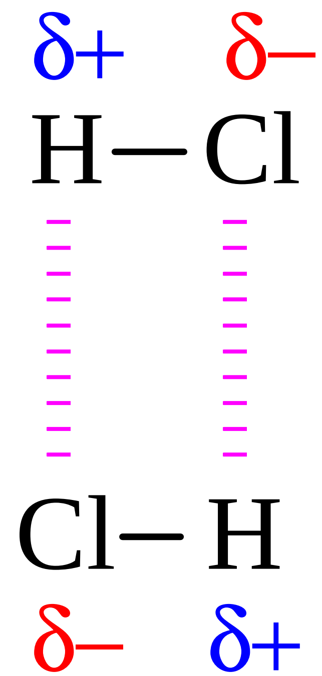
Liquids

transitional state between
solid (highly ordered)
and gas (highly random)

What holds liquid particles together?

Dipole-Dipole Interactions

among polar molecules,
opposite ends of the dipoles attract (like magnets)

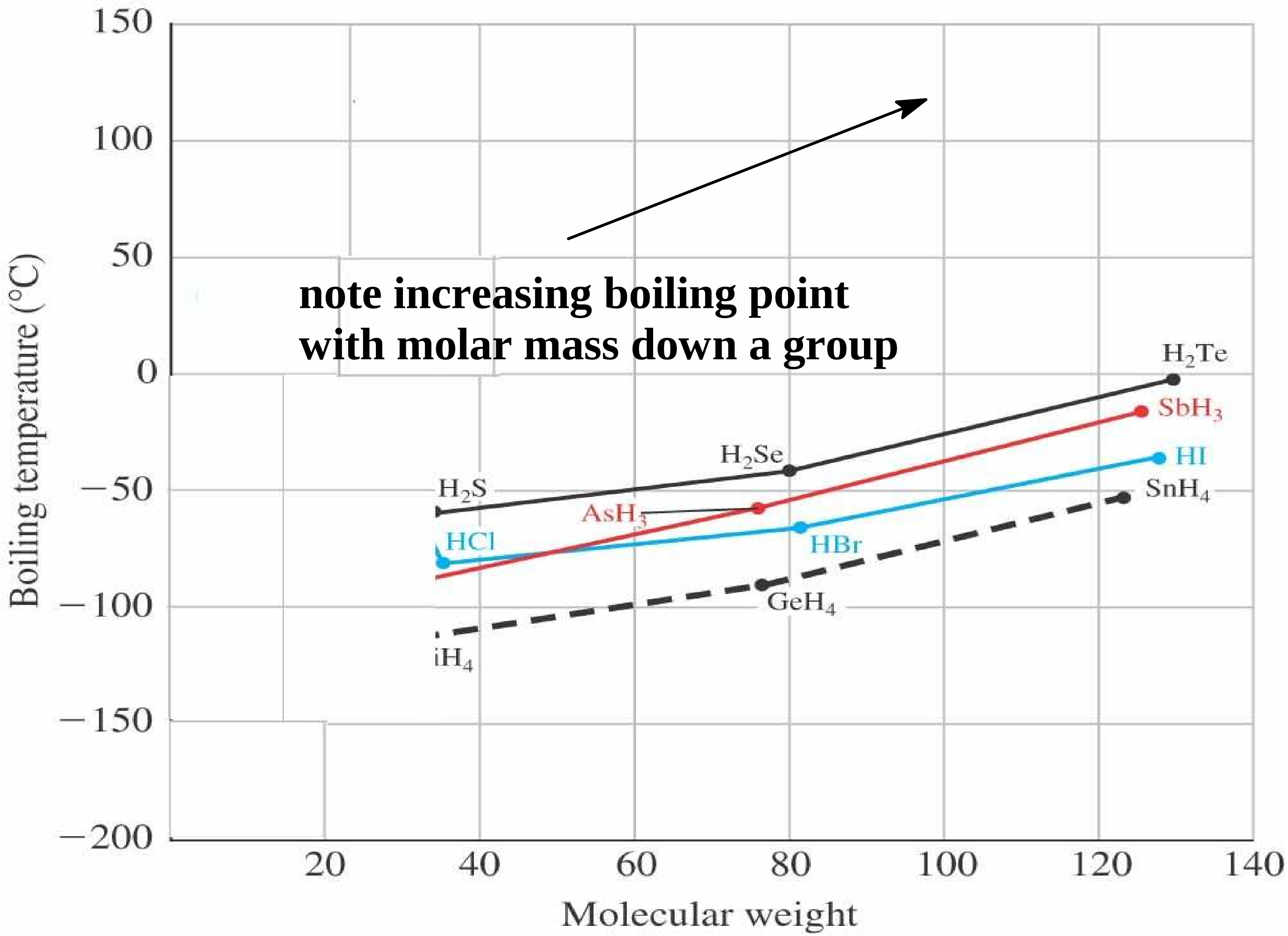


Hydrogen Bonding
Extreme Dipole Interactions

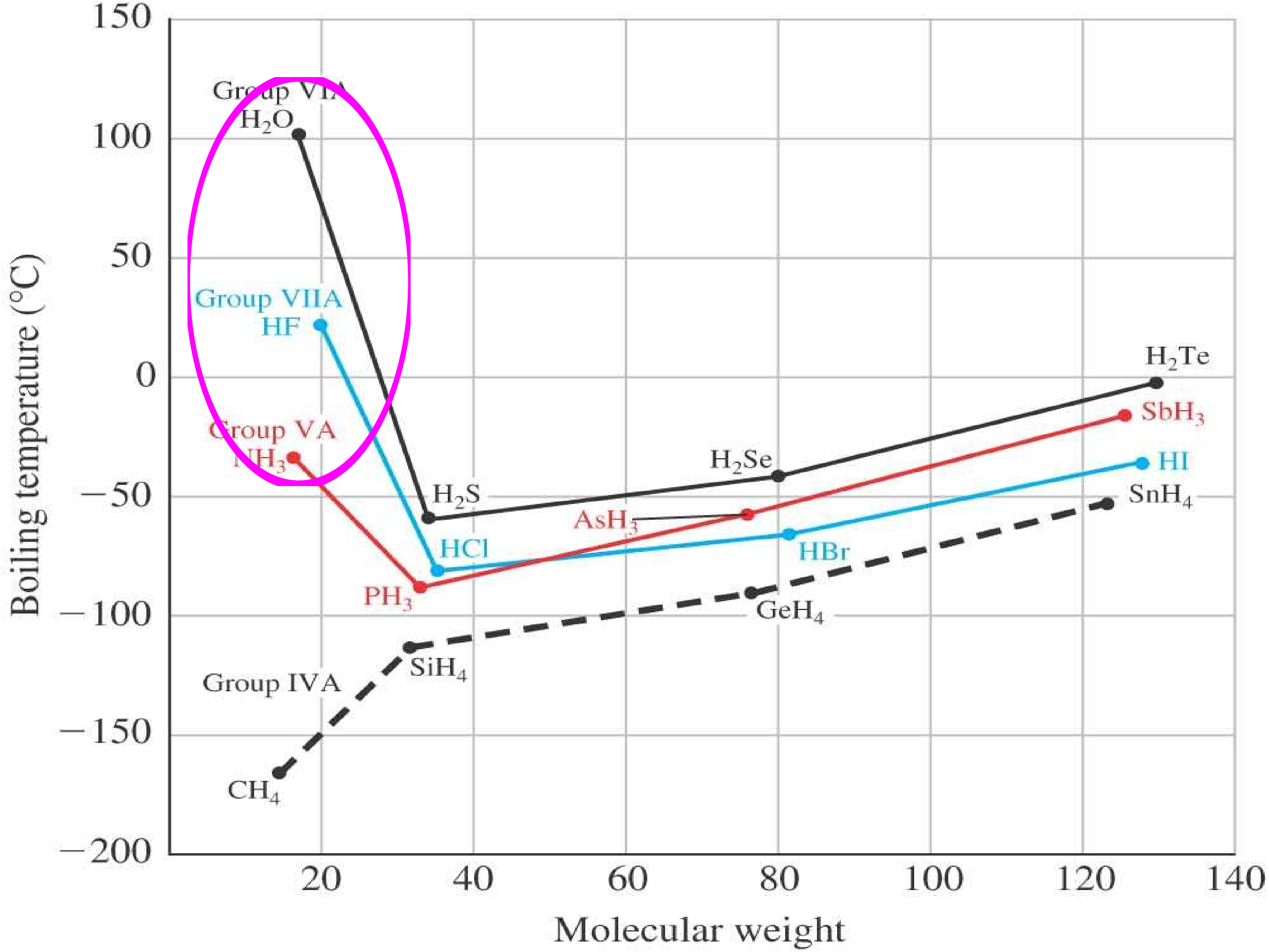
H— F   H— O   H— N

the stronger the intermolecular attractions,
the higher the boiling point

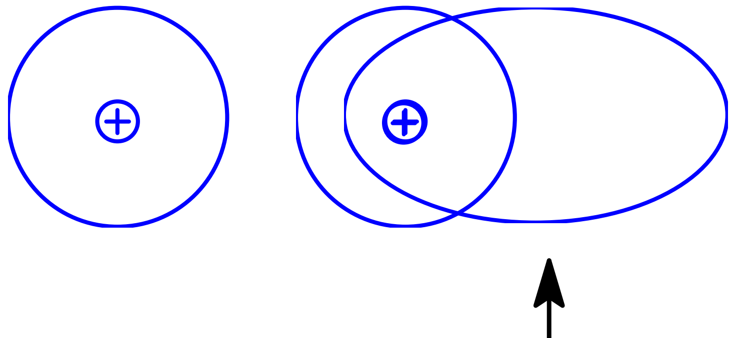
H-Bonding and Periodic Properties



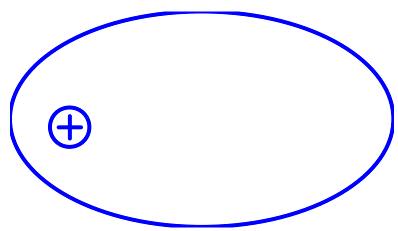
Including First Set of Data



Non-Polar Molecules?



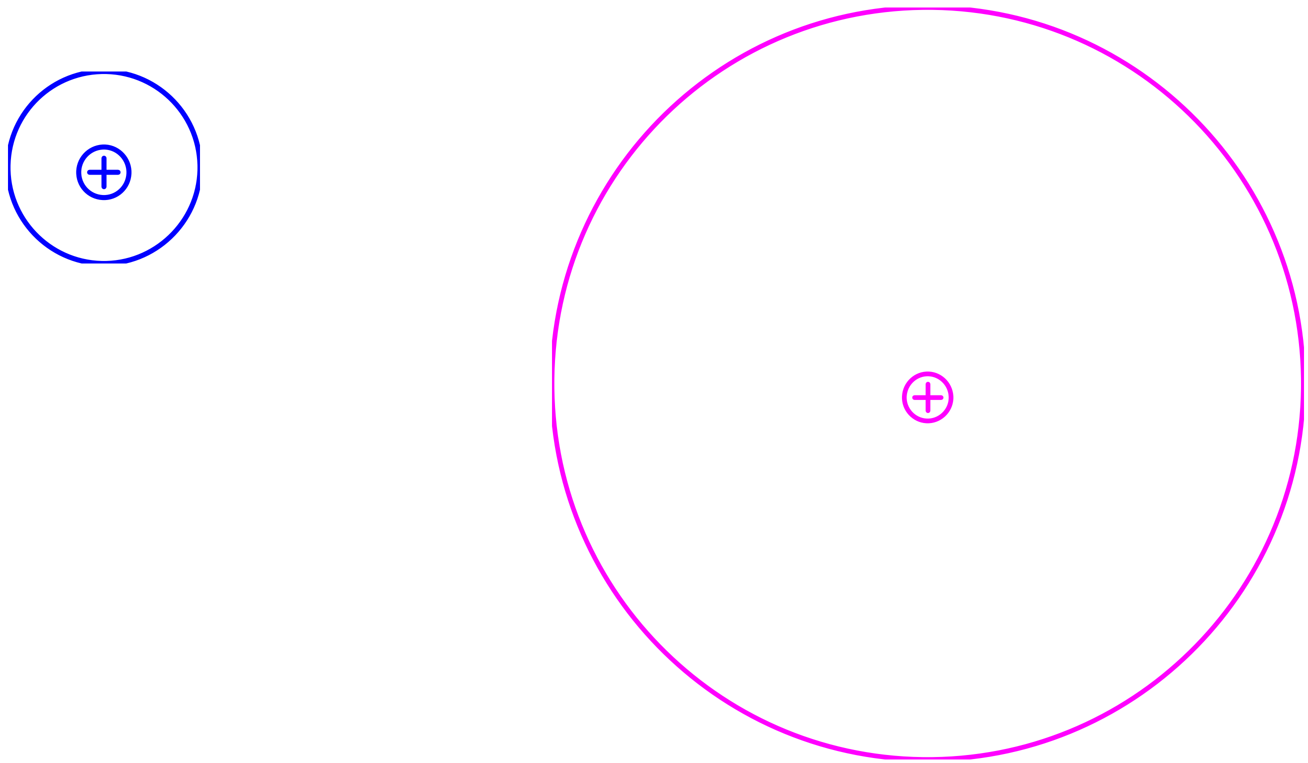
this molecule has been "polarized"(temporarily)



$\delta+$ $\delta-$

“London Forces”

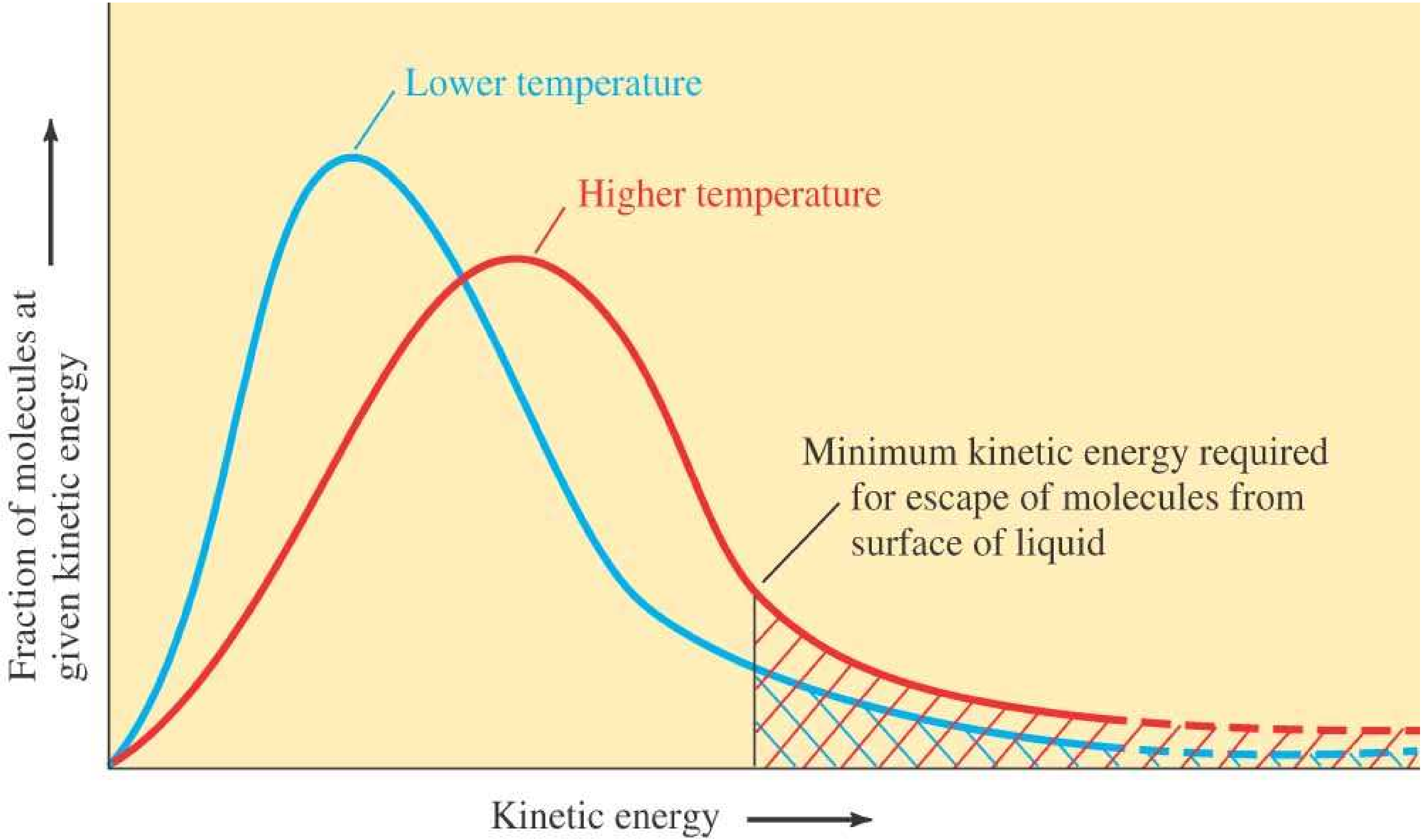
the attraction of non-polar molecules for each other to hold them in the liquid state



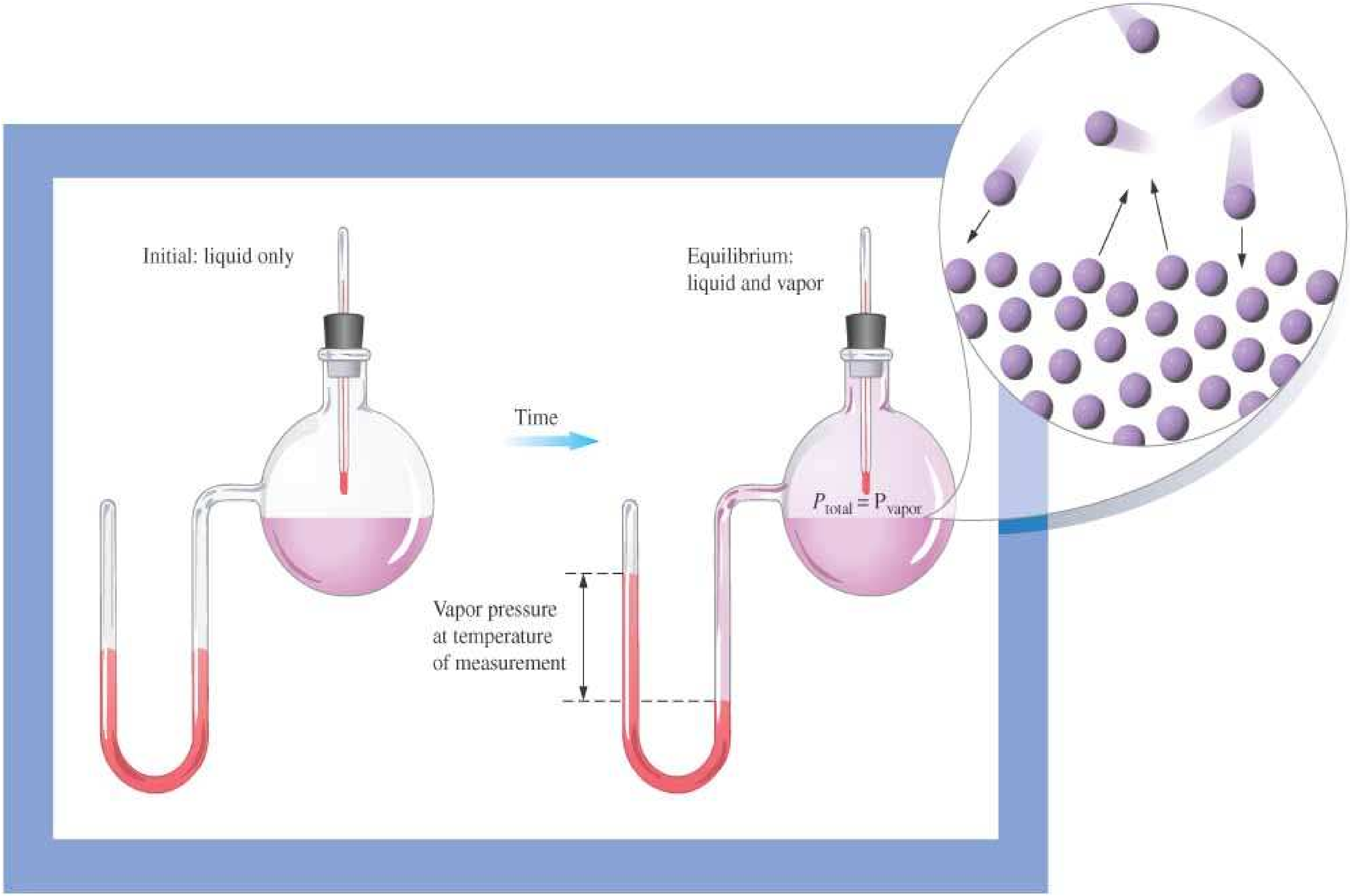
which should be more polarizable?

Properties of Liquids

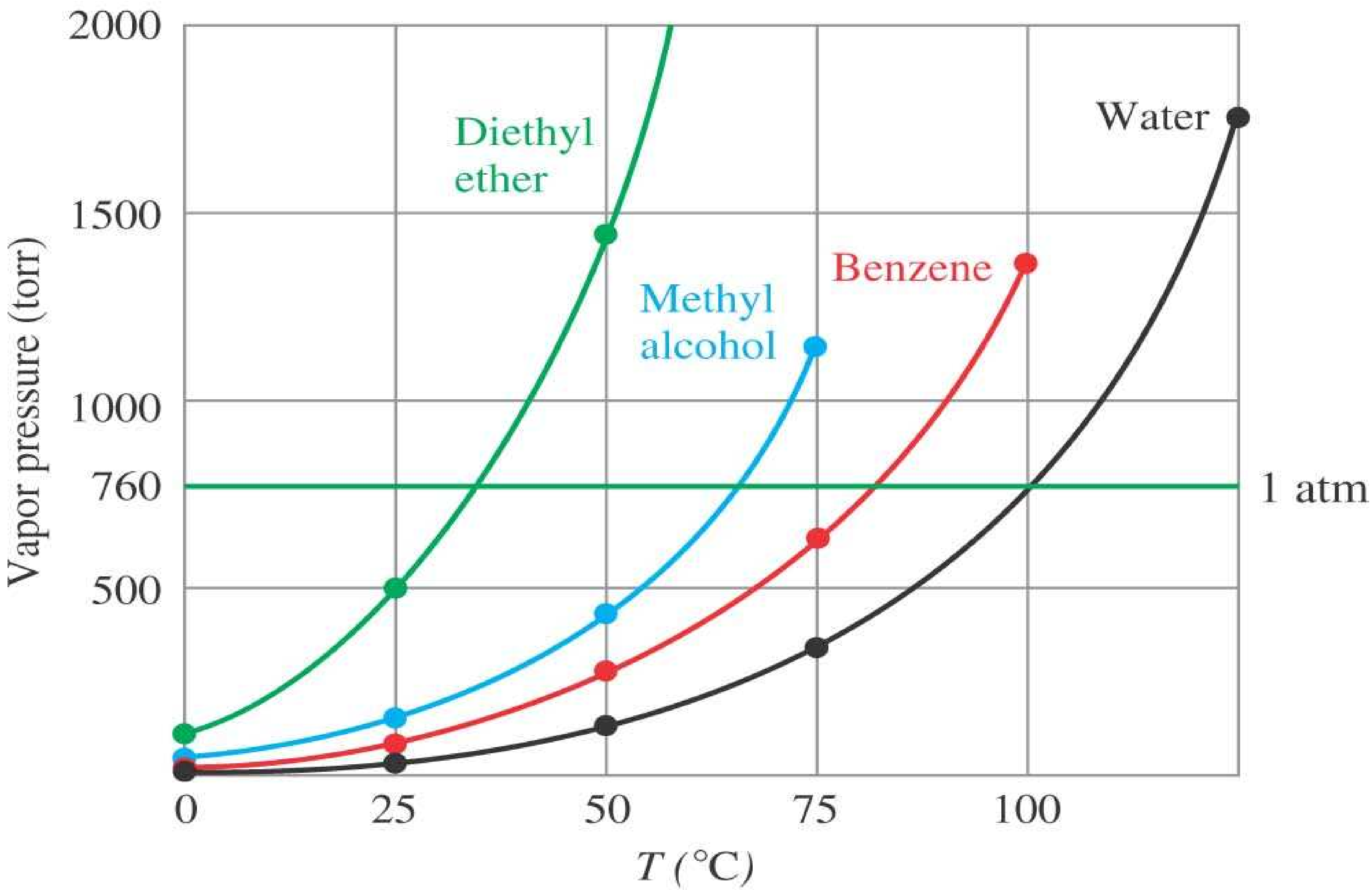
vapor pressure and evaporation



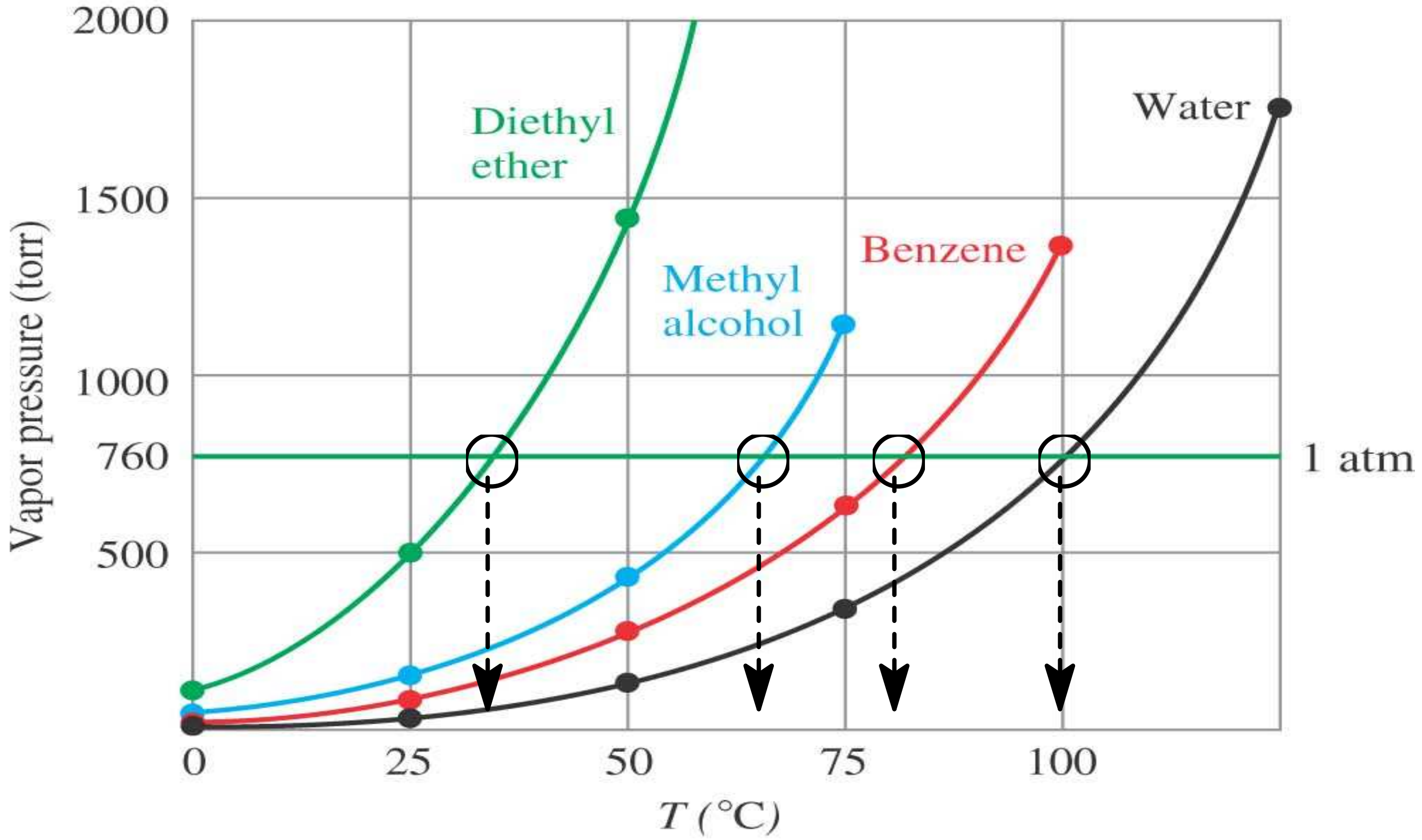
Measuring Vapor Pressure



Vapor Pressure of Some Liquids



Boiling



Vapor pressure (torr)
2000
1500
1000
760
500
0
25
50
75
100
T (°C)
Diethyl ether
Methyl alcohol
Benzene
Water
1 atm

Heats of Vaporization

the amount of energy required to separate 1 mol of a liquid into gas at the boiling temperature

A Table of Values

TABLE 13-5 *Heats of Vaporization, Boiling Points, and Vapor Pressures of Some Common Liquids*

Liquid	Vapor Pressure (torr at 20°C)	Boiling Point at 1 atm (°C)	Heat of Vaporization at Boiling Point *J/g*	Heat of Vaporization at Boiling Point *kJ/mol*
water, H_2O	17.5	100.	2260	40.7
ethyl alcohol, CH_3CH_2OH	43.9	78.3	855	39.3
benzene, C_6H_6	74.6	80.1	395	30.8
diethyl ether, $CH_3CH_2OCH_2CH_3$	442.	34.6	351	26.0
carbon tetrachloride, CCl_4	85.6	76.8	213	32.8
ethylene glycol, CH_2OHCH_2OH	0.1	197.3	984	58.9

The Clausius Clapeyron Equation

relates vapor pressure to temperature through Heat of Vaporization data

$$\ln\left(\frac{P_2}{P_1}\right) = \frac{\Delta H_{vap}}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

R = 8.314 J/mol K

A Problem

The normal boiling point of ethanol is 78.3^{o}C and the heat of vaporization is 39.3 kJ/mol.

Calculate the vapor pressure of ethanol at 50.0^{o}C.

P_1 = 760 torr

P_2 = ?

from the table ---> ΔHvap = 39.3 kJ/mol = 3.93x10^4 J/mol

T_1 = 78.3+ 273.2 = 351.5K

T_2 = 50.0+ 273.2 = 323.2K

$$\ln\left(\frac{P_2}{P_1}\right) = \frac{\Delta H_{vap}}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

Solution

P_2 = 234 torr

Q1

The vapor pressure of liquid potassium is 10.00 torr at 443^{o}C and 400.0 torr at 708^{o}C . Calculate ΔH vap for liquid potassium.

$$\Delta H_{vap} = 8.13x10^{4}\ J/mol = 81.3kJ/mol$$

Mol Fraction
% by number of molecules (mols)

symbol

X

$X_a = 0.23$
means that 23% of
all molecules in a mixture
are "a" molecules

for a binary system:

$$X_a + X_b = 1$$

$$X_a = \frac{\text{mols a}}{\text{total mols}}$$

Dalton's Law of Partial Pressure

$$P_T = P_a + P_b + \ldots.$$

Vapor Pressure of Solutions
Raoult's Law

$$P_{sol'n} = P_a + P_b + \ \ldots$$

$$P_a = P^o{}_a \ X_a$$

$$P_b = P^o{}_b \ X_b$$

$$P_{sol'n} = P^o{}_a \ X_a + P^o{}_b \ X_b$$

A Problem

A solution is made by dissolving 85.0 g of $C_6H_4Cl_2$ (a non-volatile solute) into 275 g C_6H_6 at 35^{o}C. The vapor pressure of pure C_6H_6 at 35^{o}C is 81.3 torr. Calculate the vapor pressure of the solution.

$$P_{sol'n} = P^o_{solvent}\ X_{solvent}$$

$$275\text{ g } C_6H_6 \left(\frac{1\text{ mol } C_6H_6}{78.12\text{ g } C_6H_6}\right) = 3.52\text{ mol } C_6H_6$$

$$85.0\text{ g } C_6H_4Cl_2 \left(\frac{1\text{ mol } C_6H_4Cl_2}{147.00\text{ g } C_6H_4Cl_2}\right) = 0.578\text{ mol } C_6H_4Cl_2$$

= 69.8 torr

Q2

63.0g of glycerin ($C_3H_8O_3$), a non-volatile solute, is added to 500.g of water at 25^oC. Calculate the vapor pressure of the solution. The vapor pressure of water at 25^oC is 23.8 torr.

$P_{sol'n}$ = (23.8 torr)(0.975) = 23.2 torr

Q3

A solution is made by mixing 125 g of C_3H_8O (vapor pressure at 25^oC = 137 torr) with 375 g of C_2H_5Br (vapor pressure at 25^oC = 286 torr). Calculate the vapor pressure of the solution at 25^oC.

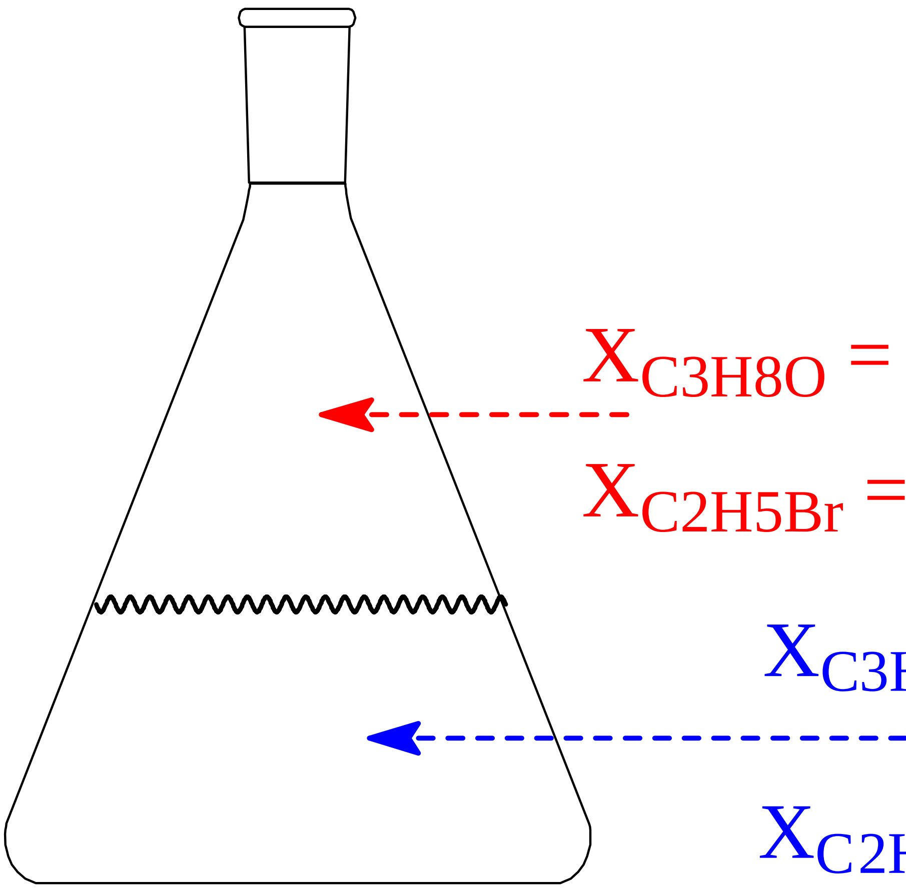
$$P_{sol'n} = P^o_{C3H8O}\ X_{C3H8O} + P^o_{C2H5Br} X_{C2H5Br}$$

Composition of the Vapor in Q3?

$$X_{a\text{-}vap} = \frac{P_a}{P_{sol'n}}$$

Q4

the composition of the vapor



$X_{C3H8O} = 0.225$

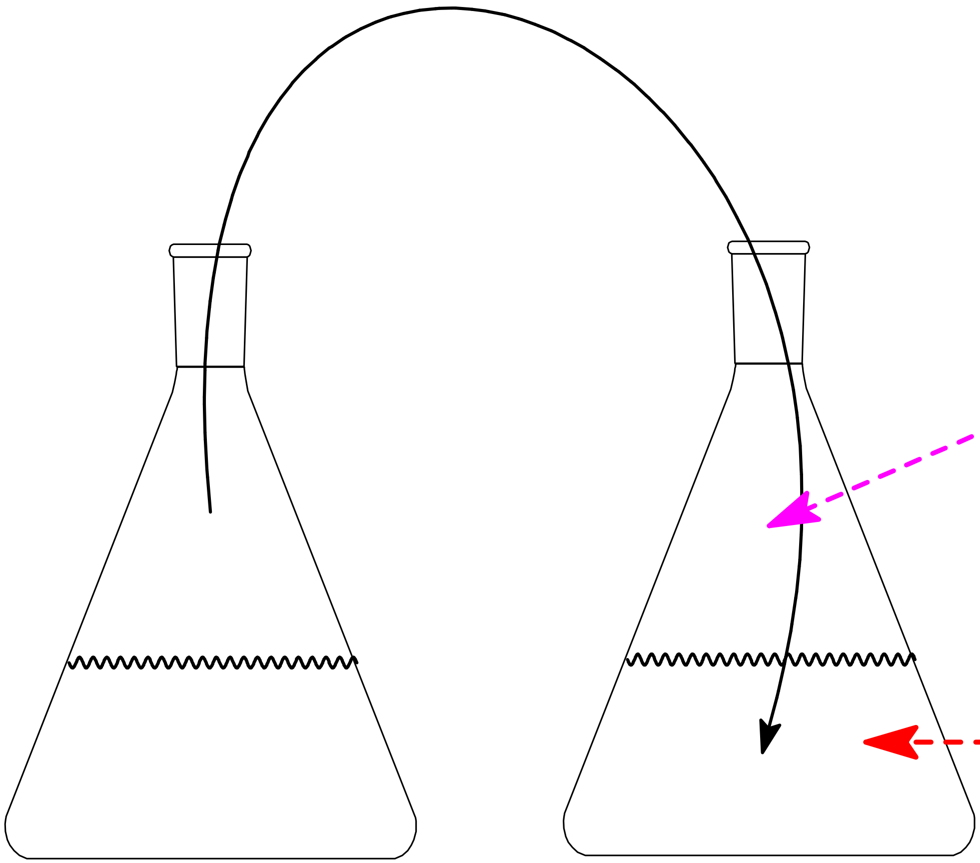
$X_{C2H5Br} = 0.775$

$X_{C3H8O} = 0.377$

$X_{C2H5Br} = 0.623$

Distillation

condense the vapor to a liquid and repeat



Q5

What is the composition of the vapor above this liquid?

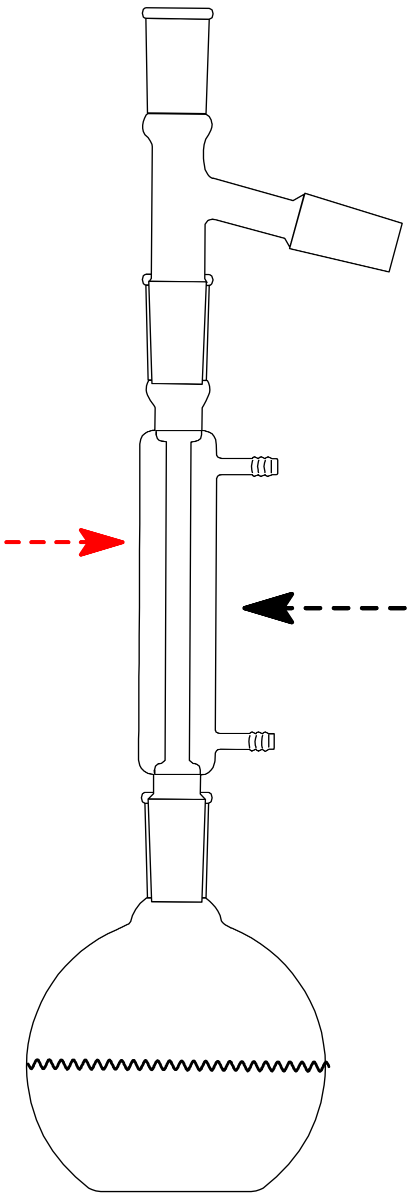
$X_{C3H8O} = 0.225$

$X_{C2H5Br} = 0.775$

Q5
Answer

Theoretical Plate

each time we condense the vapor to a liquid then revaporize



50-200 theoretical plates

this is where the vaporizing/recondensing occurs