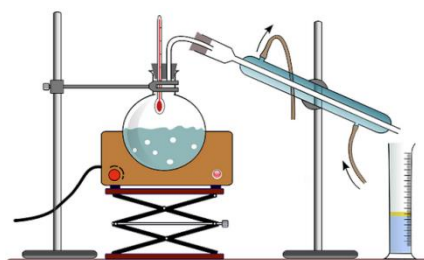


PW 02: Distillation of a Binary Mixture (Alcohol–Water) by Simple Distillation



1. Introduction

Distillation is a fundamental separation technique commonly used to purify liquid compounds containing solid impurities or to separate mixtures of two or more liquids with significantly different boiling points.

This method is widely applied to:

- ✚ Purify a crude reaction mixture at the end of a synthesis;
- ✚ Isolate a specific compound from a natural source;
- ✚ Drive a chemical equilibrium by continuously removing one of the products.

Depending on the purpose of the operation and the miscibility of the components in the liquid state, different distillation setups and operating conditions may be employed.

Among the various distillation techniques, this experiment focuses on simple distillation, one of the most frequently used and straightforward methods for separating mixtures such as **ethanol** and **water**.

2. Principle

Distillation is based on the fundamental principle that, in a liquid mixture, the **most volatile component** (the one with the lowest boiling point) **evaporates first**.

The process consists of two main stages:

- **Heating** the impure liquid or mixture until it reaches its boiling point, allowing the more volatile component(s) to vaporize;

- **Condensing** the vapors by cooling them, so that the purified liquid (distillate) can be collected separately from the less volatile components remaining in the flask.

3. Experimental Procedure

3.1. Simple (Elementary) Distillation

- In a single-neck flask, pour a **100 mL equi-volumetric mixture of water and ethanol**.
- Place a **distillation head** fitted with a **thermometer** on the flask.
- Connect the head to a **lateral condenser** to condense the vapors by cooling.
- At the other end of the condenser, attach a **dry receiving vessel** (flask, Erlenmeyer, etc.) to collect the distillate.
- Start the **cooling water circulation** before heating.
- Begin distillation by heating the reaction mixture using a **heating mantle**.
- Monitor the setup until the **first drops of distillate** appear.
- **Change the receiving vessel** once you observe an increase in temperature (via the thermometer).
- **Stop the distillation** when only a small residue remains in the flask.

3.1.1. Binary Diagram

Ethanol ($\text{C}_2\text{H}_5\text{OH}$) and water (H_2O) are **miscible in all proportions** in the liquid state. Their **binary phase diagram** at **P = 1 bar** is shown below (see figure).

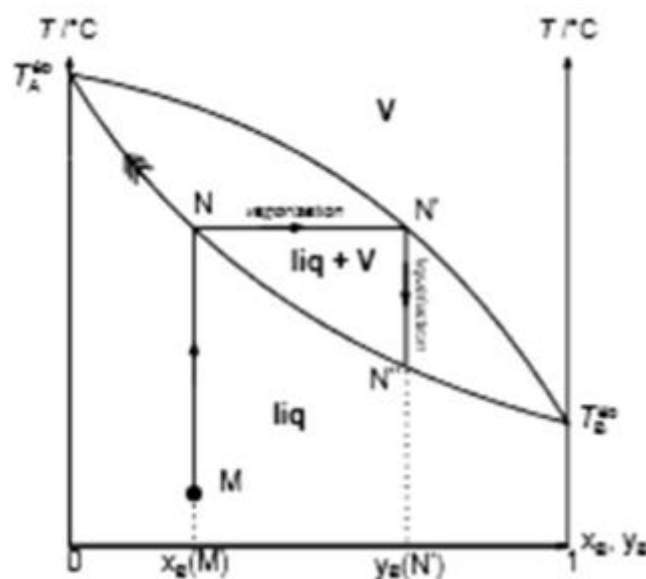


Figure: Binary diagram of simple distillation (binary mixture)

In the diagram, the initial system is represented by point **M**, which has a **mole fraction $x_B(M)$** of component B.

When heating begins, the representative point of the system moves vertically, and the **first vapor bubble** appears at point **N**. This vapor rises through the distillation head, condenses in the water-cooled condenser (**point N''**), and falls as liquid into the receiving vessel. The condensate is **enriched in component B (the more volatile compound)** compared to the initial mixture. As distillation proceeds, the liquid remaining in the boiling flask becomes **depleted in B**, and point **N** moves **to the left** on the diagram.

Eventually, component A remains alone in the flask, while the **distillate is enriched in B** relative to the starting mixture.

4. Questions

1. Draw and label the **simple distillation setup**.
2. What is the **role of heating**?
3. What is the **purpose of the condenser**?
4. What does the **thermometer placed at the top of the column** measure?
5. **Calculate the yield** of this distillation.