Effect of Metal Ions on the Growth of Microorganisms
(Adapted from "Environmental Chemistry: Experiments and Demonstrations", 2nd Ed.,
M. G. Ondrus, Wuerz Publishing Ltd.)

Background Information

This experiment is designed to investigate the effect of metal ions on living organisms. It uses baker's yeast as a test subject, and Na(I), Cu(II), and Hg(II) ions as contaminants.

Yeasts are microorganisms that can grow under both aerobic (presence of oxygen) or anaerobic (absence of oxygen) conditions. This is because while they thrive in the presence of oxygen, their presence rapidly depletes the oxygen in a closed system. They then continue to grow obtaining the energy they need for metabolism (the set of chemical reactions that happen in living organisms to maintain life) from fermentation of carbohydrates instead of oxygen metabolism. The fermentation of glucose may be represented by the following chemical equation:

$$C_6H_{12}O_6\ (aq) \rightarrow 2\ C_2H_5OH\ (aq) + 2\ CO_2\ (g) + \text{energy}$$

In the experiment, yeast will be allowed to grow in the presence of glucose, $C_6H_{12}O_6$. The growth of the microorganism is estimated by measurement of the volume of carbon dioxide gas, CO_2, evolved. The yeast environments will be varied to test how the presence or absence of metal ions affects the yeast metabolism. The relative rate of yeast metabolism in different systems can be estimated by comparing the relative amounts of carbon dioxide produced in each environment over a given time period. The specific contaminants investigated will be mercury(II) and copper (II) ions.

Copper is abundant in the Earth's crust. However, the richest copper ores have been depleted and the costs for mining the remaining reserves are becoming prohibitively high. The United States has significant reserves of copper, which are extracted in large open pit mines, which can cause environmental problems. Leachates (soluble substances that are washed out of soil) from open pit mines often contain high levels of dissolved metal ions. It has been observed that some lakes, rivers, and streams downhill from open pit mines contain high levels of dissolved metal ions. These waters are sometimes lifeless, so that despite being beautiful, clear waters, they possess no living species.

Mercury ions constitute a specific and prevalent contaminant in many natural waters. A number of human activities and products, such as fluorescent light bulbs and mining, result in airborne mercury, which is deposited all over the surface of the planet. Mercury is known to have a harmful effect on living organisms.

In this experiment, each team will perform four trials and observe the amount of carbon dioxide produced in the presence and absence of metal ions. The carbon dioxide produced in each trial will be collected (see picture). After collecting data, the class will share results. Using the results from all the teams, the effect of metal ions on yeast metabolism can be determined with some quantitative certainty.

Experiment

You will be assigned to work in one of the following teams: sodium, copper, or mercury.

1. Your bench is equipped with a plastic bin, a stopper equipped with a rubber tube, a 50-mL graduated cylinder, a beaker, a bag of yeast, two ring stands, two clamps, a hot water bath, and four 50-mL Erlenmeyer flasks.

2. Open the yeast. Place one of the 50-mL flasks on the balance and tare it. Carefully pour 1.20 g of yeast into the flask. Repeat this process with the other three flasks.

3. Fill the plastic bin fairly full of water (see picture). Then, fill the graduated cylinder with water by completing immersing it in the tub and standing it up while keeping the open end under water. Clamp the filled cylinder so that approximately the bottom ½ inch remains submerged. Insert the end of the rubber tube into the inverted cylinder.

4. Add glucose water (sugar water) to the 20 mL line in one of the flasks. Using the information in Table 1, add 2.0 mL of water or metal ion solution.

Table 1: Aliquots added

Experiment	Na^+ Team	Cu^{2+} Team	Hg^{2+} Team
1	2.0 mL water	2.0 mL water	2.0 mL water
2	2.0 mL water	2.0 mL water	2.0 mL water
3	2.0 mL 1000 ppm Na	2.0 mL 1000 ppm Cu	2.0 mL 1000 ppm Hg
4	2.0 mL 1000 ppm Na	2.0 mL 1000 ppm Cu	2.0 mL 1000 ppm Hg

5. Stir the solution while heating it gently in the water bath. Use a thermometer to monitor the temperature. Stir the flask in the warm water bath at 40 °C for 1.5-2 minutes to bring the water in the flask to 40 °C.

6. Connect the flask to the end of the tube, similar to Figure 1. When gas evolution begins, you will see bubbles in the solution and the water in the cylinder will be displaced. Allow the reaction to proceed for 10 minutes.

7. After 10 minutes, record the amount of water displaced in the graduated cylinder.

8. Dispose of the yeast solution in the appropriately labeled bins. Rinse the flask with deionized water.

9. Repeat Steps 3-8 until data for all four experiments has been collected.

10. Write your results on the board

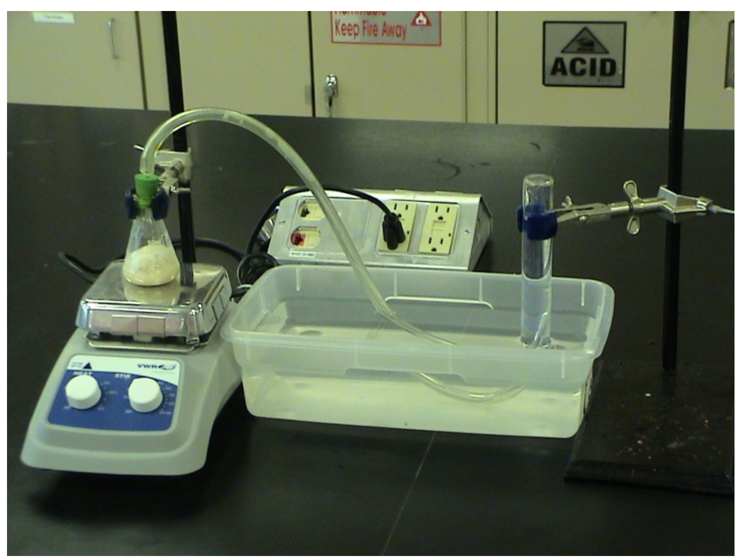

Figure 1: An experimental setup. You will use a water bath instead of a hot plate.