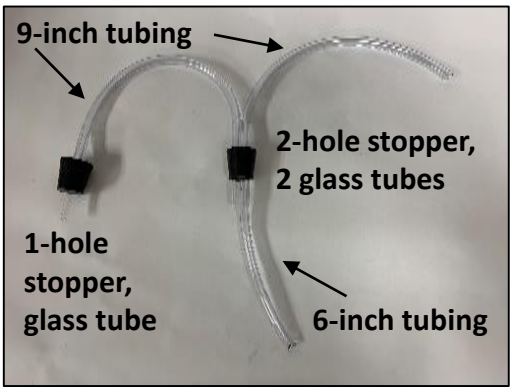
Biofuels

Materials for Gasometer

2 clear plastic bottles,
narrow mouth with cap, 500 ml
3 glass tubes (5 mm, 3” long)
Rubber stopper, #4, 1-hole
Rubber stopper, #4, 2-hole
Vinyl tubing, 4.8 mm, 2 ft
Graduated cylinder, 100 ml



Gasometer Setup

1. **Insert** a glass tube into each hole in rubber stoppers. Lubricate outside of glass tube with oil or Vaseline before inserting.
2. **Cut** 3 pieces of tubing: 6-inch length, 9-inch length, 9-inch length.
3. **Attach** first 9-inch tubing to glass tube in top of 1-hole stopper. Connect other tubing end to first glass tube in top of 2-hole stopper. See diagram.
4. **Connect** second 9-inch tubing to second glass tube in top of 2-hole stopper, leaving free end.
5. **Attach** 6-inch tubing to second glass tube in bottom of 2-hole stopper, where top of glass tube is connected to tubing with free end.
6. **Fill** reservoir bottle with 400 ml water, add a few drops of blue food coloring.
7. **Insert** 2-hole stopper assembly into reservoir bottle. Place free tubing end in graduated cylinder, just at top. Insert 1-hole stopper assembly into reaction bottle with yeast as described below.

Yeast Fermentation Analysis

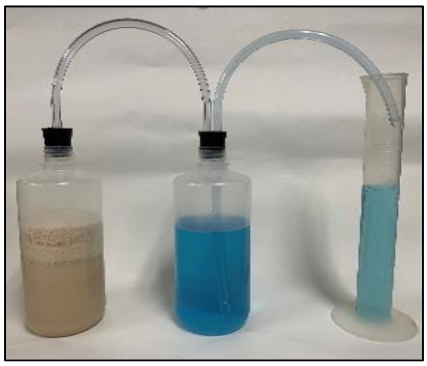
$$C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2$$
glucose ethanol carbon dioxide

As yeast ferments sugar, the reaction produces ethanol and carbon dioxide gas. Gas produced in the reaction bottle volumetrically displaces water from reservoir bottle into graduated cylinder.

1. **Prepare yeast solution**: Add one packet of Rapid Rise yeast (7g) to reaction bottle. Add 3 tsp of table sugar (sucrose) or other feedstock. Pour 250 ml of 115 °F water into bottle and start timer. Cap bottle and swirl for 30 sec to mix. Insert 1-hole rubber stopper assembly into bottle. After lag period of 6-8 min during which yeast becomes rehydrated, solution will begin to foam.
2. **Measure** volume of water displaced into graduated cylinder, recording every minute until volume reaches 100 ml. Record on data table and graph Volume vs Time.

Extensions and Alternatives

- **Amount of Feedstock:** Analyze different amounts of feedstock.
- **Reaction Conditions:** Analyze at different water temperatures or pH.
- **Substrate Specificity:** Test other feedstock such as glucose, fructose, corn syrup, or corn starch.
- **Enzyme Additives:** Test corn starch with addition of α-amylase enzyme (found in saliva). Test milk with addition of lactase (add crushed Lactaid tablet).



Reaction bottle **Reservoir bottle**

Learn more at *J. Chem Ed.,* 2018, 95, 828-832

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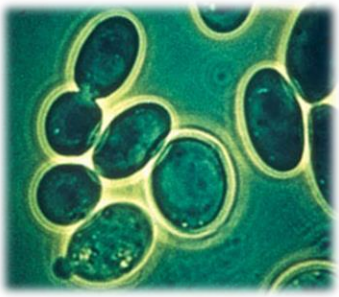

Enzyme Action

Yeast can directly convert glucose, a simple sugar, to ethanol by fermentation. Other sugars must first be converted to glucose using **enzymes**. Yeast naturally have enzymes fructokinase, to convert fructose to glucose, and invertase, to break down sucrose. Starch is a glucose polymer that must be pretreated with amylase enzyme before yeast fermentation. **Cellulosic ethanol**, an advanced biofuel, is produced from plant fibers, which require complex pretreatment steps before fermentation.

Fermentation for Fuel

Biofuels are produced from renewable **biomass**, such as plant materials. Biomass feedstocks such as sugar or corn can be converted to **ethanol** by **fermentation**. As a fuel, ethanol has a high octane number and is cleaner-burning, reducing air pollution when blended with gasoline. Sugar can be directly fermented by **yeast**, a micro-organism, to produce ethanol, with carbon dioxide as a byproduct. Corn starch is a polymer of glucose. It must be processed by heating and adding enzymes to break it down before it can be fermented to produce ethanol. After fermentation, ethanol is purified by **distillation**.

NAVY NOTES

In 2016, the **Great Green Fleet** showcased the Navy's commitment to increasing usage of biofuels. The Department of Energy Bioenergy Research Centers focus on developing biofuel from nonfood plant biomass. **Bioprospecting** researchers look to nature to find novel ways to degrade plant biomass by studying the ability of different fungi to break down cellulose. **Genetic engineering** could be used to create modified microbial strains containing additional enzymes for cellulosic ethanol production. Another strategy looks for ways to genetically engineer plants that break down more easily.

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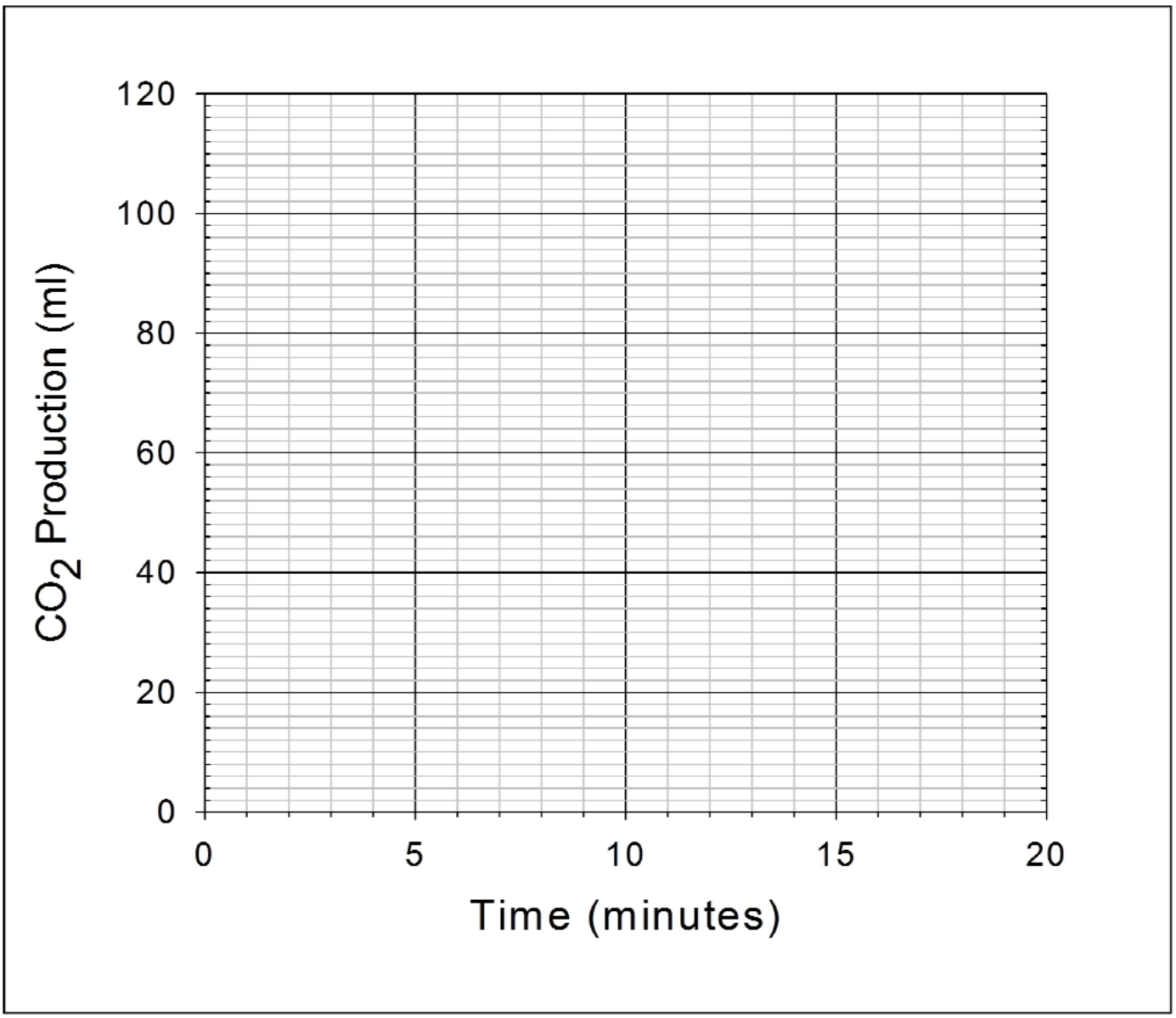
YEAST FERMENTATION DATA SHEET

Group Members: _____

Type of Feedstock: _____ Amount of Feedstock: _____

Other Materials Added: _____

Time (minutes)	Volume (ml)	Time (minutes)	Volume (ml)	Time (minutes)	Volume (ml)	Time (minutes)	Volume (ml)
1		6		11		16	
2		7		12		17	
3		8		13		18	
4		9		14		19	
5		10		15		20	



Lag Time _____min

Reaction Rate _____ml/min