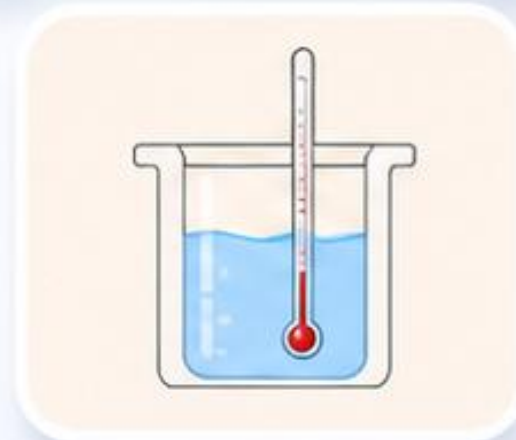
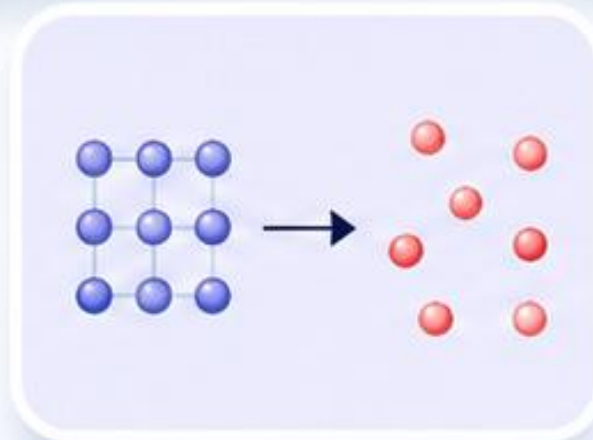


Chapter 10

Thermal Properties of Matter

Heat • Expansion • Calorimetry



TEMPERATURE, HEAT & THERMAL EQUILIBRIUM

① TEMPERATURE

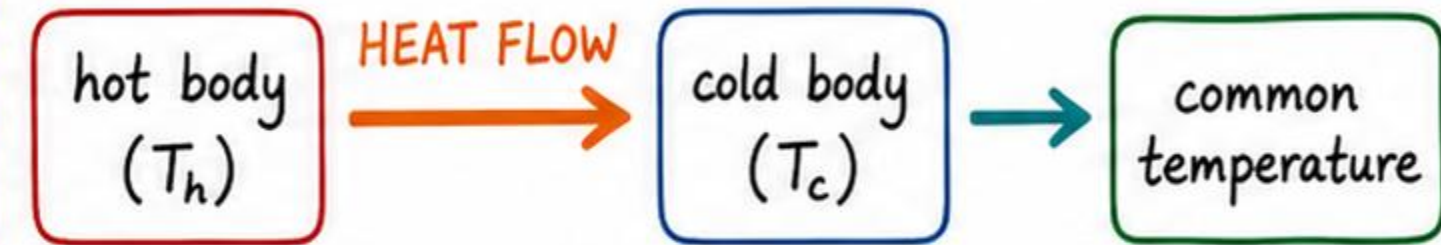
- Temperature tells how hot or cold a body is.
- It decides the direction of **heat transfer**.
- Touch is not a reliable scientific measurement.
- SI unit: kelvin (K). Degree Celsius ($^{\circ}\text{C}$) is also commonly used.



② HEAT

- Heat is energy transferred between two systems, or between a **system** and its **surroundings**, only because their temperatures are different.
- Heat flows spontaneously from **higher temperature** to **lower temperature**.
- SI unit of heat: joule (J).
- Heating may raise temperature, cause **expansion**, or **change the state**.

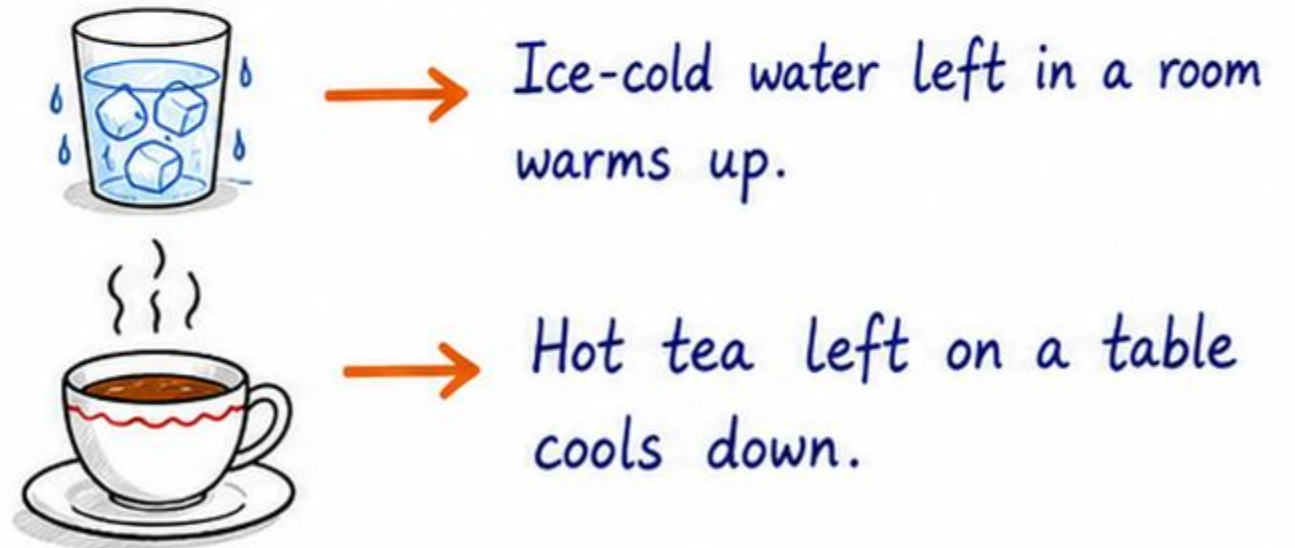
③ THERMAL EQUILIBRIUM



Before equilibrium: $T_h > T_c$

At thermal equilibrium: no net heat transfer.

EVERYDAY EXAMPLES

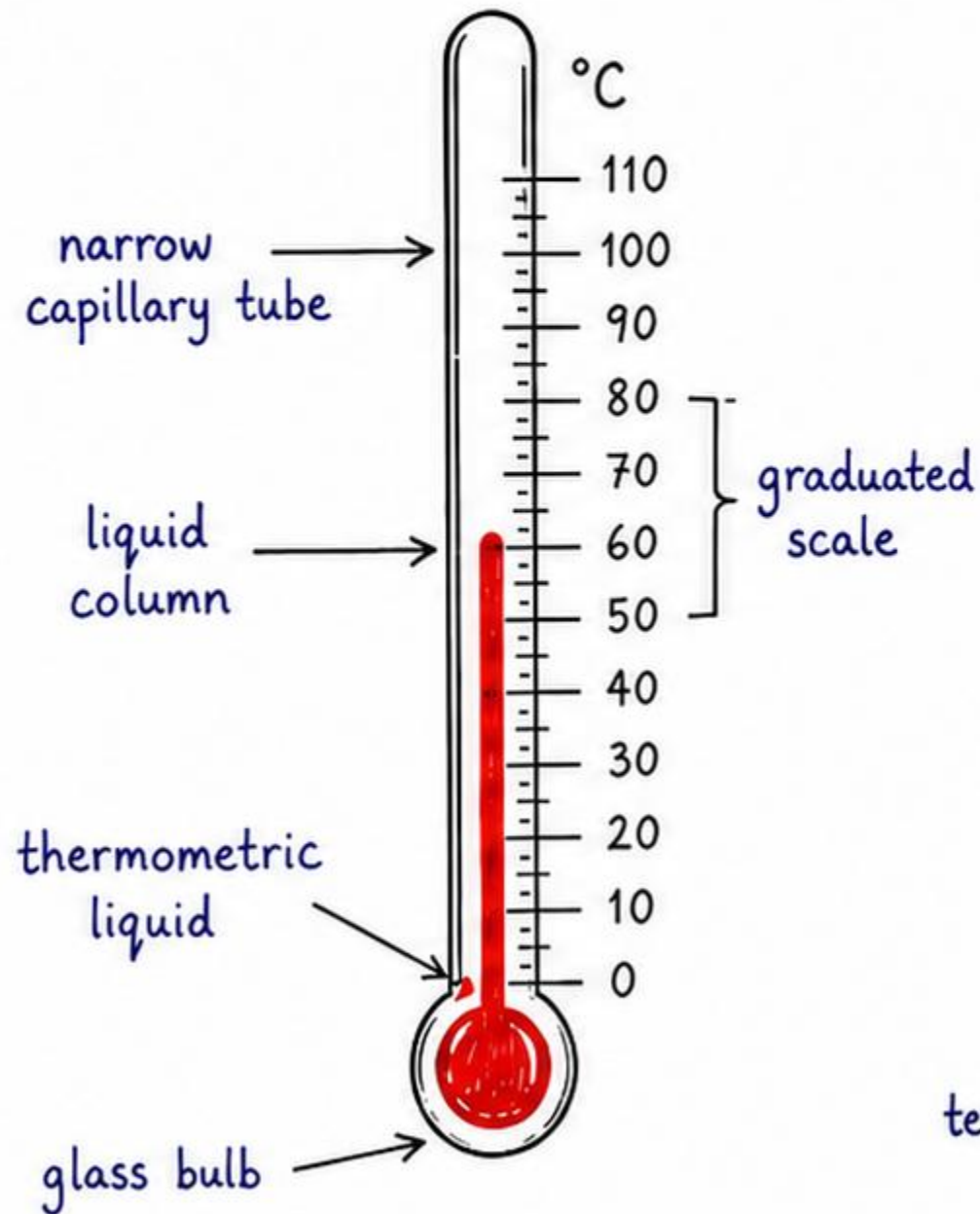


Heat is energy in transit; temperature measures the thermal state.

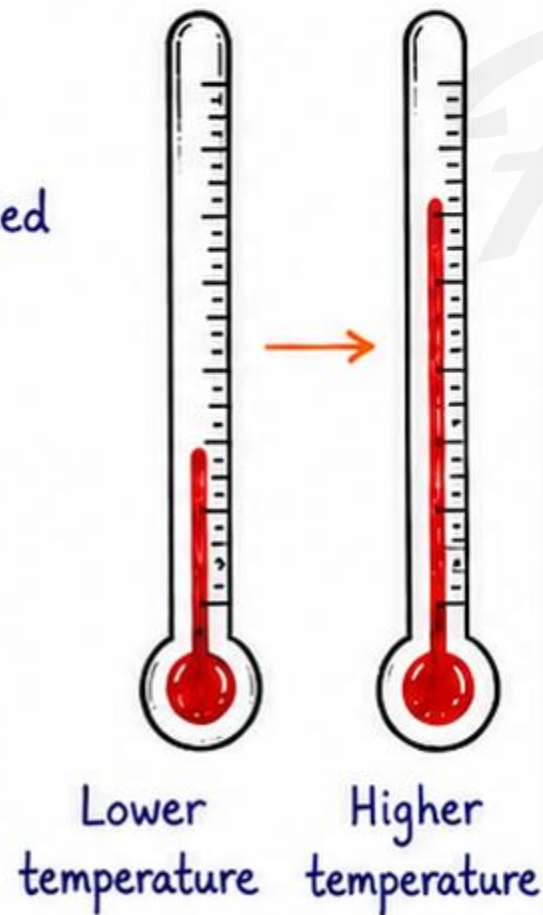
MEASURING TEMPERATURE

THERMOMETER

1. A thermometer is an instrument used to measure temperature.



When temperature rises, the liquid column rises.



THERMOMETRIC PROPERTY

2. A thermometric property is a measurable physical property that changes in a regular and reproducible way with temperature.

3. Common examples:

- volume of a liquid
- pressure of a gas at constant volume
- electrical resistance of a conductor

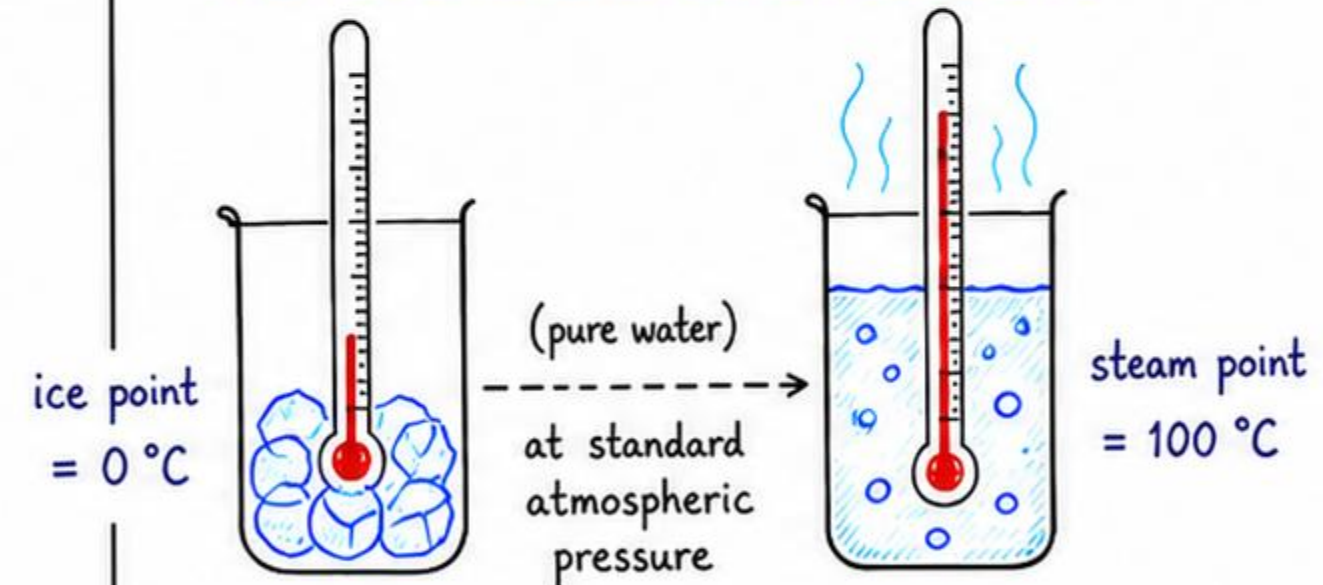
IMPORTANT NOTE:

Touch can only give a rough sensation; a calibrated thermometer gives a numerical temperature.

CALIBRATION

- ① choose two reproducible fixed reference temperatures
- ② mark their values on the scale
- ③ divide the interval into equal parts

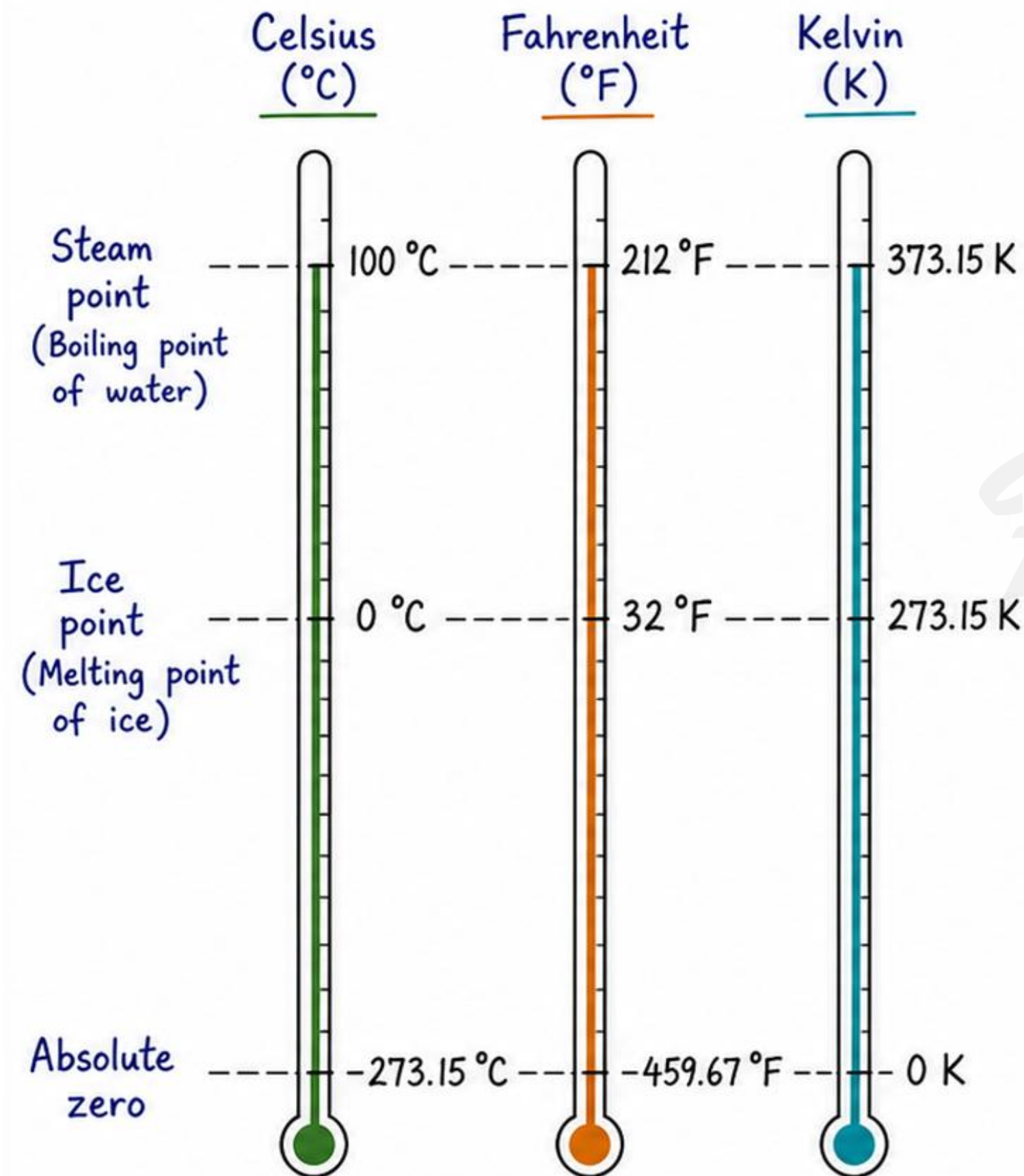
Traditional water fixed points
(at standard atmospheric pressure):



CAUTION:

Different thermometer substances may expand differently, so careful calibration is essential.

CELSIUS, FAHRENHEIT & KELVIN SCALES



Celsius – Fahrenheit relation

The relation between the two scales is linear. Using the fixed points:

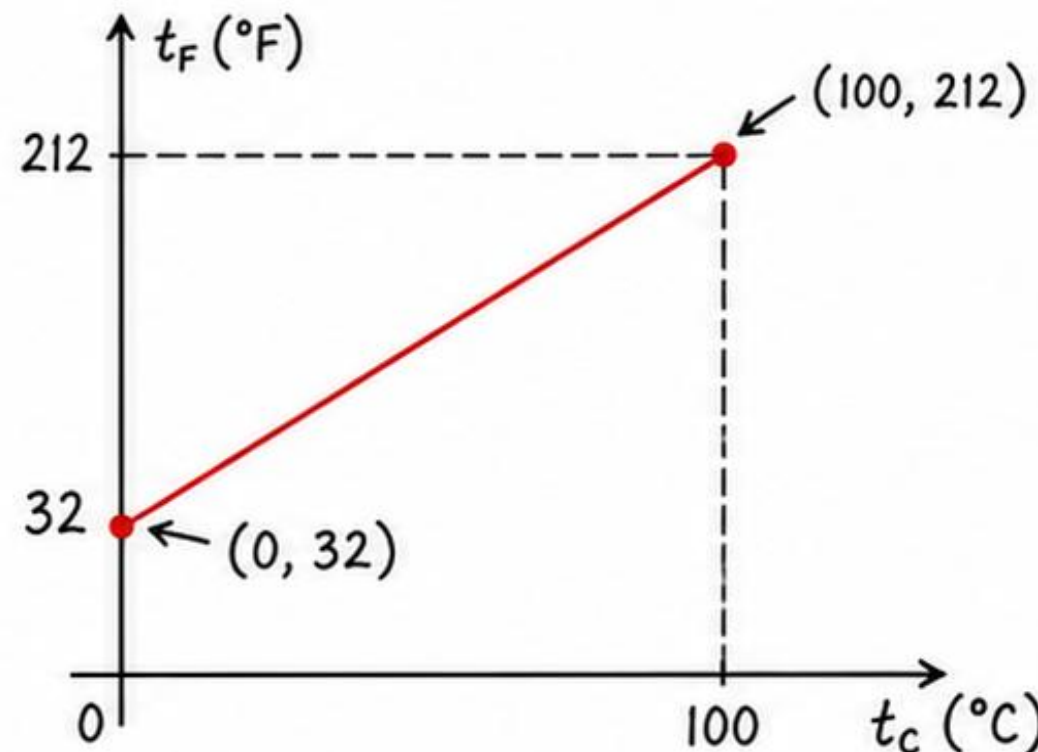
$$\frac{t_F - 32}{180} = \frac{t_C}{100} \quad \left(\begin{array}{l} 180 = 212 - 32, \\ 100 = 100 - 0 \end{array} \right)$$

Simplifying,

$$t_F = \frac{9}{5} t_C + 32$$

$$t_C = \frac{5}{9} (t_F - 32)$$

Celsius versus Fahrenheit (straight line)



Kelvin – Celsius relation

$$T = t_C + 273.15$$

$$t_C = T - 273.15$$

Important facts

- ① A change of 1 K has the same size as a change of 1 °C.
- ② Write kelvin as K, not °K.
- ③ Temperature differences satisfy $\Delta T \text{ (K)} = \Delta t_C \text{ (°C)}$.

Examples

- ① $25 \text{ °C} = 77 \text{ °F} = 298.15 \text{ K}$
 - $t_F = \frac{9}{5} \times 25 + 32 = 77 \text{ °F}$
 - $T = 25 + 273.15 = 298.15 \text{ K}$
- ② $68 \text{ °F} = 20 \text{ °C} = 293.15 \text{ K}$
 - $t_C = \frac{5}{9} (68 - 32) = 20 \text{ °C}$
 - $T = 20 + 273.15 = 293.15 \text{ K}$

GAS LAWS & THE IDEAL-GAS EQUATION

STATE VARIABLES

for a fixed sample:

P = pressure

V = volume

T = absolute temperature

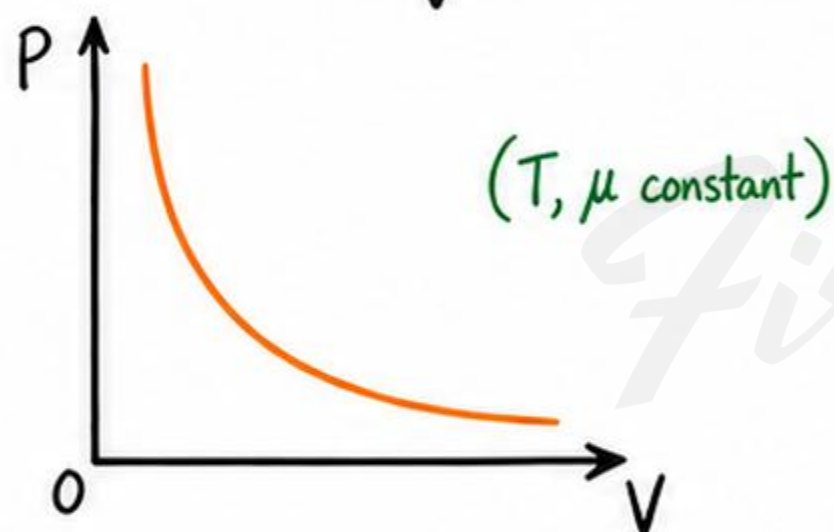
μ = number of moles

1. BOYLE'S LAW

temperature constant

$$PV = \text{constant}$$

$$P \propto \frac{1}{V}$$

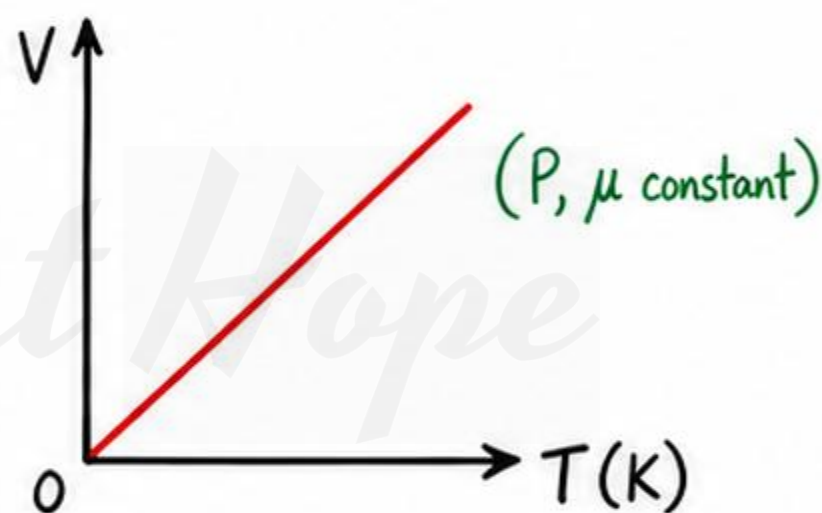


2. CHARLES' LAW

pressure constant

$$\frac{V}{T} = \text{constant}$$

$$V \propto T$$

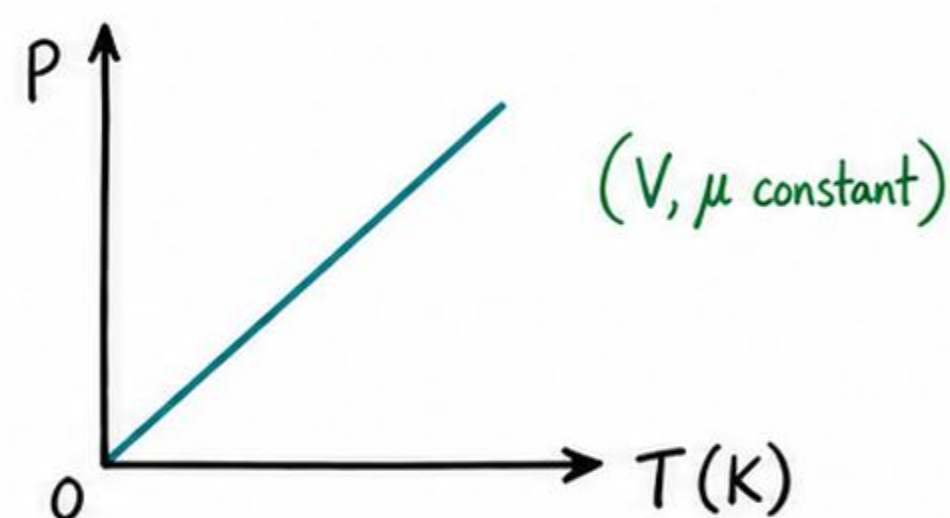


3. PRESSURE LAW

volume constant

$$\frac{P}{T} = \text{constant}$$

$$P \propto T$$



COMBINATION:

$$\frac{PV}{T} = \text{constant} = \mu R$$

$$PV = \mu RT$$

- $R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$
(universal gas constant)
- T must be in kelvin.
- For a fixed amount of gas, μ is constant.
- Low-density gases approximately obey the ideal-gas equation over a suitable range.

COMPARISON STRIP:

constant T $\longrightarrow$ P changes with V

constant P $\longrightarrow$ V changes with T

constant V $\longrightarrow$ P changes with T



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