

## 13: Heat and Thermodynamics

Key Physics Terms	Variables Used and Their Metric Units
<ul style="list-style-type: none"> <li><b>Thermodynamics:</b> The study of processes in which energy is transferred as work or heat.</li> <li><b>Temperature:</b> A measure of the average kinetic energy of the particles. The higher the temperature the faster the molecules move.</li> <li><b>Linear Expansion:</b> A change in length of a solid due to a temperature change. Proportional to the linear expansion coefficient, <math>\alpha</math>, for the material.</li> <li><b>Volume Expansion:</b> A change in volume of a solid due to a temperature change. Proportional to the volume expansion coefficient, <math>\beta</math>, for the material. Note <math>\beta = 3\alpha</math>.</li> <li><b>Energy:</b> The ability to do work or supply heat.</li> <li><b>System:</b> The object or objects being studied.</li> <li><b>Surroundings:</b> Everything surrounding the system.</li> <li><b>Internal Energy:</b> The total energy of all the molecules in the system.</li> <li><b>Heat:</b> The transfer of energy from one object to another due to a difference in temperature.</li> <li><b>Work:</b> In thermodynamics the work done <b>by</b> the system is positive; the work done <b>on</b> the system is negative.</li> <li><b>Calorie:</b> The amount of heat required to raise the temperature of 1g of water by 1°C. 1 calorie = 4.18 Joules.</li> <li><b>State Functions:</b> Quantity which is dependent only on the current state of the system not the path taken to reach that state, e.g. Temperature.</li> <li><b>Specific Heat Capacity:</b> The amount of energy required to change a unit mass of a substance by 1°C.</li> <li><b>Heat Capacity:</b> The amount of heat needed to raise a mass of a substance, given by the product of mass and specific heat capacity.</li> <li><b>Endothermic reactions:</b> A reaction in which energy is absorbed into the system from the surroundings.</li> <li><b>Exothermic reactions:</b> A reaction in which energy is released from the system into the surroundings.</li> <li><b>Calorimetry:</b> A quantitative measurement of energy lost/gained from the system, which is equal &amp; opposite to that lost/gained from the surroundings.</li> <li><b>Latent Heat:</b> The energy required to change the phase of a substance, without changing the temperature of the substance.</li> <li><b>Heat of fusion:</b> The heat required to change 1kg of a substance from a solid to a liquid state, which is equal to the heat lost when the liquid changes to a solid state.</li> <li><b>Heat of vaporization:</b> The heat required to change 1kg of a substance from a liquid to a vapor phase, which is equal to the heat lost when the vapor changes to a liquid phase.</li> <li><b>Thermal Equilibrium:</b> Two objects in thermal contact cease to exchange net energy.</li> <li><b>Zeroth Law of Thermodynamics:</b> If two systems are separately in thermal equilibrium with a third system. The first two systems are in thermal equilibrium with each other.</li> <li><b>1<sup>st</sup> Law of Thermodynamics (Law of Conservation of Energy):</b> When heat flows into a system the energy must either appear as increased internal energy or work done by the system on its surroundings.</li> <li><b>Entropy:</b> A quantitative measure of the disorder of a system.</li> <li><b>2<sup>nd</sup> Law of Thermodynamics:</b> The total entropy of the universe can never decrease. Natural processes tend towards disorder, greater entropy.</li> <li><b>Heat Engine:</b> A device that converts thermal energy into mechanical work.</li> <li><b>Ideal Heat Engine:</b> An engine with an efficiency of 1.</li> <li><b>Efficiency:</b> The ratio of the work done by the heat engine to the heat input to the engine.</li> </ul>	<ul style="list-style-type: none"> <li><math>T</math> = Temperature, °C, K</li> <li><math>\alpha</math> = Linear expansion coefficient, (°C)<sup>-1</sup></li> <li><math>\beta</math> = Volume expansion coefficient, (°C)<sup>-1</sup></li> <li><math>L</math> = Length, m</li> <li><math>V</math> = Volume, m<sup>3</sup></li> <li><math>U</math> = Internal energy, J</li> <li><math>Q</math> = Heat, J</li> <li><math>W</math> = Work, J</li> <li><math>C_m</math> = Specific heat, J/kg•°C</li> <li><math>m</math> = Mass, kg</li> <li><math>C</math> = Heat capacity, J/°C</li> <li><math>L_{fus}</math> = Heat of Fusion, kJ/kg</li> <li><math>L_{vap}</math> = Heat of Vaporization, kJ/kg</li> <li><math>S</math> = Entropy, J/kg</li> <li><math>\epsilon</math> = Efficiency</li> </ul>
	<b>Key Formulas</b> <ul style="list-style-type: none"> <li><math>\Delta L = L \alpha \Delta T</math></li> <li><math>\Delta V = V \beta \Delta T</math></li> <li><math>\beta = 3\alpha</math></li> <li><math>Q = C_m m \Delta T</math> or <math>Q = C \Delta T</math> where <math>C = C_m m</math></li> <li><math>\Delta Q_{fus} = m \times L_{fus}</math></li> <li><math>\Delta Q_{vap} = m \times L_{vap}</math></li> <li><math>U = Q - W</math></li> <li><math>\Delta S_{univ} \geq 0</math></li> <li><math>\Delta S_{univ} + \Delta S_{sur} \geq 0</math></li> <li><math>\epsilon = \frac{W_{out}}{Q_{in}}</math></li> </ul>
	<b>1<sup>st</sup> Law of Thermodynamics</b> <p><b>1<sup>st</sup> Law of Thermodynamics</b> When heat flows into a system the energy must either appear as increased internal energy or work done by the system on its surroundings. This is a statement of the conservation of energy.</p> $U = Q - W$ <p><math>Q</math> is the heat added to the system. <math>W</math> is <b>positive</b> when work is done <b>by</b> the system on its surroundings: <math>U = Q - W</math> <math>W</math> is <b>negative</b> when work is done <b>on</b> the system, by surroundings: <math>U = Q - (-W) = Q + W</math></p> <p>Special cases of the 1<sup>st</sup> Law  <b>Adiabatic:</b> No heat transfer, <math>Q = 0</math>, <math>\Delta U = -W = -P\Delta V</math>  <b>Constant volume:</b> No work is done, <math>W = 0</math>, <math>\Delta U = Q</math>  <b>Cyclic:</b> No change in internal energy, <math>\Delta U = 0</math>, <math>Q = -W</math>  <b>Free expansion processes:</b> Irreversible, <math>\Delta U = Q = W</math></p>
	<b>2<sup>nd</sup> Law of Thermodynamics</b> <p>Entropy is a measure of disorder. If the entropy of the system decreases during a reaction, the entropy of the surroundings increases by an equal or greater amount.</p> <p>Statements of the 2<sup>nd</sup> Law of Thermodynamics:</p> <ol style="list-style-type: none"> <li>The total entropy of the universe can never decrease, only increase or remain the same. <math>\Delta S \geq 0</math>.</li> <li>Heat flows from a hot object to a cold object but never the reverse.</li> <li>There cannot be a 100% efficient heat engine; one that changes a given amount of heat entirely into work:</li> </ol> $\epsilon = \frac{W_{out}}{Q_{in}} < 1$

How to Use This Cheat Sheet: These are the keys related this topic. Try to read through it carefully twice then write it out on a blank sheet of paper. Review it again before the exams.

# Acs Thermodynamics Practice Exam

**Kirk-Othmer**



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