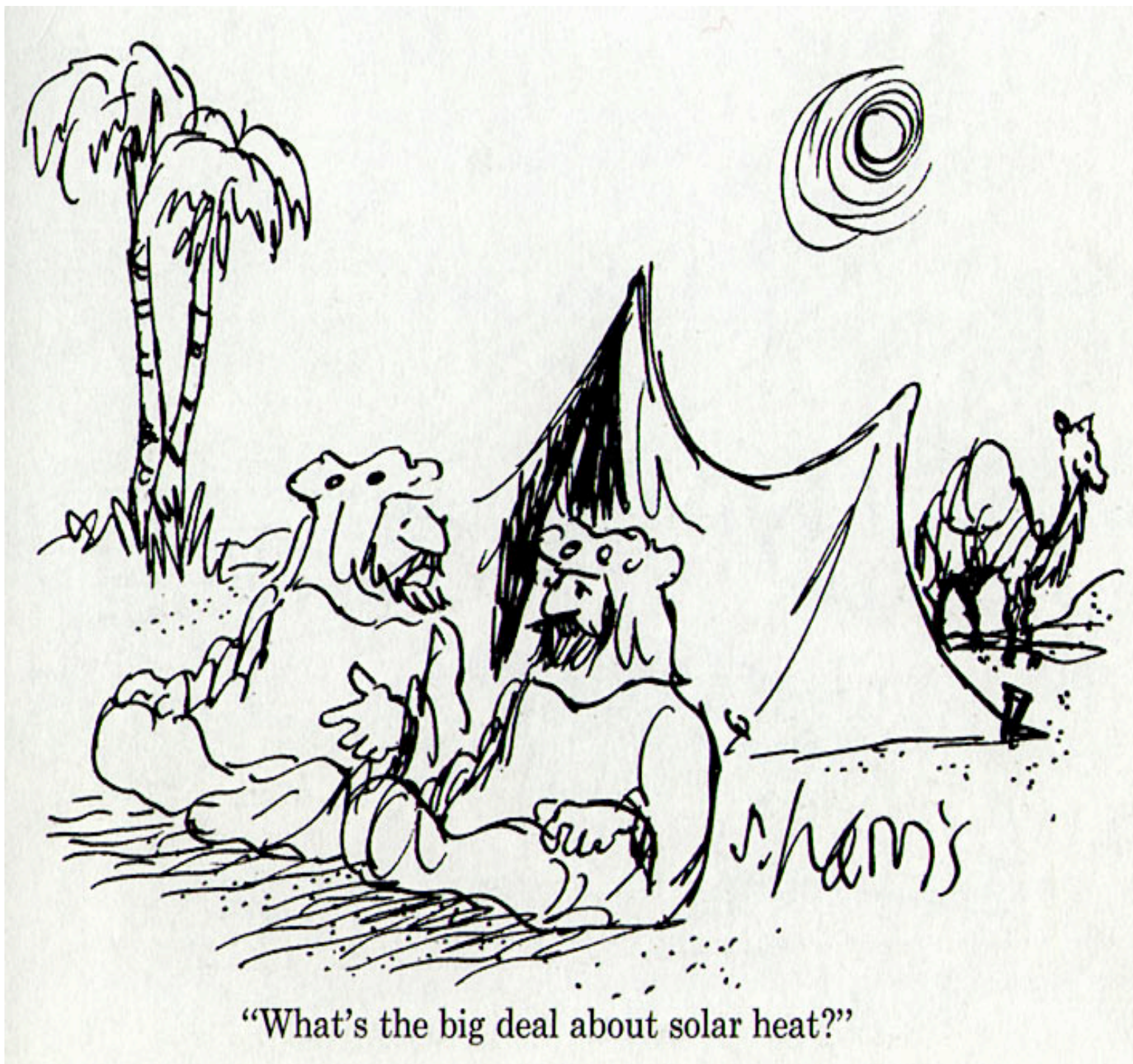




“What’s the big deal about solar heat?”

HOMEWORK PROBLEM

Fuel Consumption

About 5-6 ounces of methane are required to provide enough heat for a comfortable bath for an average-sized adult in a tub appropriate in size for containing 20 gallons of water.

Do a Best Estimate/Good guess/Back-of-the-envelope approximate calculation to validate that assumption.

**(1) To take 20 gallons of water
from say 15°C → 45°C**

$$\mathbf{20\ gal = 80\ qt = 80\ L = 80\ kg = 80,000\ g}$$

$$\mathbf{sp.\ ht\ of\ water = 4.184\ J/g/deg}$$

$$\mathbf{heat = mass\ X\ sp.\ ht\ X\ \Delta T}$$

$$\mathbf{= (80,000\ g) \left(\frac{4.184\ J}{g\ deg} \right) (45 - 15)deg}$$

$$\mathbf{= 10,041,600\ J}$$

(2) Methane required to do that job:

$$(10,041,600 \text{ J}) \left(\frac{1 \text{ mol}}{890 \text{ kJ}} \right) \left(\frac{1 \text{ kJ}}{1000 \text{ J}} \right) = 11.28 \text{ mol}$$

$$(11.3 \text{ mol}) \left(\frac{16 \text{ g}}{1 \text{ mol}} \right) \left(\frac{1 \text{ lb}}{454 \text{ g}} \right) \left(\frac{16 \text{ oz}}{1 \text{ lb}} \right) = 6 \text{ oz}$$

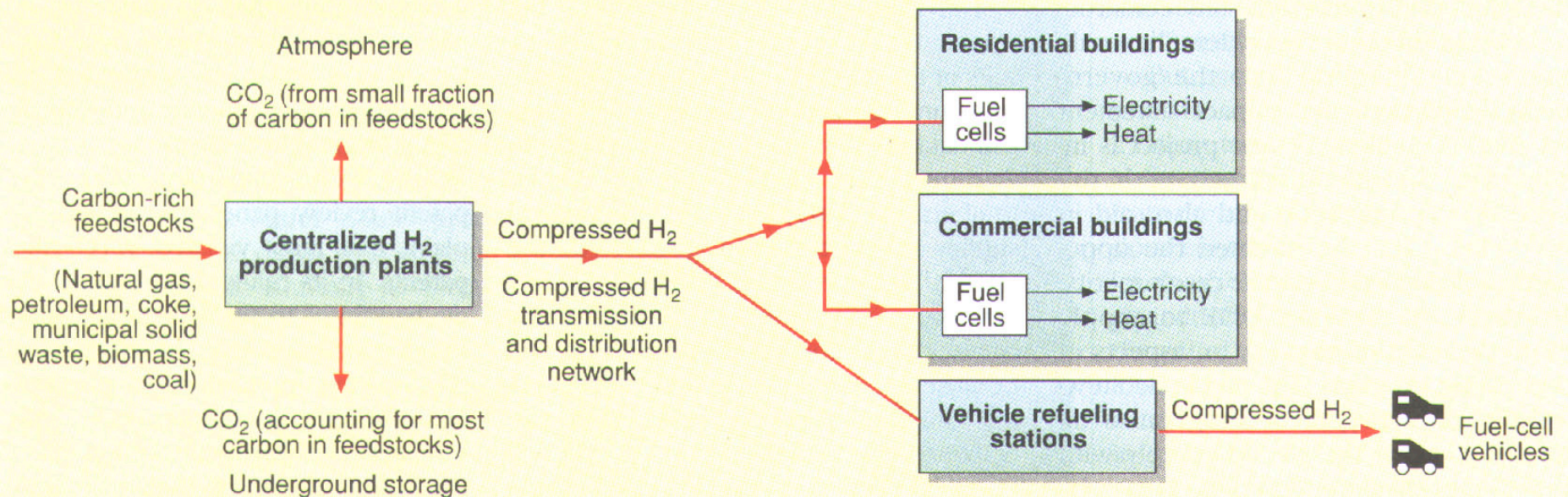
..... or about 0.4 lb

..... or if propane (C_3H_8) is combusted, then about 2.5 ounces of fuel..... which means the heat of combustion of propane must differ from methane by a factor of

$$\left(\frac{6}{2.5}\right) (890 \text{ kJ/mol}) = 2250 \text{ kJ/mol}.$$

A HYDROGEN ECONOMY IN OUR FUTURE?

Hydrogen energy system would release little carbon dioxide to the atmosphere



Source: Robert H. Williams

Chrysler PULSE

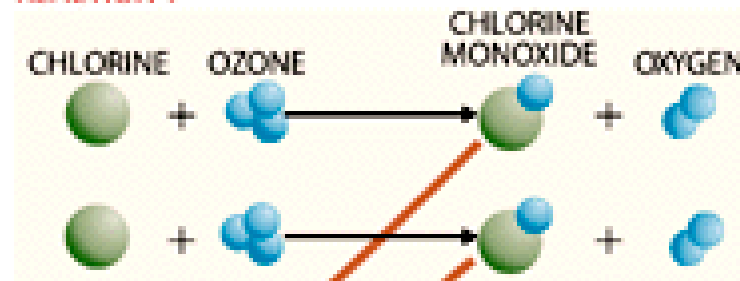
Smart Car Hybrid Vehicle



Chlorine Destroys Ozone

but is not consumed in the process

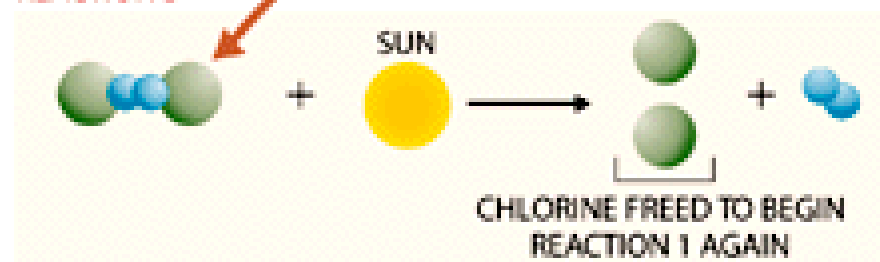
REACTION 1

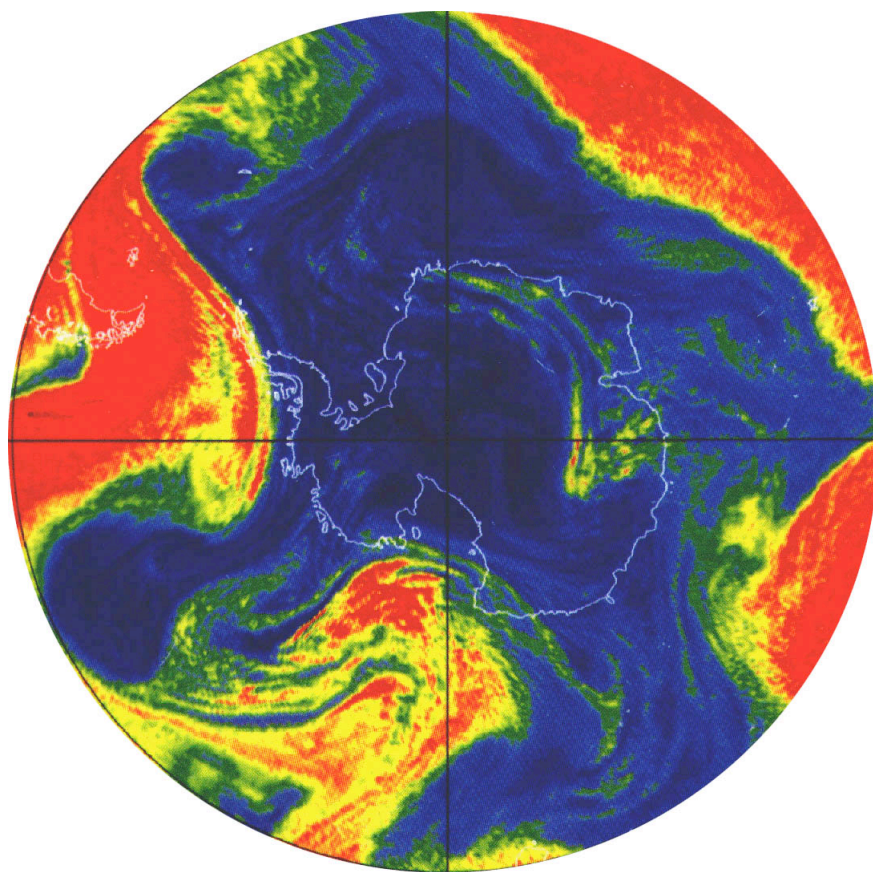


REACTION 2



REACTION 3







Crutzen



Molina



Rowland

Paul Crutzen

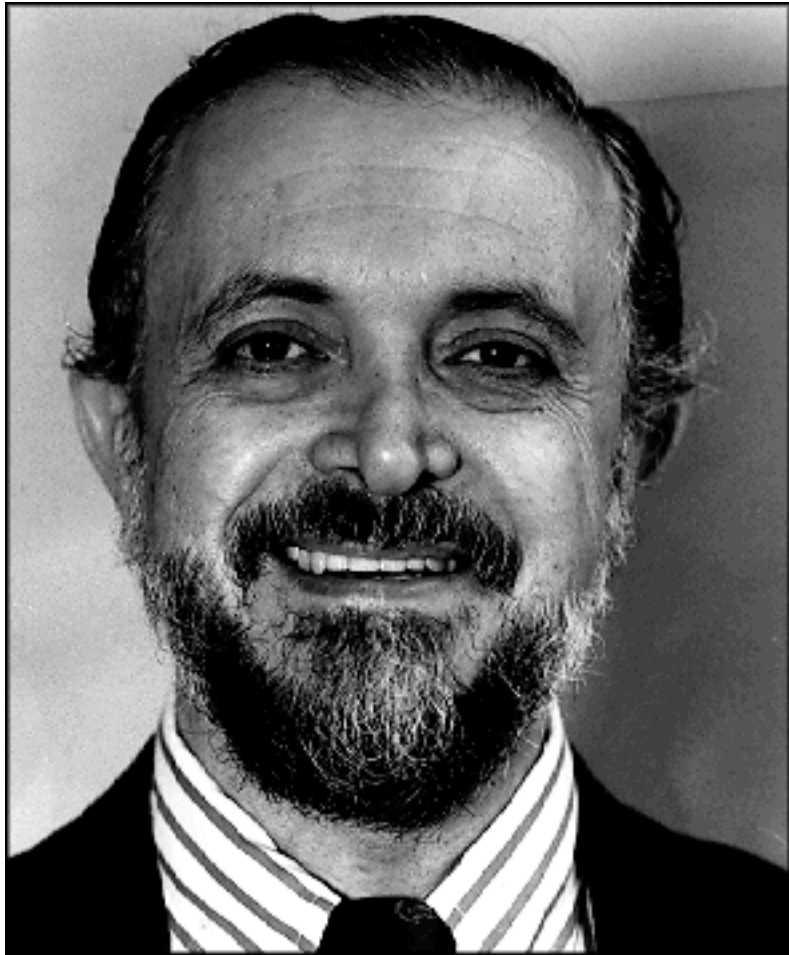


Holland (The Netherlands)

Max-Planck-Institute
for Chemistry
Mainz, Germany

1933 -

Mario Molina



USA (Mexico)

Earth/Atmospheric/Planetary
Sciences and Chemistry
MIT

1943 -

Sherwood Rowland



USA

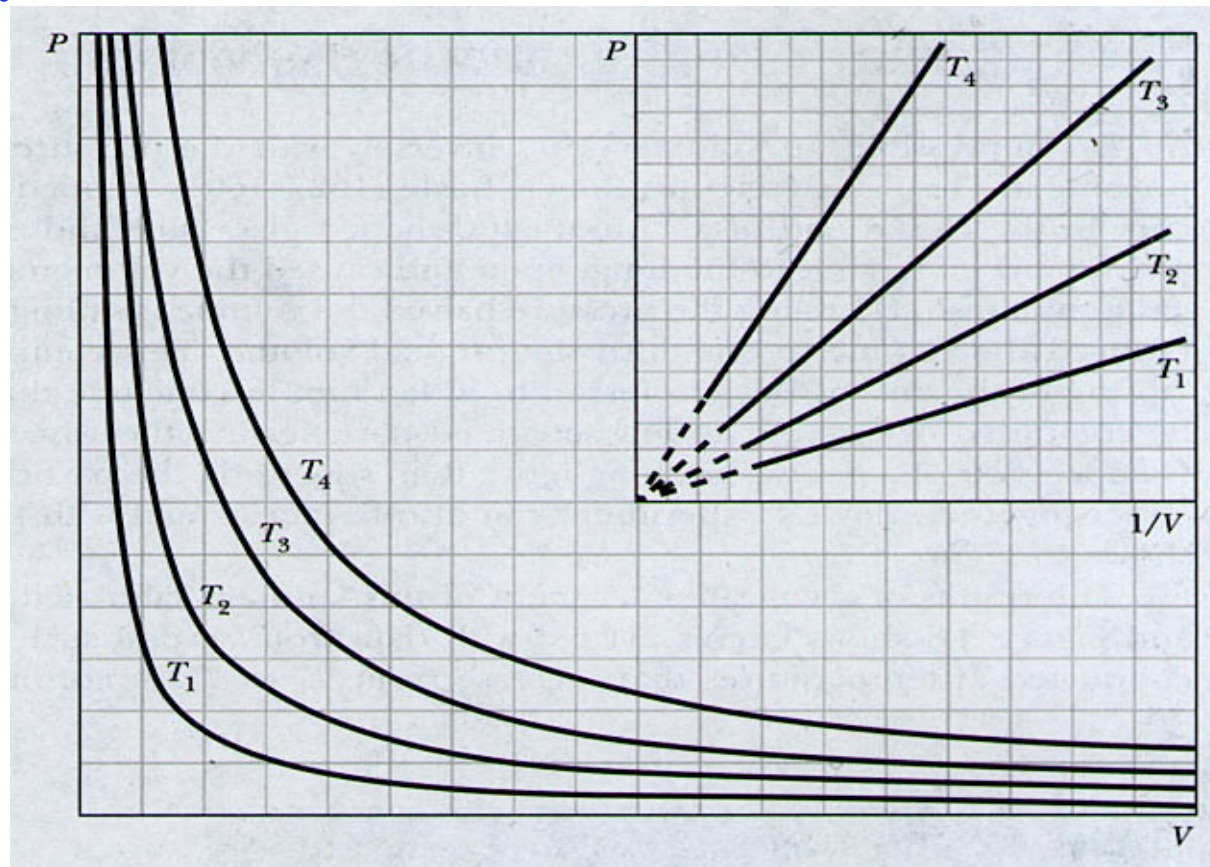
Chemistry
University of California
at Irvine

1927 -

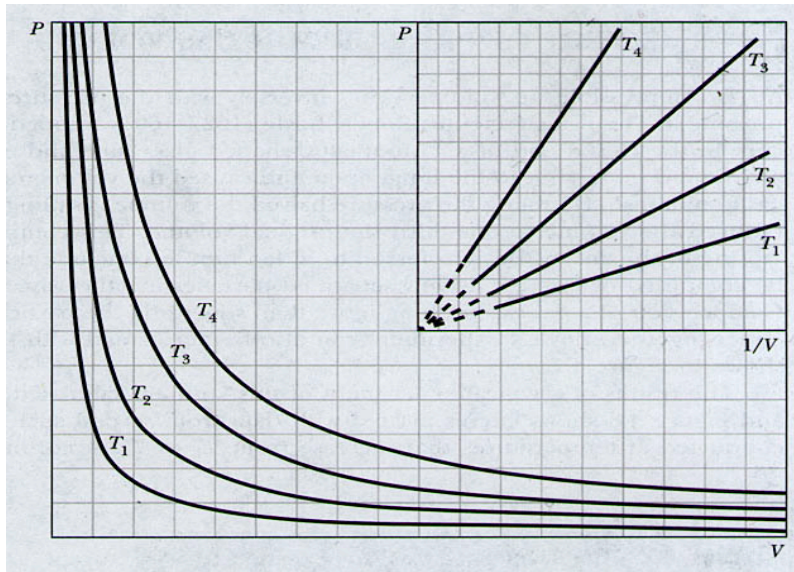
Three States of Matter

- By assuming the existence of attractive and repulsive forces...
- By assuming the existence of thermal energy...
- it is possible to explain nearly all of the bulk properties of gases, liquids, and solids
- it is possible to explain the colligative properties of solutions.

Ideal (Perfect) Gases Obey
Boyle's Law for which $PV = k$



Ideal (Perfect) Gases Obey Boyle's Law for which $PV = k$



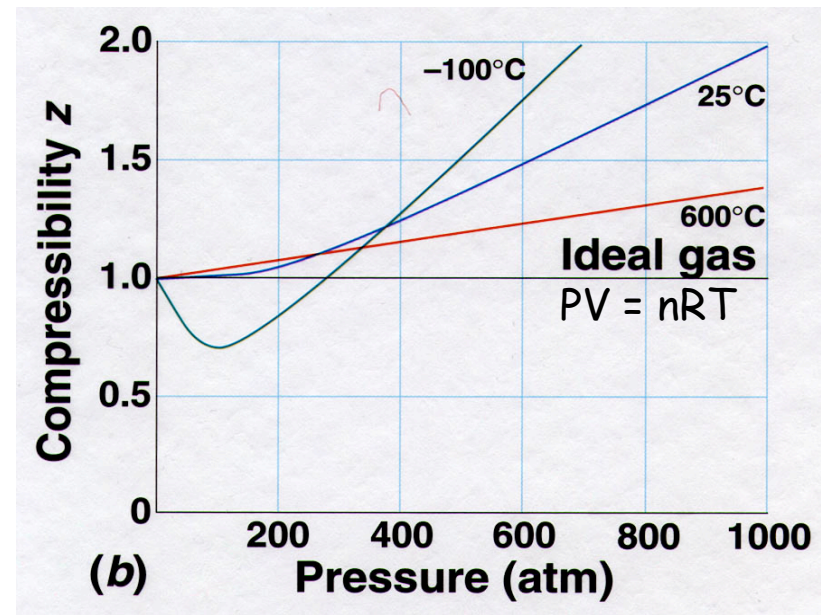
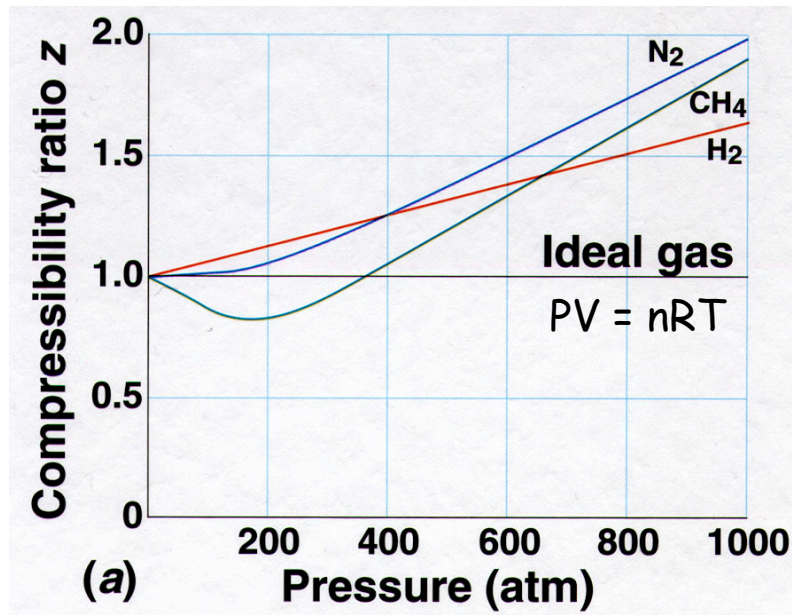
- HOWEVER, if you...

- Increase P
- Increase n in a given V
- Lower the K.E. (T)

THEN gas particles can
COALESE

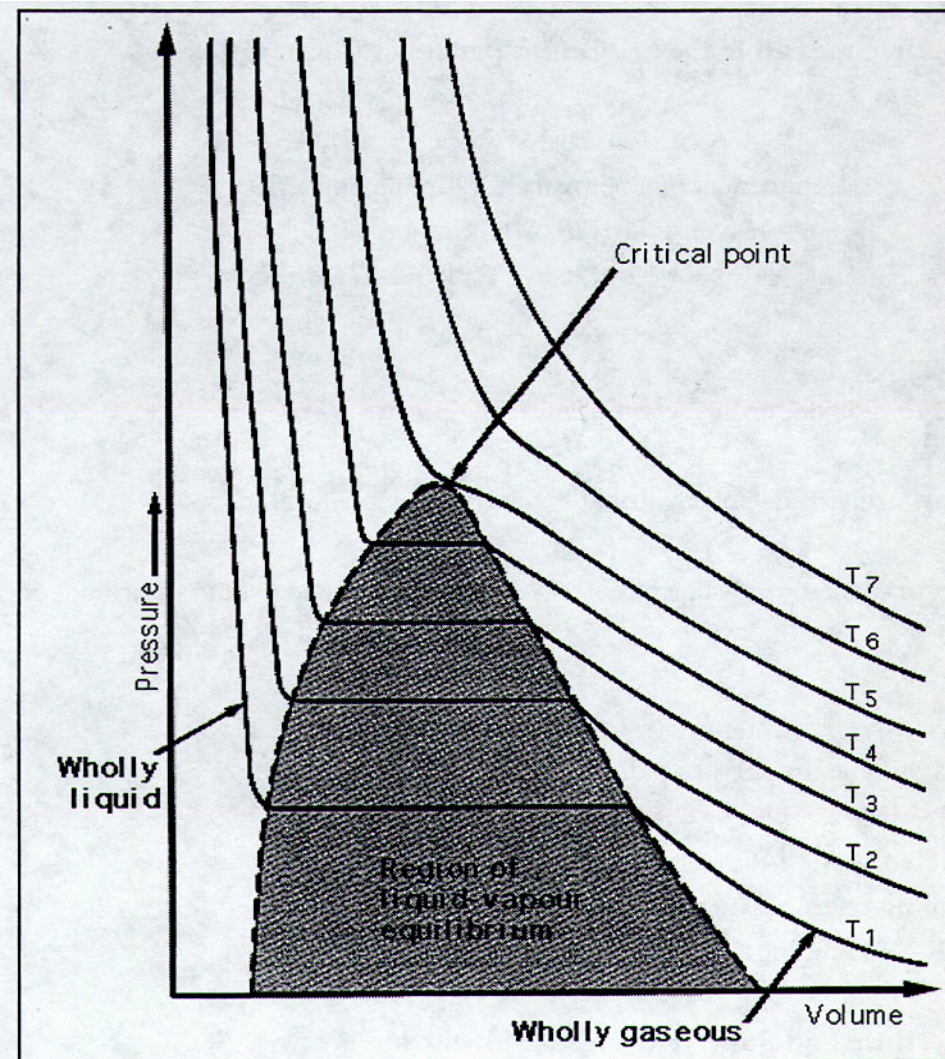
BUT before condensation
occurs, $PV = nRT$ deviates
from ideal behavior

Real (van der Waals) gases deviate from ideal behavior



$$(P + n^2a/V^2)(V - nb) = nRT$$

Critical Properties of CO_2



Critical Conditions

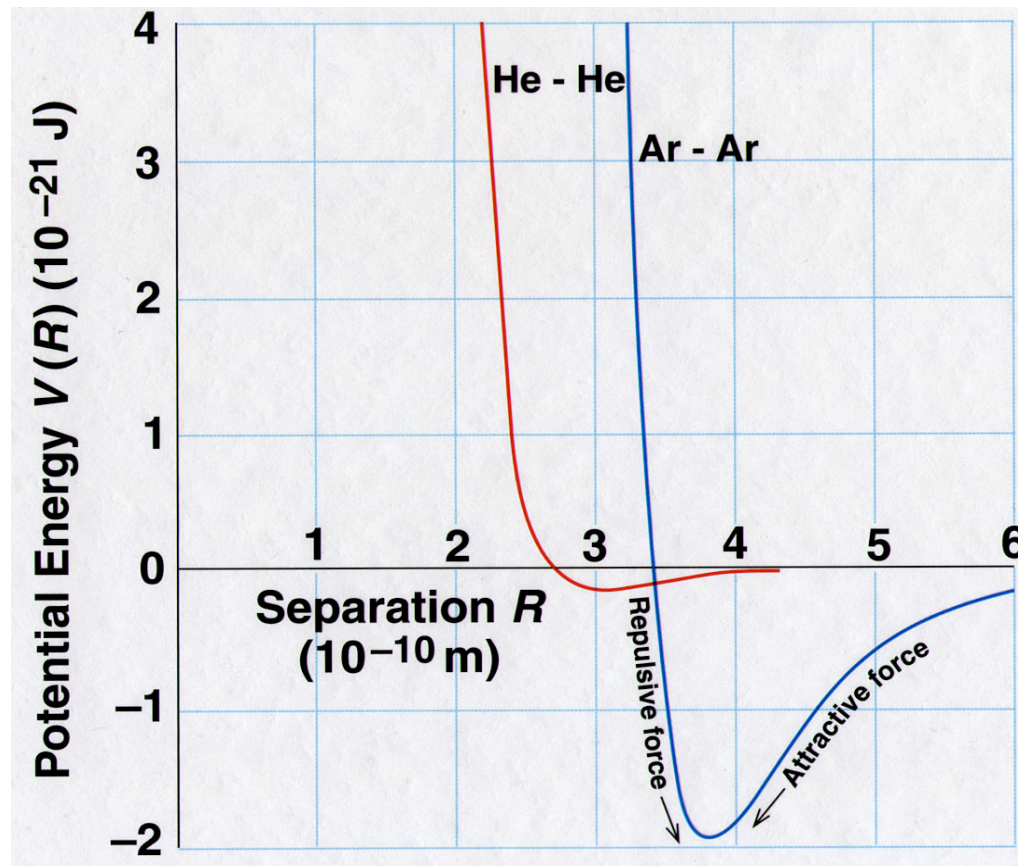
- Condensable Gases

	T_c	P_c
- NH_3	132	112
- Cl_2	144	76
- H_2O	374	218

- Permanent Gases

	T_c	P_c
- O_2	-118	50
- N_2	-147	33.5
- H_2	-239	12.8
- He	-267	2.3

SIGNIFICANCE OF T_c

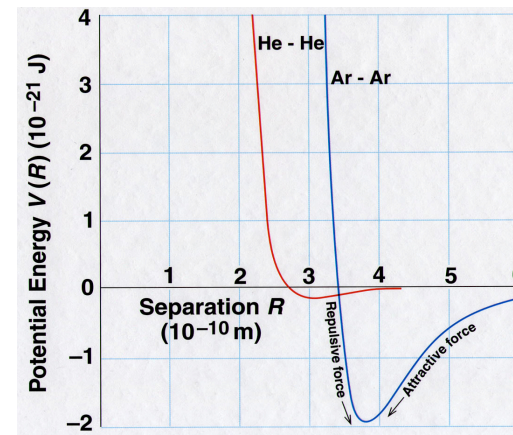
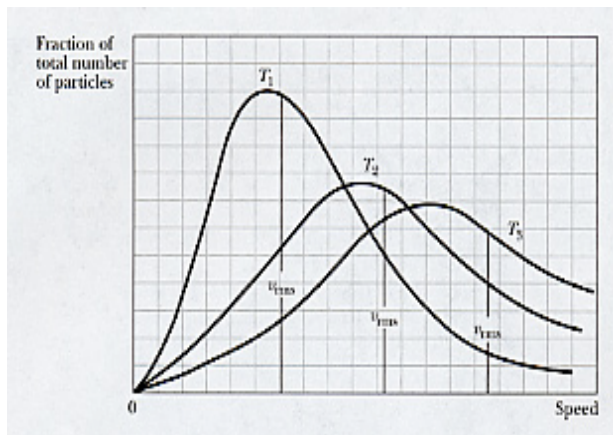


SIGNIFICANCE OF T_c

EVALUATE THERMAL vs POTENTIAL ENERGY

Thermal energy

Potential Energy



CHEMICAL BONDS

Ionic and Covalent Bonds (10^2)

Salt (NaCl) and water (H₂O)

H-bonding Forces (10^0)

Liquids and solutions

Van der Waals Forces (10^{-2})

Instantaneous and permanent
dipolar forces

The Liquid State

- **Gases**

- Study is simplified by the facts that atoms and molecules are...

- far apart.
- randomly arranged.
- weakly interacting.

- **Solids**

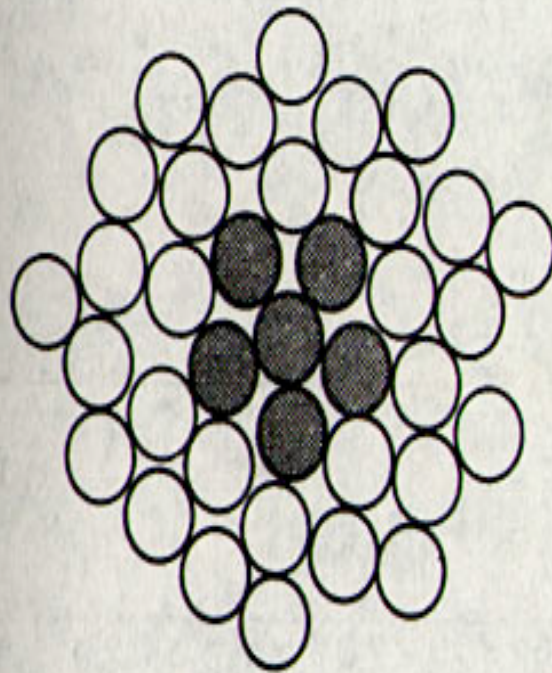
- Study is simplified by the facts that atoms and molecules are...

- close together.
- regularly arranged.
- strongly interacting.

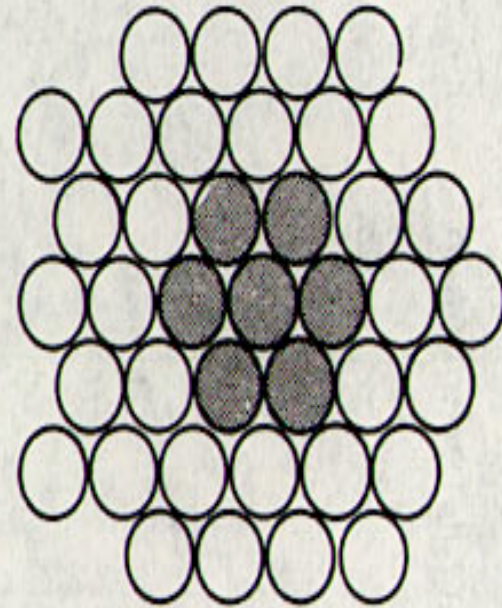
The Liquid State

- Gaseous state model for liquids:
 - Liquids as dense gases are characterized by...
 - DISORDER
 - fluidity
 - taking the shape of their container
 - low density
- Solid state model for liquids:
 - Liquids as disordered solids characterized by....
 - ORDER
 - strong inter-atomic/molecular interactions
 - definite volumes
 - high density

The Liquid State

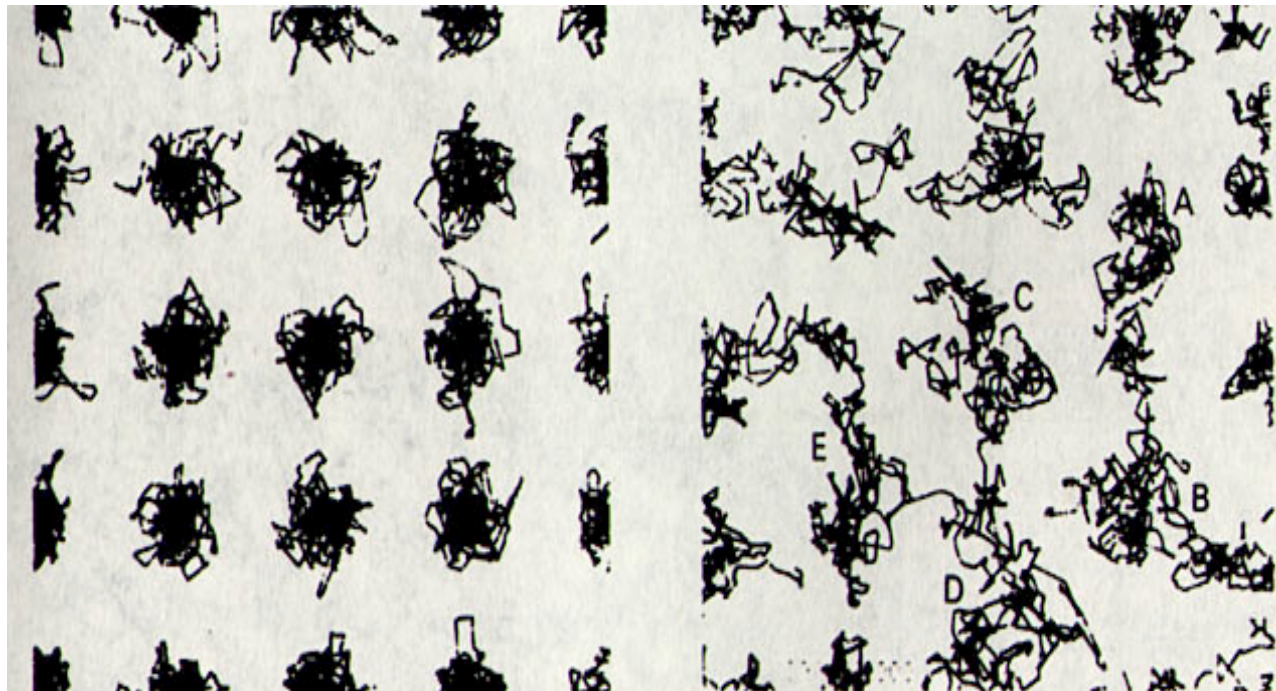


5-fold

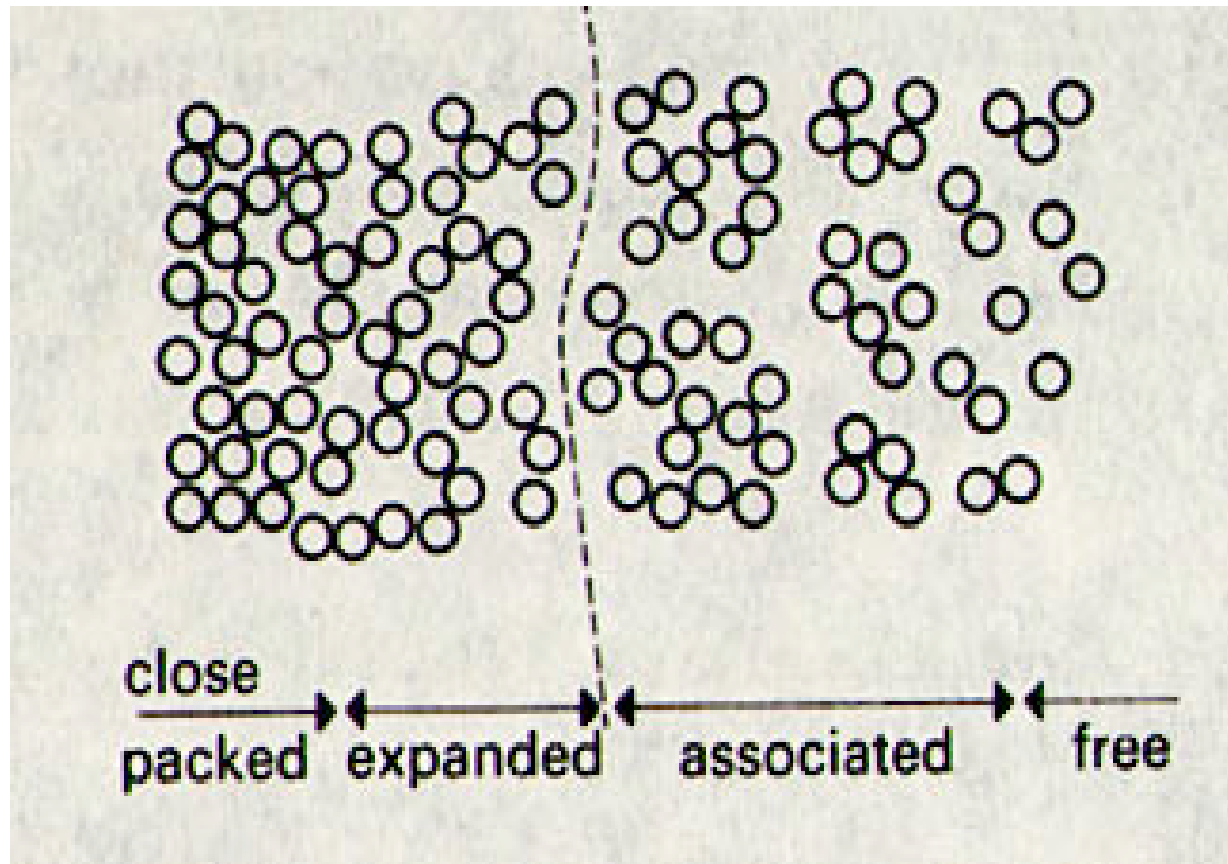


6-fold

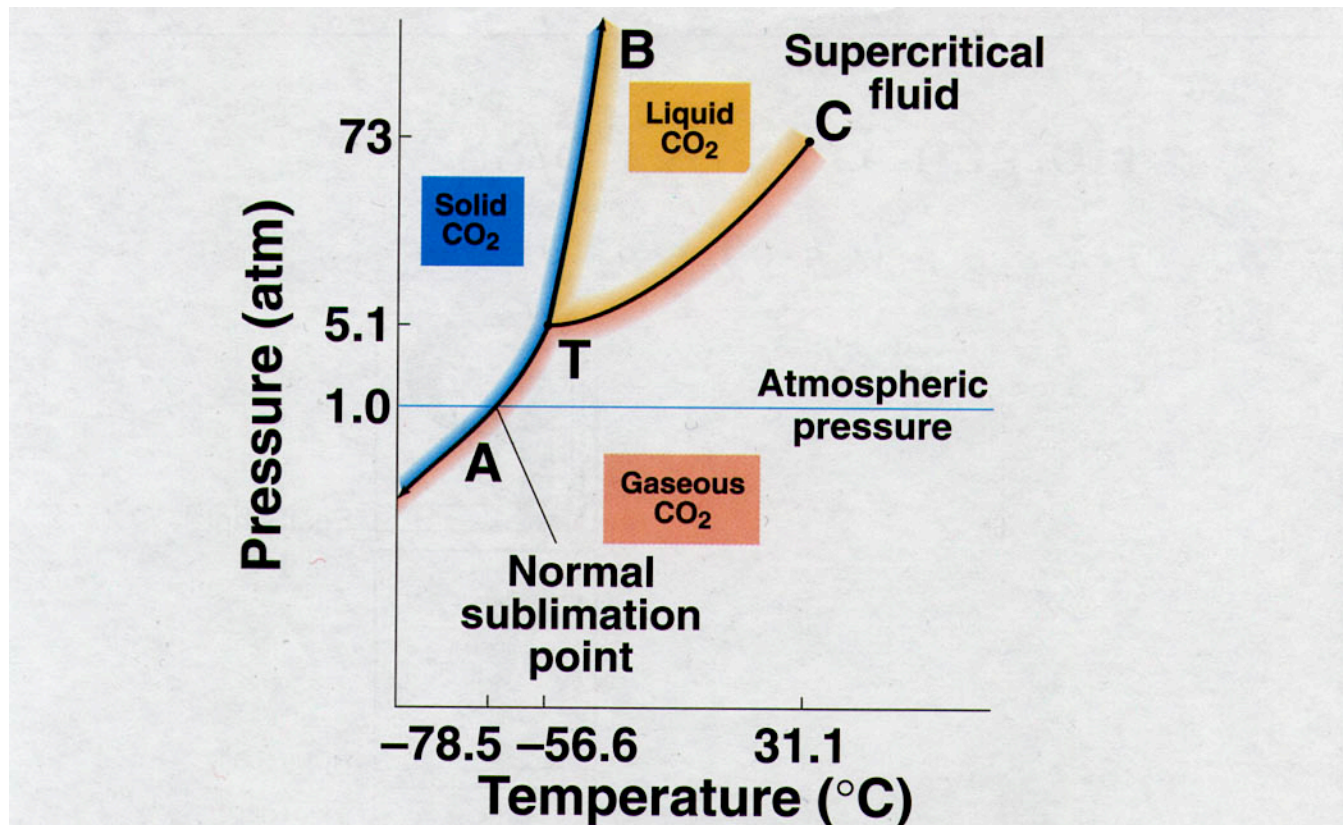
Trajectories for Atoms at Lattice Points in Solids



The Liquid State



Phase Diagram for CO_2



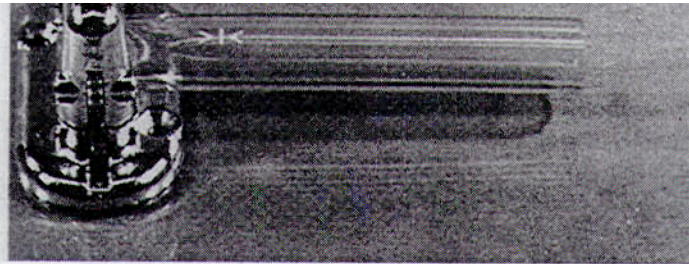


Figure 2a

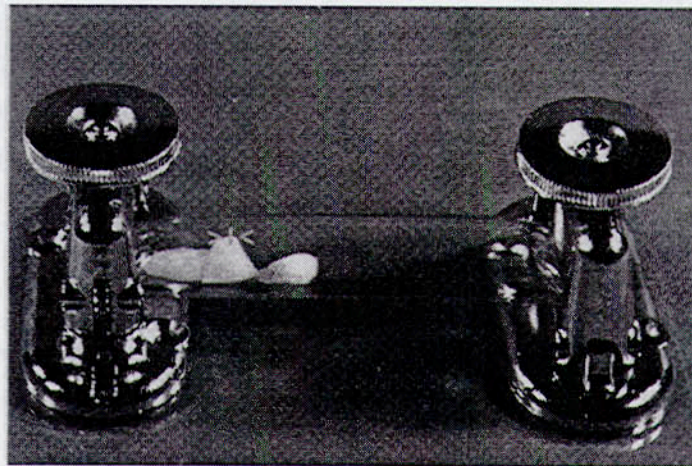


Figure 2b

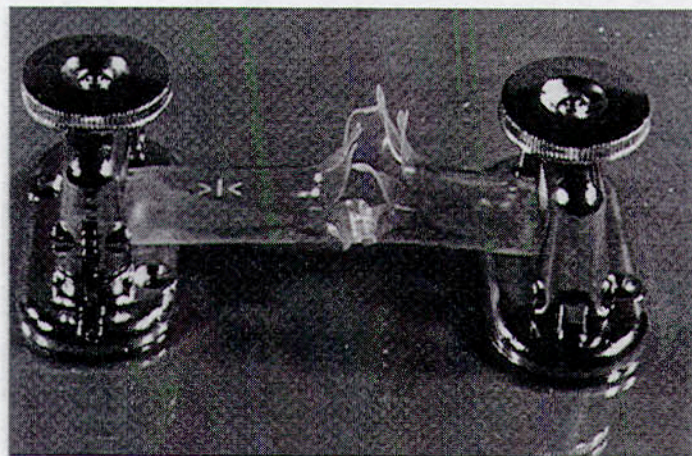
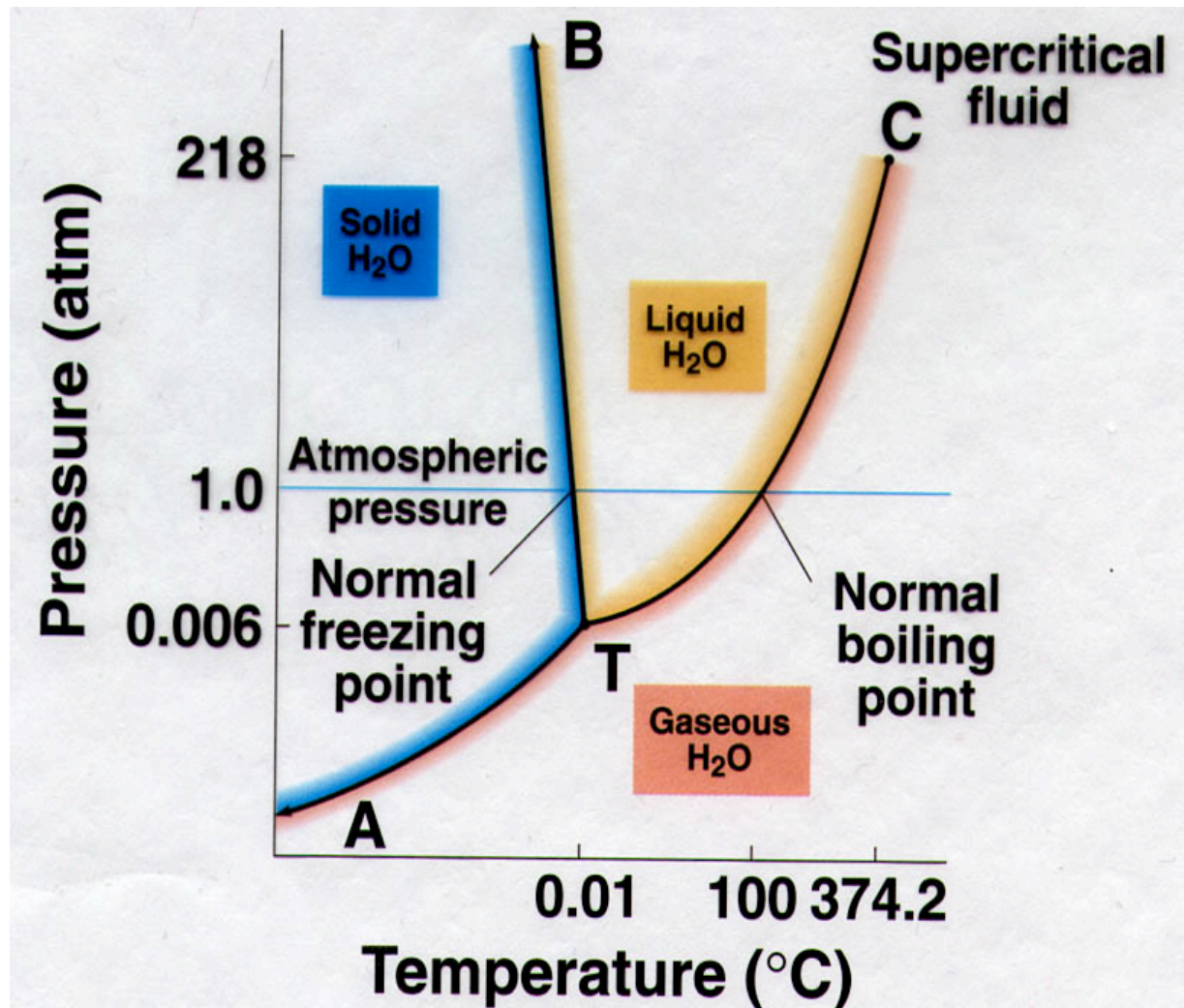


Figure 2c

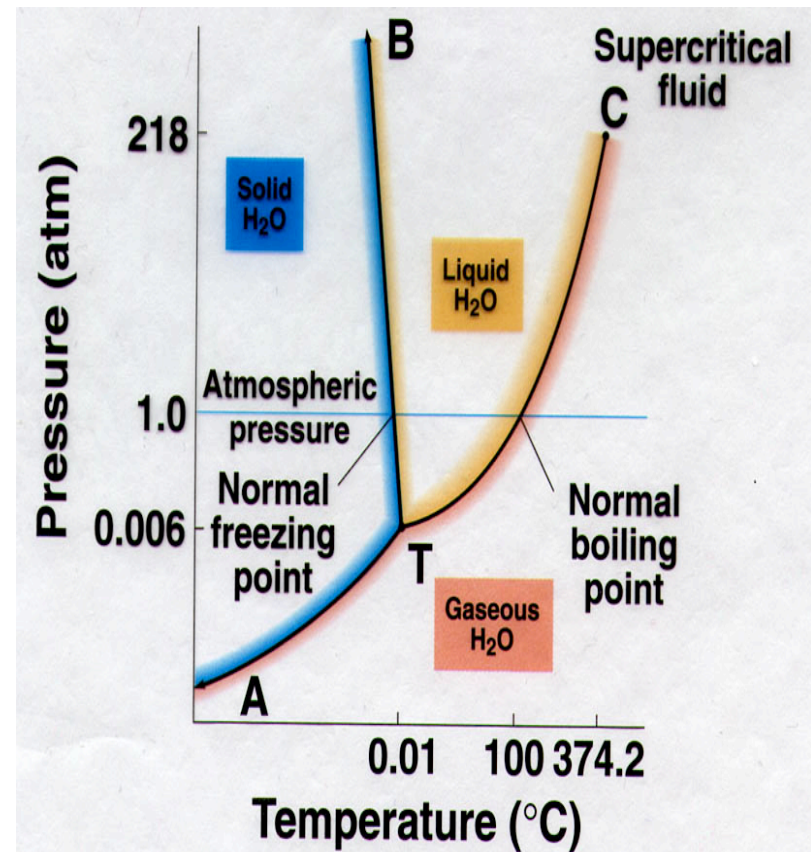
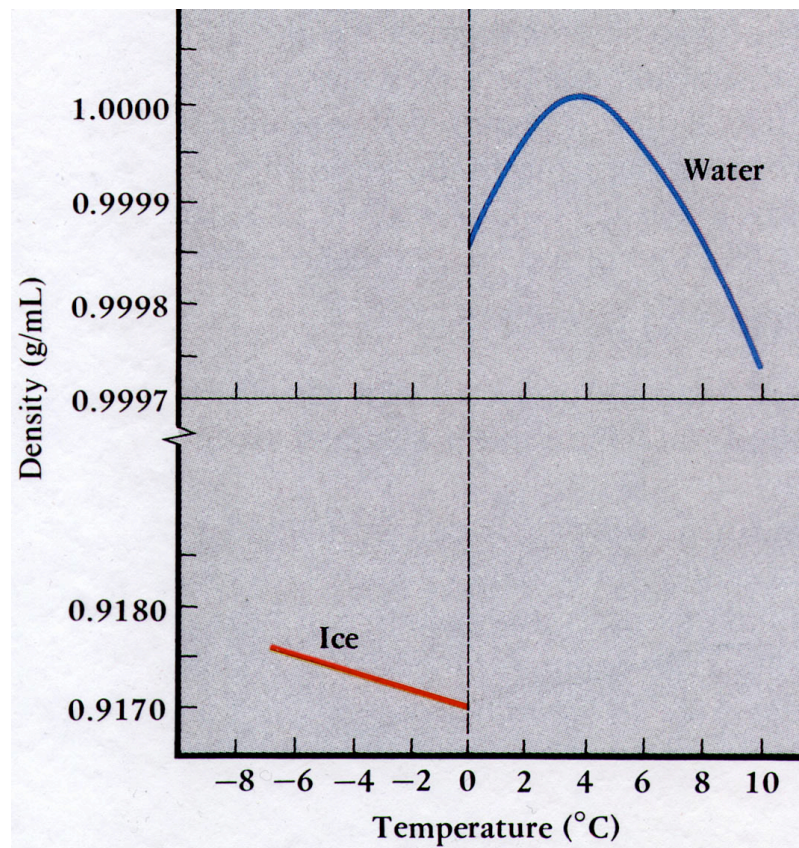
Phase Diagram for H_2O



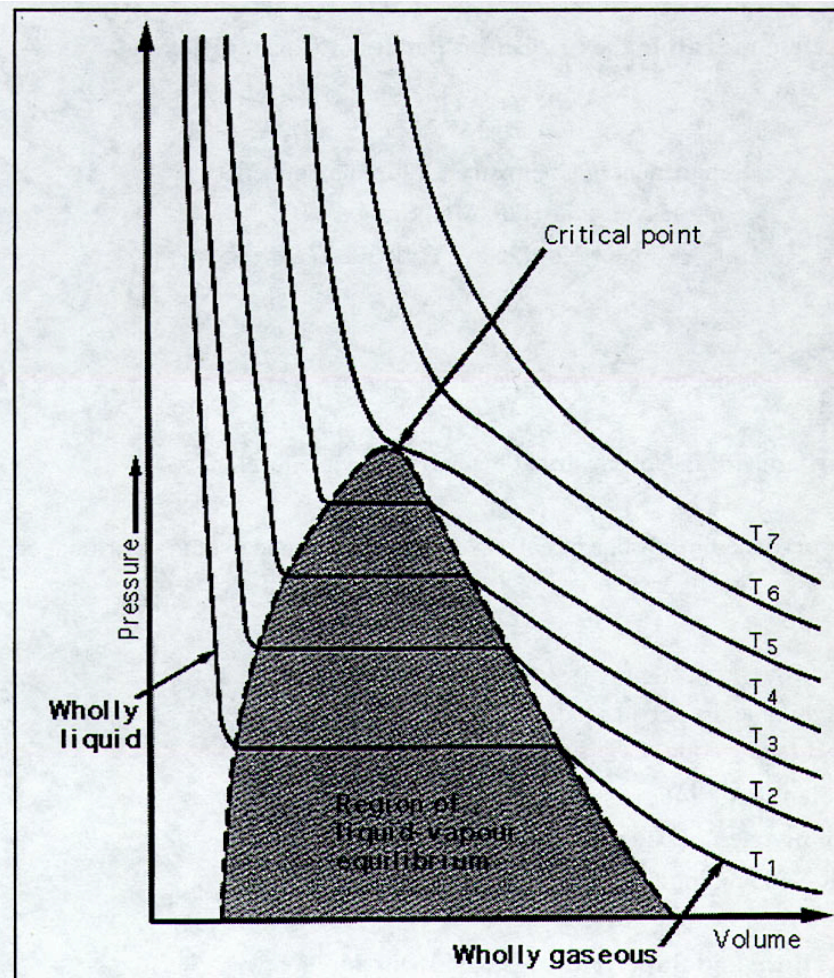
The Liquid State

- Density
- Compressibility
- Diffusion
- Evaporation
- Vapor pressure
- Surface tension
- Viscosity
- Adhesive/cohesive forces
- Capillary action

Density of Ice and Water



Compressibility



Surface Tension

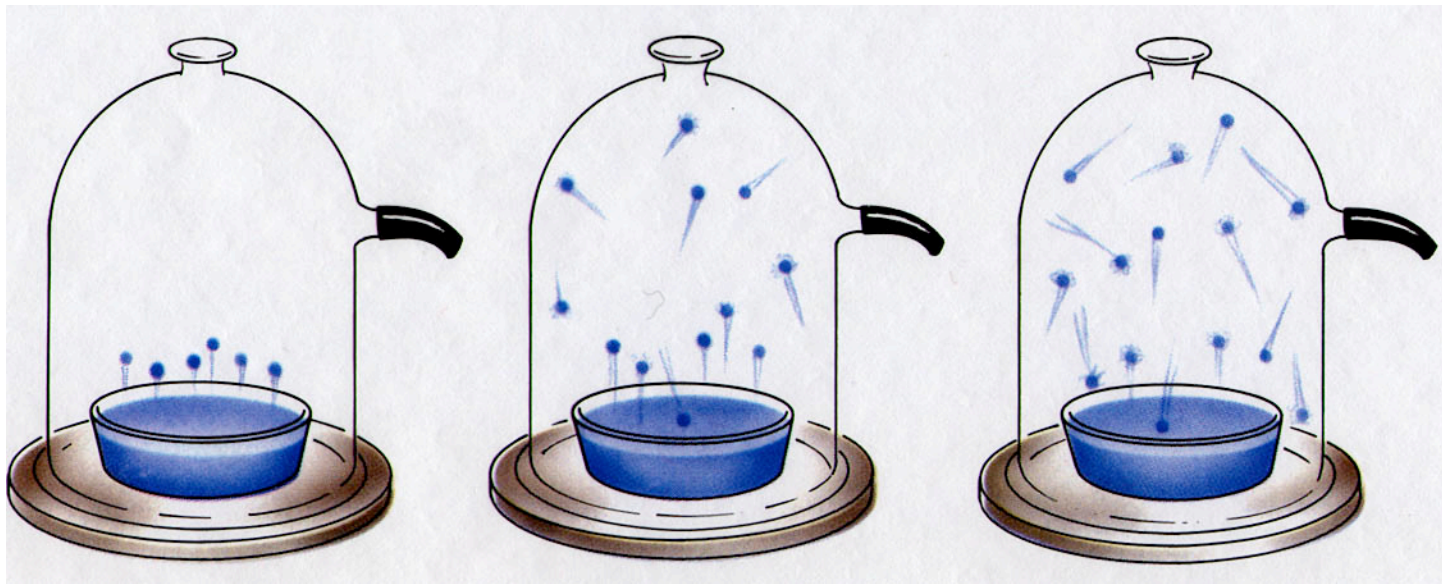


Masterpiece in Focus

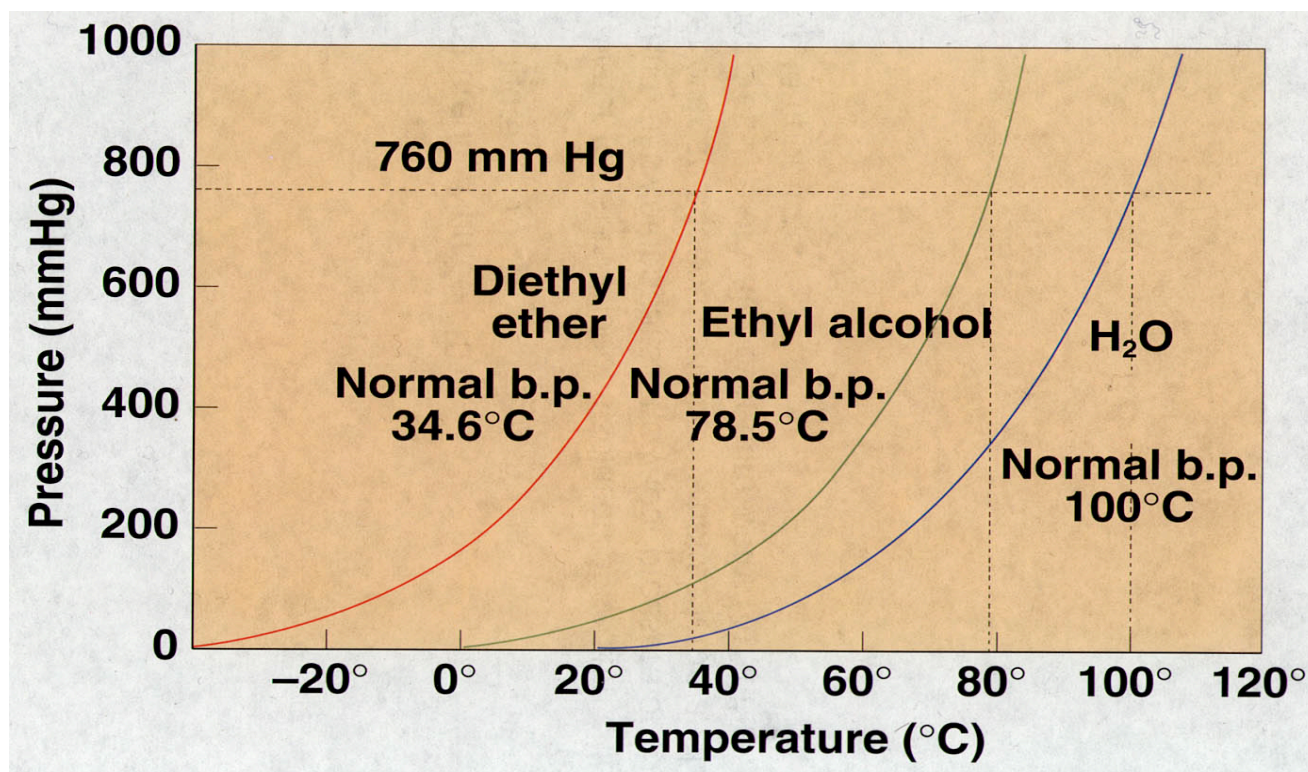
Soap Bubbles

BY JEAN-SIMÉON CHARDIN

Equilibrium Vapor Pressure



Vapor Pressure Curves



Trouton's Rule

An interesting and useful "approximation:

- Says that the ratio of the heat of vaporization and the boiling point is (roughly) constant

$$\Delta H_{\text{vap}}/T_{\text{b.p.}} \sim 88 \text{ J/mol}$$

- Boiling point of cyclohexane is 69°C. Therefore,

$$\Delta H_{\text{vap}} = (69 + 273)(88) \sim 30 \text{ kJ/mol}$$

which is within 2-3% of the experimental value

- Works well for unassociated liquids and gives useful information about degree of association.

Trouton's Rule

Unassociated (ideal) liquids, $\Delta H_{\text{vap}}/T_{\text{b.p.}} \sim 88 \text{ J/mol}$

carbon tetrachloride

benzene

cyclohexane

Associated liquids, $\Delta H_{\text{vap}}/T_{\text{b.p.}} > 88 \text{ J/mol}$

water (110)

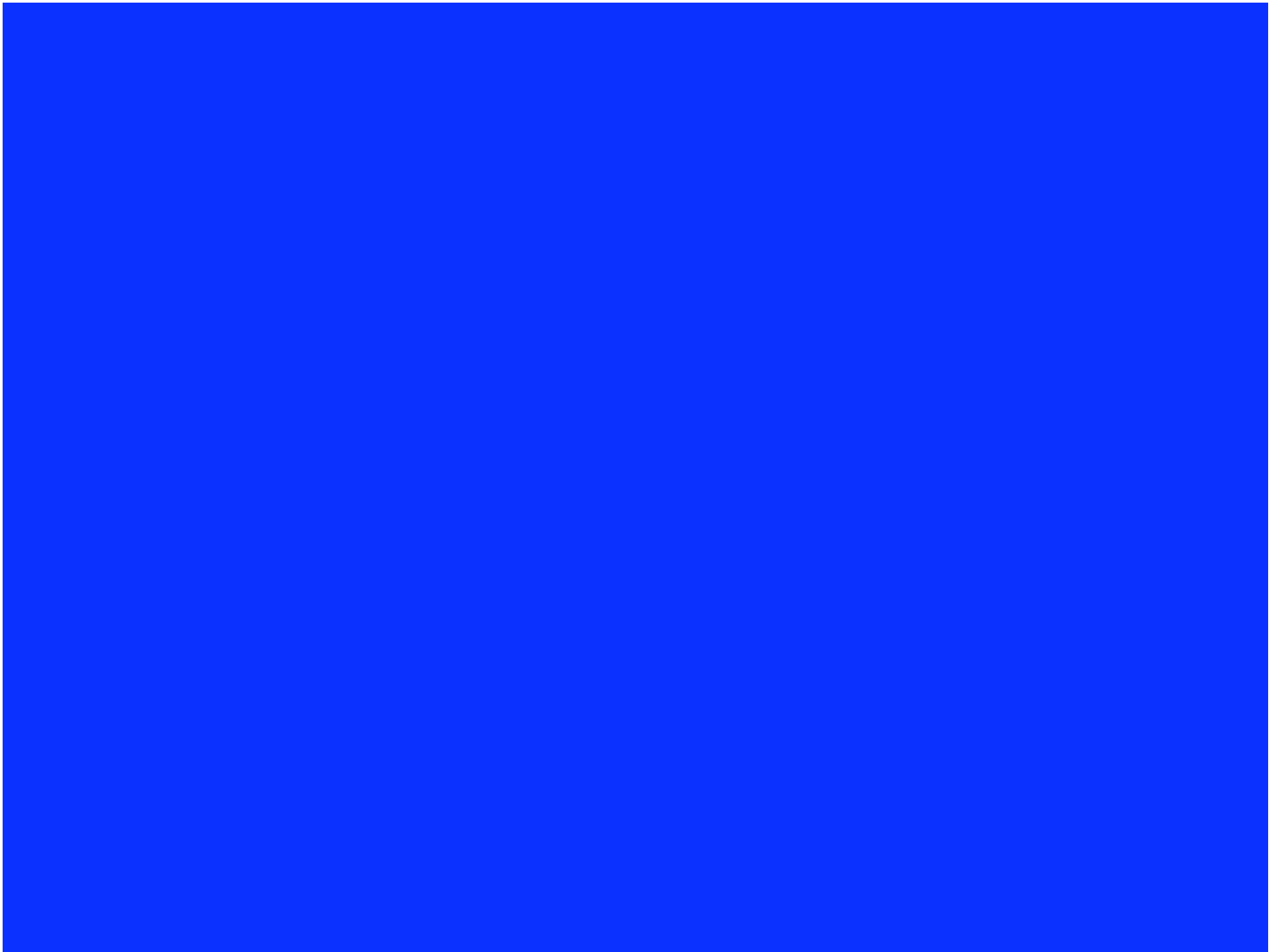
methanol (112)

ammonia (97)

Association in the vapor state, $\Delta H_{\text{vap}}/T_{\text{b.p.}} < 88 \text{ J/mol}$

acetic acid (62)

hydrogen fluoride (26)





Masterpiece in Focus

Soap Bubbles

BY JEAN-SIMÉON CHARDIN