ABSTRACT-

Presented are the teacher's guide and student manual for one of a series of self-instructional, computer-based learning modules for an introductory, undergraduate chemistry course. The student manual for this unit on the concept of the mole includes objectives, prerequisites, discussion, problem exercises, and 20 problem sets. Included in the teacher's guide are implementation instructions, references, answers to problem sets, sample run of the program showing a quiz being printed and students' answers being graded, a listing of the computer program in BASIC, and 10 unit tests. (ST)
Unit 1. The Mole Concept

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A Computer-enriched Module for Introductory Chemistry

\[ 6.02 \times 10^{23} \]

atoms of carbon

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OBJECTIVES

When you finish this unit you will know

1. what a mole is, and how to convert between moles and
   a. the number of atoms or molecules
   b. the weight of a chemical species
   c. the gaseous volume under ideal conditions.
2. how to solve percent composition problems.
3. how to calculate the empirical and molecular formulas from a given percent composition analysis.

PREREQUISITES

You should have mastered the use of conversion factors, before attempting this module. Read the Appendix on Conversion Factors. If you can answer the questions in that manual, you are ready to start this module.

INTRODUCTION

The mole concept is the foundation on which all quantitative chemistry is built. An understanding of this concept is essential to solving problems in chemistry. In this module, we will explain what a mole is, and show some typical uses of this concept.

DISCUSSION

You have learned that units are attached to numbers to give them physical significance. You also learned to convert between different sets of units. One reason for converting between different sets of units is that some units are more useful than others for a given situation. For example, we would normally report the distance between New York and Chicago in miles or kilometers rather than in inches or millimeters. Conversely, we might measure a collar size in inches or centimeters, but we probably wouldn't use miles or kilometers. A baker often measures bakery goods in dozens, because he makes too many items to conveniently classify them in smaller units. In each case, the units used are chosen for their convenience.

Because atoms are such small entities, it is impossible to use or work with individual atoms in most chemical reactions. What is needed is a unit representing a number of atoms which can reasonably and conveniently be handled by the average chemist. This unit is the "mole", and is to a chemist what the dozen is to a baker. A mole of anything is defined as $6.023 \times 10^{23}$ of these things. While this unit could be used to describe anything (just as we could express a collar size in kilometers), its size makes it most convenient to use for atoms and molecules. The
number $6.023 \times 10^{23}$ is called "Avogadro's number".

<table>
<thead>
<tr>
<th>1 dozen</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 gross</td>
<td>144</td>
</tr>
<tr>
<td>1 mole</td>
<td>$6.023 \times 10^{23}$</td>
</tr>
</tbody>
</table>

**Example 1.** How many moles are there in $1.506 \times 10^{24}$ atoms of helium? This problem is a simple conversion problem, from atoms to moles. The conversion factors are $1$ mole He = $6.023 \times 10^{23}$ He atoms. We use this conversion factor as follows:

$$1.506 \times 10^{24} \text{ atoms He} \times \frac{1 \text{ mole He}}{6.023 \times 10^{23} \text{ atoms He}} = 2.5 \text{ moles He}$$

**Example 2.** How many molecules are there in $0.75$ moles of CH₄? How many atoms?

Answer to the first part:

$$0.75 \text{ moles CH}_4 \times \frac{6.023 \times 10^{24} \text{ molecules CH}_4}{1 \text{ mole CH}_4} = 4.5 \times 10^{23} \text{ molecules CH}_4$$

Answer to the second part:

Since there are four hydrogen atoms and one carbon atom for each molecule, there are five atoms per molecule of CH₄.

$$0.75 \text{ moles CH}_4 \times \frac{6.023 \times 10^{24} \text{ molecules CH}_4}{1 \text{ mole CH}_4} \times \frac{5 \text{ atoms}}{1 \text{ molecule}} = 2.25 \times 10^{24} \text{ atoms}$$

The weight in grams of an Avogadro's number of atoms or molecules is numerically equal to the atomic or molecular weight in atomic mass units (amu). Thus, one mole of sodium atoms (atomic weight = 23.0 amu) weighs exactly 23.0 grams, and one mole of hydrogen chloride gas (molecular weight = 36.46 amu) weighs 36.46 g. When referring to one mole of atoms, the term "gram-atom" is often used instead of "mole".

**Example 3.** How many moles are there in 30.0 g of carbon?

The required conversion factor is

$$1 \text{ mole C} = 12.0 \text{ g C}$$

Then the problem is solved

$$30.0 \text{ g C} \times \frac{1 \text{ mole C}}{12.0 \text{ g C}} = 2.5 \text{ mole C}$$

**Example 4.** How much do 3 moles of water weigh?

Answer: 3 moles $H_2O \times \frac{18 \text{ g } H_2O}{1 \text{ mole } H_2O} = 54.0 \text{ g } H_2O$

**Example 5.** How many grams is 3.820 gram atoms of Si?

$$9.820 \text{ gram atoms of Si} \times \frac{28.086 \text{ g Si}}{1 \text{ gram atom Si}} = 276 \text{ g}$$

**Example 6.** If one atom of element X weighs $6.658 \times 10^{-23}$ g, what is the atomic weight of X?

$$\frac{6.658 \times 10^{-23} \text{ g}}{1 \text{ atom}} \times \frac{6.023 \times 10^{23} \text{ atoms}}{1 \text{ mole}} = 40.1 \text{ g/mole}$$
Example 7. What is the molecular weight of SiF_4?

Atomic weights:  
- Si: 28.086  
- F: 19

Molecular weight of SiF_4 = 28.086 + 4(19) = 104.086

Example 8. What is the mass in grams of \(3.46 \times 10^{24}\) atoms of S?

\[
3.46 \times 10^{24} \text{ S atoms} \times \frac{1 \text{ mole S}}{6.02 \times 10^{23} \text{ S atoms}} \times \frac{32 \text{ g}}{1 \text{ mole S}} = 184 \text{ g}
\]

Example 9. How many grams of F are in 0.650 moles of SeF_4?

0.650 moles of SeF_4 \times \frac{4 \text{ moles of F}}{1 \text{ mole SeF}_4} \times \frac{19 \text{ g of F}}{1 \text{ mole F}} = 49.4 \text{ g}

EXERCISES

1. What is the mass in grams of \(3.96E+24\) atoms of O?
2. How many grams is \(9.33E+24\) gram atoms of O?
3. If one atom of element X weighs \(1.796E-23\) g, what is the atomic weight of X?
4. How many atoms are there in \(11.797\) grams of Cu?
5. How many gram atoms of C are there in \(77.798\) grams of C?
6. What is the molecular weight of NO_2?
7. One mole of C, is placed on the left pan of a two-pan balance. How many moles of PCl_3 must be placed on the other pan to exactly balance the mole of CO_2?
8. What is the mass (in grams) of \(6.620\) moles of SiC?
9. How many molecules of HF add up to a mass of \(19.900\) grams?
10. How many moles of Br_2 molecules are there in \(14.950\) grams of Br_2?
11. How many atoms of Ca are there in \(5.646\) grams of CaF_2?
12. How many atoms of C are there in \(2.3357E+24\) molecules of CO?
13. How many grams of N are in \(5.611E+24\) molecules of N_2?
14. How many grams of Ca are in \(1.765\) moles of CaF_2?
15. How many moles of Cr atoms are there in \(10.799\) grams of Cr_2O_3?
One mole of a gas will occupy a volume of 22.4 liters at 0°C and one atmosphere of pressure. The combination of 0°C and 1 atmosphere is called standard temperature and pressure, abbreviated STP. Later, you will learn how to convert between volume and moles under other conditions, but for now we will limit our discussion to STP.

Example 10. How many moles of chlorine gas are there in 33.6 l at STP?

The required conversion factor is

\[ 1 \text{ mole } \text{Cl}_2 = 22.4 \text{ l } \text{Cl}_2 \text{ (STP)} \]

Then unit conversion gives the answer

\[ 33.6 \text{ l } \text{Cl}_2 \text{ (STP)} \times \frac{1 \text{ mole } \text{Cl}_2}{22.4 \text{ l } \text{Cl}_2 \text{ (STP)}} = 1.5 \text{ moles } \text{Cl}_2 \]

Example 11. How much volume will 3.5 moles He occupy at STP?

Answer: \( 3.5 \text{ moles } \text{He} \times \frac{22.4 \text{ l } \text{He} \text{ (STP)}}{1 \text{ mole} \text{H}} = 78.4 \text{ l } \text{STP} \)

Problems on Relationship between Moles and Volume at STP

1. How many moles ClO₂ are there in 29.498 liters of ClO₂ at standard conditions (0 degrees and 1 atm pressure)?

2. How many grams of NO₂ occupy 1.260 liters at standard conditions?

3. How many molecules of NH₃ are in 75.597 liters of NH₃ at standard conditions?

4. How many gram atoms of H are in 3.250 liters of PH₃ at standard conditions?

5. What is the weight (in grams) of Si atoms in 87.798 liters of SiH₄ at standard conditions?

6. How many O atoms are there in 5.630 liters of SO₃ at standard conditions?

* This section may be skipped.
PERCENT COMPOSITION

Occasionally, it is necessary to calculate the percent composition of a particular component in a compound or mixture. For example, Ivory soap is said to be 99.44% pure. This means that of each 100 grams of powder in the soapbox, 99.44 g are soap and 0.56 g are some other material. A particular course may contain 25% freshmen. Then, on the average, for every 100 people in the class, 25 would be freshmen. The general formula for percent composition is

\[
\% \text{ of } A \text{ in a mixture} = \frac{\text{amount of } A}{\text{amount of total mixture}} = 100\%
\]

Note that the formula doesn't specify how the "amount" is measured. In this module, we'll also measure by weight and calculate weight percents. Later on you will need to calculate volume percent and mole percent.

**Example 12.** A given brand of cat food is analyzed and found to contain 2.5 g protein in a 20.0 gram sample. What is the percent of protein in the cat food?

**Answer:**

\[
\% \text{ protein} = \frac{\text{wt protein}}{\text{wt sample}} \times 100\%
\]

\[
= \frac{2.5}{20} \times 100\% = 12.5\%
\]

You can also reverse the process; you can calculate the actual amount of a given component, if you know the percent composition and the total mixture weight.

**Example 13.** The same cat food contains "not more than 3% ash". What is the maximum amount of ash in a 40 gram sample?

**Answer:**

\[
40 \text{ g sample} \times \frac{3\% \text{ ash}}{100\% \text{ sample}} = 1.2 \text{ g ash}
\]
Example 14. Calculate the percent by weight of each element in \( \text{H}_2\text{O}_7\text{S}_2 \).

One mole of \( \text{H}_2\text{O}_7\text{S}_2 \) weighs

\[
2(1) + 7(16) + 2(32) = 178 \text{ g}.
\]

In one mole of \( \text{H}_2\text{O}_7\text{S}_2 \) are

\[
2(1) \text{ grams of H or 2 g} \\
7(16) \text{ grams of O or 112 g} \\
2(32) \text{ grams of S or 64 g}
\]

Percent by weight:

\[
\begin{align*}
\text{H:} & \quad \frac{2}{178} \times 100 = 1.12\% \text{ H} \\
\text{O:} & \quad \frac{112}{178} \times 100 = 62.92\% \text{ O} \\
\text{S:} & \quad \frac{64}{178} \times 100 = 35.96\% \text{ S}
\end{align*}
\]

**EMPIRICAL AND MOLECULAR FORMULAS FROM ANALYSIS**

In order to find the relative number of atoms of the different elements in a compound, we must determine by chemical analysis, the relative weights of the elements making up the compound. Let us see how this is done.

Example 15. Glucose, a type of sugar, is found to consist of 40.00\% carbon, 6.66\% hydrogen, and 53.33\% oxygen. What is the simplest chemical formula consistent with this analysis? The easiest way to solve this problem is to assume we have a given amount of sugar, say 100 grams. (We’ll show later that any other number would also work, but 100 is a nice, neat number.) Then in this 100 g, we have

\[
\begin{align*}
100 \text{ g sample} \times \frac{40.00\% \text{ C}}{100\% \text{ sample}} & = 40.00 \text{ g C} \\
100 \text{ g sample} \times \frac{6.66\% \text{ H}}{100\% \text{ sample}} & = 6.66 \text{ g H} \\
100 \text{ g sample} \times \frac{53.33\% \text{ O}}{100\% \text{ sample}} & = 53.33 \text{ g O}
\end{align*}
\]

We can also find the number of moles of C, H, and O in 100 g of sample.

\[
\begin{align*}
40.00 \text{ g C} \times \frac{1 \text{ mole C}}{12.0 \text{ g C}} & = 3.33 \text{ mole C} \\
6.66 \text{ g H} \times \frac{1 \text{ mole H}}{1.0 \text{ g H}} & = 6.66 \text{ mole H} \\
53.33 \text{ g O} \times \frac{1 \text{ mole O}}{16.0 \text{ g O}} & = 3.33 \text{ mole O}
\end{align*}
\]

Thus we find that in glucose the ratios of the number of atoms of C, H and O is \( \text{C:H:O} = 3.33:6.66:3.33 \), or in small whole numbers, 1:2:1. The 1:2:1 ratio is easy to see if we divide each number of moles by the smallest number:

\[
\begin{align*}
\frac{3.33 \text{ mole C}}{3.33 \text{ mole}} & = 1 \text{ C} \\
\frac{6.66 \text{ mole H}}{3.33 \text{ mole}} & = 2 \text{ H} \\
\frac{3.33 \text{ mole O}}{3.33 \text{ mole}} & = 1 \text{ O}
\end{align*}
\]
Thus the ratio of C:H:O is 1:2:1. (It's at this point that the number of grams we initially chose "cancels" out. If we had chosen 200 g, we'd have had 6.66 mole C, 13.32 mole H, and 6.66 mole O, but the ratio would still be 1:2:1.) The simplest chemical formula is C\textsubscript{1}H\textsubscript{2}O\textsubscript{1}.

Sometimes the ratios found are not of small, whole numbers. In that case, we multiply each number in the ratio by 2. If we still don't have small, whole numbers, multiply the original by 3. If that doesn't work, successively try 4, 5, up to 9. (If it doesn't work by that time, go back and check your arithmetic.)

**Example 16.** Propane is a compound which contains only carbon and hydrogen. A chemical analysis of propane reveals that it is 18.18\% hydrogen. Find the simplest chemical formula for propane.

If 18.18\% of propane is hydrogen, then the rest of propane or 81.82\% must be carbon. Then in 100 g of sample, there are 81.82 g carbon and 18.18 g hydrogen. Then there are

\[
\frac{81.82 \text{ g C}}{12.0 \text{ g C}} = 6.8 \text{ moles C}, \quad \text{and} \quad \frac{18.18 \text{ g H}}{1.0 \text{ g H}} = 18.18 \text{ moles H}.
\]

The C:H ratio is 6.8:18.18. What is it in terms of small whole numbers? Let's see. Dividing both sides by 6.8 moles, the ratio of C to H is

\[
\frac{6.8 \text{ moles C}}{6.8 \text{ moles}} = 1 \quad \text{C} \quad \frac{18.18 \text{ moles H}}{6.8 \text{ moles}} = 2.67 \quad \text{H} \quad \text{C}:\text{H} = 1:2.67
\]

Multiplying by 2 yields C:H = 2:5.34, but 5.34 is not close enough to any whole number. Multiplying by 3 gives C:H = 3:8.01. If we allow for errors in the experimental determination of percent composition, this is reasonably close to 3:8, and the simplest formula for propane is probably C\textsubscript{3}H\textsubscript{8}.

The simplest possible formula is also called the empirical formula. The molecular formula indicates the number of atoms in a molecule of a molecular substance. The molecular formula may be identical with the simplest formula, or the molecular formula may be an integral multiple of the simplest formula. The molecular formula can be determined if the molecular weight is known.

**Example 17.** The molecular weight of glucose is 180 g/mole. What is the formula of glucose?

The weight of the empirical formula for glucose C\textsubscript{1}H\textsubscript{2}O\textsubscript{1} (see Example 15) is 30 g. Since the molecular weight is 180, there must be 180/30 or 6 C\textsubscript{1}H\textsubscript{2}O\textsubscript{1} groups in glucose. Therefore, the molecular formula is C\textsubscript{6}H\textsubscript{12}O\textsubscript{6}.

**Example 18.** If the molecular weight of propane is 44 g/mole, what is the molecular formula for propane?
The weight of the empirical formula, C\textsubscript{3}H\textsubscript{8}, is 44 g/mole. Thus, the empirical formula is also the molecular formula in this case.

The steps used to solve these problems can be summarized as follows:

Step 1
Calculate the number of grams of each component, assuming some convenient amount of sample (usually 100 g).

Step 2
Calculate the number of moles of each component, by dividing the weight of each component by the atomic weight of that component.

Step 3
Divide each quotient from Step 2 by the smallest quotient from Step 2 in order to find the simplest ratios.

Step 4
If the resulting numbers are not integers, successively multiply every number in the ratio by small, whole integers, until all the numbers in the ratio are whole numbers. These numbers are the ones associated with each component in the empirical formula.

Step 5
If the molecular weight is given, divide it by the empirical weight. Multiply the empirical formula by this factor in order to get the molecular formula.

The following example shows specifically where each step is applied. Examine it carefully. Now see if you can identify the steps in Examples 15 through 18. When you thoroughly understand these examples, you may complete this module using the program MOLE which will provide additional practice problems of this type.

Example 19. Phosphorus pentoxide contains only phosphorus and oxygen. Chemical analysis reveals that this compound contains 56.33% oxygen, and has a molecular weight of 284 g/mole. Find the molecular formula.

Step 1
Assume 100 g compound.

\[ \text{g oxygen} = 100 \text{ g compound} \times \frac{56.33\% \text{ O}}{100\% \text{ compound}} = 56.33 \text{ g O} \]

\[ \text{g phosphorus} = 100 - 56.33 = 43.67 \text{ g P} \]

Step 2

\[ 56.33 \text{ g O} \times \frac{1 \text{ mole O}}{16 \text{ g O}} = 3.52 \text{ moles O} \]

\[ 43.67 \text{ g P} \times \frac{1 \text{ mole P}}{31 \text{ g P}} = 1.41 \text{ moles P} \]

Step 3

\[ \frac{3.52 \text{ moles O}}{1.41 \text{ moles P}} = 2.5 \text{ O} \]

\[ \frac{1.41 \text{ moles P}}{1.41 \text{ moles P}} = 1 \text{ P} \]
Step 4

P:O = 1:2.5
Multiply by 2: P:O = 2:5
Empirical formula = P₂O₅

Step 5

Empirical weight = 2(31) + 5(16) = 142
Formula weight = 284
\[
\frac{284}{142} = 2
\]

Molecular formula = 2 × P₂O₅ = P₄O₁₀

Now use the program MOLE to generate a unique set of problems that you may use to test your understanding of these ideas.
Problem Set 1

1. WHAT IS THE PERCENT BY WEIGHT OF EACH ELEMENT IN C₆H₆ ?

2. HOW MANY ATOMS ARE THERE IN 73.800 GRAMS OF Ti ?

3. THE PERCENTAGE COMPOSITION BY WEIGHT OF A COMPOUND IS
   C 80.00
   H 20.00
   WHAT IS ITS EMPIRICAL OR SIMPLEST FORMULA?

4. THE EMPIRICAL FORMULA OF A COMPOUND IS C₆H₆O.
   ITS MOLECULAR WEIGHT IS 46.00. WHAT IS ITS MOLECULAR FORMULA?

5. HOW MANY MOLES OF Sn ATOMS ARE THERE IN 17.797 GRAMS OF SnCl₂?

6. HOW MANY MOLES OF N₂O₄ MOLECULES ARE THERE IN 37.849 GRAMS OF N₂O₄ ?

Problem Set 2

1. THE EMPIRICAL FORMULA OF A COMPOUND IS CH₄N.
   ITS MOLECULAR WEIGHT IS 60.00. WHAT IS ITS MOLECULAR FORMULA?

2. CALCULATE THE PERCENT BY WEIGHT OF EACH ELEMENT IN C₆H₁₄.

3. WHAT IS THE MASS IN GRAMS OF 4.23789E+24 ATOMS OF C ?

4. HOW MANY MOLECULES OF O₂ ADD UP TO A MASS OF 26,299 GRAMS?

5. HOW MANY GRAMS OF Pb ARE IN 1.295 MOLES OF PbF₂?

6. THE PERCENTAGE COMPOSITION BY WEIGHT OF A COMPOUND IS:
   C 25.53
   H 6.38
   O 68.09
   WHAT IS ITS EMPIRICAL OR SIMPLEST FORMULA?
Problem Set 3

1. How many moles of CO₂ molecules are there in 47.450 grams of CO₂?
2. How many atoms of Se are there in 7.82570E+23 molecules of H₂Se?
3. What is the percent by weight of each element in C₆H₆?
4. The percentage composition by weight of a compound is:
   C 80.00
   H 20.00
   What is its empirical or simplest formula?
5. The empirical formula of a compound is CH.
   Its molecular weight is 78.00. What is its molecular formula?
6. If one atom of element X weighs 7.957E-23 g, what is the atomic weight of X?

Problem Set 4

1. How many grams of Br are in 9.391E+23 molecules of HBr?
2. How many atoms are there in 93.899 grams of Si?
3. The percentage composition by weight of a compound is:
   C 42.86
   H 2.38
   O 38.10
   N 16.67
   What is its empirical or simplest formula?
4. Calculate the percent by weight of each element in C₆H₁₄.

5. The empirical formula of a compound is CH₃N₂O₂.
   Its molecular weight is 150.00. What is its molecular formula?
6. What is the molecular weight of N₂O₄?
Problem Set 5

1. The percentage composition by weight of a compound is
   C 16.00
   H 4.00
   O 42.67
   N 37.33
   What is its empirical or simplest formula?

2. How many moles of PH₃ molecules are there in 46.999 grams of PH₃?

3. What is the mass in grams of 2.94361E+24 atoms of Ge?

4. The empirical formula of a compound is C₃H₇.
   Its molecular weight is 86.00. What is its molecular formula?

5. How many moles of H atoms are there in 25.799 grams of C₆H₆?

6. What is the percent by weight of each element in CaO?

Problem Set 6

1. The percentage composition by weight of a compound is
   C 52.17
   H 13.04
   O 34.78
   What is its empirical or simplest formula?

2. The empirical formula of a compound is C₇H₆O₃.
   Its molecular weight is 138.00. What is its molecular formula?

3. How many atoms of Zn are there in 5.780 grams of ZnCl₂?

4. What is the mass in grams of 3.82269E+24 atoms of Br?

5. How many moles of CH₃P molecules are there in 25.649 grams of CH₃P?

6. What is the percent by weight of each element in CuSO₄?
Problem Set 7

1. The percentage composition by weight of a compound is
   C 10.81
   H 2.70
   O 28.83
   S 57.66
   What is its empirical or simplest formula?

2. How many grams of O are in 6.742E+23 molecules of ClO₂?

3. How many gram atoms of Ti are there in 45.300 grams of Ti?

4. How many molecules of CO add up to a mass of 18.049 grams?

5. Calculate the percent by weight of each element in C₂H₅O₂N.

Problem Set 8

1. One mole of HBr is placed on the left pan of a two-pan balance. How many moles of BF₃ must be placed on the other pan to exactly balance the mole of HBr?

2. The empirical formula of a compound is NO₂. Its molecular weight is 92.00. What is its molecular formula?

3. How many grams of O are in 4.065 moles of CO₂?

4. How many atoms are there in 69.497 grams of Ti?

5. The percentage composition by weight of a compound is C 83.72
   H 16.28
   What is its empirical or simplest formula?

6. Calculate the percent by weight of each element in H₄N₂.
Problem Set 9

1. Calculate the percent by weight of each element in C\textsubscript{2}H\textsubscript{5}O\textsubscript{2}\textsubscript{N}.

2. What is the mass in grams of 6.00781E+24 atoms of S?

3. The empirical formula of a compound is C\textsubscript{3}H\textsubscript{7}.
   Its molecular weight is 86.00. What is its molecular formula?

4. What is the mass (in grams) of 9.260 moles of Pb(NO\textsubscript{3})\textsubscript{2}?

5. The percentage composition by weight of a compound is
   H 5.88
   O 94.12
   What is its empirical or simplest formula?

6. How many moles of C atoms are there in 24.798 grams of NaHCO\textsubscript{3}?

Problem Set 10

1. Calculate the percent by weight of each element in C\textsubscript{6}H\textsubscript{6}.

2. How many grams of O are in 2.900 moles of CO\textsubscript{2}?

3. If one atom of element X weighs 4.665E-23 g, what is the atomic weight of X?

4. The empirical formula of a compound is CH\textsubscript{3}.
   Its molecular weight is 30.00. What is its molecular formula?

5. The percentage composition by weight of a compound is
   C 10.81
   H 2.70
   O 28.83
   S 57.66
   What is its empirical or simplest formula?

6. What is the mass (in grams) of 1.510 moles of SO\textsubscript{2}?
Problem Set 11

1. THE PERCENTAGE COMPOSITION BY WEIGHT OF A COMPOUND IS
   C 67.92
   H 5.66
   N 26.42
   WHAT IS ITS EMPirical OR SIMPLEST FORMULA?

2. HOW MANY MOLECULES OF NO ADD UP TO A MASS OF 6.750 GRAMS?

3. IF ONE ATOM OF ELEMENT X WEIGHS 5.889E-23 G, WHAT IS THE
   ATOMIC WEIGHT OF X ?

4. CALCULATE THE PERCENT BY WEIGHT OF EACH ELEMENT IN C₁₆H₂O₂S₂.

5. HOW MANY GRAMS OF F APP IN 4.315 MOLES OF SeF₄?

6. THE EMPIRICAL FORMULA OF A COMPOUND IS C₃H₂NO₂;
   ITS MOLECULAR WEIGHT IS 168.00. WHAT IS ITS MOLECULAR FORMULA?

Problem Set 12

1. HOW MANY MOLECULES OF NO ADD UP TO A MASS OF 47.149 GRAMS?

2. HOW MANY GRAMS IS 2.620-GRAM ATOMS OF Ge?

3. THE EMPIRICAL FORMULA OF A COMPOUND IS C₃H₄N.
   ITS MOLECULAR WEIGHT IS 108.00. WHAT IS ITS MOLECULAR FORMULA?

4. THE PERCENTAGE COMPOSITION BY WEIGHT OF A COMPOUND IS
   H 12.50
   N 87.50
   WHAT IS ITS EMPirical OR SIMPLEST FORMULA?

5. CALCULATE THE PERCENT BY WEIGHT OF EACH ELEMENT IN C₂H₆O₄S₄.

6. HOW MANY GRAMS OF Al APP IN 4.050 MOLES OF Al(OH)₃?
Problem Set 13

1. The percentage composition by weight of a compound is
   C 82.76
   H 17.24
   What is its empirical or simplest formula?

2. One mole of NiS is placed on the left pan of a two-pan balance. How many moles of SnCl₂ must be placed on the other pan to exactly balance the mole of NiS?

3. What is the mass in grams of 4.94832E+24 atoms of Cu?

4. The empirical formula of a compound is C₂H₄S₅, its molecular weight is 120.00. What is its molecular formula?

5. How many moles of Ni atoms are there in 80.999 grams of NiS?

6. Calculate the percent by weight of each element in C₂H₄O₂N.

Problem Set 14

1. Calculate the percent by weight of each element in C₂H₆O.

2. How many grams is 7.810 gram atoms of Zn?

3. How many molecules of F₂ add up to a mass of 44.999 grams?

4. The percentage composition by weight of a compound is
   H 1.12
   O 62.92
   S 35.96
   What is its empirical or simplest formula?

5. The empirical formula of a compound is C₂H₄O₂S. Its molecular weight is 296.00. What is its molecular formula?

6. How many atoms of Sn are there in 6.400 grams of SnCl₂?
Problem Set 15

1. The percentage composition by weight of a compound is
   C 67.92
   H 5.66
   N 26.42
   What is its empirical or simplest formula?

2. How many grams of C are in 3.135 moles of NaHCO₃?

3. One mole of CaO is placed on the left pan of a two-pan balance. How many moles of C₆H₆ must be placed on the other pan to exactly balance the mole of CaO?

4. What is the percentage by weight of each element in SO₂?

5. What is the mass in grams of 5.44803E+24 atoms of Cl?

6. The empirical formula of a compound is CH₃O₂S₂. Its molecular weight is 222.00. What is its molecular formula?

Problem Set 16

1. Calculate the percentage by weight of each element in C₄H₁₀.

2. If one atom of element X weighs 7.957E-23 g, what is the atomic weight of X?

3. The empirical formula of a compound is HNO₃. Its molecular weight is 63.00. What is its molecular formula?

4. How many molecules of NH₃ add up to a mass of 29.150 grams?

5. The percentage composition by weight of a compound is:
   C 60.87
   H 4.35
   O 34.78
   What is its empirical or simplest formula?

6. How many grams of O are in 3.335E+24 molecules of CO₂?
Problem Set 17

1. The percentage composition by weight of a compound is
   - H 2.13
   - N 29.79
   - S 68.09
   What is its empirical or simplest formula?

2. The empirical formula of a compound is $C_3H_2NO_2$. Its molecular weight is 168.00. What is its molecular formula?

3. How many grams of Br are in $5.881E+24$ molecules of Br$_2$?

4. One mole of Pb(NO$_3$)$_2$ is placed on the left pan of a two-pan balance. How many moles of KI must be placed on the other pan to exactly balance the mole of Pb(NO$_3$)$_2$?

5. How many atoms are there in 75.100 grams of O?

6. Calculate the percent by weight of each element in $C_2H_2N_2$.

Problem Set 18

1. How many molecules of N$_2$ add up to a mass of 8.149 grams?

2. The empirical formula of a compound is $C_2H_4NO$. Its molecular weight is 116.00. What is its molecular formula?

3. How many grams of F are in $5.718E+23$ molecules of HF?

4. How many atoms are there in 98.498 grams of Cr?

5. The percentage composition by weight of a compound is
   - C 66.67
   - H 7.41
   - N 25.93
   What is its empirical or simplest formula?

6. What is the percent by weight of each element in AsH$_3$?
Problem Set 19

1. CALCULATE THE PERCENT BY WEIGHT OF EACH ELEMENT IN C₆H₆N₂.

2. ONE MOLE OF PCl₃ IS PLACED ON THE LEFT PAN OF A TWO-PAN BALANCE. HOW MANY MOLES OF ASH₃ MUST BE PLACED ON THE OTHER PAN TO EXACTLY BALANCE THE MOLE OF PCl₃?

3. THE EMPIRICAL FORMULA OF A COMPOUND IS C₆H₆O₅. ITS MOLECULAR WEIGHT IS 296.00. WHAT IS ITS MOLECULAR FORMULA?

4. HOW MANY GRAM ATOMS OF I ARE THERE IN 52.697 GRAMS OF I?

5. THE PERCENTAGE COMPOSITION BY WEIGHT OF A COMPOUND IS O 69.57, N 30.43. WHAT IS ITS EMPIRICAL OR SIMPLEST FORMULA?

6. HOW MANY GRAMS OF O ARE THERE IN 2.787E+24 MOLECULES OF N₂O₅?

Problem Set 20

1. THE PERCENTAGE COMPOSITION BY WEIGHT OF A COMPOUND IS H 12.50, N 87.50. WHAT IS ITS EMPIRICAL OR SIMPLEST FORMULA?

2. THE EMPIRICAL FORMULA OF A COMPOUND IS C₆H₆O₅. ITS MOLECULAR WEIGHT IS 180.00. WHAT IS ITS MOLECULAR FORMULA?

3. HOW MANY MOLES OF C ATOMS ARE THERE IN 15.600 GRAMS OF CaO?

4. ONE MOLE OF HBr IS PLACED ON THE LEFT PAN OF A TWO-PAN BALANCE. HOW MANY MOLES OF C₂H₆ MUST BE PLACED ON THE OTHER PAN TO EXACTLY BALANCE THE MOLE OF HBr?

5. HOW MANY GRAM ATOMS OF Na ARE THERE IN 49.297 GRAMS OF Na?

6. CALCULATE THE PERCENT BY WEIGHT OF EACH ELEMENT IN C₂H₆N₂S₂.
The CM Project

The Computer-enriched Module (CM) project is a collaborative effort by 19 faculty members in the disciplines of chemistry, mathematics and physics, to produce self-instructional computer-based materials at the introductory college level in those disciplines. Each module is designed to be usable in an academic environment with minimal computational facilities, and by students and faculty who are not programming experts. It may be used as an adjunct to standard textual materials, or in many cases, as a replacement for them. The primary aim of each module is to use the computer in such a way that students may take a more active role in the development and discovery of concepts and phenomena.

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TEACHER'S GUIDE TO
A MODULE ON STOICHIOMETRY
UNIT 1. THE MOLE CONCEPT

ROBERT C. WILLIAMS
UNIVERSITY OF NEBRASKA

a computer-enriched module
for introductory chemistry
featuring the program

MOLE

Supported by grants from the
National Science Foundation
Exxon Foundation

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Illinois Institute of Technology
TEACHER'S GUIDE TO UNIT ON THE MOLE CONCEPT OF THE STOICHIOMETRY MODULE

EDUCATIONAL OBJECTIVES

The purpose of this module is to introduce the mole concept, together with the necessary techniques and definitions for interconversion of weights, moles, numbers of atoms or molecules, and percent compositions. Additionally, methods for computation of empirical and molecular formulas are discussed. The pedagogical approach is straightforward. Nineteen examples of increasing complexity are scattered through the module. Twenty problem sets are also included.

IMPLEMENTATION

The unit fits in early in the first semester of the Freshman sequence. The total time for terminal use should be relatively small (only a few minutes per student) since the BASIC program (MOLE) included in this guide generates unique exams of 5 questions for each student. It is intended that he or she take the exam away, solve the problems, and then return to the terminal for checking of the answers. The program makes extensive use of the RND function of BASIC to insure individual exams are different.

For completeness, an optional section on volume of a gas at standard temperature and pressure has been included, together with several problems on these relationships.

References

Molar Masses of Compounds pp 107-121
Empirical Formulas pp 159-164
Molecular Mass and Percent Composition pp 231-236
### Answers to Problem Sets

#### Test 1
1. $4 \times 10^{7.74886}$
2. $9.28 \times 10^{23}$
3. CH$_3$
4. C$_2$H$_4$O
5. $9.39 \times 10^{-2}$
6. $4.11 \times 10^{-1}$

#### Test 2
1. C$_2$H$_6$O$_2$
2. 83.72% C, 16.28% H
3. $8.45 \times 10^{1}$
4. $4.95 \times 10^{23}$
5. $1.11 \times 10^{2}$
6. CH$_3$O

#### Test 3
1. $1.08 \times 10^{0}$
2. $7.83 \times 10^{23}$
3. H $7.74886 \times 10^{0}$
4. CH$_3$
5. C$_6$H$_6$
6. $4.79 \times 10^{1}$

#### Test 4
1. $1.25 \times 10^{2}$
2. $2.01 \times 10^{24}$
3. C$_3$H$_2$NO$_2$
4. 83.72% C, 16.28% H
5. C$_2$H$_6$O$_4$N$_4$
6. $9.20 \times 10^{1}$

#### Test 5
1. CH$_3$N$_2$O$_2$
2. $1.38 \times 10^{0}$
3. $3.55 \times 10^{2}$
4. C$_6$H$_4$
5. $1.98 \times 10^{0}$
6. $2.85207 \times 10^{1}$

#### Test 6
1. C$_2$H$_6$O
2. C$_7$H$_6$O$_3$
3. $2.55 \times 10^{2}$
4. $5.07 \times 10^{2}$
5. $7.54 \times 10^{-1}$
6. Cu $3.98115 \times 10^{1}$
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<thead>
<tr>
<th>TEST 7</th>
<th>TEST 8</th>
<th>TEST 9</th>
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<tr>
<td>1. CH₃O₂S₂</td>
<td>1. 1.19E+00</td>
<td>1. 32.00 % C</td>
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<tr>
<td>2. 3.58E+01</td>
<td>2. O₄N₂</td>
<td>6.67 % H</td>
</tr>
<tr>
<td>3. 9.46E-01</td>
<td>3. 1.30E+02</td>
<td>42.67 % O</td>
</tr>
<tr>
<td>4. 3.88E+23</td>
<td>4. 8.73E+23</td>
<td>18.67 % N</td>
</tr>
<tr>
<td>5. 32.00 % C</td>
<td>5. C₃H₇</td>
<td>5. H₂O</td>
</tr>
<tr>
<td>6. 6.67 % H</td>
<td>6. 12.50 % H</td>
<td>5. 30.7E+03</td>
</tr>
<tr>
<td>7. 42.67 % O</td>
<td>87.50 % N</td>
<td>6. 2.95E-01</td>
</tr>
<tr>
<td>8. 18.67 % N</td>
<td></td>
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<tr>
<th>TEST 10</th>
<th>TEST 11</th>
<th>TEST 12</th>
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<td>1. 92.31 % C</td>
<td>1. 9.46E+23</td>
<td>1. 9.46E+23</td>
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<td>2. 7.69 % H</td>
<td>2. 1.90E+02</td>
<td>2. 1.90E+02</td>
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<tr>
<td>3. 9.28E+01</td>
<td>3. C₆H₅N₂</td>
<td>3. C₆H₅N₂</td>
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<tr>
<td>4. 2.81E+01</td>
<td>4. 5.02E+22</td>
<td>4. NH₂</td>
</tr>
<tr>
<td>5. C₂H₆</td>
<td>3. 3.55E+01</td>
<td>5. 10.81 % C</td>
</tr>
<tr>
<td>6. 64.86 % C</td>
<td>4. 5.29E+02</td>
<td>2.70 % H</td>
</tr>
<tr>
<td></td>
<td>2.70 % H</td>
<td>10.81 % O</td>
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<td></td>
<td>10.81 % O</td>
<td>21.62 % S</td>
</tr>
<tr>
<td></td>
<td>21.62 % S</td>
<td>5. 57.66 % S</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5. 1.09E+02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6. C₆H₄O₄N₂</td>
</tr>
<tr>
<td>TEST 13</td>
<td>TEST 14</td>
<td>TEST 15</td>
</tr>
<tr>
<td>---------</td>
<td>---------</td>
<td>---------</td>
</tr>
</tbody>
</table>
| 1. C<sub>2</sub>H<sub>5</sub> | 1. 52.17 % C  
13.04 % H  
34.78 % O | 1. C<sub>3</sub>H<sub>3</sub>N |
| 2. 6.00E-01 | 2. 5.11E+02 | 2. 3.76E+01 |
| 3. 5.22E+02 | 3. 7.13E+23 | 3. 7.19E-01 |
| 5. 8.92E-01 | 5. C<sub>4</sub>H<sub>8</sub>O<sub>2</sub>S<sub>2</sub> | 5. 3.21E+02 |
| 6. 32.00 % C  
6.67 % H  
42.6 % O  
18.67 % N | 6. 2.03E+22 | 6. C<sub>2</sub>H<sub>4</sub>O<sub>4</sub>S<sub>4</sub> |

<table>
<thead>
<tr>
<th>TEST 16</th>
<th>TEST 17</th>
<th>TEST 18</th>
</tr>
</thead>
</table>
| 1. H<sub>2</sub>7.76 % C  
17.24 % H | 1. HSN | 1. 1.75E+23 |
| 2. 4.79E+01 | 2. C<sub>6</sub>H<sub>4</sub>O<sub>2</sub>N<sub>2</sub> | 2. C<sub>4</sub>H<sub>8</sub>O<sub>2</sub>N<sub>2</sub> |
| 3. HO<sub>3</sub>N | 3. 1.56E+03 | 3. 1.80E+01 |
| 4. 1.01E+24 | 4. 2.00E+00 | 4. 1.14E+24 |
| 5. C<sub>7</sub>H<sub>6</sub>O<sub>3</sub> | 5. 2.83E+2 | 5. C<sub>3</sub>H<sub>4</sub>N |
| 6. 1.77E+02 | 6. 40.00 % C  
13.33 % H  
46.67 % N | 6. As 9.61204E+01 |
<table>
<thead>
<tr>
<th>TEST 19</th>
<th>TEST 20</th>
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</thead>
<tbody>
<tr>
<td>1. 66.67 % C</td>
<td>1. NH₂</td>
</tr>
<tr>
<td>7.41 % H</td>
<td>2. C₆H₆O₆</td>
</tr>
<tr>
<td>25.93 % N</td>
<td>3. 2.78E-01</td>
</tr>
<tr>
<td></td>
<td>4. 2.69E+00</td>
</tr>
<tr>
<td>2. 1.76E+00</td>
<td>5. 2.14E+00</td>
</tr>
<tr>
<td>3. C₁₆H₁₀O₂S₂</td>
<td>6. 20.00 % C</td>
</tr>
<tr>
<td>4. 4.15E-01</td>
<td>3. 33 % H</td>
</tr>
<tr>
<td></td>
<td>23.33 % N</td>
</tr>
<tr>
<td>5. NO₂</td>
<td>53.33 % S</td>
</tr>
<tr>
<td>6. 2.96E+02</td>
<td></td>
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</tbody>
</table>
SOFTWARE

Since random number generating functions may vary from one computer to another, the random number generator in MOLE is included in the program listing. The same series of random real numbers are generated for the same initial seed. The seed used in printing a quiz requested by a student is printed out as the exam number. This same number, when typed in by the student upon return to the terminal for grading, regenerates the same series of random numbers. Thus, the identical set of questions in the quiz are regenerated, making the grading of the student's answers possible.
Sample runs of MOLE showing first, a quiz being printed and then, the student's answers being graded.

PLEASE TYPE IN YOUR NAME

STEVE

STEVE PLEASE INPUT A NUMBER FROM 1 THRU 15,000.

?12391

O.K. STEVE, DO YOU WISH TO TAKE A TEST OR HAVE YOUR TEST GRADED?
IF YOU WISH TO TAKE A TEST, ENTER A 1, AND IF YOU WISH TO HAVE AN EXAM GRADED, ENTER A 2.

?1

EXAM NUMBER 11618

STEVE

THERE ARE 7 QUESTIONS ON THIS EXAM.
THEY ARE ALL ON THE MOLE CONCEPT.
PLEASE ANSWER THE QUESTIONS AT HOME, AND COME BACK WHEN YOU ARE READY TO HAVE YOUR EXAM GRADED.

QUESTION. 1
HOW MANY MOLES ARE THERE IN 145 GRAMS OF COPPER (AT. WT. = 63.54)?

QUESTION. 2
YOU HAVE 21 MOLES OF SODIUM CHLORIDE (NACL). HOW MANY GRAMS OF SODIUM DO YOU HAVE?

QUESTION. 3
YOU HAVE 5.40002E+24 ATOMS OF SILICON (SI). HOW MANY MOLES OF SILICON DO YOU HAVE?

QUESTION. 4
HOW MANY ATOMS ARE THERE IN 6.8 GRAMS OF WATER?

QUESTION. 5
YOU HAVE 4.20001E+24 MOLECULES OF HCL. HOW MANY GRAMS DO YOU HAVE?

QUESTION. 6
HOW MANY GRAMS OF CARBON ARE CONTAINED IN 66 GRAMS OF A COMPOUND THAT IS 70.7 PER CENT CARBON?

QUESTION. 7
HOW MANY MOLES ARE CONTAINED IN 16 GRAMS OF C 35 H 70 O 1 ?

GOOD LUCK STEVE, AND HURRY BACK.
PLEASE TYPE IN YOUR NAME
STEVE

STEVE PLEASE INPUT A NUMBER FROM 1 THRU 15,000.
10.
PLEASE INPUT A NUMBER FROM 1 THRU 15,000.
157
O.K. STEVE, DO YOU WISH TO TAKE A TEST OR HAVE YOUR TEST GRADED?
IF YOU WISH TO TAKE A TEST, ENTER A 1. AND IF YOU WISH TO
HAVE AN EXAM GRADED, ENTER A 2.
12
PLEASE ENTER YOUR EXAM NUMBER.
11618
PLEASE ENTER YOUR 7 ANSWERS IN THE EXACT ORDER OF THE QUESTIONS.
PRESS (RETURN) AFTER EACH ANSWER.
12.28
1462
18.97
16.82E23
1251.2
146.7
13.2E-2

EXAM NUMBER 11618
STEVE

<table>
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<tr>
<th>CORRECT ANSWER</th>
<th>YOUR ANSWER</th>
<th>RESULT</th>
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</thead>
<tbody>
<tr>
<td>2.28202</td>
<td>2.27999</td>
<td>CORRECT</td>
</tr>
<tr>
<td>482.81</td>
<td>462</td>
<td>CORRECT</td>
</tr>
<tr>
<td>8.96564</td>
<td>8.96999</td>
<td>CORRECT</td>
</tr>
<tr>
<td>6.82040E+23</td>
<td>6.82000E+23</td>
<td>CORRECT</td>
</tr>
<tr>
<td>254.245</td>
<td>251.2</td>
<td>CORRECT</td>
</tr>
<tr>
<td>46.662</td>
<td>46.7</td>
<td>CORRECT</td>
</tr>
<tr>
<td>3.15616E-02</td>
<td>3.19999E-02</td>
<td>CORRECT</td>
</tr>
</tbody>
</table>

YOUR GRADE ON THIS QUIZ IS 100 %

MARVELOUS FRIEND, YOU HAVE BEATEN THIS BROKEN MACHINE.
WOULD YOU LIKE TO TAKE ANOTHER QUIZ?
ENTER 1 FOR YES, 2 FOR NO.
12
GOOD LUCK STEVE, AND HURRY BACK.

READY
PLEASE TYPE IN YOUR NAME
DUMB

DUMB PLEASE INPUT A NUMBER FROM 1 THRU 15,000.

O.K. DUMB. DO YOU WISH TO TAKE A TEST OR HAVE YOUR TEST GRADED?
IF YOU WISH TO TAKE A TEST, ENTER A 1. AND IF YOU WISH TO
HAVE AN EXAM GRADED, ENTER A 2.

PLEASE ENTER 1 OR 2!
IF YOU WISH TO TAKE A TEST, ENTER A 1. AND IF YOU WISH TO
HAVE AN EXAM GRADED, ENTER A 2.

EXAM NUMBER 17492

DUMB

THERE ARE 7 QUESTIONS ON THIS EXAM.
THEY ARE ALL ON THE MOLE CONCEPT.
PLEASE ANSWER THE QUESTIONS AT HOME, AND COME BACK
WHEN YOU ARE READY TO HAVE YOUR EXAM GRADED.

QUESTION. 1
HOW MANY MOLES ARE THERE IN 141 GRAMS OF
CARBON MONOXIDE (MOLECULAR WT. = 28.011)?

QUESTION. 2
YOU HAVE 65 MOLES OF METHANE (CH4).
HOW MANY GRAMS OF C DO YOU HAVE?

QUESTION. 3
YOU HAVE 4.30001E+24 ATOMS OF SILICON (Si).
HOW MANY MOLES OF SILICON DO YOU HAVE?

QUESTION. 4
HOW MANY ATOMS ARE THERE IN 6.4
MOLES OF METHANE (CH4)?

QUESTION. 5
YOU HAVE 5.80002E+24 MOLECULES OF HCL.
HOW MANY GRAMS DO YOU HAVE?

QUESTION. 6
HOW MANY GRAMS OF CARBON ARE CONTAINED IN 78
GRAMS OF A COMPOUND THAT IS 22.1 PER CENT CARBON?

QUESTION. 7
THE FORMULA OF AN ALKYL HALIDE IS C 17 H 35 Br 1.
WHAT IS THE WEIGHT % OF BROMINE FOR THIS COMPOUND?

GOOD LUCK DUMB, AND HURRY BACK.
PLEASE TYPE IN YOUR NAME

PLEASE INPUT A NUMBER FROM 1 THRU 15,000.

0: DUMB, DO YOU WISH TO TAKE A TEST OR HAVE YOUR TEST GRADED?
IF YOU WISH TO TAKE A TEST, ENTER A 1, AND IF YOU WISH TO
HAVE AN EXAM GRADED, ENTER A 2.

PLEASE ENTER YOUR EXAM NUMBER.

PLEASE ENTER YOUR 7 ANSWERS IN THE EXACT ORDER OF THE QUESTIONS.
PRESS (RETURN) AFTER EACH ANSWER.

<table>
<thead>
<tr>
<th>CORRECT ANSWER</th>
<th>YOUR ANSWER</th>
<th>RESULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.03374</td>
<td>5.09999</td>
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<tr>
<td>780.715</td>
<td>783.9</td>
<td>WRONG</td>
</tr>
<tr>
<td>7.13931</td>
<td>7.19999</td>
<td>CORRECT</td>
</tr>
<tr>
<td>1.92736E+25</td>
<td>2.40000E+19</td>
<td>WRONG</td>
</tr>
<tr>
<td>351.101</td>
<td>297.399</td>
<td>WRONG</td>
</tr>
<tr>
<td>17.238</td>
<td>12.6999</td>
<td>WRONG</td>
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<tr>
<td>25.8191</td>
<td>55.4</td>
<td>WRONG</td>
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</table>

YOUR GRADE ON THIS QUIZ IS 29%

WOULD YOU LIKE TO TAKE ANOTHER QUIZ?
ENTER 1 FOR YES, 2 FOR NO.

GOOD LUCK DUMB, AND HURRY BACK.

READY
**BASIC PROGRAM**

**NAME:** MOLE

**ON THU, AUG 21, 1975, 12:20 PM**

10 REM ******************************************************************************
20 REM ***
30 REM *** THIS IS A TWO PASS PROGRAM IN WHICH PROBLEMS WILL BE
40 REM *** SELECTED AT RANDOM. AFTER ANSWERING THE QUESTIONS
50 REM *** THE STUDENT WILL RETURN AND SUBMIT HIS ANSWERS. THE
60 REM *** COMPUTER WILL THEN GRADE HIS RESULTS.
70 REM ***
80 REM ******************************************************************************
90 DIM B(7), C(7), A$(20)
100 LET K=G=0
110 PRINT
120 PRINT
130 PRINT "PLEASE TYPE IN YOUR NAME"
140 INPUT A$
150 PRINT
160 PRINT A$
170 PRINT "PLEASE INPUT A NUMBER FROM 1 THRU 15,000.";
180 INPUT S
190 LET S=INT(S)
200 IF S<1 THEN 170
210 IF S>15000 THEN 170
220 PRINT "* K. ";
230 PRINT A$
240 PRINT ", DO YOU WISH TO TAKE A TEST OR HAVE YOUR TEST GRADED?"
250 PRINT "IF YOU WISH TO TAKE A TEST, ENTER A 1. AND IF YOU WISH TO"
260 PRINT "HAVE AN EXAM GRADED, ENTER A 2."
270 LET P=1
280 INPUT Y
290 IF Y=1 THEN 470
300 LET K=K+1
310 IF Y=2 THEN 350
320 IF K>3 THEN 3140
330 PRINT "PLEASE ENTER 1 OR 2!"
340 GOTO 250
350 PRINT "PLEASE, ENTER YOUR EXAM NUMBER."
360 INPUT X
370 PRINT "PLEASE ENTER YOUR 7 ANSWERS IN THE EXACT ORDER OF THE QUESTIONS."
380 PRINT "PRESS (RETURN) AFTER EACH ANSWER."
390 FOR U=1 TO 7
400 INPUT C(U)
410 NEXT U
420 NEXI U
430 LET S=X
440 LET R=X
450 LET P=2
460 GOTO 510
470 GOSUB 2860
480 LET S=R1
490 LET R=INT(10000.5+22000*R2)
500 LET S=R
510 PRINT
520 PRINT
530 PRINT "---------------------------------------------";
540 PRINT "---------------------------------------------"
550 PRINT
560 PRINT "EXAM NUMBER";R
570 PRINT
580 PRINT ASJ
590 PRINT
600 PRINT
610 IF P<>1 THEN 660
620 PRINT "THERE ARE 7 QUESTIONS ON THIS EXAM."
630 PRINT "THEY ARE ALL ON THE MOLE CONCEPT."
640 PRINT "PLEASE ANSWER THE QUESTIONS AT HOME, AND COME BACK"
650 PRINT "WHEN YOU ARE READY TO HAVE YOUR EXAM GRADED."
660 PRINT
670 PRINT
680 LET I=0
690 GOSUB 2860
700 LET R3=INT(31.1999+126.9*R2)
710 GOSUB 2860
720 LET R=INT(1.5+4*R2)
730 GOSUB 3080
740 IF P<>1 THEN 760
750 PRINT "HOW MANY MOLES ARE THERE IN "R3" GRAMS OF"
760 GOTO R 770,850,890,930
770 IF P<>1 THEN 790
780 PRINT " COPPER (AT. WT. = 63.54)?"
790 LET R3=R3/63.54
800 GOTO 960
810 IF P<>1 THEN 830
820 PRINT "WATER (MOLECULAR WT. = 18.016)?"
830 LET R3=R3/18.016
840 GOTO 960
850 IF P<>1 THEN 870
860 PRINT "CARBON MONOXIDE (MOLECULAR WT. = 28.011)?"
870 LET R3=R3/28.01109
880 GOTO 960
890 IF P<>1 THEN 910
900 PRINT "CALCIUM FLUORIDE, CAF2 (MOLECULAR WT. = 78.08)?"
910 LET R3=R3/78.08
920 GOTO 960
930 IF P<>1 THEN 950
940 PRINT "CARBON, C (AT. WT. = 12.011)?"
950 LET R3=R3/12.011
960 GOSUB 2860
970 LET R3=INT(20+60*R2)
980 GOSUB 2860
990 LET R=INT(1.5+3*R2)
1000 GOSUB 3080
1010 IF P<>1 THEN 1030
1020 PRINT "YOU HAVE "R3" MOLES OF "
1030 GOTO R 0F 1040,1090,1140,1190
1040 IF P<>1 THEN 1070
1050 PRINT "NITROGEN (N2)."
1060 PRINT "HOW MANY GRAMS OF N DO YOU HAVE?"
1070 LET R3=R3*28.0138
1080 GOTO 1230
1090 IF P<>1 THEN 1120
1100 PRINT "METHANE (CH4)."
1110 PRINT "HOW MANY GRAMS OF C DO YOU HAVE?"
1120 LET R3=R3*12.011
1130 GOTO 1230
1140 IF P<>1 THEN 1170
1150 PRINT "METHANE (CH4)."
1160 PRINT "HOW MANY GRAMS OF METHANE DO YOU HAVE?"
1170 LET B(I)=R$*16.043
1180 GOTO 1230
1190 IF P<>1 THEN 1220
1200 PRINT "SODIUM CHLORIDE (NaCl)."
1210 PRINT "HOW MANY GRAMS OF SODIUM DO YOU HAVE?"
1220 LET B(I)=R$*22.9909
1230 GOSUB 2860
1240 LET R3=(INT(20+60*R2)/10)*E24
1250 GOSUB 2860
1260 LET R=INT(1.5+3*R2)
1270 GOSUB 3080
1280 IF P<>1 THEN 1300
1290 PRINT "YOU HAVE";R3;
1300 GOTO R OF 1310,1360,1410,1460
1310 IF P<>1 THEN 1340
1320 PRINT "MOLECULES OF ETHANOL (C2H5OH)."
1330 PRINT "HOW MANY MOLES OF ETHANOL DO YOU HAVE?"
1340 LET B(I)=R$/6.02301E23
1350 GOTO 1500
1360 IF P<>1 THEN 1390
1370 PRINT "MOLECULES OF HYDROGEN (H2)."
1380 PRINT "HOW MANY MOLES OF H DO YOU HAVE?"
1390 LET B(I)=2*R3/6.02301E23
1400 GOTO 1500
1410 IF P<>1 THEN 1440
1420 PRINT "ATOMS OF SILICON (Si)."
1430 PRINT "HOW MANY MOLES OF SILICON DO YOU HAVE?"
1440 LET B(I)=R$/6.02301E23
1450 GOTO 1500
1460 IF P<>1 THEN 1490
1470 PRINT "ATOMS OF NITROGEN (N)."
1480 PRINT "HOW MANY MOLES OF N2 GAS DO YOU HAVE?"
1490 LET B(I)=(R$/6.02301E23)*.5
1500 GOSUB 2860
1510 LET R3=INT(20+60*R2)/10
1520 GOSUB 2860
1530 LET R=INT(1.5+3*R2)
1540 GOSUB 3080
1550 IF P<>1 THEN 1570
1560 PRINT "HOW MANY ATOMS"
1570 GOTO R OF 1580,1630,1680,1730
1580 IF P<>1 THEN 1610
1590 PRINT "OF CARBON ARE THERE IN ."
1600 PRINT R3"MOLES OF TOLUENE (C7H8)?"
1610 LET B(I)=7*R$/6.02301E23
1620 GOTO 1770
1630 IF P<>1 THEN 1660
1640 PRINT "OF FLUORINE ARE THERE IN ."
1650 PRINT R3"GRAMS OF SILICON TETRAFLUORIDE (SiF4)?"
1660 LET B(I)=(R$/.104.086)*4*6.02301E23
1670 GOTO 1770
1680 IF P<>1 THEN 1710
1690 PRINT " ARE THERM NW'S R3
1700 PRINT "MOLES OF METHANE (CH4)?"
1720 GOTO 1770
1730 IF P<>1 THEN 1760
1740 PRINT " ARE THERE IN's.; R3
1750 PRINT "GRAMS OF WATER?"
1770 GOSUB 2860
1780 LET R3=(INT(27+60*R2)/10)*1E24
1790 GOSUB 2860
1800 LET R=INT(1.5+3*R2)
1810 GOSUB 3080
1820 IF P<>1 THEN 1840
1830 PRINT "YOU HAVE";R3
1840 GOTO R OF 1850,1900,1950,2000
1850 IF P<>1 THEN 1880
1860 PRINT "ATOMS OF SILICON."
1870 PRINT "HIV MANY GRAMS DO YOU HAVE?"
1890 GOTO 2040
1900 IF P<>1 THEN 1930
1910 PRINT "MOLECULES OF NCl."
1920 PRINT "HIV MANY GRAMS DO YOU HAVE?"
1940 GOTO 2040
1950 IF P<>1 THEN 1980
1960 PRINT "ATOMS OF CARBON."
1970 PRINT "HIV MANY GRAMS OF CARBON DIOXIDE (CO2) CAN YOU MAKE?"
1980 LET BI[1]=(R3/6.02301E23)*44.009
1990 GOTO 2040
2000 IF P<>1 THEN 2030
2010 PRINT "MOLECULES OF BRoMINE."
2020 PRINT "HIV MANY GRAMS DO YOU HAVE?"
2040 GOSUB 2860
2050 LET R3=INT(10+980*R2)/10
2060 GOSUB 2860
2070 LET R=INT(1.5+R2)
2080 GOSUB 3080
2090 GOTO R OF 2100,2160
2100 LET R4=INT(13+200*R2)
2110 IF P<>1 THEN 2140
2120 PRINT "HIV MANY GRAMS OF CARBON ARE CONTAINED IN";R4
2130 PRINT "GRAMS OF A COMPOUND THAT IS";R3;"PER CENT CARBON?"
2140 LET BI[1]=R4*(R3/100)
2150 GOTO 2240
2160 GOSUB 2860
2170 LET R4=INT(150+990*R2)/100
2180 LET R5=R3+R4
2190 IF P<>1 THEN 2230
2200 PRINT "A MIXTURE OF";R5;"GRAMS OF A + B CONTAINS";R3
2210 PRINT "GRAMS OF A+
2220 PRINT "WHAT IS THE WEIGHT PERCENT OF A IN THE MIXTURE?"
2230 LET BI[1]=(R3/R5)*100
2240 GOSUB 3080
PRINT "THE FORMULA OF AN ALKYL HALIDE IS C";R3;"H";R4;"BR 1."
PRINT "WHAT IS THE WEIGHT % OF BROMINE FOR THIS COMPOUND?"
LET B1=((79.904)/((R3*12.011)+(R4*1.008)+79.904))*100
GOTO 2490
LET R4=INT(R4-1)
IF P<>1 THEN 2440
PRINT "THE FORMULA OF A KETONE IS C";R3;"H";R4;"O 1."
PRINT "WHAT IS THE WEIGHT % OF OXYGEN FOR THIS COMPOUND?"
LET B1=((15.999)/((R3*12.011)+(R4*1.008)+15.999))*100
GOTO 2490
LET R4=INT(R4-1)
GOSUB 2860
LET R5=INT(154.99*R2)
IF P<>1 THEN 2480
PRINT "HOW MANY MOLES ARE CONTAINED IN";R5
PRINT "GRAMS OF C";R3;"H";R4;"O ?"
LET B1=R5/((R3*12.011)+(R4*1.008)+15.999)
GOTO 2490
IF P=1 THEN 2610
PRINT "CORRECT";"YOUR";"ANSWER";"RESULT"
PRINT
FOR I=1 TO 7
IF B(I)>1.05*C(I) THEN 2590
IF B(I)<.95*C(I) THEN 2590
PRINT B(I);C(I);"CORRECT"
LET G=G+100/7
GOTO 2600
PRINT B(I);C(I);"WRONG"
NEXT I
PRINT "YOUR GRADE ON THIS QUIZ IS";INT(G+.5);"%"
PRINT "MARVELOUS FRIEND, YOU HAVE BEATEN THIS BROKEN MACHINE."
IF P<>1 THEN 2740
PRINT "GOOD LUCK ";
PRINT AS;
PRINT "AND HURRY BACK."
PRINT "WOULD YOU LIKE TO TAKE ANOTHER QUIZ?"
INPUT Z
LET P=1
LET G=0
2810 IF Z=1 THEN 270
2820 IF Z=2 THEN 2840
2830 GOTO 2770
2840 LET P=9999
2850 GOTO 2700
2860 REM *****************************************************************
2870 REM ***
2880 REM *** THIS IS THE RANDOM NUMBER GENERATOR.
2890 REM *** GIVEN A SEED, S, IT PRODUCES A RANDOM INTEGER (RI)
2900 REM *** FROM 1 THRU 16,384 AND A RANDOM REAL NUMBER (R2)
2910 REM *** FROM 0 THRU 1.
2920 REM ***
2930 LET A1=1
2940 LET M1=16384
2950 REM *** MAKE SURE THE SEED IS ODD.
2960 IF (INT(S/2))*2=S THEN 2980
2970 LET S=INT(S+1)
2980 LET T=A*S
2990 LET Q=INT(T/M)
3000 LET R1=T-Q*M
3010 LET R2=R1/(M-1)
3020 REM *** SET THE NEW SEED TO THE VALUE OF THE RANDOM INTEGER
3030 REM *** JUST GENERATED.
3040 LET S=R1
3050 REM *** THIS INSURES THAT THE SERIES OF RANDOM REAL NUMBERS
3060 REM *** GENERATED FOR THE SAME INITIAL SEED WILL BE IDENTICAL.
3070 RETURN
3080 REM ****************************************************************
3090 LET I=I+1
3100 IF P=2 THEN 3130
3110 PRINT
3120 PRINT "QUESTION. \\
3130 RETURN
3140 PRINT "SORRY \\
3150 PRINT AS;
3160 PRINT "PLEASE GET SOME HELP. SO LONG FOR NOW."
3170 STOP
3180 END
Unit Test on the Mole Concept

TEST 1

1. THE PERCENTAGE COMPOSITION BY WEIGHT OF A COMPOUND IS
   C 42.86
   H 2.38
   O 38.10
   N 16.67

   WHAT IS ITS EMPIRICAL OR SIMPLEST FORMULA?

2. HOW MANY MOLES OF SC₂ MOLECULES ARE THERE IN 25.849 GRAMS OF SO₂?

3. HOW MANY GRAM ATOMS OF O ARE THERE IN 70.498 GRAMS OF O?

4. WHAT IS THE PERCENT BY WEIGHT OF EACH ELEMENT IN Ti(OH)₄?

5. HOW MANY MOLES OF Li ATOMS ARE THERE IN 17.797 GRAMS OF LiOH?

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TEST 1

1. C₃H₂NO₂
2. 4.04E-01
3. 4.41E+00
4. Ti 4.13183E+01
5. 7.43E-01
Unit Test on the Mole Concept

TEST 2

1. What is the percent by weight of each element in C$_2$H$_6$?

2. How many molecules of NO add up to a mass of 38.949 grams?

3. How many grams of O are there in 75.298 grams of O?

4. How many grams of O are in 3.209E+24 molecules of N$_2$O$_4$?

5. The percentage composition by weight of a compound is
   H 1.59
   O 76.19
   N 22.22
   What is its empirical or simplest formula?

TEST 2

1. H 2.01273E+01
2. 7.82E+23
3. 4.71E+00
4. 3.41E+02

5. HNO$_3$
Unit Test on the Mole Concept

1. WHAT IS THE PERCENT BY WEIGHT OF EACH ELEMENT IN CaF₂?
2. HOW MANY IONS ARE THERE IN 23.599 GRAMS OF O?
3. THE PERCENTAGE COMPOSITION BY WEIGHT OF A COMPOUND IS
   C 47.06
   H 5.88
   O 47.06
   WHAT IS ITS EMPIRICAL OR SIMPLEST FORMULA?
4. WHAT IS THE MOLAR WEIGHT OF NO₂?
5. HOW MANY GRAMS OF Sn ARE IN 3.450 MOLES OF SnCl₂?

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TEST 3

1. Ca 5.13340E+01
2. 8.88E+23

3. C₄H₆O₃
4. 4.60E+01
5. 4.09E+02
Unit Test on the Mole Concept

1. How many atoms are there in 42.387 grams of Al?

2. How many atoms of S are there in 1.13769E+24 molecules of SO₂?

3. What is the percent by weight of each element in CO₂?

4. The percentage composition by weight of a compound is
   H 1.59
   O 76.19
   N 22.22
   What is its empirical or simplest formula?

5. How many molecules of Cl₂ add up to a mass of 48.949 grams?

   Test 4
   1. 9.46E+23
   2. 1.14E+24
   3. 0 7.27265E+01
   4. HNO₃
   5. 4.16E+23
Unit Test on the Mole Concept

TEST 5

1. WHAT IS THE PERCENT BY WEIGHT OF EACH ELEMENT IN H2S2O7?

2. HOW MANY GRAMS OF Br ARE IN 4.440 MOLES OF HBr?

3. IF ONE ATOM OF ELEMENT X WEIGHS 1.993E-23 G, WHAT IS THE ATOMIC WEIGHT OF X?

4. IF ONE MOLE OF ASH3 IS PLACED ON THE LEFT PAN OF A TWO-PAN BALANCE, HOW MANY MOLES OF NH4Cl MUST BE PLACED ON THE OTHER PAN TO EXACTLY BALANCE THE MOLE OF ASH3?

5. THE PERCENTAGE COMPOSITION BY WEIGHT OF A COMPOUND IS
   H 112
   O 6292
   S 3596
   WHAT IS ITS EMPirical OR SIMPLEST FORMULA?

TEST 5

1. H 646770E+01
2. 3.55E+02
3. 1.20E+01
4. 1.46E+00
5. H2S2O7
Unit Test on the Mole Concept

TEST 6

1. WHAT IS THE PERCENT BY WEIGHT OF EACH ELEMENT IN Cr₂O₃?

2. THE PERCENTAGE COMPOSITION BY WEIGHT OF A COMPOUND IS:
   - H 1.59
   - O 76.19
   - N 22.22
   WHAT IS ITS EMPirical OR SIMPLEST FORMULA?

3. IF ONE ATOM OF ELEMENT X WEIGHS 9.752E-23 G, WHAT IS THE
   ATOMIC WEIGHT OF X?

4. HOW MANY MOLES OF PH₃ MOLECULES ARE THERE IN 14.300 GRAMS OF PH₃?

5. HOW MANY ATOMS OF O ARE THERE IN 6.110 GRAMS OF Pb(NO₃)₂?

TEST 6

1. Cr 6.84202E+01

2. HNO₃

3. 5.87E+01

4. 4.21E-01

5. 6.66E+22
Unit Test on the Mole Concept

1. How many atoms are there in 23.498 grams of Cl?
2. How many moles of B atoms are there in 18.298 grams of BF₃?
3. Calculate the percent by weight of each element in C₂H₆O₄N₄.

4. The percentage composition by weight of a compound is:
   - C: 67.92%
   - H: 5.66%
   - N: 26.42%

   What is its empirical or simplest formula?

5. One mole of KI is placed on the left pan of a two-pan balance. How many moles of Pb(NO₃)₂ must be placed on the other pan to exactly balance the mole of KI?

   Test, 7
   1. 3.99E+23
   2. 2.70E-01
   3. 16.00 % C
   4. 0.00 % H
   42.67 % O
   37.33 % N

4. C₃H₃N

5. 5.01E-01
UNIT TEST ON THE MOLE CONCEPT

1. THE PERCENTAGE COMPOSITION BY WEIGHT OF A COMPOUND IS:
   H 2.13
   N 29.79
   S 68.09
   WHAT IS ITS EMPIRICAL OR SIMPLEST FORMULA?

2. WHAT IS THE PERCENT BY WEIGHT OF EACH ELEMENT IN CaO?

3. HOW MANY MOLES OF P ATOMS ARE THERE IN 30.70 G OF BF₃?

4. IF ONE ATOM OF ELEMENT X WEIGHS 2.654E-23 G, WHAT IS THE
   ATOMIC WEIGHT OF X?

5. WHAT IS THE MASS (IN GRAMS) OF 4.45 MOLES OF KI?
Unit Test on the Mole Concept

TEST

1. HOW MANY GRAMS OF Li ARE IN 3.055 MOLES OF LiOH?

2. CALCULATE THE PERCENT BY WEIGHT OF EACH ELEMENT IN C₃H₇O₂N.

3. WHAT IS THE MOLECULAR WEIGHT OF H₂Se?

4. IF ONE ATOM OF ELEMENT X WEIGHS 2.658E-23 G, WHAT IS THE ATOMIC WEIGHT OF X?

5. THE PERCENTAGE COMPOSITION BY WEIGHT OF A COMPOUND IS
   C 40.45
   H 7.87
   O 35.96
   N 15.73

   WHAT IS ITS EMPIRICAL OR SIMPLEST FORMULA?

TEST

1. 2.12E+01

2. 40.45 % C
   7.87 % H
   35.96 % O
   15.73 % N

3. 8.10E+01

4. 1.60E+01

5. C₃H₇O₂N
1. How many grams of P are there in 19.198 grams of P?

2. The percentage composition by weight of a compound is
   C: 25.53
   H: 14.38
   N: 68.09
   What is its empirical or simplest formula?

3. Calculate the percent by weight of each element in O₄N₂.

4. How many moles of CO₂ molecules are there in 41.799 grams of CO₂?

5. How many grams of C are in 9.812E+23 molecules of C₂H₆?