DO NOT NEED PV DIAGRAM ONLY

COULD MAKE DIAGRAM FOR ANY 2

$(P, V)$

$(P, T)$

$(V, T)$

FOR EXAMPLE $pV^{\gamma} = \text{CONST}$ ~~+~~ ADIABATIC

USE $pV = NkT \rightarrow p = Nk\frac{T}{V}$

So $pV^{\gamma} \rightarrow Nk\frac{T}{V} \cdot V^{\gamma} = \text{const}$

$$NkTV^{\gamma-1} = \text{const}$$

$Nk$ CONST

$$\gamma = \frac{f+2}{2}$$

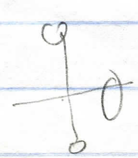
$$TV^{\gamma-1} = \text{const}$$

$$TV^{\frac{2}{3}} = \text{const}$$

$f = 1$ FOR MONATOMIC

$$\gamma = \frac{5}{3}$$

$$(\gamma - 1) = \frac{2}{3}$$



ACTUALLY CAN DO DIRECTLY FROM ENERGY

had $U = \frac{3}{2} NkT$

so $\Delta U = \frac{3}{2} Nk\,\Delta T$

& also $\Delta U = -p\,\Delta V$

$$\frac{3}{2} Nk\Delta T = -p\Delta V$$

put $p = \frac{NkT}{V}$ in here

$$\frac{3}{2} \cancel{Nk}\Delta T = -\cancel{N}kT\,\frac{\Delta V}{V}$$

$$\frac{3}{2}\,\frac{\Delta T}{T} = -\frac{\Delta V}{V}$$

$$\frac{3}{2}\ln T + \ln V = \text{const}$$

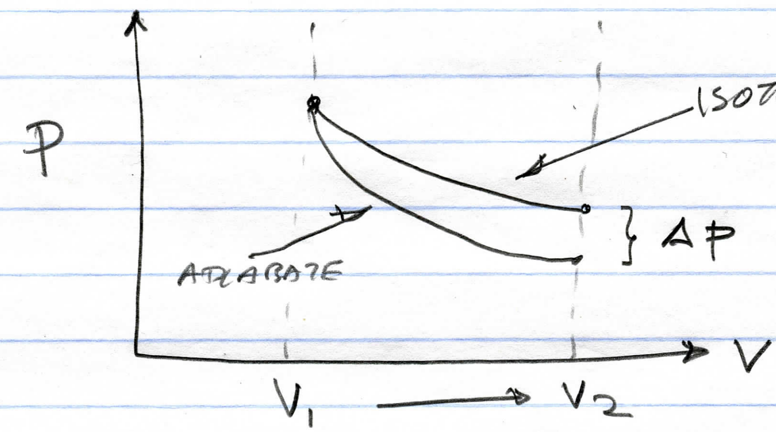
of $\int$ed.

$$\ln T^{3/2} + \ln V = \text{const}$$

Same as other $\Longrightarrow$ $T^{3/2}\cdot V = \text{const}$

$$T V^{\frac{2}{3}} = \text{const.}$$

COMPARISON OF ISOTHERMAL $\updownarrow$ ADIABATIC

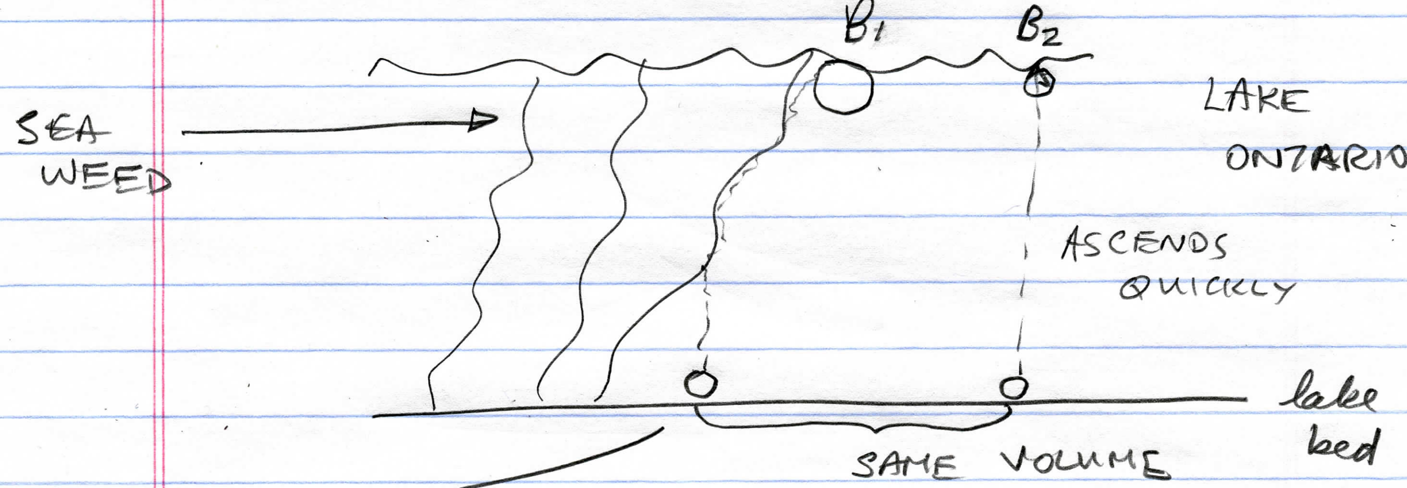



ADIABATE $\longrightarrow$ STEEPER

$\downarrow$

NOTICE PRESSURE HIGHER AFTER ISOTHERMAL

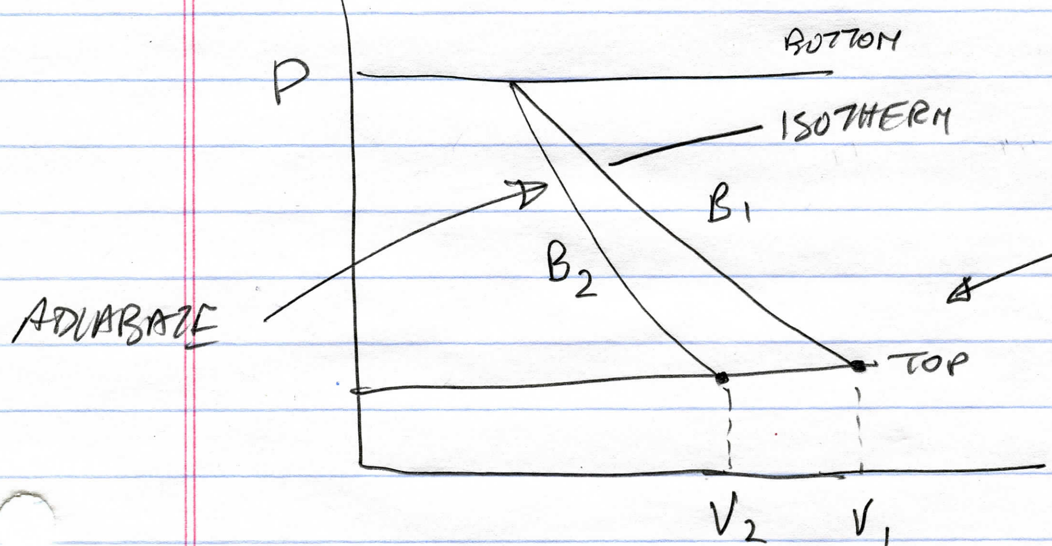
PROB 1.38 in text




gets CAUGHT ON SEA WEED EXCHAGES HEAT ISOTHERMAL

NO TIME TOO EXCHANGE HEAT WITH LAKEWATER ADIABATIC

BUBBLES END ON SURFACE → SAME PRESSURE ATMOSPHERIC



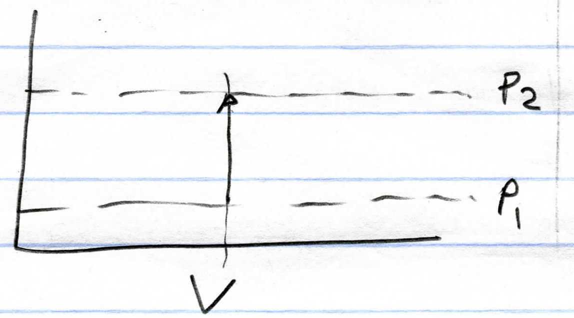

PRESSURE IN BUBBLES EQUAL

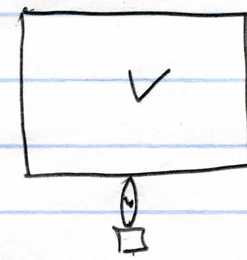
$$V_{B_1} > V_{B_2}$$

$$V_{B_1}^{I} = V_{B_2}^{I}$$

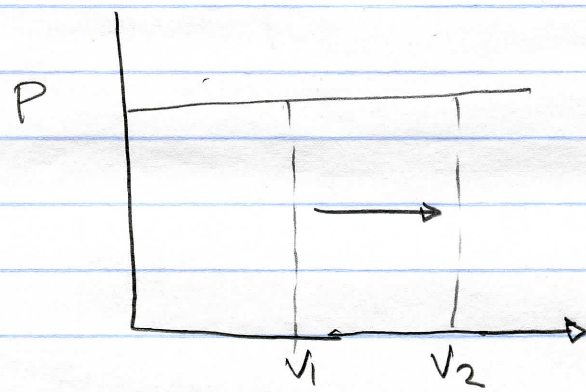
# OTHER PROCESSES

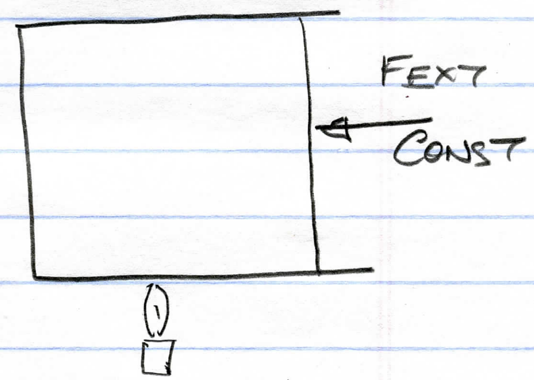
**ISOCHORIC** → FIXED VOLUME




**ISOBARIC** → FIXED PRESSURE



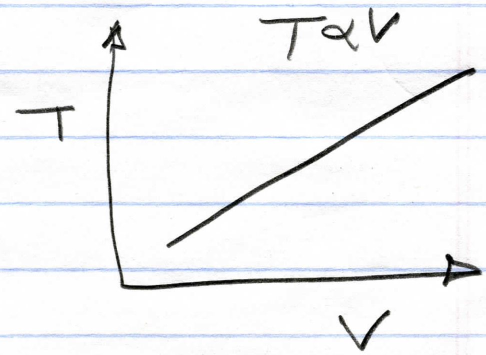




TRANSFORM ISOBARIC TO TV PLOT

$$PV = NkT$$

$$\underbrace{P}_{\text{Const}} = Nk\frac{T}{\underbrace{V}_{\text{Const}}}$$

$T \propto V$



THERMODYNAMIC EQUILIB $\longrightarrow$ MACROSCOPIC CHARACTERISE SYSEM

$P, V, T, N$

Other macroscopic quantites

$\hookrightarrow$ HEAT CAPACITY

At first sight $\rightarrow$ Amount of Heat Needed to Raise T of system by 1K

$\downarrow$ Example of ECONOMIC RELEVANCE

HEATING WATER IN A BOILER COSTS Money

$$C = \frac{Q}{\Delta T}$$ $\longleftarrow$ depends on Mass or Size of body

Specific Heat of N particles $\frac{C}{N}$

SPECIFIC HEAT of mass m $\frac{C}{m}$

For Water — 1 gream

$$C = 4.2 \frac{J}{°C} = 1 \frac{\text{CALORIE}}{°C}$$

ACTUALLY this is specific heat a FIXED VOLUME

→ C depends on DETAILS OF PROCESS by which temperature is raised

→ If T raised at fixed V

— $C_V$ ← FIXED

1ST LAW $\quad \Delta U = Q - \underbrace{P\Delta V}_{\to 0}$

$$Q = \Delta U$$

$$C_V = \left(\frac{Q}{\Delta T}\right)_V = \left(\frac{\Delta U}{\Delta T}\right)_V$$

const

$$\left(\frac{\Delta U}{\Delta T}\right)_V \xrightarrow[\text{DERIVATIVE}]{\text{PARTIAL}} \left(\frac{\partial U}{\partial T}\right)_V$$

IDeal GAS — constant V makes NO DIFFERENCE

$$U = \frac{f}{2} N k T$$

FIXED

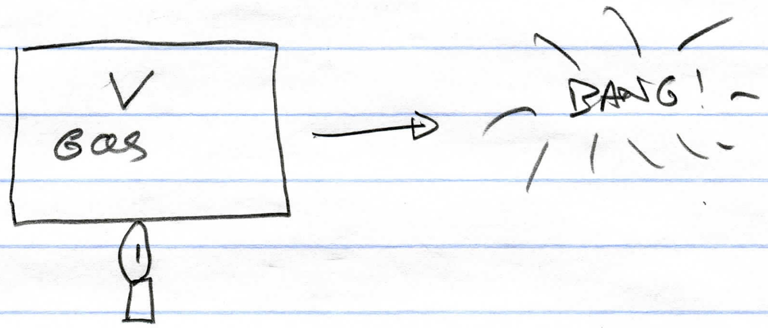
For NON IDEAL GAS $U \equiv U(V)$

$$C_{V\,\text{IDEAL GAS}} = \left(\frac{\partial U}{\partial T}\right)_V = \frac{\partial\left(\frac{f}{2} N k T\right)}{\partial T}$$

$$= \frac{f}{2} N k.$$

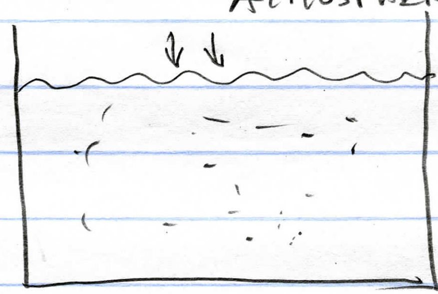
or $$\left.\frac{C_V}{N}\right|_{\text{IDEAL GAS}} = \frac{f}{2} \cdot k.$$

IN PRACTICE HARD TO KEEP $V$ CONST




EASY TO KEEP PRESSURE CONST.

ATMOSPHERIC PRESSURE



← EXPANDS $V \uparrow$

$P \rightarrow$ ATMOSPHERE

$$C_p = \left(\frac{Q}{\Delta T}\right)_P$$

$$Q = \Delta U + P\,\Delta V \longrightarrow 1^{ST} \text{ LAW}$$

$$C_p = \left(\frac{\Delta U + P\Delta V}{\Delta T}\right)_P$$

$$C_P = \left(\frac{\Delta u}{\Delta T}\right)_P + \left(\frac{P\Delta V}{\Delta T}\right)_P$$

$$= \left(\frac{\partial u}{\partial T}\right)_P + P\left(\frac{\partial V}{\partial T}\right)_P$$

matter for non-ideal

COMPARE

$$C_V = \left(\frac{\partial u}{\partial T}\right)_V$$

Again $\quad U = \frac{f}{2} NkT$

$$(*) \longrightarrow \left(\frac{\partial u}{\partial T}\right) = \frac{f}{2} Nk \leftarrow$$ does not depend on pressure or volume

$$\left(\frac{\partial V}{\partial T}\right)_{P \leftarrow \text{const}} \longrightarrow PV = NkT$$

$$P\Delta V = Nk\Delta T$$

$$P\left(\frac{\Delta V}{\Delta T}\right)_P = Nk$$

$$C_P\big|_{\text{IDEAL}} = \left(\frac{\partial u}{\partial T}\right)_P + P\left(\frac{\partial V}{\partial T}\right)_P$$

$$= \frac{f}{2} Nk + Nk$$

$$= \left(\frac{f}{2}+1\right) Nk$$

$$C_P\big|_{IDEAL} = \left(\frac{f}{2}+1\right)Nk$$

$$C_V\big|_{IDEAL} = \frac{f}{2}Nk$$

$C_P > C_V$ TRUE IDEAL GAS

ACTUALLY TRUE – THERMODYNAMICALLY STABLE SYSTEM.

$C_P \rightarrow$ More heat to raise temp
$\hookrightarrow$ Some energy goes into expanding system.

$$C_P = \left(\frac{\partial U}{\partial T}\right)_P + P\left(\frac{\partial V}{\partial T}\right)_P$$

$$C_V = \left(\frac{\partial U}{\partial T}\right)_V$$

IS THIS BECAUSE $\left(\frac{\partial V}{\partial T}\right) > 0$.

NOT Always true.

$$\left(\frac{\partial V}{\partial T}\right)_P = \frac{\text{change of } V}{\text{change of } T} > 0 \; ?$$

Normally heating → expansion.

For water $0°C \rightarrow 4°C$ contracts as it is heated, expands as it cools.
→ just before freezing.

ICE FLOATS → takes up more volume than water

$$\text{so} \quad \left(\frac{\partial V}{\partial T}\right)_P < 0.$$

water $0°C \to 4°C$ $\frac{\Delta V}{\Delta T} < 0$

$$C_p = \left(\frac{\partial u}{\partial T}\right)_p + \underbrace{P\left(\frac{\partial v}{\partial T}\right)_p}_{<0}$$

$$C_v = \left(\frac{\partial u}{\partial T}\right)_v$$

IS $C_p < C_v$ FOR water? — NO

$$\left(\frac{\partial u}{\partial T}\right)_p \neq \left(\frac{\partial u}{\partial T}\right)_v$$

NOT an ideal substance

Can show that

$$C_p = C_v - T\left(\frac{\partial p}{\partial v}\right)_T \left[\left(\frac{\partial v}{\partial T}\right)_p\right]^2$$

ANY THERMODYN STABLE

Really shows

$C_p > C_v$

THERMODYNAMICALLY STABLE

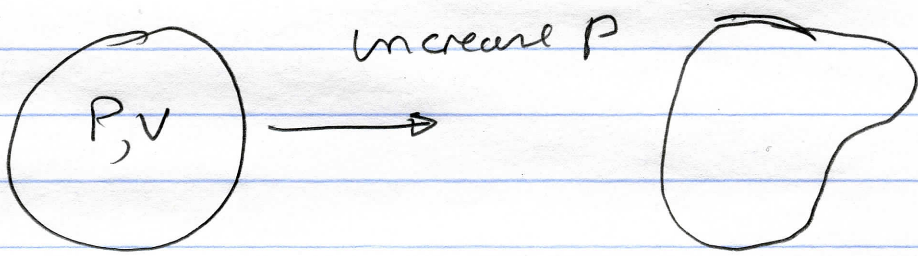
$$C_p - C_v = -T\left(\frac{\partial P}{\partial V}\right)_T \underbrace{\left[\left(\frac{\partial V}{\partial T}\right)_P\right]^2}_{>0}$$

K always >0

<0 for STABLE SYSTEM

$$\left(\frac{\partial P}{\partial V}\right)_T = \text{Pressure change for volume increase}$$

If NOT stable




$\Delta V > 0$

$\Delta P \uparrow \rightarrow \Delta V \uparrow \rightarrow \Delta P \uparrow \rightarrow \Delta V \uparrow$

UNSTABLE

if $\Delta V > 0 \rightarrow \Delta P < 0$ STABLE EQUILIB.