Experiment 3:
PROPERTIES & CHANGES:
PHYSICAL vs. CHEMICAL

Purpose: The purpose of this laboratory exercise is for you to explore the distinctions between physical and chemical properties, and between physical and chemical changes.

Introduction:

Physical and Chemical Properties

The job of a chemist often involves the identification of an unknown substance by its properties. Or, in the case of a newly discovered substance, the chemist would be describing it to other chemists by reporting its properties.

There are two types of properties used to describe a given substance. A physical property is obtained without changing the chemical identity of the substance. It could be based on a qualitative observation, such as its color, smell, physical state at room temperature, viscosity, crystal appearance, and whether it would dissolve in a particular solvent. It could also be based on a quantitative observation, one that involves numerical data, such as its melting point, boiling point, specific heat and solubility (such as how many grams would dissolve in a given volume of a solvent).

A chemical property, on the other hand, is a description of whether or how the substance is changed chemically into a different substance when in contact with another substance. The change is more than merely changing from one physical state to another. The chemical property, too, could be based on both qualitative and quantitative observations, depending on whether numerical data are involved.

Physical and Chemical Changes

In chemistry, changes that a substance undergoes also play an important role. Identification of a substance is based also on what changes it may undergo when in the presence of other substances. It is important to be able to distinguish between two types of changes. A physical change is a change in a substance that does not change its chemical composition. It would fall in one of the following categories:

- a change in size only (such as tearing a piece of paper in two),
- a change in concentration only (such as adding more water to a black cup of coffee),
- a change in physical state only (such as melting a solid into a liquid, vaporizing a liquid into a gas, or dissolving a sample in a solvent).

A chemical change (also referred to as a chemical reaction) does involve a change in the chemical composition, such as the rusting of iron (Fe changing to Fe₂O₃). This may be accompanied by a change in physical state as well, and sometimes it is difficult to decide whether it is strictly a chemical or physical change. If the change does not fall in one of the three categories of physical change described above, it is likely to be a chemical change.
Another way to tell is by examining the properties of the substance before and after the change. If the properties are sufficiently different to indicate that the substance is no longer the same substance, then it must have undergone a chemical change. In the laboratory, you can use some of your five senses to help you decide (sight, hearing, smell, or touch, but not taste, due to safety reasons). The following are signs that indicate a chemical change has very likely taken place when a substance comes in contact with another substance:

- The color of the substance changes.
- An evolution of a gas (effervescence) is observed even though no external heat has been added. You may detect this by hearing or by sight. On the other hand, if effervescence is observed only after you have heated the substance, you may be observing merely a physical change, that of the liquid vaporizing into a gas without changing its chemical composition. [e.g. H₂O (l) → H₂O (g)]
- Other changes in physical state are observed (such as a solid changing to a liquid, or a liquid to a solid) even though no external heat has been added or removed. For example, the formation of a solid when two aqueous solutions are mixed would indicate a chemical reaction. However, the evaporation of water from a solution leaving behind a residue would constitute a physical change as it involves merely removal of the solvent leaving behind the solute.
- Detection of a change in temperature of a substance may indicate a chemical reaction has taken place. This is not definitive, as some physical changes could also be accompanied by a change in temperature. For example, dilution of a concentrated acid usually is an exothermic process, causing the temperature of the solution to increase. This is considered a physical rather than a chemical change.

Keep in mind that mixing two substances together does not always lead to a reaction. In addition it is possible for a chemical reaction to take place without any easily observable change being detected. When no changes are observed, we can only assume that there is no reaction, with the understanding that there is a possibility that an unobservable reaction may have taken place.

The distinction between physical and chemical change is not always clear cut even amongst scientists. Some consider the dissolution of a solid (dissolving a solid in a solvent) as a chemical change. We will treat it here as a physical change based on the premise that the chemical formula of the solid is unchanged. For example, table salt is NaCl. When it is dissolved in water, it is still NaCl. As a solid, table salt is written as NaCl (s), and when dissolved in water it is written as NaCl (aq).

One of the ways to differentiate between a mixture and a compound is how the components can be separated. A mixture can be separated simply by physical means but the elements of a compound can be separated only by chemical means. Separation by physical means involves utilizing the difference in physical properties, and the process does not involve a chemical change. The samples obtained after the separation would have the same chemical formulas as those of the components before the separation. Separation by chemical means, on the other hand, involves a chemical change, resulting in products that have different properties and chemical formulas from those of the original components in the mixture.
In this experiment you will classify your observations as physical or chemical, qualitative or quantitative. You will also observe some changes and classify them as physical or chemical changes.

**Procedure:**

*This is a multi-part experiment. Be sure the observations and answers that you are entering in your lab notebook are clearly labeled so that you and other readers can easily tell which entry refer to which part of the experiment. You do not have to complete one part before going on to the next part. One of things you should learn in this course is how to make use of your time wisely. When you reach a waiting period in the procedure, you should think about what else you can be doing while you are waiting. However, if your Bunsen burner is lit, it should not be left unattended for long periods.*

**Part I – Physical versus Chemical Change: Separation of a Mixture**

**CAUTION!** Remember to keep your goggles in place at all times. If you have hair longer than shoulder length, be sure it is tied back safely!

In the procedure outlined below you will be observing some chemical as well as some physical changes. Part of the procedure will involve the separation of a mixture of solid calcium chloride (CaCl₂) and calcium carbonate (CaCO₃). Carefully record all observations, and answer the questions as you go. Learn to be observant, and record any changes you observe in each step. Do not rely on memory and wait until later to do this; the questions need to be answered in the order presented. Do not skip around.

You do not need to use full sentences in answering the questions in your notebook, but write legibly and include enough so that you can recall at a later date exactly what you had meant to say and what your line of reasoning was.

As usual prepare your notebook before arriving to the prelab. Other than filling in the information at the top of your notebook page, give the Purpose, followed by the sample table shown below. This would be all the preparation of the notebook you need to do for Part I of this experiment. The observations and answers to questions for the subsequent steps can be added as you go along during the experiment as it will be difficult to estimate how much space to allow for each section.
### Part IA: Step 1 – Preliminary Investigations

<table>
<thead>
<tr>
<th>Test Tube #</th>
<th>Substances added to Test Tube</th>
<th>Observations (e.g. color changes? effervescence?)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CaCl₂ + water</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>CaCO₃ + water</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>CaCl₂ + 15% HCl</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>CaCO₃ + 15% HCl</td>
<td></td>
</tr>
</tbody>
</table>

#### 1. Preliminary Investigation:

*This will be done as a demonstration by your instructor. RECORD YOUR OBSERVATIONS.*

a. Four small clean and dry test tubes are labeled #1, 2, 3, and 4. A small quantity (the size of a match head) of CaCl₂ is placed into Test Tubes #1 and 3 and CaCO₃ into Test Tubes #2 and 4.

b. Ten drops of deionized water are added into Test Tube #1 containing CaCl₂. The contents of the test tube are mixed by a rocking motion, for a minute. Record your observations in the table in your notebook. Did it dissolve? Was there effervescence? Is there a color change?

c. Ten drops of water are added to Test Tube #2 containing CaCO₃. Again the contents of the test tube are mixed as before. Record your observations. Remember to answer the questions in your lab notebook as you go, not later.

**Question 1:** Based on your observations, which is soluble in water, CaCl₂ or CaCO₃? Which of your senses helped you arrive at your conclusion? Explain.

d. Next, ten drops of 15% HCl are added to Test Tube #3 containing CaCl₂, and ten drops of 15% HCl are added to Test Tube #4 containing CaCO₃. Each time the contents of the test tubes are mixed as before. Record your observations.

**Question 2:** When you added 15% HCl to CaCl₂, which of your senses alerted you to the fact that a change has taken place? How do you tell whether it was a chemical or physical change? (Hint: Reread the introductory material at the beginning of this experiment if necessary.)

**Question 3:** When you added 15% HCl to CaCO₃, which of your senses
alerted you to the fact that a change has taken place? How do you tell whether it was a chemical or physical change?

**Question 4:** What is the most obvious difference in how CaCl$_2$ and CaCO$_3$ reacted to 15% HCl? Which of your senses helped you arrive at your conclusion? Explain.

2. Obtain a vial containing a mixture of solid calcium chloride (CaCl$_2$) and calcium carbonate (CaCO$_3$) from your instructor. Record the physical appearance of this mixture.

3. Transfer the entire mixture into a 50-mL beaker. Measure out approximately 10 mL of deionized water with your 10-mL graduated cylinder and add it to the beaker.

4. Stir the mixture thoroughly with a clean glass stirring rod and grind any lumps that you may find into fine grains. Do NOT use your metal spoonula. Traces of the metal could affect the outcome of this experiment. **Question 5:** Based on your preliminary investigations, what do you think is happening to the CaCl$_2$ and CaCO$_3$ at Step 4?

5. Set up a filtration apparatus as shown in the figure below **DIRECTLY IN FRONT OF THE HOOD AT YOUR STATION.** Place a clean 100- or 150-mL beaker under the funnel.

6. As shown in the figure, also set up an iron ring, on top of which is placed a wire gauze. Place a Bunsen burner under the iron ring, but do **NOT** light it. Remember the setup should be directly in front of the hood at your station.

![Figure 3.1](image-url)
7. Fold a piece of filter paper in half. Crease it well (Fig. 2b). Then fold it into quarters and crease it well also (Fig. 2c). Tear one small corner off the filter paper as shown (Fig. 2d). Open the paper up to form a cone with the torn corner on the OUTSIDE (Fig. 2e).

8. Place the filter paper snugly in the long-stem funnel, and with a wash-bottle of deionized water, wet the sides of the filter paper to form a tight seal to the funnel.

9. In this step, you are going to try to transfer all of your mixture of solid and liquid into the filter paper. With your glass rod, stir the contents of the 50-mL beaker containing your mixture, and before the solid settles to the bottom, pour the mixture into the filter paper. Make sure the mixture goes only into the center of the paper cone and the liquid level never overflows beyond the top of the filter paper. If it overflows you will end up with some of the solid seeping around the edges of the paper into the beaker below. Use the glass stirring rod to help transfer as much of the solid as possible into the bottom of the filter paper. Do not poke a hole in the filter paper!

10. The liquid coming through the filter paper is called the filtrate. (Learn this term!) Record what you see in the filtrate, and what you see remaining on the filter paper. While you are waiting for the mixture to filter through, you are free to review the procedure for Parts II and III. These two parts will be done as a demonstration by your instructor who will call small groups of students to the demonstration site. Step 10 is a good place to be called for the demonstration.

   Question 6: Review your observations to Step 1 (Preliminary Investigations). Do you think there is something other than water in the filtrate? How would you experimentally prove your hypothesis?

   Question 7: What do you think the solid remaining on the filter paper is? Explain your rationale.

11. After the filtration is complete (with only a small amount of liquid left in the filter paper), light the Bunsen burner and adjust the Barrel to get a very hot flame and place the burner under the wire gauze. The tip of the blue cone of the flame should be touching the bottom of the wire gauze. It may be necessary to adjust the height of the iron ring and wire gauze. Do so before they get hot!

12. Place the beaker containing the filtrate onto the wire gauze. (Be careful! Which beaker would that be?) You are now going to boil off the water from the filtrate. (Place a 250-mL beaker under the funnel at the filtration setup to catch any drops that may come through later. You do NOT want drops falling onto the ring stand.)
13. **Question 8:** Without giving any chemical names or formulas, describe what you expect to see in the 100-mL beaker after all of the water has been boiled off. Explain your answer.

14. Removal of the water will take about 15-20 minutes. Keep an eye on the progress. If you see a discoloration, you are overheating. When all the water has evaporated, allow the beaker and its content to cool to room temperature, then label the beaker as Residue A and set it aside. **DO NOT WASH THIS OUT YET!**

15. Clean your 50-mL beaker, wipe it dry and measure out 10 mL of 15% HCl (from the large stock bottles, not the dropper bottles). This is an aqueous solution of HCl (i.e. HCl dissolved in water).

16. Check to see that the 250-mL beaker is in place under the funnel. With a plastic disposable pipet, add the HCl solution dropwise to the filter paper and record your observations. Continue to do this until you have used up all of the HCl solution. **Question 9:** Is your answer to Question 7 consistent with your observations at this step? Explain. *Hint: Review your answers to Question 4.*

17. After almost all of the HCl solution has drained through the filter paper (should not be more than 10 minutes), remove the 250-mL beaker and place a watch glass under the funnel to catch any drops that may come through later. You do not want HCl dripping onto the iron stand as it will eat into the metal.

18. Place the 250-mL beaker and its content on the wire gauze and evaporate off the water from this second filtrate as before. Do not let the residue char in this process.

19. When the beaker has cooled down, label it as Residue B.

20. **ANALYSIS OF THE TWO RESIDUES:**
   (Do this only after you have BOTH residues A and B so that you can compare the observations for the two residues.)
   i) With a clean and dry spoonula obtain a **small** sample (size of a match head) of Residue A and transfer it to a small test tube labeled as “A.” Clean and dry your spoonula and place a small sample of Residue B in a test tube labeled as “B.”
ii) Add 10 drops of 15% HCl to each of the two test tubes and mix as before. Is there a significant amount of effervescence (bubbling action) in either test tube? (A small amount of effervescence can be due to contamination and is not to be considered a positive result.) Record your observations in your notebook carefully. Did the solid dissolve? How do these observations compare with those recorded back in Step 1 (Preliminary Investigations)?

**Question 10:** Based on your observations in Step 20, do you think Residue A is the same substance as the solid that was in the filter paper at Steps 10? Explain how you reached your conclusion. *Hint: What did HCl do to the solid in the filter paper as compared to Residue A?*

**Question 11:** Based on your observations in Step 20, do you think Residue B is the same substance as the solid that was in the filter paper at Steps 10? Explain how you reached your conclusion. *Hint: What did HCl do to the solid in the filter paper as compared to Residue A?*

**Question 12:** What type of change (physical or chemical) was occurring at Step 16 when you added the aqueous HCl to the solid in the filter paper? Explain. (Hint: Think about your answer to Question 11. Is Residue B the same as the solid that was remaining in the filter paper at Steps 10?)

**Question 13:** Think through all the steps you have gone through in this procedure. Exactly at which step did you separate the CaCl$_2$ from the CaCO$_3$?

21. **CLEANUP: BE SURE YOUR SAFETY GOGGLES ARE STILL IN PLACE!**

Discard excess HCl in the special waste container in the hood. All other chemicals may be discarded in the sink. Remove all labels from your glassware. Scrub glassware with brushes provided at the sink under running tap water and then rinse them with deionized water. Shake out excess water and wipe the outside dry with paper towels.

**Part II. What change is iodine undergoing?**

Examine the iodine crystals in the large hood in the corner of the lab. They are in a beaker sitting on a hotplate. The beaker is covered with a watch glass on which is placed a few ice chips. Describe what you see in the beaker and on the underside of the evaporating dish. Record your observations in your lab notebook.
**Question 14:** What is the function of the hotplate and what is the function of the ice chips?

**Question 15:** What is happening to the iodine? Is it undergoing a physical or chemical change? There is a specific name for the process that iodine is undergoing. What is the name?

**Part III. Distillation: Separation by Physical Means**

Distillation is a method of separation of a mixture of substances based on their boiling points. It is an example of separation by physical means as it does not involve any chemical reactions. The only changes are physical changes, from liquid to gas, and then gas back to liquid. No chemical bonds are broken in this process.

The figure below shows a typical distillation setup. A mixture of two or more substances is placed in the distillation flask. In the setup below, the mixture (a red dye and water) is heated by a heating mantle. When the temperature of the flask reaches the boiling point of the substance that is the most volatile (the one with the lowest boiling point), the liquid rapidly converts to its gaseous state. The vapor rises and when it reaches the condenser which has an outer jacket cooled with running tap water, the vapor condenses back into the liquid state and drips into a collector.

This process will continue until all of the most volatile substance has distilled over, leaving behind the components that are less volatile in the distillation flask. The temperature registered by the thermometer at the distillation head corresponds to the boiling point of the substance being collected. This temperature will stay constant until the entire first fraction has distilled over, at which point, the temperature in the distillation flask will rise until it reaches the boiling point of the next volatile component in the mixture. The vapor of this second substance will rise and when it reaches the thermometer at the distillation head, the temperature registered will correspond to the boiling point of the second fraction. A new collector is then put in place to collect the second fraction.
**Question 16:** What is the boiling point you recorded for the substance that is distilling over?

**Question 17:** From your observations of the distillation setup in the lab, what can you conclude about the boiling point of the red substance in the distillation flask? Explain.

**ASSIGNMENT TO BE TURNED IN NEXT WEEK:**

No formal report is required for this experiment; however, this assignment is going to take considerable thought. Be sure to allow enough time on this assignment. It would also be wise to complete this assignment as soon as you can while your observations are still fresh on your mind, rather than waiting until the night before it is due. By completing your assignment early you would have a chance to get help from your instructor if necessary! YOUR ANSWERS MUST BE TYPED.

At the top left hand corner, give the course number (Chem 107), section number, the semester and year. On the top right hand corner, give your name, the date when the experiment was performed and the date this assignment is to be submitted. This is not a formal lab report, so no abstract is necessary.

1. Search the Internet to find the identity of the gas that was produced when HCl was added (Step 19) to the solid left in the filter paper at the end of the filtration (Step 10-14). Try using Google and typing in the words “carbonate and acid.” You may have to visit several websites before finding your answer. Give your source(s) of reference. Below is an example on how to provide a reference when the source is from the Internet:

   http://pubs.acs.org/books/references.shtml (accessed June 17, 2007)

   *It is important to include the date the website was accessed because information can change from one day to the next.*

   Give the name and formula of the gas produced at that step. Based on your search you should be able to also identify what Residue B is. Give the name and formula of Residue B as well.

2. Do not attempt to answer this question until you have completed your Internet search and answered Question 1 above. Examine your answers to Questions 1 through 20 in your notebook and type all the answers, incorporating any changes in your conclusions you wish to make based on your Internet search. You are allowed to change your mind (in view of what you learned from the Internet) on how to answer the questions, but conclusions must be consistent with the observations you recorded. You can NOT change your observations. If you feel your observations are incorrect you may point it out in your answers and explain why you think they are incorrect.

   All answers must be in full sentences. You do not need to type the questions, although you may if you wish. Be sure to number your answers accordingly.

   (Continued next page)
3. Write a short but well-organized paragraph to summarize how the mixture of CaCl$_2$ and CaCO$_3$ was separated. (Do NOT give all the details of the procedure such as beaker size or number of drops, etc.) Use past tense and passive voice.

Include in your paragraph your conclusion as to whether the separation was by physical or chemical means. Was the addition of HCl necessary for the separation? Explain.