Thermo Summary Chapter 19 & 20

\[ PV = nRT = kNT, \quad \Delta E_{\text{int}} = W + Q, \quad \Delta L = \alpha L_0 \Delta T, \quad \Delta V = \beta V_0 \Delta T, \quad Q = mc \Delta T, \quad Q = mL \]

\[ P = \frac{Q}{\Delta t} = kA \frac{dT}{dx}, \quad P = e \sigma A(T^4 - T_0^4), \quad \sigma = 5.67 \times 10^{-8} J / sK^4 m^2, \quad k = 1.38 \times 10^{-23} J / K \]

\[ W = -\int_{V_i}^{V_f} P \, dV, \quad R = 8.31 J / mol \cdot K, \quad N_A = 6.02 \times 10^{23} / mol, \quad 1 \text{atm} = 1.013 \times 10^5 Pa \]

**GENERAL PRINCIPLES**

**First Law of Thermodynamics**

The first law is a general statement of energy conservation.

Work \( W \) and heat \( Q \) depend on the process by which the system is changed.

The change in the system depends only on the total energy exchanged \( W + Q \), not on the process.

**Energy**

Thermal energy \( E_h \). Microscopic energy of moving molecules and stretched molecular bonds. \( \Delta E_h \) depends on the initial/final states but is independent of the process.

Work \( W \). Energy transferred to the system by forces in a mechanical interaction.

Heat \( Q \). Energy transferred to the system via atomic-level collisions when there is a temperature difference. A thermal interaction.

**IMPORTANT CONCEPTS**

The work done on a gas is

\[ W = -\int_{V_i}^{V_f} P \, dV = -(\text{area under the } pV \text{ curve}) \]

An adiabatic process is one for which \( Q = 0 \). Gases move along an adiabat for which \( pV^\gamma \) is constant, where \( \gamma = C_p / C_V \) is the specific heat ratio. An adiabatic process changes the temperature of the gas without heating it.

Calorimetry. When two or more systems interact thermally, they come to a common final temperature determined by

\[ Q_{\text{net}} = Q_1 + Q_2 + \ldots = 0 \]

The heat of transformation \( t \) is the energy needed to cause 1 kg of substance to undergo a phase change

\[ Q = \pm ML \]

The specific heat \( c \) of a substance is the energy needed to raise the temperature of 1 kg by 1 K.

\[ Q = Mc \Delta T \]

The molar specific heat \( C \) is the energy needed to raise the temperature of 1 mol by 1 K.

\[ Q = nC \Delta T \]

The molar specific heat of gases depends on the process by which the temperature is changed:

\[ C_v = \text{molar specific heat at constant volume}, \]

\[ C_p = \text{molar specific heat at constant pressure}, \]

\[ C_r = C_v + R, \text{ where } R \text{ is the universal gas constant.} \]

**SUMMARY OF BASIC GAS PROCESSES**

<table>
<thead>
<tr>
<th>Process</th>
<th>Definition</th>
<th>Stays constant</th>
<th>Work</th>
<th>Heat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isochoric</td>
<td>( \Delta V = 0 )</td>
<td>( V ) and ( p/T )</td>
<td>( W = 0 )</td>
<td>( Q = nC_v \Delta T )</td>
</tr>
<tr>
<td>Isobaric</td>
<td>( \Delta p = 0 )</td>
<td>( p ) and ( V/T )</td>
<td>( W = -p \Delta V )</td>
<td>( Q = nC_p \Delta T )</td>
</tr>
<tr>
<td>Isothermal</td>
<td>( \Delta T = 0 )</td>
<td>( T ) and ( pV )</td>
<td>( W = -nRT \ln(V_f/V_i) )</td>
<td>( \Delta E_{\text{int}} = 0 )</td>
</tr>
<tr>
<td>Adiabatic</td>
<td>( Q = 0 )</td>
<td>( pV^\gamma )</td>
<td>( W = \Delta E_{\text{int}} )</td>
<td>( Q = 0 )</td>
</tr>
</tbody>
</table>

All gas processes

Ideal-gas law

First law

\( pV = nRT \)

\( \Delta E_{\text{int}} = W + Q = nC_v \Delta T \)