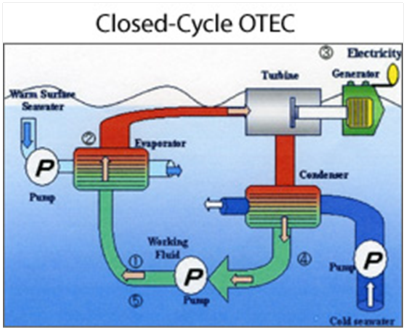
2.C.2 - Thermodynamic Processes for an Ideal Gas



Four Processes

Vocab.: prefix *iso-* means equal (from Greek *isos*)

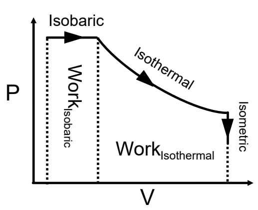
Keep your equations straight! One process' equation does not work for others.

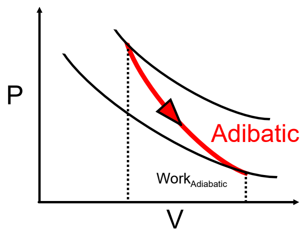
1. Isothermal: Constant Temperature
2. Isobaric: Constant Pressure
3. Isometric (Isochoric): Constant Volume
4. Adiabatic: No Constants.

Parameters change differently depending on process: the 1st Law is different for each.

Four Processes: Graphs & Work

Each process has a specific Pressure vs. Volume graph shape, where work done equals the area under the curve.





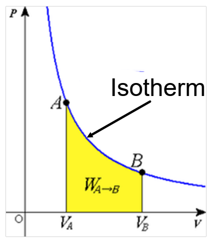
1: Isothermal Process - Constant Temp.

Heat added to a piston moves it outward, maintaining a constant temperature within.

Process path called an isotherm.

Pressure is inversely proportional to volume (Boyle's Law) in $P = nRT/V$ when T is constant.

$$P \propto 1/V$$



1: Isothermal Process: 1st Law

Since $\Delta T = 0$, $\Delta U = 0$

1st Law: $\Delta U = Q + W$

$$0 = Q + W$$

$$Q = -W$$

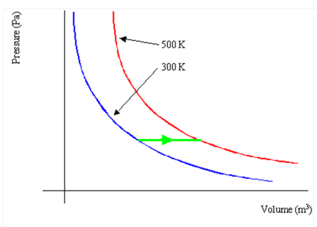
Heat added exactly equals amount of work done.

Remember reference frame, if gas expands, work done is negative (gas loses energy by working on the environment).
If gas contracts, work is positive (gas gains energy by being worked on).

2: Isobaric Process: Constant Pressure

As a gas in a cylinder is heated, the piston is pushed outwards by the gas so pressure does not change.

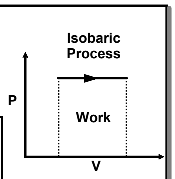
As the temperature increases, the gas expands, so it crosses to a higher temperature isotherm.



Isobaric Work

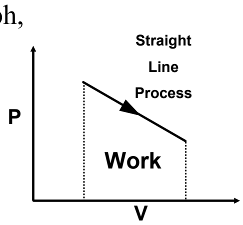
Work sometimes is calculated with a non-1st Law equation:

AP Equation	
$W = -P\Delta V$	W = Work (J) P = Pressure (Pa) V = Volume (m^3)



Also: **IF** it's a straight line graph, average pressure is used:

$$W = -\bar{P}\Delta V = -\frac{P_2 + P_1}{2} \cdot \Delta V$$



First Law: $\Delta U = Q + W$

or: $\Delta U = Q - p\Delta V$

3: Isometric (Isochoric) Process

Constant volume process: NO WORK DONE!

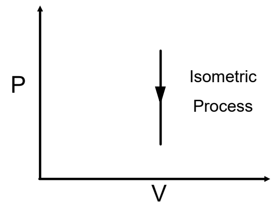
Since no volume change happens, all energy added to a gas increases its temperature and pressure.

1st Law:

$\Delta U = Q + W$

$\Delta U = Q + 0$

$\Delta U = Q$



4: Adiabatic Process

No heat transferred into or out of a system, so Q = 0, and P, V, and Tall change to allow this.

Quick changes, or heavy insulation approximates adiabatic processes.

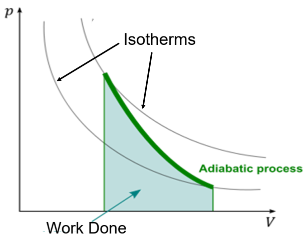
1st Law:

$\Delta U = Q + W$

$\Delta U = 0 + W$

$\Delta U = W$

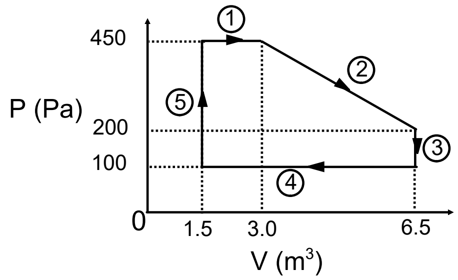
Note: this was the extra credit on the 2.A Test.



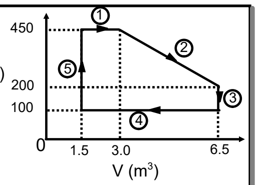
Adiabatic Graph

1. Graphical Example

How much work is done in each step of the following process? How much total?



Graphical Answer



Step 1: Isobaric:

$W = -P\Delta V$

$= -450\,Pa(3.0\,m^3 - 1.5\,m^3) = -675\,J$

Step 2: $W = -\bar{P}\Delta V$

$= -\frac{450\,Pa + 200\,Pa}{2}(6.5\,m^3 - 3.0\,m^3) = -1140\,J$

Step 3: Isometric: Work = 0 J.

Step 4: Isobaric $W = -P\Delta V$

$= -100\,Pa(1.5\,m^3 - 6.5\,m^3) = 500\,J$

Step 5: Isometric: Work = 0 J.

Total Work: -675 J + (-1140 J) + 500 J = -1315 J.

2. Numeric Example

1.2 moles of an ideal gas undergoes an adiabatic expansion, and does 250 J of work in the process. What is the change in internal energy of the gas?

For Adiabatic, Q = 0, so by the first Law:

$\Delta U = W$

$= -250\,J$

What temperature change does it undergo?

$$\Delta U = \frac{3}{2} nR\Delta T$$

$$\Delta T = \frac{2\Delta U}{3nR} = \frac{2 \cdot -250\,J}{3 \cdot 1.2\,moles \cdot 8.31\frac{J}{K \cdot mol}} = -16.7\,K$$

Homework

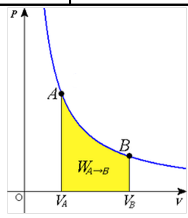
Preview 2.C.3

2.C.2 Booklet Problems.
Due: Next Class.

1: Isothermal Work

Work depends only on the ratio of the endpoint volumes: pressure plays no part.

$W_{isothermal} = nRT\ln\left(\frac{V_2}{V_1}\right)$	W = Work (J) n = moles (mol) R = 8.31 J/(K*mol) T = Temp. (K) V = Volume (m^3)



Isothermal Example.

2.00 moles of helium expand to triple its volume isothermally. The temperature is initially 293K, and the pressure is 1.0 E 5 Pa.
How much work was done in the process?

$$W_{isothermal} = nRT\ln\left(\frac{V_2}{V_1}\right)$$

$$= 2.00\,mol \bullet (8.31\,J/mol \bullet K) \bullet 293\,K \bullet \ln\left(\frac{3}{1}\right)$$

$$= 5{,}350\,J$$