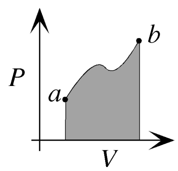
FaStudy: Thermodynamics

Major Players (Quantities)
W = Work (+ if done on system, – if done on environment)
Q = Heat (+ if added to system, – if removed from system)
U = Internal Energy: sum of random translational KE of particles in system; depends only on temperature. • ΔU = change in internal energy • V = volume • ΔV = change in volume
T = Absolute Temperature: always in kelvins! • ΔT = change in temperature.
P = Pressure • n = number of moles • R = gas constant = 8.31 J/mol·K

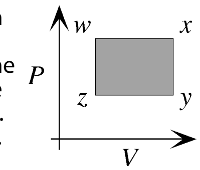
First Law of Thermodynamics
$\Delta U = Q + W$ The change in internal energy of a system is equal to the sum of the heat added and the work done on it.

Ideal Gas Law
$PV = nRT$ or $P_1V_1/T_1 = P_2V_2/T_2$

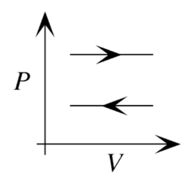
Pressure vs. Volume Graphs
Work is the area bounded by the curve.



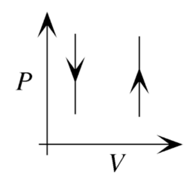
If the gas goes from *a* to *b*, it does work on the environment; work done on the gas is negative. If it goes from *b* to *a*, work is done in it; work is positive. In the cycle *wxyz*, the area enclosed is the work done BY the gas. The net work done ON the gas is negative.



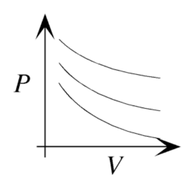
Processes
Isobaric: constant pressure: $\Delta P = 0$. $W = -P\Delta V$
$Q = nC_p\Delta T$
(C_p = molar specific heat of gas at constant pressure = $^5/_2\ R$)



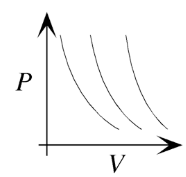
Isochoric/Isovolumic: constant volume: $\Delta V = 0$. $W = 0$ so $\Delta U = Q$
$Q = nC_v\Delta T$
(C_v = molar specific heat of gas at constant volume = $^3/_2\ R$)



Isothermal: constant temperature:
$\Delta T = 0$ and thus $\Delta U = 0$. $Q = -W$

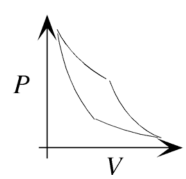


Adiabatic: no heat in or out:
$Q = 0$. $\Delta U = W$



Cycles
For a complete cycle: $-W = Q_{in} - Q_{out}$ (or $Q_H - Q_C$).
Also: $\Delta U = 0$.

A **Carnot engine** operates along two adiabats and two isotherms. Heat is added along the high isotherm and ejected along the low isotherm. Volume increases and pressure drops along the high isotherm and adiabat; volume decreases and pressure increases along the low isotherm and adiabat. Negative work is done on the gas during expansion; positive work is done on the gas during compression.



Engine Efficiencies T_C = cold temperature, T_H = hot temperature, Q_C = heat ejected, Q_H = heat added
$e = -W/Q_{in} = 1 - |Q_C/Q_H|$ (All heat engines)
$e = 1 - T_C/T_H$ (Carnot engine) thus for Carnot engine, $|Q_C/Q_H| = T_C/T_H$

Entropy
$\Delta S = Q/T$
Isentropic: no change in entropy: $\Delta S = 0$. True for a complete cycle of a Carnot engine.