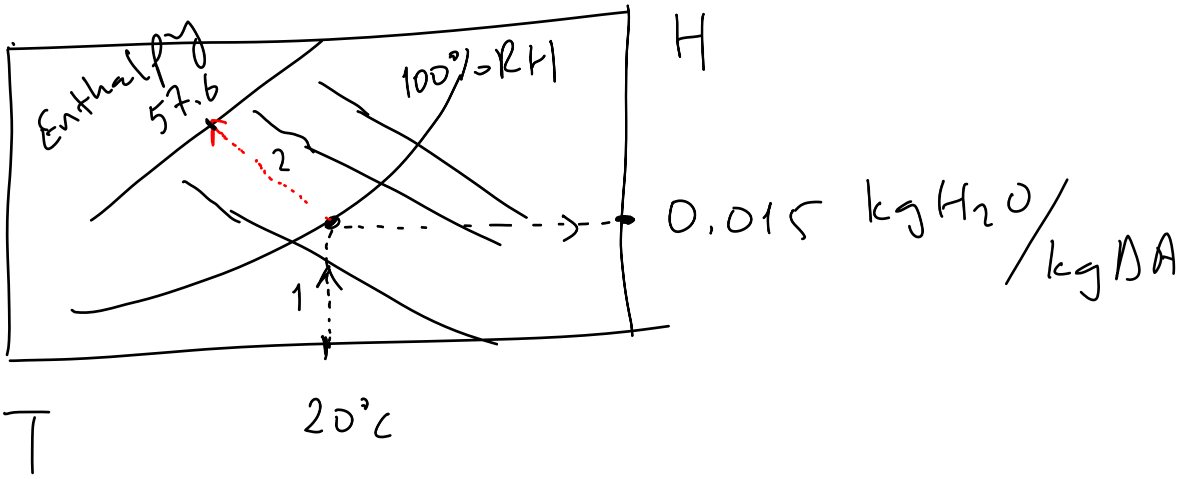
Example: A tank contains 10 kg of saturated air. The dry bulb temperature is 20°C. Find the enthalpy of this system in kJ.

Solution:



$$\text{Enthalpy of air at } 20^\circ C = 57.6 \ kJ/kg\,DA$$

X_{DA} = mass fraction of dry air ⇒

$$X_{DA} = \frac{1 \ kg\ DA}{1 + 0.015} = 0.985$$

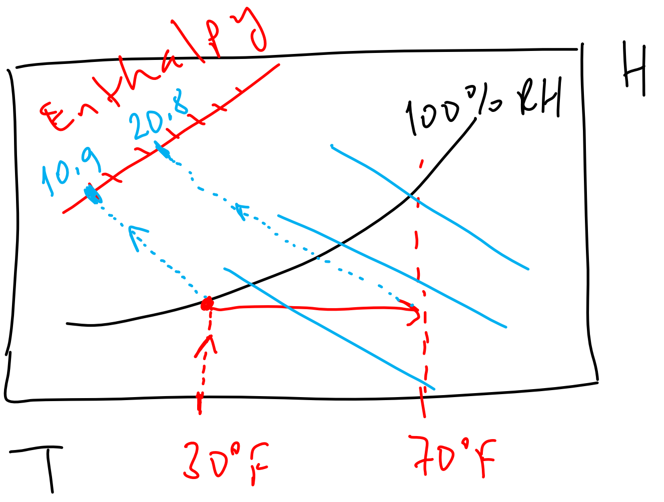
$$\text{Mass of dry air} = 10 \ kg \times (0.985) = 9.85 \ kg\ DA$$

$$\text{Enthalpy} = M \times \hat{H}_{DA} = 9.85 \ kg\,DA \times 57.6 \frac{kJ}{kg\,DA} = 576 \ kJ$$

Example: A saturated mixture contains 100 lb of dry air. How much heat is required (Btu) to raise the dry bulb temperature from 30°F to 70°F ?

Solution:

Using humidity chart ⇒

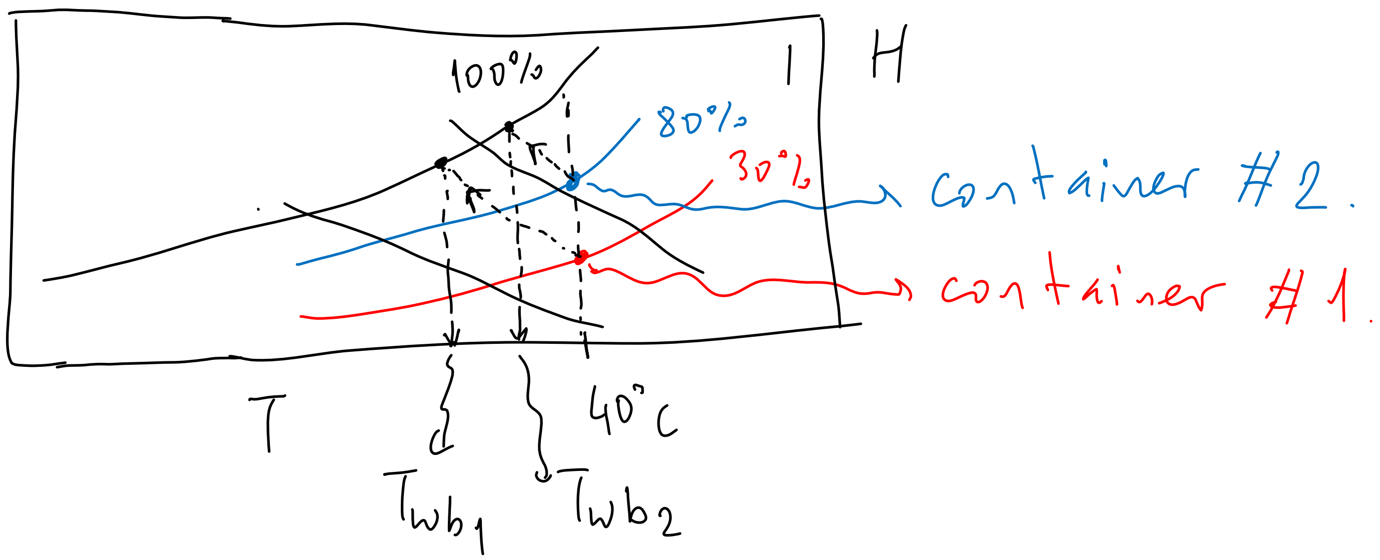


$$\text{Heat required} = (20.8 - 10.9)\,\frac{\text{Btu}}{\cancel{\text{lb}}} \times 100\,\cancel{\text{lb}}$$

$$= 990 \text{ Btu}$$

Example: Two large containers initially contain dry air at 40°C. A small amount of water is added to container #1 so that the RH is 30 %. Water ia also added to container #2 so RH is now 80 %. Which has the lower wet bulb temperature ?

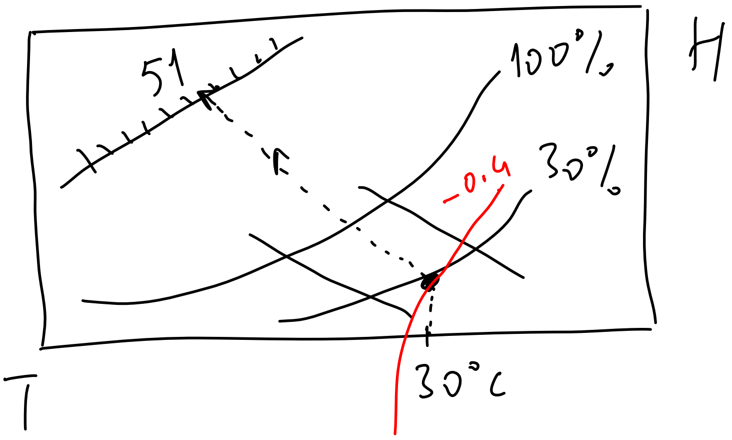
Solution:



Container #1 has lower wet bulb T.

Example: Air at 30°C and 30 % RH. Find actual enthalpy of the system in kJ/kg dry air (DA).

Solution:



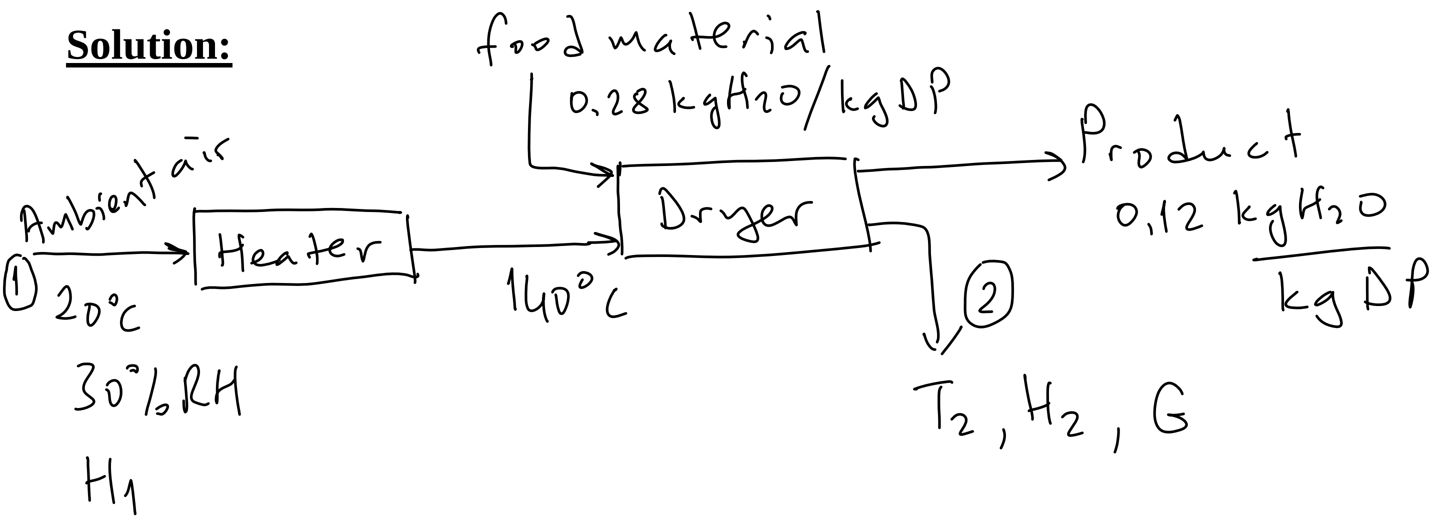
Enthalpy = 51 − 0.4 = 50.6 kJ/kg DA

(0.4: enthalpy deviation.)

Example: A food product is to be dried in an adiabatic cocurrent dryer. The inlet and outlet moisture contents are 0.28 and 0.12 kg H_2O/kg dry product (DP), respectively. Ambient air at 20°C and 30 % RH is heated indirectly by steam to the specified dryer inlet air temperature of 140°C. The difference between the dry bulb temperature of the exhaust air and its dew point should be at least 10°C in order to avoid the possibility of condensation in the downstream ductwork and air cleaning devices.

Calculate the mass flow rate of air required (kg/h).

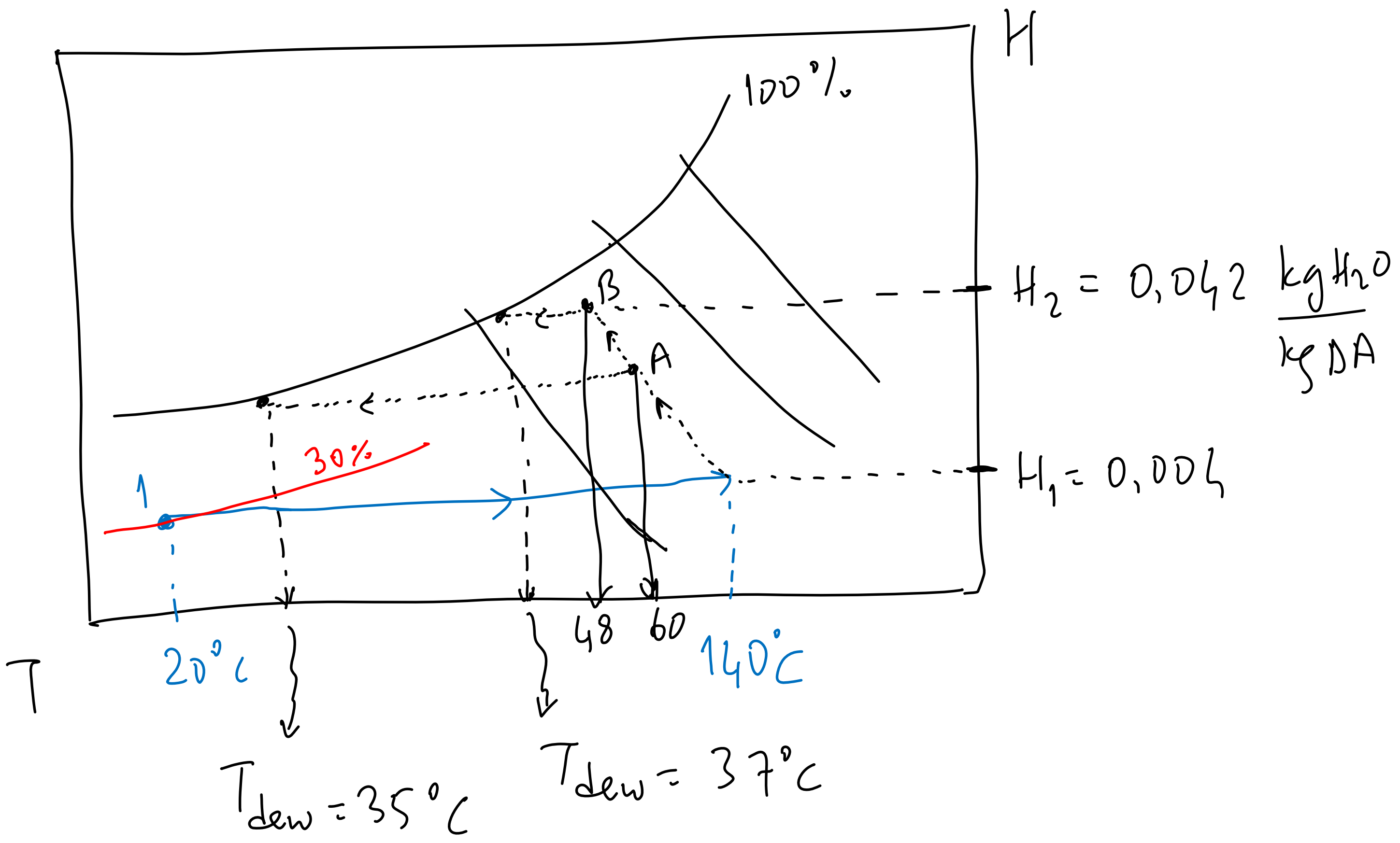
Solution:



G : air flow rate

$$T_{db_{out}} - T_{dew\ point} \cong 10°C$$

($T_{db_{out}}$ = T_2)



The condition of exhaust air at (2) has to be determined by trial and error.

1) Assume that $T_2 = 60°C$ (point A)

$60 - 35 = 25°C$ exceeds $10°C$ by a wide margin.

2) Assume that $T_2 = 48°C$ (point B)

$48 - 37 = 11°C \Rightarrow$ satisfies the criterion approximately.

Basis: 1 kg dry solids/h.

Moisture lost (kg/h) $= (0{,}28 - 0{,}12)\dfrac{kg\,H_2O}{kg\,DS} \times \dfrac{1\,kg\,DS}{h}$

$= 0{,}16\ kg\,H_2O/h.$

Moisture removed from the food = Moisture gained by air.

$(H_2 - H_1)\dfrac{kg\,H_2O}{kg\,DA} \times G = 0.16\ kg\,H_2O/h$

$(0{,}042 - 0{,}004) \times \dfrac{G}{kg\,DA} = \dfrac{0.16}{h} \Rightarrow$

$G = 4.2\ kg\,DA/h.$

Homework: Hot air with dry bulb temperature of 80°C and a wet bulb temperature of of 30°C enters the adiabatic dryer to dry food products. It exits from the dryer at 50°C.

a) Determine absolute humidity and dew point temperature of air at the dryer inlet.

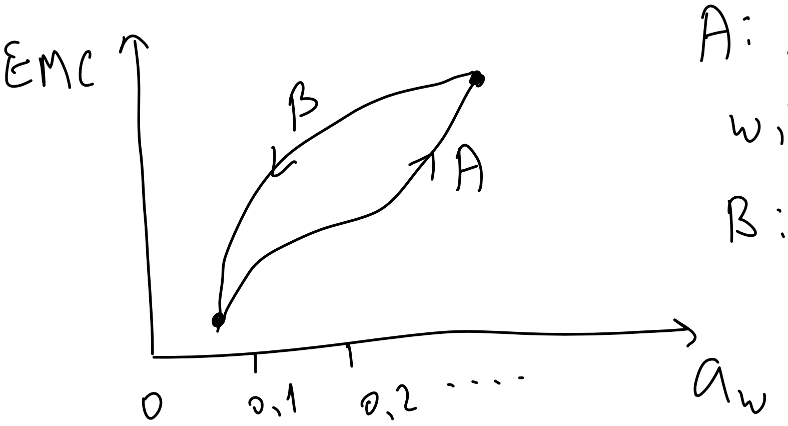
b) Determine absolute humidity and dew point temperature of air at the dryer exit.

c) If the exit air from the dryer is further cooled down to 20°C in a cooler, determine the amount of water collected in the condenser per kg of dry air.

Water Activity - Equilibrium Moisture Content (EMC or X^*):

Moisture Sorption Isotherms (MSI):

MSI show the relationships between a_w and EMC graphically.



A: Adsorption (start with a dry food)

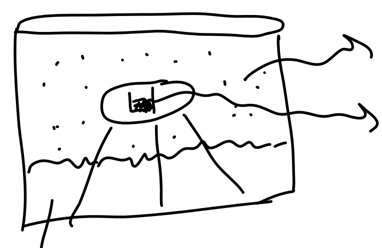
B: Desorption (start with a fresh (wet) food).

Perform an experiment at T=25°C constant.

At 25°C ⇒

Salt	a_w
NaCl	✓
LiCl	✓
⋮	

⇒ $a_w \cong 0.1$ to 0.90



t	Weight
⋮	⋮

STOP ↔ EMC

Types of Water

3 types of water

Type I: (Ionic bonded water): It is the water that is tightly bound to the ionic sites and is unavailable for rxns. These sites are;

- amino groups (NH_3^+) associated with proteins.
- carboxyl " (COO^-) " " proteins, pectins and acids.

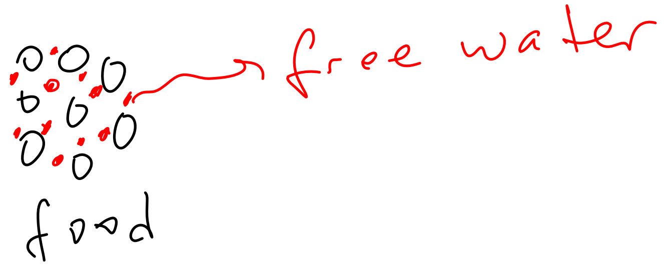
Type II: (H-bonded water): The water is more loosely bound to

- amide groups in proteins ($RCONH_2$)
- OH^- " " " and carbohydrate polymers such as pectins, starches and cellulose etc.

<u>Type III</u>: (Condensed or free water):

Water is even more loosely held in large cappilaries. It is considered as unbound, free water which represents H_2O multilayers on proteins and carbohydrate polymers. OR

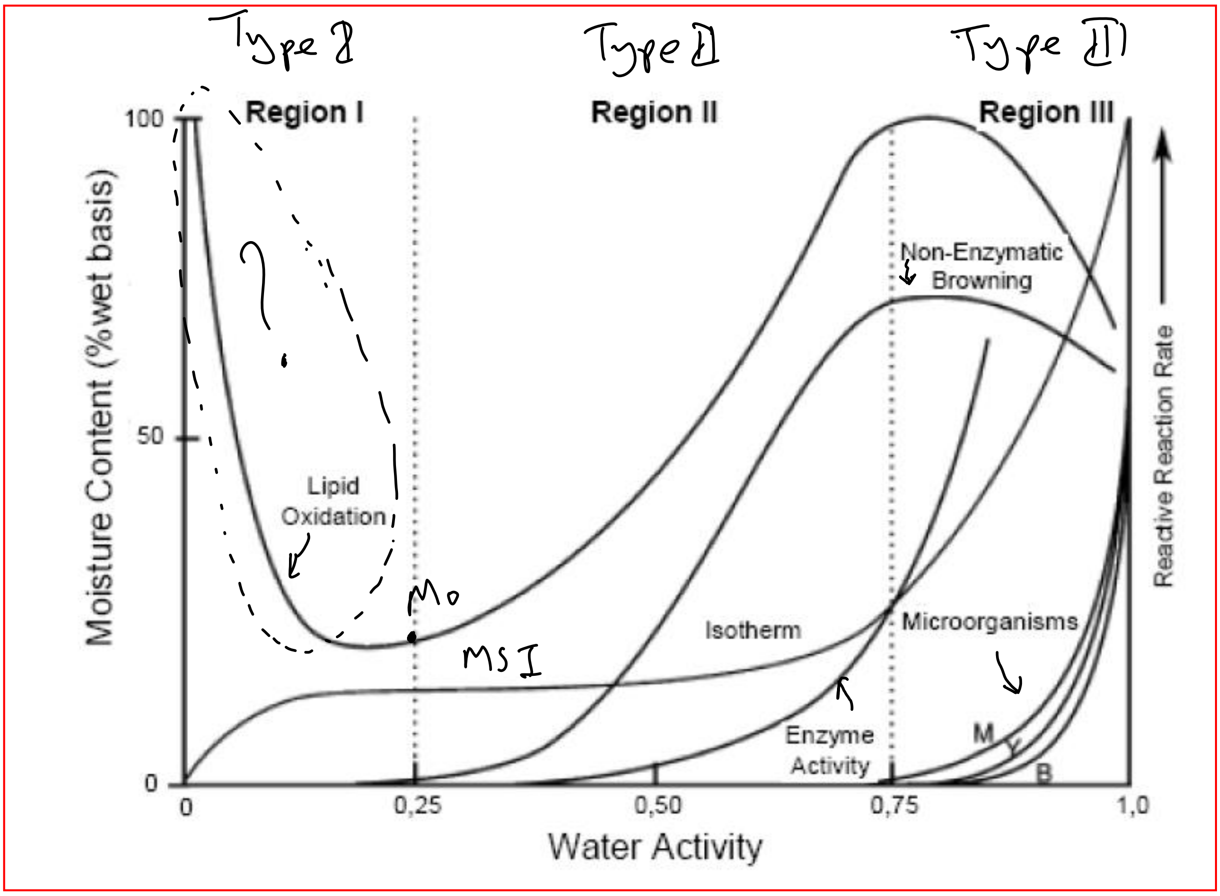
Water present in voids or pores of food.



Also, it is available for participation in reactions and as a solvent.

Order of removal of water:

Type III > Type II > Type I ⟶ more energy is required.



Mo: Monolayer moisture content.