74.

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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.

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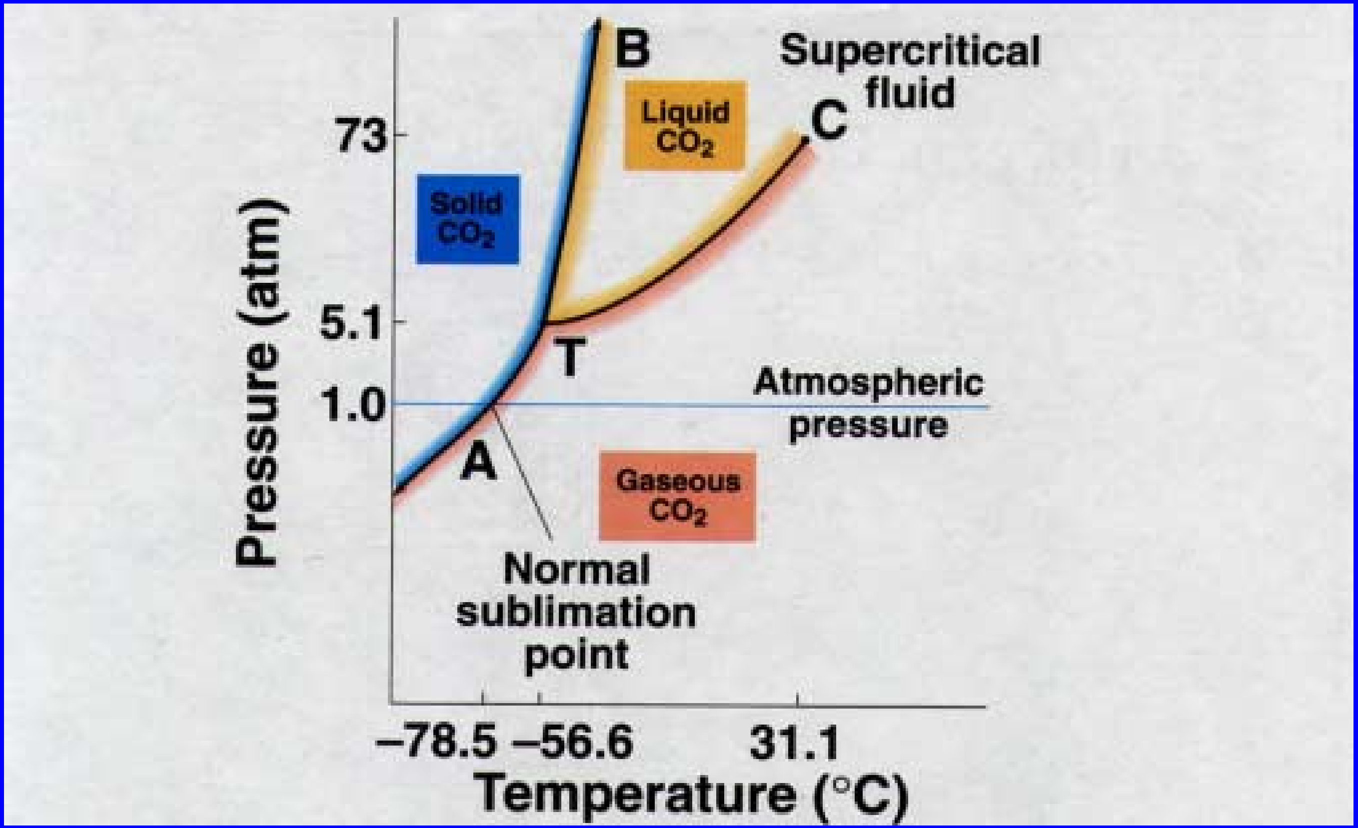
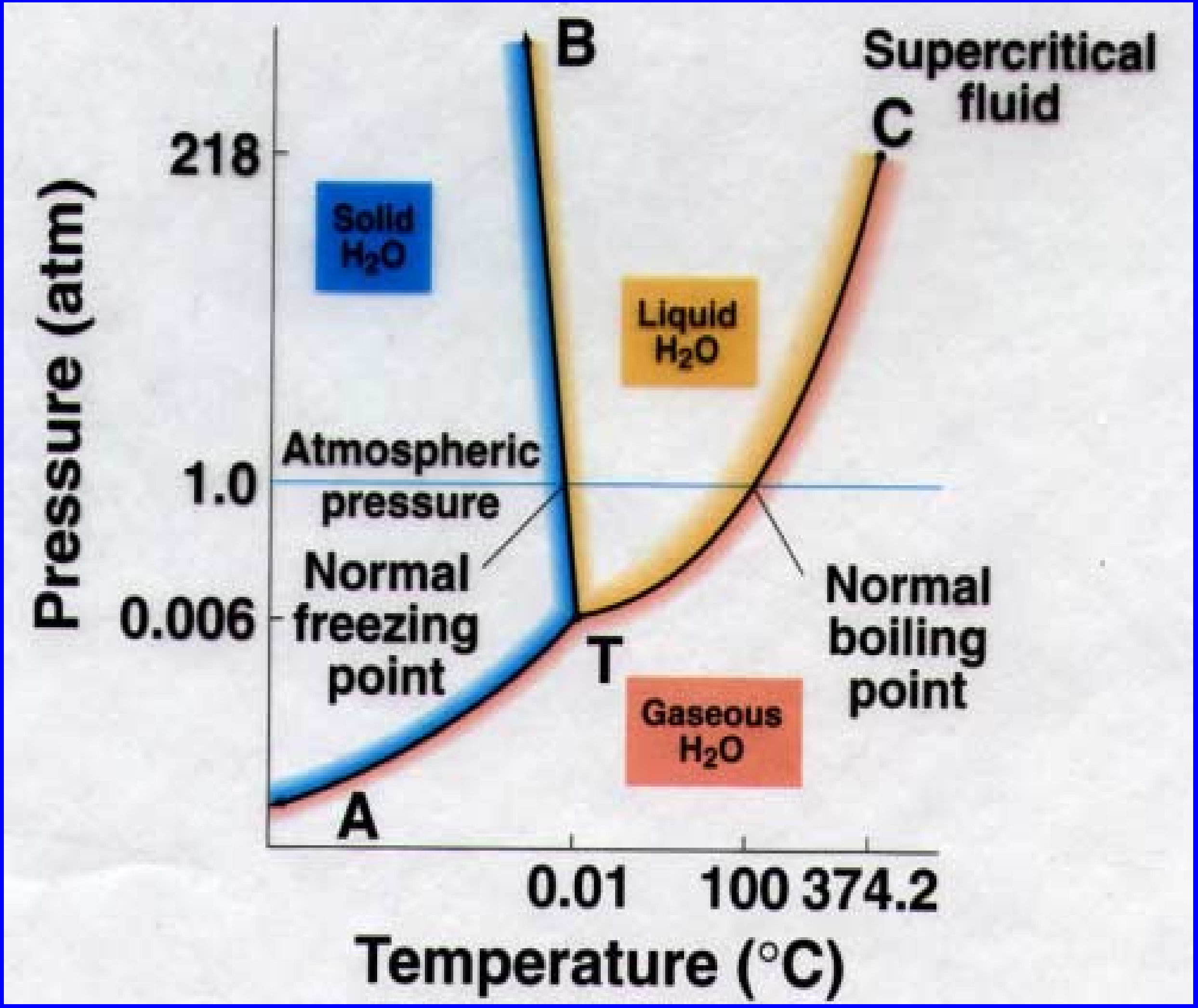
Friday. 23rd.
May.
.1890.

Phase Diagram for CO_2



Phase Diagram for H_2O



Masterpiece in Focus

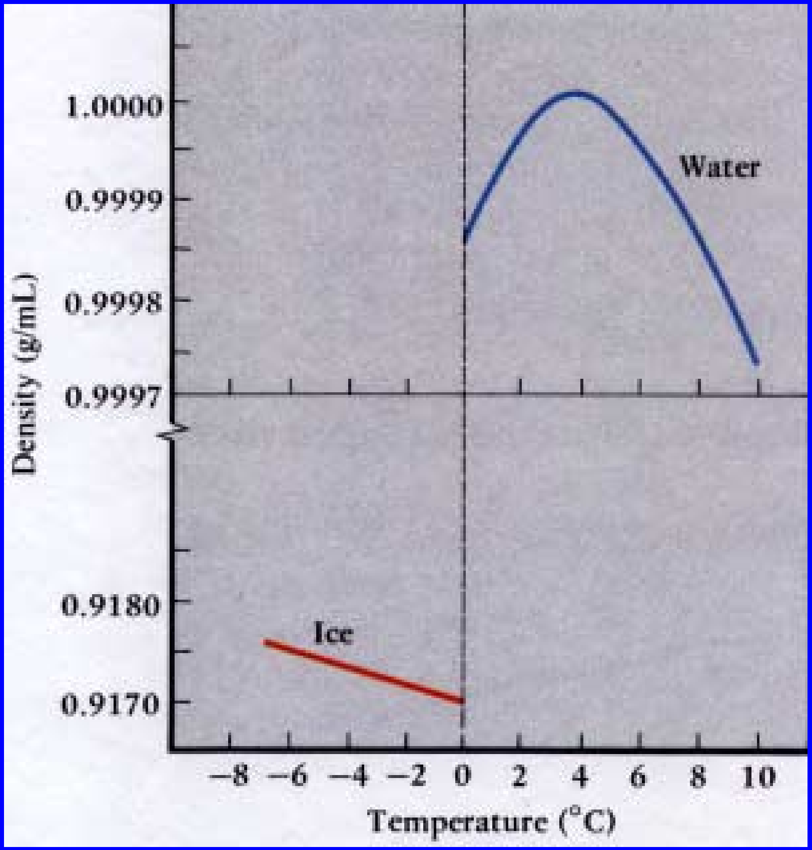
Soap Bubbles

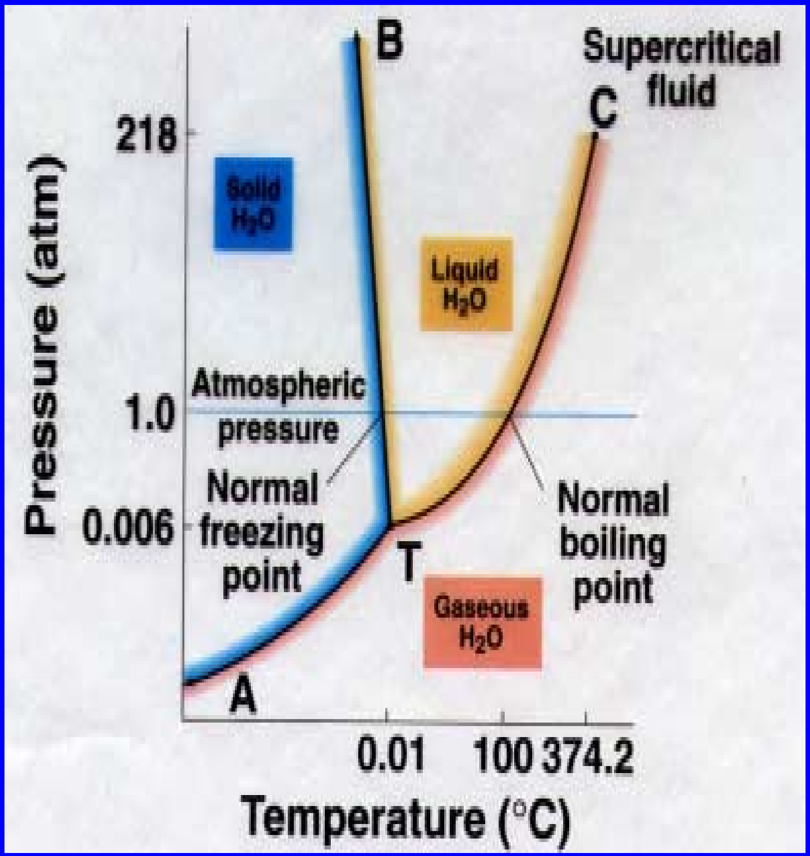
BY JEAN-SIMÉON CHARDIN

The Liquid State

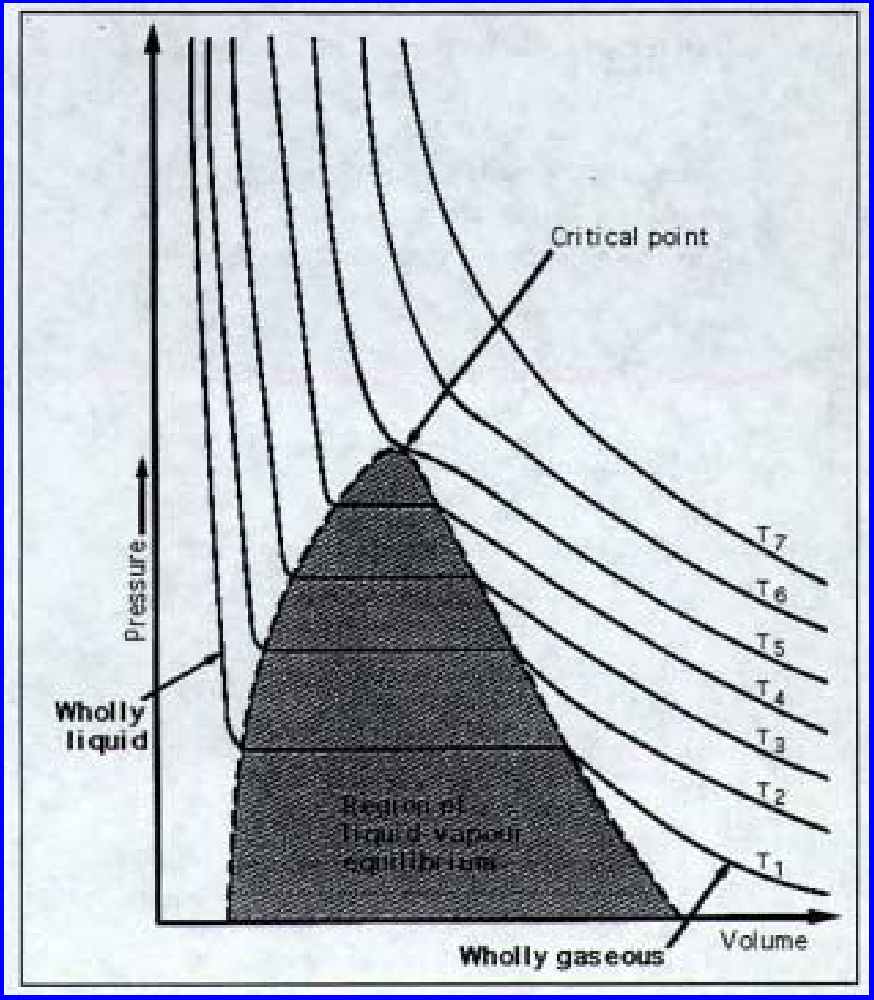
- Density
- Compressibility
- Diffusion
- Evaporation
- Vapor pressure
- Surface tension
- Viscosity
- Adhesive/cohesive forces
- Capillary action

Density of Ice and Water



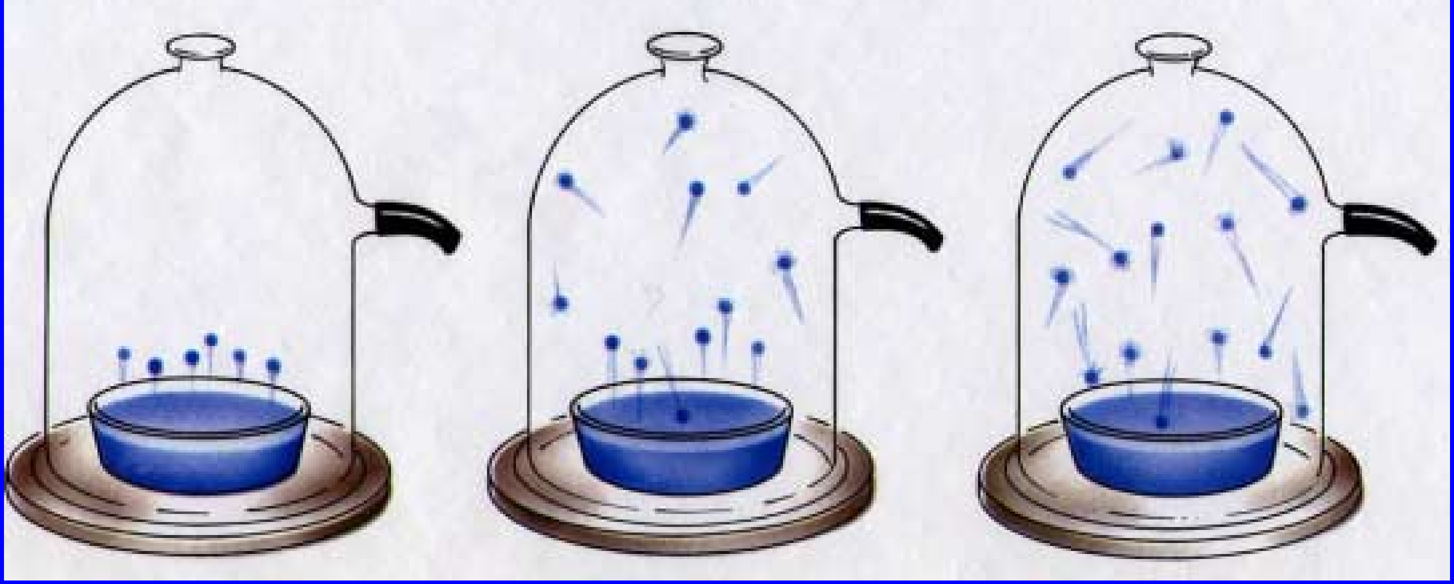


Compressibility

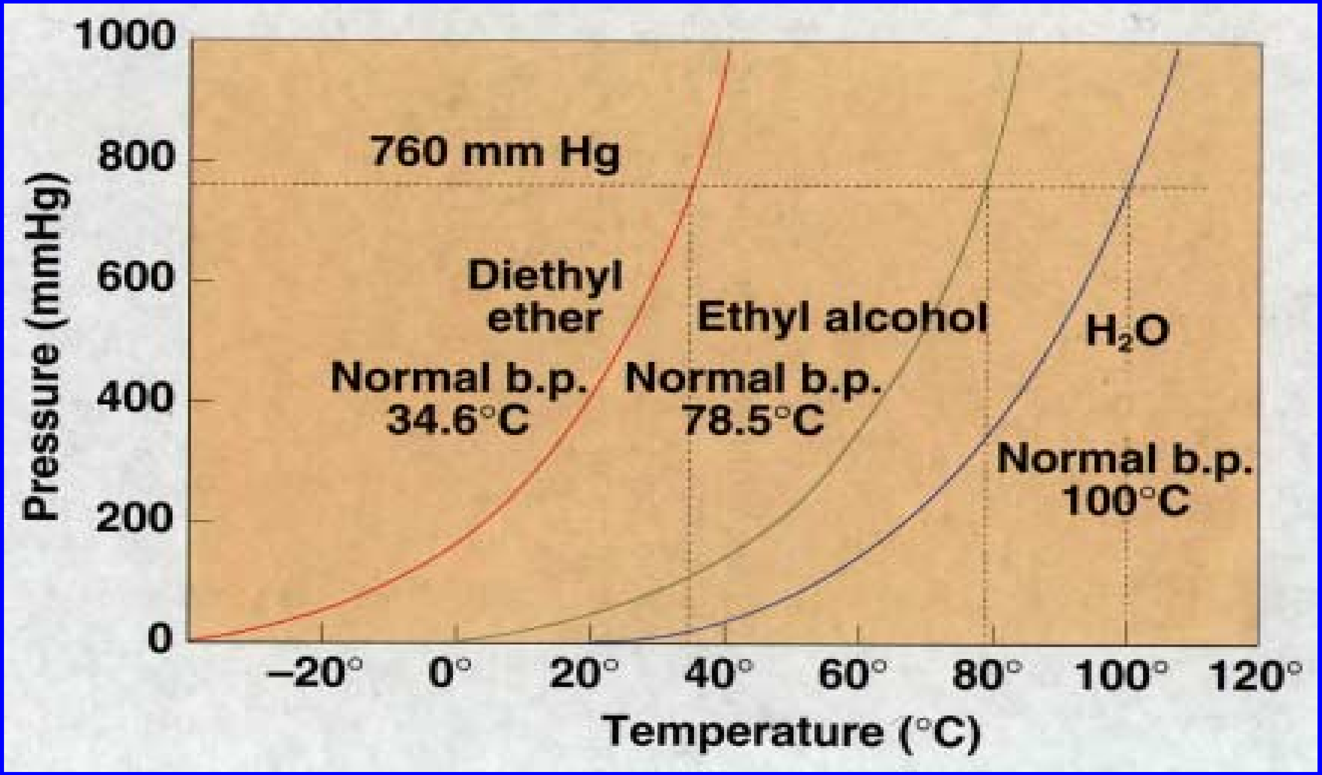


Surface Tension

Equilibrium Vapor Pressure



Vapor Pressure Curves



Trouton's Rule

An interesting and useful “approximation:

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

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

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

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

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

- carbon tetrachloride
- benzene
- cyclohexane

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

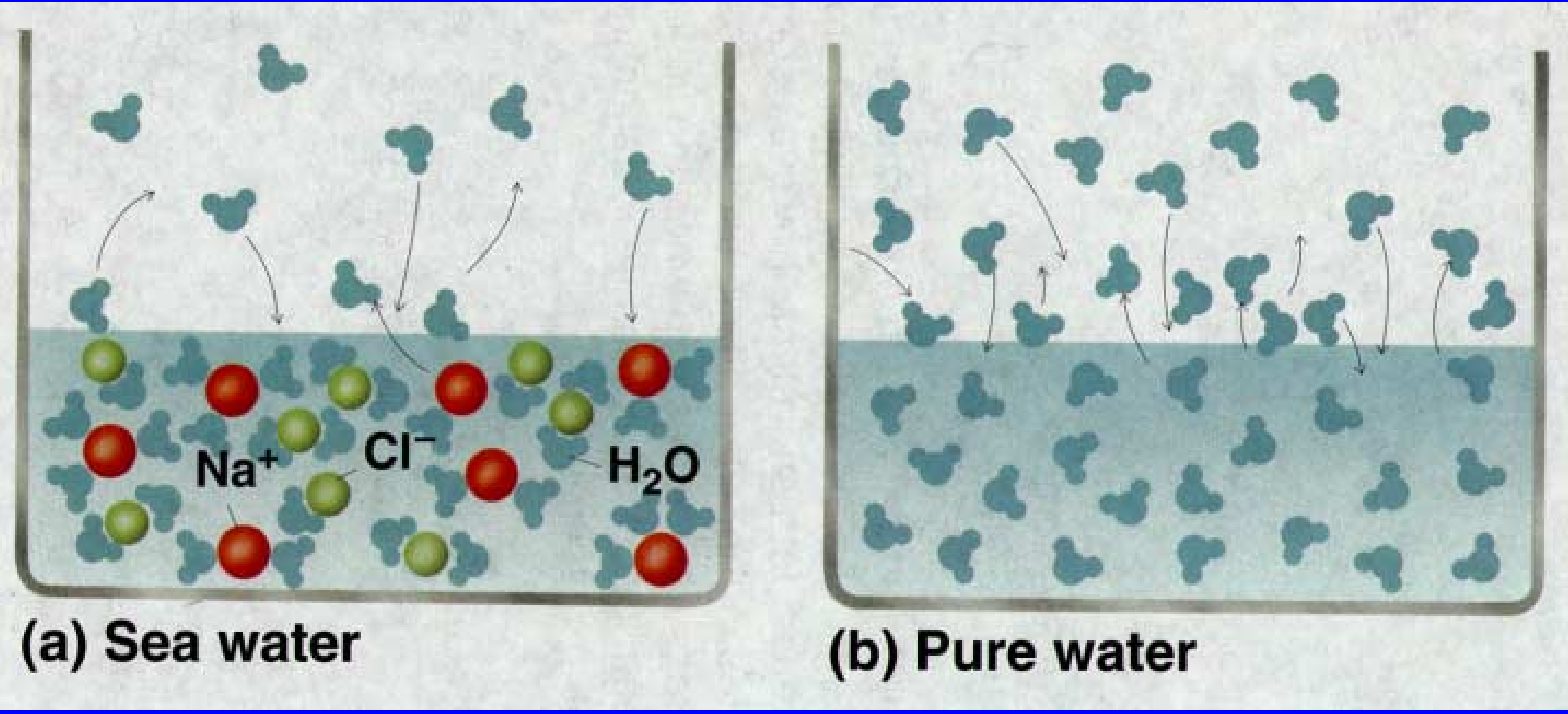
- water (110)
- methanol (112)
- ammonia (97)

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

- acetic acid (62)
- hydrogen fluoride (26)

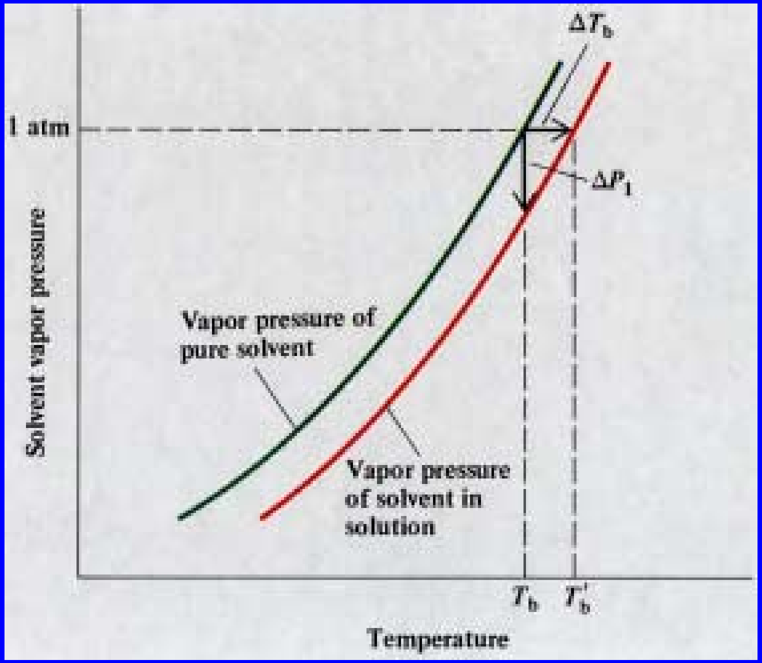
Colligative Properties

- *Thought* Experiment -

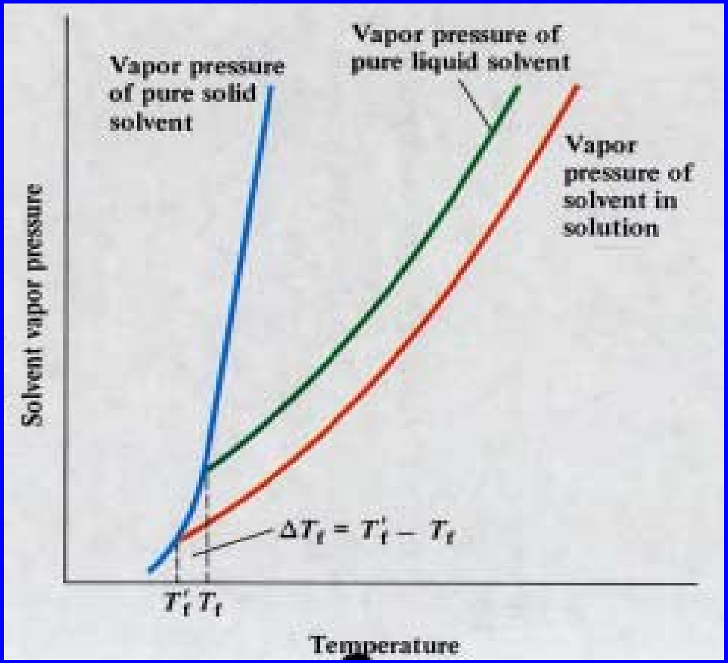


Colligative Properties

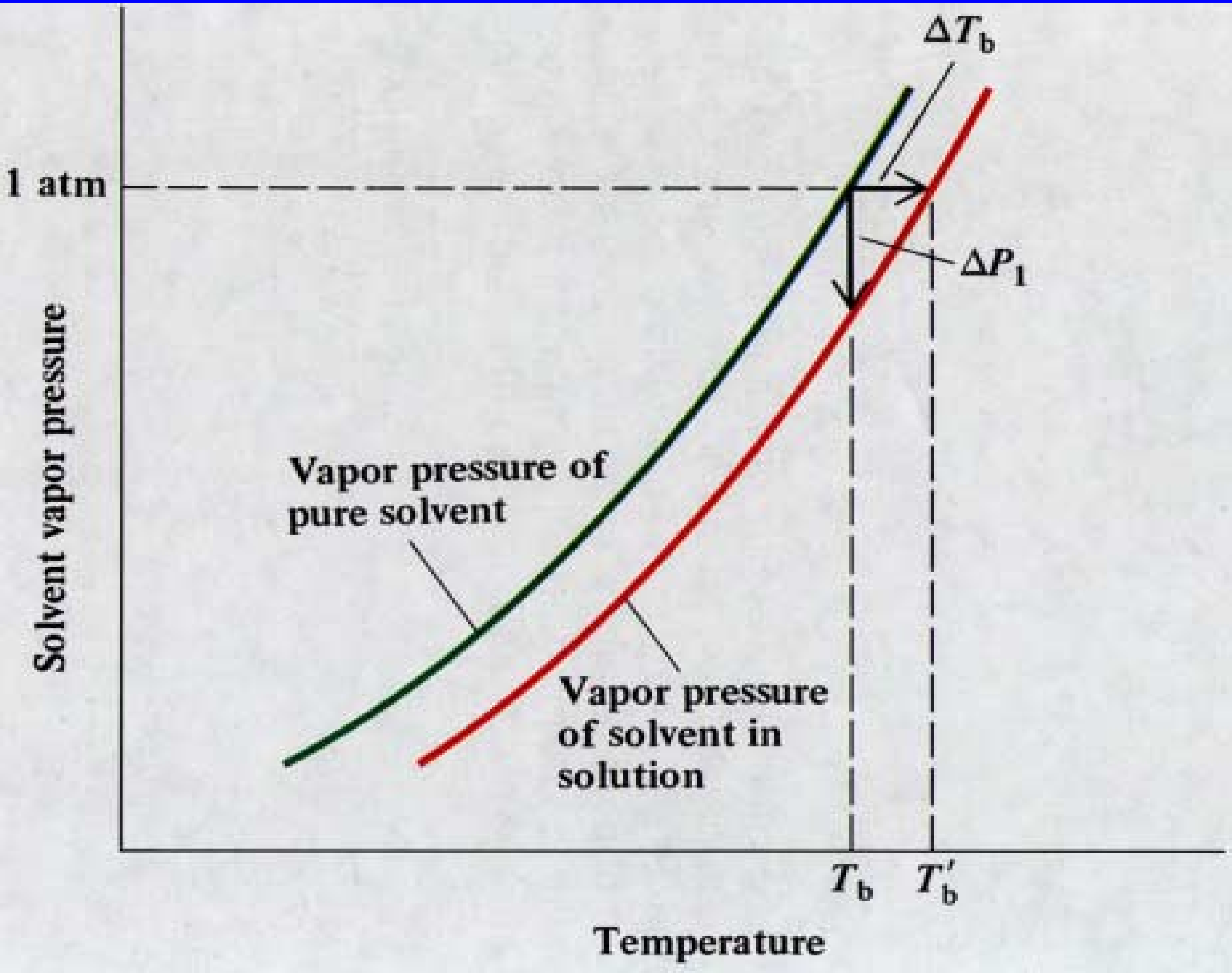
- Elevation of the normal boiling point



- Lowering of the normal freezing point



Elevation of the normal b.p.



Raoult's Law

- Nonvolatile solute in volatile solvent:

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

  $p^{\circ} - p = \Delta p = p^{\circ}X_{solute}$
- Elevation of the boiling point: $\Delta T = K_{bp}m$
- Depression of the freezing point: $\Delta T = K_{fp}m$
- Osmostic pressure: $\Pi = cRT$

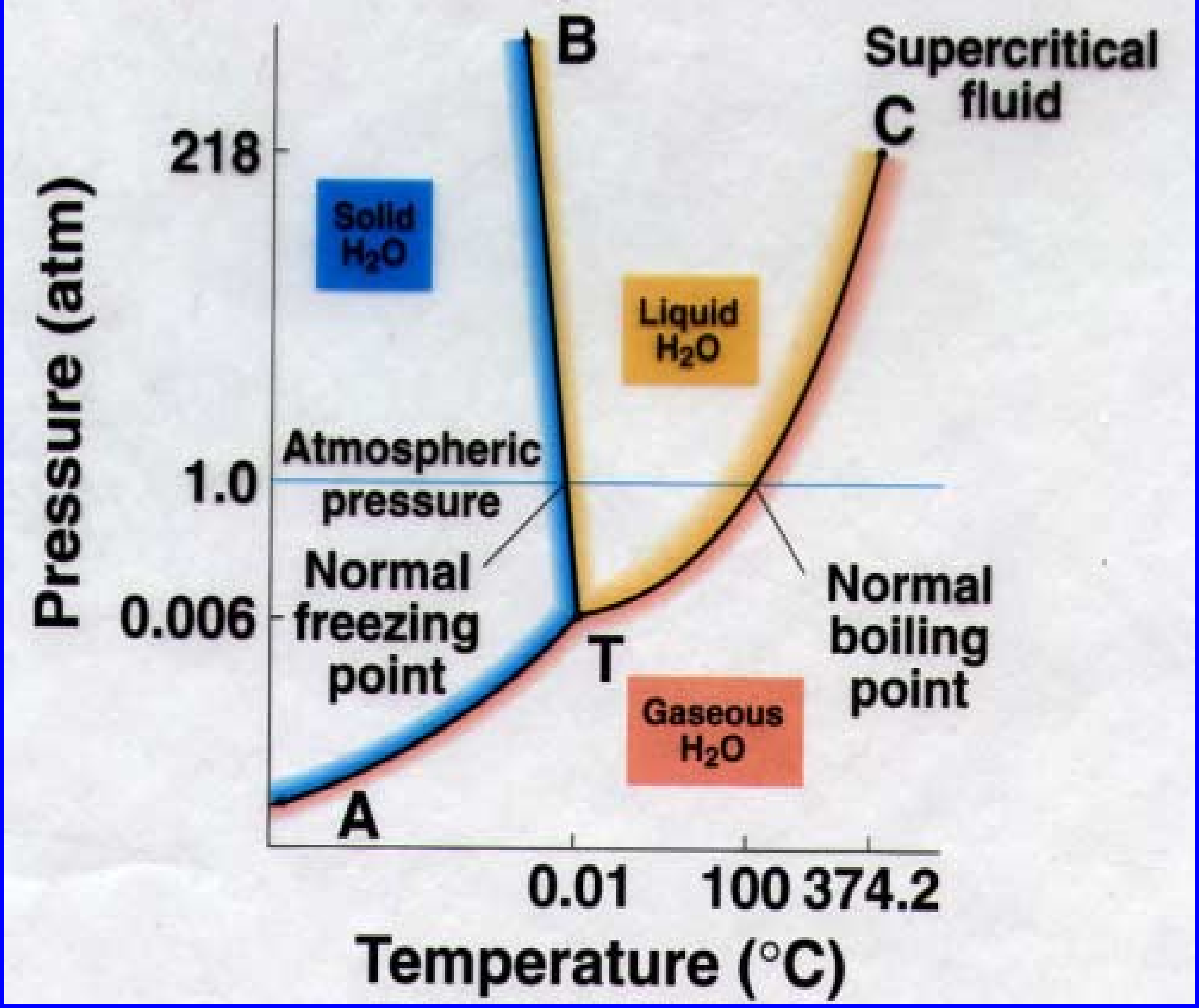
Boiling and Freezing Point Constants for Some Solvents

Solvent	K_b(°C/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(°C/m)
water	−1.86
acetic acid	−3.90
chloroform	−4.68
benzene	−5.12
naphthalene	−7.00
camphor	−40.0

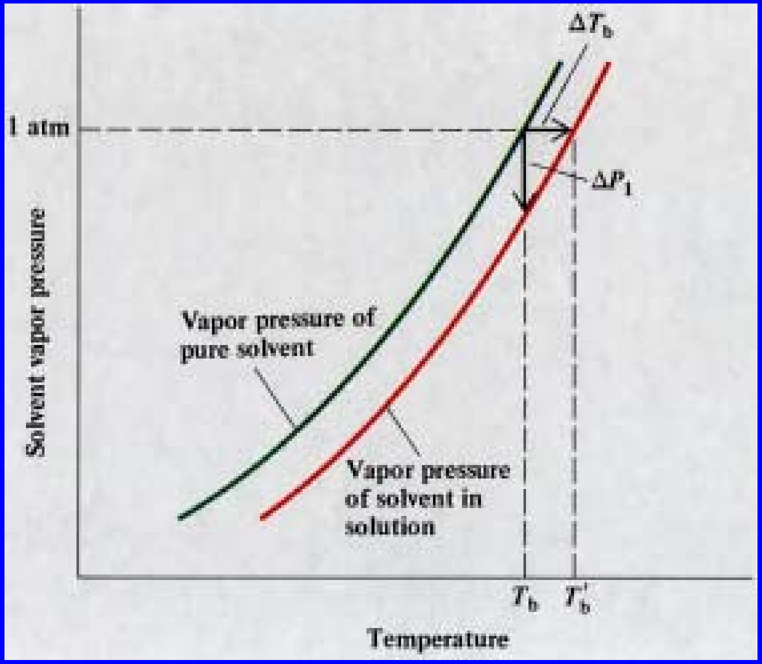

COMPACT
Pampers
phases
ULTRA DRY THINS
XL
X-Large Diapers for Boys
Walker 3
26 lbs. and over
24

Phase Diagram for H_2O



Colligative Properties

- Elevation of the normal boiling point



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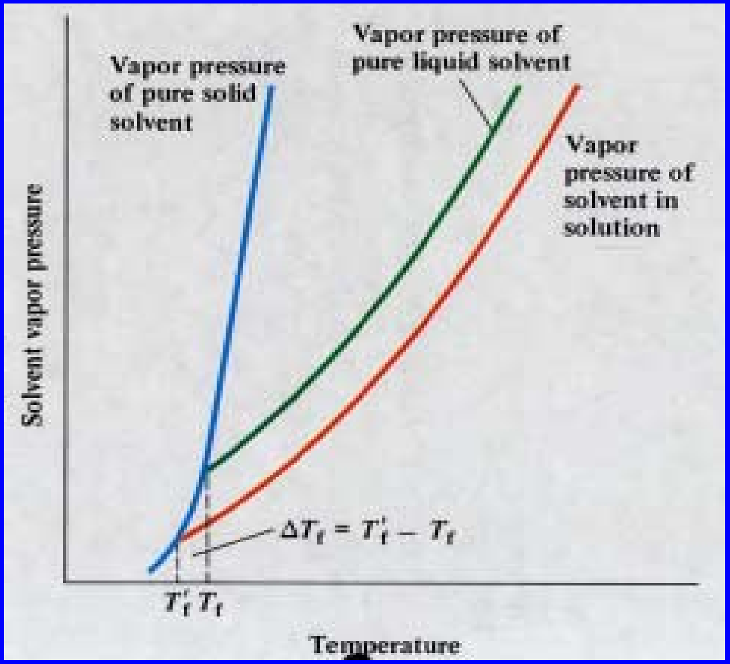
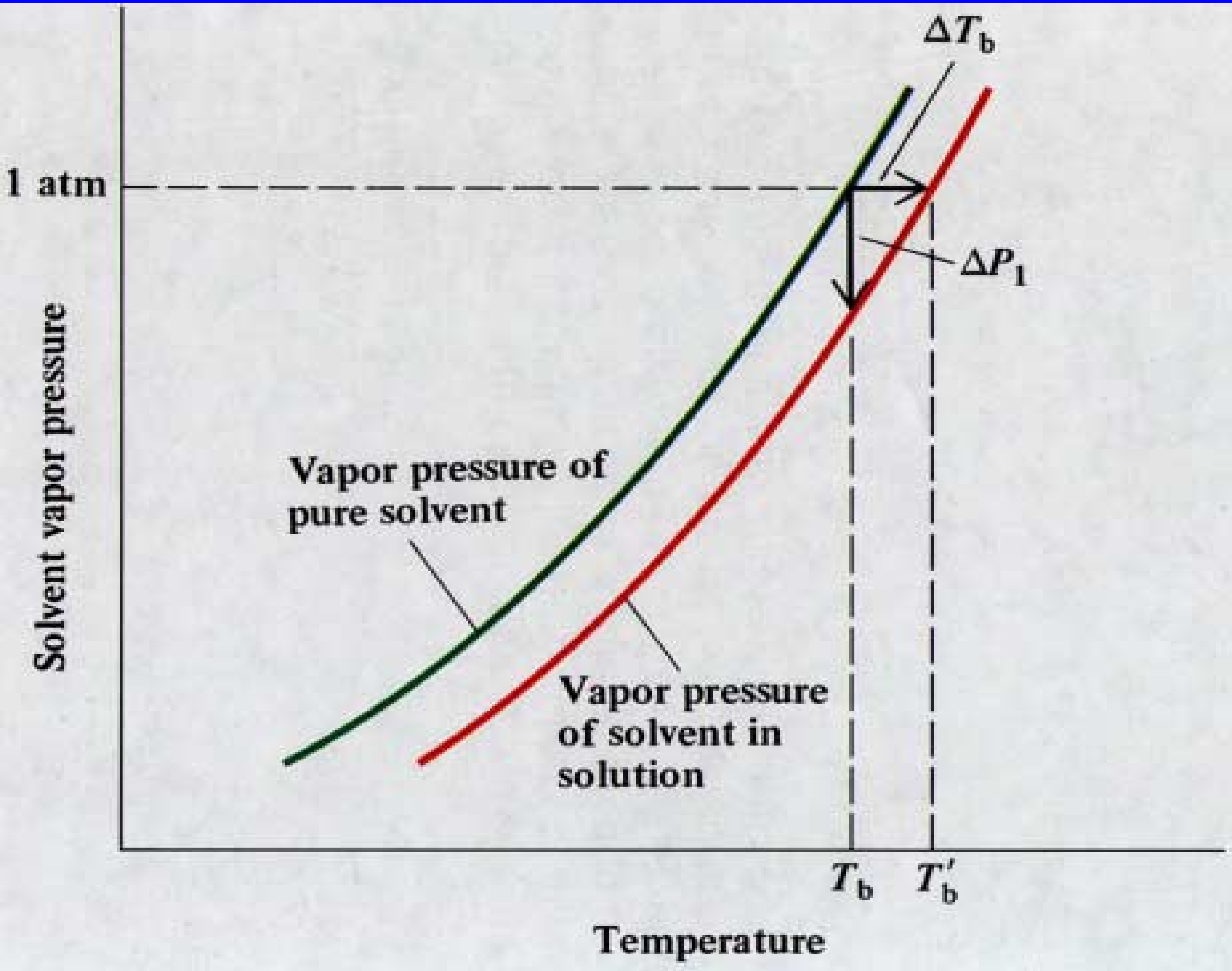
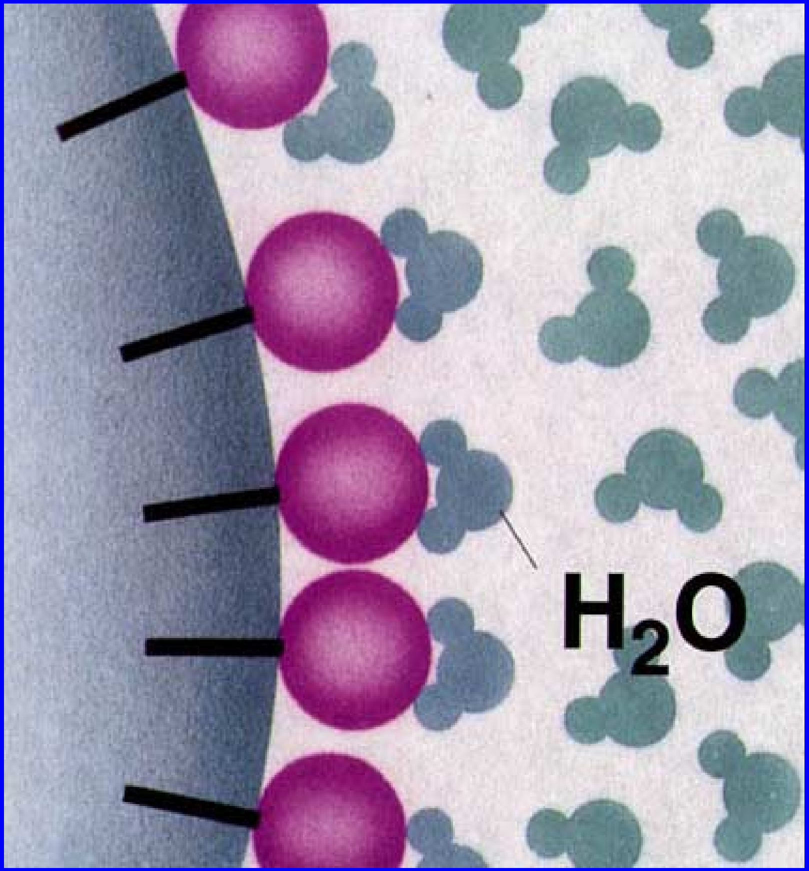


Elevation of the normal b.p.



Super Slurper

Super Slurper

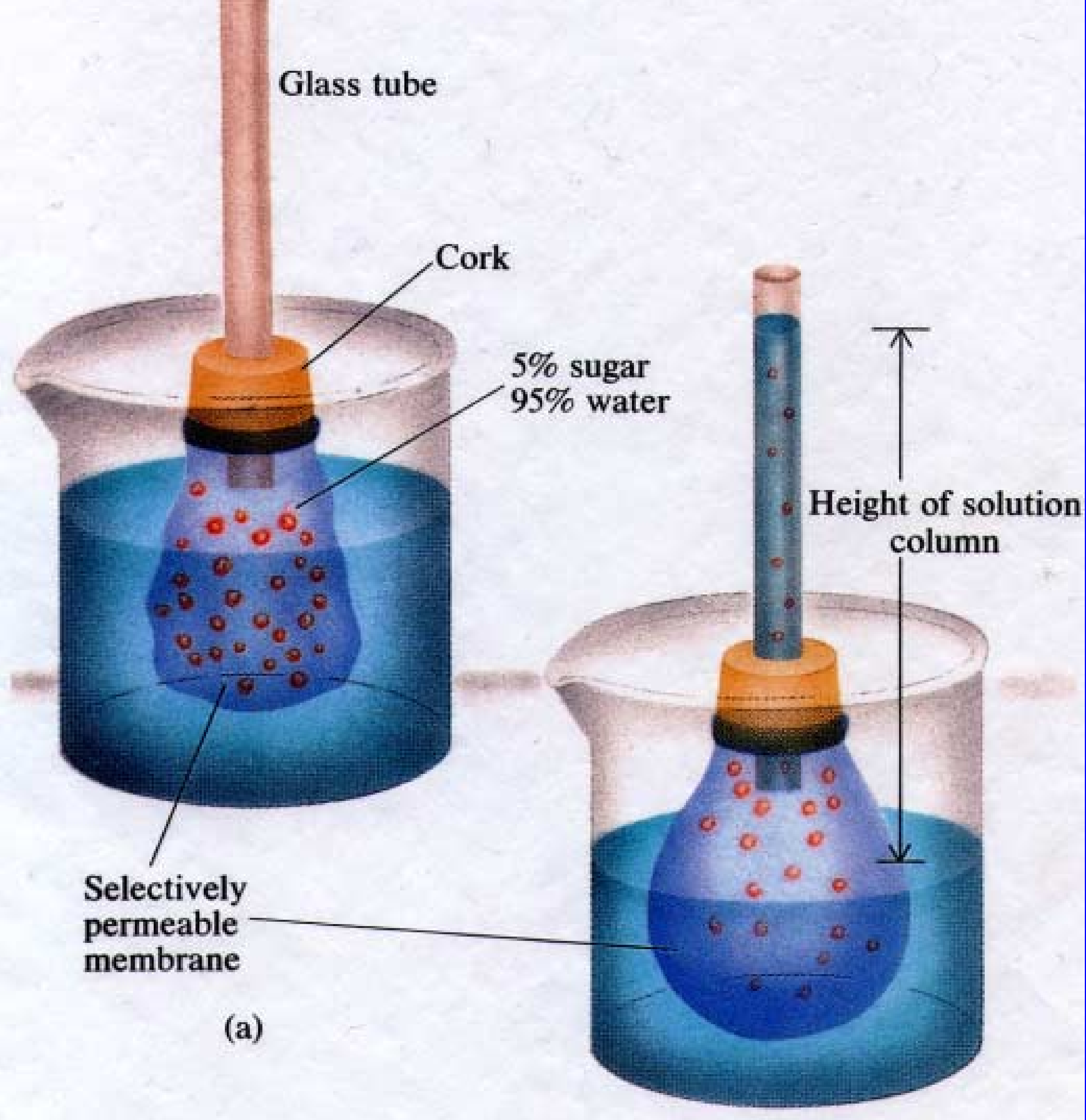


- "Slurper" molecules are polymers with hydrophilic ends that grab onto water molecules.
- Sodium salt of poly(acrylic acid).
- $R\text{-}COO^-$, Na^+

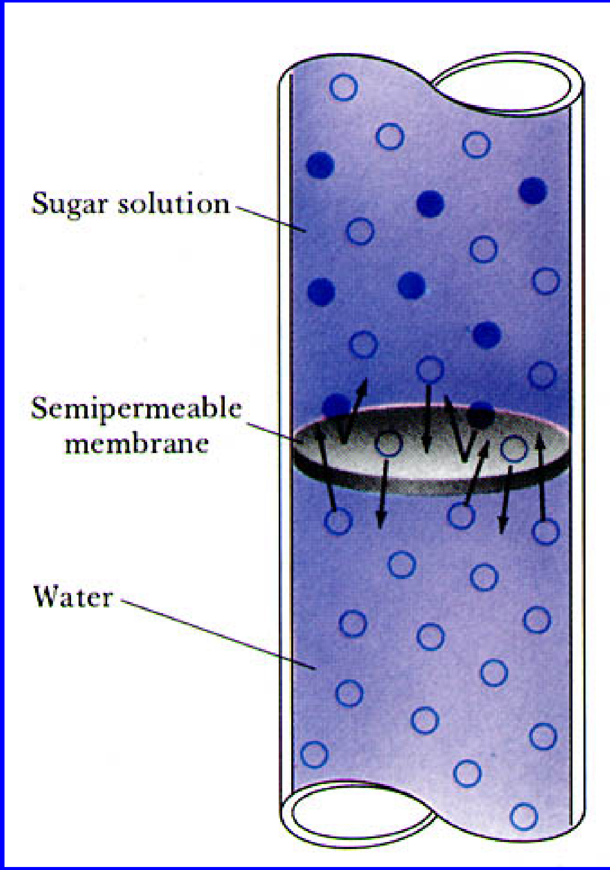
Osmosis/Osmotic Pressure

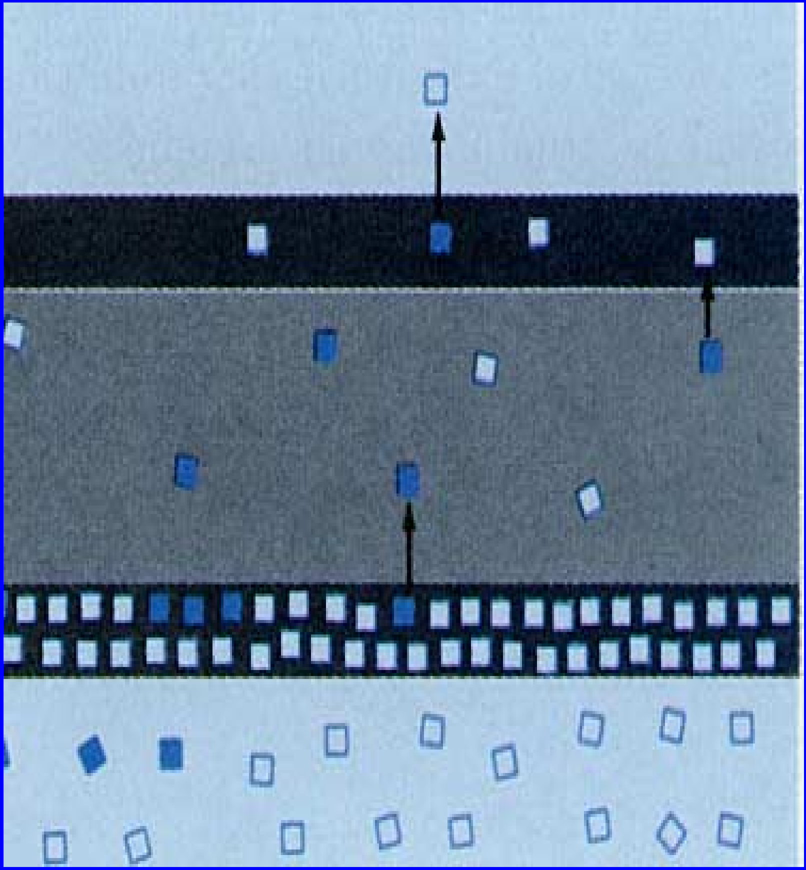
Applications:

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


Glass tube
Cork
5% sugar
95% water
Height of solution
column
Selectively
permeable
membrane
(a)

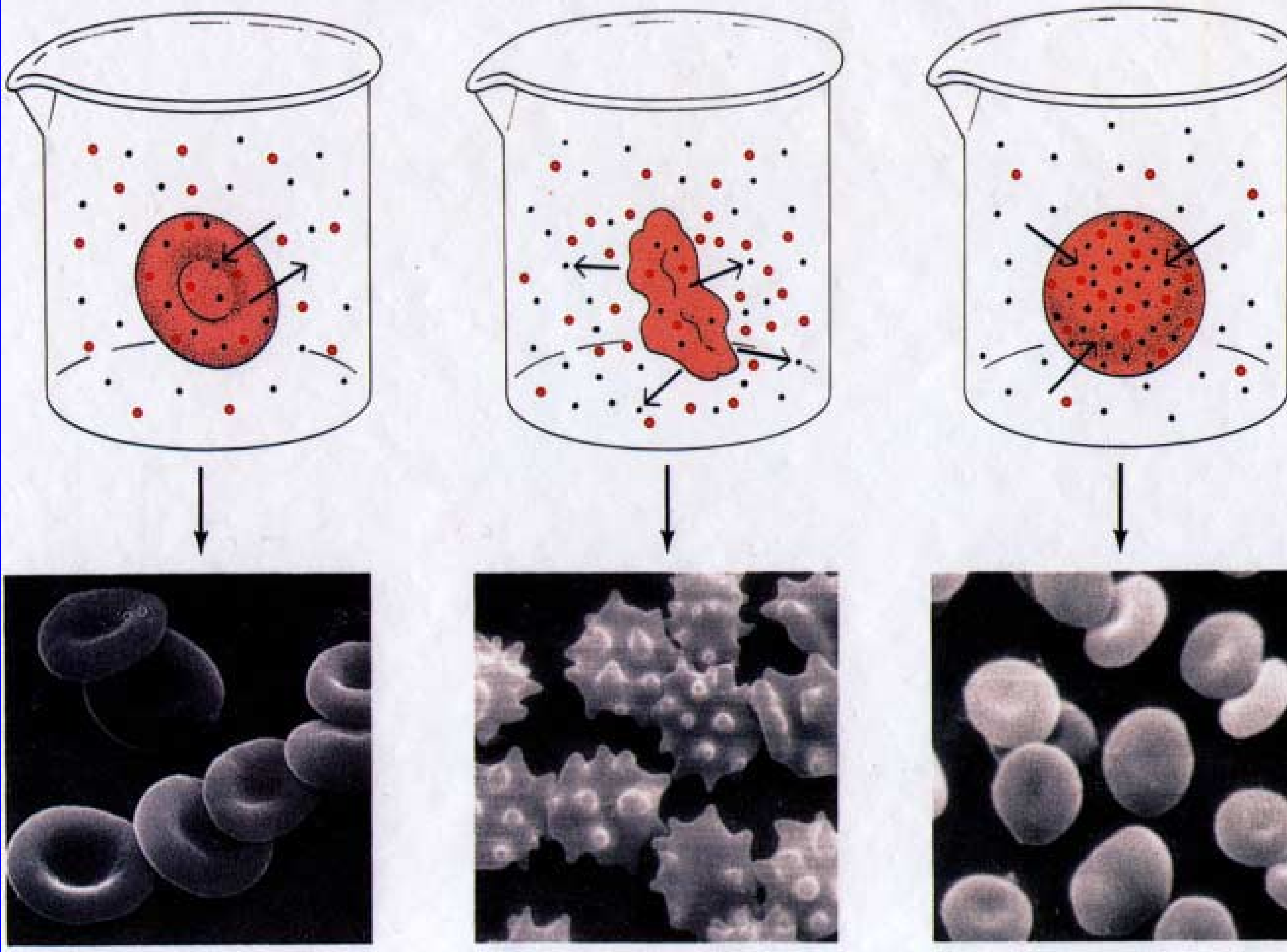
Osmosis/Osmotic Pressure





Osmosis/Osmotic Pressure

- DRIED PLUMS… (used to be"prunes")
- Carrots
- Eggs
- Blood cells



(a) Isotonic solution (b) Hypertonic solution (c) Hypotonic solution

Osmosis/Osmotic Pressure

In dilute solutions:

$\Pi V = n_2RT = [g_2/M_2]RT$

$\Pi = cRT$ where $c \sim$ mol/L

Solubility of hemoglobin in water is 5.0 g/L

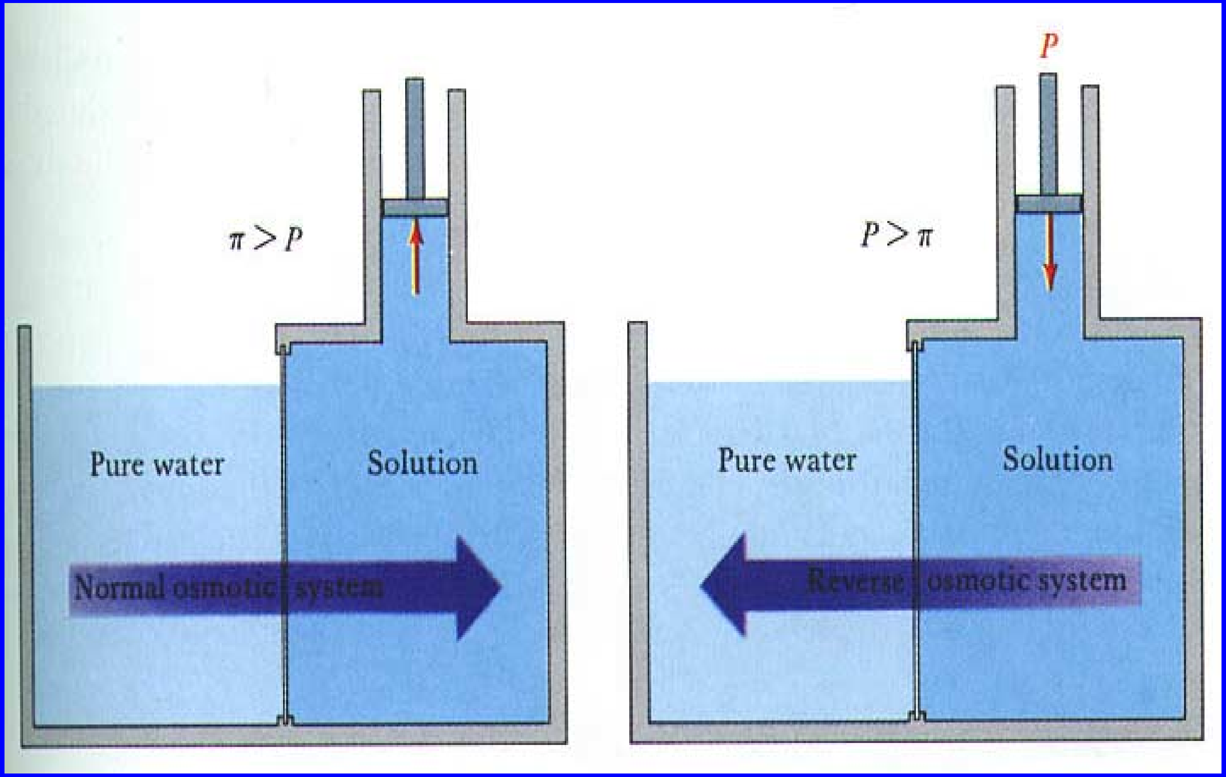
Strategy/LOGIC?

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

$C = \Pi / RT$ = mol/L

MW = [g/L]/mol/L] = g/mol

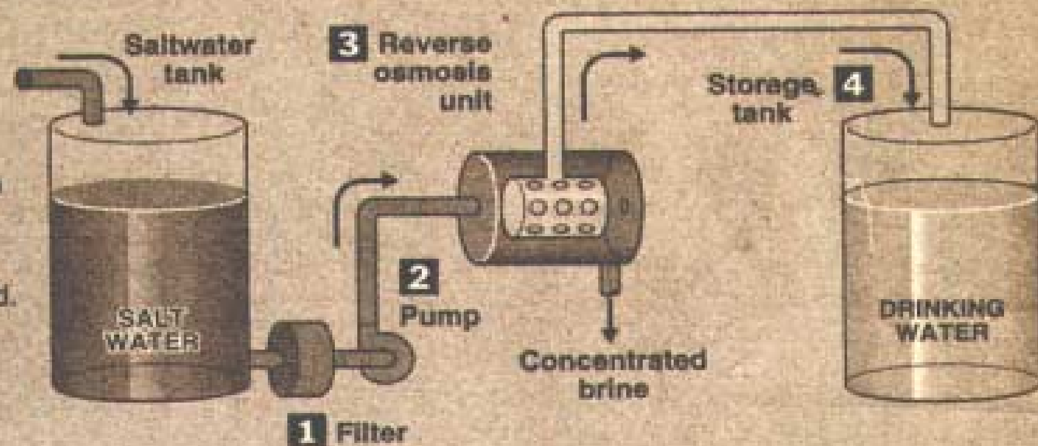
Normal and Reverse Osmotic Systems

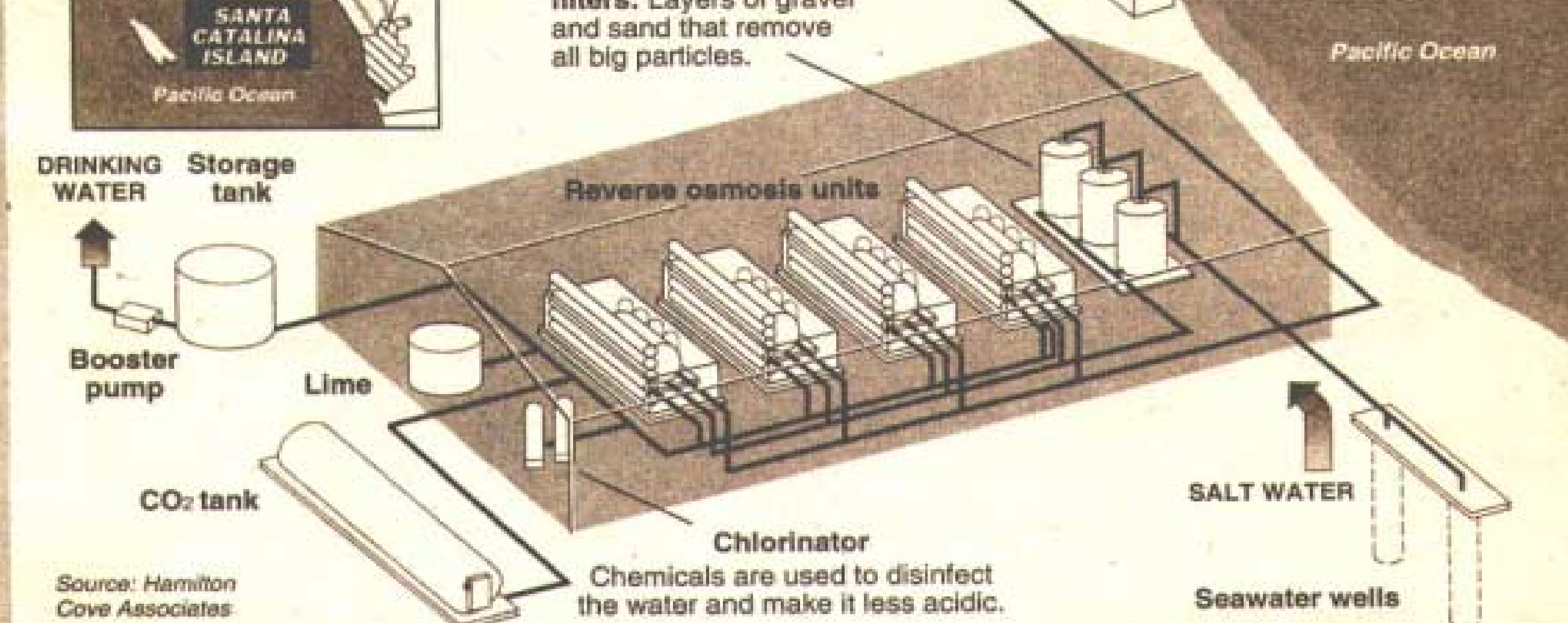


Desalting Water on Catalina Island

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.





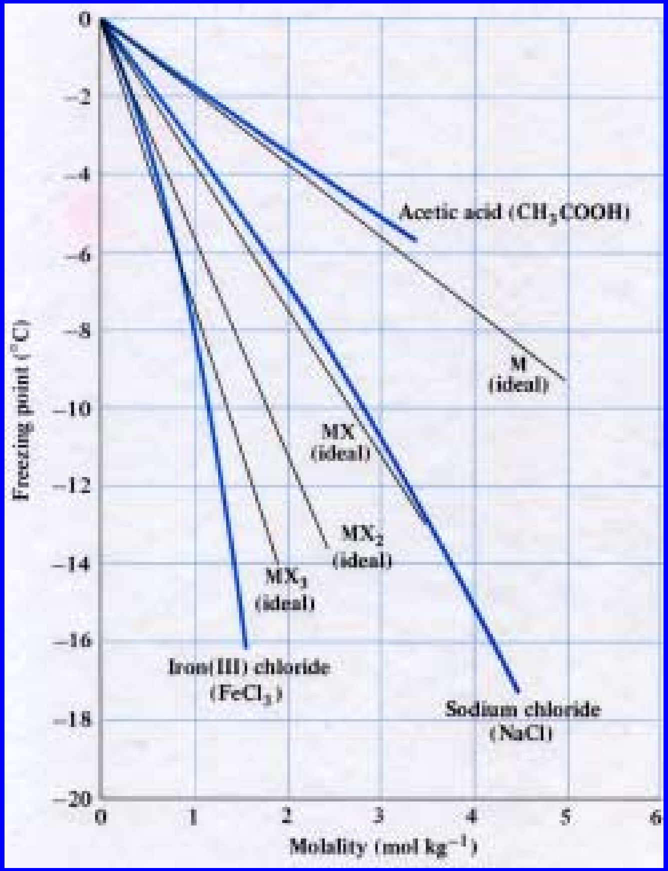
Source: Hamilton Cove Associates

Example

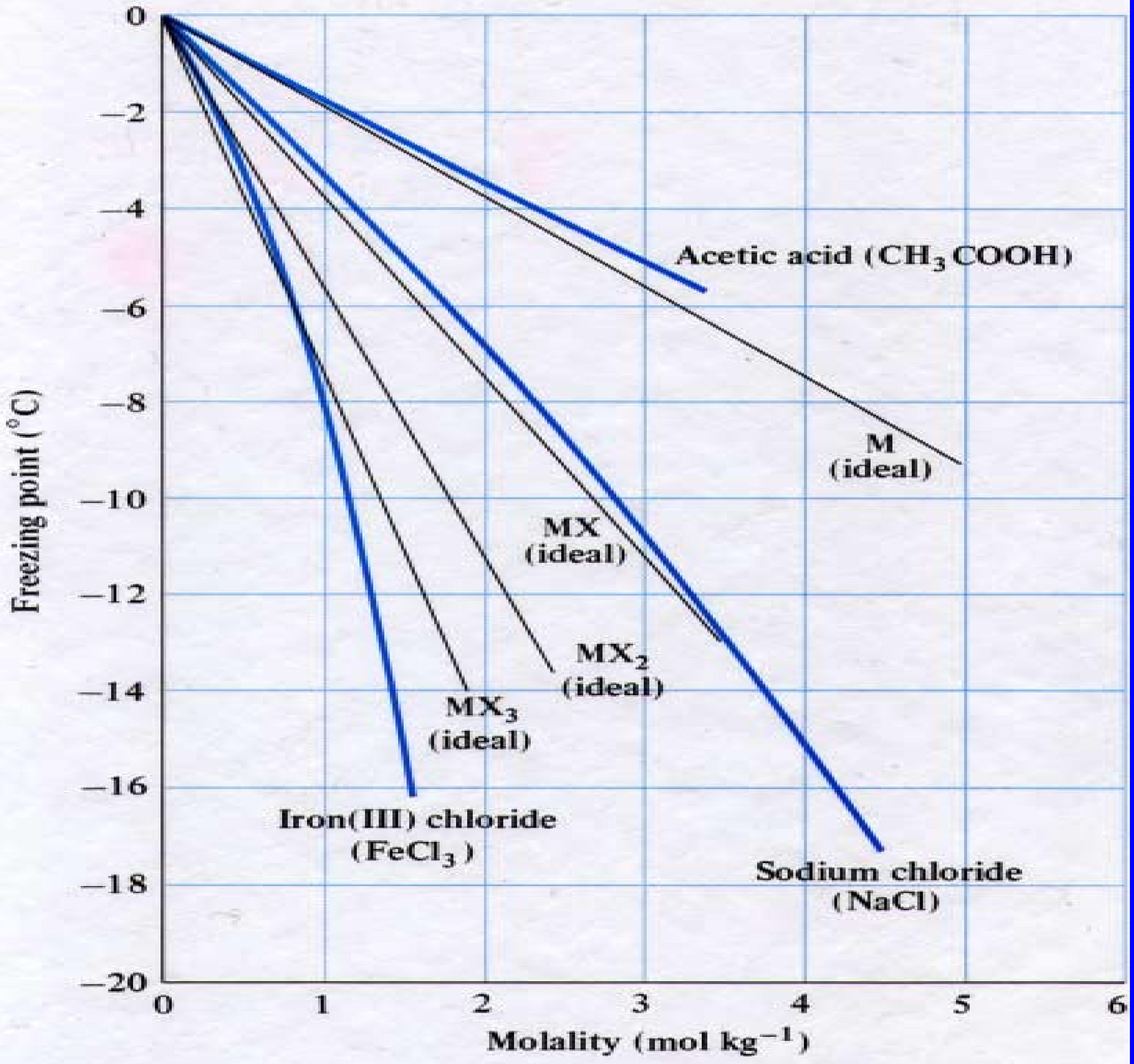
Estimate the “back pressure” needed to obtain pure water from sea water by “reverse” osmosis.

Strategy/LOGIC?

Van't Hoff i-Factor



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



Acetic acid (CH_3COOH)
M
(ideal)
MX
(ideal)
MX_2
(ideal)
MX_3
(ideal)
Iron(III) chloride
($FeCl_3$)
Sodium chloride
(NaCl)
Freezing point (°C)
0
−2
−4
−6
−8
−10
−12
−14
−16
−18
−20
0
1
2
3
4
5
6
Molality (mol kg^{-1})

Van't Hoff i-factor

$$i = \frac{\Delta T_{electrolyt}}{\Delta T_{nonelectro}}$$

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

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

$\Pi = icRT$ (osmotic pressure)

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!

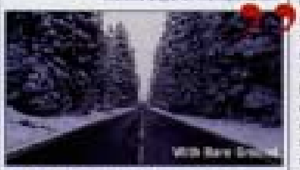
Used by road maintenance crews nationwide

"...Any ice that had formed was peeling off with the plow as if there were no bond to the road..."

Washington State Dept. of Transportation

...This product is amazing and it has saved lives, injuries and property damage...

Indiana Dept. of Transportation



Many Highway Departments prefer Bare Ground to salt.

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

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 by-products 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 snow from sticking. You can also forget about tickets for unshoveled sidewalks.

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.

Beat the snow. Stock up now on our no-risk guarantee. Bare Ground comes in neat, easy-to-store 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!

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?

74.

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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.

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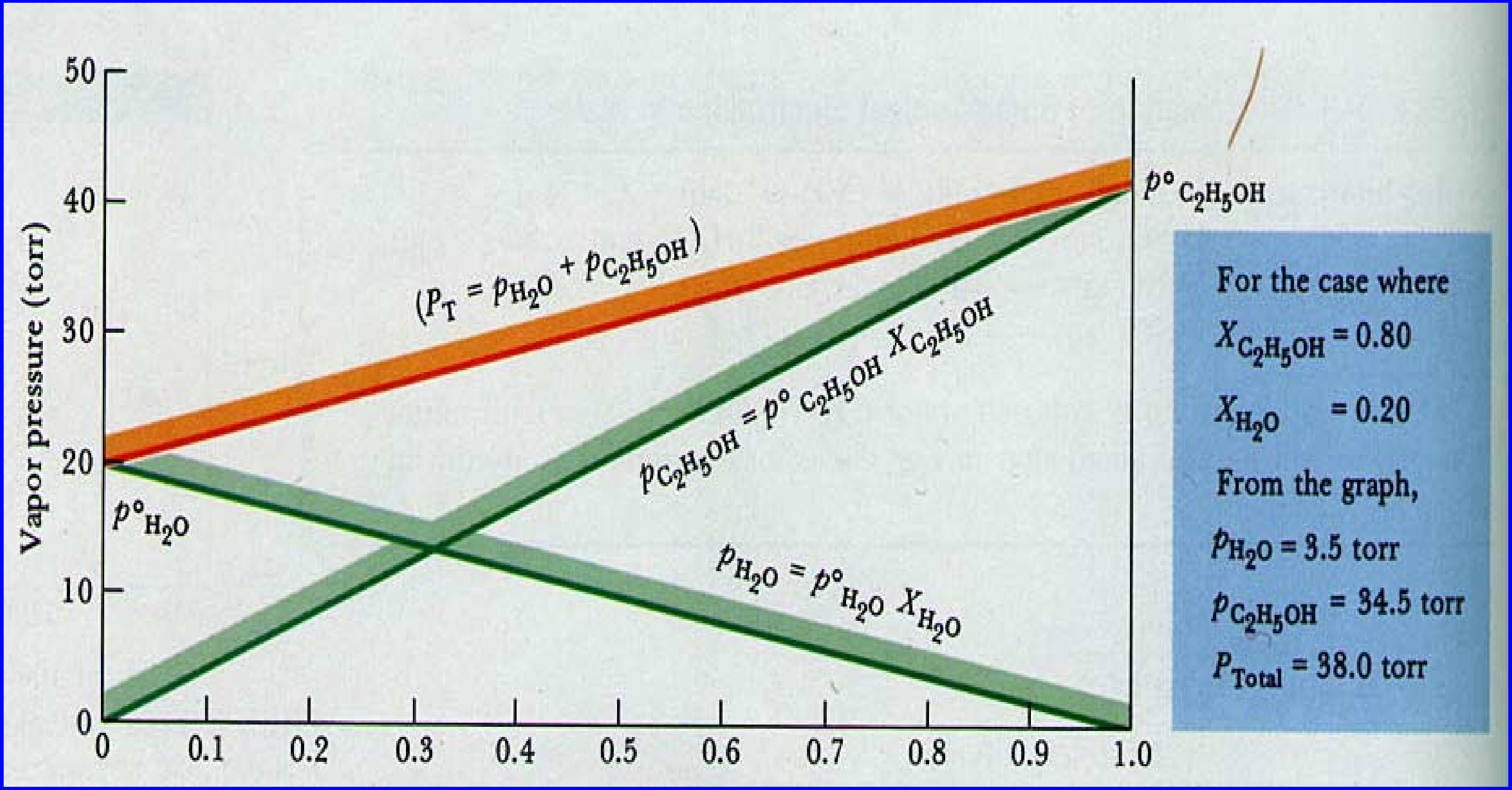
Friday. 23rd.
May.
.1890.

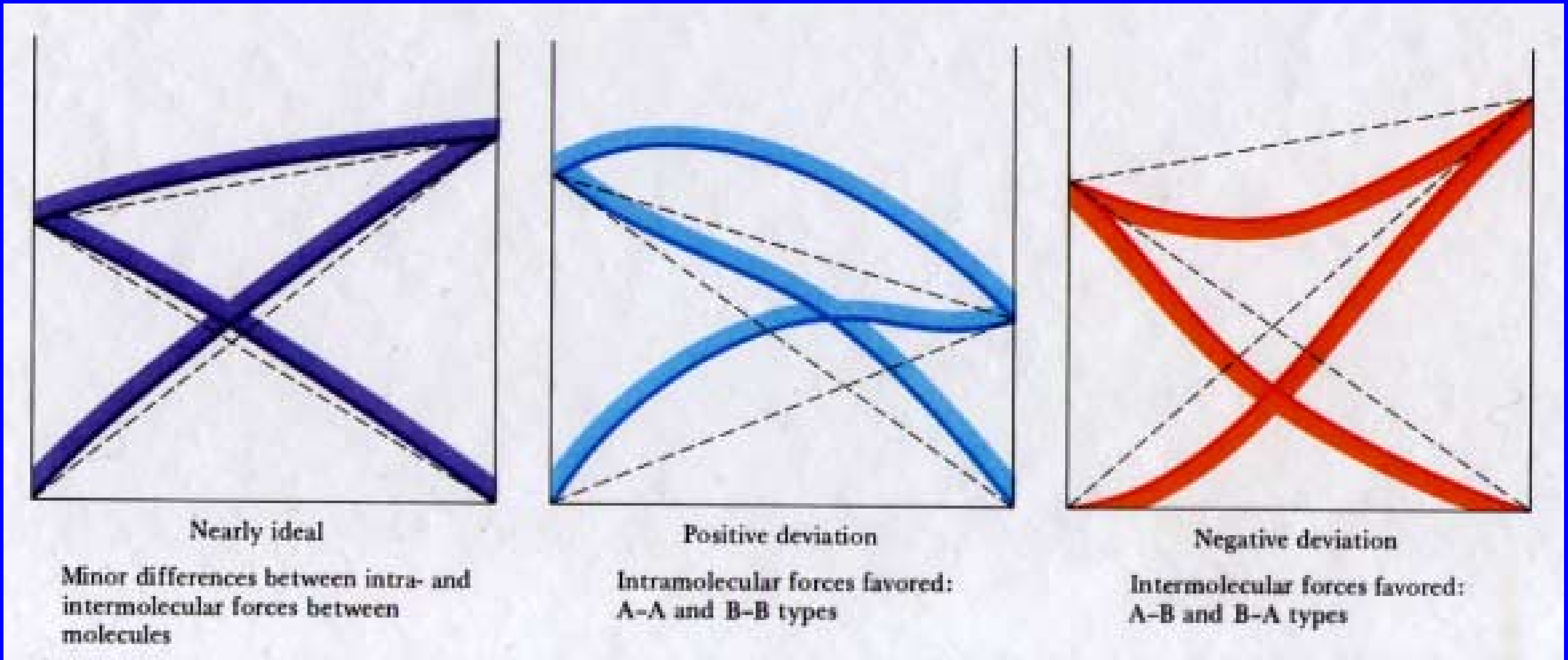
Simple Distillation

- Mixture of benzene and toluene 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

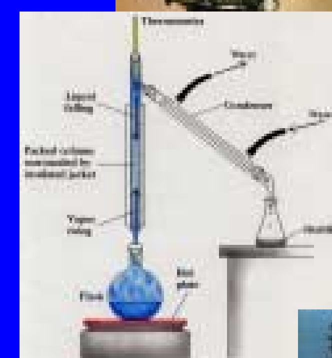


Binary mixtures of Volatile Components

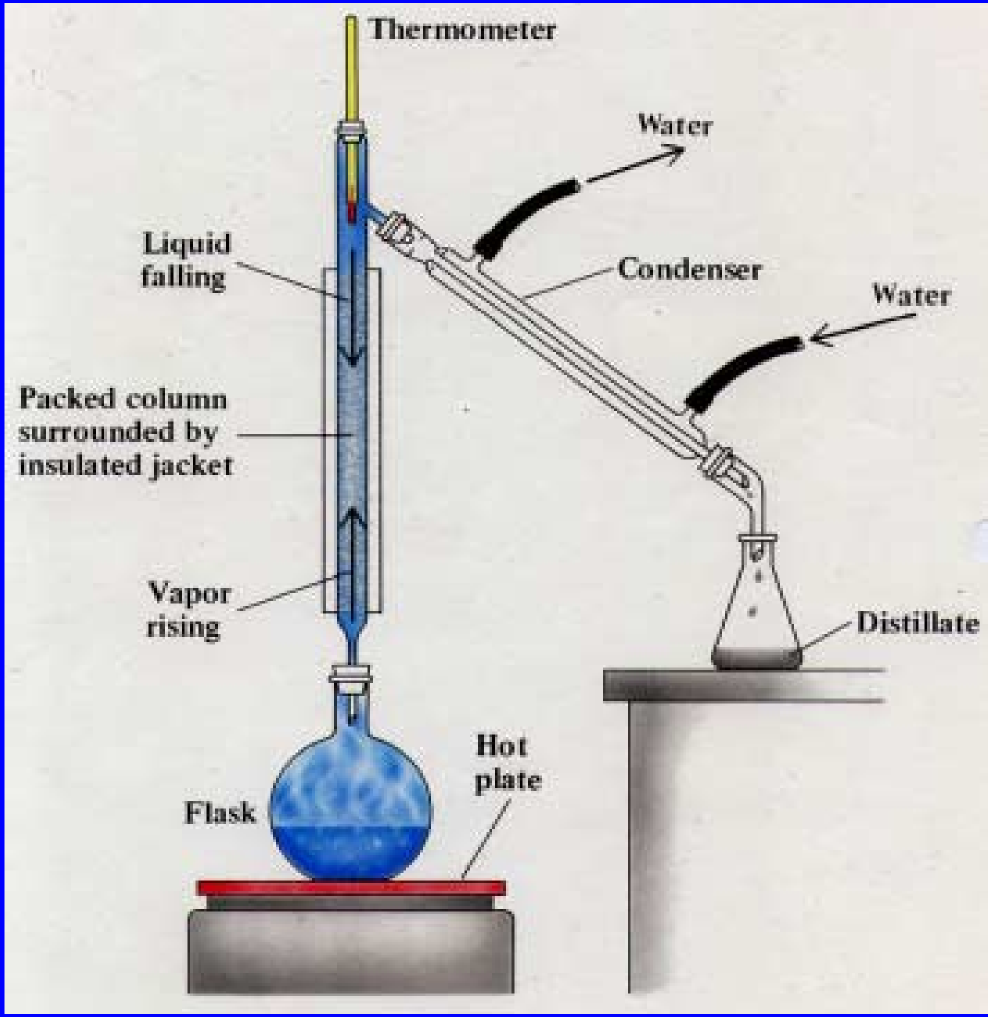


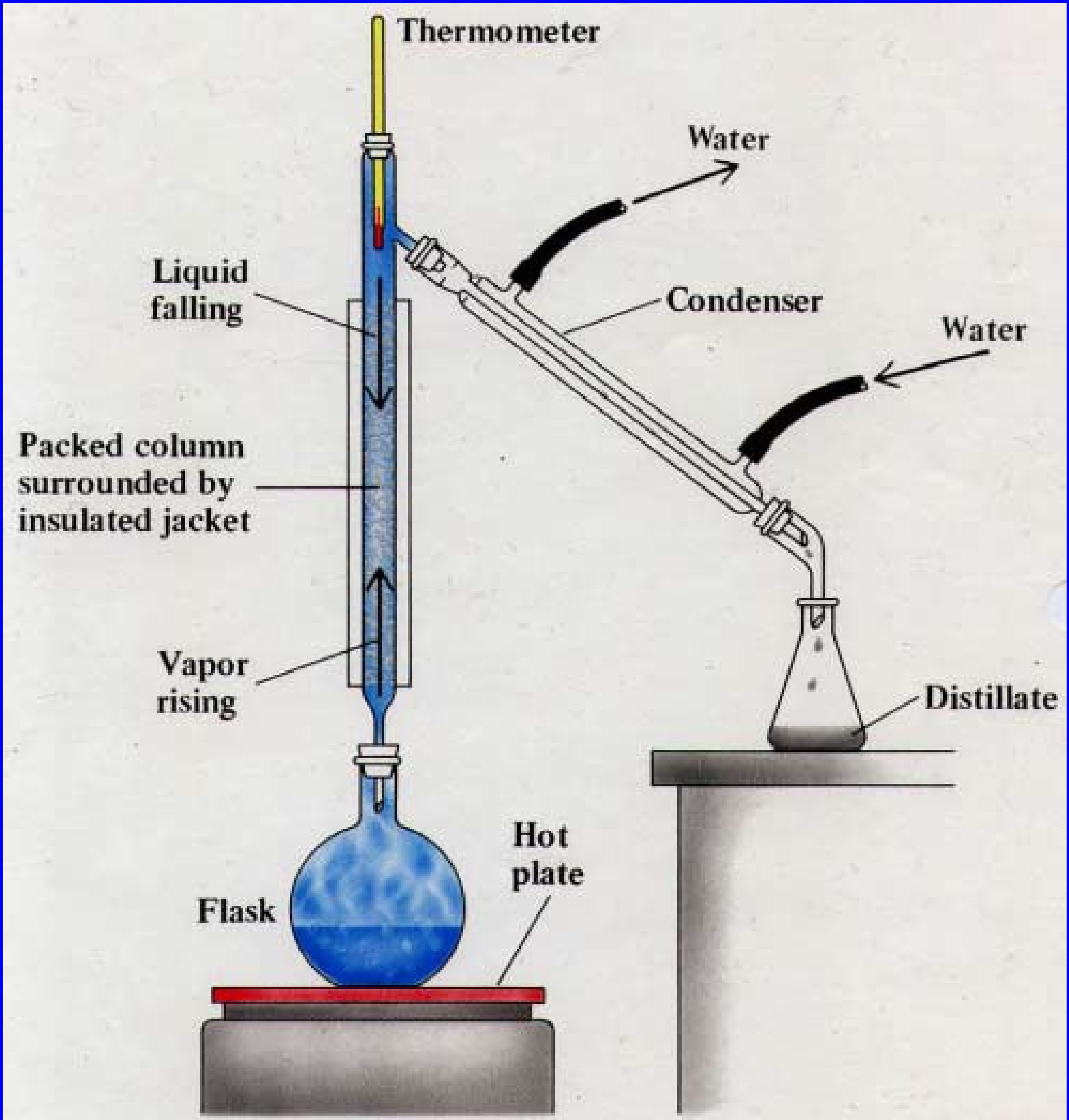
Distillation

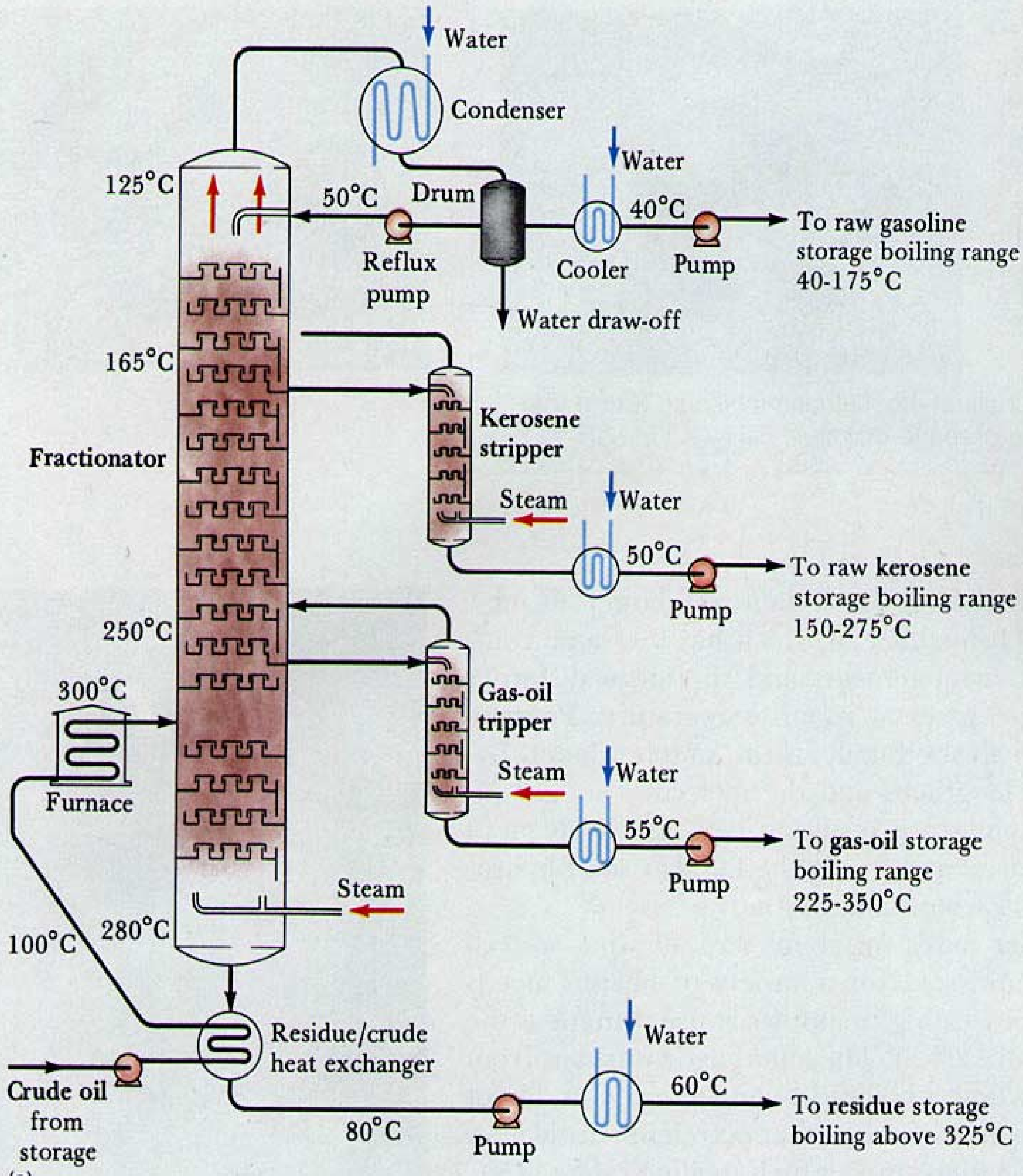
- Simple distillation…
  as recorded by Maxfield Parish
  in his freshman chemistry
  laboratory notebook.
- Fractional distillation…
  on a laboratory scale of 1000mL/h
- Separation of petroleum hydrocarbon mixtures on an industrial scale ~50,000 gal/d



Benzene and Toluene form an ideal solution




Thermometer
Water
Liquid falling
Condenser
Water
Packed column surrounded by insulated jacket
Vapor rising
Distillate
Hot plate
Flask


Water
Condenser
Water
125°C
50°C
Drum
40°C
To raw gasoline
storage boiling range
40-175°C
Reflux
pump
Cooler
Pump
Water draw-off
165°C
Kerosene
stripper
Fractionator
Steam
Water
50°C
To raw kerosene
storage boiling range
150-275°C
Pump
250°C
Gas-oil
tripper
300°C
Furnace
Steam
Water
55°C
To gas-oil storage
boiling range
225-350°C
Pump
Steam
100°C
280°C
Residue/crude
heat exchanger
Water
60°C
Crude oil
from
storage
To residue storage
boiling above 325°C
80°C
Pump