

Intermolecular forces and interactions
are all electrostatic - these are weak-but
important

covalent bond $\sim 400 \text{ kJ/mol}$

intermolecular interaction $\sim 10-50 \text{ kJ/mol}$

4 types of intermolecular interactions

strong		Ion / polar molecule
		polar / polar
		polar / nonpolar
weak		nonpolar / nonpolar

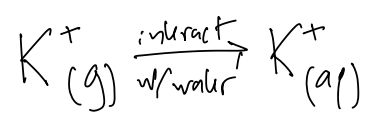
Ion/dipole interaction - requires ion and polar
~~molecule~~ molecule

- Charge of ion, polarity of
molecule, distance ~~at~~ are
what strength of interaction
depends on

dissolved ionic compounds in water have
polar H_2O interacting w/ ions



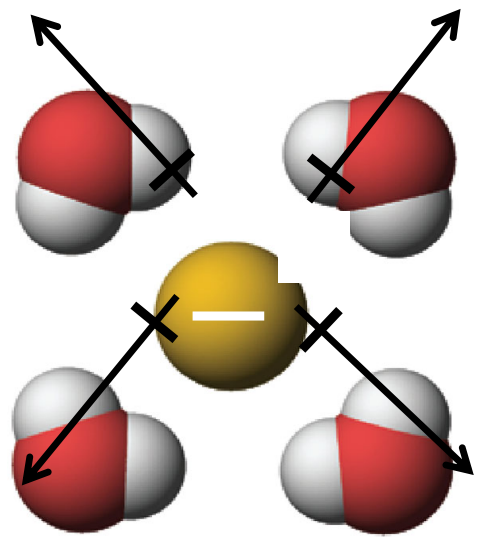
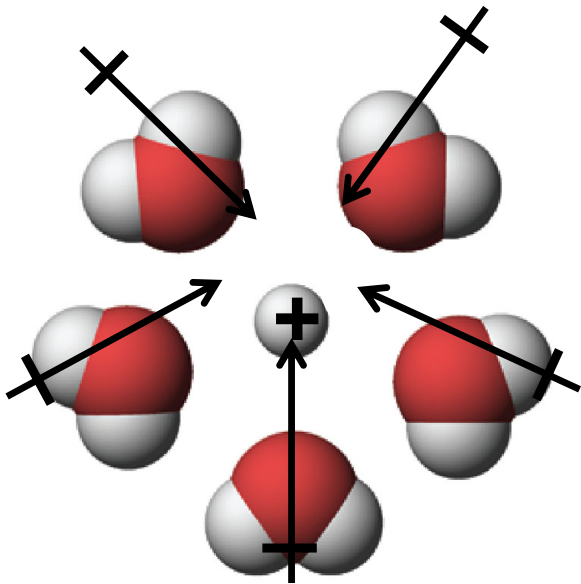
ΔH of solvation or hydration - for process of
interacting ion
w/ H_2O molecules



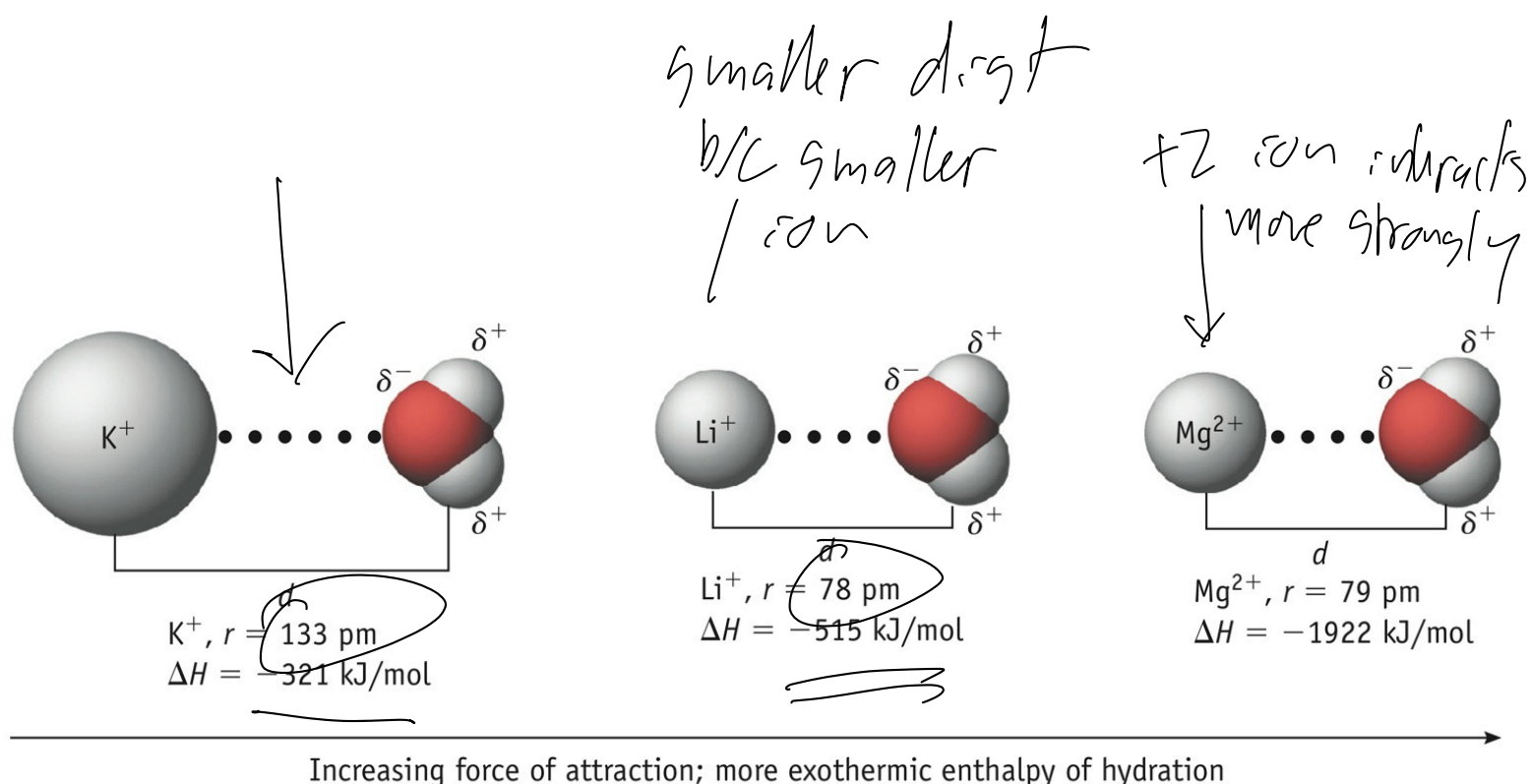
$$\Delta H_{\text{solv}} = -321 \text{ kJ/mol}$$

* typically multiple H_2O
molecules interact w/ one ion

Solvation of Ions



When a *cation* exists in solution, it is surrounded by the *negative* dipole ends of water molecules.
When as *anion* exists in solution, it is surrounded by the *positive* dipole ends of water molecules.



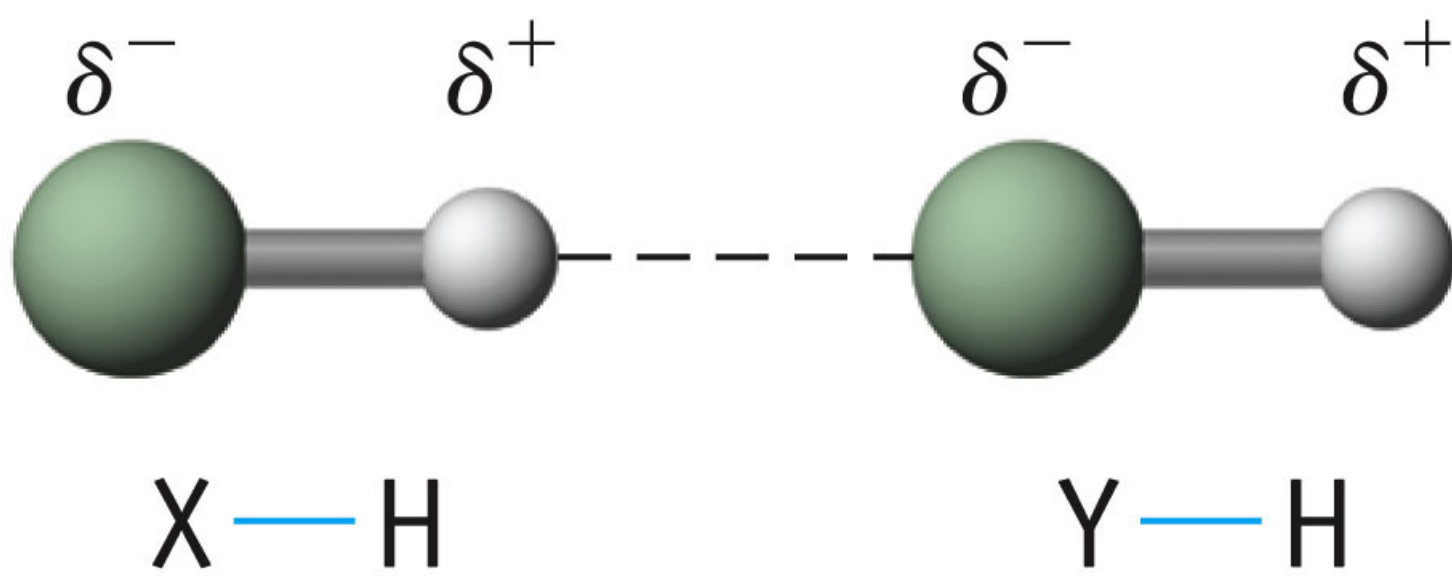
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So solubility of ionic compounds
competition b/w stability from interaction
with counterion vs stability from interaction
with water

Dipole/Dipole interaction - between
2 polar molecules

- could be 2 of same polar molecule
- could be 2 different polar molecules

For a single substance w/ polar molecules
strength of dipole/dipole interactions
will be reflected in liq $\rightarrow$ gas phase change



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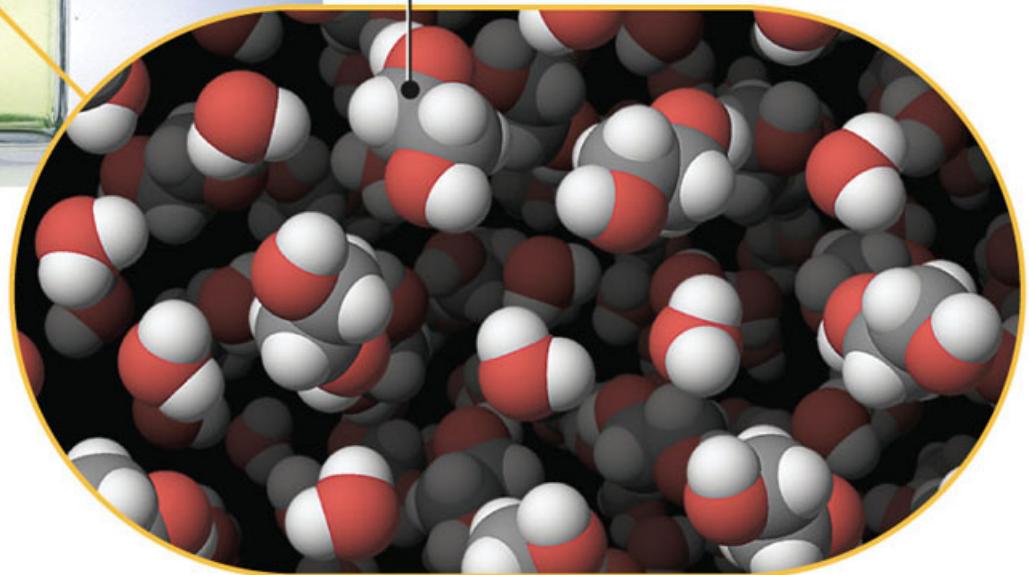
Miscibility of liquids is related to dipole-dipole interactions

W-W interactions

EG-EG interactions

W-EG interactions

↓
these cause
mixing to happen



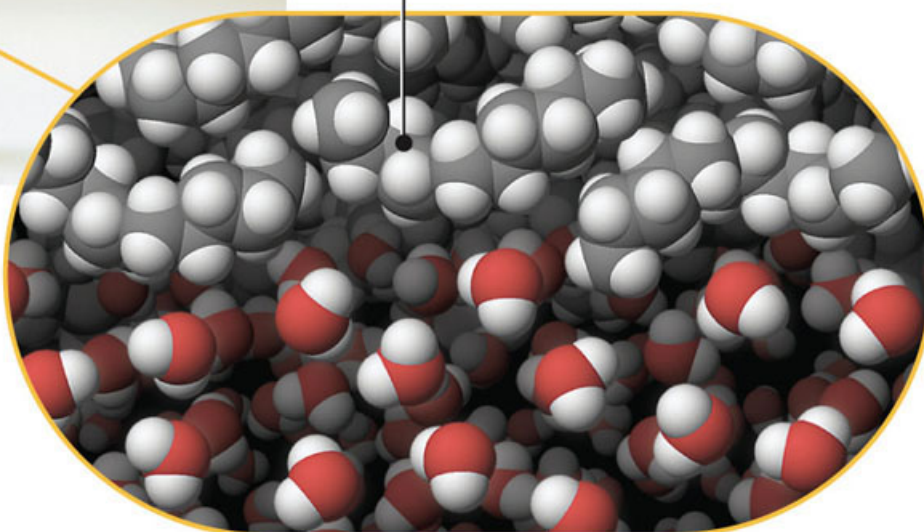
(a) Ethylene glycol ($\text{HOCH}_2\text{CH}_2\text{OH}$), a polar compound used as antifreeze in automobiles, dissolves in water.

Water and non polar oil

can't mix b/c water can't interact
with oil b/c oil isn't polar



Hydrocarbon



polar + polar will mix
non polar + polar will not mix

non polar + non polar will mix

"like
dissolves
like"

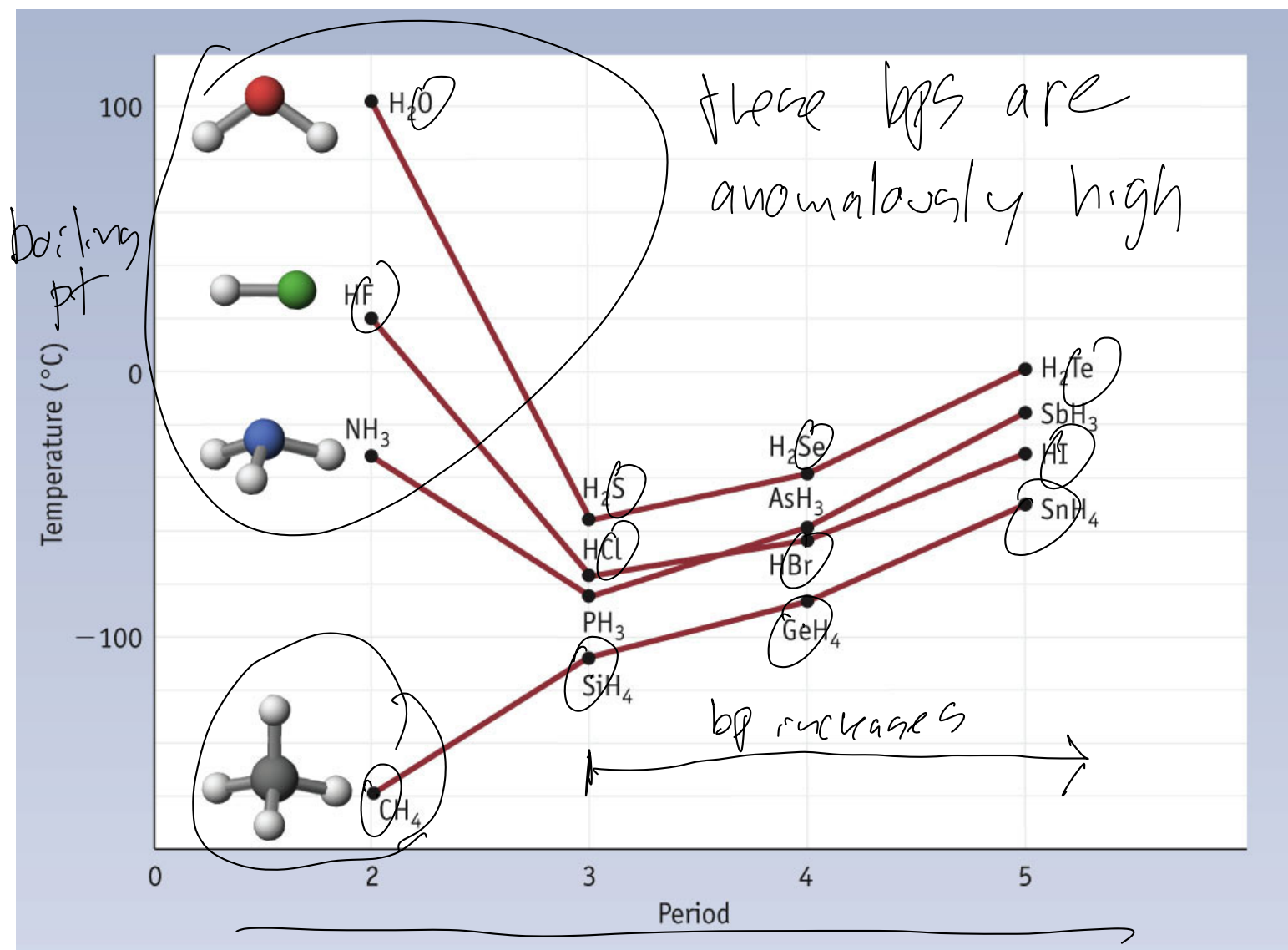
(b) Nonpolar motor oil (a hydrocarbon) dissolves in nonpolar solvents such as gasoline or CCl_4 . It will not dissolve in a polar solvent such as water, however. Commercial spot removers use nonpolar solvents to dissolve oil and grease from fabrics.

Dipole – Dipole Forces

Table 11.2 Molar Masses, Boiling Points, and $\Delta_{\text{vap}}H^\circ$ of Nonpolar and Polar Substances

NONPOLAR				POLAR			
	<i>M</i> (g/mol)	BP (°C)	$\Delta_{\text{vap}}H^\circ$ (kJ/mol)		<i>M</i> (g/mol)	BP (°C)	$\Delta_{\text{vap}}H^\circ$ (kJ/mol)
N ₂	28	−196	5.57	CO	28	−192	6.04
SiH ₄	32	−112	12.10	PH ₃	34	−88	14.06
GeH ₄	77	−90	14.06	AsH ₃	78	−62	16.69
Br ₂	160	59	29.96	ICl	162	97	—

non polar – lower bp, lower ΔH_{evap}



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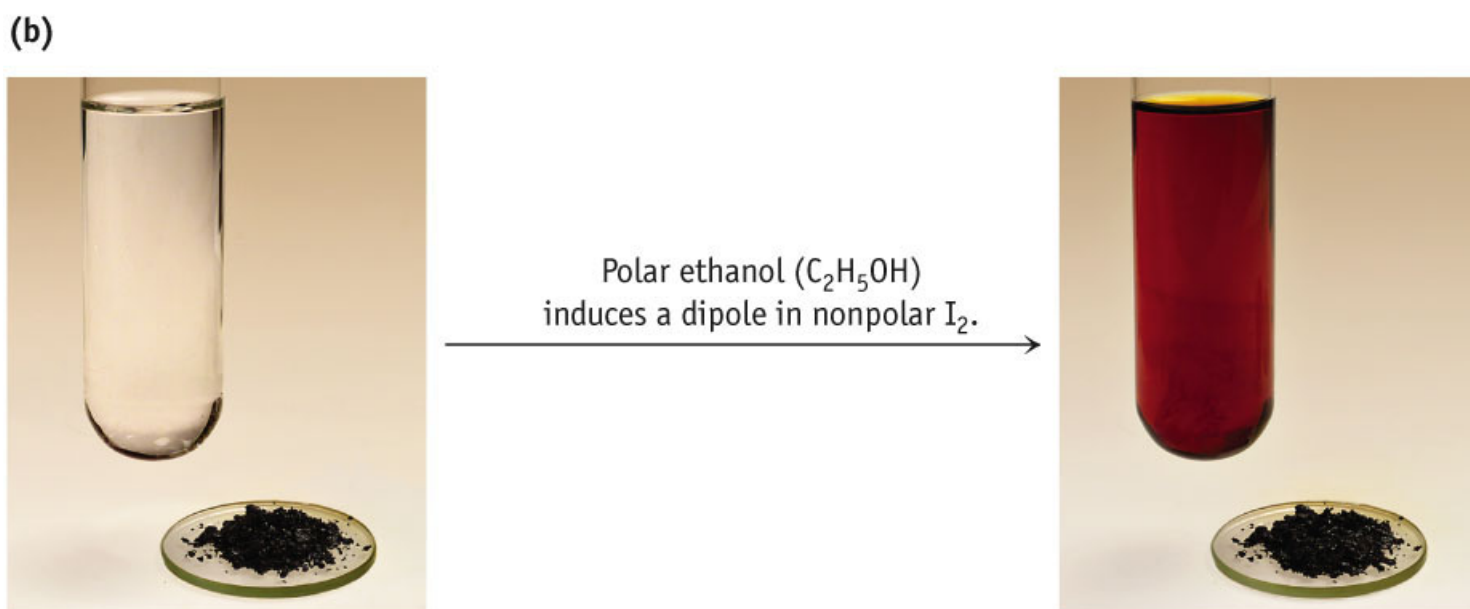
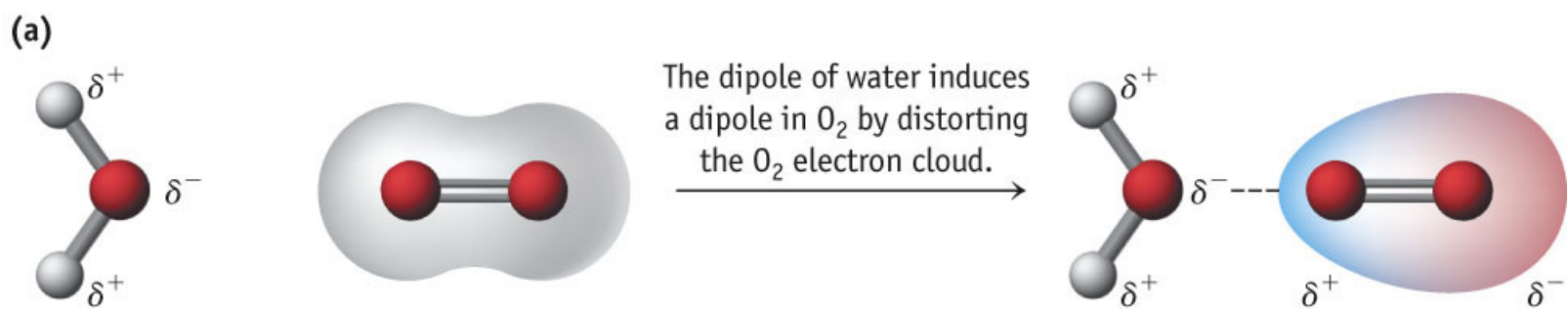
Fig. 12-6, p. 561

Hydrogen bonding is special case of dipole-dipole interaction

* Requires H connected to F, O, N (very polar bond)

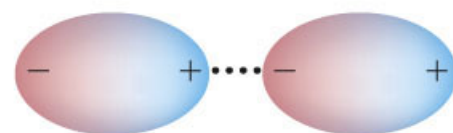
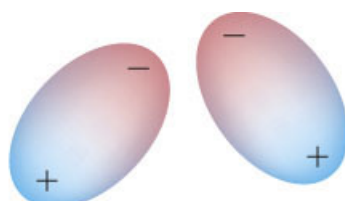
* Requires lone pair on a F, O, N





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Fig. 12-10, p. 566



Two nonpolar atoms or molecules (depicted as having an electron cloud that has a time-averaged spherical shape).

Momentary attractions and repulsions between nuclei and electrons in neighboring molecules lead to induced dipoles.

Correlation of the electron motions between the two atoms or molecules (which are now dipolar) leads to a lower energy and stabilizes the system.

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Fig. 12-11, p. 567



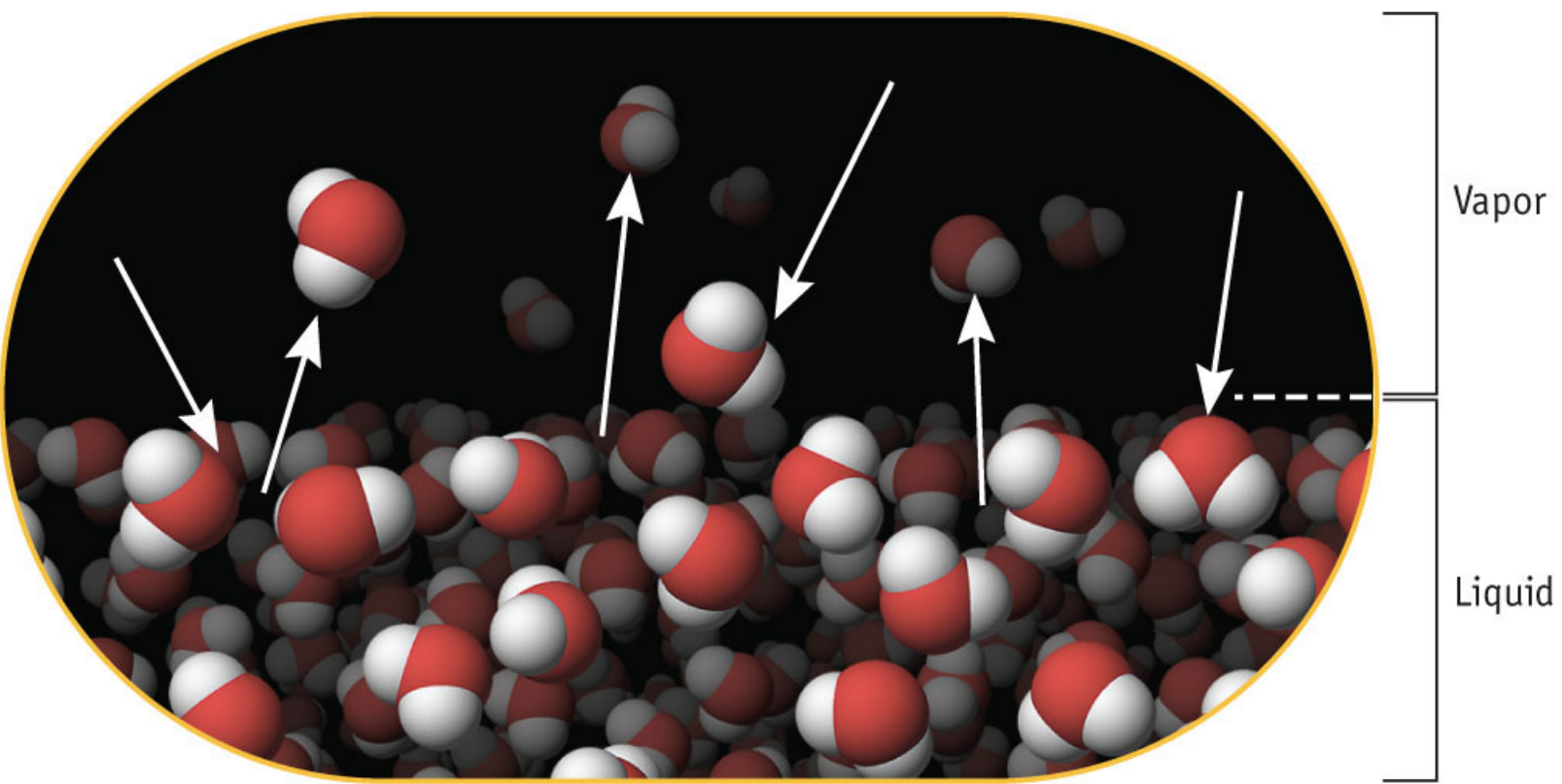
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TABLE 12.6 Molar Enthalpies of Vaporization and Boiling Points for Common Substances*

Compound	Molar Mass (g/mol)	$\Delta_{\text{vap}}H^\circ$ (kJ/mol)†	Boiling Point (°C) (Vapor pressure = 760 mm Hg)
<i>Polar Compounds</i>			
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 ₂ O	18.0	40.7	100.0
SO ₂	64.1	24.9	−10.0
<i>Nonpolar Compounds</i>			
CH ₄ (methane)	16.0	8.2	−161.5
C ₂ H ₆ (ethane)	30.1	14.7	−88.6
C ₃ H ₈ (propane)	44.1	19.0	−42.1
C ₄ H ₁₀ (butane)	58.1	22.4	−0.5
<i>Monatomic Elements</i>			
He	4.0	0.08	−268.9
Ne	20.2	1.7	−246.1
Ar	39.9	6.4	−185.9
Xe	131.3	12.6	−108.0
<i>Diatomic Elements</i>			
H ₂	2.0	0.90	−252.9
N ₂	28.0	5.6	−195.8
O ₂	32.0	6.8	−183.0
F ₂	38.0	6.6	−188.1
Cl ₂	70.9	20.4	−34.0
Br ₂	159.8	30.0	58.8

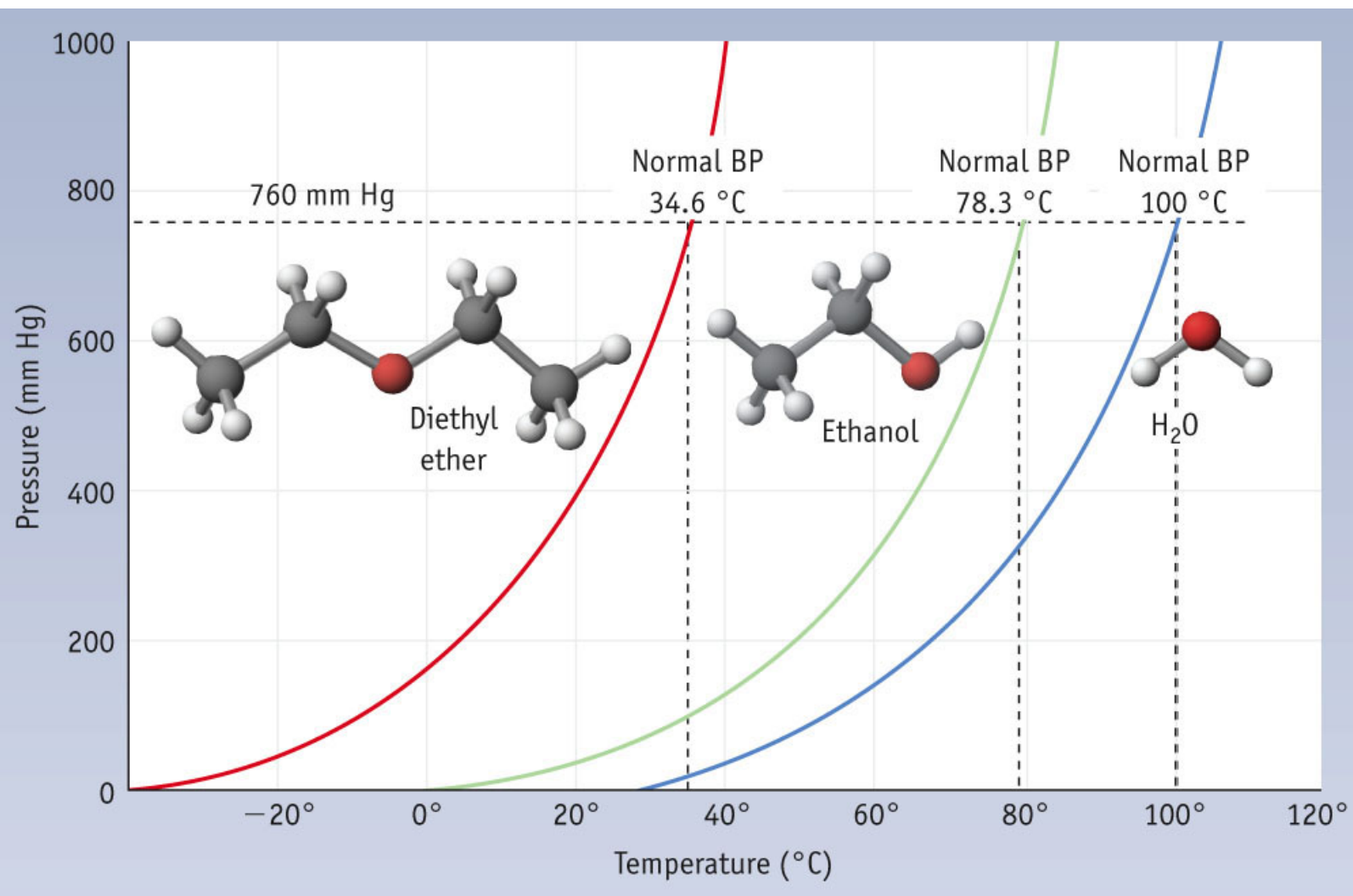
*Data taken from D. R. Lide: *Basic Laboratory and Industrial Chemicals*, Boca Raton, FL, CRC Press, 1993.

† $\Delta_{\text{vap}}H^\circ$ is measured at the normal boiling point of the liquid.



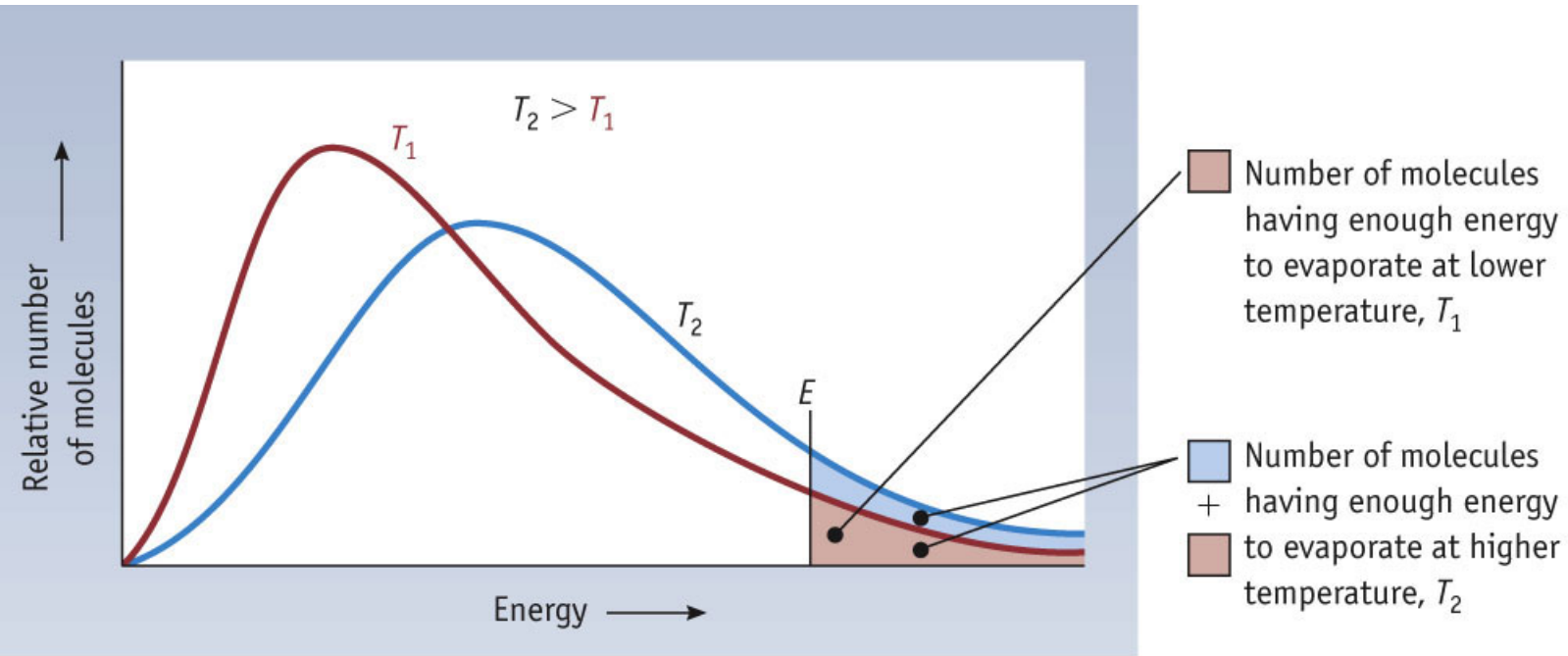
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Fig. 12-14, p. 571



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Fig. 12-17, p. 574



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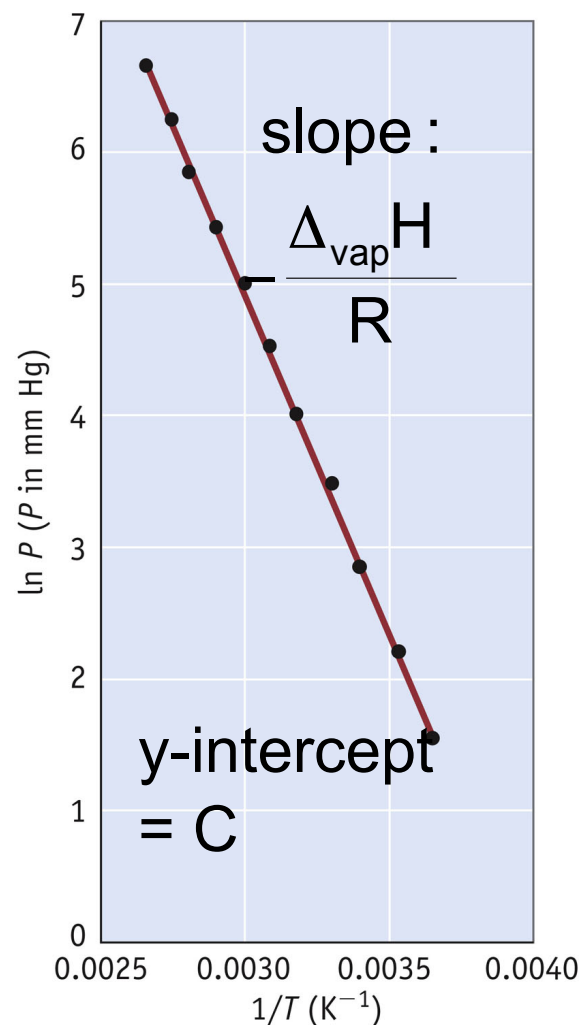
Fig. 12-13, p. 571

The Temperature Dependence of Vapor Pressure Goes As:

$$\ln P_{\text{vap}} = -\frac{\Delta_{\text{vap}} H^{\circ}}{RT} + C$$

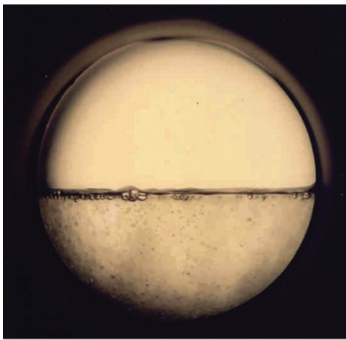
A plot of $\ln P_{\text{vap}}$ vs. $\frac{1}{T}$ yields a slope of:

$\Delta_{\text{vap}} H^{\circ}$ is related to T and P by the *Clausius-Clapeyron* equation

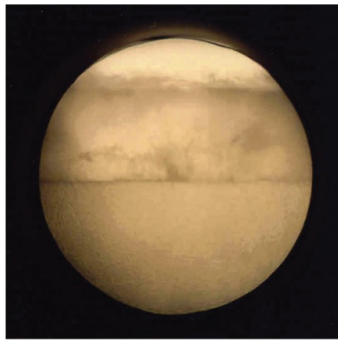


Critical Temperature and Pressure for CO₂

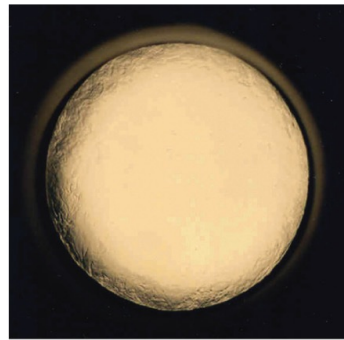
The separate phases of CO₂ are seen through the window in a high-pressure vessel.



As the sample warms and the pressure increases, the meniscus becomes less distinct.



Once the critical T and P are reached, distinct liquid and vapor phases are no longer in evidence. This homogeneous phase is "supercritical CO₂."



Photos: Dr. Christopher M. Rayner/
University of Leeds

