Grams, Moles, and Molecules

Topic

Students calculate the number of molecules of chalk in their signature.

Introduction

A chemical equation represents the *reactants* and *products* in a chemical reaction. Every balanced equation is written for the least number of atoms or molecules that could be involved in that reaction. For example, the chemical equation for the reaction of magnesium with water to produce magnesium hydroxide and hydrogen gas is written as:

$$Mg + 2H_2O \qquad Mg(OH)_2 + H_2 \neq$$

Although this equation states that only one atom of magnesium combines with two molecules of water, in an actual chemical reaction billions of atoms and molecules are involved. Working with large numbers can be cumbersome. To simplify, scientists refer to units of atoms instead of individual atoms.

You are already familiar with the use of units to refer to large numbers. For example, eggs are sold in units called "dozens," a reference to 12, and pencils are distributed in a "gross," a box of 144. In the same way, scientists refer to a mole of atoms. A mole is a unit that represents approximately 6.022×10^{23} particles.

Although moles are useful quantities for performing calculations, there is not a piece of equipment in the chemistry lab that is capable of telling you how many moles of a substance you have. Balances measure the number of grams of a material, but not the number of moles in that material. To find out the number of moles in a given mass of material, scientists perform a three-step calculation:

1. Determine the mass of the material in grams (g) by using a balance (Figure 1).
2. Use the atomic mass (found on the Periodic Table of the Elements) of the material and rewrite it as that material's *molar mass*.

3. Divide the number of grams (in step 1) by molar mass (in step 2) to find the moles of substance.

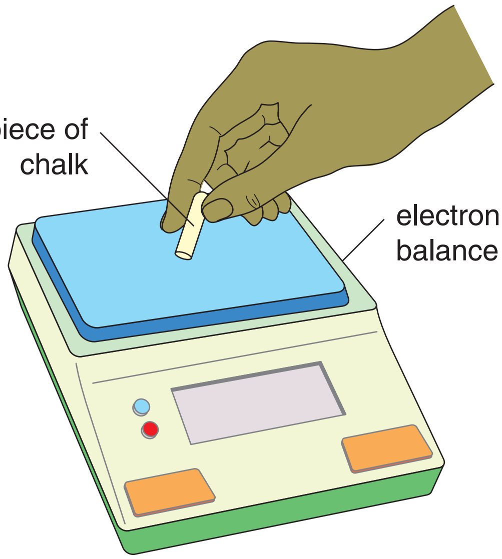


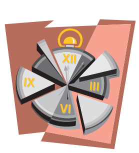
Figure 1

For example, a sample of magnesium has a mass of 72 g. On the Periodic Table, you see that magnesium has an atomic mass of 24, which means that it has a molar mass of 24 g. To find out the number of moles in the magnesium sample, divide the mass of magnesium by the molar mass.

Mass of magnesium sample = 72 g
Atomic mass of magnesium = 24
Molar mass of magnesium = 24 g
Divide mass of sample by molar mass: 72 g/24 g = 3 moles

Once you know the number of moles in a substance, you can calculate the number of particles (atoms or molecules) of that material. The number of particles equals 6.02×10^{23} multiplied by the number of moles. In the example above, the number of atoms of magnesium can be determined by multiplying 3 moles times 6.02×10^{23} atoms, as shown below:

3 moles of Mg multiplied by 6.02×10^{23} atoms = 18.06×10^{23} atoms of Mg



Time Required

50 minutes

Materials

- piece of chalk (calcium carbonate, $CaCO_3$)
- chalkboard
- electronic balance
- calculator
- Periodic Table of the Elements (see appendix, after Our Findings)

Safety Note **Please review and follow the safety guidelines.**

Procedure

1. Read all of the directions, then design and draw an appropriate data table to record your results in this experiment.
2. Find the mass of a piece of chalk (at least to the hundredth place, i.e., two places past the decimal).
3. Use the chalk to write your full name on the chalkboard.
4. Find the mass of the chalk again.
5. Calculate the difference in the beginning and final masses of the chalk to determine the mass of the chalk in your signature.
6. From the mass of chalk in your signature, calculate the number of moles of calcium carbonate used in your signature.
7. From the number of moles of calcium carbonate in your signature, calculate the number of molecules of calcium carbonate in your signature.

Analysis

1. Find the mass of calcium carbonate used by everyone in your lab group, and then calculate the average mass of chalk required to write a signature in chalk. Show your work.
2. Find the number of moles of calcium carbonate used by everyone in your group, and calculate the average number of moles for the group. Show your work.

3. Find the number of molecules of calcium carbonate used by everyone in your group, and find the average number of molecules. Show your work.
4. Calculate the number of times an average signature would have to be written on the board to use the entire piece of chalk. Show your work.
5. Calculate how many moles of hydrogen peroxide (H_2O_2) are in 17 g of hydrogen peroxide.

What's Going On?

The unit of a mole represents 602,000,000,000,000,000,000,000 (or 6.02×10^{23}) particles, a much larger number of items than is represented by more familiar units such as dozen (12 items) or gross (144 items). You would never want to purchase a mole of eggs, but you could have a mole of ions, a mole of molecules, a mole of atoms, or even a mole of stars. No matter what items you are referring to, a mole represents 602,000,000,000,000,000,000,000 (or 6.02×10^{23}) of them. This large quantity is also known as Avogadro's number.

In the chemistry lab, a mole is a convenient quantity. Molecules, atoms, and ions are such small particles that it is impossible to determine the mass of just one, or even a dozen, of them. Balances are just not that sensitive.

One gram of a substance contains 602,000,000,000,000,000,000,000 (or 6.02×10^{23}) units. For this reason, you can use the mass numbers on the Periodic Table to represent two quantities: the atomic mass of an atom and the mass of a mole of the atoms. To do so, you simply change the units from atomic mass units (amus) to grams. In the case of the element carbon (C), the atomic mass is 12.0 and the molar mass of 12.0 g. Another example is copper (Cu), whose atomic mass is 63.5 amu and whose molar mass is 63.5 g.

Want to Know More?

See Our Findings.

OUR FINDINGS

GRAMS, MOLES, AND MOLECULES

Analysis

1. Answers will vary depending on class results.
2. Answers will vary depending on class results.
3. Answers will vary depending on class results.
4. Answers will vary depending on class results.
5. $\frac{17\text{g } H_2O_2}{34.0146 \text{ g}} = 0.5$ moles of H_2O_2

   0.5 moles $\times 6.02 \times 10^{23}$ molecules $= 3.01 \times 10^{23}$ molecules of H_2O_2

SAFETY PRECAUTIONS

Review Before Starting Any Experment

Each experiment includes special safety precautions that are relevant to that particular project. These do not include all the basic safety precautions that are necessary whenever you are working on a scientific experiment. For this reason, it is necessary that you read and remain mindful of the General Safety Precautions that follow. Experimental science can be dangerous, and good laboratory procedure always includes carefully following basic safety rules. Things can happen very quickly while you are performing an experiment. Materials can spill, break, or even catch fire. There will be no time after the fact to protect yourself. Always prepare for unexpected dangers by following the basic safety guidelines during the entire experiment, whether or not something seems dangerous to you at a given moment.

We have been quite sparing in prescribing safety precautions for the individual experiments. For one reason, we want you to take very seriously every safety precaution that is printed in this book. If you see it written here, you can be sure that it is here because it is absolutely critical.

Read the safety precautions here and at the beginning of each experiment before performing each activity. It is difficult to remember a long set of general rules. By rereading these general precautions every time you set up an experiment, you will be reminding yourself that lab safety is critically important. In addition, use your good judgment and pay close attention when performing potentially dangerous procedures. Just because the text does not say "be careful with hot liquids" or "don't cut yourself with a knife" does not mean that you can be careless when boiling water or punching holes in plastic bottles. Notes in the text are special precautions to which you must pay special attention.

GENERAL SAFETY PRECAUTIONS

Accidents caused by carelessness, haste, insufficient knowledge, or taking an unnecessary risk can be avoided by practicing safety procedures and being alert while conducting experiments. Be sure to check the individual experiments in this book for additional safety regulations and adult supervision requirements. If you will be working in a lab, do not work alone. When you are working off site, keep in groups with a minimum of three students per group, and follow school rules and state legal requirements for the number of supervisors required. Ask an adult supervisor with basic training in first aid to carry a small first-aid kit. Make sure everyone knows where this person will be during the experiment.

PREPARING

- Clear all surfaces before beginning experiments.
- Read the instructions before you start.
- Know the hazards of the experiments and anticipate dangers.

PROTECTING YOURSELF

- Follow the directions step-by-step.
- Do only one experiment at a time.
- Locate exits, fire blanket and extinguisher, master gas and electricity shut-offs, eyewash, and first-aid kit.
- Make sure there is adequate ventilation.
- Do not horseplay.
- Keep floor and workspace neat, clean, and dry.
- Clean up spills immediately.
- If glassware breaks, do not clean it up; ask for teacher assistance.
- Tie back long hair.
- Never eat, drink, or smoke in the laboratory or workspace.
- Do not eat or drink any substances tested unless expressly permitted to do so by a knowledgeable adult.

USING EQUIPMENT WITH CARE

- Set up apparatus far from the edge of the desk.
- Use knives or other sharp-pointed instruments with care.
- Pull plugs, not cords, when removing electrical plugs.
- Clean glassware before and after use.
- Check glassware for scratches, cracks, and sharp edges.

- Clean up broken glassware immediately.
- Do not use reflected sunlight to illuminate your microscope.
- Do not touch metal conductors.
- Use alcohol-filled thermometers, not mercury-filled thermometers.

USING CHEMICALS

- Never taste or inhale chemicals
- Label all bottles and apparatus containing chemicals
- Read labels carefully.
- Avoid chemical contact with skin and eyes (wear safety glasses, lab apron, and gloves).
- Do not touch chemical solutions.
- Wash hands before and after using solutions.
- Wipe up spills thoroughly.

HEATING SUBSTANCES

- Wear safety glasses, apron, and gloves when boiling water.
- Keep your face away from test tubes and beakers.
- Use test tubes, beakers, and other glassware made of Pyrex™ glass.
- Never leave apparatus unattended.
- Use safety tongs and heat-resistant gloves.
- If your laboratory does not have heat-proof workbenches, put your Bunsen burner on a heat-proof mat before lighting it.
- Take care when lighting your Bunsen burner; light it with the airhole closed, and use a Bunsen burner lighter in preference to wooden matches.
- Turn off hot plates, Bunsen burners, and gas when you are done.
- Keep flammable substances away from flames and other sources of heat.
- Have a fire extinguisher on hand.

FINISHING UP

- Thoroughly clean your work area and any glassware used.
- Wash your hands.
- Be careful not to return chemicals or contaminated reagents to the wrong containers.
- Do not dispose of materials in the sink unless instructed to do so.
- Clean up all residues and put them in proper containers for disposal.
- Dispose of all chemicals according to all local, state, and federal laws.

BE SAFETY CONSCIOUS AT ALL TIMES!