Thermodynamic Processes

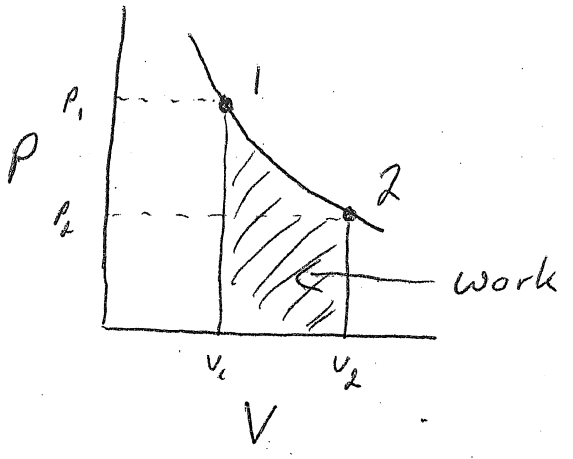
Isothermal

- constant temperature during state change
- Heat $\leftrightarrow$ work

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

↑

recall: the − indicates work done by the gas



$$P = \frac{nRT}{V} \qquad nRT = \text{constant}$$

System Variables

$\Delta T = 0$

$\Delta V \neq 0$

$\Delta P \neq 0$

$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$

$P_1 V_1 = P_2 V_2$

Thermodynamic Variables

$\Delta U = 0$

$Q \neq 0$

$W \neq 0$

$\Delta U^{\,0} = Q + W$

$\Rightarrow Q = -W$

Recall: Temperature is proportional to internal energy.

$U = \frac{3}{2} nRT$ monatomic gas

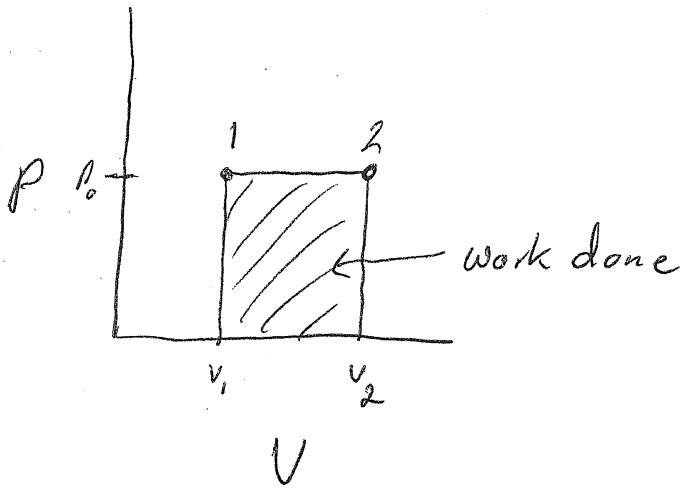
$U = \frac{5}{2} nRT$ diatomic gas

Isobaric

- process involving constant pressure

$$W_{isobaric} = -P\Delta V$$

↑ Recall: - indicates work done by the gas.



System Variables

$\Delta T \neq 0$

$\Delta V \neq 0$

$\Delta P = 0$

Thermodynamic Variables

$\Delta U \neq 0$

$Q \neq 0$

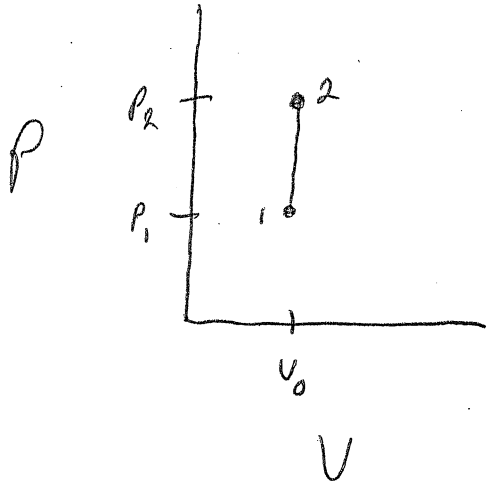
$W \neq 0$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Isometric

- process involving constant volume
- Heat ⟷ Internal Energy



No Work

System Variables

$\Delta T \neq 0$

$\Delta P \neq 0$

$\Delta V = 0$

$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$

$\frac{P_1}{T_1} = \frac{P_2}{T_2}$

Thermodynamic Variables

$\Delta U \neq 0$

$Q \neq 0$

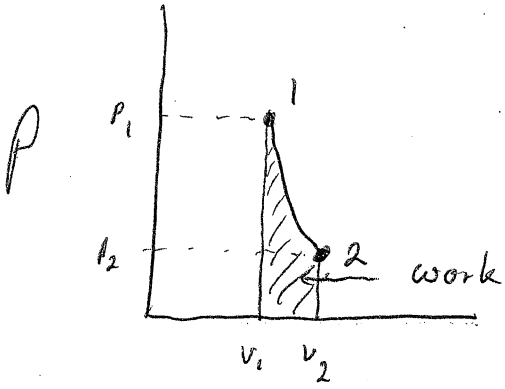
$W = 0$

$\Delta U = Q + \cancel{W}^{0}$

$\Delta U = Q$

Adiabatic

- Process where no heat is exchanged.
- All system variables change



$$PV^{\gamma} = \text{constant}$$

$$\gamma = \frac{c_p}{c_v}$$

Polyatomic $\gamma \sim 1.3$
air $\gamma \sim 1.4$
monatomic $\gamma \sim 1.67$

System Variables

$\Delta T \neq 0$

$\Delta P \neq 0$

$\Delta V \neq 0$

Thermodynamic Variables

$\Delta U \neq 0$

$Q = 0$

$W \neq 0$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

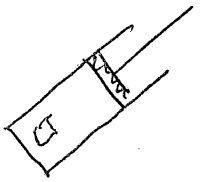
$$\Delta U = \cancel{Q}^{\,0} + W$$

$$\Delta U = W$$

$$W_{adiabatic} = \frac{P_1 V_1 - P_2 V_2}{\gamma - 1}$$

Examples

Fire Syringe - Adiabatic Process



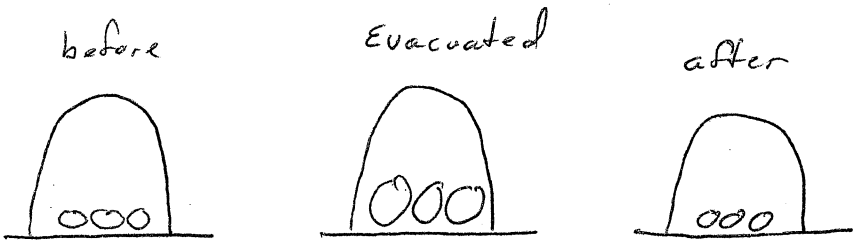
Volume, pressure, and temperature change rapidly so heat can't be exchanged with environment.

The small piece of paper burns.

Bicycle Tire Pump - Adiabatic

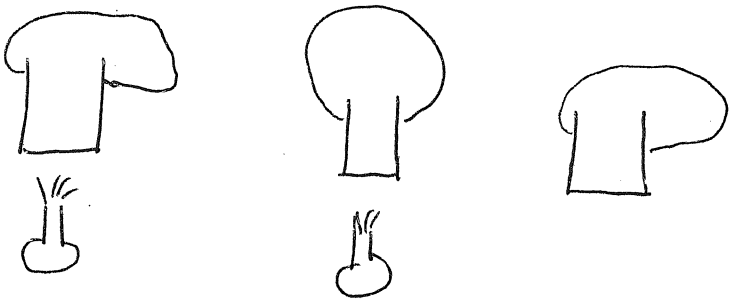
Pump shaft will be hot after repeated use since heat can't be exchanged with the environment quickly.

Marshmallows in a vacuum chamber - Isothermal



Pressure and volume are changed with a constant temperature.

Can and bag - Isobaric



A plastic bag sealed over a can will demonstrate isobaric expansion if heated. It will demonstrate isobaric contraction if cooled.