Thermodynamics

Thermodynamics: the science of thermal or internal energy

Applications:
- heating, cooling
- power generation
- transportation

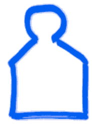
1769: James Watt: steam engine
the beginning of the Industrial Revolution

Thermodynamics

↙ Classical or phenomenological

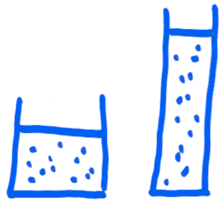
↘ corpuscular (atomic, molecular) kinetic theory

The three phases



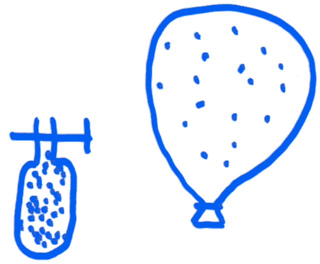
solids

keep their
- mass
- volume
- density
- shape



liquids

keep their
- mass
- volume
- density



gases

keep their
- mass

Gases will play a central role in thermodynamics ⇒ Ideal Gas

Only very few physical properties are temperature independent. (ex: mass, charge, half life) The majority of the physical properties are temperature dependent (ex: length, volume, density, resistivity, magnetization, index of refraction)

Temperature and heat

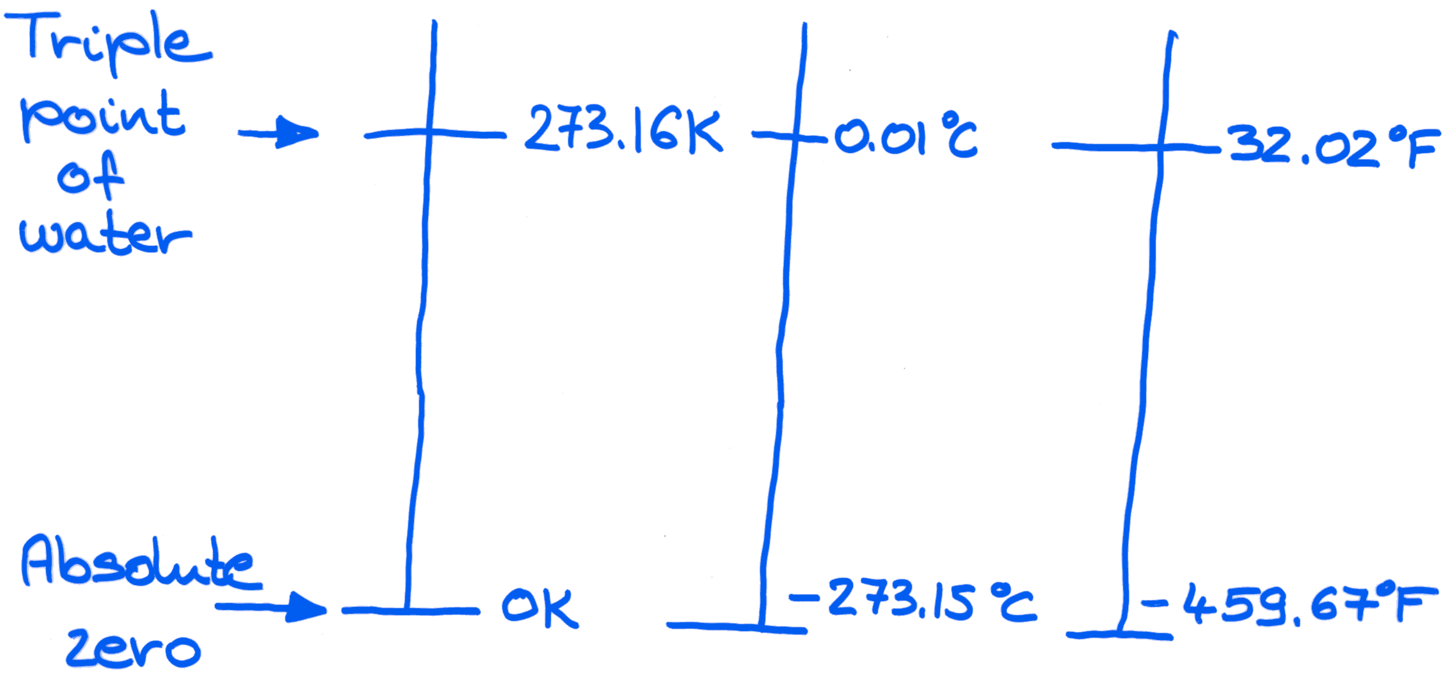
Zeroth law: temperature exists and it is transitive: if $T_A = T_B$ and $T_B = T_C$, then $T_A = T_C$.

Heat: another form of energy that is transferred between two objects, if there is a temperature difference between the object, and the objects are in „contact".

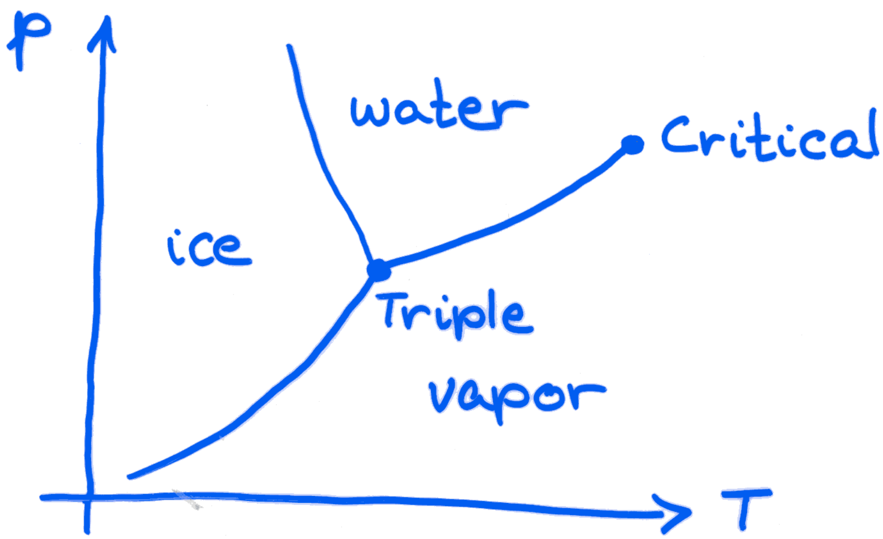
Temperature: intensive quantity

Heat: extensive quantity

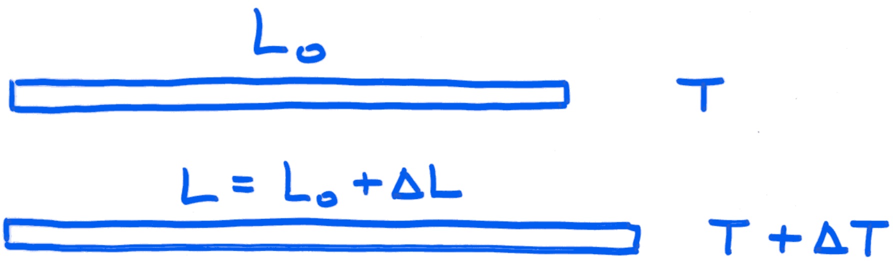
Temperature scales



Triple point of water:



Thermal expansion: Linear



$$\left.\begin{array}{l} \Delta L \sim \Delta T \\ \Delta L \sim L_0 \end{array}\right\} \Rightarrow \quad \begin{array}{l} \Delta L = \alpha L_0 \Delta T \\ L = L_0 (1 + \alpha \Delta T) \end{array}$$

α : coefficient of linear expansion

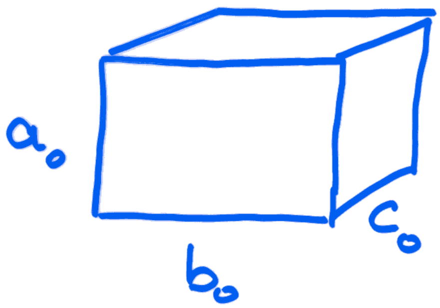
$$\alpha = \frac{\Delta L / L_0}{\Delta T} \qquad [\alpha] = \frac{1}{K} = \frac{1}{C^\circ}$$

α : fractional increase in length per unit change in temperature

Examples:

Aluminum :	2.39×10^{-5}	$1/C^\circ$
Copper :	1.62×10^{-5}	$1/C^\circ$
Steel :	1.17×10^{-5}	$1/C^\circ$
Invar :	0.12×10^{-5}	$1/C^\circ$

Thermal expansion : Volume



$$V_0 = a_0 b_0 c_0$$
$$a = a_0 (1 + \alpha \Delta T)$$
$$b = b_0 (1 + \alpha \Delta T)$$
$$c = c_0 (1 + \alpha \Delta T)$$

$$V = abc = a_0 b_0 c_0 (1 + \alpha \Delta T)^3 =$$

$$= V_0 (1 + 3\alpha \Delta T + \underbrace{3\alpha^2 \Delta T^2}_{} + \underbrace{\alpha^3 \Delta T^3}_{})$$

these two terms are small

$$V \cong V_0 (1 + \underbrace{3\alpha}_{\beta} \Delta T)$$

$$V = V_0 (1 + \beta \Delta T)$$

$$\Delta V = \beta V_0 \Delta T$$

$$\beta = \frac{\Delta V / V_0}{\Delta T} \qquad [\beta] = \frac{1}{K} = \frac{1}{C^\circ}$$

β : coefficient of volume expansion

Examples :

Petroleum : 9.6×10^{-4} $1/C^\circ$

Water : 2.0×10^{-4} $1/C^\circ$

Warning : water / ice is very unusual