Chemistry Experiments for High School

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Experiment 1
Identification of Substances by Physical Properties

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Text Connections
- *General Chemistry*, Sections 2.2.3, 5.2.6, 5.3.11
- *Chemistry for Accelerated Students*, Sections 3.1.1, 3.2.6, 3.3.12

Objective

To confirm the physical properties of a known solid and liquid and to determine the physical properties of an unknown solid and liquid. Specifically, the properties studied will be solubility, density, melting point, and boiling point.

New Lab Skills Focus for Experiment 1

1. Laboratory safety practices
2. Use of melting point apparatus
3. Use of boiling point apparatus
4. General familiarization with laboratory apparatus

Apparatus

balance
beaker, 250 mL (2)
boiling chips
Bunsen burner and hose
capillary tubes (5)
clamp, 3-finger, with ring stand clamp*
dropper
glass stirring rod
glass tubing, 6 mm, with right-angle bend
graduated cylinder, 10 mL (4)
latex tubing, 3/16-inch ID
ring stand and 3” iron burner ring
rubber bands, small
scoopula
test tube, 25 mm × 150 mm (2)
test tube, small (12)
test tube rack
test tube stopper, #000 (12)
thermometer
two-hole stopper, No. 4 (2)
watch glass, small (2)
wire gauze

* Separate 3-finger clamp and clamp holder may be substituted for the 3-finger clamp with a built-in ring stand clamp.

Chemicals

acetone
cyclohexane
ethyl alcohol
lauric acid
unknown liquid
unknown solid

Safety

Always follow the general safety practices described in the Preface for Students. In particular, the following safety precautions should be taken during this experiment:

1. Wear nitrile gloves whenever handling any substances.
2. Wear appropriate laboratory eye protection at all times.
3. Wear a laboratory apron to protect your clothing.
4. Acetone is highly flammable. Be sure to keep the acetone away from the burner flame at all times. Treat unknown substances as if they were flammable.

Background

Often the properties of a substance allow us to determine the identity of the substance based upon physical or chemical examination. For instance, suppose you examine a metallic substance and find it has a silvery, shiny appearance like many metals. You also note that this metal is lightweight, durable, malleable, and ductile. Suppose also that you determine that this metal conducts heat and electricity well. These physical characteristics narrow the range of possibilities for the identity of the substance. Upon further examination, you discover that this metal is insoluble in water, has a density of 2.70 g/mL, and has a melting point of 660°C. Thankfully, scientists have compiled data relating to physical properties of elements and compounds and this information is readily available to us. If you refer to one of these references, you would be able to say with confidence that your substance is aluminum.

In this experiment you will examine the following physical properties of known and unknown substances: solubility, density, melting point, and boiling point. Upon the conclusion of the experiment, you will be able to confirm the identity of two known substances and determine the identity of an unknown solid substance and an unknown liquid substance.

The two known substances you are confirming, one solid and one liquid, are lauric acid and acetone. In the procedure that follows these substances are referred to as the "known substances."

Procedure

Part 1: Solubility

Each of the four substances (two known, two unknown) will be added to three different solvents to determine solubility. If the substance dissolves completely, the substance is soluble (*s*), if the substance does not dissolve (remains solid or produces cloudiness) it is insoluble (*i*). A substance may also be sparingly soluble (*sp*).

Prepare a data table in your lab journal for recording solubility data. You have three different solvents and four different solutes. Your table should allow you to record the solubility of each solute in each of the solvents.

1. Obtain three clean, dry small test tubes. Add about 2 mL of water to the first tube, add about 2 mL of cyclohexane to the second tube, and about 2 mL ethyl alcohol to the third tube.
2. Add a small scoop of lauric acid to each tube. It is not necessary to measure the solute or solvent.
3. Stopper the top of each tube and shake for 5–10 seconds.
4. Record the solubility of this substance in your data table using the abbreviations *s*—soluble, *i*—insoluble, and *sp*—sparingly soluble.
5. Repeat this procedure for the remaining three substances. For liquid substances, use a clean dropper to add 4–5 drops into each solvent.

Part 2: Density

Prepare a data table in your lab journal for recording the data needed to calculate the density of each of the two solid substances you are working with. These data include the mass, initial volume, final volume, and net volume for each solid.

To determine the density of the solid substances:

1. Weigh about 1.5 g of lauric acid to the nearest 0.01 g or better and record the mass.
2. Obtain a clean, dry 10-mL graduated cylinder and add about 5 mL of the solvent in which this solid (lauric acid) was insoluble. Record the volume to the nearest 0.1 mL.

3. Add the solid lauric acid to the graduated cylinder, being careful to ensure that all the sample goes in the solvent and not on the sides of the cylinder. Record the new volume. The difference in volume readings equals the volume of the solid.
4. Calculate the density.
5. Repeat the same procedure for the unknown solid.

Prepare a data table in your lab journal for recording the data needed to calculate the density of each of the two liquid substances you are working with. These data include the volume, initial mass of cylinder, final mass of cylinder, and net mass of liquid for each liquid.

To determine the density of liquid substances:

1. Obtain a clean, dry 10-mL graduated cylinder and weigh it to the nearest 0.01 g or better. Record the mass.
2. Drop about 5 mL of acetone into the graduated cylinder. Record the volume to the nearest 0.1 mL. Weigh the cylinder and record the new mass. The difference in mass equals the mass of the liquid.
3. Calculate the density.
4. Repeat the same procedure for the unknown liquid.
5. Save the liquid samples for boiling point determination (Part 4).

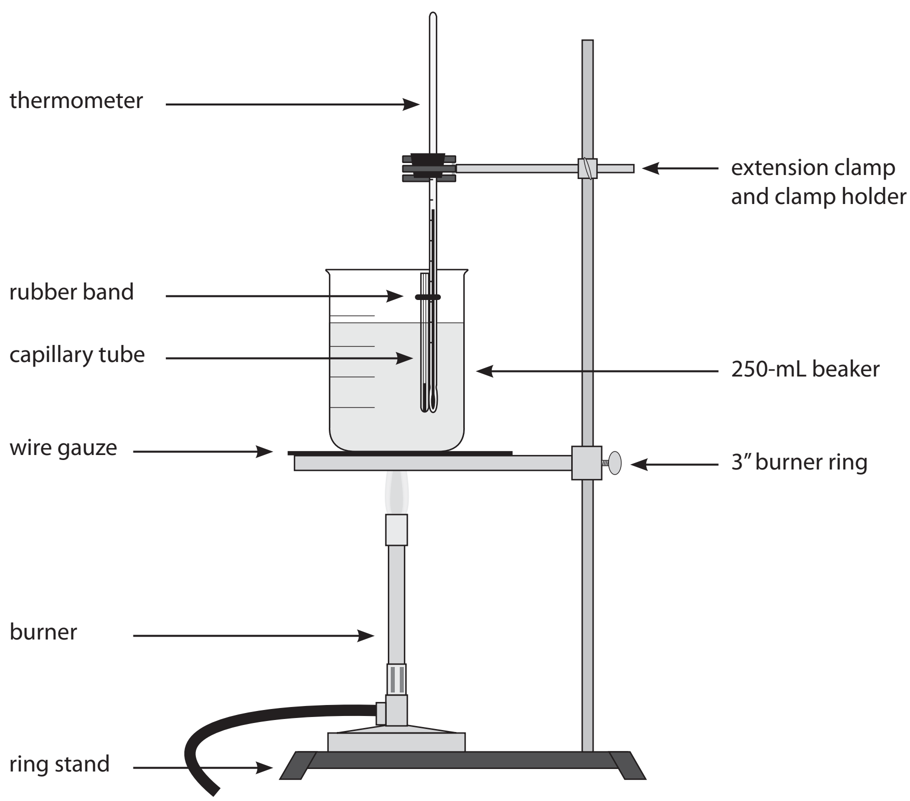

Figure 1-1. Melting point apparatus.

Part 3: Melting point of solid substances

Familiarize yourself with the melting point apparatus shown in Figure 1-1 before proceeding. Prepare a data table in your lab journal for recording melting point data. You will need to record the melting point range determined in each of two trials for the two solid substances.

1. Pulverize a small sample of lauric acid in a watch glass.
2. Fill approximately 5 mm of your sample into the open end of the glass capillary tube by tapping the open end on the sample in the watch glass.
3. Gently tap the closed end of the capillary tube on the surface of your work bench until all the sample has reached the bottom of the tube. Alternatively, the tube can be dropped through a "glass rod" to compact the sample. (Note: A "glass rod," as they are commonly called, is a hollow glass tube about 18 inches in length that is used for compacting substances in capillary tubes.)
4. Secure the capillary tube to the thermometer using a rubber band as shown in Figure 1-1.
5. Fit the thermometer into the rubber stopper and clamp it to the ring stand.
6. Place the thermometer with capillary tube into the beaker of water. Make sure the entire sample in the capillary tube is covered by the water and the open end of the tube is above the water.
7. Ignite the Bunsen burner, adjust it to produce a moderate flame, and place it under the beaker on the ring stand. Occasionally stir the water using a stirring rod.
8. Record the temperature when the sample begins to melt. Also record the temperature when the entire sample has melted. These two temperature measurements indicate the melting-

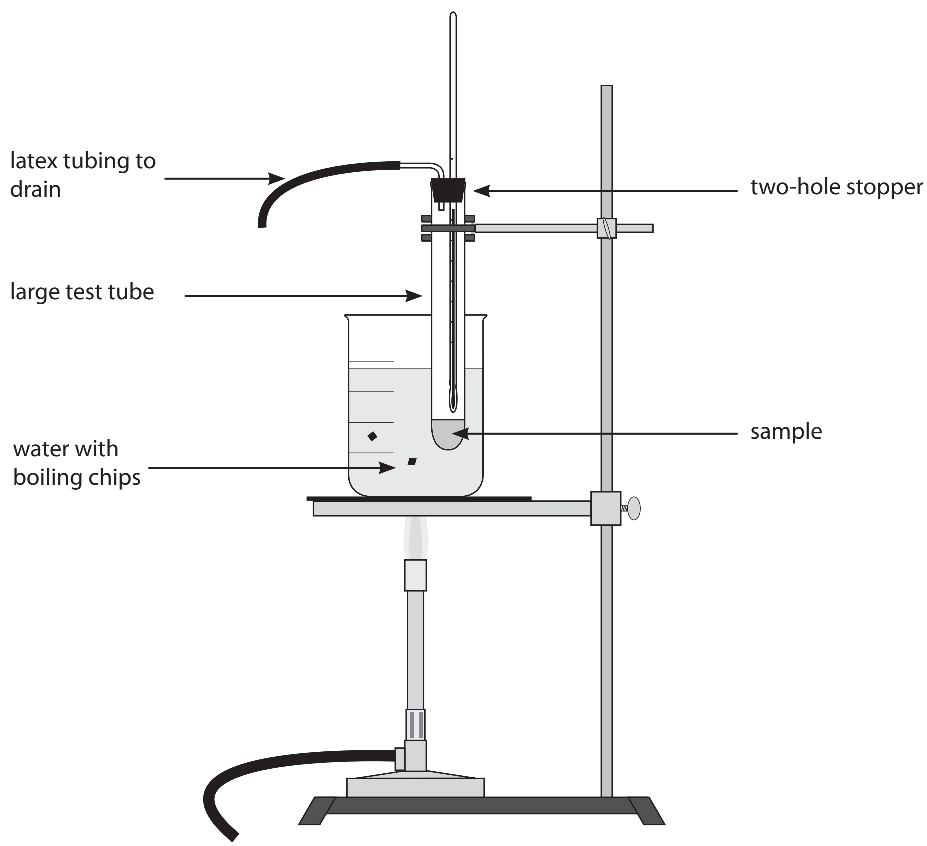

Figure 1-2. Boiling point apparatus.

point range.

9. Repeat this procedure to confirm the melting-point range. Continue to repeat until temperature ranges differ by 1°C or less.
10. Repeat the same procedure for the unknown solid.

Part 4: Boiling point of liquid substances

Familiarize yourself with the boiling point apparatus shown in Figure 1-2 before proceeding. Prepare a data table in your lab journal for recording boiling point data. You will need to record the boiling point determined in each of two trials for the two liquid substances.

1. Add about 3 mL of acetone from the sample used to calculate density (Part 2) into a clean, dry, large test tube.
2. Insert a two-hole rubber stopper into the test tube. Insert the thermometer making sure the bulb of the thermometer rests about 1 cm above the sample. Also insert a right-angle-bend glass tube connected to latex tubing. The latex tubing should be long enough to reach the sink.
3. Add two small boiling chips to the water in the beaker.
4. Position the tube in the water, making sure that the sample is submerged. Clamp the tube to the ring stand.
5. Ignite the Bunsen burner, adjust it to produce a moderate flame, and place it under the beaker on the ring stand. Watch for changes in the temperature.
6. The temperature will be constant once the sample boiling point is reached. Record the temperature.
7. Repeat this experiment to confirm the sample boiling point. Continue to repeat until temperature differs by 1°C or less.
8. Repeat steps 1–7 for the unknown liquid.

Substance	Density (g/mL)	Melting point (°C)	Boiling point (°C)	Solubility in water	Solubility in cyclohexane	Solubility in ethyl alcohol
acetone	0.79	–95	56	s	s	s
benzoic acid	1.27	122	249	i	i	s
bromoform	2.89	8	125	i	s	s
cadmium nitrate · $4H_2O$	2.46	59	132	s	i	s
cyclohexane	0.78	6.5	81.4	i	s	s
diphenylamine	1.16	53	302	i	s	s
ether, ethyl propyl	1.37	–79	64	s	s	s
hexane	0.66	–94	69	i	s	s
isopropyl alcohol	0.79	–98	83	s	i	s
lauric acid	0.88	43	225	i	s	s
methyl alcohol	0.79	–98	65	s	i	s
naphthalene	1.15	80	218	i	s	sp
phenyl benzoate	1.23	71	314	i	s	s
stearic acid	0.85	70	291	i	s	sp
toluene	0.87	–95	111	i	s	s

Table 1-1. Physical properties of pure substances.

Analysis

Using your data and the information in Table 1-1, identify the two unknown substances. Record the identities of these substances in your lab journal.

To begin your analysis, calculate the percent difference[1] for your two known substances for density, melting point, and boiling point. Record these values in your lab journal. In your discussion, refer to these values to help establish the accuracy in your measurements and the validity of your identifications of the unknown substances.

1 See the Preface for Students for an explanation of this term and the calculation involved.

Experiment 1: Identification of Substances by Physical Properties
Short Form Report Sheet

Your Name	

Your instructor will determine whether you will write a complete lab report for this experiment or use the following short form report sheet.

Part 1: Solubility

(Show your data table here.)

Part 2: Density

(Show your data table here.)

Part 3: Melting point of solids

(Show your data table here.)

Part 4: Boiling point of liquids

(Show your data table here.)

Unknown Identification

unknown solid	
unknown liquid	

Your Name	

Questions

1. Is bromoform a solid or liquid at room temperature?

2. What solvent would you use to measure the density of naphthalene?

3. If air bubbles were trapped in a sample of naphthalene during your volume measurement to calculate density, what error would result and how would that effect your density calculation?

4. A liquid was found to be insoluble in cyclohexane and had a density of 0.79. List the possible identities of this substance. What experiment could be performed to confirm the identity?

5. Osmium is the densest element known. Use the internet to research the physical properties of osmium. List the properties and their associated values. Additionally, specify your source.

Experiment 3
Flame Tests and Metal Cation Identification

3

Text Connections
- *General Chemistry*, Sections 3.1.1, 3.1.2, 3.3.3
- *Chemistry for Accelerated Students*, Sections 1.1.1, 1.1.2, 1.3.3

Objective

To relate the emission spectra of a specific metal cation to its chemical identity and to use this knowledge to identify an unknown metal cation in a solution.

New Lab Skills Focus for Experiment 3

1. Handling strong acids
2. Flame tests

Apparatus

beaker, 100 mL
Bunsen burner and gas hose
nichrome or platinum wire with loop
test tubes, small (13)
test tube rack

Chemicals

distilled water
HCl, 1.0 *M*
0.5 *M* solutions of LiCl, NaCl, $MgCl_2$, KCl, $CaCl_2$, RbCl, $SrCl_2$, CsCl, $BaCl_2$, $CuCl_2$, $ZnCl_2$, unidentified solution

Safety

Always follow the general safety practices described in the Preface for Students. In particular, the following safety precautions should be taken during this experiment:

1. Wear nitrile gloves whenever handling any substances.
2. Wear hot gloves when handling hot substances and apparatus.
3. Wear appropriate laboratory eye protection at all times.
4. Wear a laboratory apron to protect your clothing.

Background

The flame test is a qualitative method used in analytical chemistry to characterize and identify specific metal ions in solution. Metal ions emit specific wavelengths of light upon excitation. In this experiment you will characterize the color produced by metal ions and use this knowledge to identify an unknown metal ion in a solution.

Procedure

1. Make a table in your lab journal. In the left column list the 12 compounds being tested (11 known compounds and one unknown compound). Add three more columns for recording the colors you observe during three trials for each compound.
2. Obtain a test tube rack containing the 11 samples, the unknown sample, and 1.0 *M* HCl in

individual labeled test tubes.

3. Add 20–30 mL of distilled water into a clean 100-mL beaker.
4. Ignite the Bunsen burner.
5. Clean the wire loop as follows: dip the loop into the 1.0 *M* HCl solution, dip into the beaker with water, put the loop over the flame. There should be no distinguishable color rising from the loop. If there is, rinse it again.
6. Dip the loop into the first sample and place it over the hottest part of the flame, typically above the inner blue cone. As specifically and descriptively as possible, record in your lab journal the color that is emitted. Repeat this a total of three times per sample. It is not necessary to perform an HCl wash when repeating tests with the same sample, but it is necessary to wash the wire loop in the HCl solution before beginning tests on a new sample.
7. Repeat step 6 for the remaining samples.
8. After performing the flame test on the sample of unidentified solution, use your color data to identify the metal cation in the unidentified solution.

Experiment 3: Flame Tests and Metal Cation Identification
Short Form Report Sheet

Your Name	

Your instructor will determine whether you will write a complete lab report for this experiment or use the following short form report sheet.

In the space below show your data table listing the 12 samples and the colors observed during the three trials of each sample.

In the space below, identify the metal cations in the sample of unidentified solution.

Questions

1. Is there any way to relate the observed emission to the metal's location in the Periodic Table of the Elements and the number of valence electrons?

2. Every metal produces a characteristic glow when burned. Will a flame test always allow a positive identification of the presence of a particular metal? Explain why or why not.

3. Explain how light of a specific wavelength is produced by a heated metal.

Experiment 4
Determining the Empirical Formula of a Copper Chloride Hydrate

4

Text Connections
- *General Chemistry*, Sections 3.5.1, 3.5.2
- *Chemistry for Accelerated Students*, Sections 1.5.7, 1.5.8

Objective

To determine the empirical formula for the compound $Cu_xCl_y{\cdot}(H_2O)_z$ by ascertaining the mole amounts of each element present in the compound.

New Lab Skills Focus for Experiment 4

Use of a crucible

Apparatus

balance
beaker, 100 mL
Büchner funnel
Büchner funnel stopper
Bunsen burner and hose
clamp, 3-finger, with ring stand clamp
clay triangle
crucible
crucible tongs
filter paper (appropriate size to fit Büchner funnel)
glass stirring rod
ring stand
scoopula
tongs
vacuum flask
vacuum hose
wash bottle with distilled water
watch glass

Chemicals

copper chloride hydrate
distilled water
HCl, 6.0 *M*
mossy zinc

Safety

Always follow the general safety practices described in the Preface for Students. In particular, the following safety precautions should be taken during this experiment:

1. Wear nitrile gloves whenever handling any substances.
2. Wear hot gloves when handling hot substances and apparatus.
3. Wear appropriate laboratory eye protection at all times.
4. Wear a laboratory apron to protect your clothing.
5. This experiment involves concentrated hydrochloric acid, a very corrosive substance. Be very careful when handling the HCl. When pouring, pour slowly to avoid a sudden release of heat. Always pour acid into water, and never the other way around.

Background

The purpose of this experiment is to determine the empirical formula for the compound: $Cu_xCl_y{\cdot}(H_2O)_z$. This particular compound is a hydrate, which means that water has crystallized