Fermentation of Sugar

Introduction:

One celled microorganisms called yeast produce complex enzymes called zymases. In the metabolism of sugar, these enzymes catalyze the conversion of glucose to ethanol according to the equation:

\[
\text{C}_6\text{H}_{12}\text{O}_6 \xrightarrow{\text{yeast}} 2 \text{C}_2\text{H}_5\text{OH} + 2 \text{CO}_2
\]

The fermentation must be protected from air otherwise other enzymes catalyze the oxidation of ethanol to acetic acid (vinegar):

\[
\text{C}_2\text{H}_5\text{OH} + \text{O}_2 \xrightarrow{\text{yeast}} \text{HC}_2\text{H}_3\text{O}_2 + \text{H}_2\text{O}
\]

The alcohol produced is in an aqueous solution. Concentration of alcohol may be affected by the process of distillation. Distillation is the slow, controlled boiling of a mixture so that the most volatile component vaporizes preferentially. No matter how efficient the distillation, ethanol cannot be completely separated from water. The maximum concentration is about 96% ethanol.

Mixtures of ethanol and water are less dense than pure water. The density of the distillate is a measure of the percent composition. See table below:

<table>
<thead>
<tr>
<th>Percent ethanol</th>
<th>density at 20°C</th>
<th>density at 25°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>95</td>
<td>0.804</td>
<td>0.800</td>
</tr>
<tr>
<td>90</td>
<td>0.818</td>
<td>0.814</td>
</tr>
<tr>
<td>85</td>
<td>0.831</td>
<td>0.827</td>
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<tr>
<td>80</td>
<td>0.843</td>
<td>0.839</td>
</tr>
<tr>
<td>75</td>
<td>0.856</td>
<td>0.851</td>
</tr>
<tr>
<td>70</td>
<td>0.868</td>
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</tr>
<tr>
<td>65</td>
<td>0.879</td>
<td>0.875</td>
</tr>
<tr>
<td>60</td>
<td>0.891</td>
<td>0.887</td>
</tr>
<tr>
<td>55</td>
<td>0.904</td>
<td>0.889</td>
</tr>
<tr>
<td>50</td>
<td>0.915</td>
<td>0.911</td>
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<td>45</td>
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<td>0.922</td>
</tr>
<tr>
<td>40</td>
<td>0.937</td>
<td>0.933</td>
</tr>
</tbody>
</table>
**Procedure:**

*Fermentation of Glucose:*

Clean a 125 mL Erlenmeyer flask. Warm 75 mL of distilled water to 40°C. Weigh about 20 grams of glucose and dissolve it in the 75 mL of warm water. Transfer the sugar solution to the Erlenmeyer flask and add about 1 to 2 grams of yeast. Attach the “bubbler” to the flask and half-fill the test tube with saturated Ca(OH)$_2$ solution. Put the fermentation apparatus in your drawer to ferment for a week.

![Fermentation Apparatus](image)

*Distillation of Ethanol:*

Weigh a 10 mL graduated cylinder to the nearest 0.01 gram. Assemble the distillation apparatus show below. Carefully decant the fermentation mixture into the distilling flask. Avoid transferring the yeast residue. Add a couple of glass beads to the flask to aid the boiling process. Replace the thermometer and adjust the thermometer so that the top of the bulb reaches just below the side-arm of the distilling flask.

![Distillation Apparatus](image)

Using a clean, low flame apply heat to the distilling flask. Maintain a flame that keeps the mixture gently boiling so that one drop of distillate forms per second. Collect the first few drops (10 to 20) of distillate on a watch glass. Replace the watch glass with the weighed graduated cylinder. Collect distillate until the temperature of the vapor exceeds 90°C. Stop the distillation, weigh the collected distillate and record the data. Test the combustibility of the distillate with a lighted splint. Ethanol burns with a faint blue flame.
Report for Fermentation Experiment:

Data:

Weight of glucose = _________ g
Weight of graduated cylinder and distillate = _________ g
Weight of empty graduated cylinder = _________ g
Volume of distillate = _________ mL

Questions & Calculations: (show your work!)

1. How combustible was your distillate?

2. Calculate the density of the distillate.

3. Determine the percentage of ethanol in the distillate using the table on page 1.
4. Calculate the weight of ethanol in the distillate.

5. Calculate the theoretical yield of ethanol.

6. Calculate the percent yield of ethanol.