CHEM 206 section 01

LECTURE #7 Fri. Jan.25, 2008

ASSIGNED READINGS:

TODAY'S CLASS: Ch.14.1-14.2…

NEXT CLASS: Ch.14 continues…

(1)

13.4 Summary of Intermolecular Forces

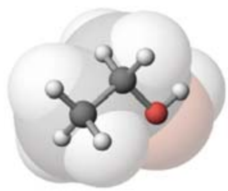
Table 13.3

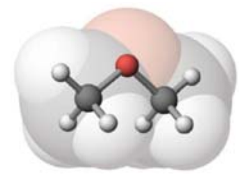
	Type of Interaction	Factors Responsible for Interaction	Example
STRONGEST	Hydrogen bonding, X—H ⋯ :Y	Very polar X—H bond (where X = F, N, O) and atom Y with lone pair of electrons. An extreme form of dipole–dipole interaction	$H_2O \cdots H_2O$
	Dipole–dipole	Dipole moment (depends on atom electronegativities and molecular structure)	H_2O, HCl
	Dipole/induced dipole	Dipole moment of polar molecule and polarizability of nonpolar molecule	$H_2O \cdots I_2$
WEAKEST	Induced dipole/induced dipole (London dispersion forces)	Polarizability	$I_2 \cdots I_2$

(2)

Which intermolecular forces would be operating in a pure sample of… and which would be dominant?

ethanol
C_2H_6O





dimethyl ether
C_2H_6O

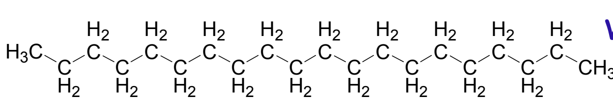
(3)

13.5 Properties of Liquids

Behaviour dominated by how strongly molecules are attracted to one another…

"Total" strength of intermolecular forces:

1. Types of forces: H-bonding, dipole-dipole, dispersion…
2. Extent of molecule over which they can act…



grease ($C_{20}H_{42}$)

actually a solid at RT

Weak forces only…

…but many points of contact between molecules since large!

⇨ IT ALL ADDS UP.

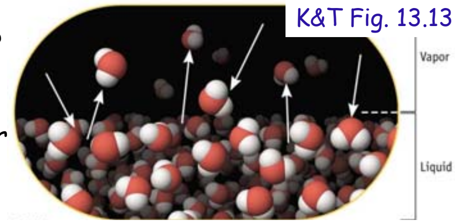
Characteristic physical properties of LIQUIDS:
1. **Ease of vaporization → vapour pressure, boiling point**
2. **Surface tension, viscosity, capillary action**

(4)

Overcoming intermolecular forces: evaporation

Std. enthalpy of vaporization: ΔH^o_{vap}

= energy required for 1 mole of liquid AT ITS BOILING POINT to have sufficient thermal E to overcome their intermolecular interactions & enter vapour phase (at 1 atm)



K&T Fig. 13.13

Stronger intermolecular forces ⇨ harder to evaporate ⇨ larger ΔH^o_{vap}

Table 13.4 • Molar Enthalpy of Vaporization and Boiling Points for Common Substances*

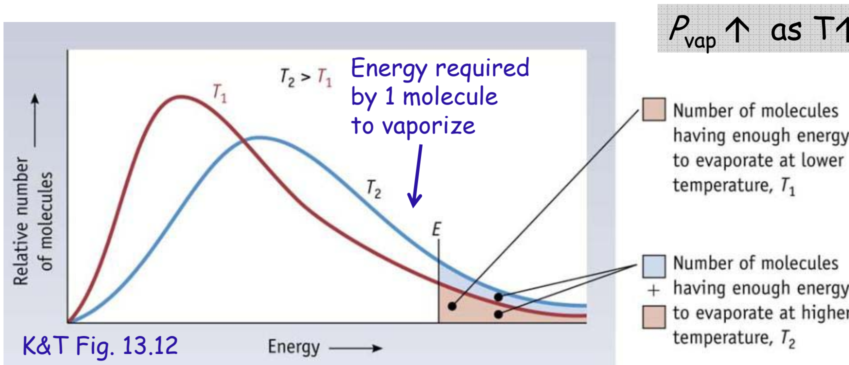
Compound	Molar Mass (g/mol)	ΔH°_{vap} (kJ/mol)†	Boiling Point (°C) (Vapor pressure = 760 mm Hg)
Polar Compounds			
HF	20.0	25.2	19.7
HCl	36.5	16.2	−84.8
HBr	80.9	19.3	−66.4
HI	127.9	19.8	−35.6
NH_3	17.0	23.3	−33.3
H_2O	18.0	40.7	100.0

Check out this table yourselves:

polar *vs.* nonpolar cmpds *and* monatomic *vs.* diatomic elements

Some molecules typically escape liquid: "vapour pressure"

P_{vap} ↑ as T↑



K&T Fig. 13.12

- For liquid in a sealed container: gas & vapour will eventually EQUILIBRATE
⇨ rate of evaporation = rate of condensation

→ Can then measure vapour P at that temp.
→ Characteristic for a given liquid
→ the higher the P_{vap} is at a given T, the more "volatile" the compound is

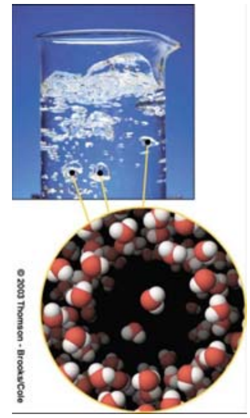
Zumdahl's Fig. 11.10

See K&T Fig.13.15

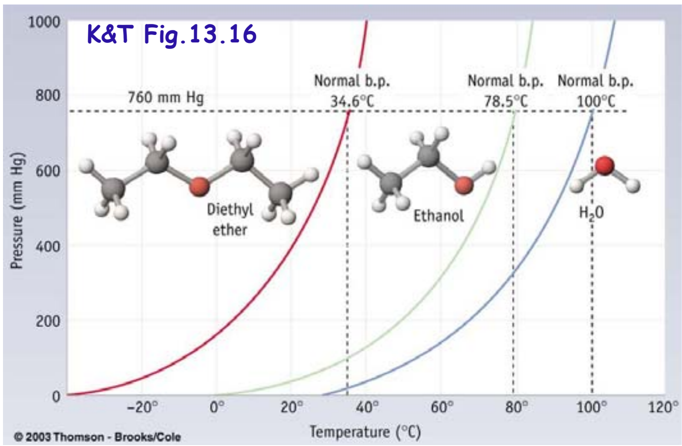
Boiling point: T at which vapour $P = P_{ext}$

When a liquid's vapour P equals the atmospheric P, vapour bubbles form inside the bulk liquid →

KITCHEN WISDOM: leave the lid ON the pot if you want the water to boil more quickly!



K&T Fig.13.17



CHAPTER 14 Solutions & their Behaviour

14.1 Units of concentration

14.2 Solution process

14.3 Factors affecting solubility: pressure & temperature

14.4 Colligative properties

14.5 Colloids

Chapter Goals:

- Learn additional methods of expressing solution concentration
- Understand the solution process
- Understand and use the colligative properties of solutions
- Describe colloids & their applications

If we want to get a feeling for how much solute should dissolve, we need to consider what's going on…

STARTING WITH SECTIONS 14.2, 14.3…

"LIKE DISSOLVES LIKE"

because solute↔solvent interactions are similar in strength to solute↔solute & solvent↔solvent

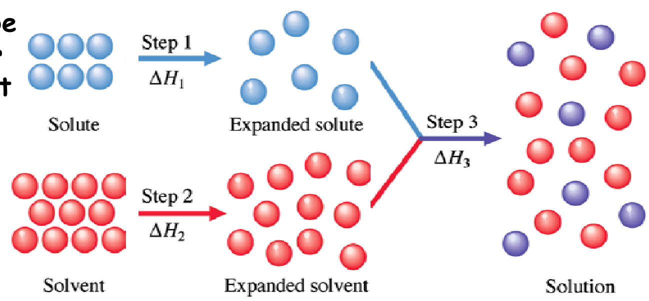
The Solution Process: energetics…

Z's Figure 11.1: SOLUTION FORMATION: hypothetical steps

1) separate solute molecules (overcome intermol. forces) ΔH_1 **endo**
2) separate solvent molecules (overcome intermol. forces) ΔH_2 **endo**
3) combine them (results in new intermolecular forces) ΔH_3 **exo**

overall: "heat of solution" ΔH_{soln}

Could be ionic or covalent

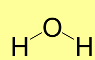


Should consider entropic changes too… but Ch.19 > Ch.14, so they don't

Determining factor: how favourable is hydration/solvation (step 3) ?
ΔH_3 often called enthalpy of hydration (or solvation)
For ionic solutes, depends on: ion charge, ion size, solvent's polarity

Factors affecting solubility: chemical structure

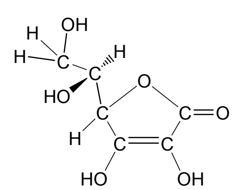
Polar solutes are "hydrophilic"
= water-loving



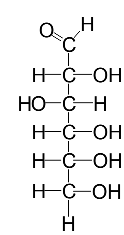
water

(in truth: H_2O is sufficiently attracted to them)

Because water interacts as favourably with them as it does with itself…

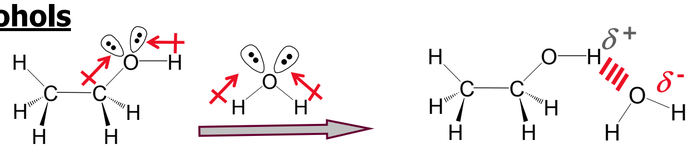


Vitamin C
(ascorbic acid)

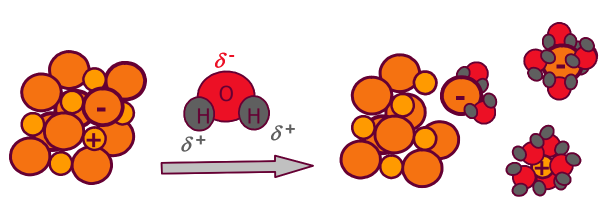


sugars

Alcohols



Salts

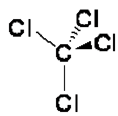


Non-polar molecules are "hydrophobic" (= water-fearing)

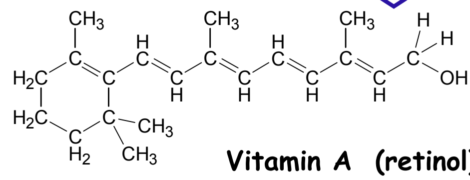
$H_2O \leftrightarrow H_2O$ interactions stronger than $H_2O \leftrightarrow$NP-molecule interactions

⇨ water prefers itself & excludes the NP substance *(NP's attraction too small)*

- **Non-polar solvents DISSOLVE non-polar solutes**



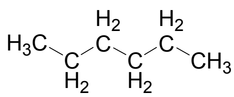
Carbon tetrachloride
(tetrachloromethane)

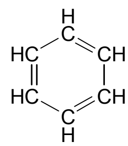


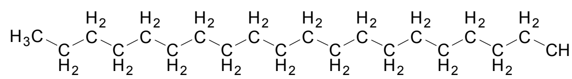
Vitamin A (retinol)

polar OH group not enough to overwhelm non-polar majority

hydrocarbons





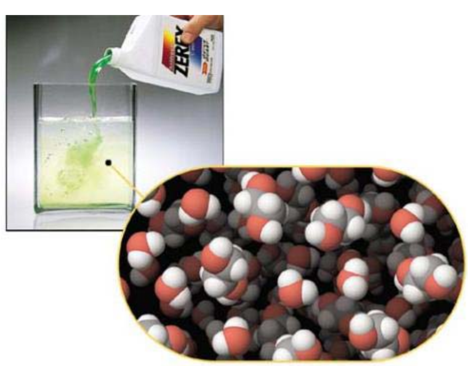


grease ($C_{20}H_{42}$)

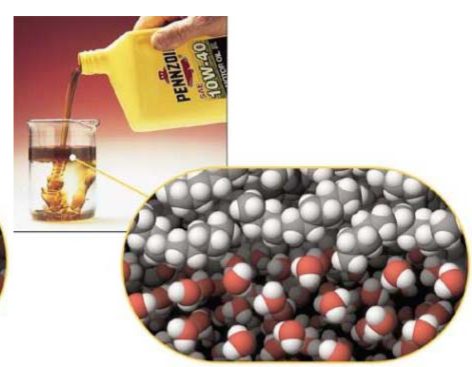
(11)

Enthalpic thinking: "like dissolves like" & liquid miscibility

- **Consider interactions between solute & solvent molecules:**
  if solvent-solvent interactions much stronger than solvent-solute int'ns, solubility will be LOW…and substances might not mix at all.
- **Liquids-liquid mixtures:** if solution forms: liquids are "miscible"
  if separate layers result: "immiscible"



(a) Ethylene glycol ($HOCH_2CH_2OH$), a polar compound used as antifreeze in automobiles, dissolves in water.



(b) Nonpolar motor oil (a hydrocarbon) dissolves in nonpolar solvents such as gasoline or CCl_4. It will not dissolve in a polar solvent such as water, however. Commercial spot removers use nonpolar solvents to dissolve oil and grease from fabrics.

Figure 13.5

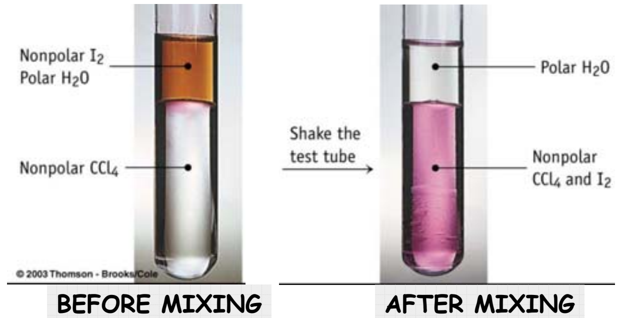
(12)

Like dissolves like: applies to solid solutes too

K&T Fig.14.5
$I_2(s)$ = nonpolar

Low solubility in water (polar)

More soluble in nonpolar solvent



Must consider nature of the solid's "building blocks":

- **ionic solids often quite soluble in water** → hydrated ions
- **polar molecular solids quite soluble in water** → hydrated molecules
- **nonpolar molecular solids can be soluble in nonpolar solvents** → solvated molecules
- **network solids: 3D array of covalent bonds** (one GIANT molecule)
  ***e.g.,* diamond, silica (sand)** (see K&T p.542 briefly)
  ⇨ **essentially not soluble in any solvent**

(13)

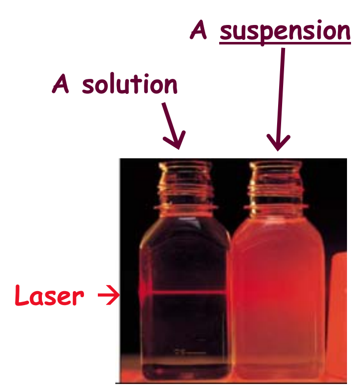
When is a solution NOT really a solution?? (14.5)

Solutions = <u>homogeneous</u> mixtures:	CLEAR (= transparent)
THUS, by definition: no chunks!	NOT cloudy (= turbid)

Colloids (14.5) = suspensions of particles…

CLOUDINESS is due to:

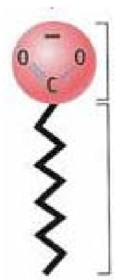
"The Tyndall effect" = light scattering off of suspended particles (even really small ones)



14.5 is filled with practical applications -but not enough class time to cover all of it. Give it a <u>quick</u> read on your own. There are a few slides at the end of today's notes.

Surfactants: "surface-active agents" *e.g.*, detergents

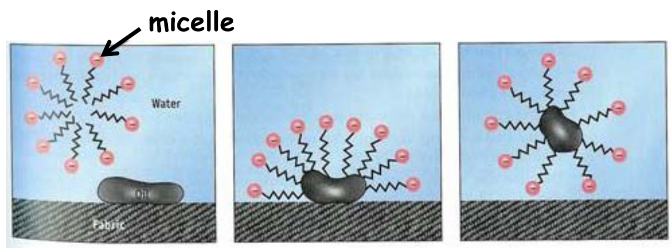
= **amphiphilic substances** *i.e.*, have polar & nonpolar regions
1.) act as "emulsifying agents" (allow immiscible substances to mix)
2.) decrease surface tension of water



HYDROPHILIC POLAR HEAD
Interacts well with water

HYDROPHOBIC NONPOLAR TAIL
Interacts well with fats/oils/greases…
& "tails" of other detergent molecules

- Hydrophobic tails pack together
  ⇨ form water-soluble globules: "micelles"
- Nonpolar cores of micelles can "dissolve" greases…



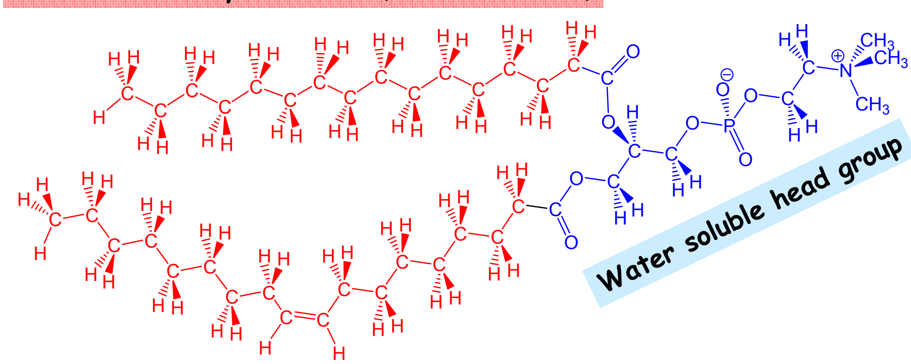
K&T Figure 14.21

(15)

This is not true dissolution, only suspension (**more in 14.5**)

Amphiphilic substances are great emulsifiers
e.g., lecithin: a phospholipid in eggs, mustard…

Fat-soluble fatty acid tails (varied structures)



Stabilizes oil-vinegar "emulsions" (oil droplets <u>suspended</u> in water)
- essential for making a vinaigrette salad dressing stay mixed

(16)

Interested in the science involved in cooking? Check out:
***On Food and Cooking: the Science and Lore of the Kitchen*, by Harold McGee.**

How much solute is dissolved? QUANTITATIVE…

14.1 Units of concentration: quantifying solute

MOLARITY = mol / L = *moles* of solute **per *litre* of solution**
(M)

$C = \frac{n}{V}$

MOLALITY = mol / kg
(m)

= *moles* of solute ***per kg* of solvent**
* mass is unaffected by temperature *
→ useful unit when analyzing melting & boiling behaviour of solutions

PARTS PER MILLION = mg / kg
(ppm)

i.e., $\frac{\text{mass units of solute}}{10^6 \text{ mass units of solution}}$

= *mg* of solute ***per kg* solution**
* used for natural waters *
& other very dilute solutions
also: parts per billion (ppb)
1 ppb = 1 μg solute/kg soln

(17) *We will see these in problems. Practice on your own !*

Fractional composition *(sum of parts = whole)*

MASS PERCENT = $\frac{m_A}{m_A + m_B + m_C + \ldots} \times 100\%$
(wt %)

= *mass* of solute A
per total mass soln

$$\frac{m_A}{m_{TOTAL}} + \frac{m_B}{m_{TOTAL}} + \frac{m_C \ldots}{m_{TOTAL}} = 1$$

Often seen in commercial products
e.g., vinegar = 5% acetic acid… (other 95% is water!)

MOLE FRACTION = $\frac{n_A}{n_A + n_B + n_C + \ldots}$
(χ_A)

= *moles* of solute A
per total moles soln

$$\chi_A + \chi_B + \chi_C + \ldots = 1$$

(18) *Useful soon for predicting solutions' vapour pressures.*

Example: mass percent & molality… & freezing pt?

The electrolyte in car batteries (12 V lead storage batteries) is a 3.75 M sulfuric acid solution with a density of 1.230 g/mL. Calculate the mass percent and molality of the sulfuric acid. *Hint: solvent is water…* H_2SO_4 MM=98.07 g/mol

ANS:

- **Molality** ($n_{solute}/kg_{solvent}$) is linked to density and molarity…start there.

1 L has mass of 1230 g = 1.230 kg total = $m_{solute} + m_{solvent}$

and

3.75 M means 1 L contains 3.75 mol H_2SO_4 = 367.8 g H_2SO_4

thus

$m_{solvent}$ (in 1L soln) = 1.230 – 0.3678 kg = 0.8623 kg solvent

$$\Rightarrow \text{Molality} = \frac{3.75 \text{ mol } H_2SO_4}{0.8623 \text{ kg } H_2O} = 4.35 \text{ mol/kg} = 4.35\ m$$

- **Mass %:** $100\% \times \frac{m_{solute}}{m_{solution}} = \frac{367.8\text{g } H_2SO_4}{1230\text{g total}} \times 100\% = 29.9\% \text{ (wt) } H_2SO_4$

What is the battery acid's freezing point? Next class…
(…car won't start if battery is frozen…)

(19)

ASSIGNED READINGS:

BEFORE NEXT CLASS:

Read: Ch.14.1-14.2

+ WORK ON conc. unit problems

Review: molarity (Ch.5), mass % (Ch.1&3?)

practice interconverting concentration units

Next class: Ch.14…

(20)

Extra concentration unit question: mass %, mass fraction

Vinegar is a 3-5% (wt %) solution of acetic acid in water. How can we prepare such a solution starting with what chemical companies sell, *i.e.*, glacial acetic acid (17.4 M)?
(Acetic acid MM=60.05 g/mol; water MM=18.02 g/mol)
And once it's made: what is its concentration in molarity?

ANS: arbitrarily decide to make 100g of it (since not specified)
To prepare a 5% (wt) solution:
- carefully add 5 g of glacial acetic acid to 95 g of H_2O, & mix…

To calculate molarity: $c = n_{solute}/V_{soln}$
- Need to find: #moles acetic acid AND total volume of solution

1.) #mol acetic acid in 100g soln = (5g) / (60.05g/mol) = 0.0833 mol

2.) To find V_{soln}: need density (don't have); so, make an assumption
→ assume solution has same density as water (1.00g/mL)
→ then can convert total mass of 100g to volume = 100mL

(21) THUS: molarity = (0.0833 mol solute) / (0.1L) = 0.8 M *1 SF*

Extra slides about colloids (14.5)

For your information…

FYI -- 14.5 Colloidal Dispersions (or, "colloids")

= stable suspensions of tiny **particles** in a dispersing medium
or very high MM molecules (proteins, starches) **dissolved in medium**

Table 14.6 • Types of Colloids Don't get hung up on details here…

Type	Dispersing Medium	Dispersed Phase	Examples
Aerosol	Gas	Liquid	Fog, clouds, aerosol sprays
Aerosol	Gas	Solid	Smoke, airborne viruses, automobile exhaust
Foam	Liquid	Gas	Shaving cream, whipped cream
Foam	Solid	Gas	Styrofoam, marshmallow
Emulsion	Liquid	Liquid	Mayonnaise, milk, face cream
Gel	Solid	Liquid	Jelly, Jello, cheese, butter
Sol	Liquid	Solid	Gold in water, milk of magnesia, mud
Solid sol	Solid	Solid	Milk glass, alloys (for example, steel or brass)

familiar

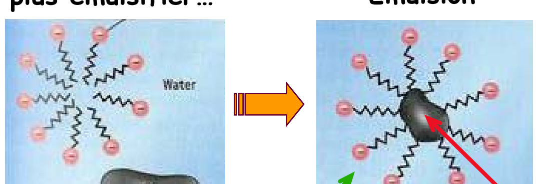
Particles are large enough to see, but too small to settle out

2 general kinds of colloids (classified based on dispersed phase):
1. **Hydrophilic colloids:** strong attractions to water (*e.g.,* H-bonds)
2. **Hydrophobic colloids:** *not…more detail soon.*

Stable emulsions are colloidal suspensions, not solutions

Mix oil & water, plus emulsifier… **Emulsion**

K&T Figure 14.21



Hydrophilic outside
- Interacts well with H_2Os
- Dissolved in the water
- Optically:
  homogeneous
  looks similar to water

Hydrophobic inside
- NOT in contact with H_2Os
- NOT dissolved in the water!
- Optically:
  very different refractive index
  ⇨ scatters light

Make your own stable emulsion: pernod + water = pastis
(instantly…) colourless colourless milky…

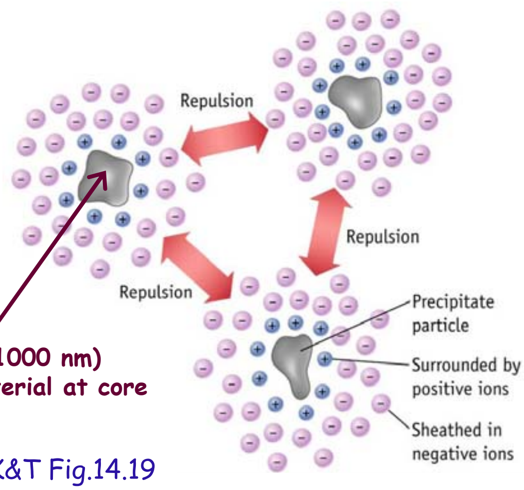
Why do colloidal particles stay separated (∴ suspended)?

SHOWN HERE:

A hydrophobic colloid

→ **Forces between particles dispersing medium & too weak for dissolution**

e.g.,
highly insoluble salts
finely divided metals
soil particles



Tiny particle (1-1000 nm) of suspended material at core

K&T Fig.14.19

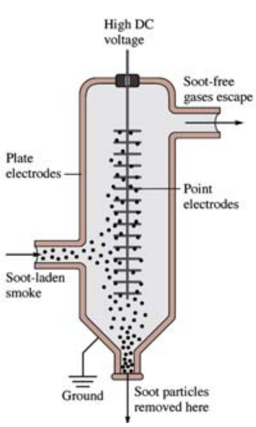
- Colloidal particles evidently "coated" with dissolved ions
  (even if they aren't charged themselves…quite interesting)
- Outer surfaces all same charge ⇨ **ELECTROSTATIC REPULSION**

To "break" a colloidal suspension

REMOVE THE SURFACE CHARGES ON PARTICLES!

- ONE WAY = **Add an electrolyte** (↑ dissolved ions…)
  → surface ions attracted elsewhere, not just to particles
  → removes surface charge → no longer repel each other

RESULT: "Coagulation" = pptn of suspended material



What if you can't <u>add</u> ions?

e.g., not dealing with a liquid…

Zumdahl's Figure 11.25:
REMOVING SOOT FROM SMOKE
(colloidal dispersion of dust in air)
in a smokestack

- charged plates attract colloidal particles
- impact knocks ions off particles
- particles aggregate & ppt as solid soot