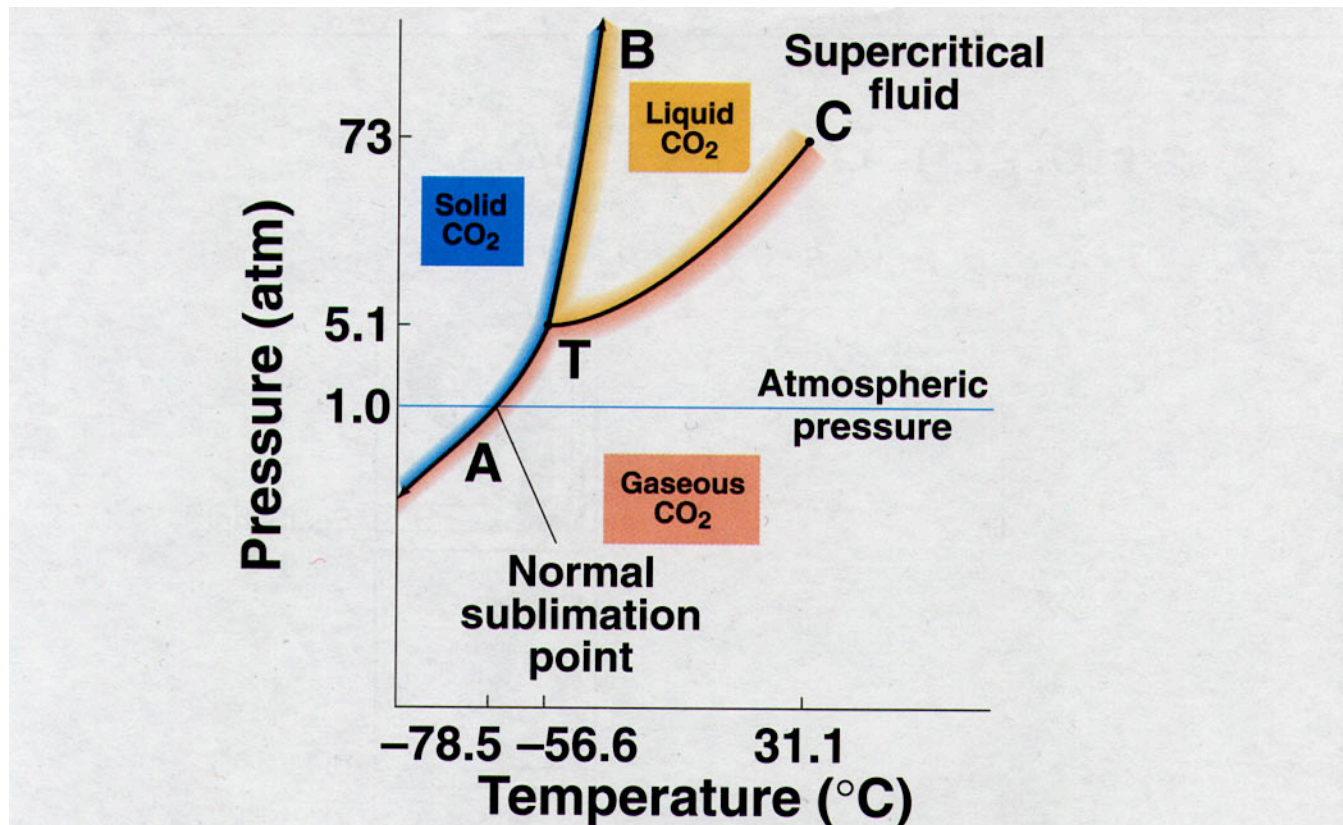


Phase Diagram for CO_2



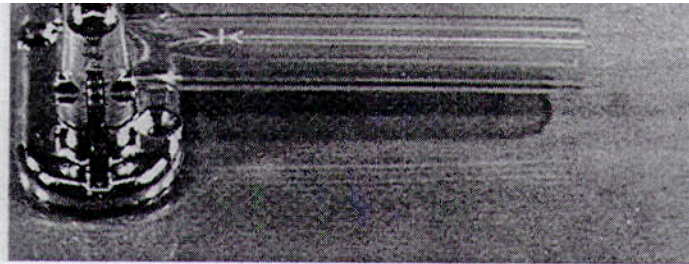


Figure 2a

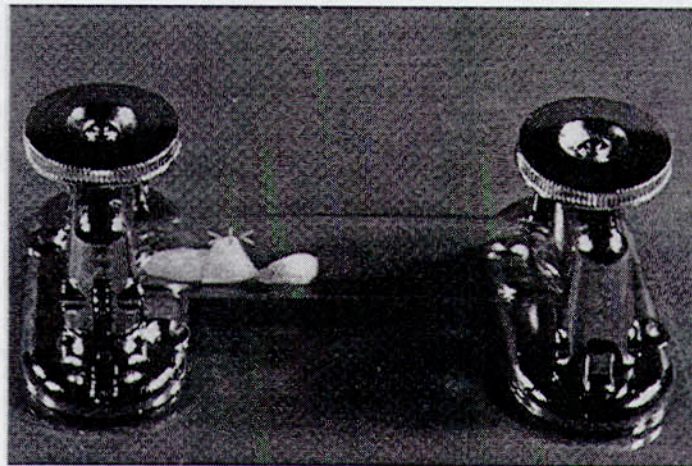


Figure 2b

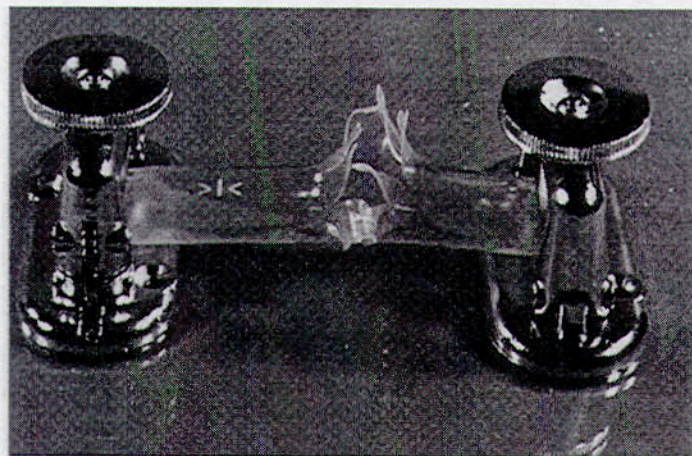
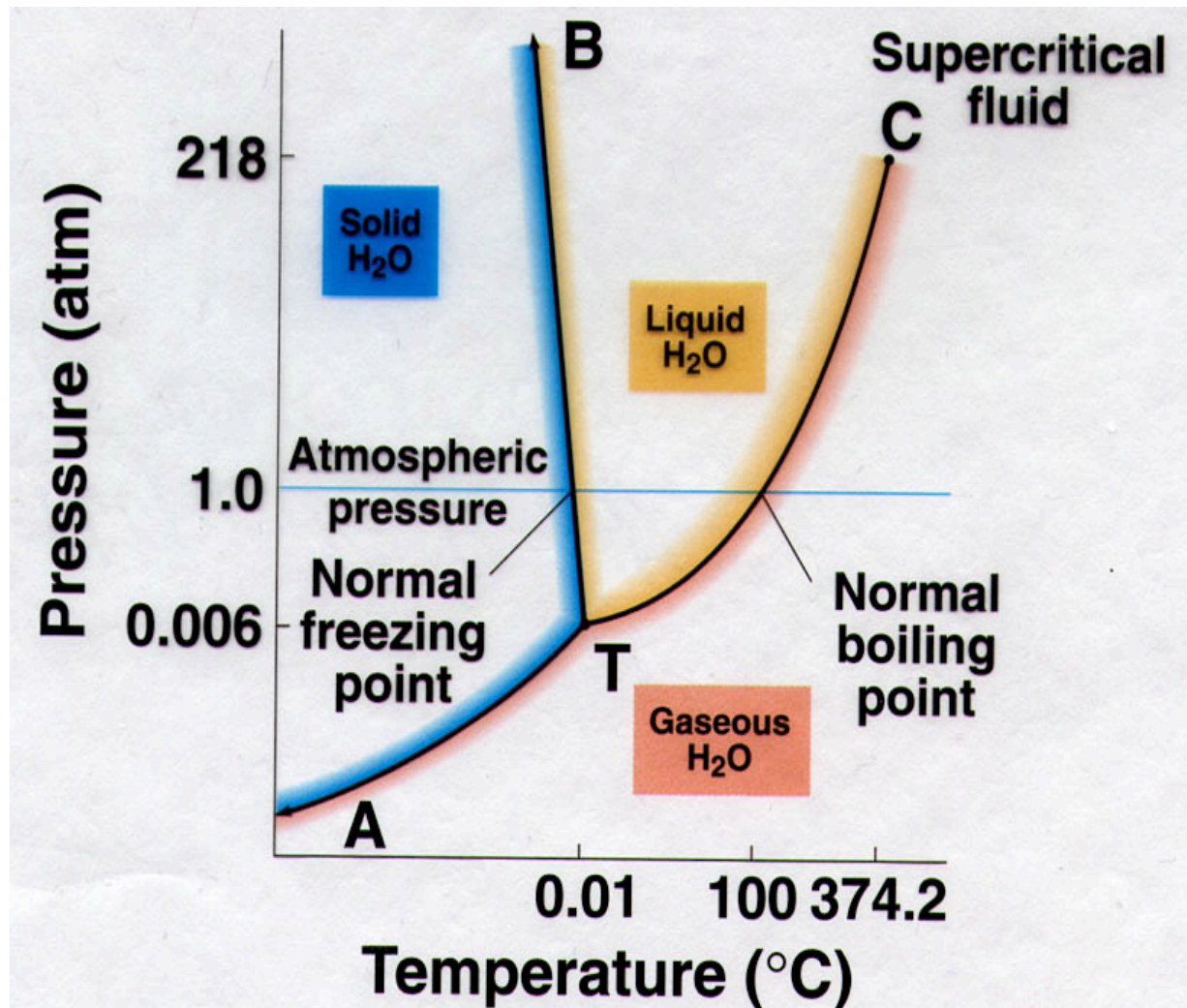


Figure 2c

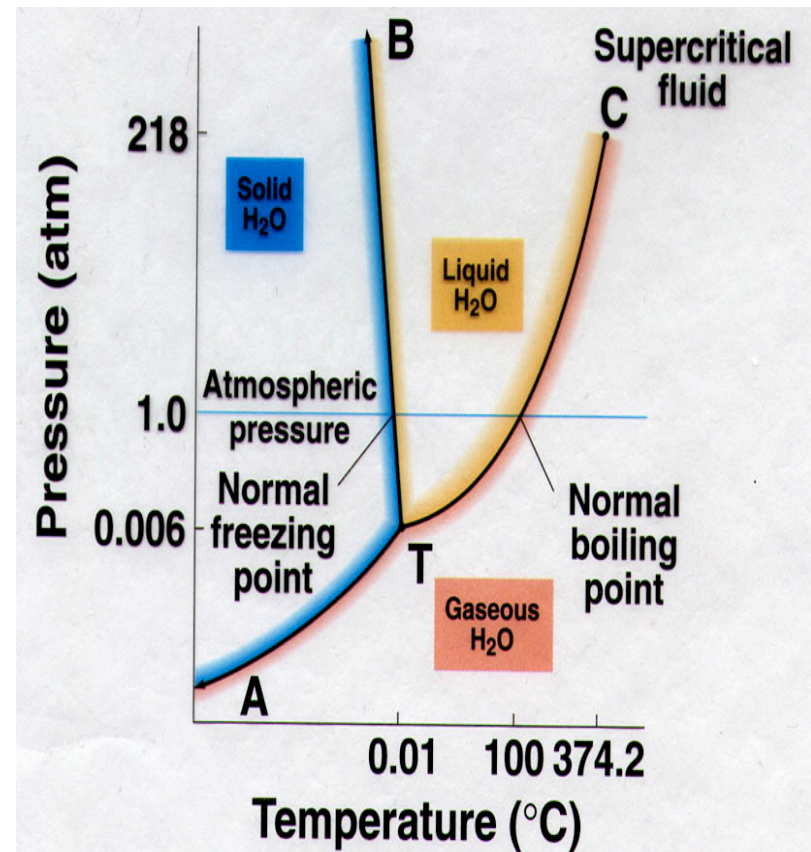
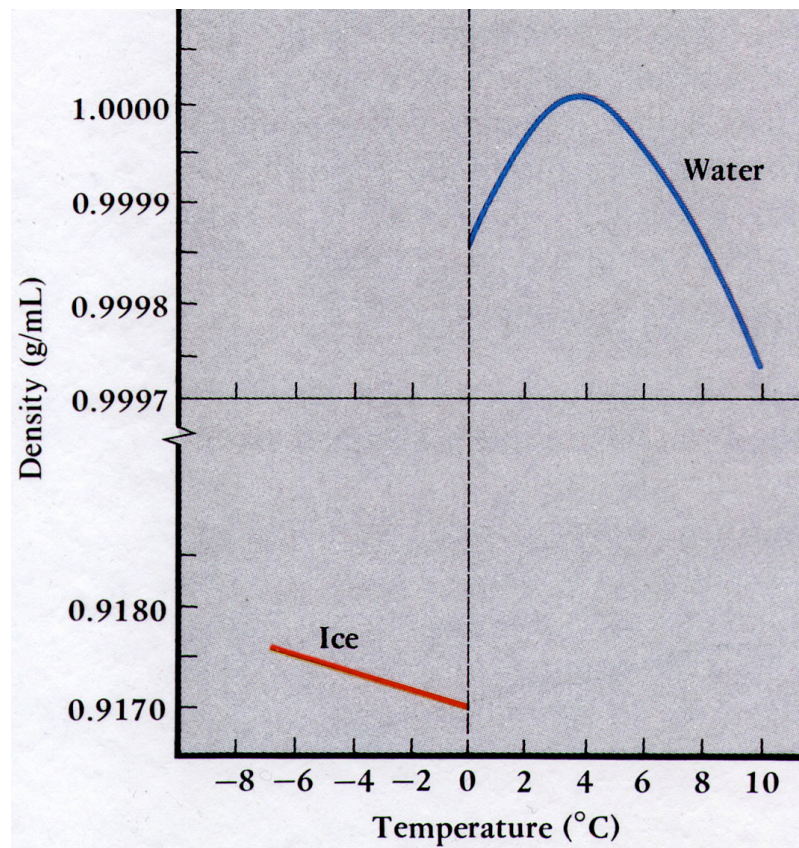
Phase Diagram for H₂O



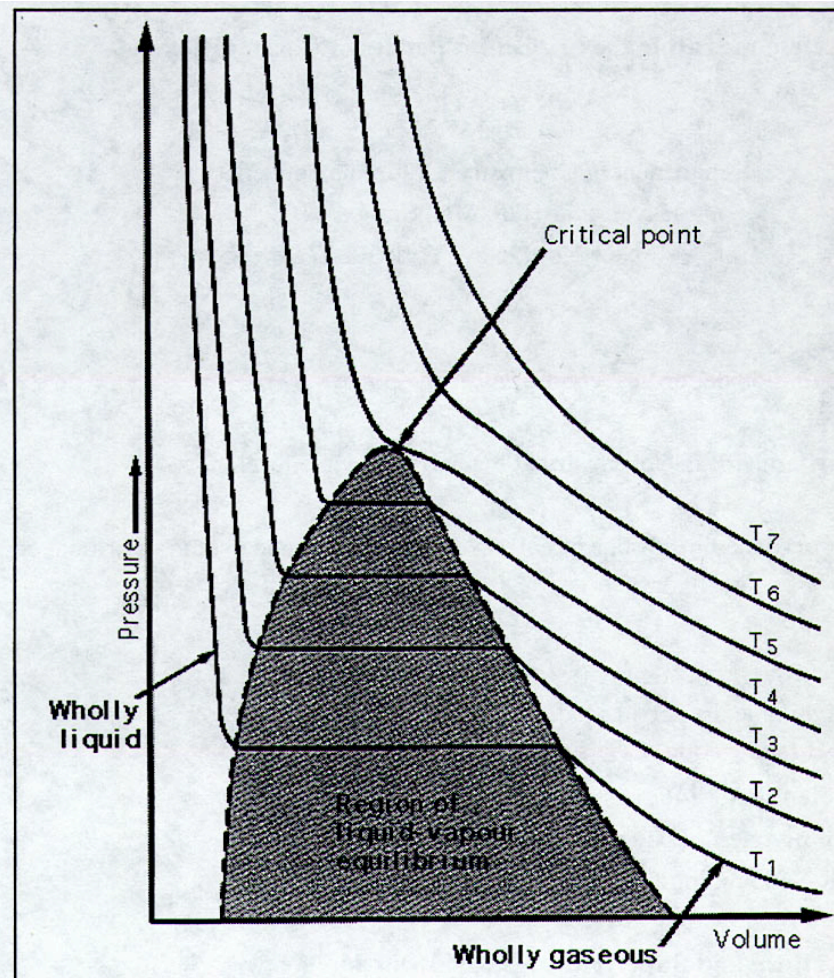
The Liquid State

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

Density of Ice and Water



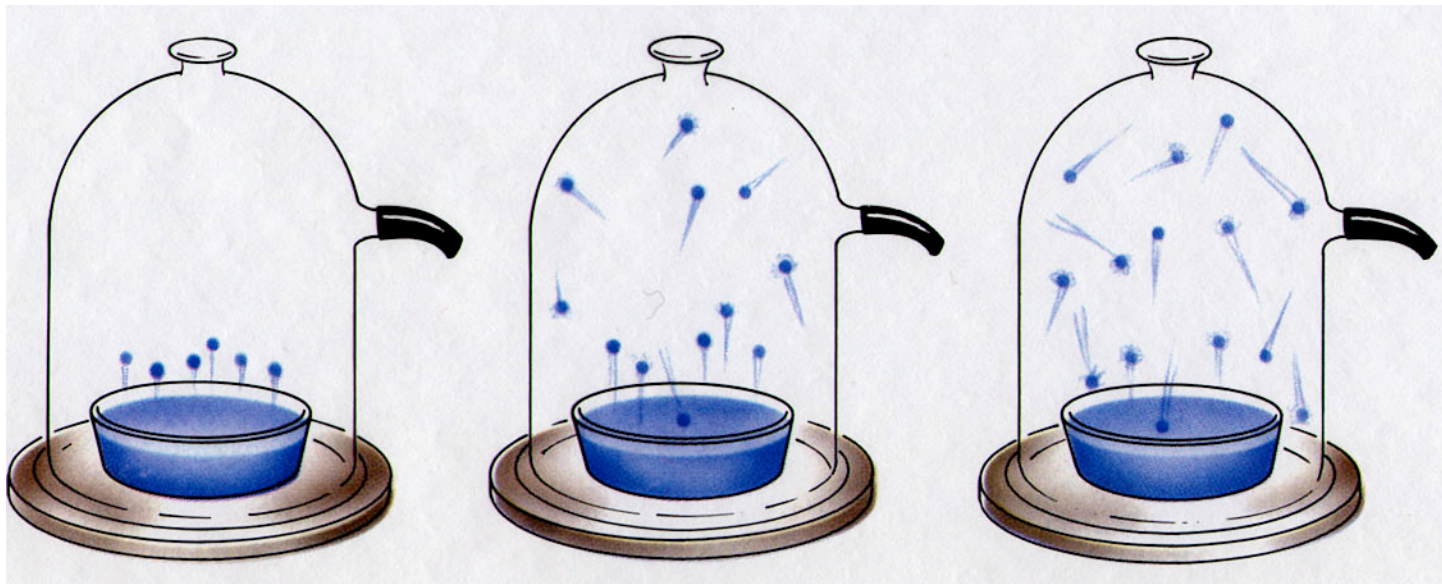
Compressibility



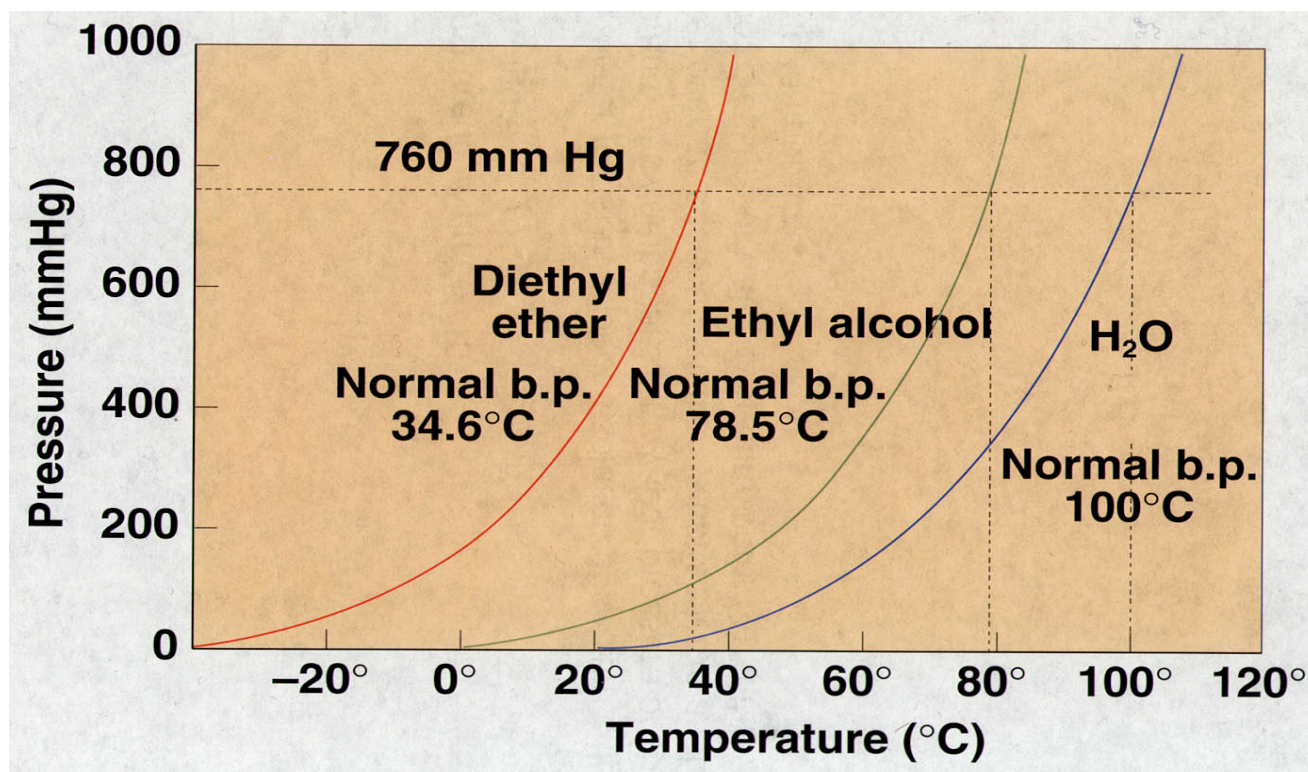
Surface Tension



Equilibrium Vapor Pressure



Vapor Pressure Curves



Trouton's Rule

An interesting and useful "approximation:

- Says that the ratio of the heat of vaporization to 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)

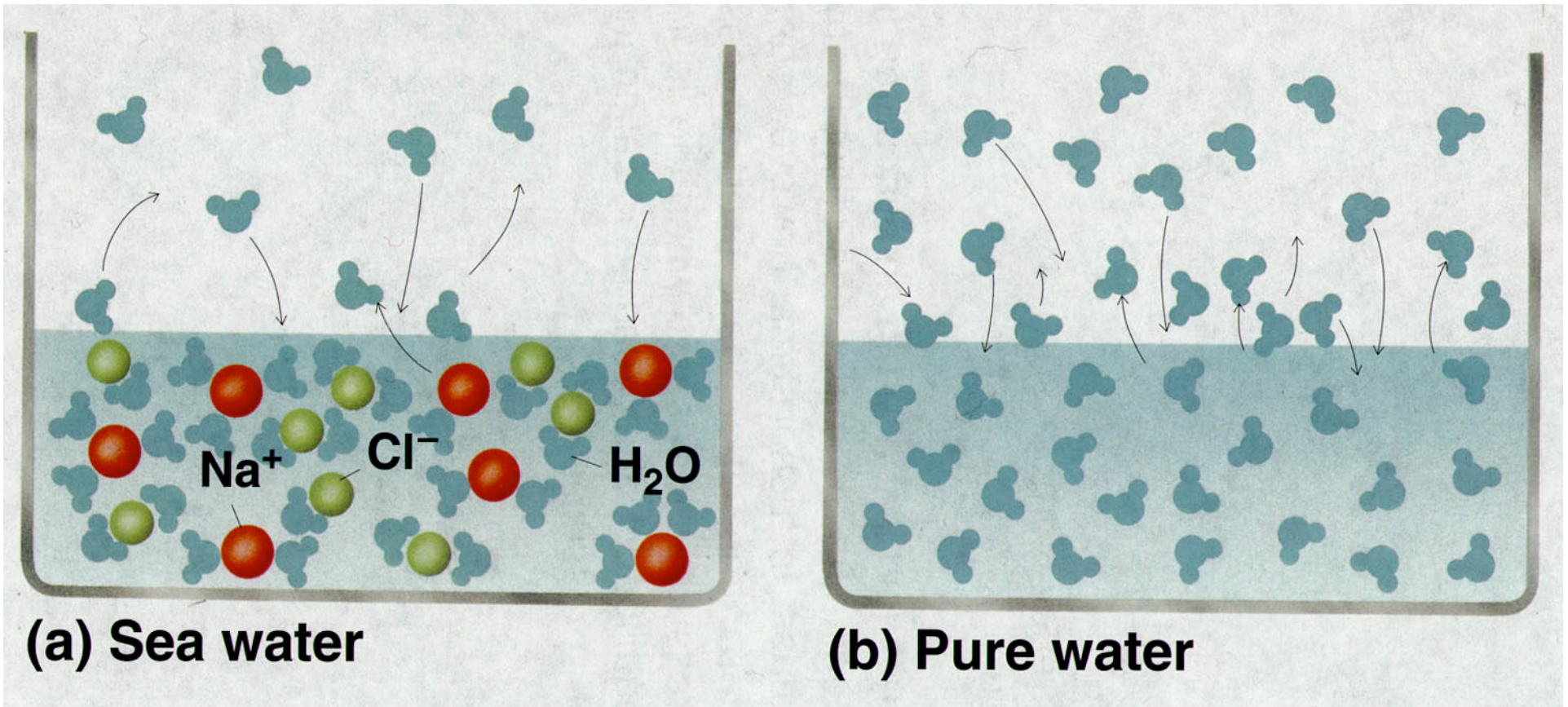
Association in the vapor state, $\Delta H_{\text{vap}}/T_{\text{b.p.}} < 88 \text{ J/mol}$

acetic acid (62)

hydrogen fluoride (26)

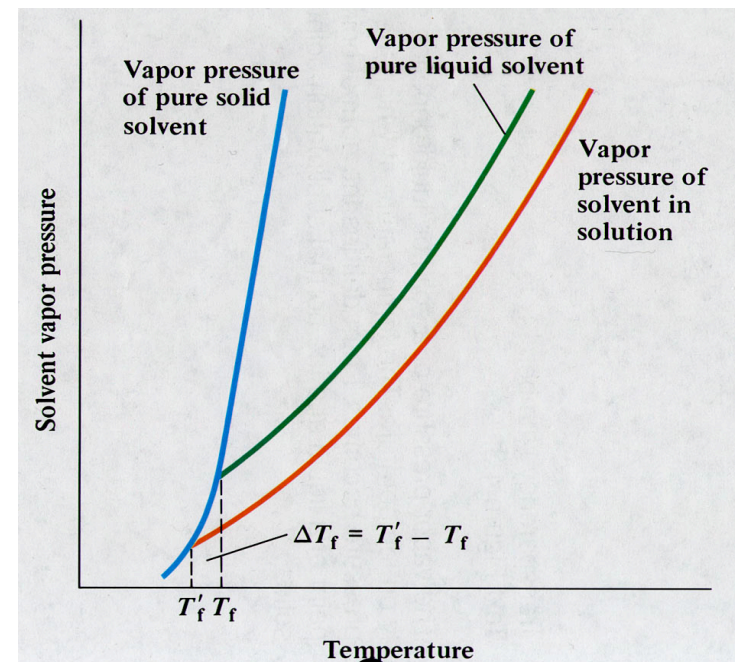
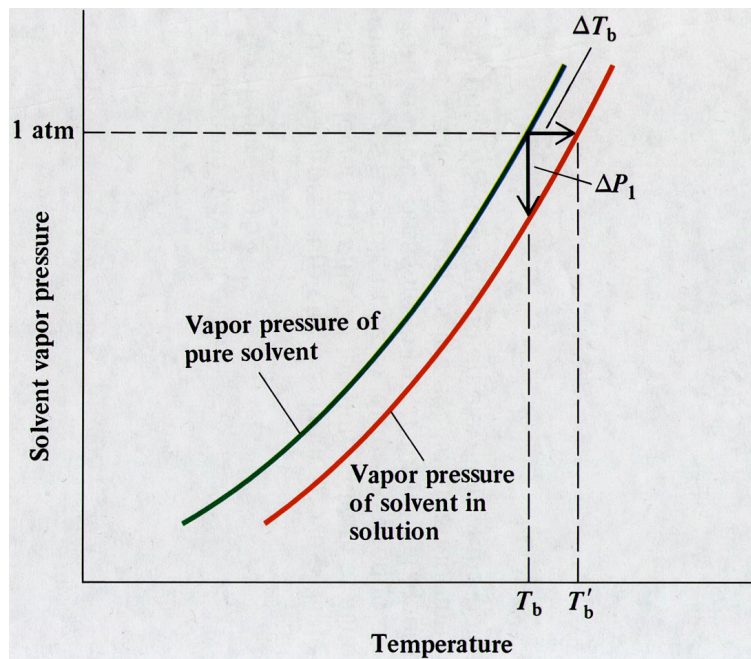
Colligative Properties

Thought Experiment

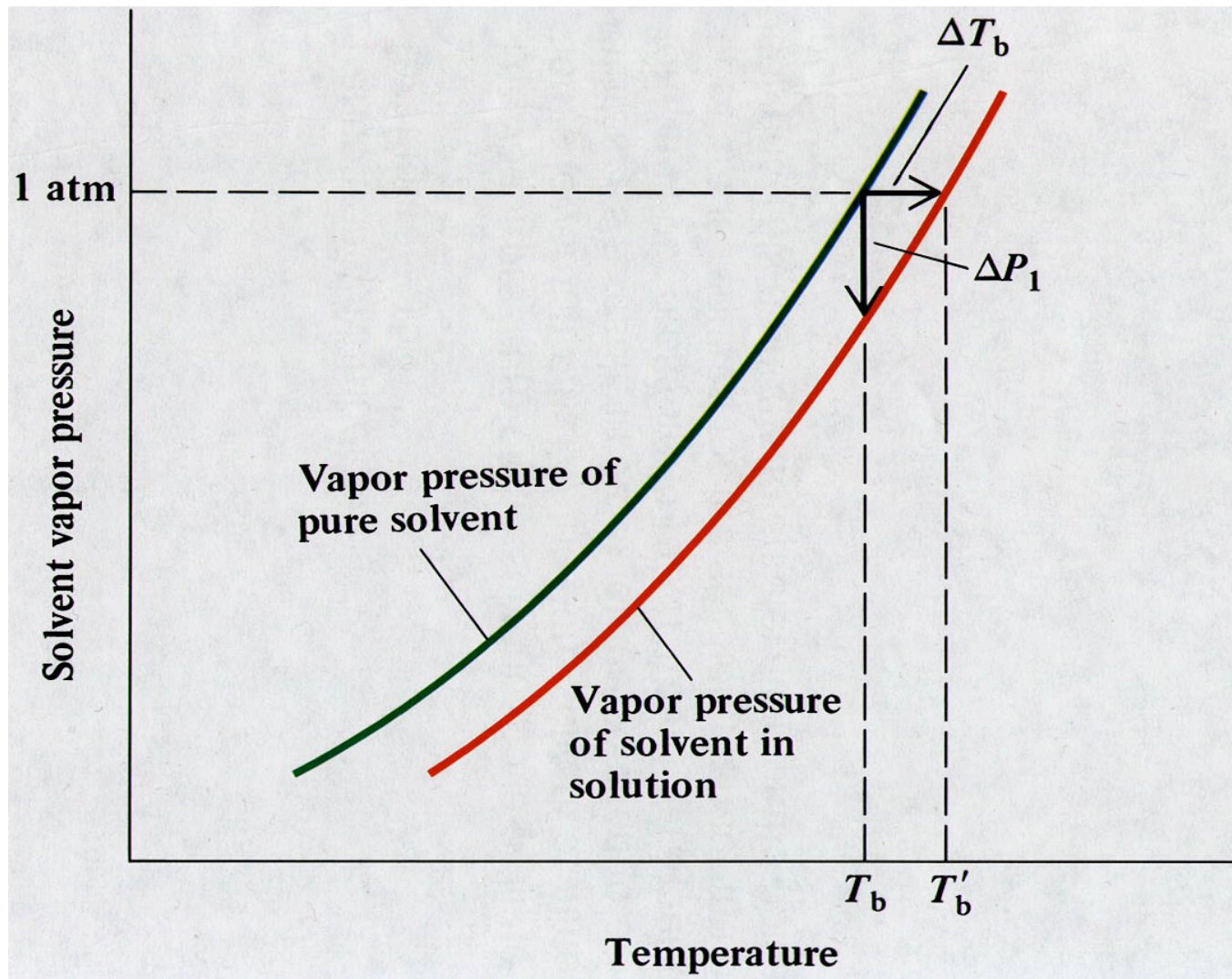


Colligative Properties

- Elevation of the normal boiling point
- Lowering of the normal freezing point



Elevation of the normal b.p.



Raoult's Law

- Nonvolatile solute in volatile solvent:

$$p = p^{\circ}X_{\text{solvent}}$$

$$p^{\circ} - p = \Delta p = p^{\circ}X_{\text{solute}}$$

- Elevation of the boiling point: $\Delta T = K_{\text{bp}}m$
- Depression of the freezing point: $\Delta T = K_{\text{fp}}m$
- Osmotic pressure: $\Pi = cRT$

Boiling and Freezing Point Constants for Some Solvents

Solvent	$K_b(^{\circ}\text{C}/\text{m})$
water	0.52
ethyl alcohol	1.20
benzene	2.67
acetic acid	2.93
chloroform	3.85
carbon tetrachloride	5.02

Solvent	$K_f(^{\circ}\text{C}/\text{m})$
water	-1.86
acetic acid	-3.90
chloroform	-4.68
benzene	-5.12
naphthalene	-7.00
camphor	-40.0



Pampers

phases

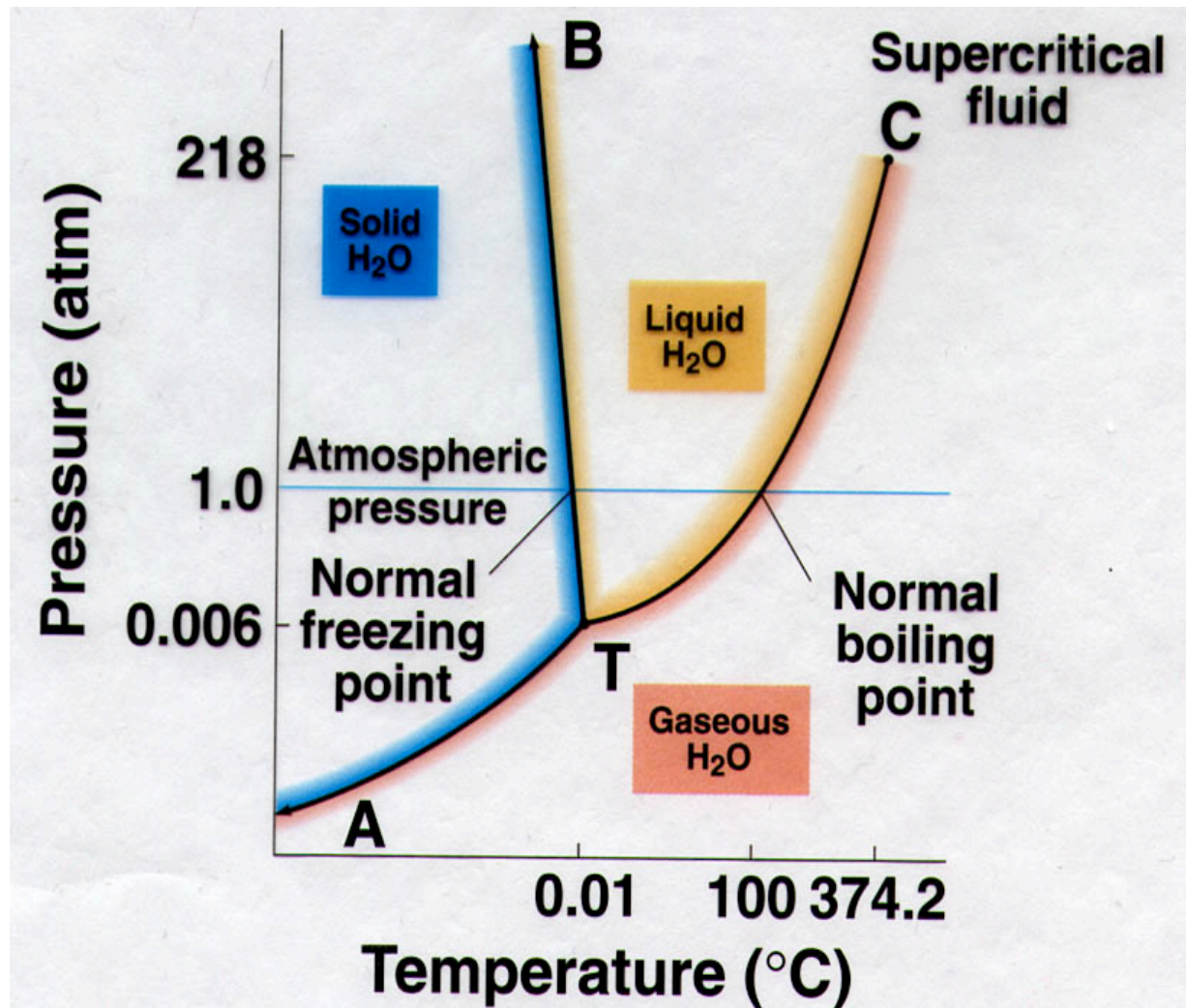
ULTRA DRY THINS



X-Large Diapers for Boys
Walker 3
26 lbs. and over

24

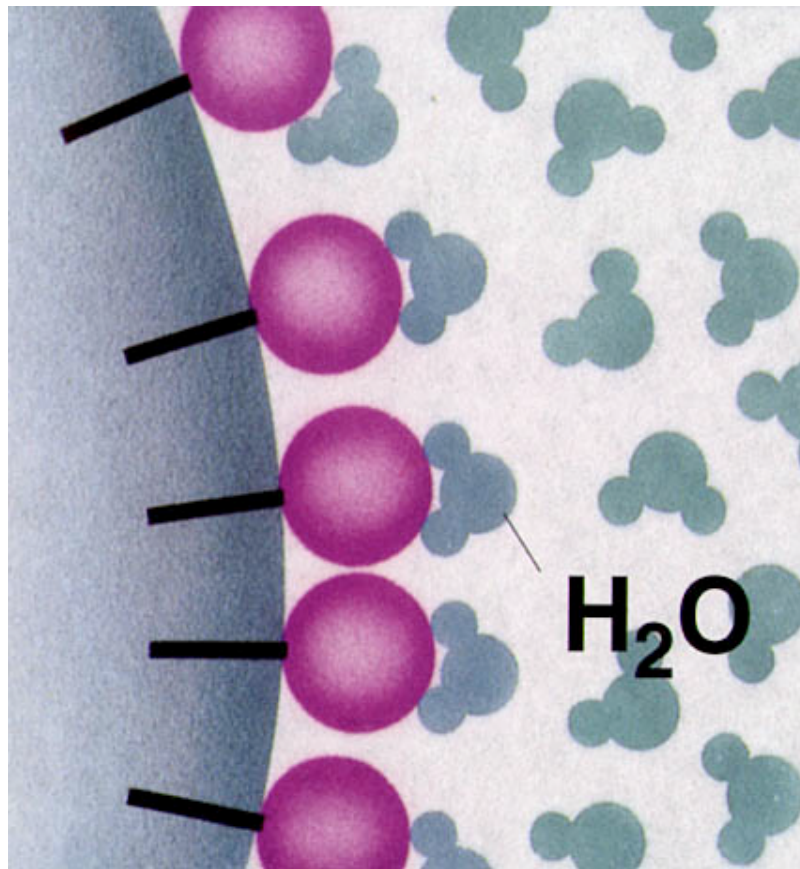
Phase Diagram for H₂O



Super Slurper



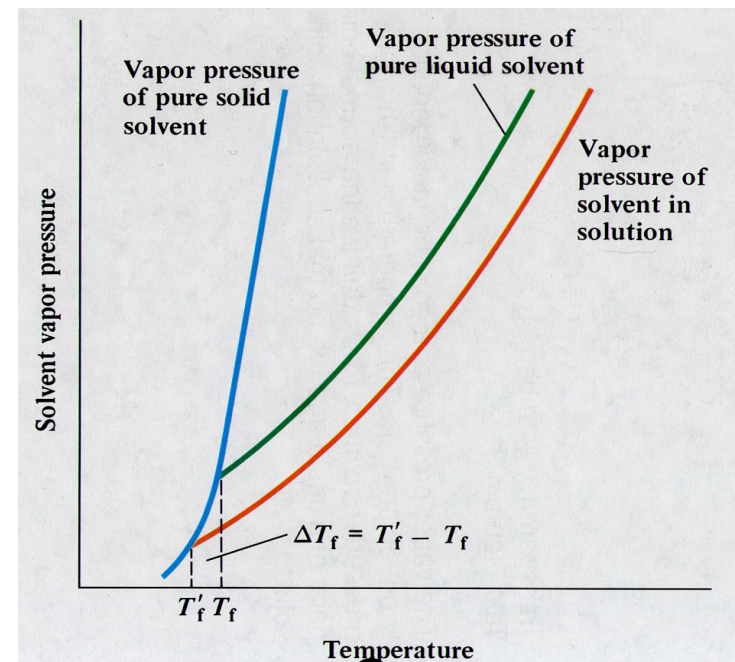
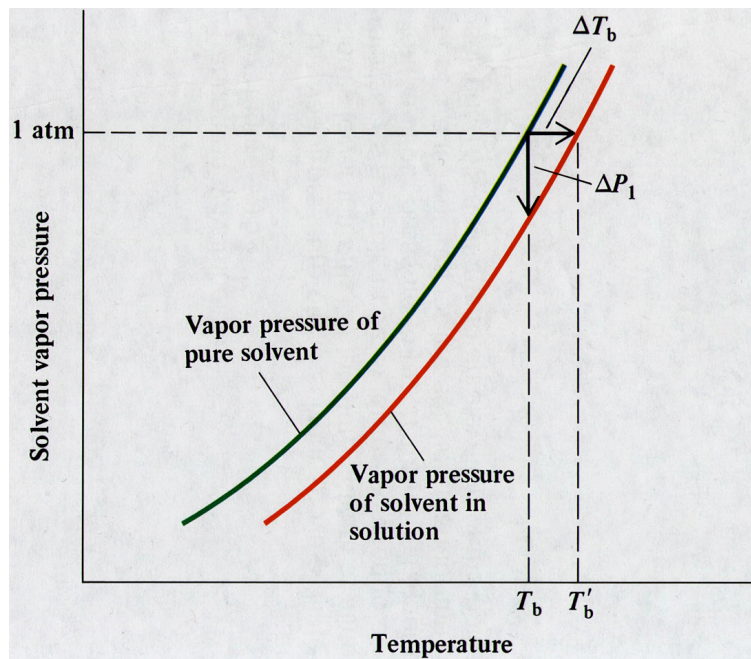
Super Slurper



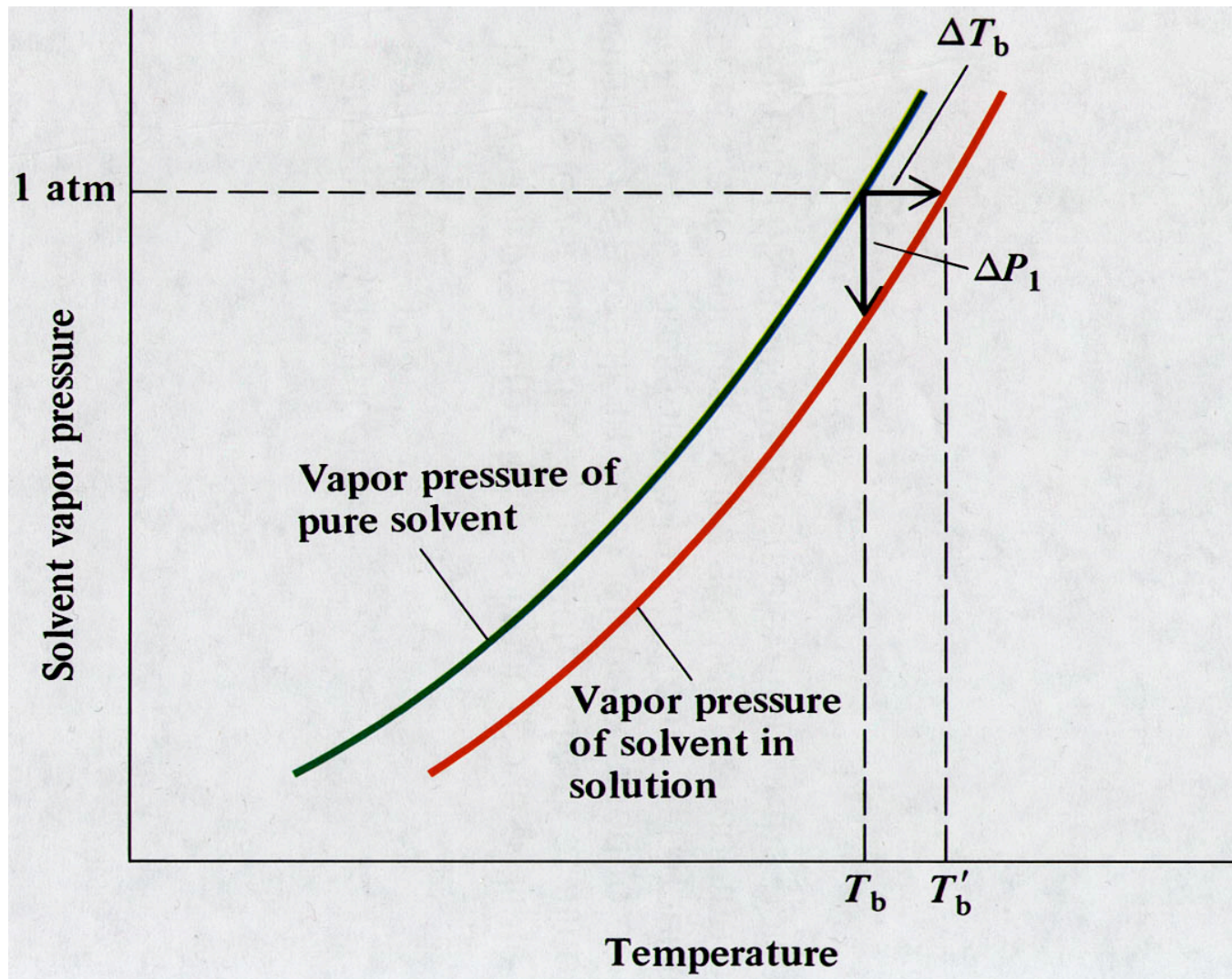
- “Slurper” molecules are polymers with hydrophilic ends that grab onto water molecules.
- Sodium salt of poly(acrylic acid).
- R-COO^- , Na^+

Colligative Properties

- Elevation of the normal boiling point
- Lowering of the normal freezing point



Elevation of the normal b.p.



Natural de-icer means you'll have to shovel less this winter

All-natural grain juices dissolve away snow, prevent snow from adhering for 10-14 days! Perfect for clearing driveways, walks and protecting plants.

Snowy nights will never keep me awake again! Now I sleep through the storm like a baby. Next morning all the other guys on the block are up wrestling with shovels, ice choppers, bags of salt—but my driveway and sidewalk are easier to clear! I'm dreaming? No sir, this stuff is real. Put it on the ground before a storm and it reduces the amount of snow that accumulates. Yeah, I didn't believe it either, until I heard what the toughest road crews in America were saying about Bare Ground. Storm-tested by state highway departments. These are the guys who stay up all night breaking through drifts, plowing, fighting hazardous road ice. If they swear by it, it must be good! And it is. Bare Ground Anti Snow/De-Icer is a liquid you spray or stream on a road or sidewalk. It not only eats up snow and ice but prevents future deposits from sticking for 10 to 14 days! It's not expensive either, because a little goes a long, long way.

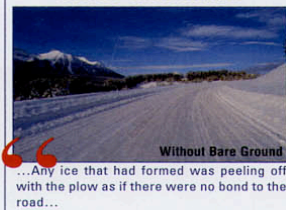
One gallon equals 50 pounds of salt. Already got snow or ice on your sidewalk or driveway? No problem. Just spray on some Bare Ground liquid. Instead of staying on top it sinks down to the bare pavement and dissolves the bond of snow or ice that holds it to the surface. No long waiting either—it starts working in about 20

minutes. Another reason the dollar-conscious pros use it: one gallon of Bare Ground is the equivalent of 50 pounds of salts or pellets!

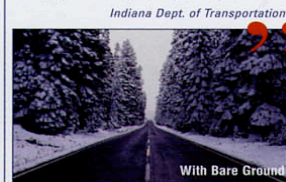
Safe for pets, kids, shrubs and carpets. Bare Ground is environmentally safe, biodegradable and non-toxic. Harmless to plants and grass, Bare Ground won't eat up the hall carpet like salt. Unlike other snow melters, you can use Bare Ground on any surface including rubber, roof shingles, slates, wood, brick or new concrete. In fact, Bare Ground is so safe, you may even wish to mix it with water and apply to trees and shrubs to prevent excessive ice buildup. It was discovered by two Hungarian distillery workers when they noticed that plant runoff water going into a local pond kept everything from freezing—even in the dead of frigid Hungarian winters. They isolated the key ingredients—all natural byproducts and patented the

formula. And now you can throw away your shovel and fire your hernia doctor forever! **One gallon protects a 20' x 50' driveway.** Think of it also as protection against a strained back, even heart strain. If a storm is due, pre-coat your driveway and sidewalk and let it snow. It not only reduces the amount of snow which accumulates but applies a non-stick coating that keeps ice and falling

Used by road maintenance crews nationwide



Washington State Dept. of Transportation
...This product is amazing and it has saved lives, injuries and property damage...



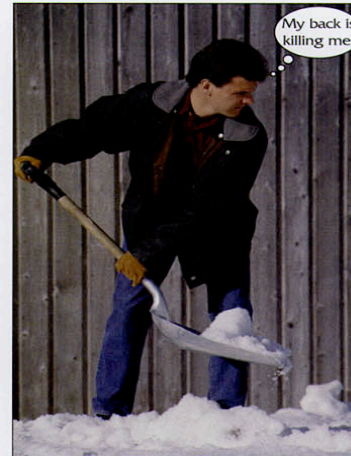
Many Highway Departments prefer Bare Ground to salt.

- About as corrosive as distilled water
- Less equipment corrosion
- Doesn't eat up cement

How does Bare Ground Work?



Unlike rock salt or pellets that lie on the surface and melt from the top down, Bare Ground sinks to the surface level, melting as it goes down, and spreads out breaking the bond of the snow or ice to the surface for a quick, easy and complete cleanup.



Make your life easier when winter arrives!

Apply Bare Ground about 2 hrs. before a snow or ice storm, or Bare Ground will begin to work about 20 minutes after its application to an existing snow or ice pack.

snow from sticking. You can also forget about tickets for unshoveled sidewalks. **Beat the snow.** Stock up now on our no-risk guarantee. Bare Ground comes in neat, easy-to-stow plastic jugs. Mist or apply with any garden-type

sprayer—or order a Bare Ground System that includes a built-in sprayer. You've got one month to try it out. If you are not completely satisfied, simply return it within 30 days for a full "No Questions Asked" refund. Hey, this winter while others are shoveling, why not relax and watch the ball game!

TechnoScout.com

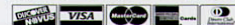
Where high tech hits home

For years, we have found high tech solutions from the innovators and brought them directly to you...months before they were available in stores. Now, TechnoScout.com is the high-tech, low-stress way to a better life.

Bare Ground Solution System with Sprayer \$39.95 \$8.95 S&H
Gallon Refill \$12.95 \$4.95 S&H
Please mention product code 7508-19671.

For fastest service, call toll-free 24 hours a day

800-992-2966



To order by mail, send check or money order for the total amount including S&H. To charge it to your credit card, enclose your account number and expiration date.

Virginia residents only—please include 4.5% sales tax.

A Comtrad Industries Company

TECHNOScout.com
1998 Ruffin Mill Road
Colonial Heights, Va 23834

Another Estimate Problem

- the lowest temperature your car radiator fluid could withstand and still remain fluid if your car radiator fluid was... VODKA!
- Strategy/LOGIC

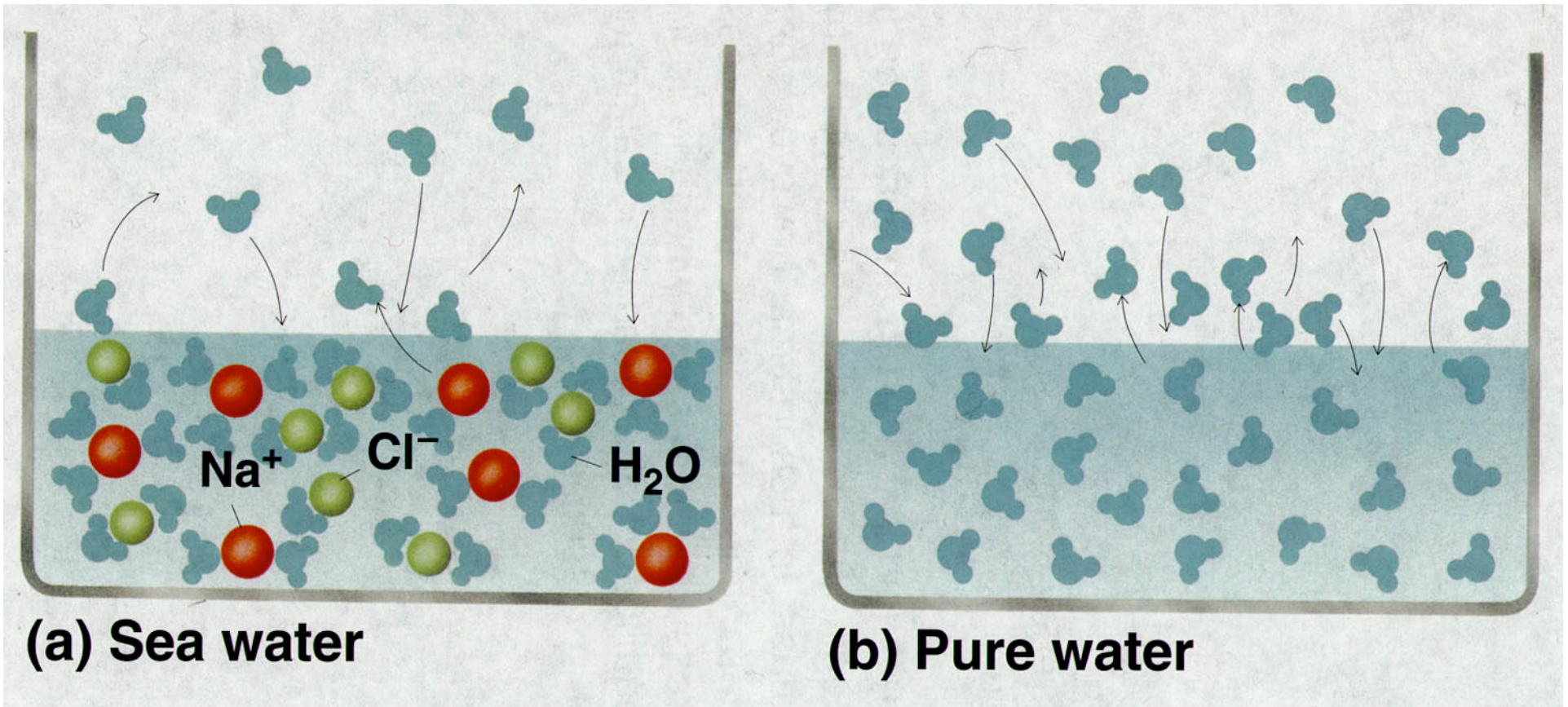
Osmosis/Osmotic Pressure

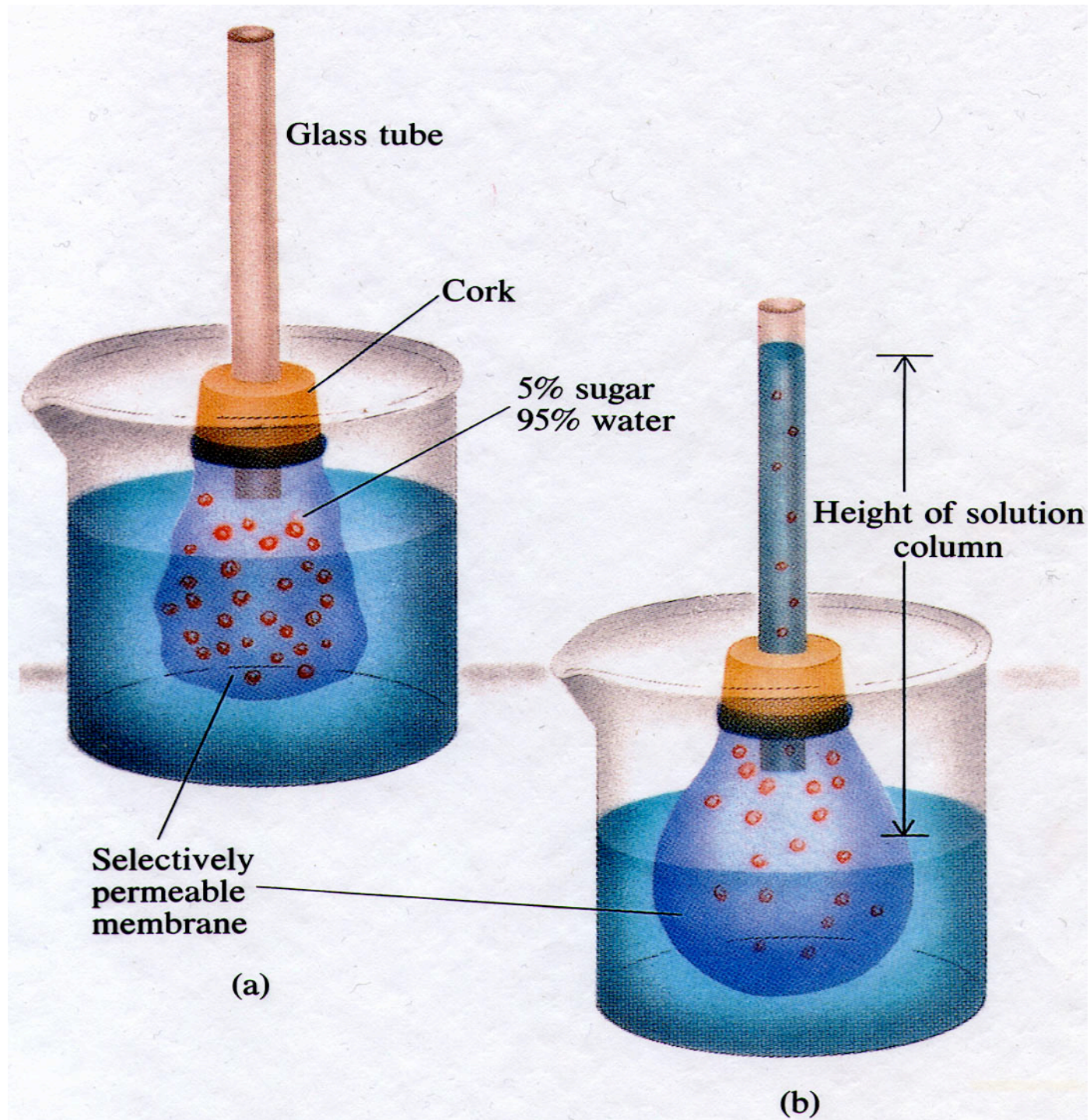
Applications:

- Treating industrial wastes
- Pulp and paper manufacture
- Reclamation of brackish/salt water
- Sewage treatment
- Electrodialysis
- Many biological/ecological processes

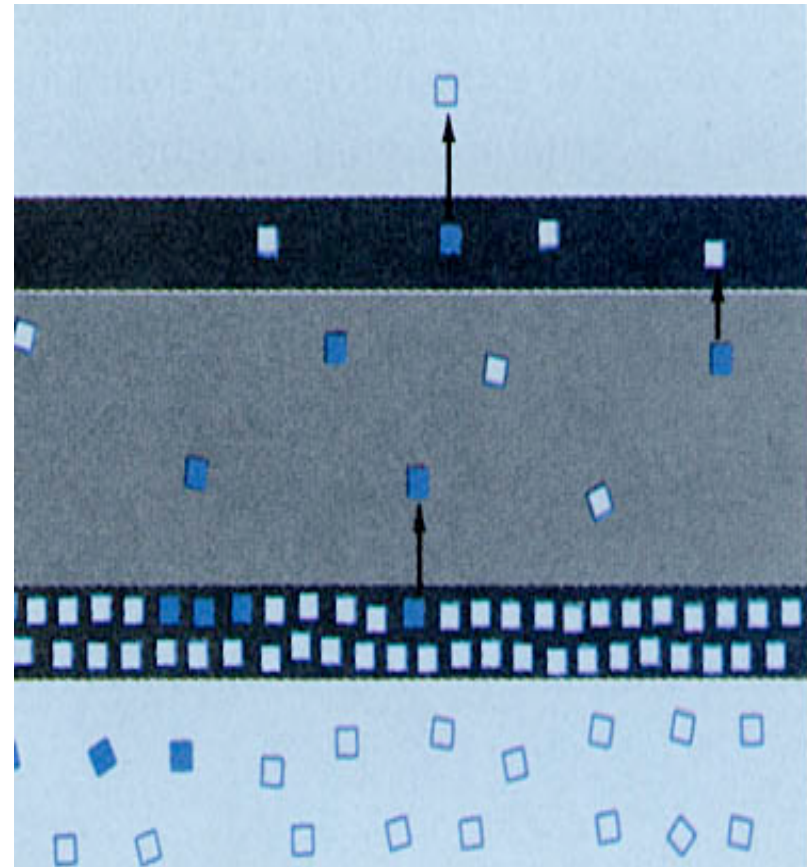
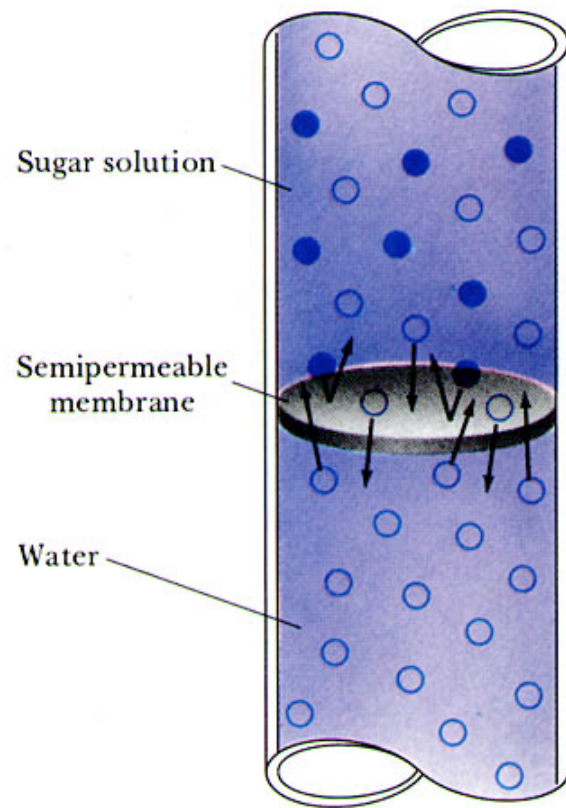
Colligative Properties

Thought Experiment



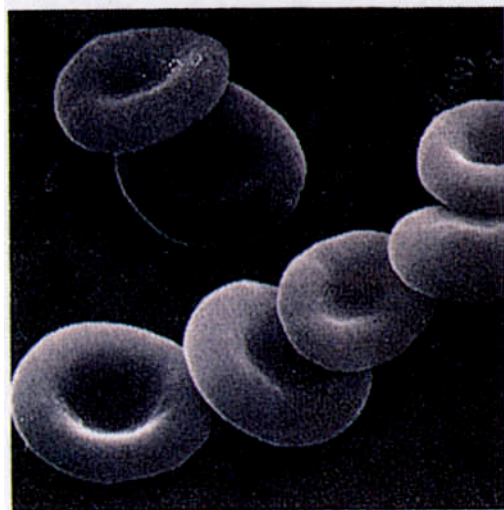
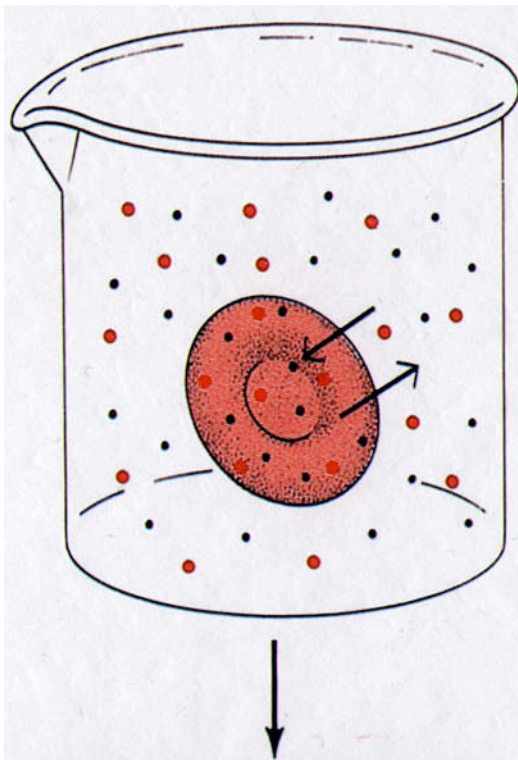


Osmosis/Osmotic Pressure

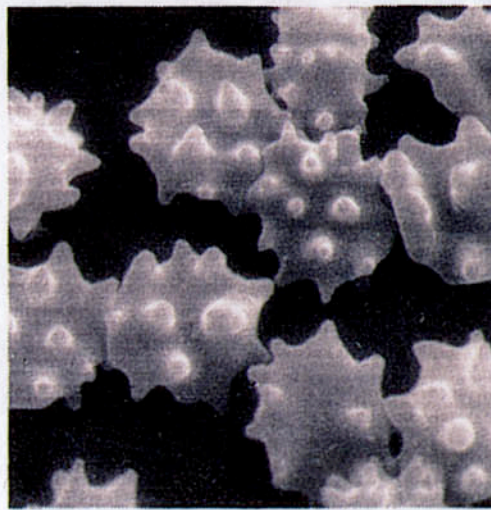
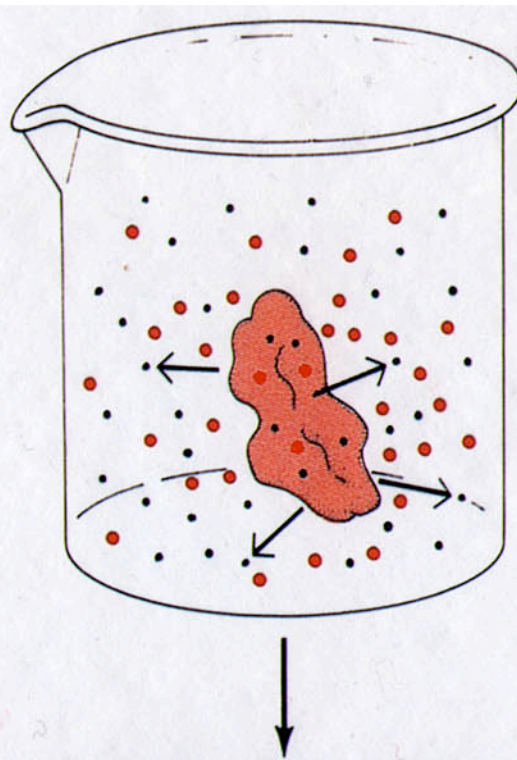


Osmosis/Osmotic Pressure

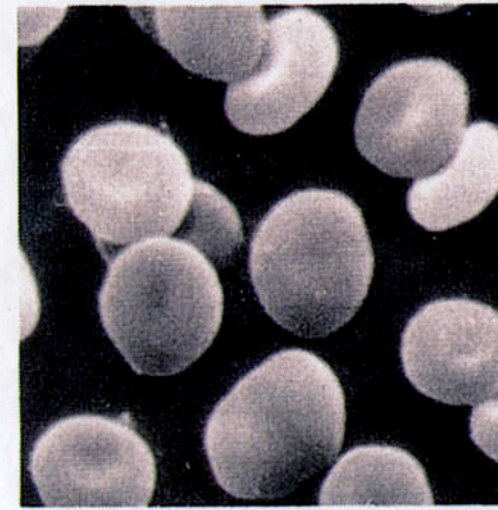
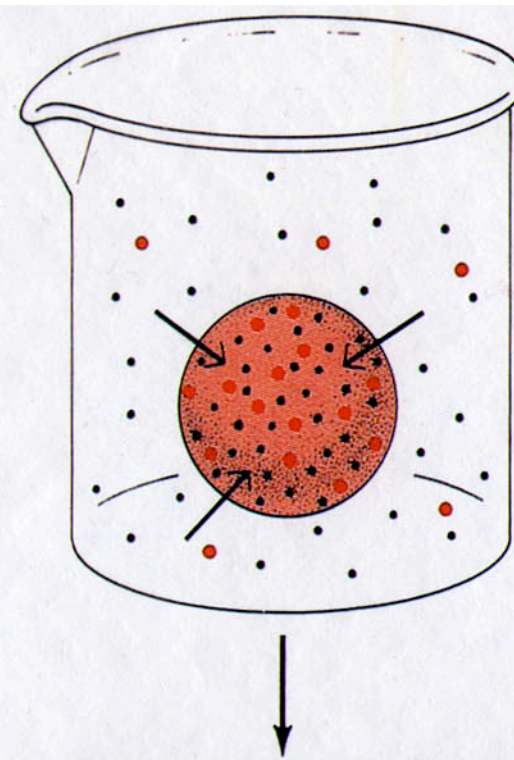
- DRIED PLUMS... "prunes"
- Carrots
- Eggs
- Blood cells



(a) Isotonic solution



(b) Hypertonic solution



(c) Hypotonic solution

Osmosis/Osmotic Pressure

In dilute solutions:

$$\Pi V = n_2 RT = [g_2/M_2]RT$$

$$\Pi = cRT \text{ where } c \sim \text{mol/L}$$

Solubility of hemoglobin in water is 5.0 g/L

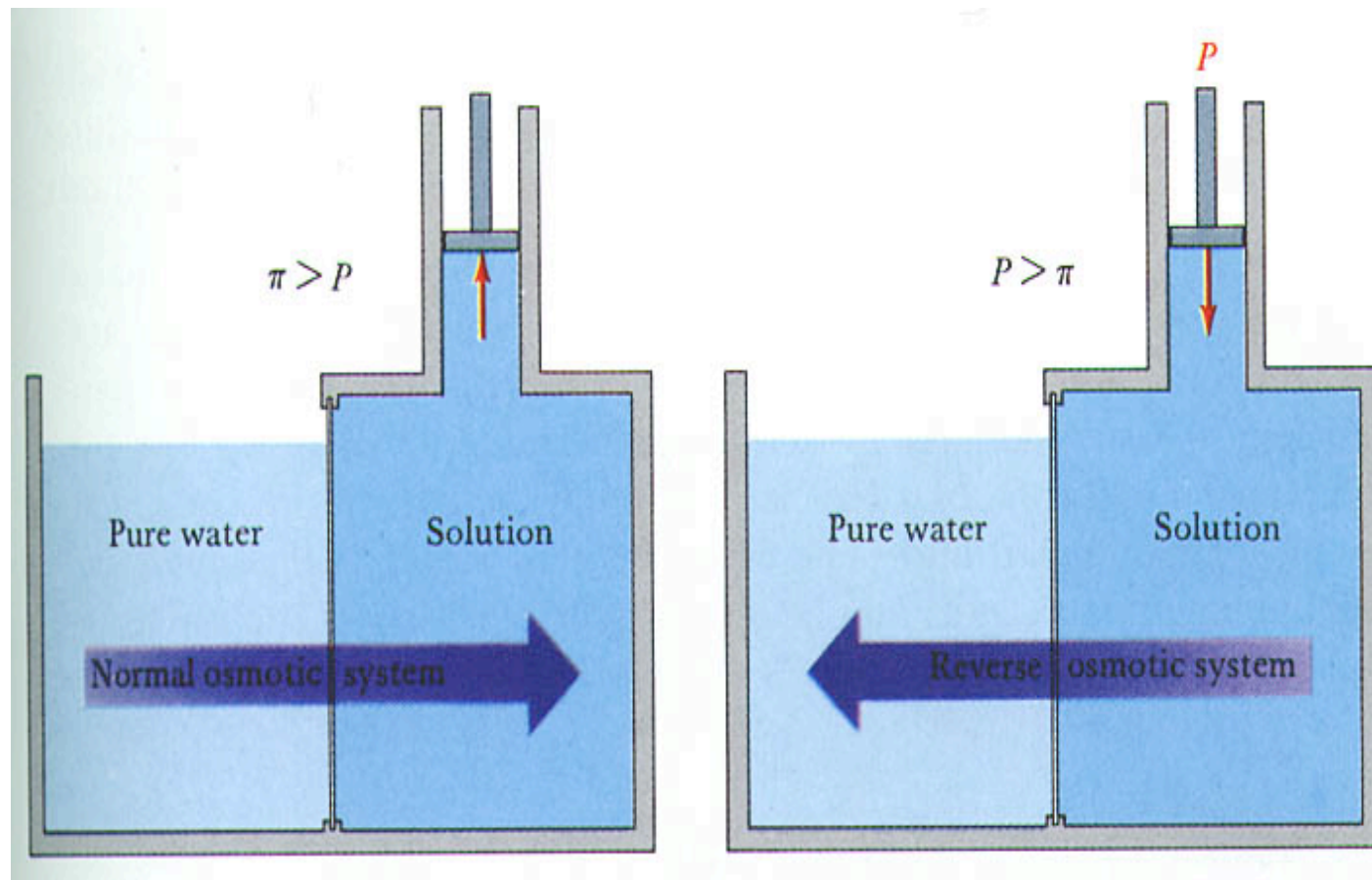
Strategy/LOGIC?

$$\Pi = 1.80 \times 10^{-3} \text{ atm @ } 25^\circ\text{C}$$

$$C = \Pi / RT = \text{mol/L}$$

$$MW = [g/L]/\text{mol/L} = g/\text{mol}$$

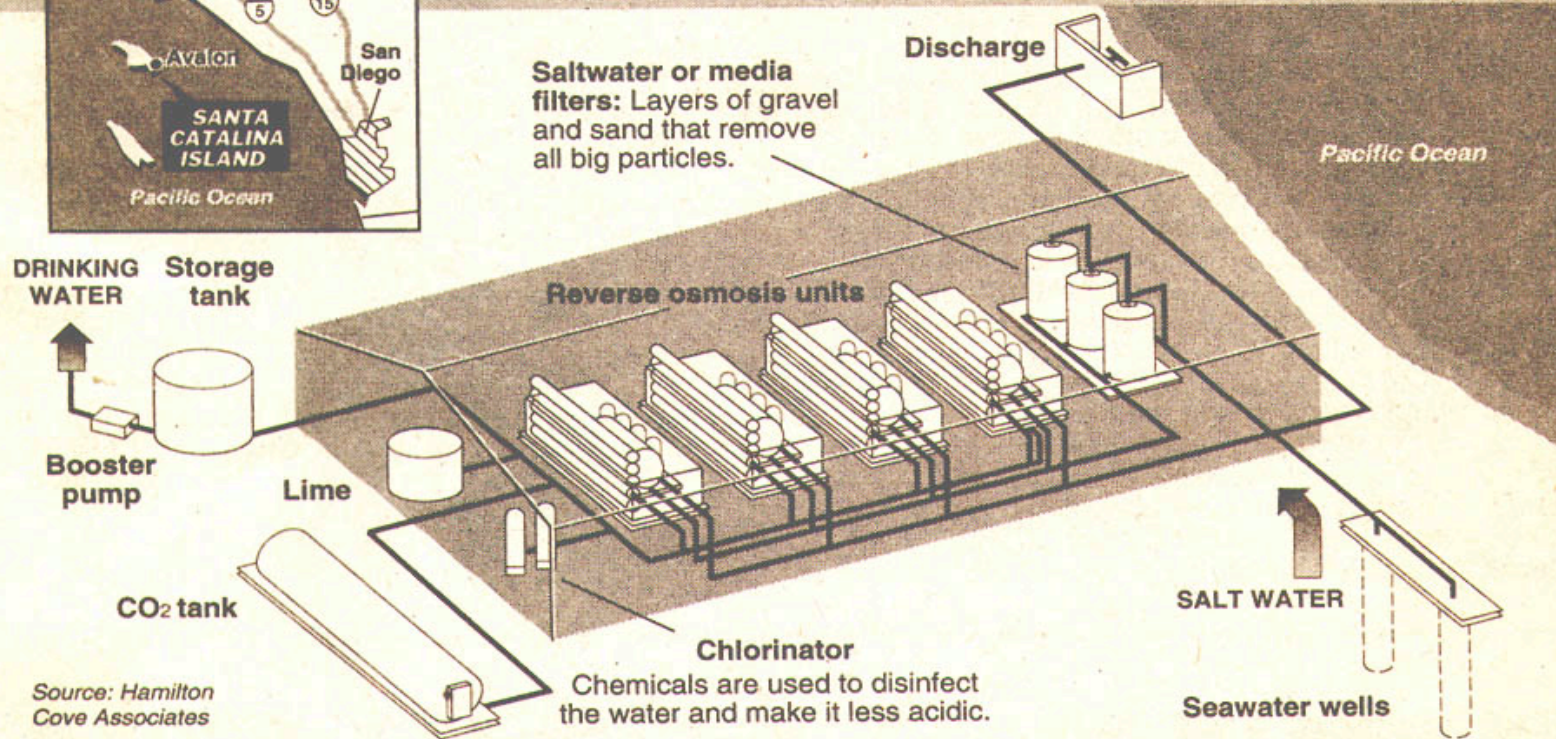
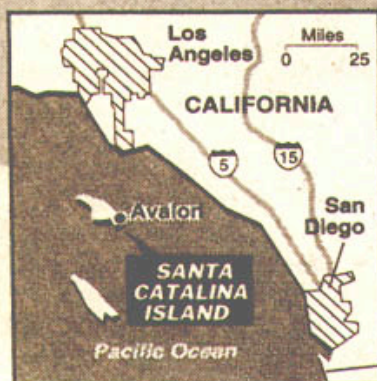
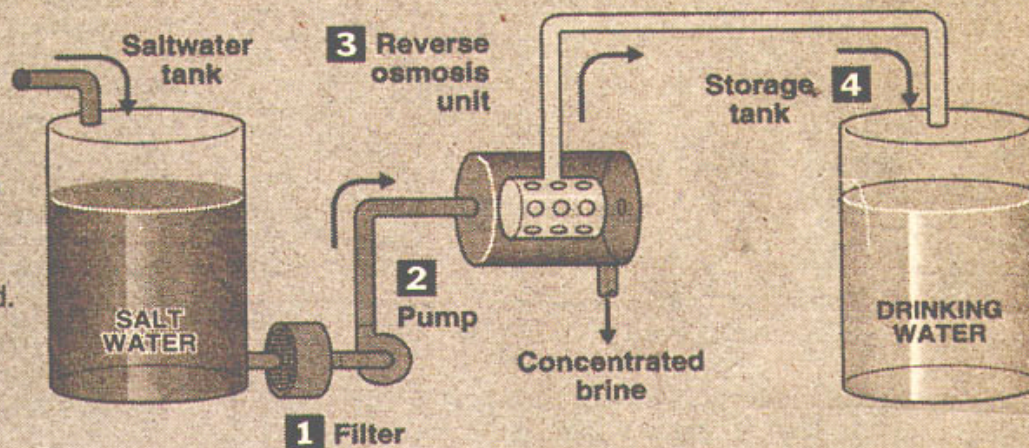
Normal and Reverse Osmotic Systems



Desalting Water on Catalina Island

Reverse osmosis, a popular technology for small- and medium-sized desalting plants, will be used on Santa Catalina Island off California. It is the first seawater-desalting plant for an American residential community.

- 1** Salt water is filtered to remove big particles.
- 2** A pump pushes the salt water into a reverse osmosis unit.
- 3** Cylinders with membranes remove impurities and salt from the water.
- 4** The water is treated with chlorine, lime and carbon dioxide and stored.



Source: Hamilton
Cove Associates

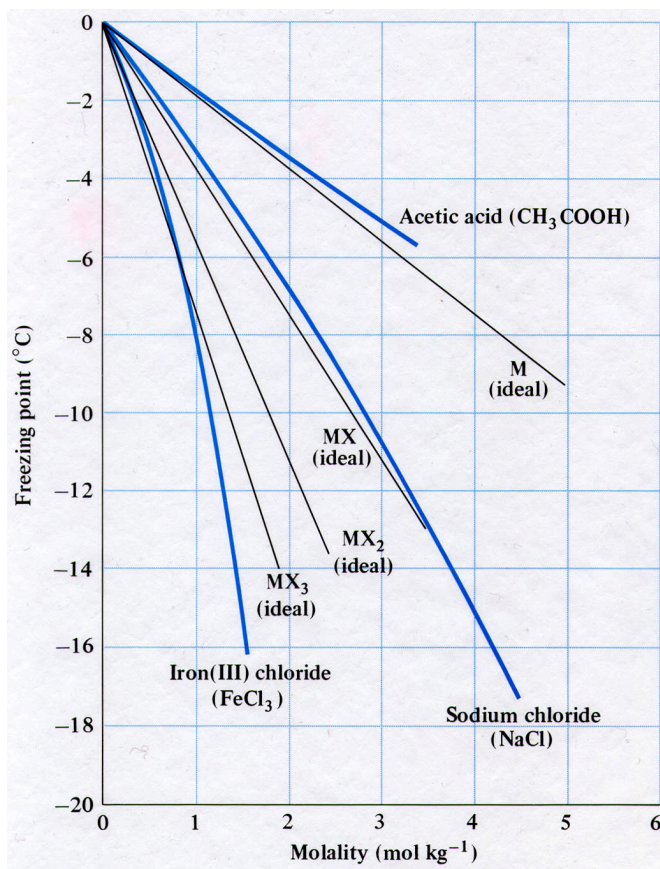
Example

Estimate the "back pressure" needed to obtain pure water from sea water by "reverse" osmosis.

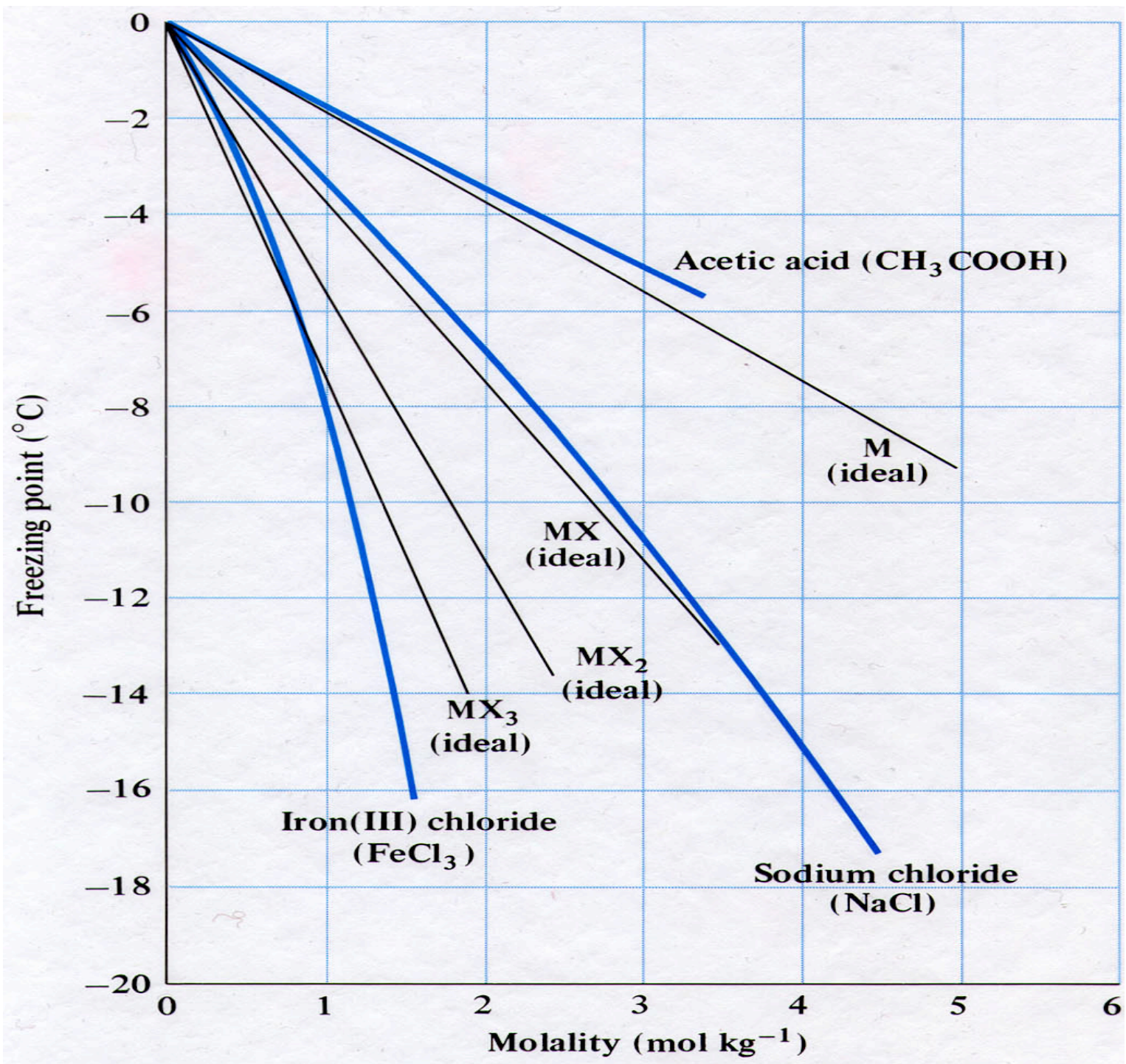
Strategy/LOGIC

$$\Pi = cRT \text{ where } c \sim \text{mol/L}$$

Van't Hoff i-Factor



- Colligative effects depend on number of particles.
- Ionization and dissociation multiply colligative effects.
- Association acts in the opposite sense.



Van't Hoff i-Factor

$$i = \frac{\Delta T_{\text{electrolyte}}}{\Delta T_{\text{nonelectrolyte}}}$$

$$\Delta T = iK_{\text{bp}}m \text{ (boiling point elevation)}$$

$$\Delta T = iK_{\text{fp}}m \text{ (freezing point depression)}$$

$$\Pi = icRT \text{ (osmotic pressure)}$$

74.



This experiment was to distill over nitric acid from a mixture of sodium nitrate and sulphuric acid. 25 grams of Sodium Nitrate or (Chili salt petre.) and 15 grams of concentrated sulphuric acid, were put into a retort.

And arranged as in figure. The receiver was kept constantly cool by cold water.

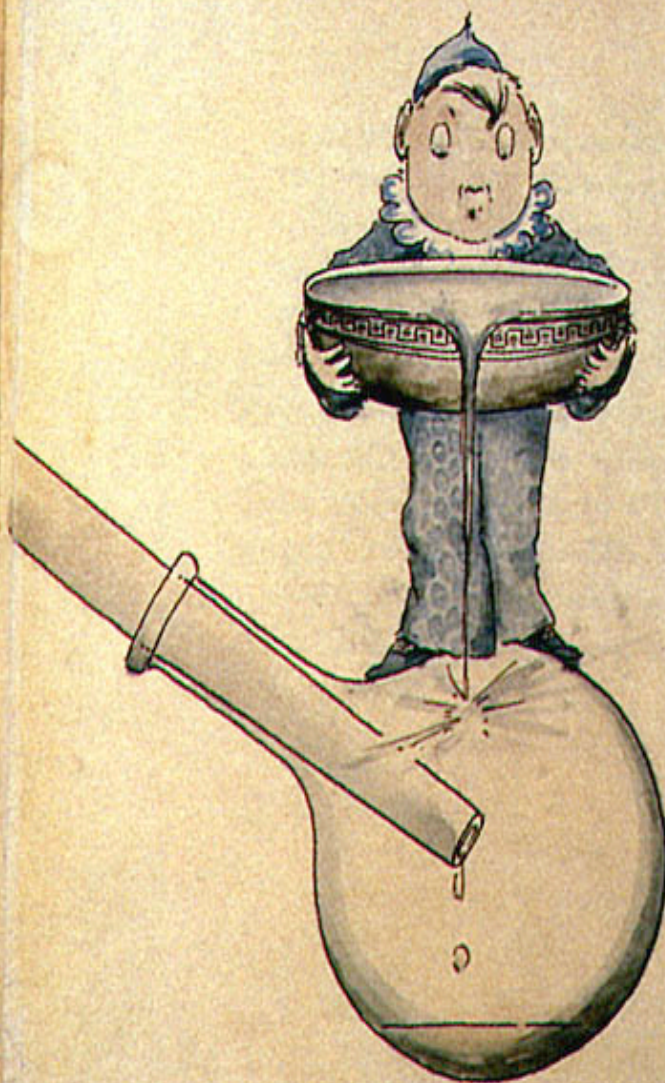
At first the retort was filled with a reddish brown gas then it became almost transparent, and towards the end of the experiment, when the mixture in the retort was almost dried up, the retort was filled with a very highly coloured brown gas.



After enough acid had been distilled, or rather when the sodium nitrate had become dry the contents of retort were crystallized from water.

The nitric acid obtained had a yellowish brown colour and appeared to be very strong as it gave off white fumes in contact with air.

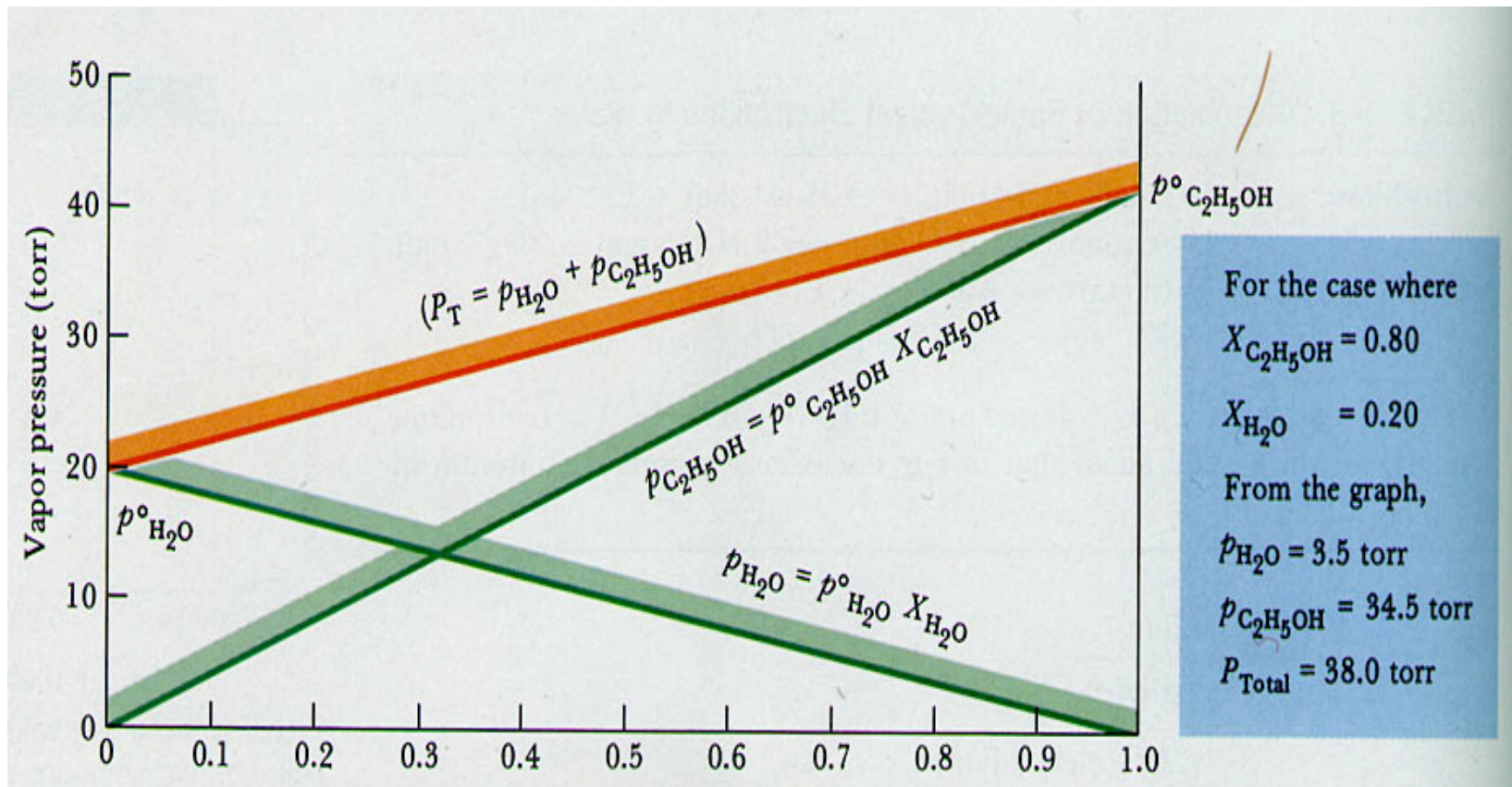
Friday. 23rd.
May.
1890.



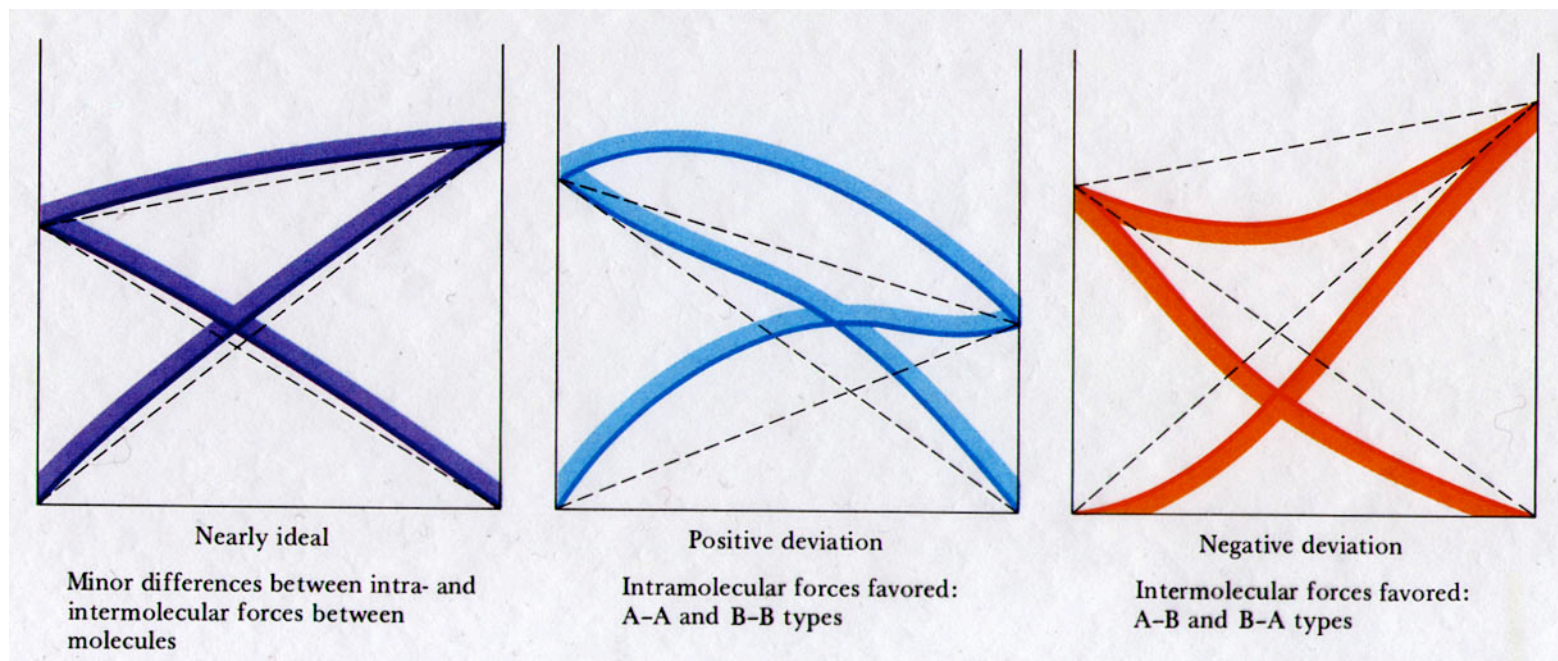
Simple Distillation

- Mixture of alcohol and water form a nearly ideal solution.
- Use Raoult's law to calculate the composition of the solution.
- Use Dalton's law to calculate the composition of the vapor above the solution
- Vapor is "richer" in the more volatile component.

Partial Pressures and Total Pressure in a Binary Mixture

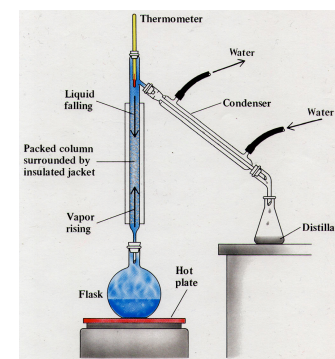


Binary mixtures of Volatile Components



Distillation

- Simple distillation...
as recorded by Maxfield Parish
in his freshman chemistry
laboratory notebook.
- Fractional distillation...
on a laboratory scale of 1000mL/h
- Separation of petroleum
hydrocarbon mixtures on an
industrial scale ~50,000 gal/d



Benzene and Toluene form an ideal solution

