# Properties of Matter and Density

## Cautions

Flames will be used and some of the chemicals will have odors and may stain your hands or clothes if you come into direct contact with them.

## Purpose

In this experiment you will characterize common substances by their physical and chemical properties.

## Introduction

Chemistry is the study of matter and its changes. Matter can be classified in many ways; atoms or molecules; elements, compounds or mixtures. Mixtures can be further classified as either homogeneous or heterogeneous. Any given substance will fit into at least one of these classes. Identification of a substance, regardless of its classification, is obtained using its unique set of physical and chemical properties. Properties a substance displays on its own, such as phase, color, odor, conductivity or density, are called *physical properties*, and changes associated with these properties (melting or boiling) are called physical changes. Properties a substance displays upon interacting with other substance(s) are called *chemical properties*, and the changes that occur are referred to as chemical changes. Chemical changes are most often in the form of a chemical reaction, which often lead to the formation of a precipitate (solid material in solution) or a gas (bubbling of a solution).

Physical and chemical properties are often determined by performing experiments and making observations. For example, if a student is given a piece of copper and told to determine its physical properties, the student may look at it and say it has a "coppery" color, is a solid at room temperature, conducts electricity on its own and it does not dissolve in water. When asked to determine some chemical properties, the student may place a small piece of copper in strong acid and see that it dissolves, forming a blue solution and a stinky brown gas (the results of a chemical change – reaction between the elemental copper and the strong acid to form new compounds). These processes will be observed later this semester in the transforming copper lab.

Substances can exist as elements (substances made up of identical atoms) or compounds (substances composed of atoms of different elements chemically bound together as molecules). In both of these cases, the substance has a uniform composition throughout (chemically homogeneous). Mixtures are combinations of different substances that do not have a fixed composition. For example, copper is an element, copper (II) sulfate is a compound; while bronze (an alloy of copper, zinc and tin) is a mixture. Mixtures can be classified further as being physically homogeneous or heterogeneous. In homogeneous mixtures, no physical boundaries can be observed. Examples of homogeneous mixtures are solutions (sugar in water) or bronze. In heterogeneous mixtures, the boundaries of the individual components can be seen. Italian salad dressing is a good example of a heterogeneous mixture, as the phase boundaries between the different substances (oil, water, spices) that make up the dressing can be observed.

One physical property of matter that is useful in identifying a wide variety of substances is density, which is dependent on the mass and volume of a sample of matter. The density is expressed as the ratio of the mass of a sample to the volume the sample occupies, $d = m/V$. Density is most often expressed in grams per milliliter (g/mL) for liquids and grams per cubic centimeter ($g/cm^3$) for solids.

To determine the density of a liquid, first the mass of the sample is measured using a balance, then the volume of the sample can be measured using a piece of calibrated glassware. When determining the density of

solid samples, the mass is still measured using a balance, while the volume can either be determined using the dimensions of the sample (if the sample is of a simple shape, such as a cube or rectangle V = L×W×H) or by volume displacement. When using volume displacement, pour water into a graduated cylinder and record this initial volume, then carefully place the solid sample into the graduated cylinder and measure the new volume (making sure that the solid sample is completely covered by water). The difference between these measurements is the volume of water displaced by the solid, and is also the volume of the solid itself. This displaced volume method cannot be used for solids that react with water (e.g. sodium metal) or for solids that are water-soluble (e.g. NaCl, $K_2CO_3$).

**Reference Data**

| **Density of Liquid Sample** | |
|---|---|
| **Liquid** | **Density (g/mL)** |
| Rubbing Alcohol | 0.8981 |

| **Density of Metal Samples** | |
|---|---|
| **Metal** | **Density (g/mL)** |
| Aluminum | 2.70 |
| Stainless Steel | 7.90 |
| Brass | 8.75 |
| Copper | 8.92 |

## Procedure

1. Obtain 8 (eight) test tubes, and label them according to the table (Table 1) on page 4. In each test tube, place approximately 1-2 cm of each individual solid or liquid sample.

2. **PHYSICAL APPEARANCE:** On the data sheets, describe the physical appearance of the samples, noting any odors or colors or phases.

3. **SOLUBILITY:** Obtain eight test tubes, and add 5-8 mL of deionized water to each tube. Label the first test tube "Sugar", and add 0.5 grams of sugar to the water. Stir and see if the sugar dissolves. Label the next test tube "Vinegar", and add 2 mL of vinegar to the water. Again, stir and see if the vinegar dissolves. Repeat this process for the remaining unknowns, using 0.5 grams of solid or 2 mL of liquid depending on the nature of the sample. Record your observations on the data sheet. ***SAVE*** these solutions, as they will be used later to test acidity.

4. **EFFECT OF THE APPLICATION OF HEAT:** ***Gently*** heat the sample in each test tube using a Bunsen burner. Observe any changes that occur to the sample and record these on the data sheet. It is possible that more than one change may be observed for a given sample.

5. **DETERMINING THE DENSITY OF A LIQUID:** Weigh a clean, dry 10 mL graduated cylinder. Record this mass on your data sheets in Table 2. Pour 5 or 6 mL of rubbing alcohol into the graduated cylinder (use a beaker for transfer). Measure the exact volume of alcohol and re-weigh the graduated cylinder. Return your alcohol sample to the transfer beaker, make sure the graduated cylinder is dry, and repeat this measurement two more times.

6. **DETERMINING THE IDENTITY OF AN UNKNOWN METAL:** Obtain an unknown metal sample from your instructor. Describe its appearance on your data sheets in Table 3. Wipe your sample with a damp cloth and dry completely. Weigh your sample. Choose the smallest graduated cylinder that the metal will fit into. Measure the volume of water. Add enough water so that the metal will be completely submerged once placed in the graduated cylinder. Slightly tilt the graduated cylinder and carefully let your metal sample slide down the side; avoid splashing water out of the cylinder. Read the new volume of water in the graduated cylinder. Pour the water and sample out of your graduated cylinder. Repeat this measurement two more times.

**Calculations:**

*Show all work for your calculations on page 7.*

1. Determine the mass of alcohol by subtracting the mass of the empty graduated cylinder from the mass of the filled graduated cylinder
2. Use the mass of alcohol and the measured volume of alcohol to calculate the measured density of alcohol.
3. Calculate an average alcohol density value, and use the accepted value provided on page 2 to calculate a percent error in the measurement.
4. Determine the volume of the metal by taking the difference in the measured graduated cylinder volume before and after the metal piece was added. Use this volume and the measured mass to calculate the density of the metal.
5. Identify the metal based on the measured density as well as the physical characteristics of the metal.
6. Calculate an average density of the metal for the three trials. Obtain the actual density of the identified metal from the table on page 2, and use this value to calculate a percent error in the measurement.

**Waste Disposal**

Place all materials in the appropriate beakers in the laboratory.

**Clean-Up**

Clean the lab space, replacing borrowed items where they were found. Return unused sample portions back to their original container

**Properties of Matter and Density**

**Data Sheets**

**Table 1: Observations of Physical and Chemical Properties**

**Name:** _____

| ***Sample Name*** | ***Physical Properties*** *(of pure substance)* | ***Water Soluble?*** *(Yes/No)* | ***Change upon Heating?*** *(Yes/No)* | ***Change Observed*** *(new property)* |
|---|---|---|---|---|
| Deionized water (*used as reference*) | | | | |
| Sucrose (table sugar) | | | | |
| Vinegar | | | | |
| Sodium chloride (table salt) | | | | |
| Vegetable oil | | | | |
| Sand | | | | |
| Sodium bicarbonate (baking soda) | | | | |
| Copper(II) sulfate pentahydrate ($CuSO_4 \cdot 5H_2O$) | | | | |

**Table 2: Determining the Density of a Liquid**

| | Trial 1 | Trial 2 | Trial 3 |
|---|---|---|---|
| Initial mass of graduated cylinder | | | |
| Final mass of graduated cylinder | | | |
| Mass of liquid | | | |
| Volume of liquid | | | |
| Calculated density | | | |
| Accepted density | | | |
| % Error | | | |

**Table 3: Determining the Identity of an Unknown Metal**

| | Trial 1 | Trial 2 | Trial 3 |
|---|---|---|---|
| Mass of unknown metal | | | |
| Initial volume of water in graduated cylinder | | | |
| Final volume of water in graduated cylinder | | | |
| Volume of object | | | |
| Calculated density | | | |
| Physical description of metal sample | | | |
| Identity of Unknown Metal | | | |
| Density Percent Error | | | |

**Calculations:**

**Properties of Matter and Density**

**Post-lab Assignment**

**Name:** _____

Many chemical and physical properties are listed in reference sources, including Material Safety Data Sheets (MSDS's) and in the CRC Handbook of Chemistry and Physics. Use one of these resources to determine the properties of the following substances. Be sure to include proper units. List your references in the space below.

| Element | Color | Density* | Melting point | Water solubility |
|---|---|---|---|---|
| Lead metal | | | | |
| Benzene | | | | |
| Calcium chloride | | | | |

**May be stated as specific gravity*

**References:** _____

**Properties of Matter and Density**

**Pre-lab Assignment**

**Name:** _____

1. A piece of platinum metal has a mass of 47.73 grams and a volume of 2.22 $cm^3$. What is the density of platinum?

2. What is the basic difference between a physical change and a chemical change?

3. Classify the following as either chemical (C) or physical (P) changes"

| | | | |
|---|---|---|---|
| iron melting | _____ | cider changing to vinegar | _____ |
| gasoline evaporating | _____ | wood burning | _____ |
| digestion of food | _____ | steam condensing | _____ |

4. Does a physical or chemical change occur when sugar dissolves in water? Explain your reasoning.