Laboratory Exercise 3

Chemistry of Life

Materials Needed

For pH Tests:
Chopped fresh red cabbage
Beaker (250 mL)
Distilled water
Tap water
Vinegar
Baking soda
Laboratory scoop for measuring
Pipets for measuring
Full-range pH test papers
7 assorted common liquids clearly labeled in closed bottles on a tray or in a tub
Droppers labeled for each liquid

For Organic Tests:
Test tubes
Test-tube rack
Test-tube clamps
China marker
Hot plate
Beaker for hot water bath (500 mL)
Pipets for measuring
Benedict's solution
Biuret reagent (or 10% NaOH and 1% $CuSO_4$)
Iodine-potassium-iodide (IKI) solution
Sudan IV dye
Egg albumin
10% glucose solution
Clear carbonated soft drink
10% starch solution
Potatoes for potato water
Distilled water
Vegetable oil
Brown paper
Numbered unknown organic samples

Safety

- Review all safety guidelines inside the front cover of your laboratory manual.
- Clean laboratory surfaces before and after laboratory procedures using soap and water.
- Use extreme caution when working with chemicals.
- Safety goggles must be worn at all times.
- Wear disposable gloves while working with the chemicals.
- Precautions should be taken to prevent chemicals from contacting your skin.
- Do not mix any of the chemicals together unless instructed to do so.
- Clean up any spills immediately and notify the instructor at once.
- Wash your hands before leaving the laboratory.

The complexities of the human body arise from the organization and interactions of chemicals. Organisms are made of matter, and the most basic unit of matter is the chemical element. The smallest unit of an element is an atom, and two or more of those can unite to form a molecule. All processes that occur within the body involve chemical reactions—interactions between atoms and molecules. We breathe to supply oxygen to our cells for energy. We eat and drink to bring chemicals into our bodies that our cells need. Water fills and bathes all of our cells and allows an amazing array of reactions to occur, all of which are designed to keep us alive. Chemistry forms the basis of life and thus forms the foundation of anatomy and physiology.

Purpose of the Exercise

To review the organization of atoms and molecules, types of chemical interactions, and basic categories of organic compounds, and to differentiate between types of organic compounds.

LEARNING OUTCOMES

After completing this exercise, you should be able to

1. Associate and illustrate the basic organization of atoms and molecules.
2. Measure pH values of various substances through testing methods.
3. Determine categories of organic compounds with basic colorimetric tests.
4. Discover the organic composition of an unknown solution.

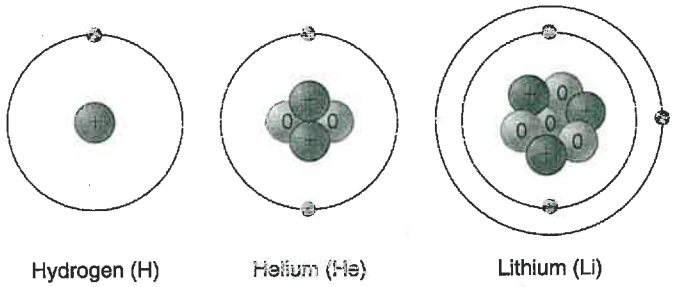
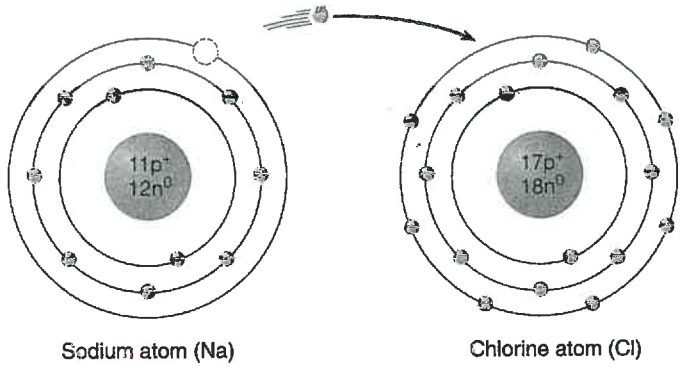
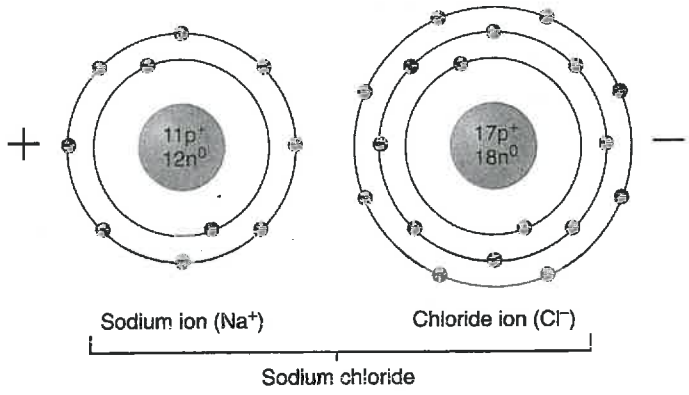


Figure 3.1 The single electron of a hydrogen atom is located in its first shell. The two electrons of a helium atom fill its first shell. Two of the three electrons of a lithium atom are in the first shell, and one is in the second shell.



(a) Separate atoms
If a sodium atom loses an electron to a chlorine atom, the sodium atom becomes a sodium ion (Na^+), and the chlorine atom becomes a chloride ion (Cl^-).



(b) Bonded ions
These oppositely charged particles attract electrically and join by an ionic bond.

Figure 3.2 Formation of an ionic bond.

EXPLORE

Procedure A—Matter, Molecules, Bonding, and pH

1. Review the section entitled "Structure of Matter" in chapter 2 of the textbook. Use the Periodic Table of Elements, located inside the back cover of the laboratory manual, as a reference.
2. Review figures 3.1, 3.2, and 3.3, which show molecular diagrams, formation of an ionic bond, and formation of a covalent bond, respectively.
3. Complete Part A of Laboratory Report 3.

EXPLORE

Procedure B—The pH Scale

1. Review the section entitled "Acid and Base Concentrations" in chapter 2 of the textbook.
2. Review figure 3.4, which shows the pH scale. Note the range of the scale and the pH value considered neutral.
3. **Cabbage water tests.** Many tests can determine a pH value, but among the more interesting are colorimetric tests in which an indicator chemical changes color when it reacts. Many plant pigments, especially anthocyanins (which give plants color, from blue to red), can be used as colorimetric pH indicators. One that works well is the red pigment in red cabbage.
   a. Prepare cabbage water to be used as a general pH indicator. Fill a 250 mL beaker to the 100 mL level with chopped red cabbage. Add water to make 150 mL. Place the beaker on a hot plate and simmer the mixture until the pigments come out of the cabbage and the water turns deep purple. Allow the water to cool. (You may proceed to step 4 while you wait for this to finish.)
   b. Label three clean test tubes: one for water, one for vinegar, and one for baking soda.
   c. Place 2 mL of cabbage water into each test tube.
   d. To the first test tube, add 2 mL of distilled water and swirl the mixture. Record the color in Part B of the laboratory report.

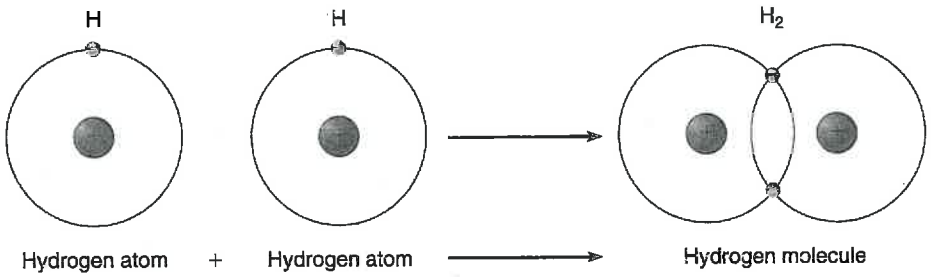


Figure 3.3 A hydrogen molecule forms when two hydrogen atoms share a pair of electrons and join by a covalent bond.

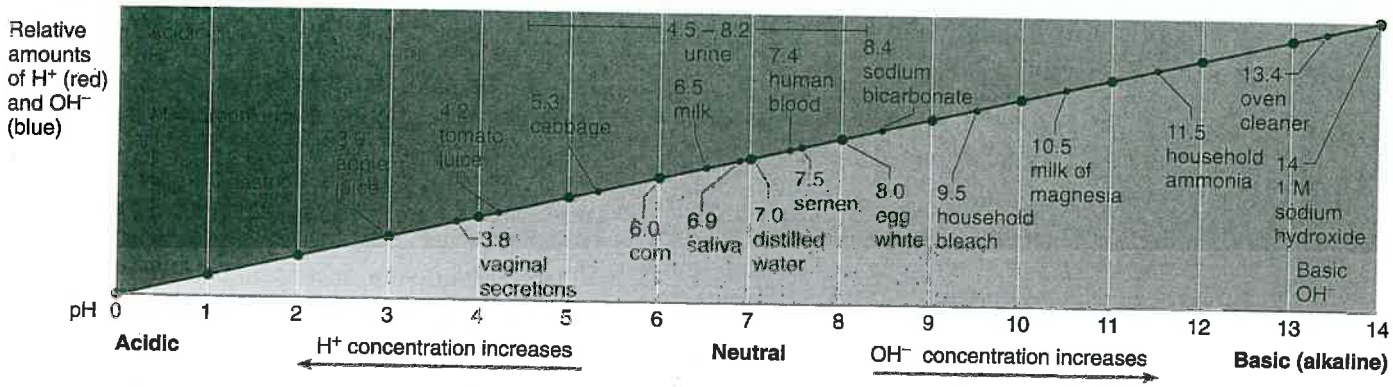


Figure 3.4 As the concentration of hydrogen ions (H^+) increases, a solution becomes more acidic, and the pH value decreases. As the concentration of ions that combine with hydrogen ions (such as hydroxide ions) increases, a solution becomes more basic (alkaline), and the pH value increases. The pH values of some common substances are shown.

e. Repeat this procedure for test tube 2, adding 2 mL of vinegar and swirling the mixture. Record the results.

f. Repeat this procedure for test tube 3, adding one laboratory scoop of baking soda. Swirl the mixture. Record the results.

4. **Testing with pH paper.** Many commercial pH indicators are available. A simple one to use is pH paper, which comes in small strips. Don gloves for this procedure so your skin secretions do not contaminate the paper, and to protect you from the chemicals you are testing.

a. Test the pH of distilled water by dropping one or two drops of distilled water onto a strip of pH paper, and note the color. Compare the color to the color guide on the container. Record the pH value in Part B of the laboratory report.

b. Repeat this procedure for tap water. Record the results.

c. Individually test the various common substances found on your lab table. Record your results.

d. Complete Part B of the laboratory report.

EXPLORE

Procedure C—Organic Molecules

In this section, you will perform some simple tests to check for the presence of the following categories of organic molecules (biomolecules): protein, sugar, starch, and lipid. Specific color changes will occur if the target compound is present. Please note the original color of the indicator being added so you can tell if the color really changed. For example, Biuret reagent and Benedict's solution are both initially blue, so an end color of blue would indicate no change. Use caution when working with these chemicals, and follow all directions. Carefully label the test tubes and avoid contaminating any of your samples. Only the Benedict's test requires heating and a time delay for accurate results. Do not heat any other tubes. To prepare for the Benedict's test, fill a 500 mL beaker half full with water and place it on the hot plate. Turn the hot plate on and bring the water to a boil. To save time, start the water bath before doing the Biuret test.

1. **Biuret test for protein.** In the presence of protein, Biuret reagent reacts with peptide bonds and changes to violet or purple. A pinkish color indicates that shorter polypeptides are present. The color intensity is proportional to the number of peptide bonds, thus the intensity reflects the length of polypeptides (amount of protein).

a. Label six test tubes as follows: 1W, 1E, 1G, 1D, 1S, and 1P.

b. To each test tube, add 2 mL of one of the samples as follows:

1W—2 mL distilled water

1E—2 mL egg albumin

1G—2 mL 10% glucose solution

1D—2 mL carbonated soft drink

1S—2 mL 10% starch solution

1P—2 mL potato juice

c. To each, add 2 mL of Biuret reagent, swirl the tube to mix it, and note the final color. [*Note:* If Biuret reagent is not available, add 2 mL of 10% NaOH (sodium hydroxide) and about 10 drops of 1% $CuSO_4$ (copper sulfate)]. **Be careful—NaOH is very caustic.**

d. Record your results in Part C of the laboratory report.

e. Mark a "+" on any tubes with positive results and retain them for comparison while testing your unknown sample. Put remaining test tubes aside so they will not get confused with future trials.

2. **Benedict's test for sugar (monosaccharides).** In the presence of sugar, Benedict's solution changes from its initial blue to a green, yellow, orange, or reddish color, depending on the amount of sugar

present. Orange and red indicate greater amounts of sugar.

a. Label six test tubes as follows: 2W, 2E, 2G, 2D, 2S, and 2P.
b. To each test tube, add 2 mL of one of the samples as follows:
   2W—2 mL distilled water
   2E—2 mL egg albumin
   2G—2 mL 10% glucose solution
   2D—2 mL carbonated soft drink
   2S—2 mL 10% starch solution
   2P—2 mL potato juice
c. To each, add 2 mL of Benedict's solution, swirl the tube to mix it, and place all tubes into the boiling water bath for 3 to 5 minutes.
d. Note the final color of each tube after heating and record the results in Part C of the laboratory report.
e. Mark a "+" on any tubes with positive results and retain them for comparison while testing your unknown sample. Put remaining test tubes aside so they will not get confused with future trials.

3. **Iodine test for starch.** In the presence of starch, iodine turns a dark purple or blue-black color. Starch is a long chain formed by many glucose units linked together side by side. This regular organization traps the iodine molecules and produces the dark color.
   a. Label six test tubes as follows: 3W, 3E, 3G, 3D, 3S, and 3P.
   b. To each test tube, add 2 mL of one of the samples as follows:
      3W—2 mL distilled water
      3E—2 mL egg albumin
      3G—2 mL 10% glucose solution
      3D—2 mL carbonated soft drink
      3S—2 mL 10% starch solution
      3P—2 mL potato juice
   c. To each, add 0.5 mL of IKI (iodine solution) and swirl the tube to mix it.
   d. Record the final color of each tube in Part C of the laboratory report.
   e. Mark a "+" on any tubes with positive results and retain them for comparison while testing your unknown sample. Put remaining test tubes aside so they will not get confused with future trials.
4. **Tests for lipids.**
   a. Label two separate areas of a piece of brown paper as "water" or "oil."
   b. Place a drop of water on the area marked "water" and a drop of vegetable oil on the area marked "oil."
   c. Let the spots dry several minutes, then record your observations in Part C of the laboratory report. Upon drying, oil leaves a stain (grease spot) on brown paper; water does not leave such a spot.
   d. In a test tube, add 2 mL of water and 2 mL of vegetable oil and observe. Shake the tube vigorously then let it sit for 5 minutes and observe again. Record your observations in Part C of the laboratory report.
   e. Sudan IV is a dye that is lipid-soluble but not water-soluble. If lipids are present, the Sudan IV will stain them pink or red. Add a small amount of Sudan IV to the test tube that contains the oil and water. Swirl it then let it sit for a few minutes. Record your observations in Part C of the laboratory report.

EXPLORE

Procedure D—Identifying Unknown Compounds

Now you will apply the information you gained with the tests in the previous section. You will retrieve an unknown sample that contains none, one, or any combination of the following types of organic compounds: protein, sugar, starch, or lipid. You will test your sample using each test from the previous section and record your results in Part D of the laboratory report.

1. Label four test tubes (1, 2, 3, 4).
2. Add 2 mL of your unknown sample to each test tube.
3. **Test for protein.** Add 2 mL of Biuret reagent to tube 1. Swirl the tube and observe the color. Record your observations in Part D of the laboratory report.
4. **Test for sugar.** Add 2 mL of Benedict's solution to tube 2. Swirl the tube and place it in a boiling water bath for 3 to 5 minutes. Record your observations in Part D of the laboratory report.
5. **Test for starch.** Add several drops of iodine solution to tube 3. Swirl the tube and observe the color. Record your observations in Part D of the laboratory report.
6. **Test for lipid.** Add 2 mL of water to tube 4. Swirl the tube and note if there is any separation.
7. Add a small amount of Sudan IV to test tube 4, swirl the tube and record your observations in Part D of the laboratory report.
8. Based on the results of these tests, determine if your unknown sample contains any organic compounds and, if so, what are they? Record and explain your identification in Part D of the laboratory report.