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#20 Introduction to the Mole

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Introduction

Description

This unit uses a discovery-based method to introduce the mole concept without relying on students' strong background. The lessons contain activities with candy that lead students to develop the rules for mole-item, item-mole, mole-mass, and mass-mole "conversions." Experiences that engage different types of learners are utilized to reinforce the concepts. The unit provides students with opportunities to make the connection between the mole concept and familiar counting units, like a dozen, and apply the concept of the mole to measuring out a given quantity of a substance.

Student Audience

This unit can be used to introduce the mole concept in any chemistry class, grades 9-12.

Goals for the Activities

At the completion of this unit students will

1. Have a conceptual understanding of the mole as the method of "counting" items and finding the mass of items that can't be seen.
2. Be able to calculate the number of items (molecules, atoms, ions, and formula units) if given the number of moles.
3. Be able to calculate the number of moles if given the number of items.
4. Be able to calculate the mass of a sample if given the number of moles in a sample.
5. Be able to calculate the number of moles in a sample if given the mass of a sample.
6. Be able to prepare a sample containing a given number of moles.

Recommended Placement in the Curriculum

These activities can be used at any point before introducing the mole. Students should have already mastered calculating formula mass if given the formula and a table of atomic masses or the Periodic Table of Elements. Students will need to know how to multiply and divide numbers written in scientific notation. Students should be familiar with the use of a balance.

If scientific calculators are available, a lesson on using the calculators to perform operations on numbers in scientific notation should precede these activities.

These activities could be used in conjunction with concentration calculation and stoichiometry.

Student Handout

Activity #1 Introduction to the Mole Name _____

Purpose

To discover a method of counting "things" that you are not able to see.

Information

When you buy eggs you usually ask for a _____ eggs. You know that one dozen of any item is _____.

Paper is not packaged by the dozen. Paper is packaged by a ream. A ream of paper has 500 sheets. Why is it useful to use units like a dozen or a ream?

_____

What determines how many items should make up a particular unit? _____

_____

If you were asked to design a new unit to count something, what would you consider when choosing how many items should be included in your new counting unit?

_____

Safety, Handling, and Disposal

Do not open the packages in the lab area. Follow your teacher's instruction for disposal. Dispose of used reagents according to local ordinances.

Materials

3 packages of different types of candy, balance, worksheet, calculator, pencil

Procedure

1. Record the number of items in each package. Measure the mass of each package. Record the mass of each package in the data table.
2. Answer questions in Analysis and Interpretations.
3. Record masses your group measured on a transparency summarizing class data.

Data

Each package contains _____ items.

Name of items in the package	Mass of the package

ANALYSIS AND INTERPRETATION

1. As you know, a dozen represents 12 items. Since I did not have enough items to make a dozen, I decided to make a new counting unit. I called this unit an OWL. Each of your packages contains _____ items. We will call this number of items an OWL. If you understand the concept of OWL as a counting unit, just like a dozen for counting by 12, you should be able to complete the following questions.

Questions

An OWL of oranges will have _____ oranges.
An OWL of pretzels has ____ pretzels. An OWL of desks has _____ desks.
An OWL of molecules of water has ____ molecules of water.
An OWL of particles has ___ particles.
An OWL of atoms of iron has _____ atoms of iron.
An OWL of formula units of salt has _____ formula units of salt.
Now that you understand the meaning of an OWL, you should be able to answer the following questions:

a. How many Hershey's Kisses are in 2 OWLS? _____

b. How many caramels are in 10 OWLS? _____

c. How many Hershey's Kisses are in 400 OWLS? _____

d. How many caramels are in 1/2 OWL? _____

WRITE DIRECTIONS FOR **FINDING THE # OF ITEMS** IF GIVEN THE **# OF OWLS.**

_____

_____

Show your directions to the teacher. Use the above directions to answer the following questions. Show what you did to find each answer.

Show work below

1. How many pencils are in 20 OWLS? _____
2. How many pencils are in 100 OWLS? _____
3. How many apples are in 10 OWLS? _____
4. How many oranges are in 5 OWLS? _____
5. How many pencils are in 0.5 OWLS? _____
6. How many pencils are in 0.25 (1/4) OWLS? _____
7. How many atoms of silver are in 20 OWLS? _____
8. How many molecules of water are in 10 OWLS? _____

Finding the Number of OWLS

If you are given the number of items you can tell the number of OWLS. For example, since one OWL is 4 items, 8 items make up 2 OWLS.

e. How many OWLS are 16 Hershey's Kisses? _____

f. How many OWLS are 100 pretzels? ____

g. How many OWLS are 400 desks? ____

h. How many OWLS is 1 orange? _____ (Write a fraction or a decimal.)

i. How many OWLS are 2 caramels? _____

Write directions for finding the **number** of OWLS if **given** the **number of pieces**.

_____

_____

Show work below

1. How many OWLS are 48 Hershey's Kisses? _____
2. How many OWLS are 2 Hershey's Kisses? _____
3. How many OWLS are 32 Hershey's Kisses? _____
4. How many OWLS are 3 Hershey's Kisses? _____
5. How many OWLS are 24 Minty Bells? _____
6. How many OWLS are 2 Minty Bells? _____
7. How many OWLS are 20 caramels? _____

As you can imagine, an OWL of molecules of water would be too small to see. Scientists had to select a bigger unit for counting molecules of substances. The unit scientists use is called a **MOLE**.

One **MOLE** of anything has **602,200,000,000,000,000,000,000** items.

This number is called **AVOGADRO'S NUMBER** and is usually written in scientific notation as **6.022 x 1023**

One MOLE of anything has 6.022 x 1023 items.

Use the rules you have written for calculations involving **OWLS** to answer questions about **MOLES**. Remember to use **6.022 x 1023** for the number of items in a MOLE.

Recall how to multiply numbers written in scientific notation.
[4 x 6.022 x 10^{23} ‡ (6.022 x4)x10^{23} = 24.08 x 10^{23} = 2.408 x 10^{24}].

Note: Atoms and molecules in these questions are words meaning items.

1. How many Hershey's Kisses make up 1 **MOLE**? _____

2. How many caramels make up 10 **MOLES**? _____

3. Find the number of Minty Bells in 4 **MOLES**. _____

4. Find the number of atoms of sodium in 2 **MOLES**. _____

5. Find the number of molecules of water in 6 **MOLES**. _____

6. Find the number of caramels in 0.5 **MOLES**. _____

7. How many **moles** of caramels are 6.022x10^{23} of caramels? _____

8. How many **moles** of desks are 6.022x10^{23} of desks? _____

9. How many **moles** of pens are 12.04x10^{23} of pens? _____

10. How many **moles** of sodium atoms are 12.04x10^{23} of sodium atoms? _____

Mole Worksheet #1 Name _____

Reminder: One MOLE has $6.022 * 10^{23}$ items or there are $6.022 * 10^{23}$ items/mole.

Items may mean: caramels, Hershey's Kisses, bananas, oranges, ATOMS, FORMULA UNITS, MOLECULES, IONS, etc.

Show work!

1. How **many atoms** of potassium make up one MOLE ? _____

2. How **many atoms** of potassium make up 2 MOLES? _____

3. How **many formula units** of salt make up 10 MOLES? _____

4. How **many molecules** of water make up 1 MOLE? _____

5. How **many molecules** of water make up 5 MOLES? _____

6. How **many moles** are 6.022×10^{23} atoms of sodium? _____

7. How **many moles** are 12.04×10^{23} atoms of carbon? _____

8. How **many moles** are 18.06×10^{23} atoms of sodium? _____

9. How many moles are 60.22×10^{23} atoms of sodium? _____

10. How many moles are 6.022×10^{23} molecules of water? _____

11. How many moles are 12.04×10^{23} molecules of water? _____

12. How many moles are 30.10×10^{23} molecules of water? _____

13. How many moles are 18.06×10^{23} formula units of salt? _____

14. How many **FORMULA UNITS** are 6 MOLES of NaCl? _____

Reminder:
When MULTIPLYING numbers in scientific notation, multiply the number part, times ten to the power of the sum of the exponents. For example: $(2 \times 10^4) \times (3 \times 10^5) = 6 \times 10^9$.

When dividing numbers in scientific notation, divide the number part. The answer is multiplied by 10 to the power which is the difference between the exponents. For example:

$$\frac{6x10^{45}}{3x10^{30}} \Rightarrow 2x10^{45-30} \Rightarrow 2x10^{15}$$

Student Handout
Activity # 2 Introduction to the Mole Name _____

Purpose
To discover a method of using a scale to count "things" that you are not able to see.

Safety, Handling, and Disposal
None.

Materials
Student Handout: Activity # 1 Introduction to the Mole, Periodic Table of Elements, calculator, pencil

Procedure
1. In addition to being able to tell the number of items in an OWL, you can now tell the mass of an OWL of Hershey's Kisses, Minty Bells, and caramels. Use your data table on page # 1 of **ACTIVITY # 1 Introduction to the Mole** or class data to fill in the information below:

Based on your measurements, the mass of 1 OWL of Hershey's Kisses is _____ g.

The measured mass of 2 OWLS of Hershey's Kisses is _____ g. (If measured)

The mass of 1 OWL of Minty Bells is _____ g.

The mass of 1 OWL of caramels is ____g

2. Calculate each of the following:

The mass of 100 OWLS of Hershey's Kisses is ____ g.

The mass of 1/2 OWL of Hershey's Kisses is ____ g.

Complete the directions for **finding the mass** of a given number of OWLS.

1. Measure or find the mass of 1 OWL.

2.

NOTE THAT ALTHOUGH THE NUMBER OF ITEMS (PARTICLES) IN AN OWL IS THE SAME, THE **MASS** OF AN **OWL OF DIFFERENT ITEMS IS DIFFERENT**.

Questions

Use your directions above to answer the following questions:

The mass of 4 OWLS of Minty Bells is ____ g.

The mass of 25 OWLS of Minty Bells is ____ g.

The mass of 0.5 OWLS of Minty Bells is ____ g.

The mass of 3 OWLS of caramels is _____ g.

The mass of 100 OWLS of caramels is _____ g.

The mass of 1/5 OWLS of caramels is _____ g.

The mass of 60 OWLS of Hershey's Kisses is _____ g.

The mass of 0.1 OWLS of Hershey's Kisses is _____ g.

How would you calculate the number of OWLS if you know the mass of a package of Hershey's Kisses?

How would you calculate the number of OWLS if you know the mass of a package of caramels?

How would you calculate the number of OWLS if you know the mass of a package of Minty Bells?

Complete the directions for **finding the number** of an item if given one OWL of the item.

1. Measure or find the mass of 1 OWL.

2.

Student Handout

Name _____

Finding THE MASS OF A MOLE

Purpose:

To become familiar with a mole of different substances.

Safety, Handling, and Disposal

Follow instructions of your teacher. Dispose of used reagents according to local ordinances.

Materials

Containers with one mole of substances. Each sample contains one MOLE of the substance.

Procedure

1. Record the name and the formula of each substance in the data table.
2. Use the balance to find the mass of a mole of each substance. Record in the table.
3. The mass of the container is indicated on the label. Record the mass of the container in the table.

Note: Mass of Sample = Mass measured - Mass container

4. Calculate the formula mass of each substance. Record the formula mass in the table.

Note: It is a good time to do the calculations of the formula mass while all samples you need are being used by another group and you can't do anything else.

Data and Observations:

Name of Substance	Formula	Calculated Formula mass	Mass of the sample and container	Mass of the container	Mass of the sample

Questions

1. Compare the mass of a mole of each sample and the formula mass. What pattern do you observe?

2. What do you need to do to predict the mass of a mole of any substance if the formula is known?

3. Predict the mass of one mole of each of the following:

a. $Ca(OH)_2$

b. H_2SO_4

c. $Al(NO_3)_3$

4. Find the mass of 3 moles of each of the substances in # 3.

a. $Ca(OH)_2$

b. H_2SO_4

c. $Al(NO_3)_3$

5. Write the **steps for calculating the mass of a given number of moles**.

   1.

   2.

6. Use the above rule to find the mass of each of the following:

a. One mole of CO

b. Five moles of CO

Student Handout
LAB ACTIVITY: MOLE-MASS Name _____

Purpose
To be able to calculate the number of moles in a sample if the mass and the formula of the substance is known.

Safety, Handling, and Disposal
Follow instructions of your teacher. DO NOT OPEN PACKAGES! Dispose of used reagents according to local ordinances.

Materials
Containers with different substances, balance, worksheet, calculator, pencil

Procedure
In this activity you have to find the mass of each sample, then find the number of moles of the substance in each package. Record the information in the proper box in the table.
Write the procedure you will use to complete the table below.

Complete the table. SHOW WORK FOR EACH QUESTION ON THE SIDE or back of this sheet.

WORK

#	Formula	What is the mass of the sample and bag in grams?	What is the mass of the bag in grams?	What is the mass of the sample in grams?	Formula mass in grams	What is the number of **moles** in the sample?	What is the number of **formula units** in the sample?

#	Formula	What is the mass of the sample and bag in grams?	What is the mass of the bag in grams?	What is the mass of the sample in grams?	Formula mass in grams	What is the number of **moles** in the sample?	What is the number of **formula units** in the sample?

Quiz Name _____

Purpose

To evaluate students' comprehension of the mole as a counting unit.

Safety, Handling, and Disposal

Follow instructions of your teacher. Dispose of used reagents according to local ordinances.

Materials

Containers for different substances such as bags that zip or jars with covers, balance, sugar ($C_{12}H_{22}O_{11}$) or salt (NaCl), calculator, pencil.

Procedure

1. Write the procedure you will use to measure out 0.2 moles of table sugar ($C_{12}H_{22}O_{11}$). Show all calculations.

Write **your name on the container**.

Write the formula of the substance you are placing into the container **on the container.**

Record the **mass of the empty container on the container** and here _____ .

Formula mass of your substance _____

Record the mass of the sample you will place in the bag _____

Record the mass of the container and sample _____

2. Give your prepared sample to another student as directed by the teacher.
3. Get a sample prepared by another student as directed by the teacher.
4. Write the procedure you will use to find the number of moles in the container you received from another student.

Show all work.

The name of the student whose sample you checked. _____

Formula of the substance _____

Formula mass of the sample _____

Mass of the container _____

Mass of the sample and container _____

Mass of the sample _____

Number of moles in the sample _____

Quiz Name _____

Purpose

To evaluate students' comprehension of the mole as a counting unit.

Safety, Handling, and Disposal

Follow instructions of your teacher. Dispose of used reagents according to local ordinances.

Materials

Containers for different substances such as bags that zip or jars with covers, balance, sugar ($C_{12}H_{22}O_{11}$) or salt (NaCl), calculator, pencil

Procedure

1. Write the procedure you will use to measure out 1.1 moles of table salt (NaCl).

Use 35.5 as the atomic mass of Cl. Show all calculations.

Write **your name on the container**.

Write the formula of the substance you are placing into the container **on the container.**

Record the **mass of the empty container on the container** and here _____ .

Formula mass of your substance _____

Record the mass of the sample you will place in the bag _____

Record the mass of the container and sample _____

2. Give your prepared sample to another student as directed by the teacher.
3. Get a sample prepared by another student as directed by the teacher.
4. Write the procedure you will use to find the number of moles in the container you received from another student.

Show all work.

The name of the student whose sample you checked. _____

Formula of the substance _____

Formula mass of the sample _____

Mass of the container _____

Mass of the sample and container _____

Mass of the sample _____

Number of moles in the sample _____

Quiz **Name _____**

971 Make a bag filled with 0.2 moles of table sugar, C12H22O11.

Attach a label to the bag. On the label write the #, formula of the substance, and the number of moles you need to measure. Find the mass of the bag. Record the mass of the bag on the label and on this paper on the bottom of the sheet. **Show all calculations**. Write the mass of the sugar, the bag, and the total mass of the bag with the sample in it on the lines provided below. When the bag is prepared, check with your teacher to find out who should check your work. Check the work of a student as assigned by your teacher. Write your name on the bottom of the quiz paper of the student whose work you checked.

Mass of the sugar _____
Mass of the bag _____
Total Mass _____

Checked by _____

Quiz **Name _____**

#972 Make a bag filled with 1.0 mole of salt, NaCl. (Use 35.5 as the mass of Cl.)

Attach a label to the bag. On the label write the #, formula of the substance, and the number of moles you need to measure. Find the mass of the bag. Record the mass of the bag on the label and on this paper on the bottom of the sheet. **Show all calculations**. Write the mass of the salt, the bag, and the total mass of the bag with the sample in it on the lines provided below. When the bag is prepared, check with your teacher to find out who should check your work. Check the work of a student as assigned by your teacher. Write your name on the bottom of the quiz paper of the student whose work you checked.

Mass of the salt _____
Mass of the bag _____

Total Mass _____

Checked by _____

Instructor Notes
INTRODUCTION TO THE MOLE

Time Required

Activity # 1, Introduction to the Mole, and possibly Mole worksheet # 1 could be done in one class period of 40 minutes with some classes. Some classes will have to complete the worksheet at home or during the next class meeting.

Activity # 2, Introduction to the Mole, class discussion of the concepts and the challenge should be completed in one 40-minute class.

Lab # 1, Finding the Mass of a Mole, should take 40 minutes, but could take longer if many samples are used.

Lab Activity: Mole-Mass should take 40 minutes, but could take longer if many samples are prepared.

Quiz should take 30 to 40 minutes depending on the group.

Group Size

Activity # 1 and Activity # 2 could be done in groups of four. All other activities could be done individually. The only limitation is the number of balances and prepared samples for Lab # 1.

Materials needed

Plastic zip-lock bags, bottles with stoppers, labels, three types of candy (You will need to make packages of four. Each group gets three types of candy, a total of 12 candies per group). Copper, aluminum, and iron nails or pellets, table salt, sugar, sulfur, baking soda, and other substances as available. Containers with attached labels for the quiz. Calculators, transparency, overhead projector.

Safety, Handling, and Disposal

You decide if students may eat the candy, not in the lab area, after the activity. I save the samples from year to year. Dispose of used reagents according to local ordinances.

Points to Cover in the Pre-Lab Discussion

Warn the students not to open packages. Tell students to return packages to you for disposal or storage.

In Activity # 1, you'll need to tell students the average mass of the plastic bag to subtract that mass from the total mass of the candy and the bag. Discuss the questions in the introduction section before students perform the activity. Review operations with numbers written in scientific notation and the use of calculators. You may also want to discuss significant figures.

Tell the students to record the masses for each type of candy in a table either on a sheet of paper or on a transparency. If time permits have students find the mass of 2 OWLS of Hershey's Kisses by combining their OWL of Hershey's Kisses with the OWL of another group. Have the masses of 2 OWLS recorded in a separate table or transparency.

In Activity # 2, use the transparency of class data of masses of one OWL of each type of candy or write the data on the board. Specify what unit to use when reporting masses (i.e., grams). Elicit that although an OWL of any item contains the same number of items, the masses of OWLS of different items are different. Elicit that the mass of one OWL of Hershey's Kisses is always approximately _____ g . Elicit that the mass of one OWL of caramels is always approximately _____ g and that the mass of one OWL of Minty Bells is always approximately _____ g.

Use the transparency on which the students recorded the mass of 2 OWLS. Discuss how to find the mass of a given number of OWLS.

Distribute Lab # 2.

Procedural Tips and Suggestions

- I make packages containing four candies because that is the size of the groups in my class. I make three packages of candy per group. As listed in the student handout, I used Hershey's Kisses, Minty Bells, and caramels.

- I used an OWL as a counting unit because the owl is the school mascot.

- Warn the students not to open the packages in the lab area.

- After students complete activity # 2, an application activity that can be used is as follows: Challenge students to guess the number of Kisses in a jar. The student with the closest count gets the candy. You will need to have the mass of the jar recorded, but tell students that you will provide them with some information and equipment, if they can explain the reasons for its use. Give out the mass of the jar only if students have a reasonable procedure.

- For the lab "Finding the Mass of a Mole" prepare 1 mole samples of elements and compounds in bottles or plastic zip-lock bags. Attach a label to each container before finding the mass of the container. You may want to write the formula on the label or write the name and ask students to find the formula. Record the mass of each container on the label. I save these from year to year. Water has to be refilled, but the solids keep fine.

<u>Some examples of a mole :</u>

Water: 18 g	Copper: 64 g	Aluminum: 27 g
Salt(NaCl): 58.5g	Carbon : 12g	etc.

For the lab activity "Mole-Mass" prepare samples of different substances. Attach a label to each container before finding the mass of the container. Record the name or formula of the substance and the mass of the container on each label. Some samples made as part of the quiz may be used in future years for this activity. In this activity, the last column may be omitted.

<u>Possible samples</u>:		<u>Key</u>	
iron	14 g	0.25 moles	
sulfur	21 g	0.67 moles	
copper sulfate (anhydrous)	12.5g	0.08 moles	etc.

If the students will be expected to solve multi-step problems, introduce factor-label method after students have a good understanding of the concepts. Additional practice problems should be assigned from the text used for the course.

The quiz is presented in two formats. Pages 14 and 15 are examples of a quiz that gives a great deal of guidance to students. I make up enough quizzes, each with a different amount of moles, so that each student in a class has a unique assignment. You may use other substances, like baking soda. Make sure that the sample will fit into the container and the total weight does not exceed the range of the balance. The second type of quiz, on page 16, has fewer directions for the students.

Sample Results

See possible samples above.

References

I have not used any specific references. I just combined many ideas I heard from different people.