

The Fundamental Mechanism

Distillation separates volatile liquids from non-volatile impurities, or liquid mixtures with sufficient boiling point differences.

The Boiling Condition

$$\text{Vapour Pressure} = \text{Atmospheric Pressure}$$

Boiling occurs strictly when the vapor pressure of the liquid equals the surrounding atmospheric pressure.



1. Vaporisation

Heating converts the target volatile liquid into vapour.



2. Condensation

Vapours are routed through a cold-water condenser, extracting heat.

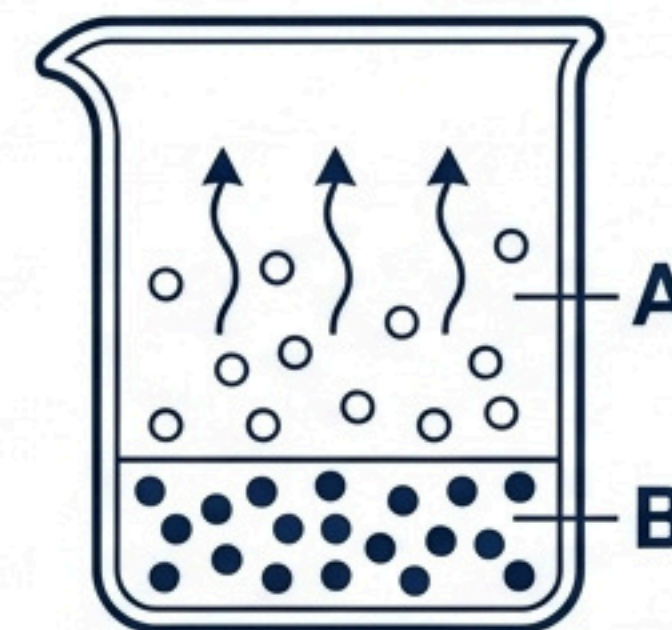


3. Collection

The pure liquid (distillate) is collected in a separate receiver.

The Requisite Condition

Applicable solely for liquid mixtures where components have a significant difference in their boiling points.



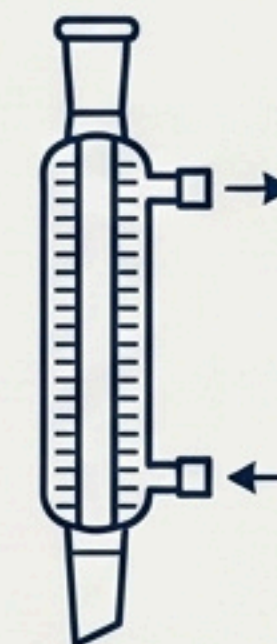
Distillation Flask

Contains the original mixture; heat is applied strictly to the boiling point of the more volatile component.



Water Condenser

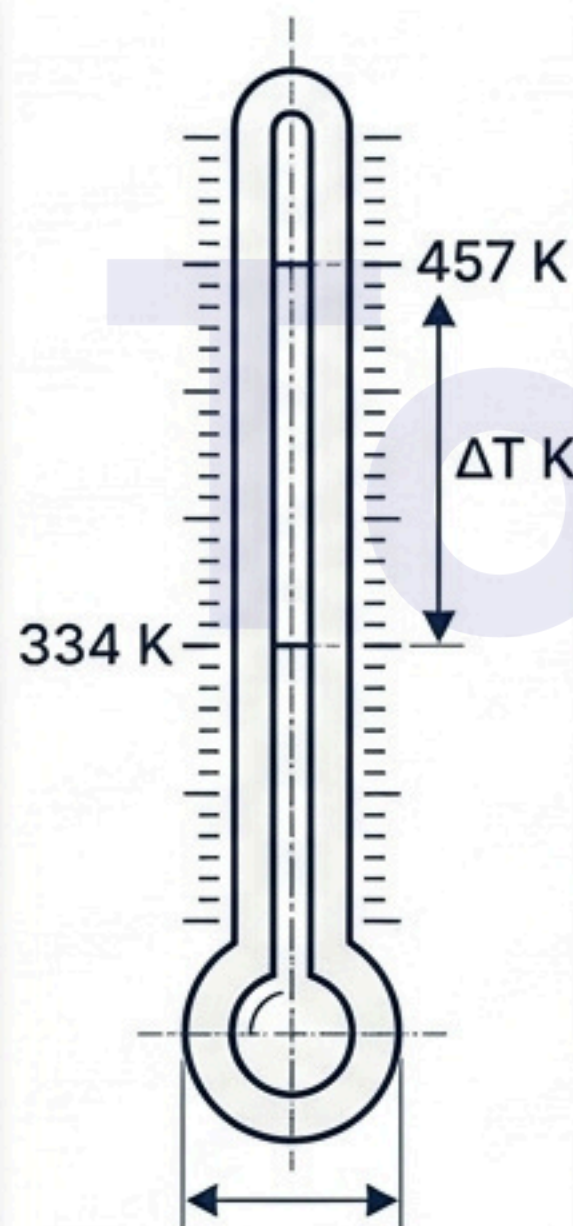
Circulates continuous cold water to extract thermal energy from ascending vapours, forcing a phase change back to liquid.



A standard simple distillation application made possible by a massive boiling point differential ($\Delta T = 123 \text{ K}$).

Chloroform (CHCl_3)
Boiling Point:
334 K

Highly volatile.
Highly volatile. Vaporizes first, easily passes through the water condenser, and is collected cleanly as the distillate.



Aniline ($\text{C}_6\text{H}_5\text{NH}_2$)
Boiling Point:
457 K

Less volatile. Remains stable in the distillation flask as the system temperature is intentionally capped near 334 K.



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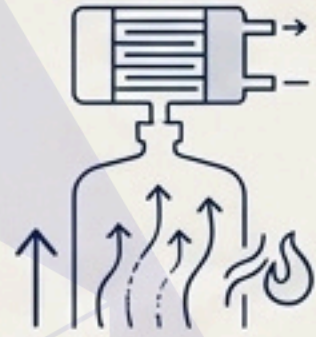
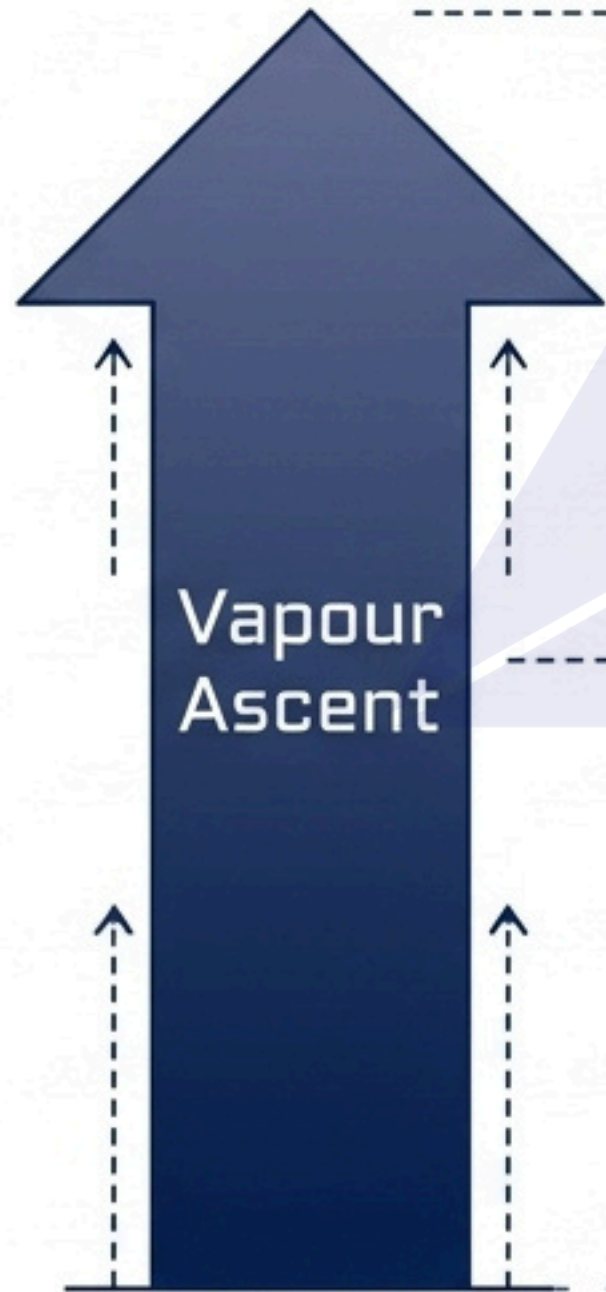
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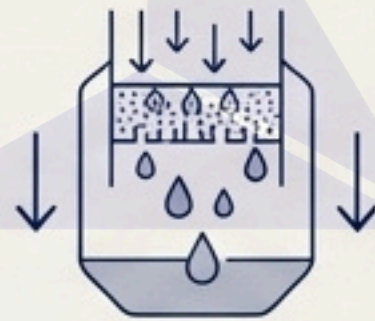
The Challenge: Small Boiling Point Difference

When boiling points are close, simple distillation fails. The resulting vapours contain significant, inseparable amounts of both components.



Vapour Enrichment

The heat released from the condensation vaporizes more of the volatile liquid. The ascending vapour becomes progressively richer in the volatile component.



Selective Condensation

Vapours of the higher boiling (less volatile) liquid condense prematurely and fall back into the flask.

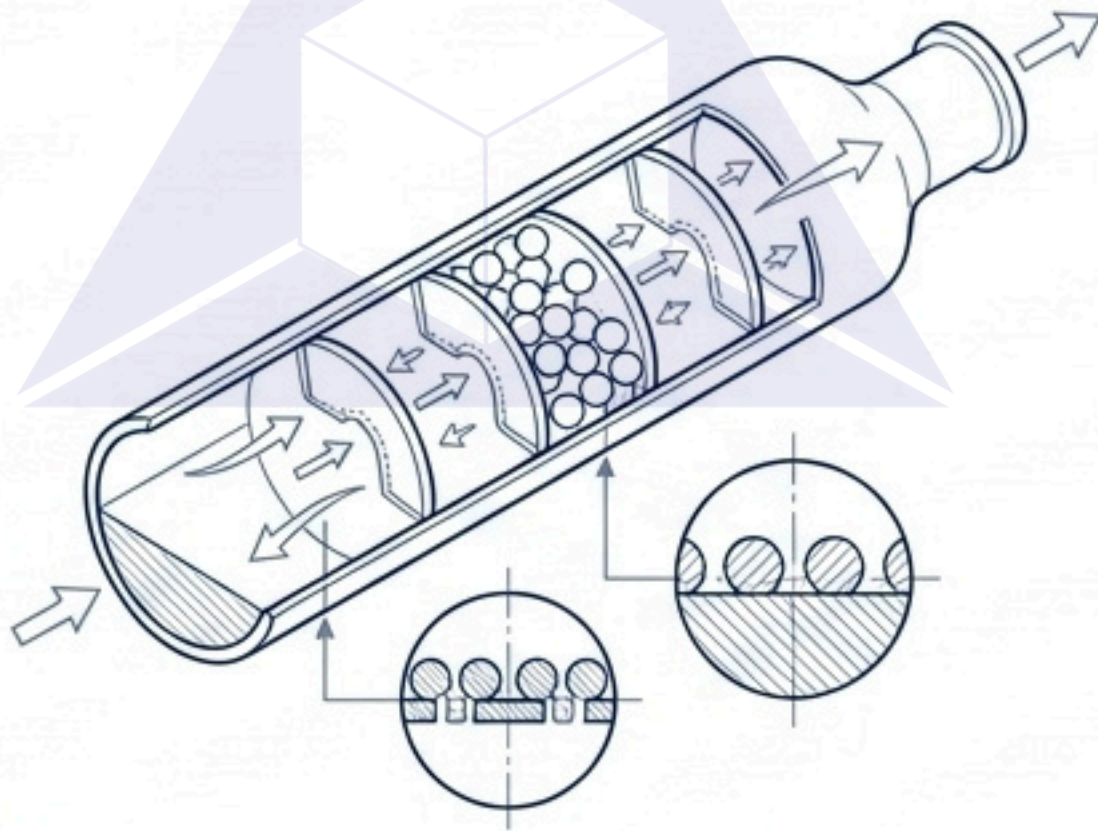


Vapour Ascent

Vapours of the heated liquid mixture rise into the base of a fractionating column.

Structure & Function

- Fitted directly over the mouth of the round bottom flask.
- Provides vast internal surface area for heat exchange.
- Intentionally obstructs both the upward movement of vapours and downward movement of liquid.



The Theoretical Plate

Each successive, complete condensation and vaporization event within the column is defined as one theoretical plate.

The Petroleum Industry

This exact principle is used at a massive scale to separate the complex fractions of crude oil.

Thermal

Decomposition

Certain liquids chemically decompose at or below their normal boiling points, rendering heating via simple distillation impossible.

Lowering P_{atm}

A liquid boils when $P_{\text{vapour}} = P_{\text{atm}}$. By attaching a vacuum pump to artificially lower the system's atmospheric pressure, the liquid reaches its boiling condition at a significantly lower, safer temperature.



Industrial Example

Used successfully for the separation of glycerol from spent-lye in the soap manufacturing industry.

Prerequisites: 1. Substance must be steam volatile. 2. Substance must be entirely immiscible with water.

$$P_{\text{total}} = P_1 + P_2$$

P_{total} = Atmospheric pressure

P_1 = Vapour pressure of the organic liquid

P_2 = Vapour pressure of water

Because P_1 and P_2 combine to reach atmospheric pressure, P_1 is strictly less than P_{total} .
Therefore, the organic liquid vaporizes at a profoundly lower temperature than its standard boiling point.

Classic Example Separation of an Aniline / Water mixture.



Distillation Method	Core Principle / Condition	Canonical Example
Simple Distillation	Liquids with large boiling point difference	Chloroform (334 K) & Aniline (457 K)
Fractional Distillation	Liquids with close boiling points (utilizes vapour enrichment)	Fractions of crude oil
Reduced Pressure	Liquids that decompose at or near their normal boiling point	Glycerol from spent-lye
Steam Distillation	Steam volatile but immiscible with water ($P_{\text{total}} = P_1 + P_2$)	Aniline & Water mixture



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