Psychrometric Chart

- A psychrometric chart provides a concise compilation of a large quantity of physical and thermodynamic properties of a air-water mixture.
- The air-water vapor chart is useful for the design of humidification, drying and air conditioning processes.
- If we know any two properties of humid air at 1 atm, other properties can be obtained using this chart.

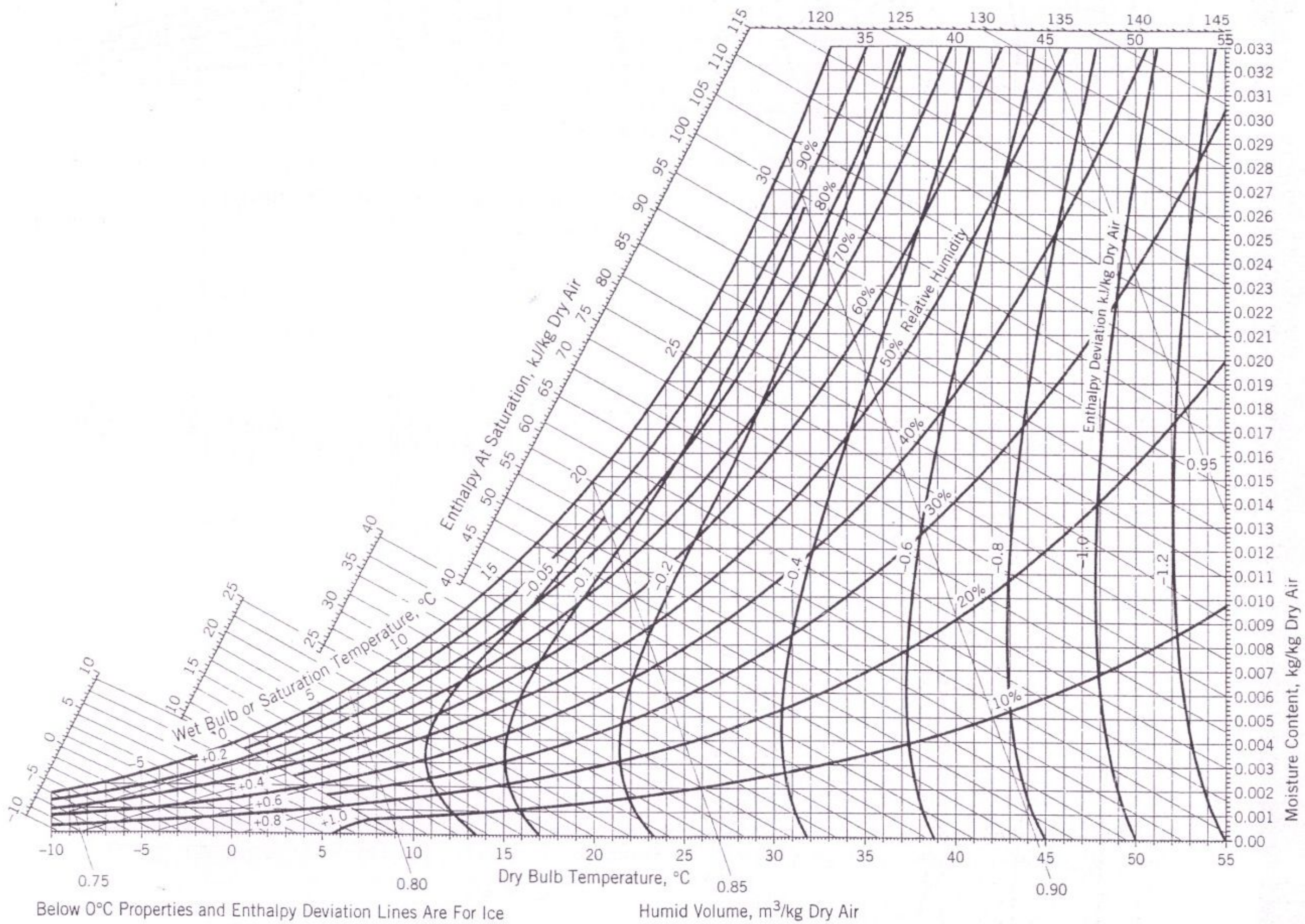


Figure 8.4-1 Psychrometric chart—SI units. Reference states: H_2O (L, 0°C, 1 atm), dry air (0°C, 1 atm). (Reprinted with permission of Carrier Corporation.)

Reference: Felder & Rousseau

Psychrometric Chart

- Dry bulb temp is on the X-axis of this chart
- Absolute humidity = kg water/kg DA on Y-axis
- %Relative humidity = 100 $\{p_{H2O} / p^*_{H2O}\}$

10% RH to 100% RH Curves shown on the chart. 100% RH curve is on the left boundary of the chart.

- Dew Point temp (T_{dp}) – the temperature at which humid air becomes saturated when cooled at constant pressure .

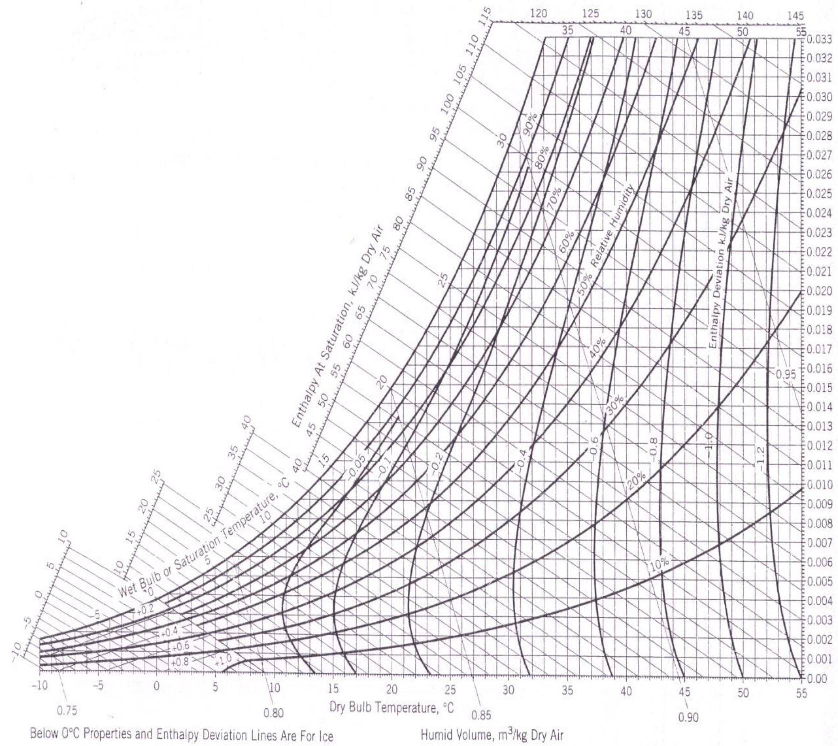


Figure 8.4-1 Psychrometric chart—SI units. Reference states: H_2O (L, 0°C, 1 atm), dry air (0°C, 1 atm). (Reprinted with permission of Carrier Corporation.)

Exercise

- Locate the dew point of air which is at 29 ^{O}C and 20% RH.

✔ Locate the point on the graph for ai at 29 ^{O}C ($T_{dry\ bulb}$) and 20%RH (which property that will not change while cooling at constant pressure?).

✔ When air is cooled the moisture content will not change hence move towards the saturation curve on constant moisture content line and locate the point where this line cuts saturation line.

✔ Read from X-axis the $T_{dew\ point}$ corresponding to this point.

✔ Ans T_{dp} = 4 deg C

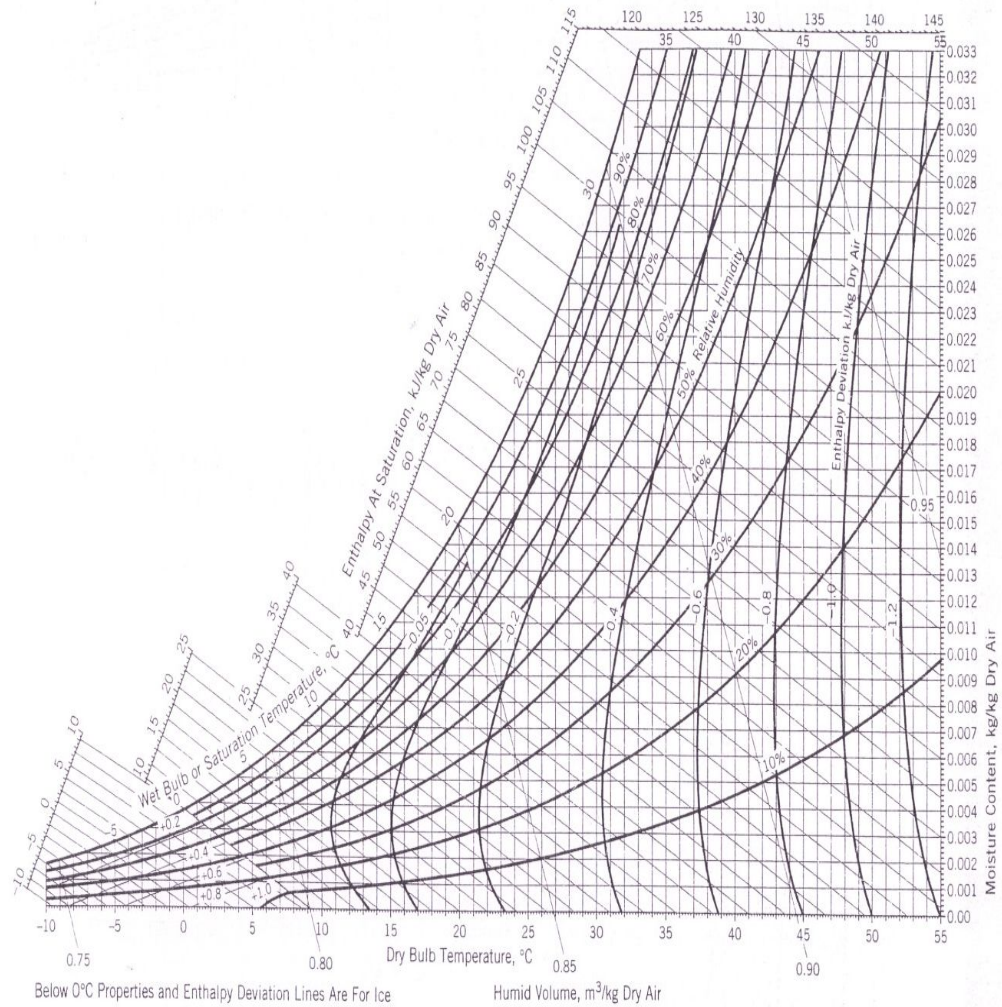


Figure 8.4-1 Psychrometric chart—SI units. Reference states: H_2O (L, 0°C, 1 atm), dry air (0°C, 1 atm). (Reprinted with permission of Carrier Corporation.)

- Humid Volume- The volume occupied by 1 kg of dry air and the moisture associated with this air. The lines are shown corresponding to 0.75, 0.8,0.85, 0.9 m^3/kgDA

To calculate the volume of a given mass of humid air, use the mass of DA from absolute humidity

Exercise

Calculate the volume occupied by 150 kg of Humid air at 30 ^{0}C and having 30%RH

- From the chart Absolute Humidity =0.008 kgH_2O/kgDA
- Therefore, total mass of 1kg DA and water =1.008 kg
- Humid volume = 0.87 m^3/kgDA
- Volume of 150 kg Humid air = (150 kg HA)*0.87 (m^3/kgDA)*(1kgDA/1.008kgHA) = 129 m^3

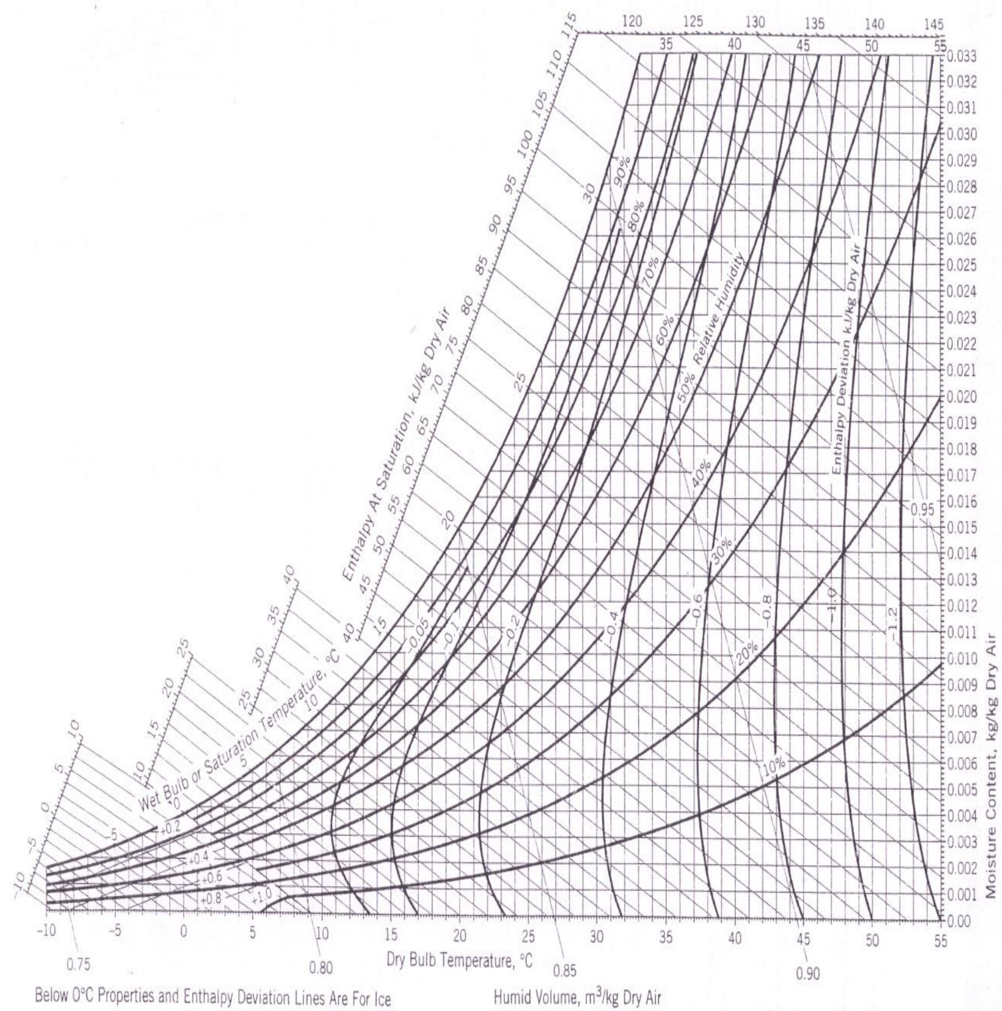


Figure 8.4-1 Psychrometric chart—SI units. Reference states: H_2O (L, 0°C, 1 atm), dry air (0°C, 1 atm). (Reprinted with permission of Carrier Corporation.)

Exercise

Wet bulb temperature (T_{wb})- The humid air condition that corresponds to a given wet-bulb temperature fall on a straight line (constant enthalpy) on the psycrometric chart, called a constant wet-bulb temp line.

- Determine the wet bulb temp of Humid air at 30 ^{0}C and having 30%RH

✔Use the given data and locate the point of intersection

✔Follow constant enthalpy line till the saturation line

- Answer Wet Bulb Temp.= 18 ºC

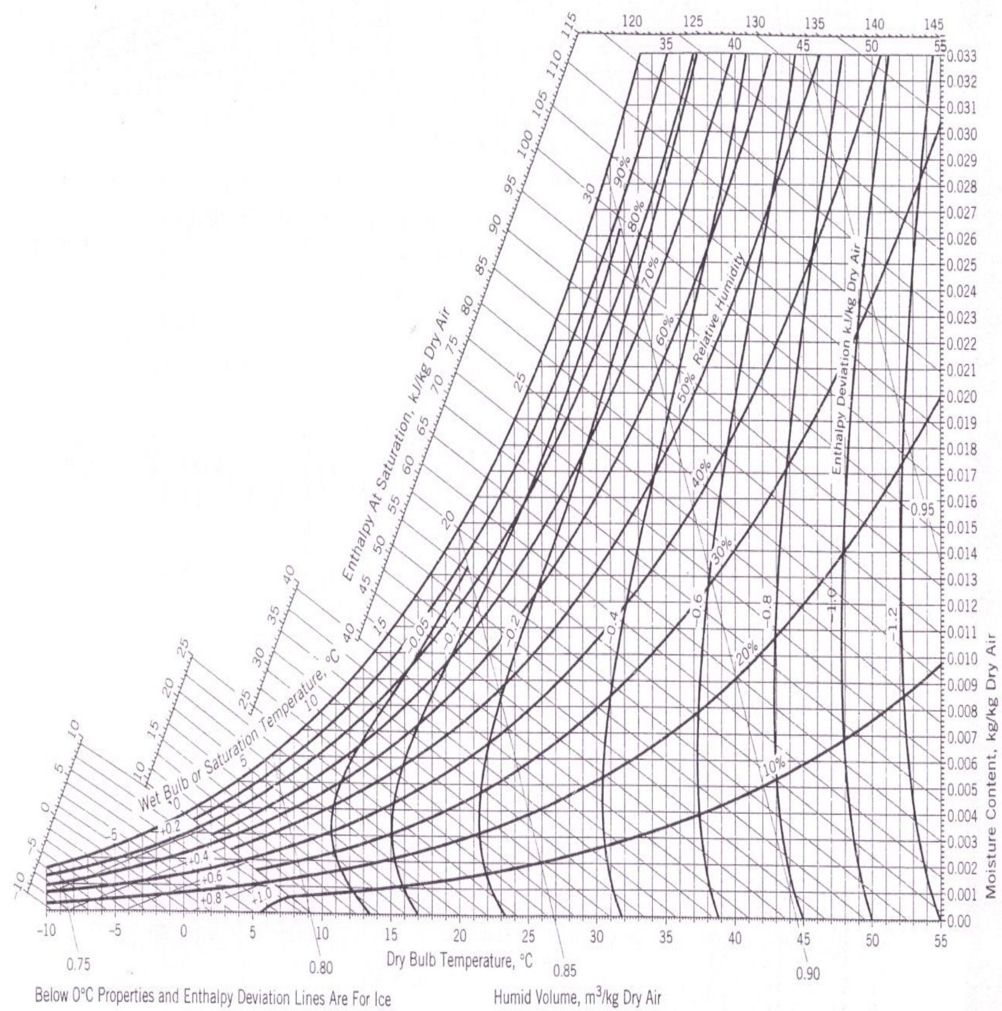


Figure 8.4-1 Psychrometric chart—SI units. Reference states: H_2O (L, 0°C, 1 atm), dry air (0°C, 1 atm). (Reprinted with permission of Carrier Corporation.)

Exercise

Enthalpy deviation- the vertical curves (-0.05, -0.1,-0.2 etc). The enthalpy of HA that is not saturated is calculated using these curves.

Exercise: Calculate enthalpy of air at 35 deg C and 10%RH.

- ✔Enthalpy deviation from chart is about -0.52 kJ/kgDA (using interpolation of the data)
- ✔The enthalpy of saturated air is = 45 kJ/kgDA
- ✔**The enthalpy of humid air =45-0.52=44.48 kJ/kgDA**

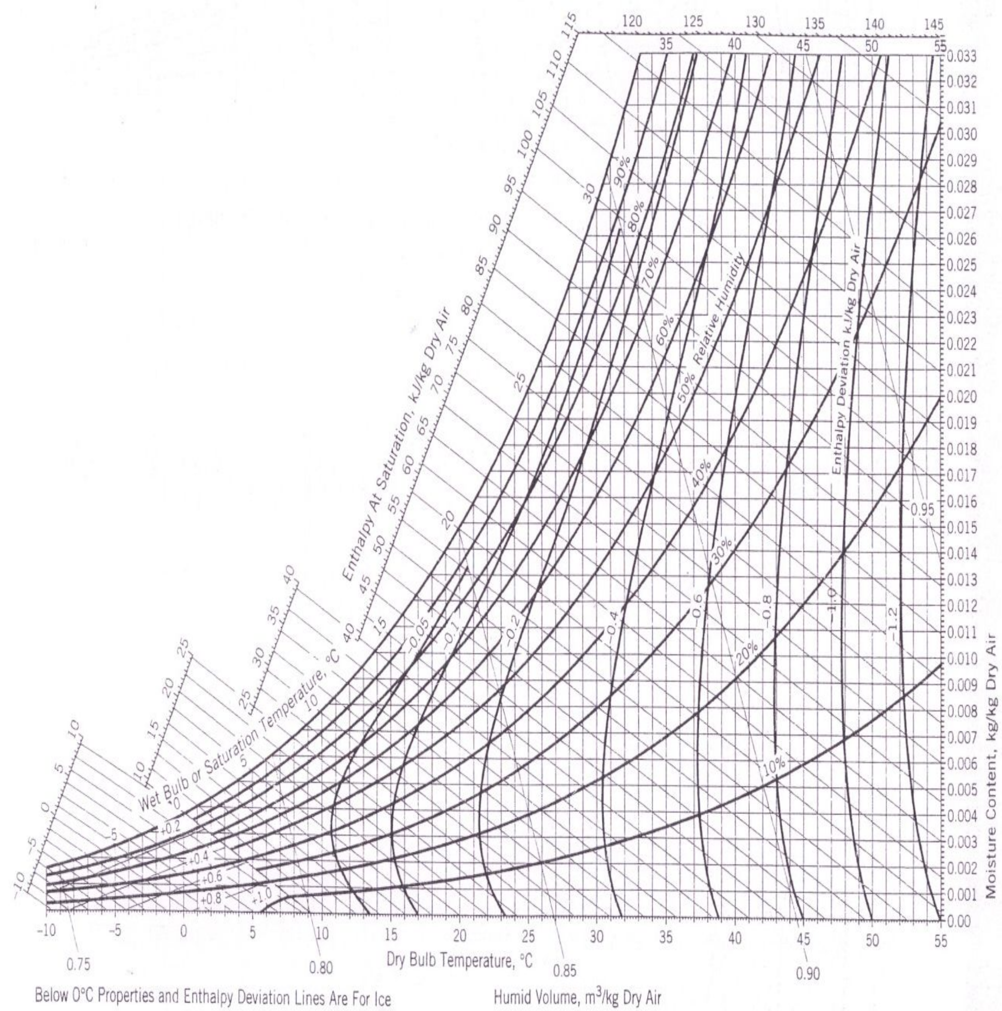


Figure 8.4-1 Psychrometric chart—SI units. Reference states: H_2O (L, 0°C, 1 atm), dry air (0°C, 1 atm). (Reprinted with permission of Carrier Corporation.)

HEATS of MIXING AND SOLUTION

- When two different liquids are mixed or when a gas or solid is dissolved in a liquid, bonds are broken between molecules of the feed materials, and new bonds are formed between molecules in the product solution.
- If less energy is required, to break the bonds in the feed materials, than the energy released when the solution bonds form, a net release of energy results.
- If this energy is not transferred from the solution to its surroundings, it goes into raising the solution temperature.

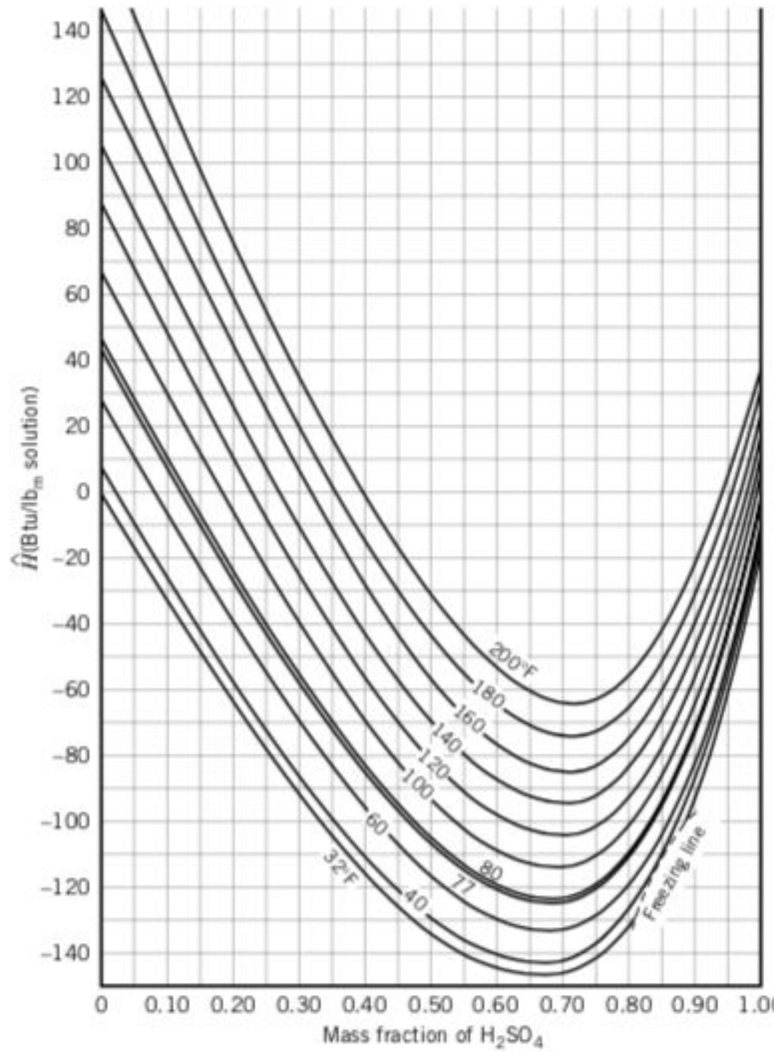
- For an **ideal mixture** the heat of mixing or solution is negligible.
- This assumption works well for nearly all gas mixtures and for liquid mixtures of similar compounds
- For other mixtures and solutions—such as aqueous solutions of strong acids or bases, and aqueous solution of solids (such as sodium hydroxide) : heats of solution should be included in energy balance calculations.

Heat of mixing

- When heat of mixing is incorporated in the Energy balance calculations, these calculations become cumbersome.
- For a binary (two-component) system, these calculations can be simplified by the use of **enthalpy–concentration chart.**
- This chart is a plot of specific enthalpy versus mole fraction (or mole percent) or mass fraction (or weight percent) of one component.

H-*x* Chart for aqueous solution of H_2SO_4 at different temperatures

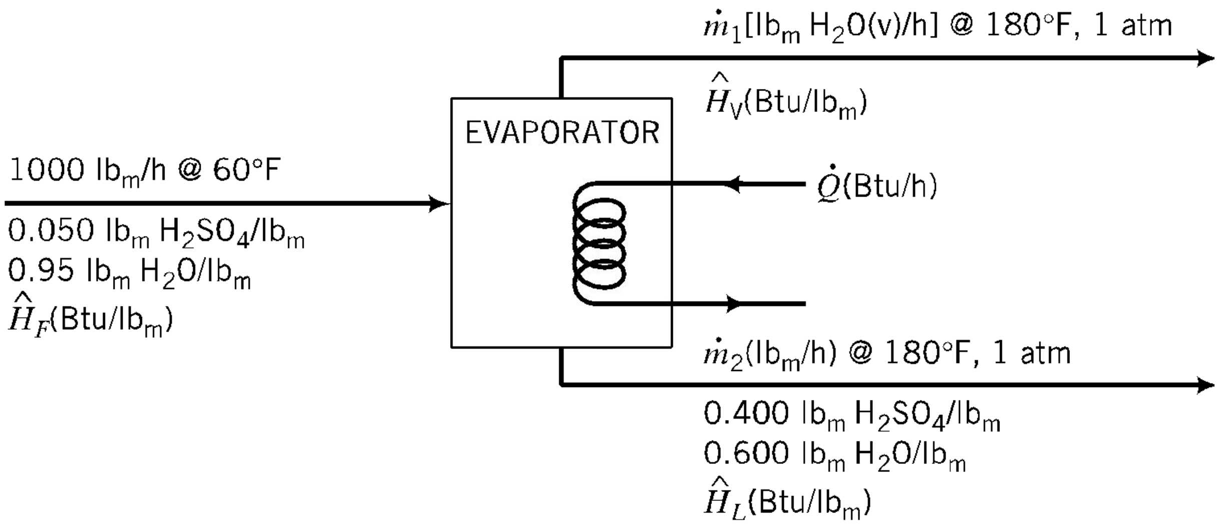
The reference conditions for the plotted enthalpies are pure liquid H_2SO_4 at 77□ ºF and liquid water at 32□ ºF.



Exercise

- A 5.0 wt% H_2SO_4 solution at 60 $^{\circ}$F is to be concentrated to 40.0 wt% by evaporation of water. The concentrated solution and water vapor emerge from the evaporator at 180 $^{\circ}$F and 1 atm. Calculate the rate at which heat must be transferred to process 1000 lb_m/h of the feed solution.

Solution



- Basis: 1000 lb$_m$/h of feed solution

- Energy balance will reduce to:

$$Q = \Delta H = \sum m_i H_{i\ (outlet)} - \sum m_i H_{i\ (inlet)}$$

We need the values of mi and Hi to solve this problem.

Material balance:

H_2SO_4 balance: $1000*0.05 = m_1*0 + m_2*0.4$

$m_2 = 125\ lb_m/h$

Total Balnce: $m_1 = 1000-125 = 875\ lb_m/h$

Estimation of Enthalpies of the Streams

- Reference for enthalpies:

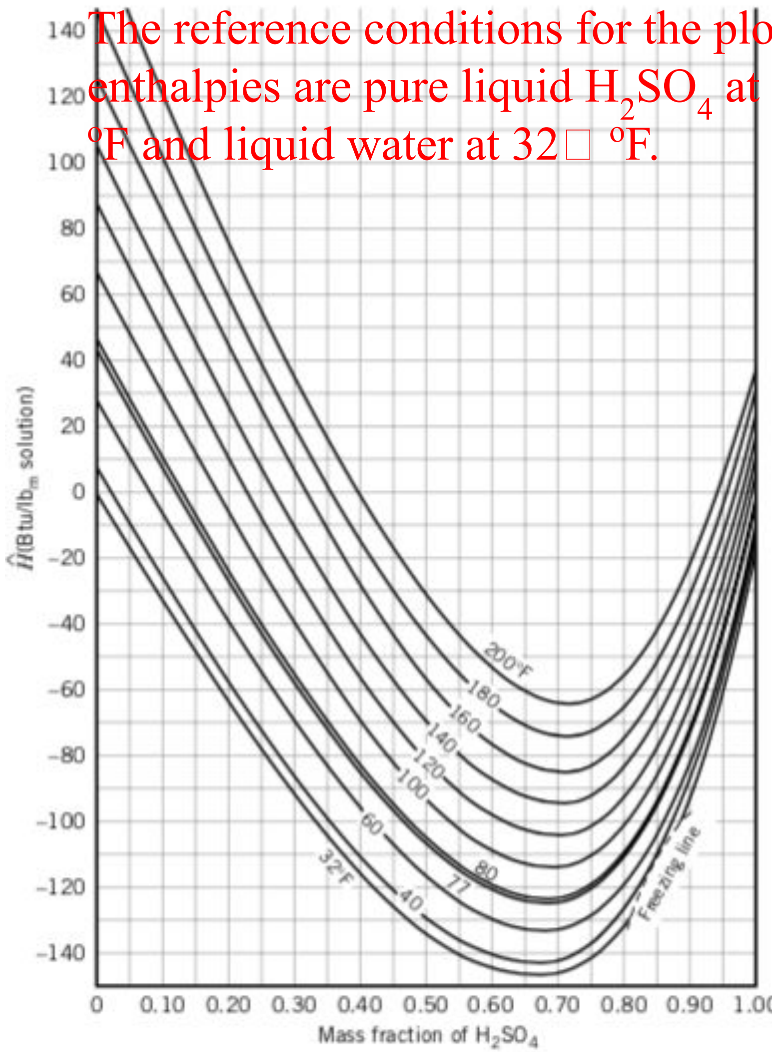
  H_2O (l, 32 ºF), H_2SO_4 (L, 72 ºF)

$H_{Feed} = H_F = 10$ BTU/lb_m

$H_L = -17$ BTU/lb_m

Enthalpy of water vapor (H_V) can be obtained from steam table:

$H_V = 1138$ BTU/lb_m



The reference conditions for the plotted enthalpies are pure liquid H_2SO_4 at 77□ ºF and liquid water at 32□ ºF.

- Substituting the values of enthalpies and mass flows in E.B.:

$m_F = 1000$; $m_1 = 875$; $m_2 = 125$;

$H_F = 10$ BTU/lb_m; $H_L = -17$ BTU/lb_m; $H_V = 1138$ BTU/lb_m

$$Q = \Delta H = \sum m_i H_{i\ (outlet)} - \sum m_i H_{i\ (inlet)}$$

$$\Delta H = 875*1138 + 125*(-17) - 1000*10$$

$$= 983625 \text{ BTU/h}$$

Rate of heat transfer = 983625 BTU/h