

## **CHE 205 MASS AND ENERGY BALANCES**

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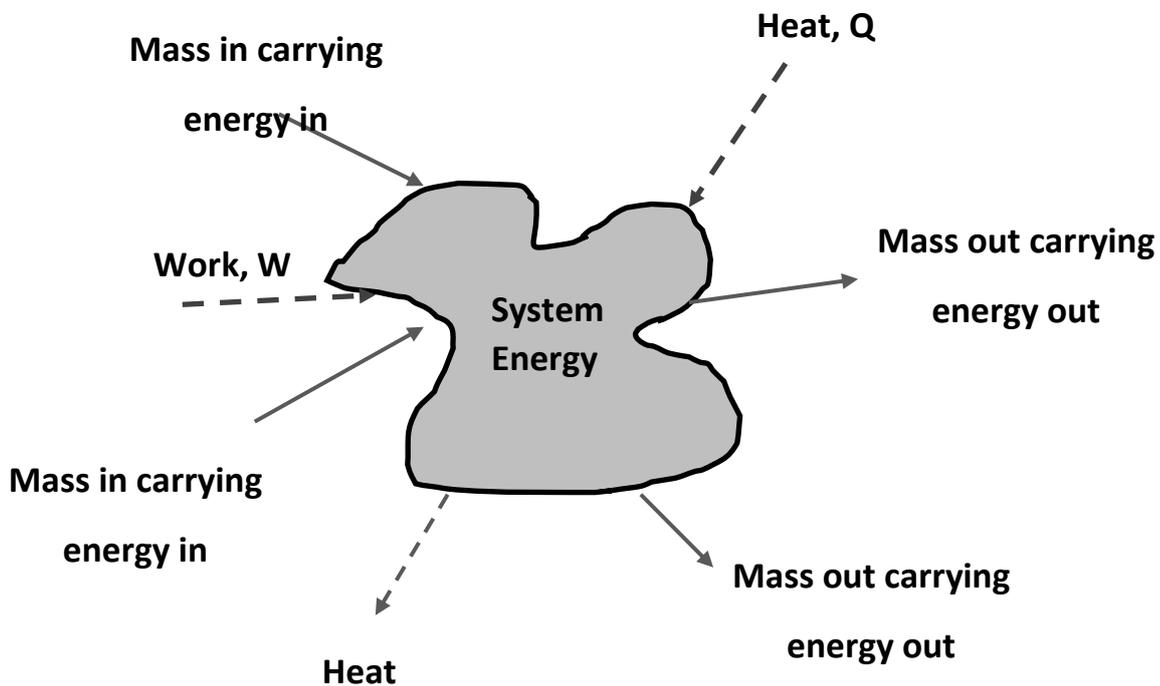
### **ENERGY BALANCES:**

Huge amounts of energy are needed to proceed most chemical processes. In order to improve process profitability, it is necessary to reduce the energy requirement of the processes. Therefore, to determine the net energy requirement for the process, chemical engineers should use energy balances to consider for the energy that flows into or out of each unit of process.

### **PROCESS SYSTEM TOTAL ENERGY**

- 1. Kinetic Energy ( $E_k$ )**
- 2. Potential Energy ( $E_p$ )**
- 3. Internal Energy ( $U$ )**

## PROCESS ENERGY CALCULATION



Energy can enter or leave the system through:

1. Material flows in and out of the system (OPEN SYSTEM)
2. The absence of material transfer (HEAT and WORK) (CLOSED SYSTEM)

THE FIRST LAW OF THERMODYNAMICS FOR A CLOSED SYSTEM AT STEADY STATE

$$\Delta U + \Delta E_k + \Delta E_p = Q + W$$

- (a) For ISOTHERMAL (constant temperature) systems,  $\Delta U \approx 0$
- (b) For non-accelerating systems,  $\Delta E_k = 0$
- (c) For systems at constant position in a force field,  $\Delta E_p = 0$
- (d) For ADIABATIC (insulated) systems,  $Q = 0$
- (e) For system where the energy is not transferred across the system boundary by a moving part (like an impeller, a piston),  $W = 0$

**THE FIRST LAW OF THERMODYNAMICS FOR AN OPEN SYSTEM AT STEADY STATE**

$$\Delta \dot{H} + \Delta \dot{E}_k + \Delta \dot{E}_p = \dot{Q} + \dot{W}$$

**BALANCES ON NONREACTIVE PROCESSES:**

The first law of thermodynamics states that for a closed system with constant volume, if the kinetic energy and potential energy changes are zero and there is no work the general energy balance equation becomes:

$$Q = \Delta U = \sum_{final\ state} n_i U_i - \sum_{initial\ state} n_i U_i$$

For constant external pressure the equation is:

$$Q = \Delta H = \sum_{final\ state} n_i H_i - \sum_{initial\ state} n_i H_i$$

For an open system;

$$Q = \Delta H = \sum_{out} n_i H_i - \sum_{in} n_i H_i$$

The general procedure to evaluate  $\Delta U$  and  $\Delta H$  (in case the tabulated values are not available) involves the following steps:

1. A reference state should be chosen (T, P and phase) for each substance in the process.
2. A path should be chosen from the reference state to initial and final states for each substance and evaluate  $\Delta U$  or  $\Delta H$ .
3. Determine all  $n_i$  values from the material balances and substitute the results in the energy balance equation.
  - To organize energy balance calculations for a process or process unit, construct an inlet-outlet enthalpy table which lists the  $n_i$  and  $\Delta H$  values for each substance at each state in the process streams.
  - As internal energy and enthalpy are state functions, the pathway to calculate these values starting from the reference state will make no difference in the calculated values.
  - For a substance undergoing an isothermal pressure change;

$\Delta U \sim 0$  for liquids and solids,  $\Delta U = 0$  for ideal gases.

$\Delta H = V\Delta P$  for solids and liquids

$\Delta H = 0$  for ideal gases.

- As temperature increases, the specific internal energy of a substance increases. When a substance undergoes a change in temperature from  $T_1$  to  $T_2$  without any phase change then,

$$\Delta U \approx \int_{T_1}^{T_2} C_v(T) dT$$

- The specific enthalpy of a substance increases with increasing temperature as well.

$$\Delta H \approx \int_{T_1}^{T_2} C_p(T) dT$$

**PSYCHROMETRIC CHART (HUMIDITY CHART):**

For an air-water system at 1 atm the process variables are shown on a chart. These variables include, dry-bulb temperature, absolute humidity, relative humidity, humid volume, wet bulb temperature and enthalpy per mass of dry air.

