Solvation of Ions

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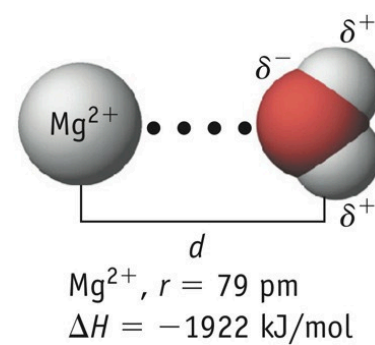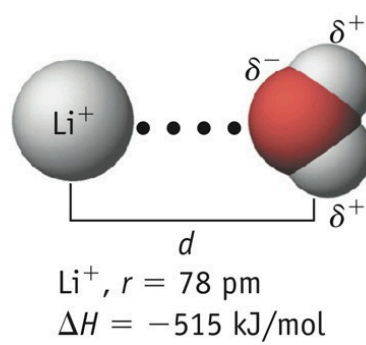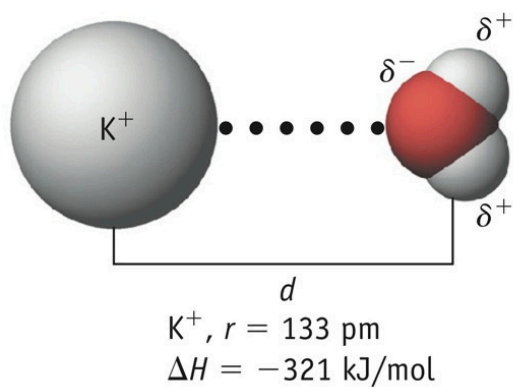
When as *anion* exists in solution, it is surrounded by the *positive* dipole ends of water molecules.

K$^+$, r = 133 pm
ΔH = $-$321 kJ/mol

Li$^+$, r = 78 pm
ΔH = $-$515 kJ/mol

Mg^{2+}, r = 79 pm
ΔH = $-$1922 kJ/mol

Increasing force of attraction; more exothermic enthalpy of hydration
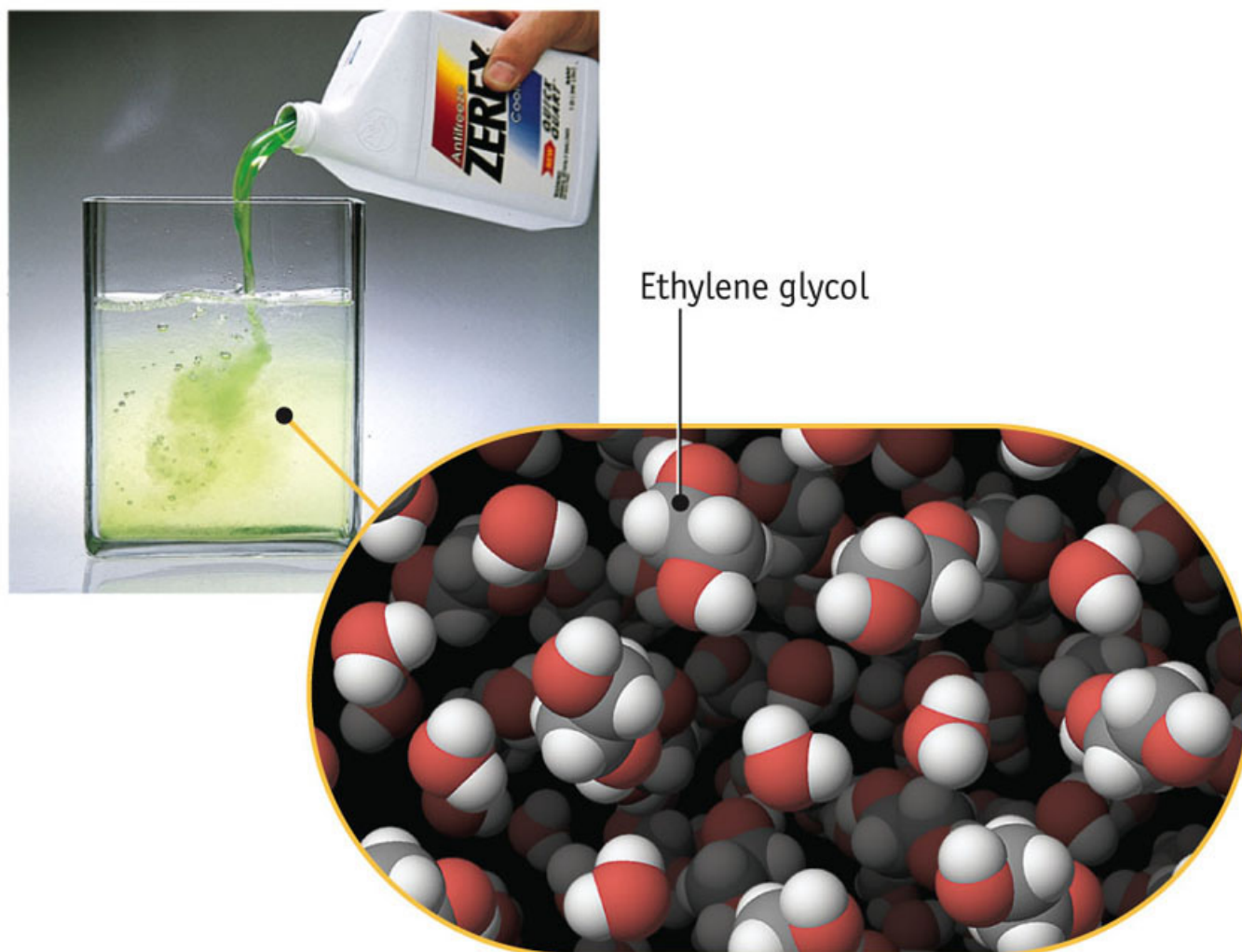
δ^- δ^+ δ^- δ^+
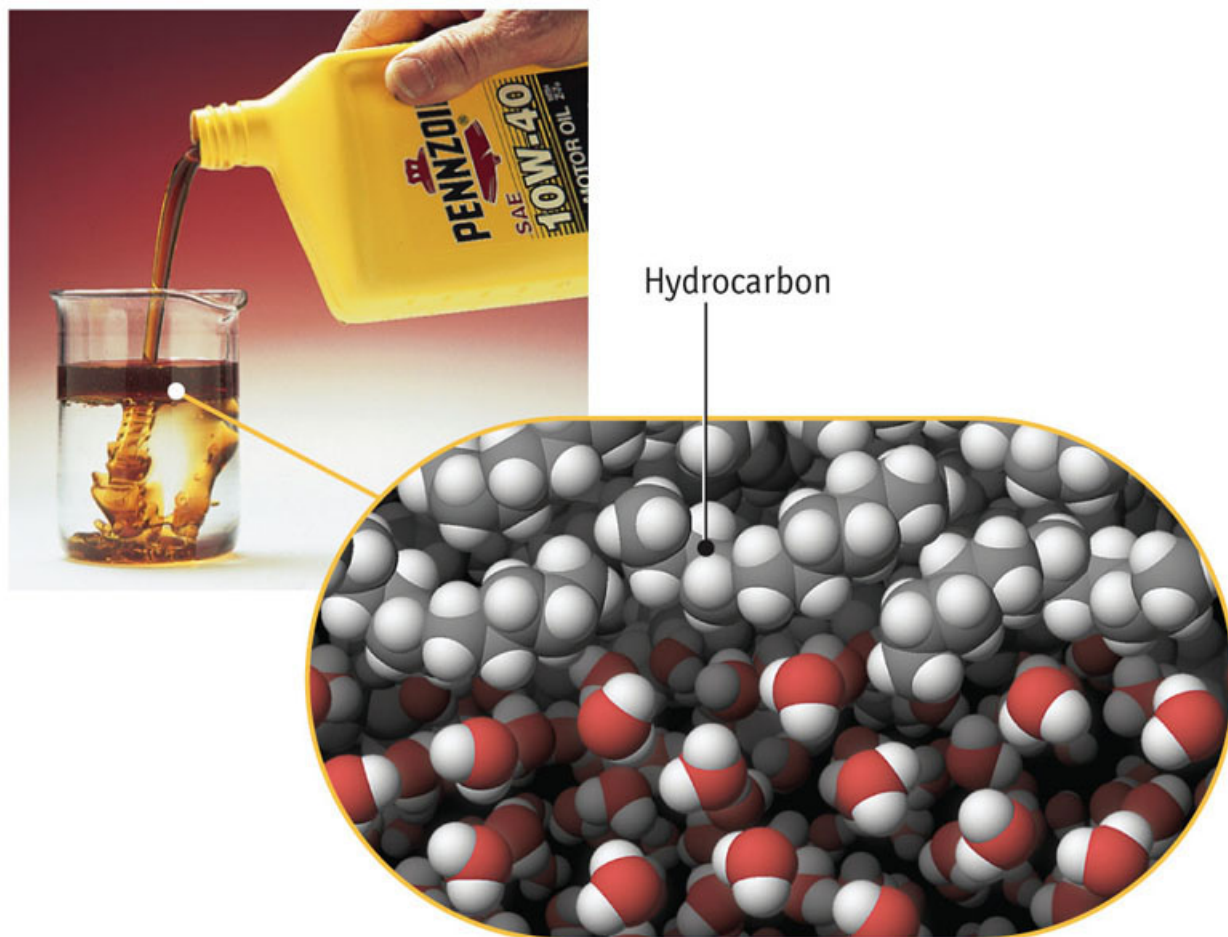
X—H   Y—H
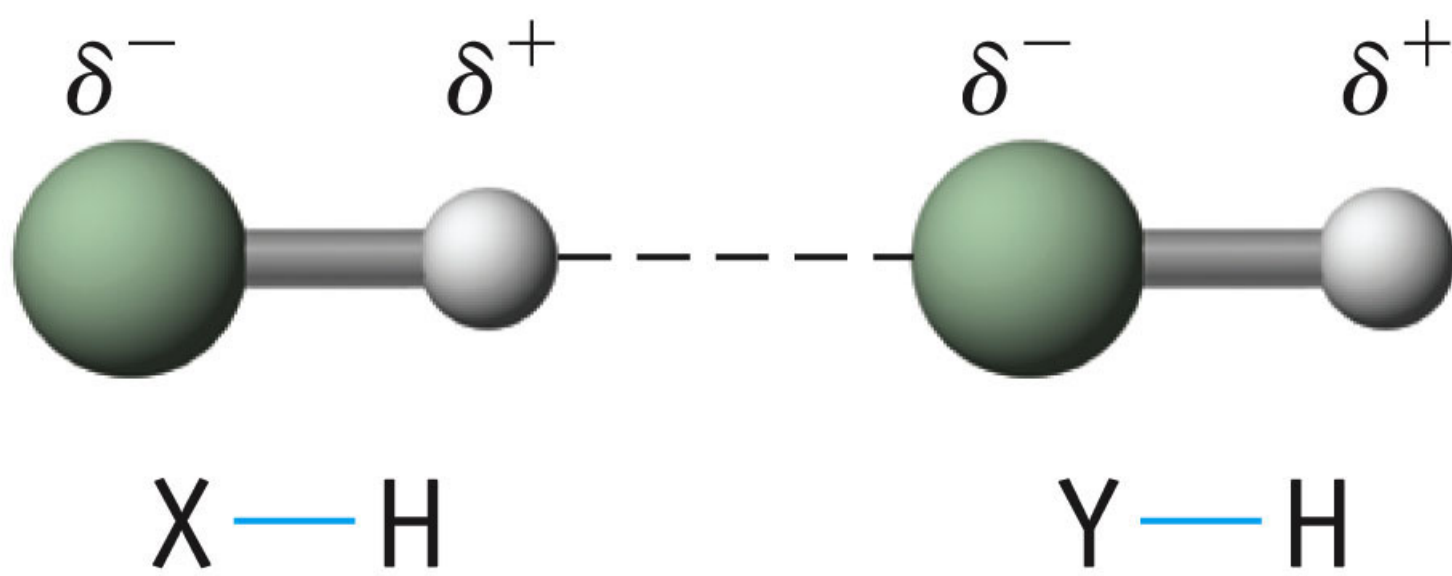
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Dipole – Dipole Forces

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

	NONPOLAR				POLAR		
	M (g/mol)	BP (°C)	$\Delta_{vap}H°$ (kJ/mol)		M (g/mol)	BP (°C)	$\Delta_{vap}H°$ (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	—

Ethylene glycol

(a) Ethylene glycol ($HOCH_2CH_2OH$), a polar compound used as antifreeze in automobiles, dissolves in water.
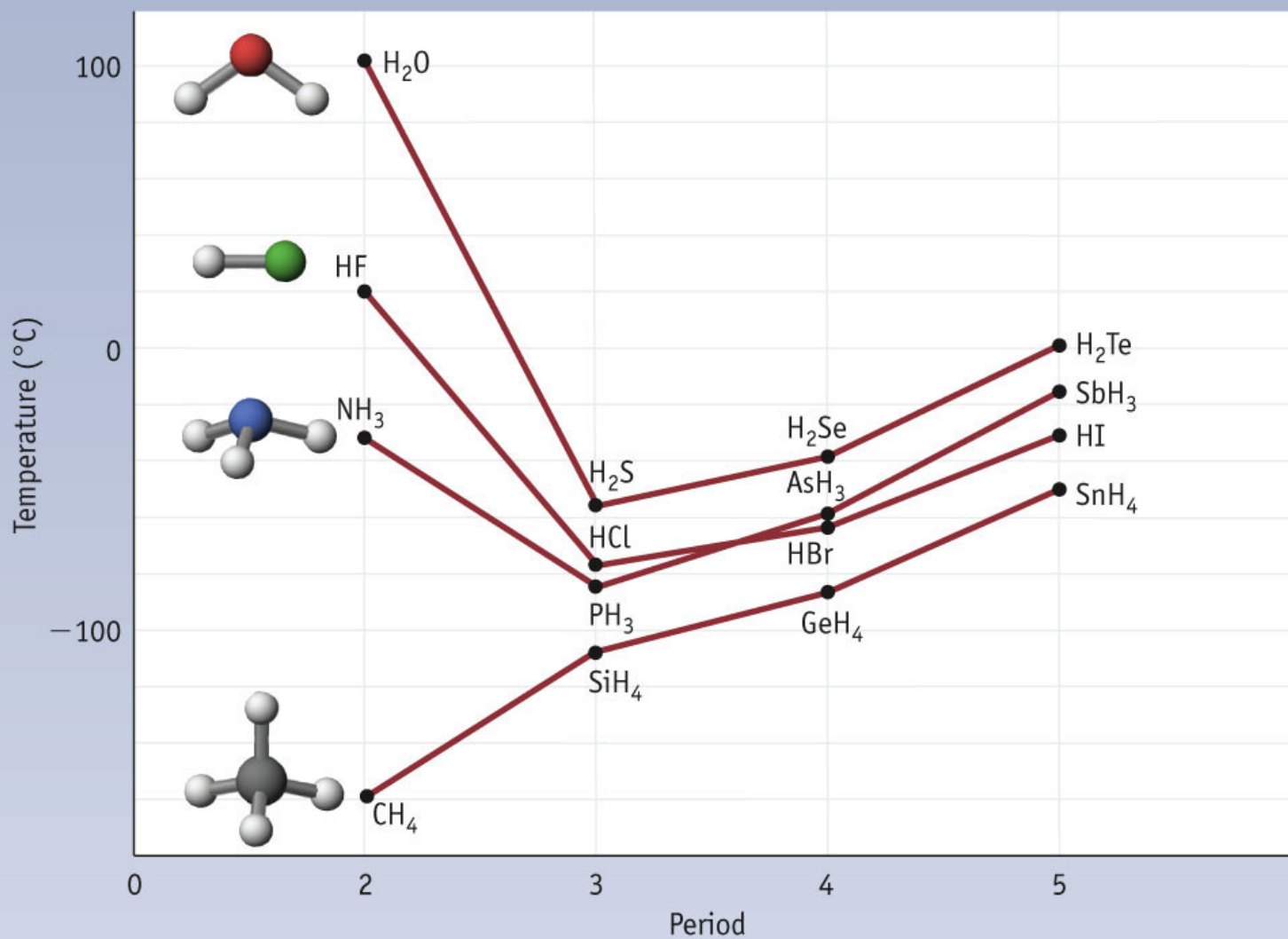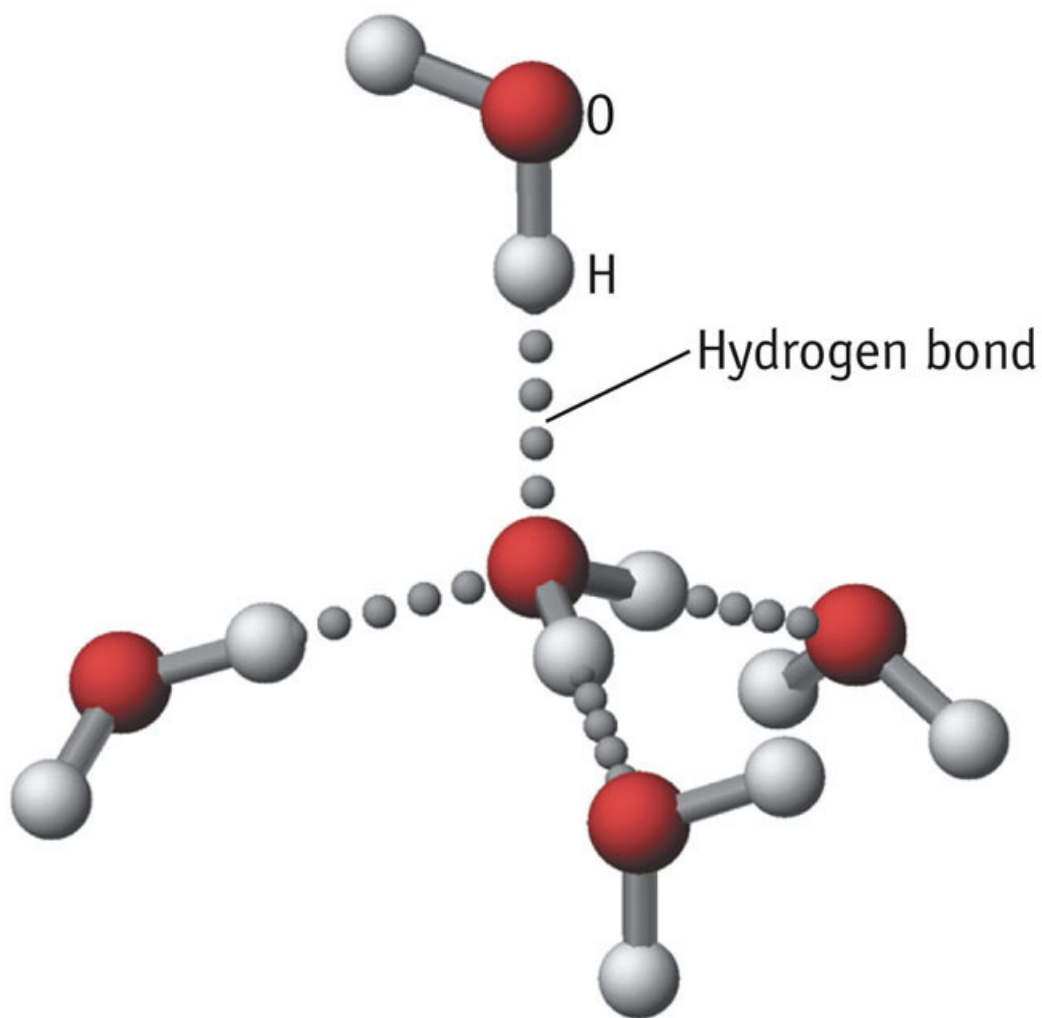
Fig. 12-5, p. 560

Hydrocarbon

(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.

Fig. 12-5, p. 560

Dipole – Dipole Forces

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

	NONPOLAR				POLAR		
	M (g/mol)	BP (°C)	$\Delta_{vap}H°$ (kJ/mol)		M (g/mol)	BP (°C)	$\Delta_{vap}H°$ (kJ/mol)
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GeH_4	77	−90	14.06	AsH_3	78	−62	16.69
Br_2	160	59	29.96	ICl	162	97	—

O

H

Hydrogen bond

(a)

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Fig. 12-8, p. 564

(a)

The dipole of water induces a dipole in O_2 by distorting the O_2 electron cloud.

(b)

Polar ethanol (C_2H_5OH) induces a dipole in nonpolar I_2.
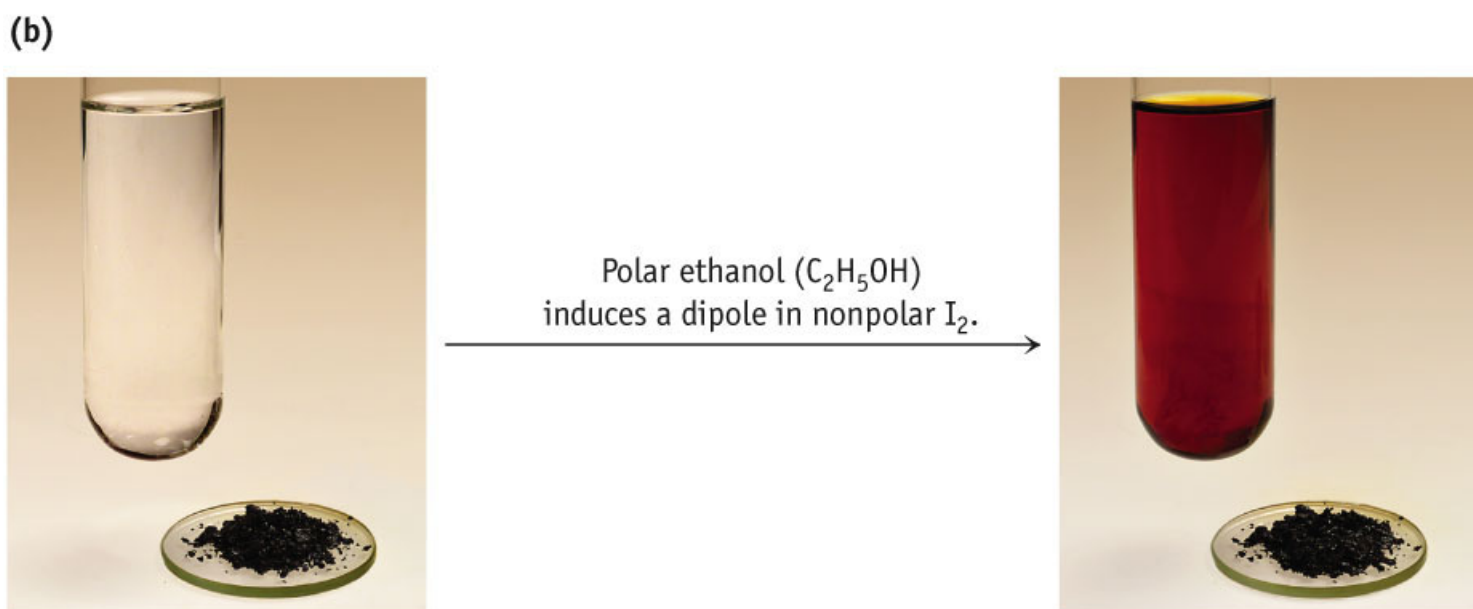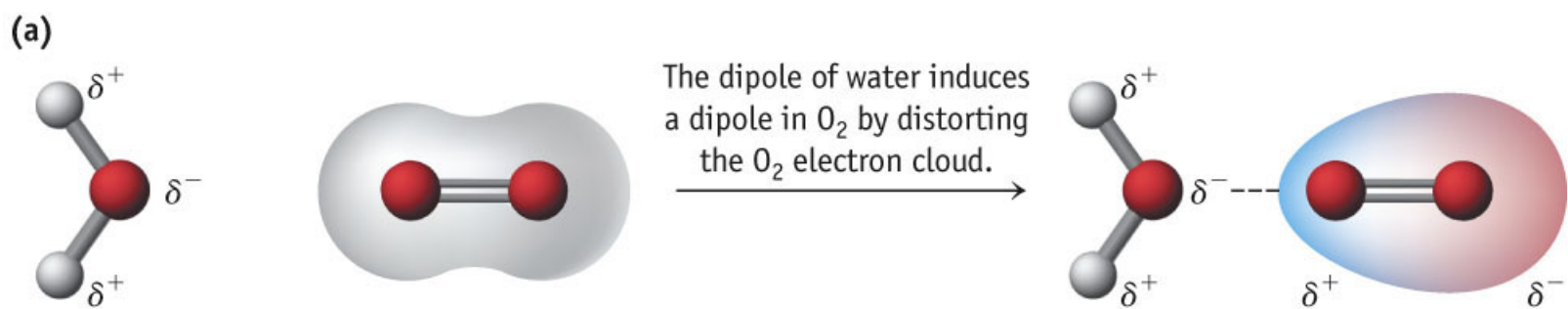
Fig. 12-10, p. 566
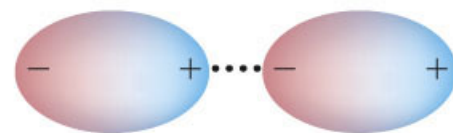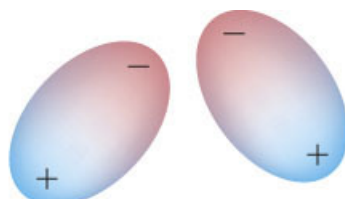
Two nonpolar atoms or molecules (depicted as having an electron cloud that has a time-averaged spherical shape).

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.
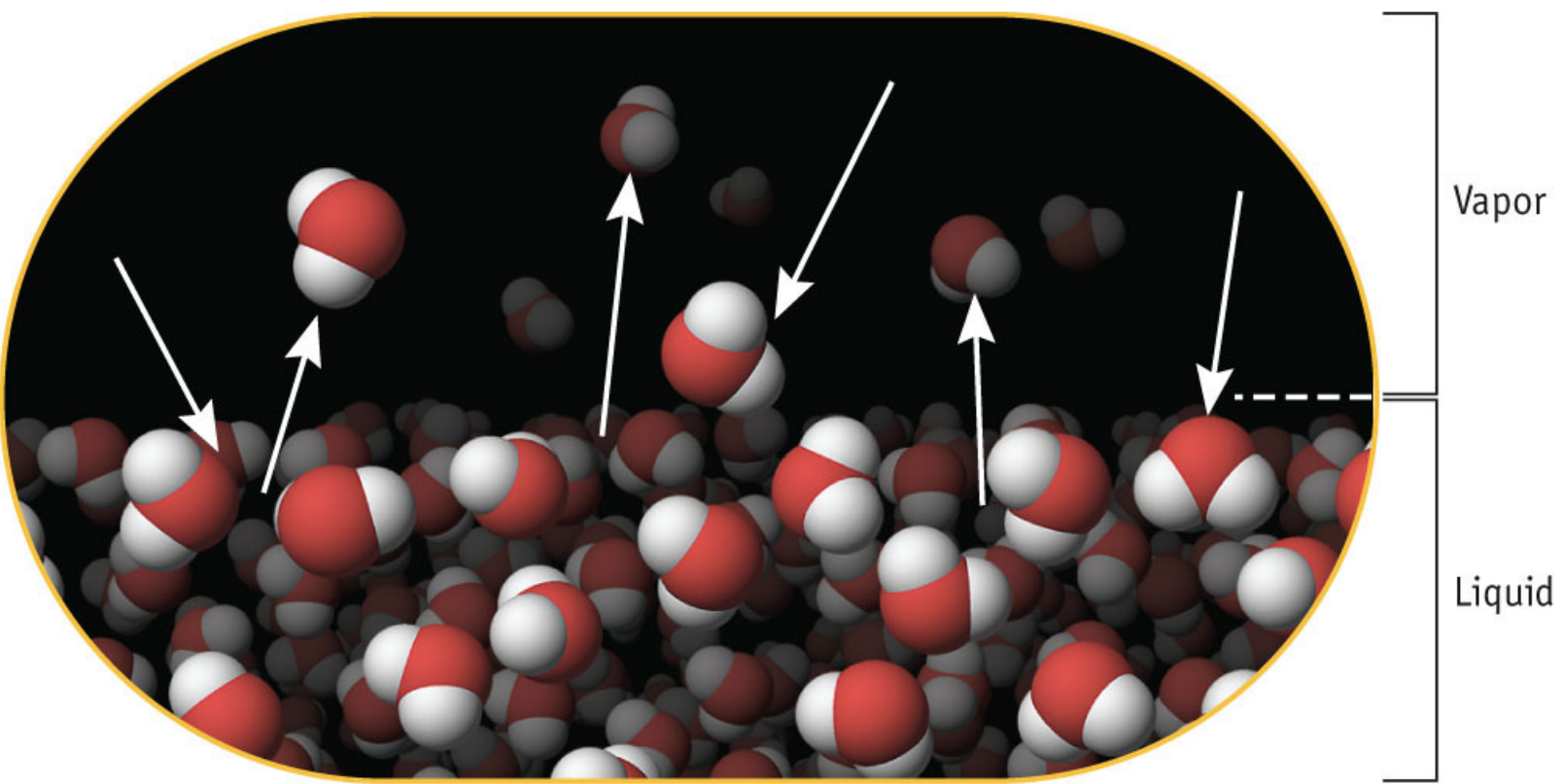
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Fig. 12-11, p. 567

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

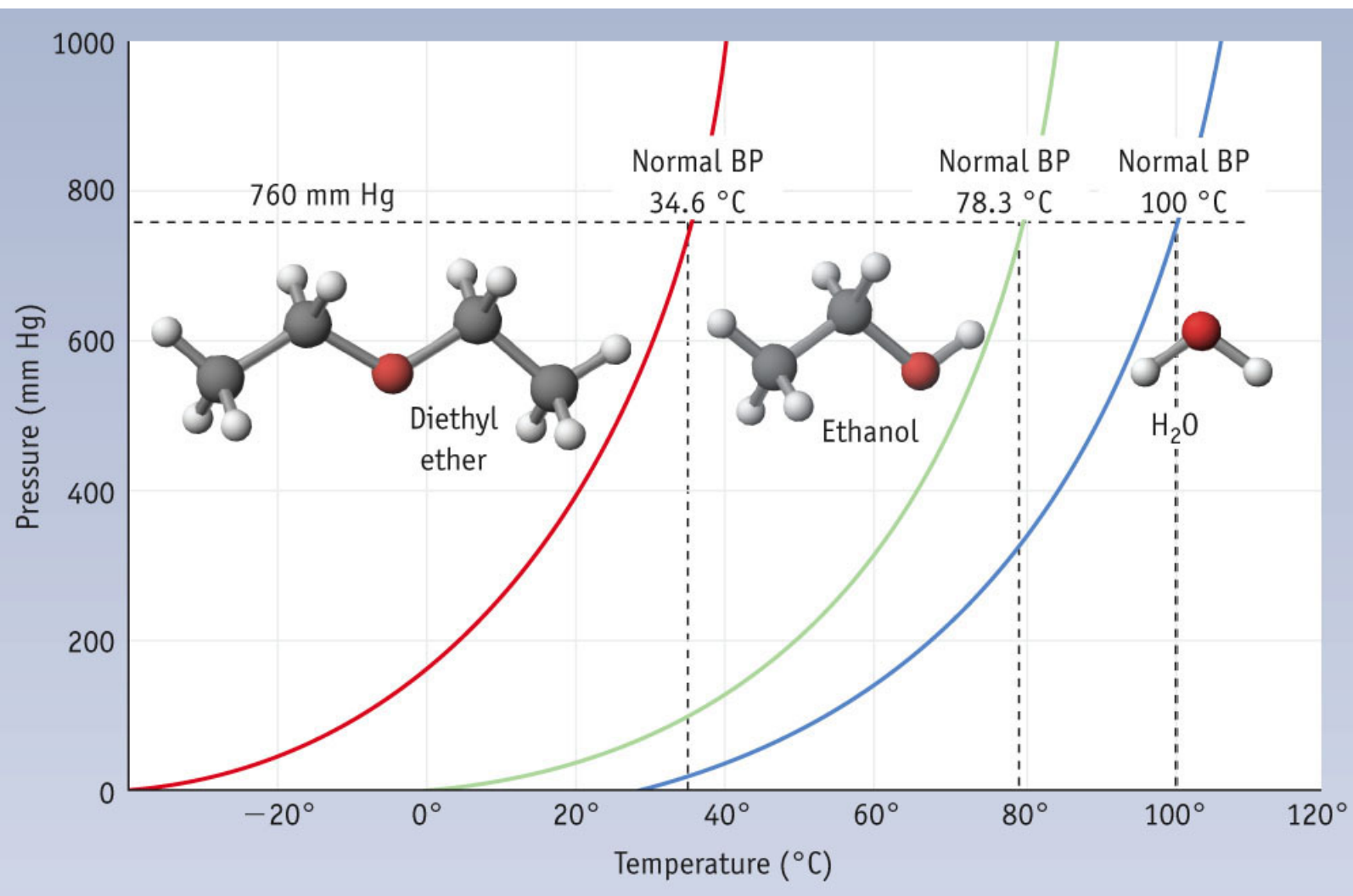| Compound	Molar Mass (g/mol)	$\Delta_{vap}H°$ (kJ/mol)†	Boiling Point (°C) (Vapor pressure = 760 mm Hg)
Polar Compounds			
HF	20.0	25.2	19.7
HCl	36.5	16.2	−84.8
HBr	80.9	19.3	−66.4
HI	127.9	19.8	−35.6
NH_3	17.0	23.3	−33.3
H_2O	18.0	40.7	100.0
SO_2	64.1	24.9	−10.0
Nonpolar Compounds			
CH_4 (methane)	16.0	8.2	−161.5
C_2H_6 (ethane)	30.1	14.7	−88.6
C_3H_8 (propane)	44.1	19.0	−42.1
C_4H_{10} (butane)	58.1	22.4	−0.5
Monatomic Elements			
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
Diatomic Elements			
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.

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

Table 12-6, p. 572
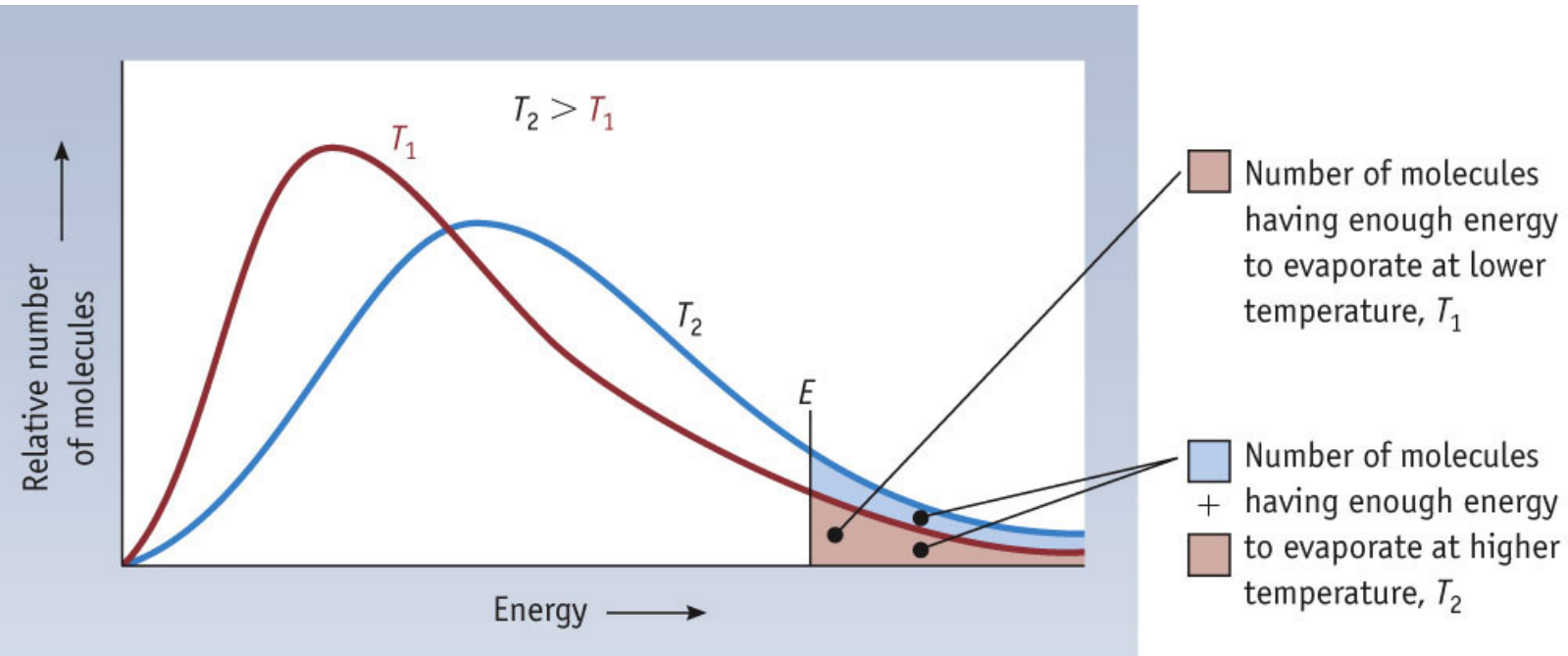
Vapor

Liquid

Fig. 12-14, p. 571

Fig. 12-17, p. 574

T₂ > T₁

Relative number of molecules

T_1

T_2

E

Energy

Number of molecules having enough energy to evaporate at lower temperature, T_1

Number of molecules having enough energy to evaporate at higher temperature, T_2
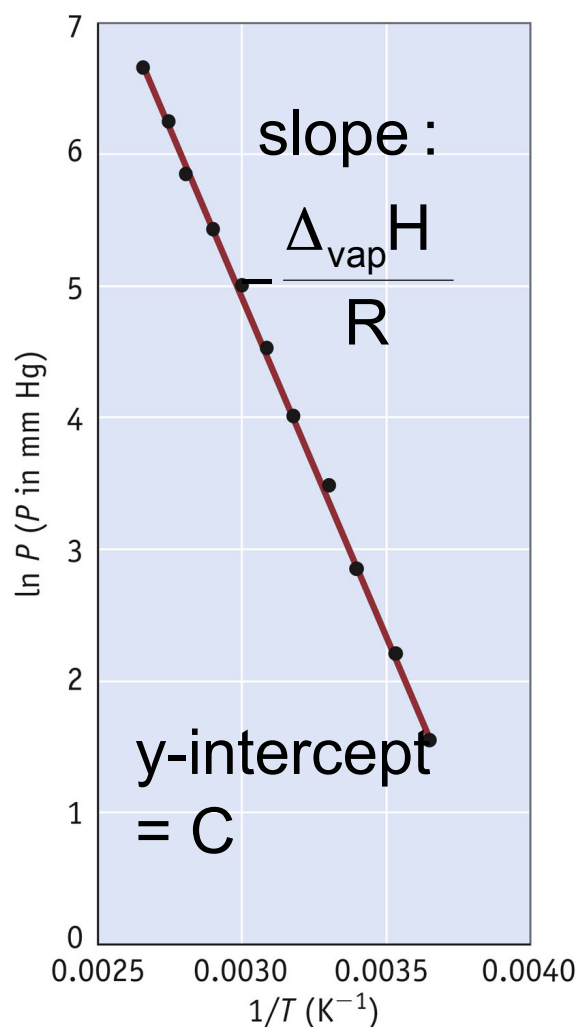
+

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Fig. 12-13, p. 571

The Temperature Dependence of Vapor Pressure Goes As:

$$\ln P_{vap} = -\frac{\Delta_{vap}H^{\circ}}{RT} + C$$
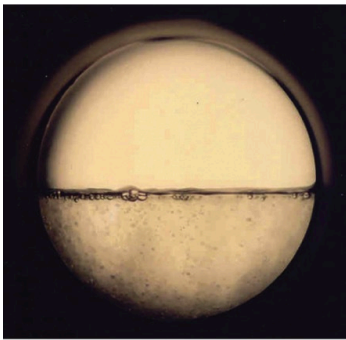
A plot of $\ln P_{vap}$ vs. $\frac{1}{T}$ yields a slope of:

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

slope :
$$-\frac{\Delta_{vap}H}{R}$$
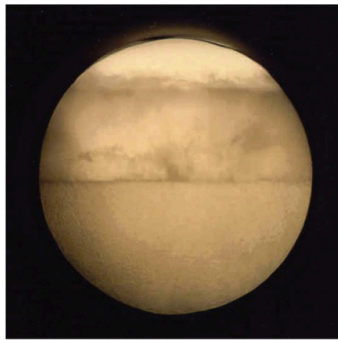
y-intercept = C
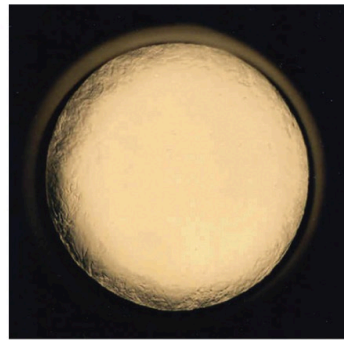
Critical Temperature and Pressure for CO$_2$

The separate phases of CO$_2$ 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 CO$_2$."

Super critical fluid

P_c = 72.8 atm

Critical point

Liquid

Gas

T_c = 30.99 °C

Pressure

Temperature →