# Empirical and Molecular Formula Lab

**Introduction**:
A big question in chemistry is simply 'what is this stuff?!' In efforts to determine what this stuff is, a couple of things need to be done. Ultimately, we want to find out what this stuff is made of and how it is put together, both in quantity and connectivity (structure). In this lab we are going to model determining the composition of a compound (what is it made of) and in what quantity. We will not investigate how they are all connected, but we will know how much of each element it has.

We will use Legos as a model for atoms; each element will have different dimensions with different atomic masses (Element X is the 1x4x1 piece). This information is provided to you on the Lego Periodic Table. Colors will not be used to distinguish between different elements; we can consider these different isotopes of each element. Simply, ignore the colors.

So how do chemists do this kind of work? How do they figure out what elements compounds are made of? How do they determine the molecular formulas? I am glad you asked!

Here is an overly simplified explanation. In order to determine what elements are in a compound, they can take a sample and break it apart into each element. They can then separate these elements and measure how much of each is present in the sample. This will allow them to determine the empirical formula; the simplified ratio of the elements in the compound. For example; $CH_2O$ is an empirical formula. It tells us that for every C, there are 2 H and 1 O. The actual molecule may not be $CH_2O$, but it will be in that ratio; $C_2H_4O_2$ or $C_3H_6O_3$, etc.

Another thing that can be done is to determine the molecular mass of the sample. This could be done a number of different ways, but each way wont tell us about its composition, just the mass of each molecule. What we can do, is look at the empirical formula we determined and the molecular mass we determined to figure out what multiple of the empirical formula makes up the molecule. For example;

We determine a sample to have an empirical formula of $CH_2O$, and a molecular mass of 180 grams/mole. We can determine how many multiples of the empirical formula we need to give us the molecular mass and use that to determine the molecular formula (how many atoms of each element are actually in EACH molecule).

- **(molecular mass) / ( Empirical formula Mass** $CH_2O$ **) = multiplier**
  180g/mole / 30 g/mole = 6x

- **Multiplier X Empirical formula = Molecular Formula**
  6 X $CH_2O$ = $C_6H_{12}O_6$

In this example, the actual molecule would be made of 6 C, 12 H and 6 O so its molecular formula would be $C_6H_{12}O_6$.

Objective:
Experimentally determine the molecular formula of a model compound.

Procedure
1. Grab the corresponding container for your molecule that has the substance broken down into its parts. Record the compound you are working with in your data table underneath ‘Compound’.
2. Determine the empirical formula by Massing them and converting to moles (grams → moles)
    a. Experimentally, we cant count individual atoms or molecules, but we can break them into their parts, separate them and weigh how much of each element we have. Thats what we will do here.
    b. Separate the legos into their different elements (based on their dimensions and NOT their color)
    c. Record what elements are present on your data tables (E1:X__, etc.). Use the Lego periodic table to record the average mass in your data table.
    d. Measure the mass ALL the atoms of each Lego element and record it in your data table
    e. Use the Average Atomic Mass to determine the # of moles you have of each element present in your sample (grams→moles). Show your work in the data table.
    f. Divide by the smallest # of moles to give you your element ratio. Determine the empirical formula this way. How to round your mole ratio:
        i. If the ratio values are within 0.3 of a whole number, round to the whole number (1.7 - 2.3 would round to 2)
        ii. If you end up with a decimal that is outside of that range (1.4-1.6), round it to 1.5 and double all the rest of the values so you end up with a whole numer ratio
            - Example X : Y having a ratio of 1 : 1.4 → 1 : 1.5 →double → 2:3 ratio. Empirical formula would be $X_2Y_3$
3. Determine the molecular mass
    a. A lego creation can obviously be examined directly in a way that molecules cant; we can not directly observe molecules to see what elements its made of and in what way (its structure). To emulate this in the lab, the molecule has been placed inside of a container to keep those things a mystery, but the mass of the EMPTY container has been recorded on it.
    b. Find the container that has the intact molecule in it.
    c. Measure the mass of the container WITH the molecule in it. Record it in your data table
    d. Record the mass of the empty container, which is written on the container, in your data table
    e. Determine the molecular mass, showing your work in the data table.
4. Determine the molecular formula
    a. Using the lego Periodic table, calculate the mass of the empirical formula. Show your work in the data table
    b. Determine the multiplier for the molecule; divide the molecular mass by the mass of the empirical formula. This will tell you how many multiples of the empirical formula are in the molecular formula.
    c. Use the multiplier to determine the molecular formula of your mystery lego compound.
5. Repeat these steps for a second molecule.

**Name:______________________** **Empirical and Molecular Formula Lab**

**Post lab questions**

1. If you counted the lego pieces, you would get a whole number integer. When you calculated how many using the grams and GFM, you may have gotten a decimal. Explain why there may be this discrepancy.

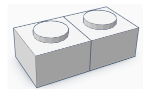
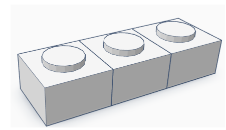
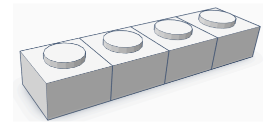
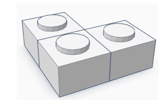
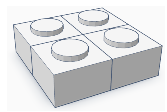
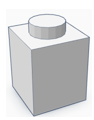
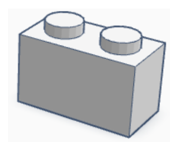
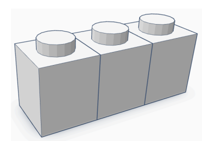
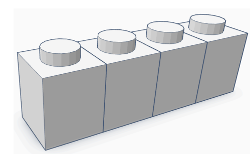
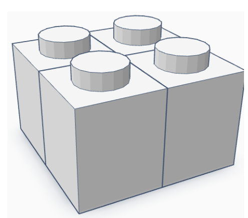
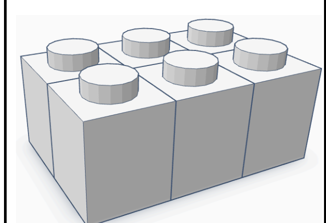
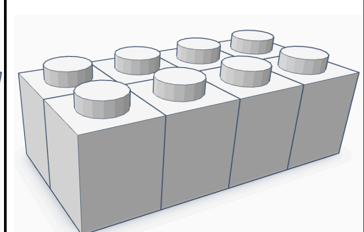
2. What do we know about the molecule at the end of this exercise? What do we NOT know about the molecule?
   Known:

   Unknown

3. Describe how to convert from molecular formula to empirical formula, using the molecular formula $C_6H_{12}O_6$ as an example. NOTE: I want you to explain the steps, not just solve for it.

4. A compound was found to be made of 25% carbon, 58.3% nitrogen and 16.8% hydrogen by mass with a molecular weight of 144.26 grams/mole. What is its molecular formula? Show all work.

**Lego Periodic Table (Symbol and average atomic mass)**

| Height | Width | x1 | x2 | x3 | x4 | L |
|---|---|---|---|---|---|---|
| 1/2 height | 1x | | **L**  0.3334 g/mol | **E**  0.48995 g/mol | **G**  0.64975 g/mol | **Ll**  0.48825 g/mol |
| | 2x | | **Le**  0.5896 g/mol | | | |
| 1x height | 1x | **Ge**  0.423 g/mol | **Lg**  0.7964 g/mol | **Lo**  1.15915 g/mol | **Eg**  1.4974 g/mol | |
| | 2x | | **Go**  1.2951 g/mol | **Eo**  1.8691 g/mol | **Ee**  2.338 g/mol | |

Empirical Formula Data Table

| | | Element ID and Avg. Mass | Mass of Element in sample | Calculated moles (show work | Whole number Ratio |
|---|---|---|---|---|---|
| Compound: | E1: | | | | |
| | E2: | | | | |
| | E3: | | | | |
| | | | | | Empirical Formula: |

Molecular Formula Data Table

| Mass of container AND compound | Mass of empty container | Molecular Mass | Empirical Formula Mass | Multiplier | Molecular Formula |
|---|---|---|---|---|---|
| | | | | | |

| | | Element ID and Avg. Mass | Mass of Element in sample | Calculated moles (show work | Whole number Ratio |
|---|---|---|---|---|---|
| Compound: | E1: | | | | |
| | E2: | | | | |
| | E3: | | | | |
| | | | | | Empirical Formula: |

Molecular Formula Data Table

| Mass of container AND compound | Mass of empty container | Molecular Mass | Empirical Formula Mass | Multiplier | Molecular Formula |
|---|---|---|---|---|---|
| | | | | | |