UNIVERSITY OF TORONTO

Tutorial 8 (Week 9)

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Land Acknowledgment

I wish to acknoledge this land on which the University of Toronto operates. For thousands of years it has been the traditional land of the Huron-Wendat, the Seneca, and most recently the Mississaugas of the Credit River. Today, this meeting place is still the home of many Indigenous people from across Turtle Island and we are grateful to have the opportunity to work on this land.

Anouncements

- Last problem set will be due on December 2nd (Friday)

Theory Review: Thermodynamics

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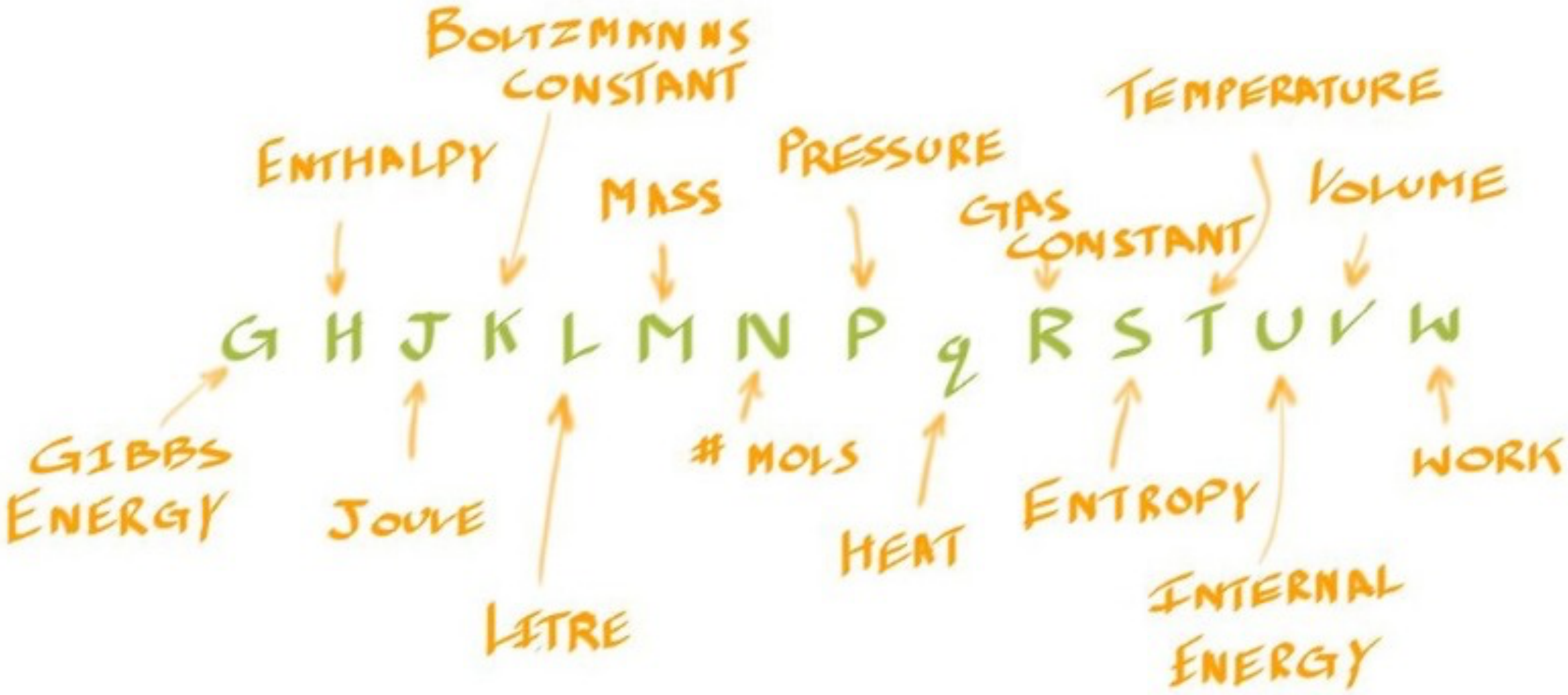
- First Law: Conservation of Energy
  - $\Delta U = q + w$

- Second Law: "The entropy of the Universe increases during any spontaneous process"
  - Entropy = disorder
    - $\Delta S = \frac{q_{rev}}{T}$

Theory Review: Thermodynamics



Theory Review: Thermodynamics

- Enthalpy Change for a Chemical Reaction

$$2\,C_8H_{8(l)} + 25\,O_{2(g)} \rightarrow 16\,CO_{2(g)} + 18\,H_2O_{(g)}$$

$$\Delta_r H^0 = 16 * \Delta_f H^0(CO_{2(g)}) + 18 * \Delta_f H^0(H_2O_{(g)}) - 2 * \Delta_f H^0(C_8H_{8(l)}) - 25 * \Delta_f H^0(O_{2(g)})$$

standard conditions

reaction

formation

products

reactants

Theory Review: Thermodynamics

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- When is a process/reaction spontaneous?
  - $\Delta S_{universe} > 0$ which is the same as $\Delta G_{system} < 0$
    - Gibbs Free Energy: $\Delta G = \Delta H - T\Delta S$
      - Spontaneity depends on the temperature!

Sample Problems

Consider the decomposition of magnesium carbonate ($MgCO_3$) into solid magnesium oxide (MgO) and carbon dioxide (CO_2) at 25 Celcius. Data for the Gibb's free energy, enthalpy, and entropy for all species is given in the table below

Component	$\Delta_f^\circ G$ (kJ/mol)	$\Delta_f^\circ H$ (kJ/mol)	S° (J/mol K)
$MgCO_3$	-1021.1	-1095.8	65.7
CO_2	-394.4	-393.5	213.6
MgO	-569.9	-601.8	27

a. Is this process spontaneous ?

b. At what temperature (in Celsius) would this be spontaneous?

Quizz (not graded)

1. The _____ law of thermodynamics states that the entropy of an isolated system never decreases, it either increases or stays the same
   a. Zeroth
   b. First
   c. Second
   d. Third

2. Which of the following is always positive for a spontaneous reaction
   a. ΔS_{system}
   b. $\Delta S_{surroundings}$
   c. ΔH_{system}
   d. $\Delta H_{surroundings}$

3. Propane is a commonly used fuel for portable barbeques.
   a. Write the balanced chemical equation for the combustion of 1 mol of gaseous propane (C_3H_8) in oxygen to form carbon dioxide gas and water vapour.
   b. Determine the standard combustion enthalpy for one mol of gaseous propane
   c. Assuming all of the heat from the combustion goes to heating 1 kg of water at 25C, how many grams of water will boil off (form gas)?

$\Delta_{vap}H^\circ = 40.7 \times 10^3$ J/mol K

$\Delta_f H^\circ\ (CO_{2(g)}) = -393.5$

$\Delta_f H^\circ\ (H_2O_{(g)}) = -241.8$

$C_p = 4.184$ J/gK

$\Delta_f H^\circ\ (C_3H_{8(g)}) = -103.8$

Quizz (not graded) – Solutions

1. C
2. C

3. a) $C_3H_{8(g)} + 5\,O_{2(g)} \rightarrow 3\,CO_{2(g)} + 4\,H_2O_{(g)}$

b) $\Delta_{comb}H^\circ = 3\Delta_f H^\circ(CO_{2(g)}) + 4\Delta_f H^\circ(H_2O_{(g)}) - \Delta_f H^\circ(C_3H_{8(g)})$

$= 3(-393.5) + 4(-241.8) - (-103.8) = -2040\ kJ$

c) $\Delta_{comb}H^\circ = m\,c\,\Delta T + (\Delta_{vap}H^\circ)\frac{m}{A}$

$c = 4.184\ \frac{J}{g\cdot K}$

$m = 10^3\ g$

$\Delta T = 75\ K$

$\Delta_{vap}H^\circ(H_2O) = 40.7(10^3)\ \frac{J}{mol}$

$m = \frac{(\Delta_{comb}H^\circ - mc\Delta T)\cdot A}{\Delta_{va}H^\circ}$ [=] $\left(\frac{J - g\cdot\frac{J}{g\cdot K}\cdot K}{\frac{J}{mol}}\right)\frac{J}{mol}$

$m = \frac{[2040(10^3) - 4.184(10^3)\,75]\,18}{40.7(10^3)} = 763\ g$