Unit 5 Study Guide
Avogadro's number & the mole

Targets:

E4. *Describe an application of the Law of Conservation of Matter.*

J1. *Make accurate observations using appropriate tools and units of measure.*

J2. *Verify, evaluate, and use results in a purposeful way. This includes analyzing and interpreting data, making predictions based on observed patterns, testing solutions against the original problem conditions, and formulating additional questions.*

Activity #1 – Scientific Notation

1) Write a 6 followed by 24 zeros. This is the mass of the earth in kilograms. That was a lot of work, huh? Are you hungry? Want a sandwich?

2) Now write a decimal point followed by 26 zeros and then the number 17. This is the mass of a hydrogen atom in kilograms.

3) In scientific notation, the numbers above are 6.0×10^{24} kg and 1.7×10^{-27} kg respectively. Why do you think learning scientific notation might be a good thing?

Scientific Notation

A positive number is written in scientific notation if it is written in the form:

$$a \times 10^{r}$$

where $1 \leq a < 10$ and r is an integer power of 10.

Read this tutorial on scientific notation and then play some games!

Got it? Let's try the King Kong Scientific Notation Game.

What was your score? Have your teacher initial here _____ when you finish the quiz.

How about another game? Can you sink all of the enemy's ships? Your knowledge of scientific notation will help.

Have your teacher initial here _____ when you finish the game.

Answer the first ten questions on this quiz.

1) Determine whether or not the number is written in scientific notation: 4.37×10^5.

2) Determine whether or not the number is written in scientific notation: 2,380,000.

3) Determine whether or not the number is written in scientific notation: 20.04×10^3.

4) Express the number in scientific notation: 4,737.

5) Express the number in scientific notation: 75.384.

6) Express the number in scientific notation: 0.000155.

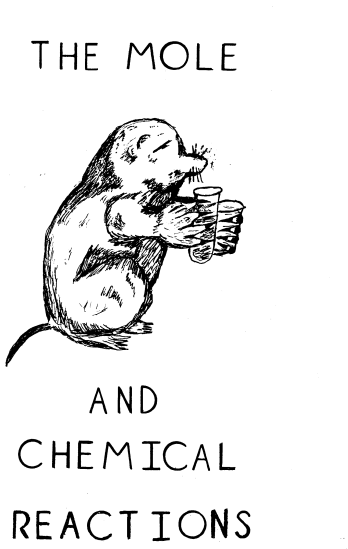
7) Express the number in scientific notation: 0.000042315

8) Express the number in standard notation: 6.07×10^4.

9) Express the number in standard notation: 6.94×10^{-4}.

10) Express the number in standard notation: 1.769×10^{-5}.

Activity #2 – The Mole and Avogadro's Number



THE MOLE

You say a mole is brown and furry
with eyes developed wrong,
You ask a chemist his description
which is quite a different song.
A chemists mole is not of fur,
nor is it very brown,
It comes in many varieties-square, oblong,
or round.

The mole can stand for numbers, formulas
or items of everyday,
A mole of girls, a mole of boys, whatever
you wish to say.
Chemists indulge jubilantly,
solving problems it creates,
My brains find problems no fun at all
pondering them till it aches.

CHEM 13 NEWS, February 1972, p. 393

Read avogadro's number & the mole. For some questions you will need to follow the link to a different website.

1) What is a **"mole"** in chemistry? How the word mole like the word dozen?

2) What is **Avogadro's number**

   a) in standard notation?

   b) in scientific notation?

3) If you spread a mole of marbles over the earth, how thick would the layer be?

4) Do you think you could spend a mole of dollars in your lifetime? Explain.

5) What kinds of things to scientists measure in moles?

6) The atomic mass of an element on the periodic table is given in amu's. What is an **amu**?

7) How can you find the mass of a mole of atoms of an element in grams?

8) Consider a mole of iron atoms.

   a) How many iron atoms in a mole?

   b) What is the mass (in grams) of a mole of iron atoms?

9) Why is the mass in grams of one mole of an element (the gram atomic weight) more useful than the mass in amu's?

10) On what date and during what times is National Mole Day celebrated? Why?

11) Who the heck is Avogadro anyhow?

Avogadro – chemist, mathematician…ladies' man?

Go to Professor Mole's Mole Facts and fill in the blanks.

12) 6.02×10^{23} Watermelon Seeds: Would be found inside a melon slightly larger than the _____.

13) 6.02×10^{23} Donut Holes: Would cover the earth and be___ miles (___ km) deep.

14) 6.02×10^{23} Pennies: Would make at least _____ stacks that would reach the _____.

15) 6.02×10^{23} Grains of Sand: Would be more than all of the sand on _____.

16) 6.02×10^{23} Blood Cells: Would be more than the total number of blood cells found in every_____ on _____.

Need a break? How about some games!

Mole Game - Lead the mole to his nest by piecing together his tunnel. Accompanied by some debatable catchy or annoying music.

Wack-A-Mole – online version of a classic arcade game.

Activity #3 – Molecular & Formula Mass

As you might expect, the term **molecular mass** refers to the mass of a molecule. Fortunately, calculating the molecular mass is no harder than understanding the concept. The masses shown on the periodic table are the atomic masses or mass of a mole of atoms in grams. To determine the mass of a mole of molecules, simply add up all of the molar masses for the elements that make up the molecule. The number in bold is the # of moles of that element in one mole of molecules (from the subscripts in the formula).

Molecular Mass of CO_2		**Molecular Mass of $C_6H_{12}O_6$**	
C = 12.0 g/mol x **1**	= 12.0 g/mol	C = 12.0 g/mol x **6**	= 72.0 g/mol
O = 16.0 g/mol x **2**	= 32.0 g/mol	H = 1.01 g/mol x **12**	= 12.1 g/mol
	---	O = 16.0 g/mol x **6**	= 96.0 g/mol
Total	= **44.0 g/mol**		---
		Total	= **180.1 g/mol**

Finding the **formula mass** of an ionic compound is just as easy, in fact, the calculation is exactly the same. The only difference has to do with terminology. We don't call ionic compounds molecules, so you can't find the molecular mass of an ionic compound. Instead, we do the exact same calculation, but we call the results the formula mass of the compound. The table below shows how to calculate the formula mass of two ionic compounds. If you have parentheses, you must multiply everything inside the parentheses by the subscript outside. Ex. $Ca_3(PO_4)_2$, has 3 Ca, 2 P and 8 O.

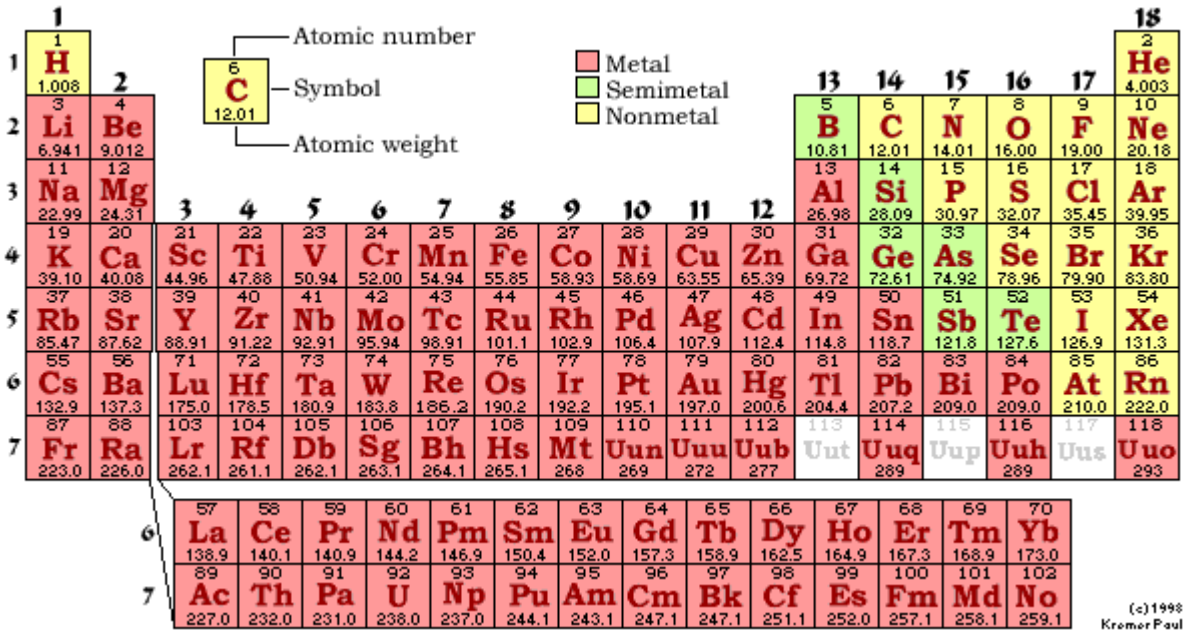
Formula Mass of $CuSO_4$		**Formula Mass of $Ca(OH)_2$**	
Cu = 63.5 g/mol x **1**	= 63.5 g/mol	Ca = 40.1 g/mol x **1**	= 40.1 g/mol
S = 32.1 g/mol x **1**	= 32.1 g/mol	O = 16.0 g/mol x **2**	= 32.0 g/mol
O = 16.0 g/mol x **4**	= 64.0 g/mol	H = 1.01 g/mol x **2**	= 2.0 g/mol
	---		---
Total	= **159.6 g/mol**	Total	= **74.1 g/mol**

MOLECULAR MASS -Determine the molecular mass of each of the following. Show your work in the spaces provided. Check your answers using the Molar Mass Calculator. Here is a cool periodic table to use (or use the printed one on the next page).

CH_4	**H_20**	**NO_2**
C_3H_8	**CH_3OOH**	**HBr**

FORMULA MASS -Determine the formula mass of each of the following. Show your work in the spaces provided. Check your answers using the Molar Mass Calculator. Here is a cool periodic table to use (or use the printed one below).

KBr	**LiOH**	**$NaNO_3$**
$Ba(OH)_2$	**$(NH_4)_2O$**	**$CaCO_3$**



Use Google to help with the clues. Write the "word" answer next to each question and then find and circle the word in the puzzle.

A V O G A D R O S N U M B E R O T
G T F V C M C L S S D S A Y K K S
I V I O B D D X S M R L J J V X T
A V I O W S Y V A R U H U E N E N
O U M D S V N O M M W B D F W J E
Y G R A M O H W R J U T S A M B I
S Q W O B X X O A V X T D A G O C
T V N R R T F T L Z B P F D G L I
E D A Y R T E M O I H C I O T S F
D C F Z B G T I M S N W X Y R D F
M C M O L E C U L E S A X A L P E
S T W X T I Z Y L U E L O M J K O
D X R I I O O C D R S F W U G K C

Words about the concepts in this module can be obtained from the clues given. Find these words in the block of letters:

1. A ___ of a substance represents Avogadro's number of units of that substance.
2. 6.02×10^{23} (2 words).
3. Mass, in grams, of 1 mole of a substance (2 words).
4. SI unit of mass ÷ 1000
5. _____ describes the quantitative relationships among elements and compounds as they undergo chemical changes.
6. Symbolism showing a substance's chemical composition.
7. Smallest units of compounds.
8. Numerical multipliers showing ratios between reactants and products in a chemical equation.
9. One mole of a substance in this state at STP occupies a volume of 22.4 L.
10. One mole of this element weighs 12.0 g.

Activity #4 – Percent Composition

Let's start with something really basic and simple to make sure that we understand percentages...

Example 1. Homer has a box of assorted doughnuts. 3 of these doughnuts are chocolate. What percentage of Homer's doughnuts are chocolate and what are not? (note, we are talking about total number, not mass, in this case.)

$$\% \text{ of doughnuts that are chocolate} = \frac{\text{number of chocolate doughnuts}}{\text{total number of doughnuts}} \times 100$$

% of doughnuts that are chocolate = (3/12) x 100 = 25%

# of doughnuts that are not chocolate = 12 – 3 = 9

% of doughnuts that are not chocolate = (9/12) x 100 = 75%

1) Suppose we had a bushel of fruit, containing a mixture of apples and oranges and we know that there are a total of 100 fruits in the basket. If we also know that 55 of the fruits are oranges, then what percent of the fruit is made up of apples? Show your work and check your answer here.

Now, let's take a look at a different aspect of percentage related to these same apples and oranges...

2) Suppose the same numbers of apples and oranges seen in the problem above apply once more, but this time we are given some additional information which tells us that the apples are all roughly the same size and have an average mass of 175 grams each, while the oranges are a small variety which have an average mass of 125 grams each. What is the percentage composition of apples by mass? Show your work (following the steps below) and check your answer here.

   _____ apples X (175 g/apple) = _____ grams of apples

   _____ oranges X (125 g/orange) = _____ grams of oranges

   _____ grams of apples + _____ grams of oranges = _____ grams of fruit

   (_____ grams of apples) / (_____ grams of fruit) x 100 = _____ % apples

   (_____ grams of oranges) / (_____ grams of fruit) x 100 = _____ % oranges

It's interesting to note that even though the greater percent of fruits are oranges, the greater mass of fruit is apples. This is a realistic analogy to percent composition in chemical compounds, since the percent composition by mass many times depends on the size of the atoms involved, not just the number.

When you are asked to determine the ***percent composition*** *of a compound, it should be understood that this refers to the* percentage by mass. *In other words, the percent composition of water shows what percentage of the mass of a water molecule is made up of hydrogen and what percentage of the mass is made up of oxygen.*

Example 2. What is the percentage composition of glucose ($C_6H_{12}O_6$) ?

Solution:

Find the mass of the entire molecule:

C = 12.0 g/mol x 6 atoms = 72.0 g/mol
H = 1.01 g/mol x 12 atoms = 12.1 g/mol
O = 16.0 g/mol x 6 atoms = 96.0 g/mol
= 180 g/mol

Then use the formula for each element in the compound:

$$\frac{\text{partial mass from element}}{\text{total mass of the compound}} \times 100 = \%\text{ of the mass of the compound that is made up by an element}$$

$$\%\text{ for Carbon} = \frac{72.0\text{ g/mol}}{180\text{ g/mol}} \times 100 = 40.0\%$$

$$\%\text{ for Hydrogen} = \frac{12.1\text{ g/mol}}{180\text{ g/mol}} \times 100 = 6.7\%$$

$$\%\text{ for Oxygen} = \frac{96.0\text{ g/mol}}{180\text{ g/mol}} \times 100 = 53.3\%$$

One way to check your answer is to make sure that all of the percentages add up to approximately 100%. (i.e. 40.0% + 6.7% + 53.3% = 100%) Your total may be off by a few tenths of a percent, due to rounding.

Now you should be ready to try some on your own!

Calculate the **percentage composition by mass** of the following compounds. Show your work and check your answers using the Molar Mass and Percent by Mass Calculator.	
1) HgO	**2) Na_2S**

3) $(NH_4)_2S$	**4) $Sr(NO_3)_2$**

Activity #4 – Grams to Moles & Moles to Grams calculations

Read Don't Make a Mountain out of a Mole Hill.

1) Draw the "mole hill" in the handout below.

2) What 3 equations can you get from the "mole hill"? The units of each quantity are included in parentheses.

   mole (mol) =

   mass (g) =

   molecular mass (g/mol) =

3) Convert 0.25 moles of CO_2 to grams. Show your work.

4) Try problem #3 using this calculator. You are using the choice that says "Number of moles to number of grams". In the first box (at the top of the page), enter "# of Moles" (in this case 0.25). In the second box, you are going to enter the molecular mass of CO_2. First click in box 2 so the cursor is there. You may enter the molecular mass if you know it **OR**, on the periodic table at the bottom, click "C" once and "O" twice. To get your answer, click the gray button that says "Moles → Grams". Does it agree with what you got in #3? If not, ask your teacher for help.

5) Use the calculator to answer the following. Check your answers at *Professor Mole's Mole Facts*.

1 Liter bottle of Water (1000 g) contains _____ moles H_20

5 Pound Bag of Sugar contains _____ moles Of $C_{12}H_{22}O_{11}$

*For the following problems, **YOU MUST** show your work. Check your answers using this calculator. Remember – you will not be allowed to use the calculator on the test so make sure you use it **ONLY** to check your answer.*

Given the following, find the number of moles:

6) 30 grams of H_3PO_4

7) 25 grams of HF

8) 110 grams of $NaHCO_3$

9) 1.1 grams of $FeCl_3$

Given the following, find the number of grams:

10) 4 moles of $Cu(CN)_2$

11) 5.6 moles of C_6H_6

12) 21.3 moles of $BaCO_3$

13) 1.2 moles of $(NH_4)_3PO_3$

Possible worksheets/labs for Unit 5:

Scientific Notation
IIC.3 Understanding the Mole
Moles of Chalk lab
Molecular Formula Mass
The Mole and Molar Mass
Percent Composition of an Egg
Determination of Moles of Copper and Iron in Reaction
Activity 8.1: Balancing Chemical Equations
Analyzing the 'Pop" in Popcorn
Percent Water In Popcorn

Bonus Activity – Mole Jokes

Answer as many of the following as you can for extra credit. Credit will be given for anything that makes sense! All answers have "mole" in them somewhere.

From *The Mole Joke Book (CHEM 13 NEWS, February 1983, p. 12 and October 1983, p. 3):*

1. What did Avogadro give his ex-wife every month?
2. What did Avogadro have on his pancakes?
3. On which American mountain was Avogadro's face carved in stone?
4. What song did Avogadro's family sing on New Year's Eve?
5. Where did Avogadro send his CARE packages?
6. Why was there only one Avogadro?
7. What was Avogadro's favorite board game?
8. What kept Avogadro in bed for two months?
9. Who was Avogadro's favorite singing group?
10. Who was Avogadro's favorite composer?
11. Avogadro loved to watch M.A.S.H. Which character did he like the most?
12. What did Avogadro call his church services?
13. How would you have described Avogadro's room while he was a teenager?
14. Which was Avogadro's favorite Indian tribe?
15. Which recent movie would Avogadro have really liked?
16. What did Avogadro think of hemorrhoids? 17. What did Avogadro put into the pockets of his tweed suit?
18. Can you name two movies that Avogadro really liked?
19. What was Avogadro's best day in golf?
20. How did Avogadro send a secret message with his walkie-talkie?
21. What is Avogadro's favorite kind of music?
22. Which Walt Disney characters was Avogadro fond of?
23. What is Avogadro teaching his astronomy class about?
24. What do you get when you have a bunch of moles acting like idiots?
25. How did Avogadro help his team win the soccer playoffs?
26. Which is one of Avogadro's best songs?
27. What did Avogadro invent for his wife to use as a night cream?
28. What was Avogadro's favorite drink?
29. Why did people say Avogadro was lazy?
30. What is Avogadro's favorite chocolate bar?
31. What did Avogadro get when he mixed ice cream, chocolate syrup, and milk?
32. What kind of shell-fish did Avogadro like to eat?
33. Which tooth did Avogadro have pulled out?
34. What religion did Avogadro belong to?
35. What did Avogadro's bird do when it was time for him to send his feathers?
36. What was the mad bomber's favorite drink?
37. Where did Mrs. Avogadro do her shopping?
38. What did Avogadro teach his students in math class?
39. What are moles made of?
40. Which team lost the World Series in 1982?
41. What brand of cigarettes did Avogadro smoke?
42. What are mammoles?

43. What do you sue to flatten hot asphalt?
44. How did Avogadro get through the desert?
45. What do chemists do in a math class?
46. Which part of the universe did Avogadro like to study?
47. What kind of fruit did Avogadro eat in the summer?
48. How much money did Avogadro make from being a chemist?
49. What is Avogadro's favorite sport?
50. What is Avogadro's favorite drink?
51. What happened to Avogadro when he had to drive over a bridge?
52. What area did Avogadro explore?
53. What were Avogadro's houses made of?
54. How much does Avogadro exaggerate?
55. What did J. J. Thomson have for dessert?
56. What happens to Avogadro's dog in the summer?
57. What did Avogadro do when he lost his job?
58. Where does Avogadro plant his trees?
59. What was Avogadro's best subject?
60. What was Avogadro dressed as when he went to the masquerade ball?
61. Where did Avogadro go sailing?
62. What was the problem Avogadro had with his shoes?
63. At what time was Avogadro at his romantic best?
64. What are Avogadro's favorite places?
65. What scientist was a member of the pig family?
66. What is Avogadro's favorite character?
67. What was Avogadro full of?
68. What is Avogadro's favorite song?
69. What did Avogadro collect at the seashore?
70. Where do students graduate?