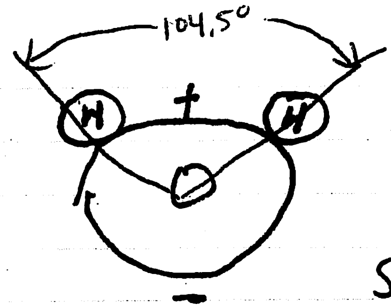
1/

10-11-2005

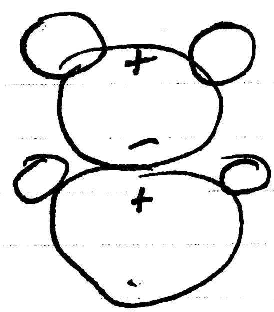
Water, a most common and unusual substance



Slight + on H side

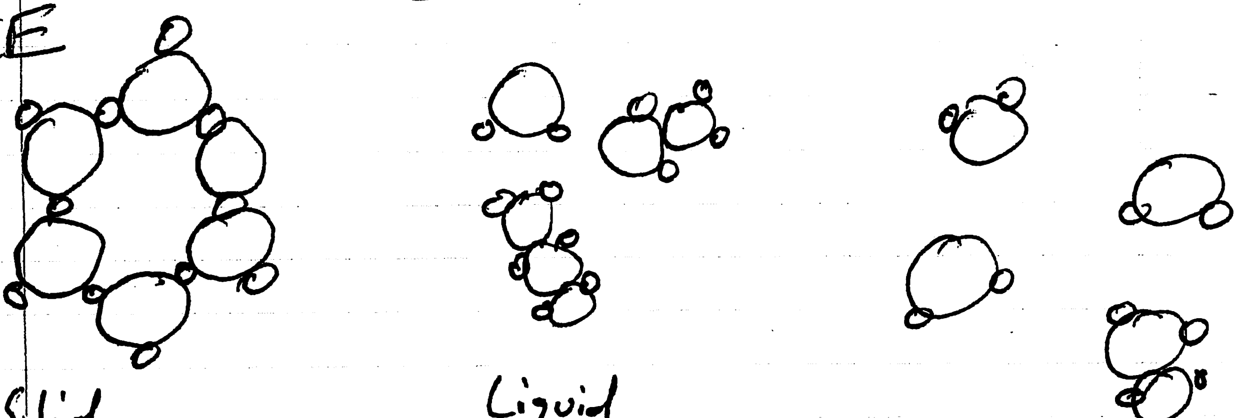
Slight - on Other Side

Polar molecule - powerful solvent - much dissolves in Water and runs off to lakes. Also causes its surface tension when in liquid form.



ICE

Near Atmos Temp Press



Solid (Hexagonal crystal symmetry) ordered

Liquid Semi ordered

Vapor (less ordered)

(Trade entropy, disorder, to move betw the states)

Water has ...

high specific heat → much energy as heat to change its temperature.
because of strength of H bonds between molecules - Lots of energy → in to tweak these bonds.
Helps moderate climate.

High thermal conductivity ⇒ helps stabilize T structure of lakes + oceans.

Liquid from 0 C to 100C - wide range

High surface tension ⇒ Allows plants to move water and dissolved nutrients from their roots to their leaves.

Exists in 3 Phases in the atmosphere
Vapor
Liquid
Solid
} transformations involve huge heat exchange - latent heat.
$\frac{3}{4}$ of all heat transfer in the Atmos by evap + condens.

does ice float or sink?

T (C)	Density (g/cc)
0 (Solid-ice)	0.9150
0 (liquid)	0.9999
4	1.0000
20	0.9982
40	0.9922
60	0.9832
80	0.9718
100 (gas)	0.0006

Since it floats Allows ice to melt in summer

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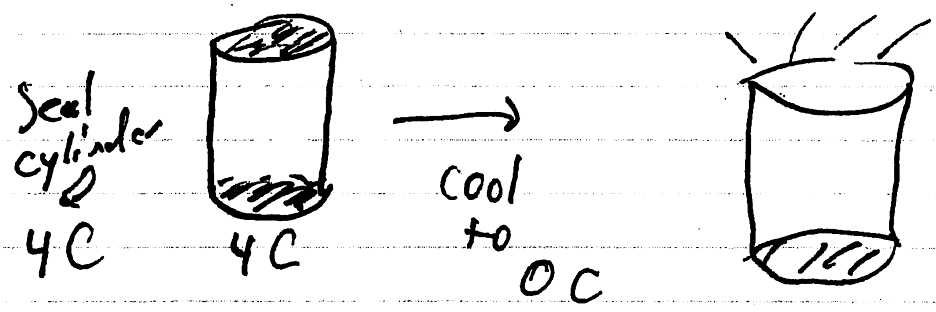
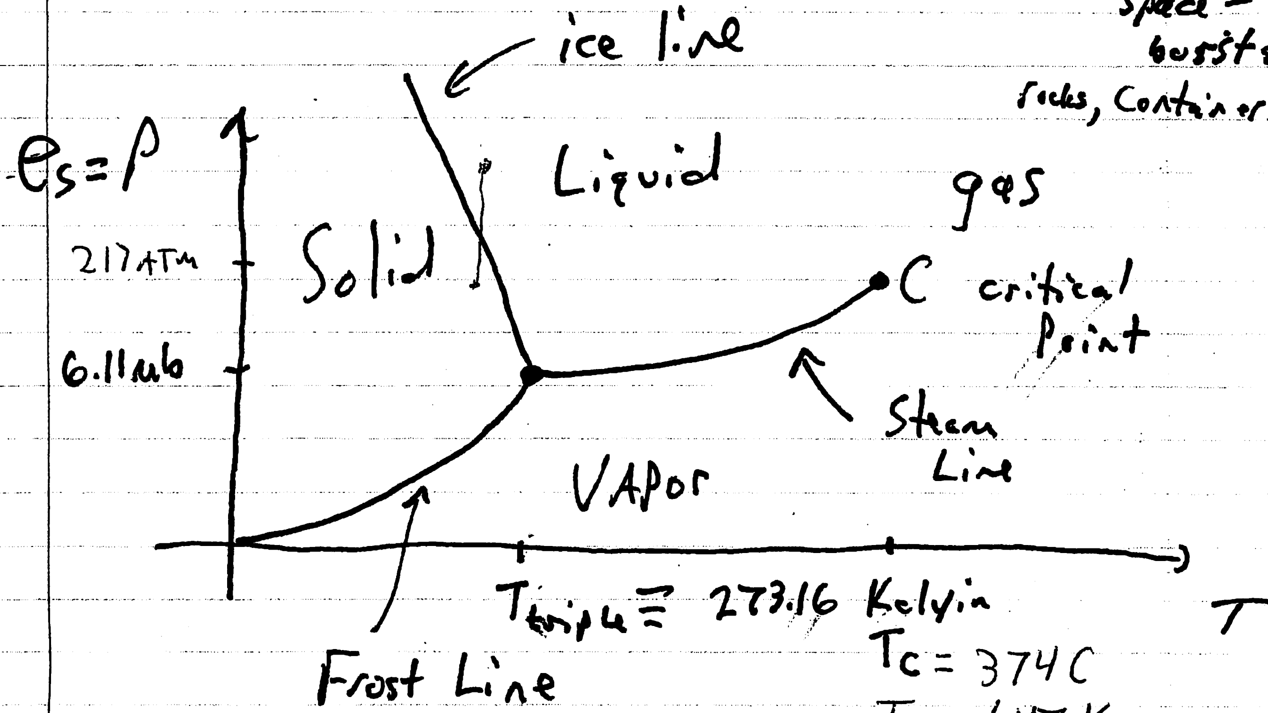
Water is a jackhammer - Erodes rocks through Freeze - Thaw cycle.



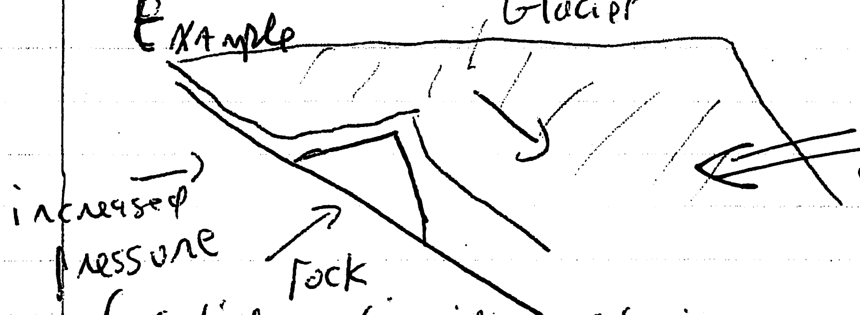
$\rho_L > \rho_{ice}$

$V_L < V_{ice}$ — ice wants to occupy more space - bursts rocks, containers



$T_c = 374C$

$T_c = 647K$



Solid ice ⇒ Liquid water due to pressure at the rock. Glaciers ooze around obstacles.

(solid → liquid → Glacier can ooze around obstacles)

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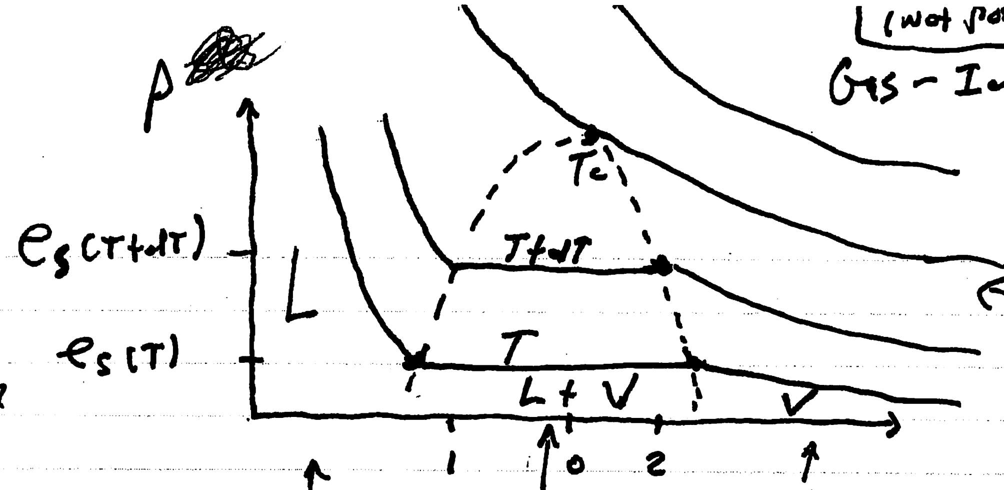
(not possible to compress to liquid)

Gas - Ideal Gas Law

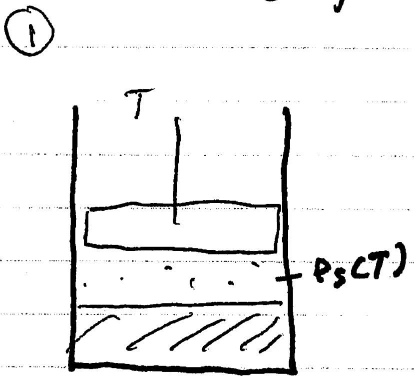


in coexistance region

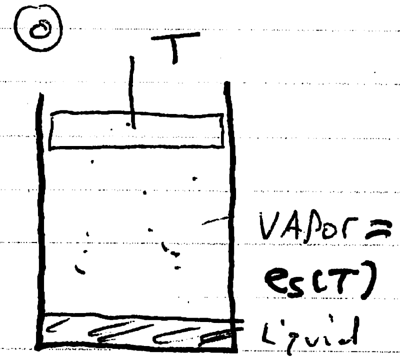
Liquid
Low compressibility

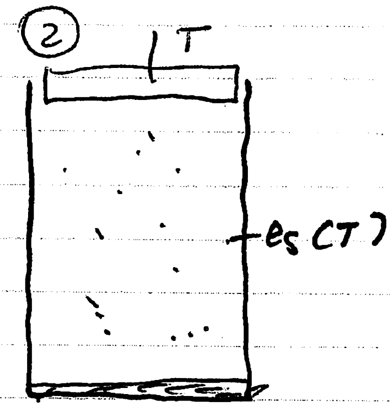
Non-Saturated Vapor
Highly compressible

→ Surrounded by heat Bath T



Compression only causes more liquid to form, not pressure to go up



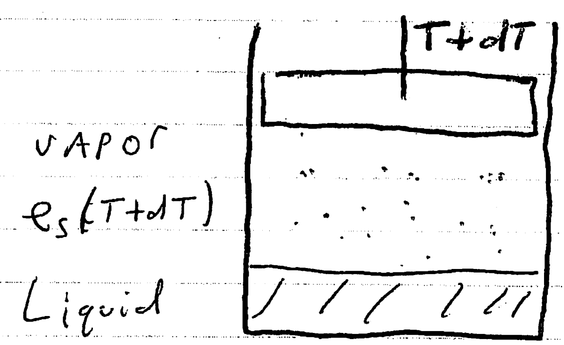


Expansion causes more liquid to evaporate to keep $e_s(T)$ fixed.

Heat flows into liquid from bath to make up for evaporative cooling and latent heat absorption.

How does the vapor pressure change with temperature in the coexistance Region?

Need to know because the temperature varies with altitude.



If heat were released by liquid on evaporation → Process would run away. Cooling helps relieve the instability.

Fermi's direct exposition

$p \equiv$ Pressure

$V_\ell \equiv$ volume / mass liquid $= 1/\text{density}$

$V_v \equiv$ vapor

$\epsilon_\ell \equiv$ internal energy / mass liquid

$\epsilon_v \equiv$ " vapor

We use α_ℓ, α_v in ATMS

$m = m_\ell + m_v$ total mass

Total System Values

$$V = m_\ell V_\ell + m_v V_v$$

$$E = m_\ell \epsilon_\ell + m_v \epsilon_\ell$$

At constant T,
make dm liquid $\rightarrow$ vapor, dm_{ev}

dV + dE ?

$$V + dV = (m_\ell - dm) V_\ell(T) + (m_v + dm) V_v(T)$$

or

$$V + dV = V + (V_v - V_\ell)\, dm$$

so

$$\underline{dV} = (V_v - V_\ell)\, dm$$

Similarly

$$\underline{dE} = (\epsilon_v - \epsilon_\ell)\, dm$$

First LAW OF THERMODYNAMICS

$$dQ = \overline{dE} + p\,\overline{dV}$$

$$dQ = dm \{ \epsilon_v - \epsilon_\ell + p(V_v - V_\ell) \}$$

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$$\frac{dQ}{dm} \equiv \text{Latent heat of Vaporization} = L_{lv}$$

$\equiv$ heat needed to vaporize 1 kg Liquid @ constant temperature

or

(1) $$L_{lv} = \epsilon_v - \epsilon_l + p(V_v - V_l)$$

or

Entropy per unit mass → $$L_{lv} = T\Delta S = T(S_v - S_l)$$

⇒ disorder - pure form.

Since Change was made isothermally,

$$\left.\frac{\partial E}{\partial V}\right)_T = \frac{E_v - E_l}{V_v - V_l}$$

From (1),

$$\epsilon_v - \epsilon_l = L - p(V_v - V_l).$$

So

$$\left.\frac{\partial E}{\partial V}\right)_T = \frac{L}{V_v - V_l} - p$$

Applying Math to Thermodynamics, can show

$$\left.\frac{\partial E}{\partial V}\right)_T + p = T \left.\frac{\partial p}{\partial T}\right)_V !$$

Since $p(T)$ alone,

$$\boxed{T\frac{dp}{dT} = \frac{L_{lv}}{V_v - V_l}}$$

Examples

Similarly

$$T\frac{dP}{dT} = \frac{L_{sl}}{V_l - V_s}$$

(1)
S = Solid
l = liquid

Now $V_l = \frac{1}{\rho_l}$, $\rho_l > \rho_s$ ∴

ICE — $V_l < V_s$

$$T\frac{dP}{dT} < 0$$

Slope of the solid to liquid line is <0.
FOR ICE

(2) l-V

Next, ~~$\rho_v > \rho_l$~~

$\rho_l >> \rho_v$ so

Volume/mass → $V_l << V_v$

$$T\frac{dP}{dT} = \frac{L_{ev}}{V_v} \qquad V_v = \frac{R_v T}{P}$$

$R_v = \frac{R_o}{M_{w\,water\,vapor}}$

I.G.L. for vapor

$R_v = \frac{R_o \text{ kmole}}{18 \text{ kg}}$

$R_o = 8314.3 \frac{J}{\text{kmole}\,°K}$ — Universal gas constant

$$\int_{P_v}^{P}\frac{dP}{P} = \frac{L_{ev}}{R_v}\int_{T_o}^{T}\frac{dT}{T^2}$$

← Assuming $L_{ev} \neq f(T)$

Solving,

$$P = P_o \exp\left[\frac{L_{ev}}{R_v}\left(\frac{1}{T_o} - \frac{1}{T}\right)\right]$$

$T_o = 273.16$ $P_o = 6.11\,mb$