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)

$s \xrightarrow{\Delta} l$ endothermic

T ↑ KE ↑, until KE ≈ IAF

molec. vibrate & overcome IAF

ΔH_{fus} ≡ molar heat of fusion $\left(\frac{kJ}{mol}\right)$

heat (enthalpy) req. to melt 1 mole of solid

B) Vaporization (Evaporation)

$l \xrightarrow{\Delta} g$ endothermic

Molecule must:

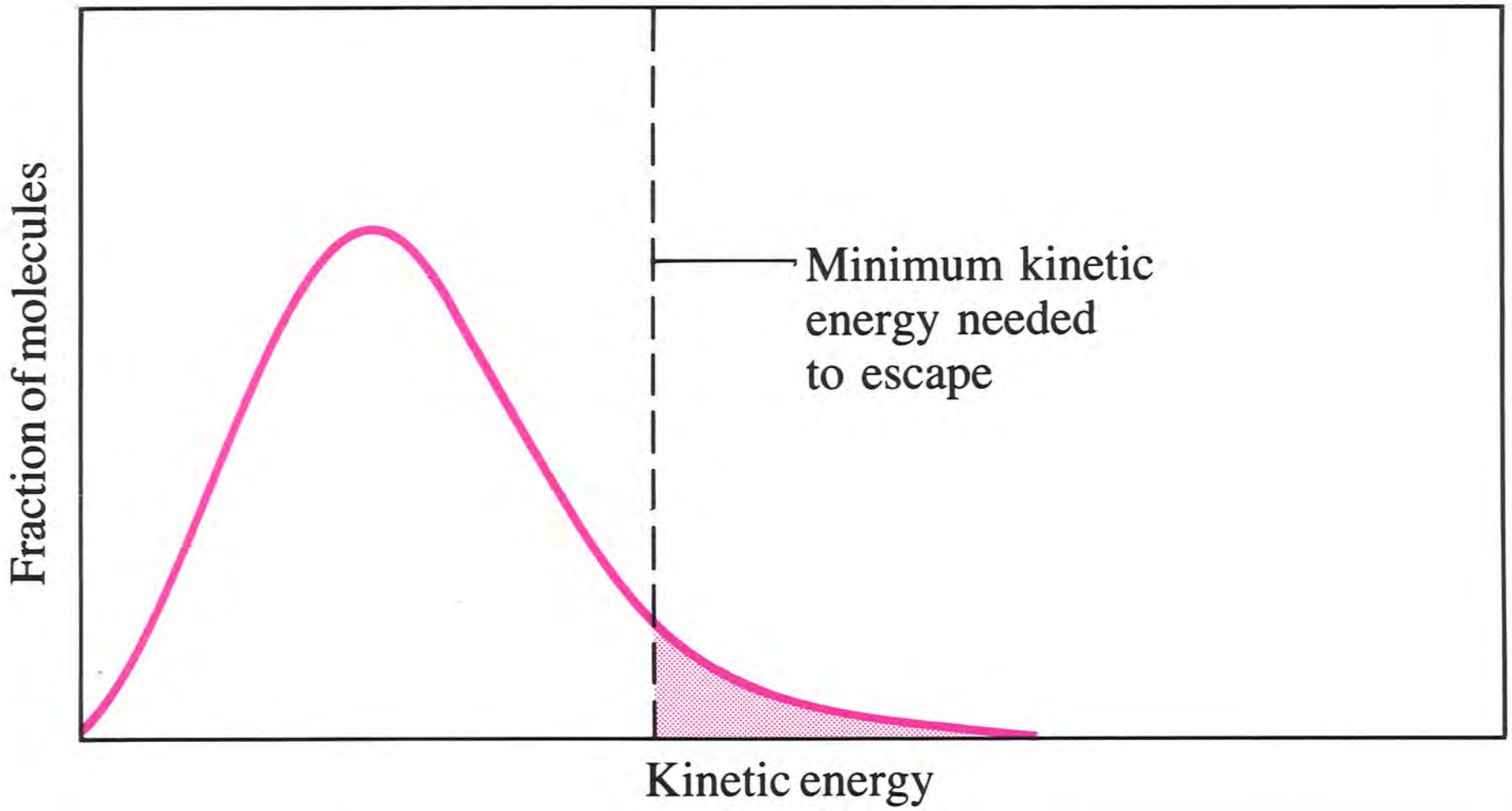
1) be near surface

2) have sufficient energy to overcome IAF
   - inc. T (add heat)

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

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



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c) ΔH and IAF

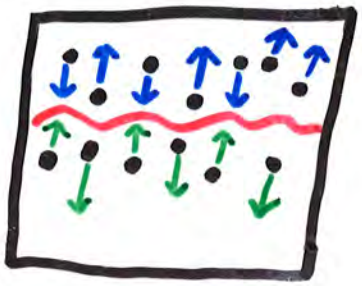
larger ΔH_v $\Rightarrow$ stronger IAF in liquid

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

$$l \underset{\text{condensation}}{\overset{\text{vaporization}}{\rightleftharpoons}} g$$

Vapor Pressure

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

V.P. depends on IAF in liquid

stronger IAF ⇒ lower V.P.

Also,

T ↑ V.P. ↑

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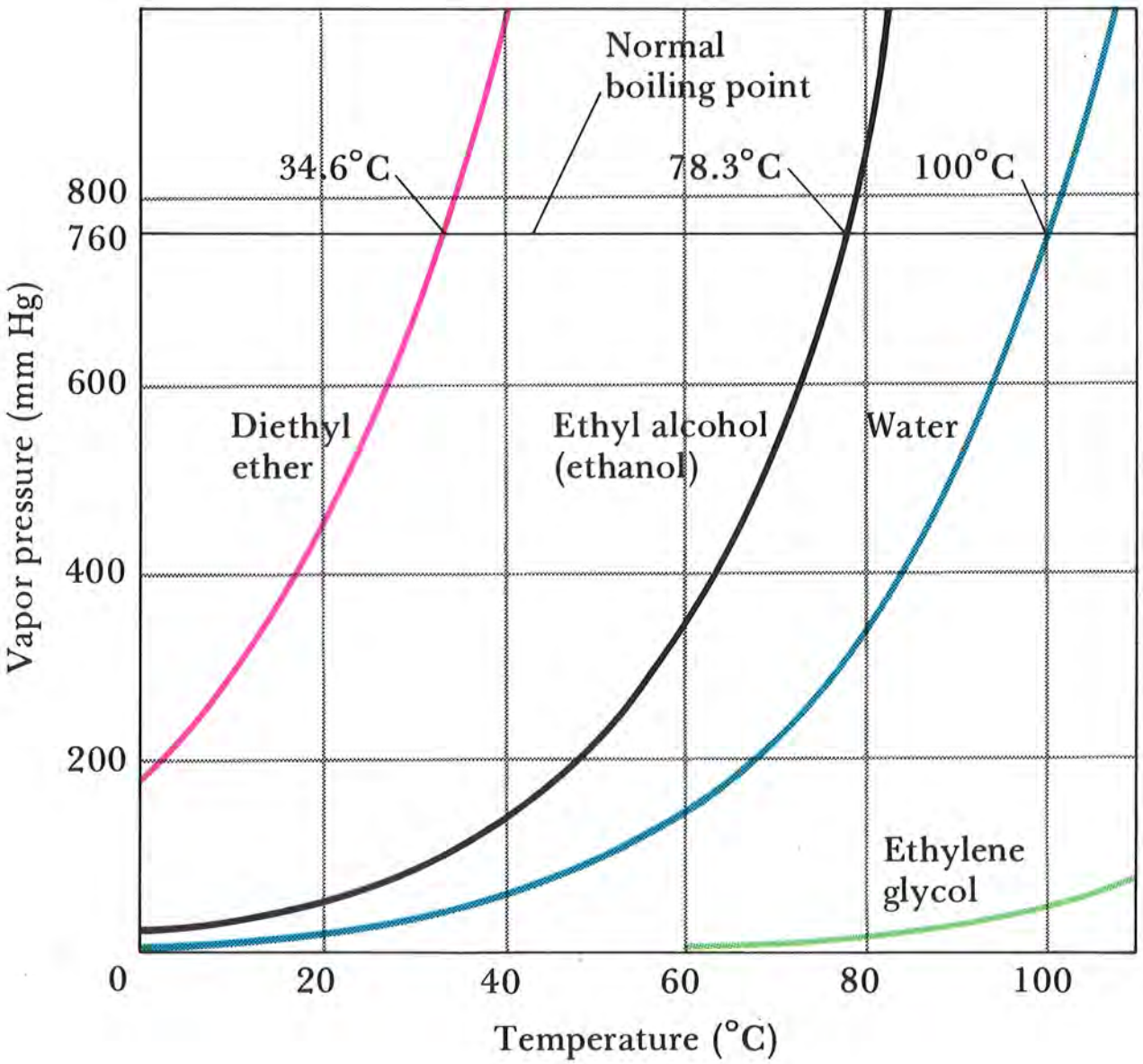
Figure 11.18 Vapor pressure of four liquids as a function of temperature



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V) Boiling Points

Heat a liq. open to atmosphere

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

V.P. = atm. pressure

Bubbles of vapor form throughout liquid

Boiling

Boiling Pt.

Temp. at which

$V.P. = P_{atm}$

Normal b.p ≡ b.p. at 1 atm

A) Clausis - Clapeyron Eq.

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

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

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

$C \equiv$ 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

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

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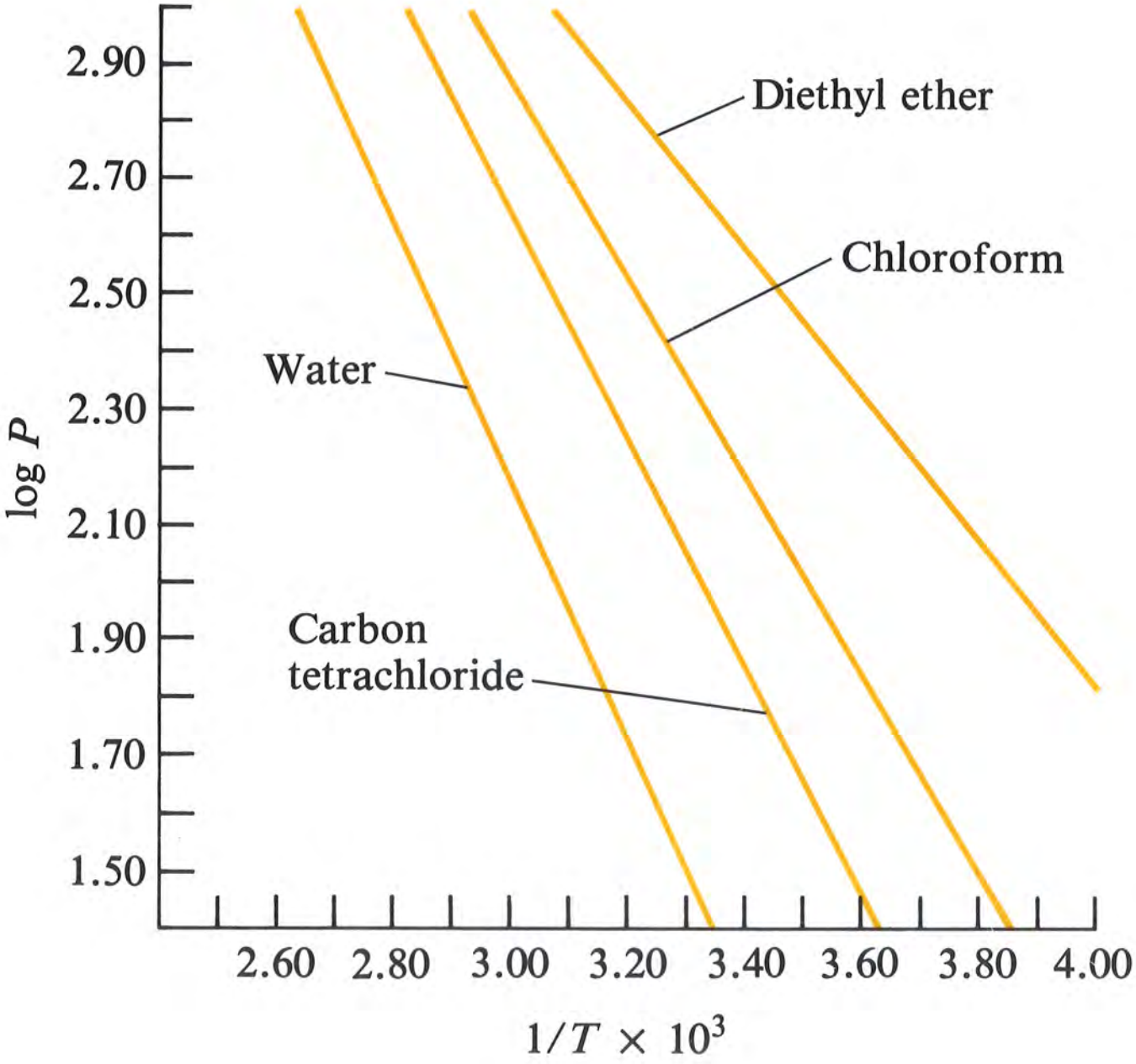
Figure 11.9 Logarithm of vapor pressure versus $1/T$



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

$P_1 = 43.9$ torr at $T_1 = 20°C$

$P_2 = 352.7$ torr at $T_2 = 60°C$

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

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

$$\Delta H_v = 42.3\ kJ/mol$$

VI) Melting Point

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

$$s \underset{\text{freezing}}{\overset{\text{melting}}{\rightleftharpoons}} l$$

normal m.p. ≡ m.p. at 1 atm

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

VII) Vapor Pressure of Solids

$s \underset{\text{deposition}}{\overset{\text{sublimation}}{\rightleftharpoons}} g$

$T \uparrow \quad P_{vap} \uparrow$

$IAF \uparrow \quad P_{vap} \downarrow$

Generally,

$V.P._{solid} < V.P._{liq.}$

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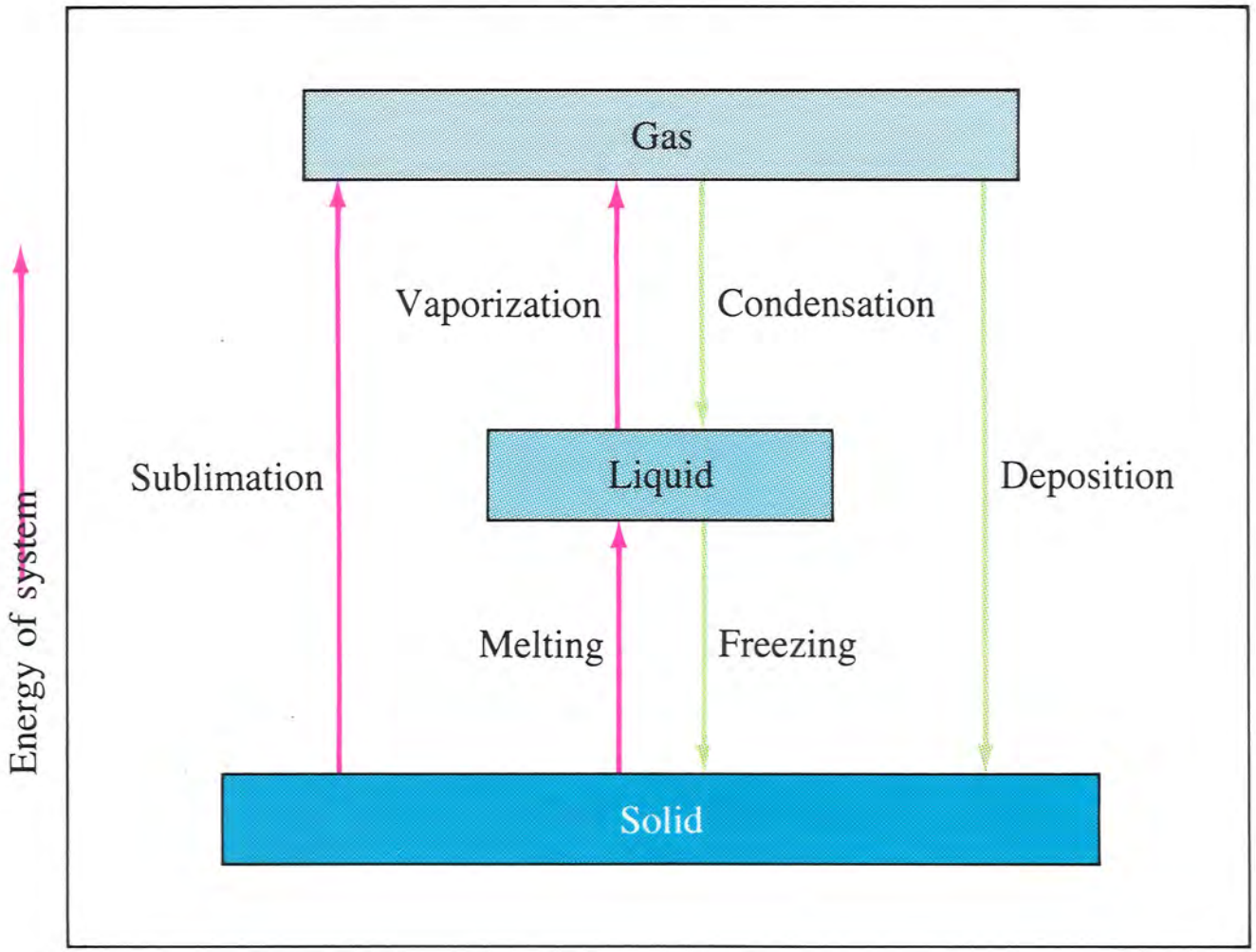
Figure 11.14 Energy changes accompanying phase changes



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