Review Exam
Energy comes in many forms and total energy (like total mass) is always conserved

Energy is not created or destroyed, it simply changes form (like reactants in our mass systems)

Total Energy $E_T = E_p + E_k + U$

Total rate of energy $\dot{E}_T = \dot{E}_p + \dot{E}_k + \dot{U}$

$H = U + PV$

Enthalpy = internal energy + pressure * volume
Non Reactive processes can have changes in enthalpy

We can still write the accounting equation for energy, but there will be some differences...

\[
\varphi_{\text{in}} - \varphi_{\text{out}} = \varphi_{\text{acc}} = \frac{d\varphi}{dt}
\]

\[
\sum_i E_{T,i} - \sum_j E_{T,j} + \sum \dot{Q} + \sum \dot{W} = \frac{dE_{T}^{\text{sys}}}{dt}
\]

Where \(E_{T} = E_{p} + E_{k} + \dot{U}\)
We will focus mostly this week on heat and heat transfer, $Q$

$$\dot{Q} = hA(T_{surr} - T_{sys})$$

$H =$ heat transfer coefficient (per unit area, units $\text{W/m}^2\text{K}$)

$A =$ area

Heat is defined as positive if it moves to the system from the surroundings, and likewise, is negative when it leaves a system.

If a system is insulated and has no exchange of heat, it is called adiabatic.
Enthalpy is a state function (an intrinsic property) where only the current state matters; it is the total sum of heat energy in a system.

- enthalpy increases
  - heat energy in

- enthalpy decreases
  - heat energy out
\[ \sum_i m_i \dot{E}_{T,i} - \sum_j m_j \dot{E}_{T,j} + \sum \dot{Q} + \sum W_{nonflow} = \frac{dE_T^{sys}}{dt} \]

For flowing systems, \( \dot{E}_T = \dot{E}_p + \dot{E}_k + \dot{H} \),

We can calculate multiple states (A and B) using \( \Delta \dot{H} = \dot{H}_A - \dot{H}_B \) or, more generally, \( \Delta \dot{H} = \sum_k \Delta \dot{H}_k \) for \( k \) steps between initial and final states.
Liquid nitrogen is used in numerous research and clinical settings. Suppose gaseous N2 is at room temperature (298 K) and is cooled to liquid N2, just below its boiling point at 77K. The specific enthalpy change for this step is -1435 cal/mol. The heat of vaporization, the specific change from liquid to vapor is 1336 cal/mol. What is the overall change in enthalpy?

1. Draw a diagram of the process
2. Write the enthalpy equation showing the overall change in enthalpy
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1. Draw a diagram of the process
2. Write the enthalpy equation showing the overall change in enthalpy

\[
\Delta H = -H_{vap} + H_1 = -1336 \text{ cal/mol} - 1435 \text{ cal/mol} = -2770 \text{ cal/mol}
\]
Another important concept is heat capacity

\[ C_p(T) = \lim_{\Delta T \to 0} \left( \frac{\Delta \hat{H}}{\Delta T} \right) \]

Heat capacity is the slope of the line as \( \Delta T \) goes to zero

Can also be phrased as

\[ \Delta \hat{H} = \int_{T_1}^{T_2} C_p(T) \, dT \]