Figure 16.44: Behavior of a liquid in a closed container

Figure 16.47: The number of molecules in a liquid with a given energy versus kinetic energy at two temperatures.

Figure 16.48: The vapor pressure of water, ethanol, and diethyl ether as a function of temperature.

Figure 16.55: The phase diagram for water
A liquid with $\Delta H_{\text{vap}}=8.3145 \text{ J/mol}$ boils on earth at 26.8 °C. What is its boiling point on planet X with a pressure of 0.1 atmosphere?

$$\ln \left( \frac{P_{\text{vap}}}{P} \right) = \frac{\Delta H_{\text{vap}}}{R} \left( \frac{1}{T_2} - \frac{1}{T_1} \right)$$

$$\ln \left( \frac{1}{0.1 \text{ atm}} \right) = \frac{8.3145 \times 10^{-3} \text{ J/mol} \cdot \text{K}}{8.3145 \times 10^{-3} \text{ J/mol} \cdot \text{K}} \left( \frac{1}{177.5^\circ \text{K}} - \frac{1}{268^\circ \text{K}} \right)$$

$$\rightarrow 2.3 = \frac{1}{177.5^\circ \text{K}} - \frac{1}{268^\circ \text{K}}$$

$$\rightarrow T_1 = 177.5^\circ \text{K} = -95.7^\circ \text{C}$$

### Table 16.9: Boiling Point of Water at Various Locations

<table>
<thead>
<tr>
<th>Location</th>
<th>Feet Above Sea Level</th>
<th>$P_{\text{vap}}$ (mm)</th>
<th>Boiling Point (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top of Mt. Everest, Tibet</td>
<td>29,028</td>
<td>240</td>
<td>70</td>
</tr>
<tr>
<td>Top of Mt. McKinley, Alaska</td>
<td>20,320</td>
<td>340</td>
<td>79</td>
</tr>
<tr>
<td>Top of Mt. Whitney, Calif.</td>
<td>14,494</td>
<td>430</td>
<td>85</td>
</tr>
<tr>
<td>Leadville, Colo.</td>
<td>10,150</td>
<td>510</td>
<td>89</td>
</tr>
<tr>
<td>Top of Mt. Washington, N.H.</td>
<td>6,293</td>
<td>590</td>
<td>93</td>
</tr>
<tr>
<td>Boulder, Colo.</td>
<td>5,430</td>
<td>610</td>
<td>94</td>
</tr>
<tr>
<td>Medford, Wis.</td>
<td>900</td>
<td>730</td>
<td>99</td>
</tr>
<tr>
<td>New York City, N.Y.</td>
<td>30</td>
<td>780</td>
<td>100</td>
</tr>
<tr>
<td>Death Valley, Calif.</td>
<td>-282</td>
<td>770</td>
<td>100.3</td>
</tr>
</tbody>
</table>

---

**Figure 16.57: The phase diagram for water**

**Figure 16.50: The heating curve for a given quantity of water where energy is added at a constant rate.**

Let’s heat 5 grams of water from -20 °C to +150 °C. This takes 5 steps.

**STEP 1: HEATING the ice:**
Specific heat capacity, $s_{\text{ice}} = 2.1 \text{ J/g.°C}$
Energy to raise 1 gram 1 degree

$q_1 = 2.1 \text{ J/g.°C} \times 5 \text{ g} \times 20 \text{ °C} = 210 \text{ J}$

**STEP 2: MELTING the ice:**
Heat of fusion, $\Delta H_{\text{fus}} = 6.01 \text{ kJ/mol}$

$q_2 = 6.01 \times 10^3 \text{ J/mol} \times 5 \text{ g} \times (1 \text{ mol}/18.02 \text{ g}) = 1651 \text{ J}$
STEP 3: HEATING the water:
Specific heat capacity, $s_{\text{water}} = 4.2$ J/g.°C
Energy to raise 1 gram 1 degree
$q3 = 4.2$ J/g.°C x 5 g x 100 °C = 2100 J

STEP 4: VAPORIZING the water:
Heat of vaporization, $\Delta H_{\text{vap}} = 40.7$ kJ/mol
$q4 = 40.7 \times 10^3$ J/mol x 5 g x (1 mol/18.02 g) = 11181 J

STEP 5: HEATING the steam:
Specific heat capacity, $s_{\text{steam}} = 2.0$ J/g.°C
Energy to raise 1 gram 1 degree
$q5 = 2.0$ J/g.°C x 5 g x 50 °C = 500 J

$Q_{\text{total}} = q1 + q2 + q3 + q4 + q5$

Glass of tea at 100 °C, content 150 mL = 150 g
Add 5 ice cubes of 1 cc each = 5 g

STEP 1: melting the ice
$6.01$ kJ mol$^{-1}$ x 10$^3$ J mol$^{-1}$ x 5 g = 1667 J

STEP 2a: heating the melted ice to equilibrium temperature $x$
$4.2$ J g$^{-1}$°C x 5 g x $x$ °C = 21 x $J$

STEP 2b: cooling the tea to equilibrium temperature $x$
$4.2$ J g$^{-1}$°C x 150 g (100 – $x$) °C = (630 x – 63000) J

Now solve for $x$:
$651 x - 61332 = 0$
$\rightarrow x = 94.2$ °C