR | S
(11)	**Solutions of lead(II) nitrate and potassium iodide are mixed together** Lead(II) nitrate + potassium iodide →	C | D | DR | SR | S
(12)	**Candle wax ($C_{30}H_{62}$) reacts with oxygen in the air through combustion** Candle wax + oxygen →	C | D | DR | SR | S
(13)	**A piece of zinc metal is placed in a solution of sulfuric acid (hydrogen sulfate)** Zinc + hydrogen sulfate →	C | D | DR | SR | S

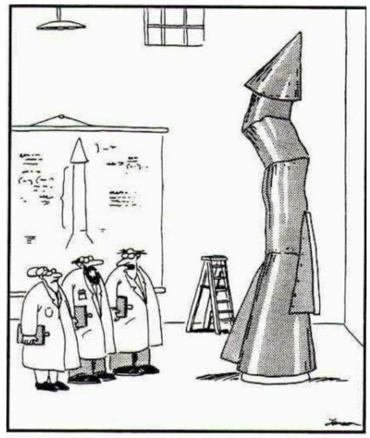
ACTIVITY #4 – STOICHIOMETRY INTRO PROBLEMS

1.	Name the following substances:			
	$KClO_3$:	KCl:	O_2:	
2.	Find the molar mass of each substance:			
	$KClO_3$:	KCl:	O_2:	
3.	Given 0.58 mol sample of O_2 (g) at STP.			
(a)	Find the mass of this sample.			
(b)	Find the volume of this sample.			
(c)	Find the number of molecules in this sample.			
4.	Identify the type of reaction and balance the equation. … $KClO_3$ (s) → … KCl (s) + … O_2 (g)			
5.	How many moles of $KClO_3$ are required to produce 0.58 mol O_2?			
	GIVEN: DESIRED:	WORK:		ANSWER:
6.	How many moles of O_2 (g) are produced with 0.88 mol KCl?			
	GIVEN: DESIRED:	WORK:		ANSWER:
7.	What is the mass of KCl produced when 55.1 g $KClO_3$ reacts?			
	GIVEN: DESIRED:	WORK:		ANSWER:
8.	What mass of $KClO_3$ is required to produced 15.6 L O_2 (g) at STP?			
	GIVEN: DESIRED:	WORK:		ANSWER:

ACTIVITY #5 – I'M A ROCKET MAN!

PART 1: PLANNING OUR FUEL MIXTURE

The first thing to determine is the appropriate ratio of hydrogen and oxygen to use in your rocket. You need an explosive mixture to launch your rocket. A mixture too rich in hydrogen will burn quietly like a Bunsen burner instead of igniting explosively. A mixture too rich in oxygen will produce suboptimal thrust. A proper stoichiometric mixture will produce maximum power for your rocket.



"It's time we face reality, my friends. ... We're not exactly rocket scientists."

The unbalanced equation for the propulsion reaction is as follows:

$$\_\_\_H_2\,(g) + \_\_\_O_2\,(g) \rightarrow \_\_\_H_2O\,(g)$$

1. Balance the propulsion equation above to determine the correct **mole ratio** of hydrogen to oxygen.

2. Use a 1-liter graduated cylinder to **accurately measure the total volume** of your bottle. Record this value below.

3. Using the mole ratio of H_2 to O_2 that you discovered from your balanced equation, determine the gas volume ratio of H_2 to O_2. Remember, 1 mole of any gas = 22.4 L of that gas at standard temperature and pressure (STP).

$$\frac{2 \text{ mol } H_2}{1 \text{ mol } O_2} = \frac{?\text{ L } H_2}{?\text{ L } O_2}$$

4. Based on this volume ratio, what fraction of your bottle or jug will need to be hydrogen gas and what fraction will need to be oxygen gas?

5. Use a graduated cylinder to accurately mark off the fraction above on your bottle. Use a Sharpie or permanent marker for this. How many litres of each gas do you need?

PART 2: PRODUCING OXYGEN GAS

OXYGEN gas can be generated from the decomposition of H_2O_2. The unbalanced equation is:

$$\_\_\_H_2O_2 \rightarrow \_\_\_H_2O + \_\_\_O_2$$

This reaction is extremely **slow** at room temperature unless a catalyst is added. You will use the salt potassium iodide (KI) as a catalyst to hasten this reaction. *Note: When running the actual reaction, a small scoop of the catalyst (about 0.7 grams) will be "packaged" in weighing paper and then added to the hydrogen peroxide solution. You will place a stopper on the reaction flask and then shake to allow the catalyst to come out of its package. This method should enable you to collect ~100% of the gases created in this reaction.*

6. Balance the equation shown above and use stoichiometry to calculate the MASS of hydrogen peroxide needed to generate the volume of O_2 you need for your rocket.

7. The hydrogen peroxide that you will use to generate oxygen gas will be provided as an **aqueous solution** of hydrogen peroxide. The solution contains **10%** hydrogen peroxide by mass (the other 90% being water). Use your number from #6 to calculate how many grams of this SOLUTION you will need to use

8. Assuming that the 10% peroxide solution has a density of **1.03 g/ml**, convert the grams you calculated in #6 into milliliters of solution.

PART 3: PRODUCING HYDROGEN GAS

Hydrogen can be generated in many ways. You will use the reaction shown here:

$$\_\_\_Ca\ (s) + \_\_\_HOH\ (aq) \rightarrow \_\_\_H_2\ (g) + \_\_\_Ca(OH)_2\ (aq)$$

9. Balance the equation shown above.

10. Use stoichiometric calculations to determine the MASS of calcium metal needed to produce the volume of hydrogen gas you need for your rocket.

ACTIVITY #6 – MORE STOICH PROBLEMS!

1.	Nitrogen gas reacts with hydrogen gas, forming ammonia gas.			
(a)	Write the balanced equation for the reaction.			
(b)	Find the molar masses of the substances in the reaction. N_2:	H_2:	NH_3:	
(c)	Find the moles of NH_3 (g) formed when 5.00 moles of H_2 (g) reacts. GIVEN: 5.0 mol H_2 DESIRED: ? mol NH_3	WORK:		ANSWER:
(d)	Find the moles of H_2 (g) required when 3.5 grams of N_2 (g) reacts. GIVEN: DESIRED:	WORK:		ANSWER:
(e)	Find the grams of H_2 (g) needed to form 21.1 grams of NH_3 (g). GIVEN: DESIRED:	WORK:		ANSWER:
(f)	Find the liters of NH_3 (g) produced at STP when 9.62 grams of N_2 (g) is used. GIVEN: DESIRED:	WORK:		ANSWER:
2.	Solid potassium chlorate decomposes to form solid potassium chloride and oxygen gas.			
(a)	Write the balanced equation for the reaction.			
(b)	Find the molar masses of the substances in the reaction. $KClO_3$:	KCl:	O_2:	
(c)	Find the mass of KCl (s) produced when 42.0 grams of $KClO_3$ (s) decomposes. GIVEN: DESIRED:	WORK:		ANSWER:
(d)	Find the volume of O_2 (g) produced at STP when 42.0 grams of $KClO_3$ (s) decomposes. GIVEN: DESIRED:	WORK:		ANSWER:

3.	Zinc metal is placed in a solution of hydrochloric acid (hydrogen chloride). A reaction occurs.
(a)	Write the balanced equation for the reaction.
(b)	Find the mass of Zn (s) required to produce 12.6 L of H_2 (g) at STP. GIVEN: WORK: ANSWER: DESIRED:
(c)	Calculate the moles of HCl (aq) required to produce 12.6 L of H_2 (g) at STP. GIVEN: WORK: ANSWER: DESIRED:
4.	A solution of lead(II) acetate reacts with a solution of hydrochloric acid (hydrogen chloride).
(a)	Write the balanced equation for the reaction.
(b)	Find the molar masses of the substances in the reaction. $Pb(C_2H_3O_2)_2$: HCl: $PbCl_2$ $HC_2H_3O_2$:
(c)	Find the mass of lead(II) acetate required to react to form 94.5 g of lead(II) chloride. GIVEN: WORK: ANSWER: DESIRED:
(d)	Calculate the molecules of acetic acid produced when 94.5 g of lead(II) chloride is formed. GIVEN: WORK: ANSWER: DESIRED:

ACTIVITY #7 – HI YO SILVER AWAY!

When working with chemical reactions, it is important not only to be able to predict the identity of the chemicals produced, but also to be able to predict the quantities of those chemicals. Fo the latter, we use stoichiometry, the act of performing calculations of chemical reactions. Every year throughout the world, the production of major chemical is measured in the millions of tons, so mistakes involving calculations of such large amounts can be very costly. Even small calculation errors involving rare chemicals can cost a company a lot of money! In this experiment, you will react an excess amount of copper metal with a solution of silver nitrate. You will predict the mass of product that should be produced using stoichiometry. You will then collect the product using a technique called filtration and compare the mass of your product to the predicted mass.

Pre-Lab:

1. What type of reaction are we going to perform?

2. Write the word equation for this reaction?

3. Write the balanced formula equation for this reaction.

4. If 5.0 grams of copper was used up in this reaction, what mass of silver would be produced?

Procedure:

Day 1:

1. Obtain a clean, dry test tube and put your name on it with a piece of masking tape.
2. Obtain a piece of copper wire. Rub the wire with a piece of steel wool to remove the oxide coating and expose the copper atoms.
3. Wrap the wire around your pencil to form a coil. Stretch the coil so that it is about the length of your test tube.
4. Measure the mass of the coil and record it in the data table.
5. Fashion a small hook on one end of the coil. Place the coil inside your test tube and hook the end on the edge of the test tube.

6. Fill your test tube about ¾ full of silver nitrate solution. If you get any solution on your hands, wash them immediately. Record your initial observations below.

   Observations:

7. Place a small piece of cling film over the top of your tube to prevent evaporation. Place your test tube in the rack provided and let it sit undisturbed until next class.

<u>Day 2:</u>

8. Obtain your test tube from the test tube rack. Be careful not to disturb it too much. Make some more observations in the space below.

   Observations:

9. Shake the crystals off the coil and allow them to settle to the bottom of the tube.
10. Lift the coil out of the solution and use your wash bottle to rinse any remaining crystals off into the tube. When you are satisfied you have removed as many crystals as you can, place the coil on a piece of paper towel and allow it to dry.
11. Once the crystals have all settled, decant the liquid layer of your test tube into a beaker. Stop decanting before any solid crystals escape the tube.
12. Wash your crystals by filling your test tube ¾ full of distilled water. Allow the crystals to settle again for a couple of minutes.
13. Decant the liquid layer a second time into the beaker.
14. Obtain a piece of filter paper and fold it as instructed. Measure the mass of the filter paper and record it in the data table.
15. Assemble the filtration apparatus. Filter all of the crystals from the test tube into the filter paper. Use the wash bottle to rinse all the crystals from the test tube onto the filter paper.
16. Wash the crystals one more time by spraying them with the wash bottle.
17. Once all of the liquid has left the filter paper, remove the paper and place it in a piece of paper towel. Put your name on the paper towel and put it aside to dry until next class.
18. Weigh your dried copper coil and record its mass in the data table.

Day 3:

19. Obtain your filter paper and weigh it. Record its mass in the data table.
20. Open the filter paper and observe the crystals. Record your observations below.

Observations:

RESULTS

Copper Data	
Mass of Copper Wire Before (g)	
Mass of Copper Wire After (g)	

Silver Data	
Mass of Filter Paper (g)	
Mass of Filter Paper and Silver Crystals (g)	

ANALYSIS OF RESULTS

1. Write the balanced chemical equation for the chemical reaction that occurred in your test tube.
2. Calculate the mass of copper that reacted.
3. Calculate the theoretical mass of silver crystals that should have been produced.
4. Calculate the actual mass of silver crystals recovered from the reaction.
5. Determine the percent yield of your reaction.

6. Determine the ratio of $\frac{actual\ moles\ of\ silver\ produced}{actual\ moles\ of\ copper\ reacted}$. Communicate the answer as a fraction. What should this ratio be theoretically?

7. List as many errors that occurred in the lab that WERE BEYOND YOUR CONTROL but would have influenced your results. Pay attention to whether the error would have resulted in you obtaining >100% yield or <100% yield.

POST-LAB QUESTIONS

1. Diborane, B_2H_6, is a valuable compound in the synthesis of new organic compounds. One of several ways this born compound can be made is by the reaction

$$2\ NaBH_4(s) + I_2(s) \rightarrow B_2H_6(g) + 2\ NaI(s) + H_2(g)$$

[Molar masses: 37.84 253.8 27.67 149.9 2.02]

Suppose you use 1.203 g of $NaBH_4$ with an excess of iodine and obtain 0.295 g of B_2H_6. What is the percent yield of B_2H_6?

2. Disulfur dichloride, which has a revolting smell, can be prepared by directly combining S_8 and Cl_2, but it can also be made by the following reaction:

$$3\ SCl_2(l) + 4\ NaF(s) \rightarrow SF_4(g) + S_2Cl_2(l) + 4\ NaCl(s)$$

[Molar masses: 103.0 41.99 108.1 135.0 58.46]

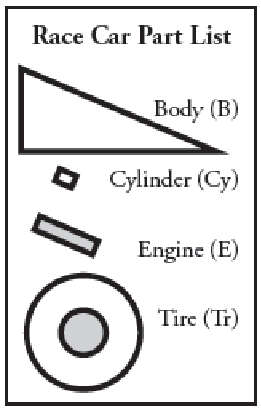
Assume you begin with 5.23 g of SCl_2 and excess NaF. What is the theoretical yield of S_2Cl_2? If only 1.19 g of S_2Cl_2 is obtained, what is the percent yield of the compound?

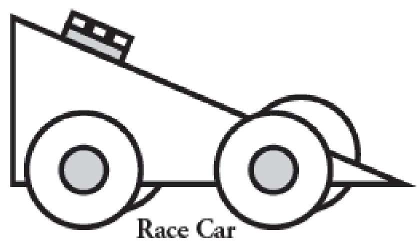
ACTIVITY #8 – INTRODUCTION TO LIMITING REACTANTS

Why?

If a factory runs out of tires while manufacturing cars, production stops. No more cars can be fully built without ordering more tires. A similar thing happens in a chemical reaction. If there are fixed amounts of reactants to work with in a chemical reaction, one of the reactants may be used up first. This prevents the production of more products. In this activity, you will look at several situations where the process or reaction is stopped because one of the required components has been used up.

Model 1 – Assembling a Race Car





1. How many of each part are needed to construct 1 complete race car?

   Body (B) Cylinder (Cy) Engine (E) Tire (Tr)

2. How many of each part would be needed to construct 3 complete race cars? Show your work.

   Body (B) Cylinder (Cy) Engine (E) Tire (Tr)

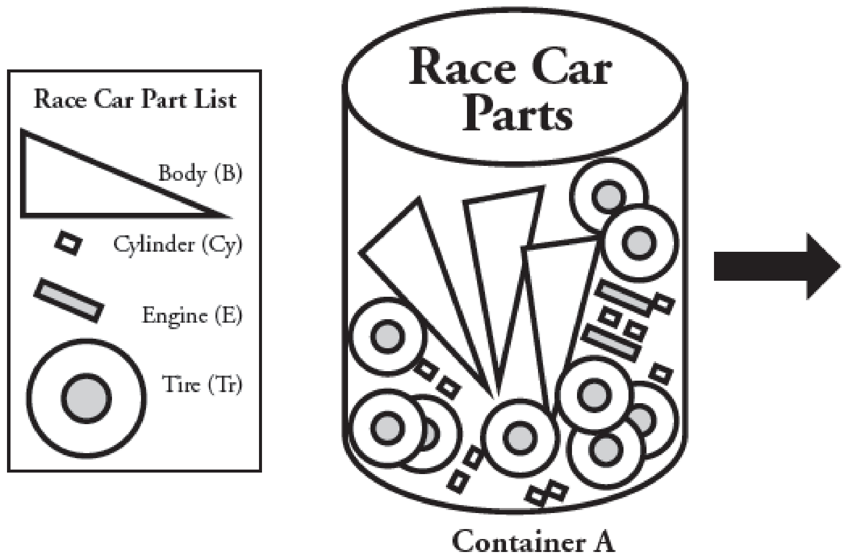
3. Assuming that you have 15 cylinders and an unlimited supply of the remaining parts:

   a. How many complete race cars can you make? Show your work.

   b. How many of each remaining part would be needed to make this number of cars? Show your work.

STOP

Model 2 – Manufacturing Race Cars



4. Count the number of each Race Car Part present in Container A of Model 2.

   Body (B) Cylinder (Cy) Engine (E) Tire (Tr)

5. Complete Model 2 by drawing the maximum number of cars that can be made from the parts in Container A. Show any excess parts remaining also.

6. A student says "I can see that we have three car bodies in Container A, so we should be able to build three complete race cars." Explain why this student is incorrect in this case.

7. Suppose you have a very large number (dozens or hundreds) of tires and bodies, but you only have 5 engines and 12 cylinders.

   a. How many complete cars can you build? Show your work.

   b. Which part (engines or cylinders) limits the number of cars that you can make?

8. Fill in the table below with the maximum number of complete race cars that can be built from each container of parts (A–E), and indicate which part limits the number of cars that can be built. Divide the work evenly among group members. Space is provided below the table for each group member to show their work. Have each group member describe to the group how they determined the maximum number of complete cars for their container. Container A from Model 2 is already completed as an example.

1 B + 3 Cy + 4 Tr + 1 E = 1 car

Container	Bodies	Cylinders	Tires	Engines	Max. Number of Completed Cars	Limiting Part
A	3	10	9	2	2	Engines
B	50	12	50	5		
C	16	16	16	16		
D	4	9	16	6		
E	20	36	40	24		

9. The Zippy Race Car Company builds toy race cars by the thousands. They do not count individual car parts. Instead they measure their parts in "oodles" (a large number of things).

   a. Assuming the inventory in their warehouse below, how many race cars could the Zippy Race Car Company build? Show your work.

Body (B)	Cylinder (Cy)	Engine (E)	Tire (Tr)
4 oodles	5 oodles	8 oodles	8 oodles

   b. Explain why it is not necessary to know the number of parts in an "oodle" to solve the problem in part *a*.

10. Look back at the answers to Questions 8 and 9. Is the component with the smallest number of parts always the one that limits production? Explain your group's reasoning.

ACTIVITY #9 – ICE ICE BABY!

An ICE table is an organizational tool used in chemistry to keep track of chemical quantities before, during, and after a reaction.

Consider the following reaction:

$$2\ N_2O + O_2 \rightarrow 4\ NO$$

If we started with 1.0 mole of each reactant, which one would run out first? How much of the excess reactant would remain? How much product would be produced? Try the following!

Step 1: Insert initial (I) molar quantities into the table. If you don't have molar quantities, you know what to do…when in doubt, mole it out!

	$2\ N_2O$ +	O_2 →	$4\ NO$
Initial	1.0	1.0	0
Change			
End			

Step 2: Pick the reactant with the biggest balancing number and assume it runs out first.

	$2\ N_2O$ +	O_2 →	$4\ NO$
Initial	1.0	1.0	0
Change			
End	0		

Step 3: Determine the change that occurs for this to happen.

	$2\ N_2O$ +	O_2 →	$4\ NO$
Initial	1.0	1.0	0
Change	-1.0		
End	0		

Step 4: MOST IMPORTANT STEP! Use the mole ratios from the balanced equation to predict the rest of the changes that will occur. Remember…reactants decrease, products increase. If the change for a reactant is more than the initial amount, go back to step 2 and choose another reactant.

	$2\ N_2O$ +	O_2 →	$4\ NO$
Initial	1.0	1.0	0
Change	-1.0 →	-0.5 →	+2.0
End	0		

Step 5: Fill in the rest. The “End” row is you final molar amounts in the reaction. Convert to another unit if required.

	$2\ N_2O$ +	O_2 →	4 NO
Initial	1.0	1.0	0
Change	-1.0	-0.5	+2.0
End	0	0.5	2.0

Got it? Ok…you try a few…

1)

$2N_2O(g)$ + $O_2(g)$ → $4NO(g)$

Initial	2.0	2.0	0
Change			
Ending			

2)

$2N_2O(g)$ + $O_2(g)$ → $4NO(g)$

Initial	5.0	2.0	0
Change			
Ending			

3)

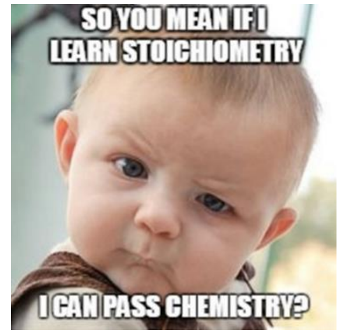
$N_2(g)$ + $3H_2(g)$ → $2NH_3(g)$

Initial	2.0	2.0	0
Change			
Ending			

4)

$N_2(g)$ + $3H_2(g)$ → $2NH_3(g)$

Initial	1.0	2.0	0
Change			
Ending			



ACTIVITY #10 – LIMITING REACTANT PRACTICE PROBLEMS

1. The reaction of methane and water is one way to prepare hydrogen:

$$CH_4(g) + H_2O(g) \rightarrow CO(g) + 3\ H_2(g)$$

[Molar masses: 16.04 18.02 28.01 2.02]

If you begin with 995 g of CH_4 and 2510 g of water, what is the maximum possible yield of H_2?

2. Disulfur dichloride, S_2Cl_2, is used to vulcanize rubber. It can be made by treating molten sulfur with gaseous chlorine:

$$S_8(l) + 4\ Cl_2(g) \rightarrow 4\ S_2Cl_2(l)$$

[Molar masses: 256.6 70.91 135.0]

Starting with a mixture of 32.0 g of sulfur and 71.0 g of Cl_2, which is the limiting reactant? What mass of S_2Cl_2 (in grams) can be produced? What mass of the excess reactant remains when the limiting reactant is consumed?

3. Aspirin ($C_9H_8O_4$) is produced by the reaction of salicylic acid ($C_7H_6O_3$) and acetic anhydride ($C_4H_6O_3$) (page 163).

$$C_7H_6O_3(s) + C_4H_6O_3(l) \rightarrow C_9H_8O_4(s) + CH_3CO_2H(aq)$$

[Molar masses: 138.1 102.1 180.1 60.05]

If you mix 100. g of each of the reactants, what is the maximum mass of aspirin that can be obtained?

ACTIVITY #11 – UNIT TEST REVIEW

TOPIC 1: BALANCING EQUATIONS

Balance the following formula equations and identify the type of chemical reaction it is (synthesis, decomposition, single replacement, double replacement, combustion, or "other"):

	TYPE:
__H_2 + __Br_2 → __HBr	____________________
__$LaCl_3$ + __Na_2CO_3 → __$La_2(CO_3)_3$ + __NaCl	____________________
__C_4H_{10} + __O_2 → __CO_2 + __H_2O	____________________
__Fe_2O_3 + __H_2SO_4 → __$Fe_2(SO_4)_3$ + __H_2O	____________________
__Al + __Fe_3O_4 → __Al_2O_3 + __Fe	____________________
__$Ca(OH)_2$ + __H_3PO_4 → __$Ca_3(PO_4)_2$ + __H_2O	____________________
__$C_7H_6O_2$ + __O_2 → __CO_2 + __H_2O	____________________
__NO_2 + __H_2O → __NO + __HNO_3	____________________

TOPIC 2: WRITING CHEMICAL EQUATIONS

Write the balanced formula equations for each reaction. Use the 4-step method used in class.

a) A piece of magnesium ribbon is reacted with oxygen in a crucible.

b) A piece of magnesium ribbon is placed in hydrochloric acid (HCl). Bubbles form.

c) Natural gas (CH_4) captured in bubbles is combusted.

d) Solutions of lead(II) nitrate and potassium iodide are mixed and a bright yellow colour emerges.

TOPIC 3: BASIC STOICHIOMETRY

Solve the following general stoichiometry problems. Show work beautifully.

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

Calculate the mass of ammonia, NH_3, formed when 45.0 L $N_2(g)$ reacts with excess $H_2(g)$ at STP.

What mass of H_2 is needed to completely react with 10.0 grams of N_2?

Dinitrogen monoxide (N_2O) – known also as nitrous oxide or “laughing gas” – was one of the earliest anesthetics used in surgery. It has regained its popularity in dentistry. It is made from the decomposition of ammonium nitrate, as shown below.

$$\underline{\mathbf{1}}\ NH_4NO_3 \rightarrow \underline{\mathbf{1}}\ N_2O + \underline{\mathbf{2}}\ H_2O$$

a) How many moles of water are created when 5 moles of ammonium nitrate is decomposed?

b) How many grams of ammonium nitrate are required to produce 500.0 g of laughing gas?

c) How many litres of laughing gas can be created with 50.0 grams of ammonium nitrate?

TOPIC 5: LIMITING REACTANTS

Solve the following stoichiometry problem using an ICE table. Show work beautifully.

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

What mass of NH_3 is formed when 135.00 g N_2 reacts with 32.00 g H_2?

TOPIC 6: MORE LIMITING REACTANTS

15.5 g of aluminum is reacted with 46.7 g of chlorine to form aluminum chloride, as shown by the equation below:

$$2Al \quad + \quad 3Cl_2 \quad \rightarrow \quad 2AlCl_3$$

a) Identify the limiting and the excess reactant.

b) What mass of excess reactant remains at the end of the reaction?

c) What mass of aluminum chloride is produced?

TOPIC 7: PERCENT YIELD

Solve the following problem:

Hydrogen gas was generated according to the equation $Zn + 2HCl \rightarrow H_2 + ZnCl_2$

When 25.00 grams of Zn metal reacted with excess HCl, 7.50 L $H_2(g)$ was collected at STP.

The **actual yield** of $H_2(g)$ for this reaction is:

The **theoretical yield** of $H_2(g)$ for this reaction is: (show work)

The **percentage yield** for this reaction is

TOPIC 8: LAB WORK

In the lab, you collected silver created from the reaction of copper and silver nitrate. The following data was collected:

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

Mass of copper wire before reaction	1.45 g
Mass of copper wire after reaction	1.23 g
Mass of filter paper	0.34 g
Mass of filter paper and silver produced	0.61 g

Calculate the theoretical yield, the actual yield, and the percent yield of your reaction.

TOPIC 9: MORE LAB WORK!

A 4 litre milk jug "rocket" is filled with hydrogen gas and oxygen gas in the correct stoichiometric ratio as communicated in the balanced formula equation below:

$$2\,H_2 + 1\,O_2 \rightarrow 2\,H_2O$$

With gases at STP, the mole ratio from the formula equation is the same as the correct volume ratio for the reaction. As such, the volume ratio required for this reaction is 2 litres H_2 for every 1 litre O_2.

a) How many litres of each gas are required to fill your 4 litre milk jug with the correct ratio of gases?

b) How many grams of calcium metal will be required to produce the required volume of hydrogen gas, according to the reaction:

$$\_\_\_Ca + \_\_\_\,H_2O \rightarrow \_\_\_\,Ca(OH)_2 + \_\_\_\,H_2$$

Fundamental Constants

Name	Symbol	Value
Speed of light in a vacuum	c	3.00×10^{8} m/s
Magnitude of charge of electron	e	1.602×10^{-19} C
Planck's constant	h	6.626×10^{-34} J·s
Boltzmann constant	k	1.381×10^{-23} J/K
Avogadro's number	N_A	6.022×10^{23} particles/mol
Gas constant, SI	R	8.314 L·kPa/mol·K
Gas constant	R	0.08206 L·atm/mol·K
Mass of electron	m_e	9.109×10^{-31} kg
Mass of proton	m_p	1.673×10^{-27} kg
Mass of neutron	m_n	1.675×10^{-27} kg
Faraday constant	$\mathcal{F}$ or F	96 485 C/mol e^-

International System (SI) Units

Physical Quantity	Name of Unit	Symbol
	base units	
Length (l)	Meter	m
Mass (m)	Kilogram	kg
Time (t)	Second	s
Temperature (T)	Kelvin	K
Electric Current (I)	Ampere	A
Luminous Intensity (φ)	Candela	cd
Amount of Substance	Mole	mol
	derived units	
Area (A)	square meter	m^2
Volume (V)	cubic meter	m^3
Frequency (ν)	Hertz	Hz [s^{-1}]
Speed, velocity (v)	meter per second	m/s
Force (F)	Newton	N [kg·m/s^2]
Pressure (P)	Pascal	Pa [N/m^2]

Common SI Prefixes

Factor	Prefix	Symbol	Factor	Prefix	Symbol
10^{12}	tera	T	10^{-2}	centi	c
10^{9}	giga	G	10^{-3}	milli	m
10^{6}	mega	M	10^{-6}	micro	µ
10^{3}	kilo	k	10^{-9}	nano	n
			10^{-12}	pico	p
			10^{-15}	femto	f

e.g. 1 km = 1 x 10^3 m

e.g. 1 µg = 1 x 10^{-6} g

TABLE OF POLYATOMIC IONS					
acetate	CH_3COO^-	dihydrogen phosphate	$H_2PO_4^-$	oxalate	$C_2O_4^{2-}$
arsenate	AsO_4^{3-}	hydrogen carbonate	HCO_3^-	perchlorate	ClO_4^-
arsenite	AsO_3^{3-}	hydrogen oxalate	$HC_2O_4^-$	periodate	IO_4^-
benzoate	$C_6H_5COO^-$	hydrogen sulfate	HSO_4^-	permanganate	MnO_4^-
borate	BO_3^{3-}	hydrogen sulfide	HS^-	peroxide	O_2^{2-}
bromate	BrO_3^-	hydrogen sulfite	HSO_3^-	phosphate	PO_4^{3-}
carbonate	CO_3^{2-}	hydroxide	OH^-	pyrophosphate	$P_2O_7^{4-}$
chlorate	ClO_3^-	hypochlorite	ClO^-	sulfate	SO_4^{2-}
chlorite	ClO_2^-	iodate	IO_3^-	sulfite	SO_3^{2-}
chromate	CrO_4^{2-}	monohydrogen phosphate	HPO_4^{2-}	thiocyanate	SCN^-
cyanate	CNO^-	nitrate	NO_3^-	thiosulfate	$S_2O_3^{2-}$
cyanide	CN^-	nitrite	NO_2^-	POSITIVE POLYATOMIC IONS	
dichromate	$Cr_2O_7^{2-}$	orthosilicate	SiO_4^{4-}	ammonium	NH_4^+
				hydronium	H_3O^+

PERIODIC TABLE OF IONS

KEY: 26 (atomic number) Fe^{3+} (symbol, ion charge) iron (III) (ion name (IUPAC)) / Fe^{2+} iron (II)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H^+ hydrogen																1 H^- hydride	2 He helium
3 Li^+ lithium	4 Be^{2+} beryllium											5 B boron	6 C carbon	7 N^{3-} nitride	8 O^{2-} oxide	9 F^- fluoride	10 Ne neon
11 Na^+ sodium	12 Mg^{2+} magnesium											13 Al^{3+} aluminum	14 Si silicon	15 P^{3-} phosphide	16 S^{2-} sulfide	17 Cl^- chloride	18 Ar argon
19 K^+ potassium	20 Ca^{2+} calcium	21 Sc^{3+} scandium	22 Ti^{4+} titanium (IV) / Ti^{3+} titanium (III)	23 V^{3+} vanadium(III) / V^{5+} vanadium (V)	24 Cr^{3+} chromium (III) / Cr^{2+} chromium (II)	25 Mn^{2+} manganese(II) / Mn^{4+} manganese(IV)	26 Fe^{3+} iron (III) / Fe^{2+} iron (II)	27 Co^{2+} cobalt (II) / Co^{3+} cobalt (III)	28 Ni^{2+} nickel (II) / Ni^{3+} nickel (III)	29 Cu^{2+} copper (II) / Cu^+ copper (I)	30 Zn^{2+} zinc	31 Ga^{3+} gallium	32 Ge^{4+} germanium	33 As^{3-} arsenide	34 Se^{2-} selenide	35 Br^- bromide	36 Kr krypton
37 Rb^+ rubidium	38 Sr^{2+} strontium	39 Y^{3+} yttrium	40 Zr^{4+} zirconium	41 Nb^{5+} niobium (V) / Nb^{3+} niobium(III)	42 Mo^{6+} molybdenum	43 Tc^{7+} technitium	44 Ru^{3+} ruthenium(III) / Ru^{4+} ruthenium(IV)	45 Rh^{3+} rhodium	46 Pd^{2+} paladium(II) / Pd^{4+} paladium(IV)	47 Ag^+ silver	48 Cd^{2+} cadmium	49 In^{3+} indium	50 Sn^{4+} tin (IV) / Sn^{2+} tin (II)	51 Sb^{3+} antimony(III) / Sb^{5+} antimony(V)	52 Te^{2-} telluride	53 I^- iodide	54 Xe xenon
55 Cs^+ cesium	56 Ba^{2+} barium	57 La^{3+} lanthanum	72 Hf^{4+} hafnium	73 Ta^{5+} tantalum	74 W^{6+} tungsten	75 Re^{7+} rhenium	76 Os^{4+} osmium	77 Ir^{4+} iridium	78 Pt^{4+} platinum(IV) / Pt^{2+} platinum(II)	79 Au^{3+} gold (III) / Au^+ gold (I)	80 Hg^{2+} mercury (II) / Hg_2^{2+} mercury (I)	81 Tl^+ thallium (I) / Tl^{3+} thallium(III)	82 Pb^{2+} lead (II) / Pb^{4+} lead (IV)	83 Bi^{3+} bismuth(III) / Bi^{5+} bismuth(V)	84 Po^{2+} polonium(II) / Po^{4+} polonium(IV)	85 At^- astatide	86 Rn radon
87 Fr^+ francium	88 Ra^{2+} radium	89 Ac^{3+} actinium															

58 Ce^{3+} cerium	59 Pr^{3+} praseodymium	60 Nd^{3+} neodymium	61 Pm^{3+} promethium	62 Sm^{3+} samarium(III) / Sm^{2+} samarium(II)	63 Eu^{3+} europium (III) / Eu^{2+} europium (II)	64 Gd^{3+} gadolinium	65 Tb^{3+} terbium	66 Dy^{3+} dysprosium	67 Ho^{3+} holmium	68 Er^{3+} erbium	69 Tm^{3+} thulium	70 Yb^{3+} ytterbium(III) / Yb^{2+} ytterbium(II)	71 Lu^{3+} lutetium
90 Th^{4+} thorium	91 Pa^{5+} protactinium(V) / Pa^{4+} protactinium(IV)	92 U^{6+} uranium (VI) / U^{4+} uranium (IV)	93 Np^{5+} neptunium	94 Pu^{4+} plutonium(IV) / Pu^{6+} plutonium(VI)	95 Am^{3+} americium(III) / Am^{4+} americium(IV)	96 Cm^{3+} curium	97 Bk^{3+} berkelium(III) / Bk^{4+} berkelium(IV)	98 Cf^{3+} californium	99 Es^{3+} einsteinium	100 Fm^{3+} fermium	101 Md^{2+} mendelevium (II) / Md^{3+} mendelevium (III)	102 No^{2+} nobelium(II) / No^{3+} nobelium(III)	103 Lr^{3+} lawrencium

The Periodic Table of the Elements

Average relative masses are rounded to two decimal places.

Element name → Mercury
Atomic # → 80
Symbol → Hg
Avg. Mass → 200.59

1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Hydrogen 1 H 1.01																		Helium 2 He 4.00
Lithium 3 Li 6.94	Beryllium 4 Be 9.01												Boron 5 B 10.81	Carbon 6 C 12.01	Nitrogen 7 N 14.01	Oxygen 8 O 16.00	Fluorine 9 F 19.00	Neon 10 Ne 20.18
Sodium 11 Na 22.99	Magnesium 12 Mg 24.31												Aluminum 13 Al 26.98	Silicon 14 Si 28.09	Phosphorus 15 P 30.97	Sulfur 16 S 32.07	Chlorine 17 Cl 35.45	Argon 18 Ar 39.95
Potassium 19 K 39.10	Calcium 20 Ca 40.08		Scandium 21 Sc 44.96	Titanium 22 Ti 47.88	Vanadium 23 V 50.94	Chromium 24 Cr 52.00	Manganese 25 Mn 54.94	Iron 26 Fe 55.85	Cobalt 27 Co 58.93	Nickel 28 Ni 58.69	Copper 29 Cu 63.55	Zinc 30 Zn 65.39	Gallium 31 Ga 69.72	Germanium 32 Ge 72.61	Arsenic 33 As 74.92	Selenium 34 Se 78.96	Bromine 35 Br 79.90	Krypton 36 Kr 83.80
Rubidium 37 Rb 85.47	Strontium 38 Sr 87.62		Yttrium 39 Y 88.91	Zirconium 40 Zr 91.22	Niobium 41 Nb 92.91	Molybdenum 42 Mo 95.94	Technetium 43 Tc (97.91)	Ruthenium 44 Ru 101.07	Rhodium 45 Rh 102.91	Palladium 46 Pd 106.42	Silver 47 Ag 107.87	Cadmium 48 Cd 112.41	Indium 49 In 114.82	Tin 50 Sn 118.71	Antimony 51 Sb 121.76	Tellurium 52 Te 127.60	Iodine 53 I 126.90	Xenon 54 Xe 131.29
Cesium 55 Cs 132.91	Barium 56 Ba 137.33	57-70 *	Lutetium 71 Lu 174.97	Hafnium 72 Hf 178.49	Tantalum 73 Ta 180.95	Tungsten 74 W 183.84	Rhenium 75 Re 186.21	Osmium 76 Os 190.23	Iridium 77 Ir 192.22	Platinum 78 Pt 195.08	Gold 79 Au 196.97	Mercury 80 Hg 200.59	Thallium 81 Tl 204.38	Lead 82 Pb 207.20	Bismuth 83 Bi 208.98	Polonium 84 Po (208.98)	Astatine 85 At (209.99)	Radon 86 Rn (222.02)
Francium 87 Fr (223.02)	Radium 88 Ra (226.03)	89-102 **	Lawrencium 103 Lr (262.11)	Rutherfordium 104 Rf (265.12)	Dubnium 105 Db (268.13)	Seaborgium 106 Sg (271.13)	Bohrium 107 Bh (270)	Hassium 108 Hs (277.15)	Meitnerium 109 Mt (276.15)	Darmstadtium 110 Ds (281.16)	Roegentium 111 Rg (280.16)	Copernicium 112 Cn (285.17)	Nihonium 113 Nh (284.18)	Flerovium 114 Fl (289.19)	Moscovium 115 Mc (288.19)	Livermorium 116 Lv (293)	Tennessine 117 Ts (294)	Oganesson 118 Og (294)

*lanthanides	Lanthanum 57 La 138.91	Cerium 58 Ce 140.12	Praseodymium 59 Pr 140.91	Neodymium 60 Nd 144.24	Promethium 61 Pm (145)	Samarium 62 Sm 150.36	Europium 63 Eu 151.97	Gadolinium 64 Gd 157.25	Terbium 65 Tb 158.93	Dysprosium 66 Dy 162.50	Holmium 67 Ho 164.93	Erbium 68 Er 167.26	Thulium 69 Tm 168.93	Ytterbium 70 Yb 173.05
**actinides	Actinium 89 Ac (227.03)	Thorium 90 Th 232.04	Protactinium 91 Pa 231.04	Uranium 92 U 238.03	Neptunium 93 Np (237.05)	Plutonium 94 Pu (244.06)	Americium 95 Am (243.06)	Curium 96 Cm (247.07)	Berkelium 97 Bk (247.07)	Californium 98 Cf (251.08)	Einsteinium 99 Es (252.08)	Fermium 100 Fm (257.10)	Mendelevium 101 Md (258.10)	Nobelium 102 No (259.10)