

Why Hot Tea Cools Fast at First

The Observation: A cup of hot tea left on a table cools down rapidly in the first few minutes, but then seems to take forever to finally reach room temperature.

The Physics Question: Why does the rate of cooling change as the tea gets cooler?



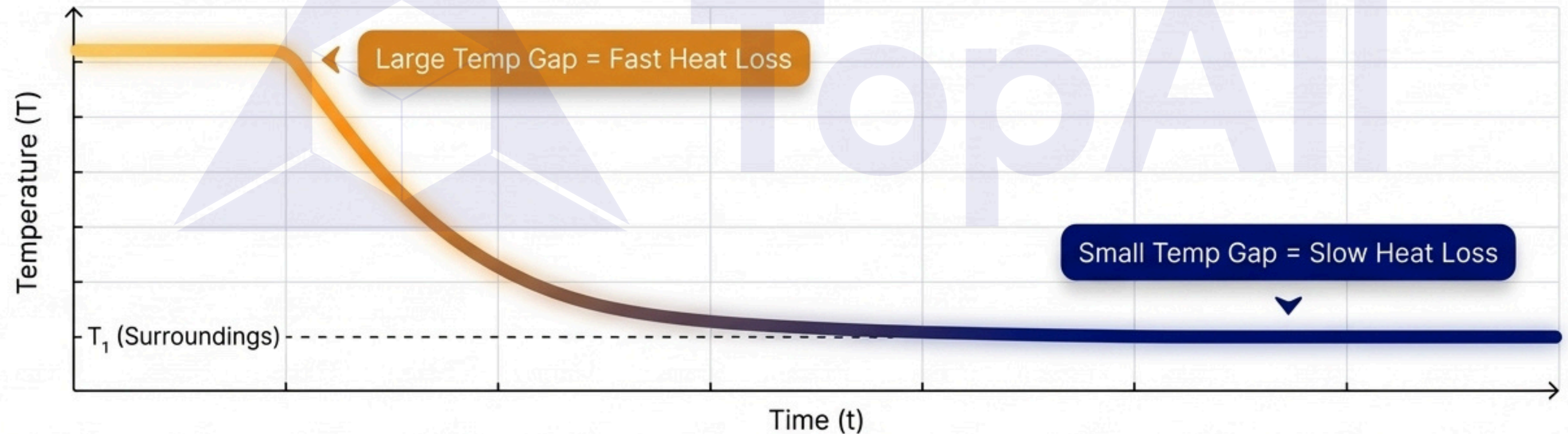
The Intuition Behind the Cooling Rate

Core Concept:

A hot body loses heat to its surroundings in the form of heat radiation.

The Golden Rule:

The rate of loss of heat depends directly on the difference in temperature between the body and its surroundings.



Newton's Law of Cooling

The rate of loss of heat of a body is directly proportional to the difference of temperature of the body and the surroundings.



$$\frac{-dQ}{dt} \propto \Delta T = (T_2 - T_1)$$

Constant (k) Dependencies:

1. Nature of the surface of the body.
2. Area of the exposed surface.

⚠ Crucial Condition

This law holds good only for small differences of temperature.

The Mathematics of Cooling

Differential Form

$$\frac{dT_2}{T_2 - T_1} = -K dt$$

(Where $K = k/ms$)

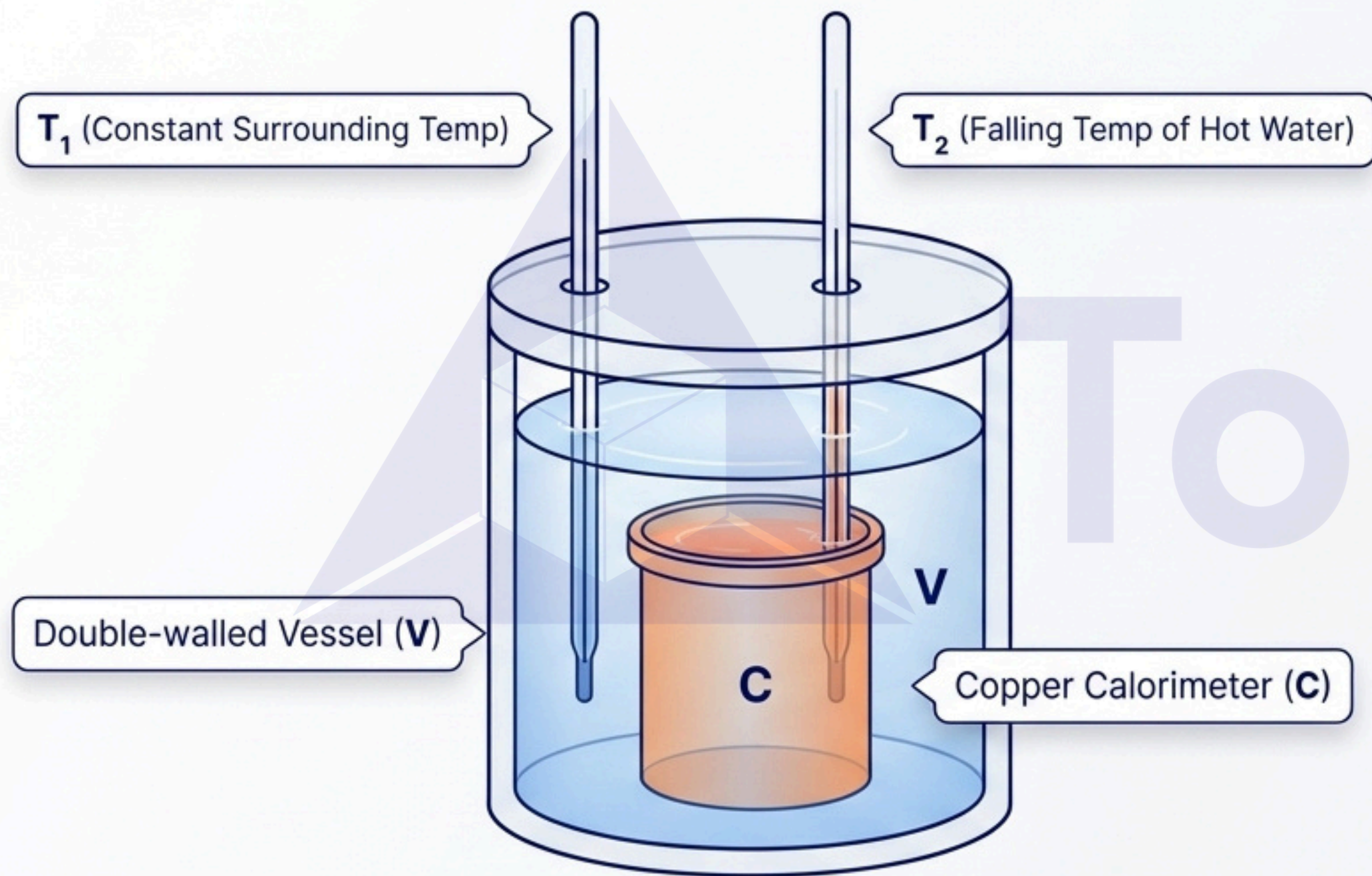
Integrated Form

$$\log_e(T_2 - T_1) = -Kt + c$$

Final Master Formula

$$T_2 = T_1 + C' e^{-Kt}$$

Experimental Verification



The Setup

- **Vessel (V):** Double-walled to maintain a perfectly constant surrounding temperature.
- **Calorimeter (C):** Made of copper, holds the hot water being measured.

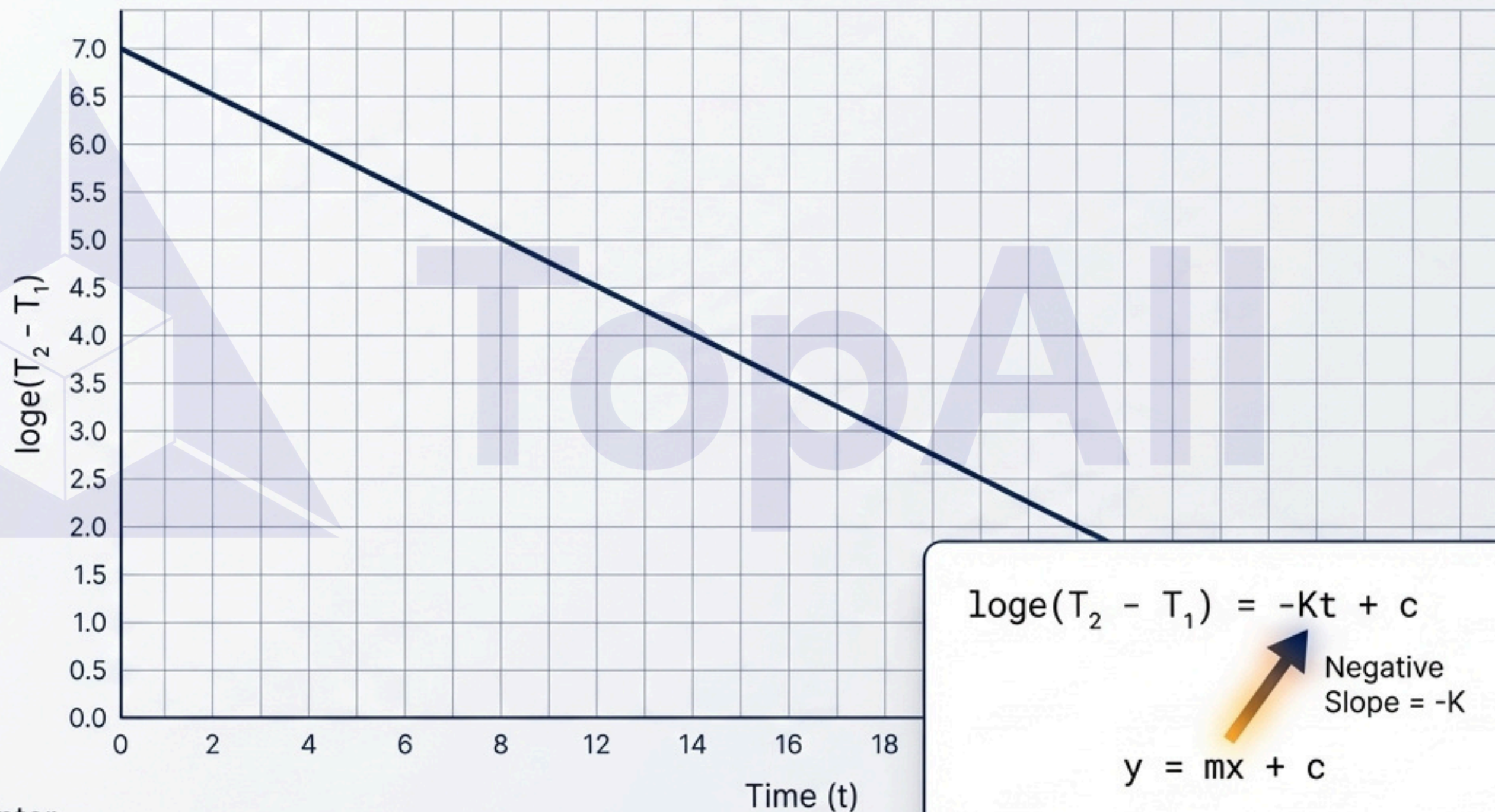
The Measurement

- Thermometer T₁ tracks the stable environment.
- Thermometer T₂ tracks the falling temperature over equal time intervals.

Interpreting the Cooling Graph

The Plot: Graphing the natural log of the temperature gap against time.

The Result: A perfectly straight line with a negative slope, validating the integrated formula (Eq. 10.22).



$$\log_e(T_2 - T_1) = -Kt + c$$

Negative
Slope = $-K$

$$y = mx + c$$

Key Takeaways & Exam Traps

The Core Rule

Cooling rate is proportional to the temperature gap.
Bigger gap = faster cooling.

$$T_2 = T_1 + C'e^{-Kt}$$

Cooling follows an exponential decay curve.



! Condition Check

Newton's Law of Cooling is an approximation. It only applies to small temperature differences. Do not apply it to massive temperature drops without noting this limitation.