AP Physics - Thermodynamics - 4 Basic P-V Process Diagrams

<table>
<thead>
<tr>
<th>PROCESS</th>
<th>ΔU = Q - W</th>
<th>P-V GRAPH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isothermal</td>
<td>U = ( \frac{3}{2} nRT )</td>
<td>nRT = constant</td>
</tr>
<tr>
<td>(Constant</td>
<td>( \Delta U = \frac{3}{2} nR \Delta T )</td>
<td>PV = constant</td>
</tr>
<tr>
<td>Temperature)</td>
<td>If ( \Delta T = 0 )</td>
<td>P = ( \frac{constant}{V} )</td>
</tr>
<tr>
<td></td>
<td>( \Delta U = 0 )</td>
<td>( \therefore \text{Hyperbola} )</td>
</tr>
<tr>
<td></td>
<td>( Q_{in} = W_{by} )</td>
<td>( \int )</td>
</tr>
</tbody>
</table>

- Happens only during slow processes \( \rightarrow \) Temp has a chance to fully equalize with the surroundings.

Adiabatic

<table>
<thead>
<tr>
<th>PROCESS</th>
<th>Q = 0</th>
<th>P-V GRAPH</th>
</tr>
</thead>
<tbody>
<tr>
<td>(No heat</td>
<td></td>
<td>nR = constant</td>
</tr>
<tr>
<td>transfer)</td>
<td>( \Delta U = W_{on} )</td>
<td>PV = constant</td>
</tr>
</tbody>
</table>

- Happens only during fast processes \( \rightarrow \) Temp doesn’t have chance to equalize.

Isobaric

<table>
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<tr>
<th>PROCESS</th>
<th>W = PV</th>
<th>P-V GRAPH</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant</td>
<td></td>
<td>( \int )</td>
</tr>
<tr>
<td>Pressure)</td>
<td></td>
<td>No area!</td>
</tr>
</tbody>
</table>

Isochoric

a.k.a. Isovolumetric

a.k.a. Constant Volume

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<th>P-V GRAPH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isochoric</td>
<td>( \Delta U = Q_{in} )</td>
<td>No work!</td>
</tr>
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\( \int \)
Calculating work done during a process

\[ W = P \Delta V \]

\[ \therefore \text{ Work is equal to the area under the } P-V \text{ curve! (see your friendly neighborhood calculus teacher for an explanation)} \]

For the work done by each of the 4 processes, look at the area shaded in pink.

\[ \star \text{ If volume is increasing, } \Delta V \text{ is positive, therefore work is being done by the system.} \]

\[ \star \text{ If volume is decreasing, } \Delta V \text{ is negative therefore work is being done on the system.} \]
Thermodynamic Cycles

A thermodynamic cycle is a series of processes that a system undergoes such that the ending state is identical to the beginning state.

During any process within a cycle
Heat - may be transferred into or out of the system
Work - may be done on or by the system

Example

\[ P \begin{array}{c}
\text{A} \\
\text{B} \\
\text{C} \\
\text{D} \\
V
\end{array} \]

A-B: Work is done by the system at high pressure.
\[ W_{\text{by}} = \text{Area under curve A-B} \]

\[ P \begin{array}{c}
\text{A} \\
\text{B} \\
\text{C} \\
\text{D} \\
V
\end{array} \]

B-C: No work is done
C-D: Work is done on the system at low pressure.

D-A: No work is done

Net work done by the system = \( W_{\text{A-B}} - W_{\text{C-D}} \)

\[ P \begin{array}{c}
\text{A} \\
\text{B} \\
\text{C} \\
\text{D} \\
V
\end{array} \]

\[ \therefore W_{\text{by}} = \text{Area of rectangle ABCD} \]