

Thermodynamics Summary
SCH 4U – University Level Chemistry

Methods of Measuring Thermal Energy	$Q = mc\Delta T$	Use when a substance experiences a change in temperature (either through the absorption or release of heat). If heat is released, temperature will drop, $\Delta T = T_f - T_i$ will be negative, therefore $Q = -$ value. If heat is absorbed ΔT will be positive, therefore $Q = +$ value. More often than not, the substance experiencing the change in temperature will be water ($c = 4.184 \text{ J/g}^\circ\text{C}$) which has been used for the purpose of measuring the heat released or absorbed during a chemical reaction. Be careful to use the mass of the substance that is being warmed, not the mass of the substance doing the warming.
	$Q = L_f m$	Use when a substance experiences a change in state from solid to liquid or liquid to solid (either through the absorption or release of heat). When a substance changes from a solid to a liquid heat must be absorbed in order to weaken the forces of attraction holding the solid together. Therefore $Q = +$ value. When a substance changes from a liquid to a solid heat must be released as forces of attraction holding the solid together are re-established. Therefore $Q = -$ value.
	$Q = L_v m$	Use when a substance experiences a change in state from liquid to a gas or gas to a liquid. See above for parallel statements
Methods of Converting	Conversion Factor – Ratio Type: $\frac{54.7 \text{ kJ}}{1.62 \text{ g}} \times \frac{17.96 \text{ g}}{1 \text{ mol}} = 606.43 \text{ kJ/mol}$	Used when information is given in a ratio form (i.e. when 1.62 g of substance is combusted, 54.7 kJ of heat is released).* This ratio can be converted to other ratios as needed. Note that the unit of /1 mol is dropped once the value of 606.43 kJ/mol is attached to a thermodynamic equation.
	Conversion Factor – Magnitude Type: $0.34 \text{ g} \times \frac{1 \text{ mol}}{85.2 \text{ g}} \times \frac{880.34 \text{ kJ}}{1 \text{ mol}} = 3.513 \text{ kJ}$	Used when a single number defines the magnitude (i.e. size) of a reaction (conversion factors are then used to change from one single number magnitude to a second single number magnitude)*
	* Frequently, lengthy calculations are required to arrive at the starting ratio in the "Ratio Type" conversion factor or to acquire the conversion needed in the "Magnitude Type" conversion factor.	
1 st Law of Thermodynamics	$\Delta H = -Q$	Use this equation to change between thermal heat energy (kinetic energy) and a change in enthalpy (potential energy). It is preferable to convert the magnitude of Q to a Q per mol before changing to a change in an enthalpy value. Only properly scaled enthalpy values can be attached to a thermodynamic equation. This equation is central to all thermodynamics. Chemical potential energy (i.e. enthalpy) cannot be measured directly, it can only be measured through changes in the kinetic energy. Enthalpy cannot be measured absolutely. All enthalpy values are relative and hence are ΔH values instead of H values. Elements have been assigned ΔH_f° values of zero as a starting point from which all other ΔH values have been determined. ΔH_f° for most substances can be found in tables and are called Enthalpies of Formation or Heats of Formation. The value represents the change in potential energy that would occur should the given substance be produced from its element through a "formation reaction"

Methods of Calculating Changes in Enthalpy	Heat Summation (Hess' Law in Disguise)	<p>Used this method when heats of formation are used to calculate a heat of reaction or a heat of combustion. eg</p> $\text{C}_6\text{H}_6(\text{l}) + \frac{15}{2}\text{O}_2(\text{g}) \rightarrow 6\text{CO}_2(\text{g}) + 3\text{H}_2\text{O}(\text{l}) \quad \Delta\text{H} = ?$ $\Delta\text{H} = [6\Delta\text{H}_{\text{CO}_2(\text{g})}^\circ + 3\Delta\text{H}_{\text{H}_2\text{O}(\text{l})}^\circ] - [\Delta\text{H}_{\text{C}_6\text{H}_6(\text{g})}^\circ + \frac{15}{2}\Delta\text{H}_{\text{O}_2(\text{g})}^\circ]$ <p>This method can also be used to find a heat of formation if you know the heat of reaction or heat of combustion plus all other heats of formation. In this case, for the above example, you would know the answer on the left and use the heats of formation for carbon dioxide, water (and oxygen) to find the heat of formation of C₆H₆(l)</p>
	Hess' Law	<p>Use this method to modify and add equations with known ΔH values together to arrive at an equation for which you wish to find ΔH.</p> <ol style="list-style-type: none"> Write out any of given equations as full thermodynamic equations first as necessary. Write out what you are trying to find If you reverse any of the given equations you must change the sign of ΔH If you multiply any of the given equations you must also multiply the ΔH value. Good Luck!!!

Exothermic vs Endothermic Reactions:			
Exothermic	Heat is release, therefore the surroundings absorb heat and warm, therefore Q = +	Endothermic	Heat is absorbed, therefore the surroundings release heat and cool, therefore Q = -
	Since kinetic energy increases, potential energy must decrease (ΔH = -Q), therefore ΔH = -		Since kinetic energy decreases, potential energy must increase (ΔH = -Q), therefore ΔH = +
	The decrease in potential energy means that the relative position of atoms are at lower energy positions which means that attractive forces have increased and hence interatomic distances have decreased .		The increase in potential energy means that the relative position of atoms are at higher energy positions which means that attractive forces have decreased and hence interatomic distances have increased .
	The closer together two attractive objects are the stronger the forces of attraction, hence lower potential energy.		The further apart two attractive objects are the weaker the forces of attraction, hence higher potential energy.

Terminology	Formation Reaction:	<p>A reaction in which one mole of a compound is produced directly from elements in their natural state at 25 °C and 1 atm pressure. Fractional coefficients are frequently used for reactants!</p> $6\text{C(s)} + 3\text{H}_2\text{(g)} \rightarrow \text{C}_6\text{H}_6\text{(l)} \quad \Delta\text{H}^\circ = +49.0 \text{ kJ}$
	Combustion Reaction:	<p>A reaction in which a substance is reacted with O₂(g) to produce oxide products. In the case of the combustion of a hydrocarbon, the oxide products are carbon dioxide and water. The reaction is usually written for one mole of the reactant being oxidized.</p> $\text{C}_6\text{H}_6\text{(l)} + \frac{15}{2}\text{O}_2\text{(g)} \rightarrow 6\text{CO}_2\text{(g)} + 3\text{H}_2\text{O(l)} \quad \Delta\text{H} = -3169.40 \text{ kJ}$
	Heat of Reaction:	The change in enthalpy for any reaction.
	Heat of Formation:	<p>The change in enthalpy for a formation reaction for one mole of any substance. Heats of formation are listed in the textbook starting on page 799. These heats of formation can be used directly in a "Heat Summation" calculation or can be used to write the enthalpy term for the corresponding formation reaction. eg:</p> $\Delta\text{H}_{\text{C}_2\text{H}_3\text{Cl}_2\text{(g)}}^\circ = -126.9 \text{ kJ/mol}$ <p>Is the heat of formation of 1,2-dichloroethane. This can also be expanded to:</p> $2\text{C(s)} + \frac{3}{2}\text{H}_2\text{(g)} + \text{Cl}_2\text{(g)} \rightarrow \text{C}_2\text{H}_3\text{Cl}_2\text{(l)} \quad \Delta\text{H}^\circ = -126.9 \text{ kJ}$ <p>The /mol unit can be left off once the value is attached to the thermodynamic equation. It is understood that once attached it is per mole of 1,2-dichloroethane. Also note that when the heat of formation value is attached to the formation reaction, it is no longer necessary to show the formula of 1,2-dichloroethane after the ΔH° symbol. It goes without saying.</p>
	Heat of Combustion:	The change in enthalpy for a combustion reaction
	Thermodynamic Equation:	<p>An equation followed by an enthalpy term. eg</p> $\text{H}_2\text{(g)} + \frac{1}{2}\text{O}_2\text{(g)} \rightarrow \text{H}_2\text{O(l)} \quad \Delta\text{H}^\circ = -285.8 \text{ kJ} \quad \text{or}$ $\text{CO}_2\text{(g)} \rightarrow \text{CO(g)} + \frac{1}{2}\text{O}_2\text{(g)} \quad \Delta\text{H}^\circ = 393.5 \text{ kJ}$ <p>Here the energy change is expressed as a change in chemical potential energy (i.e. change in enthalpy, ΔH)</p>
	Thermochemical Equation:	<p>An equation that includes a thermal energy term as either a reactant or a product. eg</p> $\text{H}_2\text{(g)} + \frac{1}{2}\text{O}_2\text{(g)} \rightarrow \text{H}_2\text{O(l)} + 285.8 \text{ kJ} \quad \text{or}$ $\text{CO}_2\text{(g)} + 393.5 \text{ kJ} \rightarrow \text{CO(g)} + \frac{1}{2}\text{O}_2\text{(g)}$ <p>Here the energy change is expressed as the release or absorption of kinetic energy (i.e. a Q value)</p>