Thermodynamics

Definitions

Fundamental Quantity: T [Kelvin]

Work, Heat & Entropy

$dW = p\,dV$ — The **work dW** done by a system whose volume changes by an amount dV against an external pressure p.

$dQ = dE + dW$ — The **heat dQ** absorbed by a system in a process in which the system's internal energy changes by an amount dE and the system does work dW.

$S_{\{x\}} = S_0 + \min_{\Gamma} \int_{T=0}^{\{x\}} \frac{dQ}{T}$ — The **entropy S{$\vec{x}$}** of a system with macroscopic variables {$\vec{x}$}, where $S_0 = S_{\{T\to 0\}}$, and the minimum is over all quasi-static processes from T=0 to {$\vec{x}$}.

Characterization of processes and systems

Statistical equilibrium: describes a system with macroscopic parameters that are not changing with time.

relaxation time τ_φ: the characteristic time the system takes to come to statistical equilibrium after a disturbance φ.

quasi-static process: any disturbance φ occurs slowly compared to the relaxation time τ_φ.

reversible process Γ: a process for which $\Delta S = \int_\Gamma \frac{dQ}{T}$

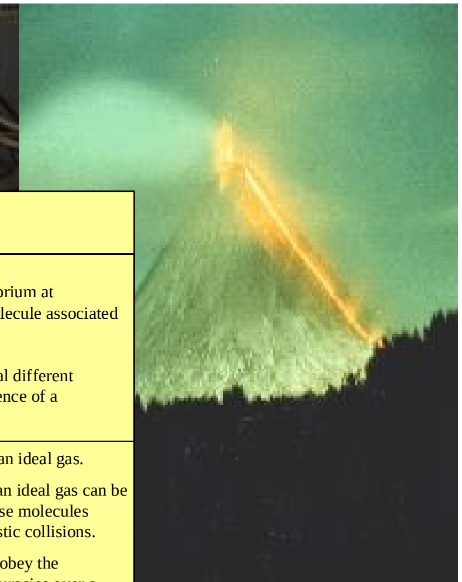
adiabatic process: dQ = 0

isothermal process: dT = 0

isentropic process: dS = 0

isochoric process: dV = 0

ideal gas: any system obeying the equation of state PV=NkT.



Observations

General

Equipartition Theorem: When a substance is in equilibrium at temperature T, there is an average energy of $\frac{1}{2}kT$ per molecule associated with each (quadratic) degree of freedom.

Existence of Phases: Many materials can exist in several different states, or phases; a phase diagram represents the dependence of a material's phase on its macroscopic parameters.

Gases

Some gases, under certain conditions, may be treated as an ideal gas.

Kinetic theory of ideal gases: Individual molecules in an ideal gas can be modeled as one or more atoms connected by springs; these molecules behave as though they are hard spheres experiencing elastic collisions.

Van der Waal equation of state: Many physical gases obey the equation of state $\left(P + a\frac{N^2}{V^2}\right)(V - bN) = NkT$ to high accuracies over a wide range of pressures; where $a_{\{g\}}$ and $b_{\{g\}}$ are numbers determined emperically for each gas g.

Solids and substances

Intensive quantities: The latent heat of vaporization (fusion), the molar specific heat, and the coefficient of thermal resistivity are all independent of the amount of material present; they thus characterize a *substance*, rather than an object.

The thermal resistance R of some objects is independent of the thermal current I flowing through it.

Dulong-Petit law: Many solids may be modeled as regular arrays of atoms coupled by springs; together with the equipartition theorem, this implies that many solids have molar heat capacity c = 3R.

Heat Flow

$L_{v,f} = \frac{Q}{m}$ — The **latent heat of vaporization (fusion)** of a substance that absorbs heat Q when a mass m of it is vaporized (melted).

$C_{\{\vec{x}\}} = \left.\frac{dQ}{dT}\right|_{\{\vec{x}\}}$ — The **heat capacity** $C_{\{\vec{x}\}}$ of an object whose temperature changes an amount dT when the object absorbs heat dQ in a process in which the macroscopic parameters {$\vec{x}$} are held fixed.

$c_{\{\vec{x}\}} = \frac{1}{\nu} C_{\{\vec{x}\}}$ — The **molar specific heat** $c_{\{\vec{x}\}}$ of a substance if ν moles of it has a heat capacity $C_{\{\vec{x}\}}$.

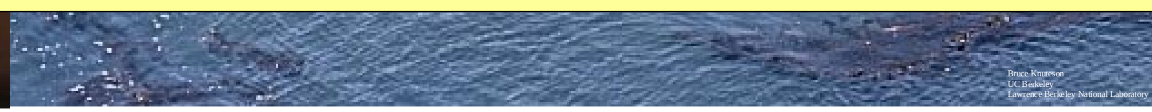
$I = \frac{dQ}{dt}$ — The **thermal current I** passing through an object that absorbs heat dQ at one end and loses heat dQ at the other in a time dt.

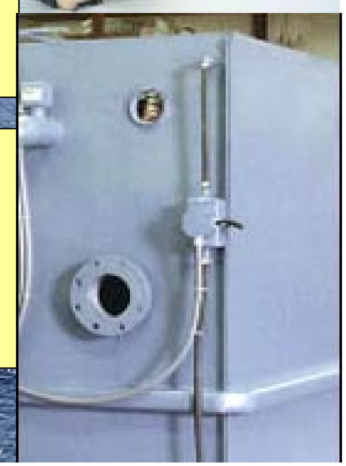
$R = \frac{\Delta T}{I}$ — The **thermal resistance R** of an object with a temperature difference ΔT between its two ends and carrying a thermal current I.

$\kappa = \frac{Ra}{l}$ — The **coefficient of thermal resistivity** κ of an object with resistance R, cross sectional area a, and length l.

$\gamma = \frac{c_p}{c_V}$ — The **ratio of molar heat capacities** γ for a substance with a heat capacity at constant pressure c_p and a heat capacity at constant volume c_V.

$\varepsilon = \frac{W}{Q_h}$ — The **efficiency** ε of a heat engine which in each cycle does work W and absorbs heat Q_h from the high-temperature reservior.





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