

IV) Changes of State

Phase Changes or Transitions

Energy must be supplied to overcome IAF when phase changes involve going to a less ordered state.

A) Fusion (Melting)



$T \uparrow$ $KE \uparrow$, until $KE \approx IAF$

molec. vibrate & overcome IAF

ΔH_{fus} \equiv molar heat of fusion ($\frac{kJ}{mol}$)
heat (enthalpy) req. to
melt 1 mole of solid

B) Vaporization (Evaporation)



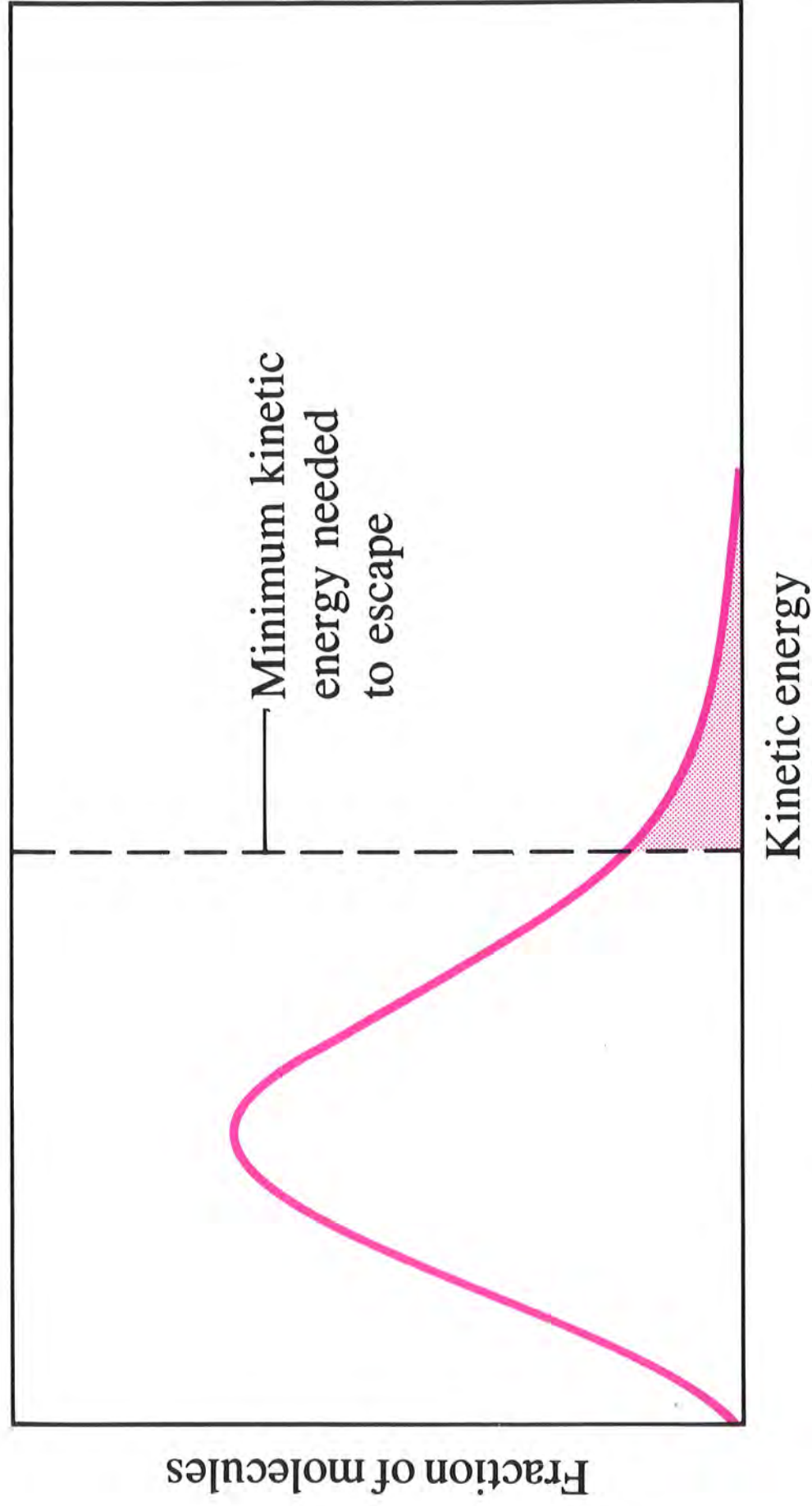
Molecule must:

- 1) be near surface
- 2) have sufficient energy to overcome IAF
- inc. T (add heat)

$\Delta H_v \equiv$ molar heat of vaporization $\left(\frac{\text{kJ}}{\text{mol}}\right)$

heat req. to convert
1 mole of liq. to vapor,
at a given temp.

Transparency 82 Figure 11.17 Distribution of kinetic energies of surface molecules



c) ΔH and IAF

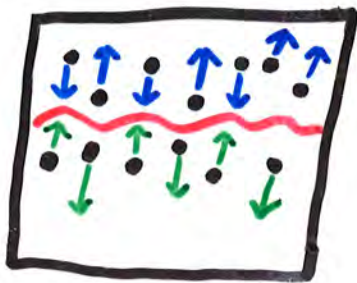
larger ΔH_v \Rightarrow stronger IAF
in liquid

larger ΔH_{fus} \Rightarrow stronger IAF
in solid

$$\Delta H_v > \Delta H_{fus}$$

V) Vapor Pressure

Evap. in a closed container



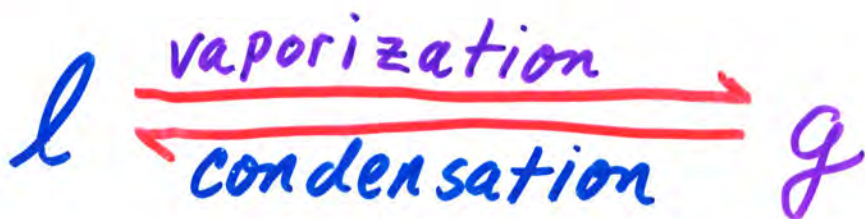
gas molecules *inc.* + they exert a pressure

- some molec. *condense* back into *liq.*

Eventually,

rate of vap. = *rate of cond*

Dynamic Equilibrium



Vapor Pressure

Pressure exerted by a gas
in **equil.** w. its liquid

V.P. depends on

IAF in liquid

stronger **IAF** \Rightarrow **lower** V.P.

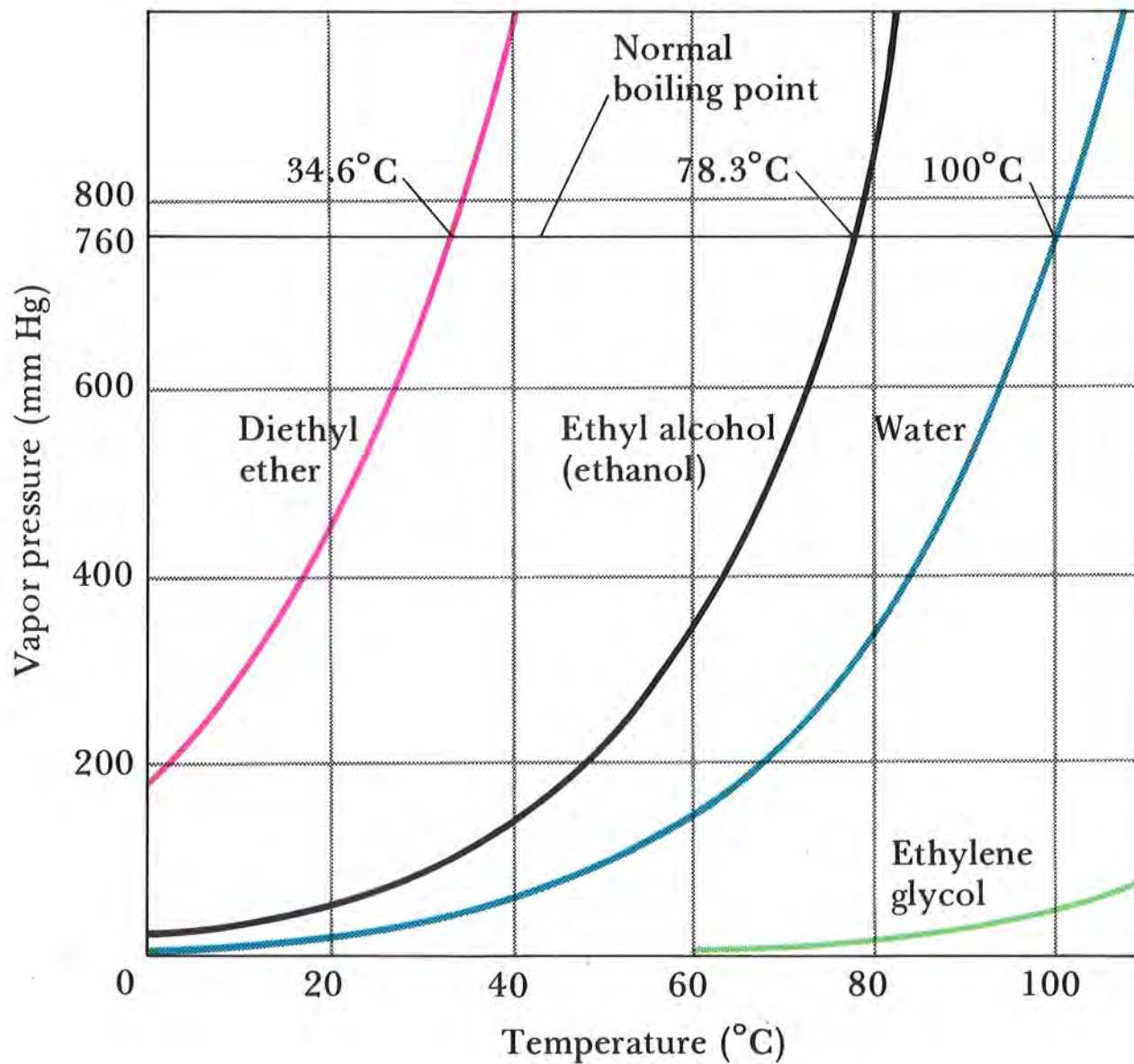
Also,

T \uparrow

V.P. \uparrow

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Figure 11.18 Vapor pressure of four liquids as a function of temperature



V) Boiling Points

Heat a liq. open to atmosphere

T inc. , V.P. inc. until,

$$V.P. = \text{atm. pressure}$$

Bubbles of vapor form
throughout liquid

Boiling

Boiling Pt.

Temp. at which

$$V.P. = P_{\text{atm}}$$

Normal b.p \equiv b.p. at 1 atm

A) Clausius - Clapeyron Eq.

$$\ln P = - \frac{\Delta H_v}{RT} + C$$

$P \equiv$ V.P. at T (K)

$R \equiv 8.314 \frac{\text{J}}{\text{mol}\cdot\text{K}}$

$C \equiv$ constant of integration

Use to find ΔH_v :

Plot $\ln P$ vs. $\frac{1}{T}$

- linear

$$\text{slope} = - \frac{\Delta H_v}{R}$$

1) Base 10 Form

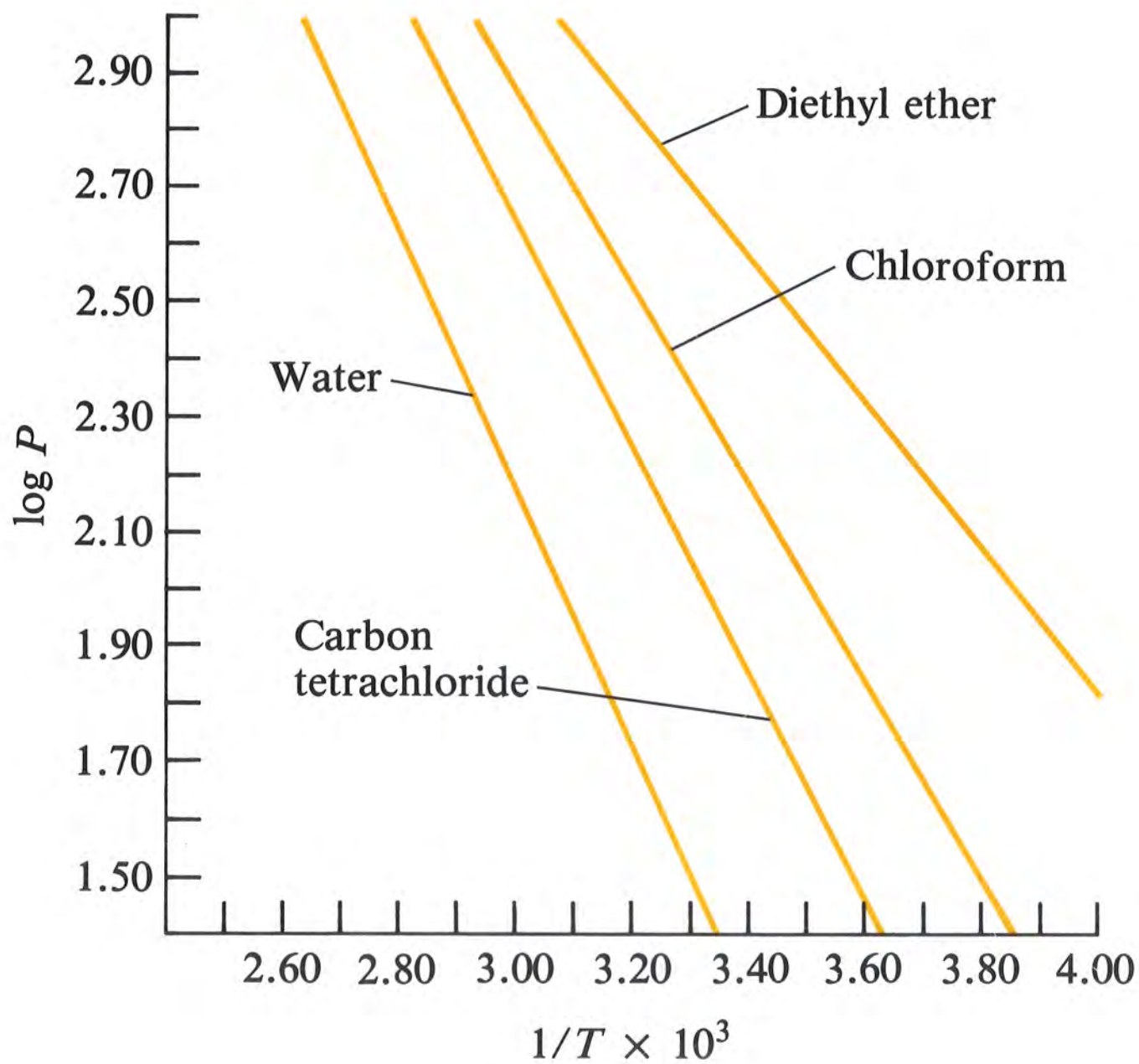
$$\log P = - \frac{\Delta H_v}{2.303 \cdot R T} + C$$

Plot $\log P$ vs. $\frac{1}{T}$

$$\text{slope} = - \frac{\Delta H_v}{2.303 \cdot R}$$

2) Two-Point Form

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



3) Ex: The following is P-T data for ethanol. What is ΔH_v ?

$$P_1 = 43.9 \text{ torr at } T_1 = 20^\circ\text{C}$$

$$P_2 = 352.7 \text{ torr at } T_2 = 60^\circ\text{C}$$

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

$$\ln\left(\frac{352.7}{43.9}\right) = \frac{\Delta H_v}{8.314 \text{ J/mol}\cdot\text{K}} \left(\frac{1}{293\text{K}} - \frac{1}{333\text{K}}\right)$$

$$\Delta H_v = 42.3 \text{ kJ/mol}$$

VI) Melting Point

m.p. is temp. at which
solid & liq. coexist in equilibrium



normal m.p. \equiv m.p. at 1 atm

Changes in P have very
small effects on m.p.

VII) Vapor Pressure of Solids



Generally,

$$V.P. \text{ solid} < V.P. \text{ liq.}$$

Transparency 79 Figure 11.14 Energy changes accompanying phase changes

