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Internal Energy and the First Law of Thermodynamics

 $U_2 - U_1 = \Delta U = Q - W$ First law of thermodynamics

Q = DL+W

while Q and W depend on the path, ALI=Q-W is independent of path

the change in internal energy of a system during any thermodynamic process depends only on the initial and final states, no on the path leading from one to the other

the internal energy of ideal gas only depends on the temperature

 $q = \frac{\partial \Gamma}{\partial E} q \Pi + \frac{\partial \Lambda}{\partial E} q \Lambda + \frac{\partial L}{\partial E} q L = 0$

if V is fixed, then dV = 0 $dF = \frac{\partial F}{\partial U} dU + \frac{\partial F}{\partial T} dT = 0$ $(\frac{\partial F}{\partial U})_{V} = -\frac{(\frac{\partial F}{\partial U})_{U,V}}{(\frac{\partial F}{\partial U})_{V,T}} (\frac{\partial F}{\partial U})_{V} = -\frac{(\frac{\partial F}{\partial U})_{V,T}}{(\frac{\partial F}{\partial U})_{V,T}}$

thus, $(\frac{\partial U}{\partial T})_V = -\frac{1}{(\frac{\partial U}{\partial T})_V}$

if Tis fixed, then dT=0 $dF = \frac{\partial F}{\partial U}dU + \frac{\partial F}{\partial V}dV = 0, \qquad (\frac{\partial V}{\partial U})_{T} = -\frac{(\frac{\partial F}{\partial U})_{V:T}}{(\frac{\partial F}{\partial V})_{U:T}}$

 $dF = \frac{\partial F}{\partial T}dT + \frac{\partial F}{\partial V}dV = 0, \qquad (\frac{\partial T}{\partial V})_{U} = -\frac{(\frac{\partial F}{\partial V})_{U,T}}{(\frac{\partial F}{\partial T})_{U,V}}$

 $\Rightarrow (\frac{\partial V}{\partial U})_{T}(\frac{\partial U}{\partial T})_{V}(\frac{\partial T}{\partial V})_{U} = -1, \qquad (\frac{\partial U}{\partial V})_{T} = -(\frac{\partial U}{\partial T})_{V}(\frac{\partial T}{\partial V})_{U}$ according to Joule experiment, $(\frac{\partial T}{\partial V})_{U} = 0 \Rightarrow (\frac{\partial U}{\partial V})_{T} = 0$ for non-ideal gas $(\frac{\partial T}{\partial V})_{U} \neq 0$

a process that eventually returns a system to its initial state is called a cyclic process

 $\bigcup_{i=1}^{N} \bigcup_{k=1}^{N} A_{i} = \bigcup_{k=1}^{N}$

isolated system: one that does no work on its surrondings and has no heat flow to or from its surroundings

W=Q=0; AL=0 - 4 Tr Pn = V Ta Vh she Tr En = Ch

du=dQ-dW=dQ-PdV

Kinds of Thermodynamic Processes

adiabatic process

no heat transfer into or out of a system : Q=0

△∐=-W

isochoric process (isovolumetric)

constant-volume process \Rightarrow it does no work on its surroundings \Rightarrow W=0

∆∐=Q

isobaric process

constant-pressure process

 $W = P(V_2 - V_1)$

isothermal process

constant-temperature process

DATE

Heat Capacities of an Ideal Gas

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Cv molar heat capacity at constant volume

Cp molar heat capacity at constant pressure

dQ=nCvdT=dU due to dW=0

dQ=nCpdT and dW=pdV=nRdT > nCpdT=dU+nRdT

= nCydT+ nRdT

ratio of heat capacities $r = \frac{C_P}{C_V} = \frac{C_V + R}{C_V} = 1 + \frac{R}{C_V}$

 $C_{V} = \begin{bmatrix} \frac{dQ}{dT} \end{bmatrix}_{V} = \begin{bmatrix} \frac{dU + PdV}{dT} \end{bmatrix}_{V} = \begin{bmatrix} \frac{\partial U}{\partial T} \end{bmatrix}_{V}$ $C_{P} = \begin{bmatrix} \frac{dQ}{dT} \end{bmatrix}_{P} = \begin{bmatrix} \frac{dU + PdV}{dT} \end{bmatrix}_{P} = \begin{bmatrix} \frac{\partial U}{\partial T} \end{bmatrix}_{P} + P \begin{bmatrix} \frac{\partial V}{\partial T} \end{bmatrix}_{P}$

 $= \begin{bmatrix} \frac{\partial H}{\partial T} \end{bmatrix}_{P}$

DATE

Adiabatic Processes for an Ideal Gas

$$\triangle Q = 0$$
, $\triangle L = \triangle Q - \triangle W \Rightarrow \triangle L = -\triangle W = -P \triangle V \Rightarrow n C v d T = -P d V$

$$\bigcirc n C v d T = -\frac{nRT}{V} dV \longrightarrow \frac{C v}{R} \frac{dT}{T} = -\frac{dV}{V}$$

$$\frac{dT}{T} + \frac{R}{C_V} \frac{dV}{V} = 0$$
 and $\frac{R}{C_V} = \gamma - 1$

$$\frac{dT}{T}$$
 + $(\gamma - 1) \frac{dV}{V} = 0$

$$\Rightarrow$$
 lnT+(γ -1)|nV = constant

$$\Rightarrow$$
 InT+InV^{r-1} = constant

$$\Rightarrow$$
 In (TV $^{r-1}$) = constant

$$\Rightarrow T_1 V_1^{r-1} = T_2 V_2^{r-1}$$

$$\Rightarrow \frac{PV}{NB}V^{k-1} = C_{\lambda}$$

$$\Rightarrow PV^{r} = C_3$$

$$\Rightarrow P_1 V_1^r = P_2 V_2^r$$

$$\frac{1}{x-1} \frac{dT}{T} = -\frac{dV}{V}$$

$$\frac{1}{|Y-1|}|NT = -|NV+C|$$

$$\ln T^{\frac{1}{k-1}} + \ln V = C$$

$$T^{\frac{1}{\gamma-1}}V=e^{c}=C_{1}$$

$$(\perp_{\frac{k-1}{4}} \land)_{k-1} = C_{k-1}^1 = C^7 = \perp_{k-1}$$

$$\frac{PV}{NR}V^{Y-1} = C_{\lambda}$$

$$PV^r = nRc_2 = C_3$$

$$PP^{r}P^{r}V^{r} = P^{1-r}(nRT)^{r}$$

PV=nBT total differention

$$PV \left(\begin{array}{c} PdV + VdP = -\frac{R}{Cv}dT \\ \frac{dV}{V} + \frac{dP}{P} = -\frac{Cv}{Cv}\frac{dV}{V} = (1-V)\frac{dV}{V} \end{array} \right)$$

$$\Rightarrow \frac{dP}{P} + r \frac{dV}{V} = 0$$

$$\nabla \Pi = -\nabla M = \int dA = \int \frac{\Lambda_{A}}{C^{3}} dA = \frac{\lambda - 1}{C^{3}} \Lambda_{1-\lambda_{1}} \int_{\Lambda^{2}} = \frac{\lambda - 1}{1} (\Lambda^{2} b^{2} - \Lambda^{1} b^{2})$$

$$= \frac{1}{r-1} NR(T_f - T_i) = NC_r(T_f - T_i)$$