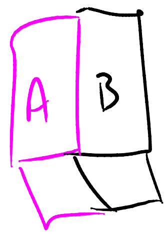
Thermo Notes



The Zeroth Law of thermodynamics: Thermal equilibrium

If $T_A = T_B$
And $T_B = T_C$
Then $T_C = T_A$

Important side effect (corollary): if A and B are in thermal equilibrium, and since $H = kA\,\Delta T_{AB} / \ell$
Then as $T_A = T_B$ $\Delta T_{AB} = 0$ and H = 0 therefore there is no NET heat flow between objects which are the same temperature

U ← internal energy of a body

ΔU = difference in internal energies

Δ = change in = final − initial

vectors

as + in relation to the object W_{on} + Q_{add} +

Thermodynamics Notes
The first law of thermodynamics allows for transfer of heat and work into an objects internal energy, it is a form of the law of conservation of energy and appears in equation as:

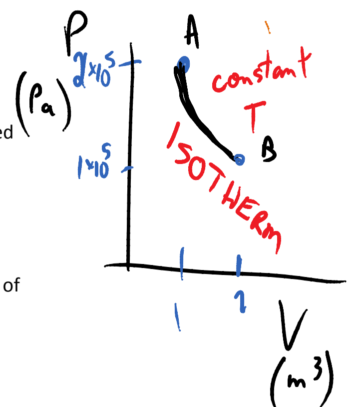
- [illegible] or $\Delta U = Q + W$ — ΔU = change in internal energy
  (text) (eqn sheet) — Q = heat energy added or removed
  W = Work done on or Work done by the system

W_{by} − Q_{remove} −

$U \propto T$
$\Delta U \propto \Delta T$

Internal energy ΔU will increase if heat energy is added or work is done on the system
Internal energy ΔU will decrease if heat energy is removed or work is done by the system

1 molecule $\left(U = \frac{3}{2} k T\right)$ × number of molecules



Q will be positive if heat is added, Q will be negative if heat energy is removed
W will be positive if work is done ON the system, W will be negative if work is done BY the system

Work is done BY the gas (values negative) if it expands, to understand why consider a gas trapped in a piston. If the gas expands pushing the piston it must be moving a force across a distance. Of course the reverse, compression of a gas required work done ON the gas and values of W are positive. This makes sense in terms of the internal energy (ΔU) in that if the work is done BY the gas it must decrease its energy, if work is done ON the gas its internal energy (ΔU) will increase.

Graphs and their interpretation are a CRUCIAL part of this topic. P vs. V graphs convey a large amount of information about the internal energy changes and the addition of heat / work done within systems.

Isolated Systems ← a closed system where no work is done on or by it and no heat enters or leaves
- W = 0, Q = 0 and $\Delta U = 0$

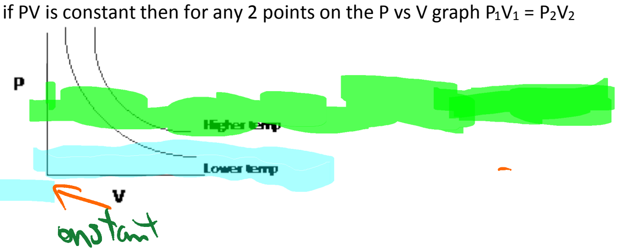
$\Delta U = Q + W$
Δ internal energy   heat energy + work

$\Delta T = 0$ isotherm

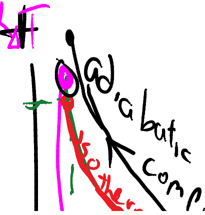
$\Delta T = 0$ $\Delta U = 0$

$0 = Q + W$ or
$W = -Q$

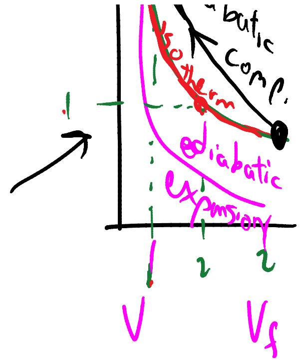
Isothermal Process ← same temperature T = constant
- so that $\Delta T = 0$ and if $\Delta T = 0$ then $\Delta U = 0$
  - for ideal gas where PV = nRT and T is constant then PV = constant
  - if PV is constant then for any 2 points on the P vs V graph $P_1V_1 = P_2V_2$



$\Delta U \propto T$



constant



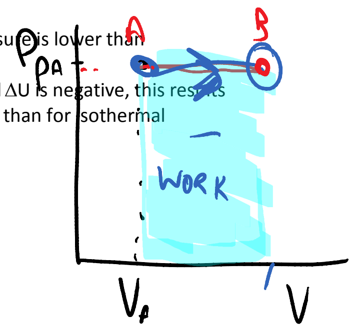
Sample Graph of an isothermal process (ideal gas)

if heat is added (Q positive) the gas must do work (W negative) to allow for T (and ΔU as a result) to remain constant

** for an isothermal process the Work done by a gas = heat added

Adiabatic Process ← no heat flows in or out of system

- Q = 0
- ΔU = W
  - occurs when system is extremely well insulated OR process happens very fast (because heat transfer is slow heat energy does not have time to react to the process)
  - ex. rapid gas expansion in an engine
  - slow process results in P vs V curve where final pressure is lower than isothermal
  - if gas expands (Work done by gas) W is negative, and ΔU is negative, this results in a lower temp and lower pressure, at same volume than for isothermal

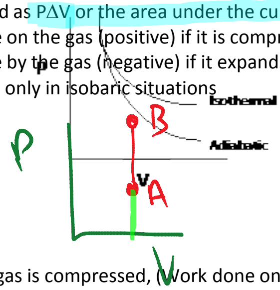


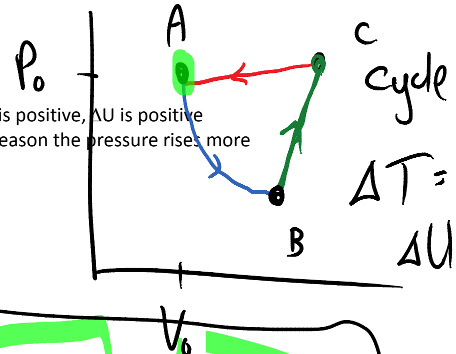
same

Isobaric Process ← pressure remains constant

Pressure

- horizontal line on the P vs V graph
- Work is found as PΔV or the area under the curve
- Work is done on the gas (positive) if it is compressed
- Work is done by the gas (negative) if it expands
- Use W = PΔV only in isobaric situations





$\Delta T = 0$

$\Delta U = 0$

  - if the gas is compressed, (Work done on gas) W is positive, ΔU is positive resulting in an increase in temperature, for this reason the pressure rises more than it would for an isothermal process

Isochoric Process ←volume remains constant

- vertical line on P vs V graph
- Work = 0, ΔU = Q

General Stuff:

Change pressures into pascals 1 atm = 101.3 kPa = 1.013×10^5 Pa

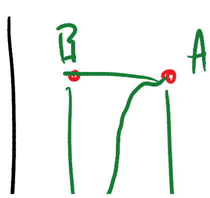
Change volume into cubic meters 1 m^3 = 1000 L = 1.0×10^6 cm^3

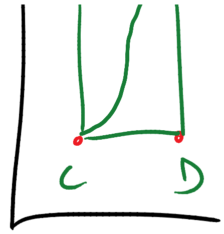
Change temps into Kelvin K = °C + 273

$$\Delta U_{AB} = Q_{AB} + W_{AB}$$
$$\Delta U_{BC} = Q_{BC} + W_{BC}$$
$$\Delta U_{CA} = Q_{CA} + W_{CA}$$
$$\Delta U_{ABCA} = 0 = Q_{ABCA} + W_{ABCA}$$

Do J

#18 - 25's





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$W = P\Delta V =$

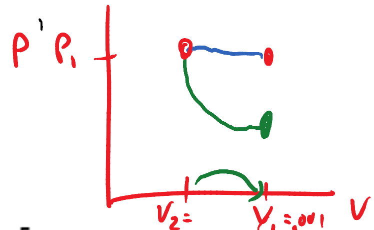
18] One liter of air is cooled at constant pressure until its volume is halved, and then it ~~is~~ allowed to expand isothermically back to its original volume. Draw the process on a PV diagram.

$.001\ m^3$

.0005

Const T

$\frac{1}{2}P_2V = nRT$



19] When 22.6 x 10^5 J of heat is added to 1.00 kg of water at 100 deg C, it is completely changed to steam at 100 deg C. Calculate a) the work done in this process (the pressure is 1 atm), and b) the change in internal energy of the water. One kilogram of steam occupies 1.67 m^3 at 100 deg C and 1 atm.
(-1.69 x 10^5 J, 2.08 x 10^6 J)

$.001\ m^3$

Iso aric $W = P\Delta V$

$(1.013\times10^5)(1.67 - .001)$
$= -1.69\times10^5\ J$

$\Delta U = Q + W$

$2.26\times10^6 + -1.69\times10^5$

$2.08\times10^6\ J$

20] An ideal gas was slowly compressed at constant temperature to one-half its original volume. In the process, 3.35 x 10^5 J of heat was given off.
a) How much work was done (in joules)? b) What was the change in internal energy of the gas?
(+3.34 x 10^5 J, 0 J)

$\Delta U = Q + W$

$0 = -3.35\times10^5 + W$

$3.35\times10^5\ J = W$

0