Physical Meteorology

Physical Meteorology 1

Lecture 10

Sahraei

Department of Physics,

Razi University

http://www.razi.ac.ir/sahraei

Implications:

Moist air has a higher "virtual" temperature than dry air. This means that moist air is less dense than dry air.

Simple explanation:

In moist air, water molecules (Molecular weight =18) replace air molecules (N_2 MW = 28, O_2 MW = 32), so volume of moist air has less mass than equivalent volume of dry air.

Why do we use Virtual Temperature?

Stability depends on the relative density between an air parcel and its environment.
In a dry atmosphere, density differences are determined by comparing the temperature of a parcel and its environment.

- In a moist atmosphere, we must compare the virtual temperature of a parcel and its environment.

Isobaric Processes for Moist Air
فرآیندهای تک فشاری برای هوای نمناک

Isobaric processes are physical processes in which the pressure of a gas is kept constant.

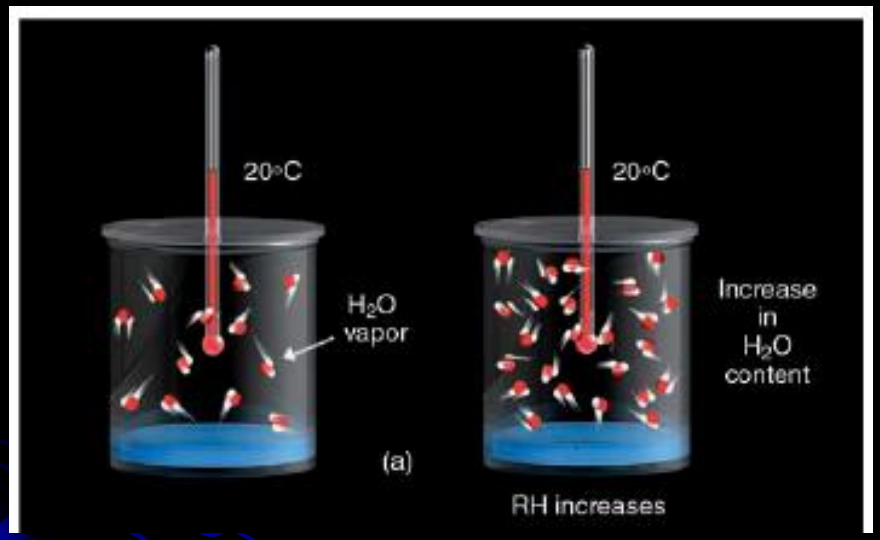
Isobaric processes take place in moist air whenever a sample is cooled or warmed at constant pressure.

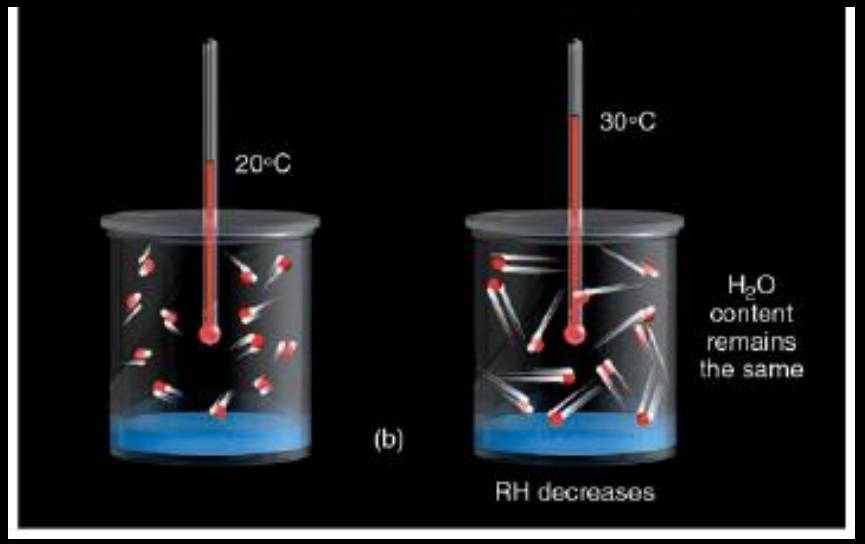
Isobaric processes may occur under special condition and we shall now consider three of these which lead to the following temperatures:

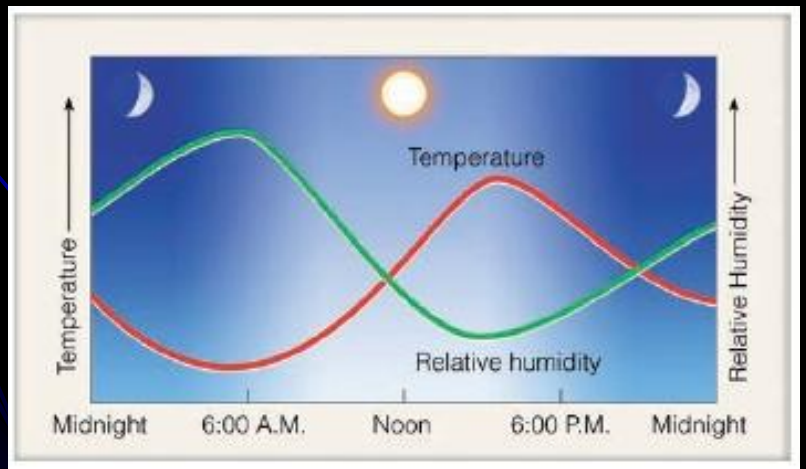
A change in relative humidity can be brought about in two primary ways:

1. by changing the air's water vapor content

2. by changing the air temperature





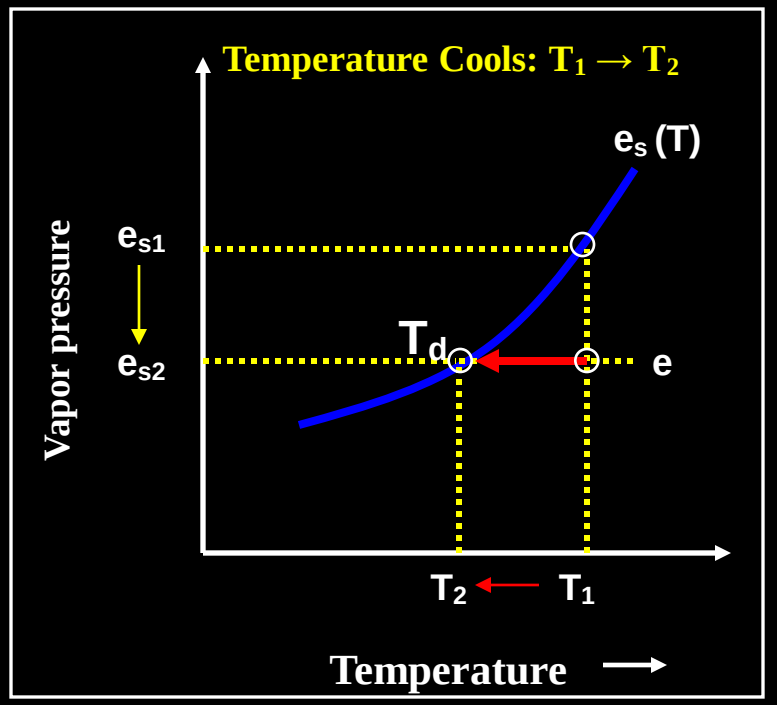


Moist Air Parameters during Processes

Isobaric Cooling: Dew Point Temperature (T_d)

Definition: Temperature at which saturation (with respect to liquid water) is reached when an unsaturated moist air parcel is cooled at constant pressure

- Parcel is a closed system
  - Mass of water vapor and dry air are constant
- Isobaric transformation
  - Total pressure (p) constant
  - Vapor pressure (e) constant
  - Mixing ratio (r) constant
- Saturation vapor pressure (e_s) and saturation mixing ratio (r_s) change since they are both functions of the temperature



Methods of Achieving Saturation

- *Adding water vapor to the air*
- *Mixing cold air with warm, moist air*
- *Lowering the temperature of the air to the dew point*

Dew point temperature دمای نقطه شبنم

- ***The saturation vapor pressure is a function of temperature, and decreases with decreasing temperature.***

Dew point temperature is defined as the temperature to which the air would have to cool (at constant pressure and constant water vapor content) in order to reach saturation.

Dew points indicate the amount moisture in the air.

Moist Air Parameters during Processes

Isobaric Cooling: Dew Point Temperature (T_d)

- Such a process regularly occurs
  - Radiational cooling near surface
  - Often occurs at night (no solar heating)
  - Can occur at ground level (dew) or through a layer (fog)

- the **difference between air temperature and dew point** is a measure of the **relative humidity** of air; the **larger the difference**, the **smaller** the relative humidity

good indicator of the air actual vapor content

High DP → high wv content

Low DP → low wv content

wet-bulb temperature دمای تر

Meteorologists commonly measure humidity by measuring the *wet-bulb temperature*.

The wet-bulb temperature is the lowest temperature that can be achieved by evaporating water into the air parcel at constant pressure.

(the evaporation requires heat, which is supplied by the air parcel).

Moist Air Parameters during Processes

Adiabatic Isobaric Process: Wet-Bulb Temperature (T_w)

Definition: Temperature at which saturation (with respect to liquid water) is reached when an unsaturated moist air parcel is cooled by the evaporation of liquid water

- Such a process regularly occurs
  - Evaporational cooling occurs near the surface during light rain
  - The temperature often feels colder when its raining → It is!

Equivalent Temperature دمای هم ارز

Another isobaric process take place for moist air, if the water in the sample condenses at constant pressure.

In this case, the latent heat released during the condensation of the water vapour is used to warm the sample of air.

The temperature reached when all the water vapour in a sample has condensed is called the *equivalent temperature*.

Adiabatic processes of Saturated Air
فرآیندهای بی دررو هوای اشباع شده

A reversible process: in which all the condensation products (water droplets or ice crystals are retained within the sample of air.

An irreversible process: in which the condensation products fall out of the air sample immediately they are formed

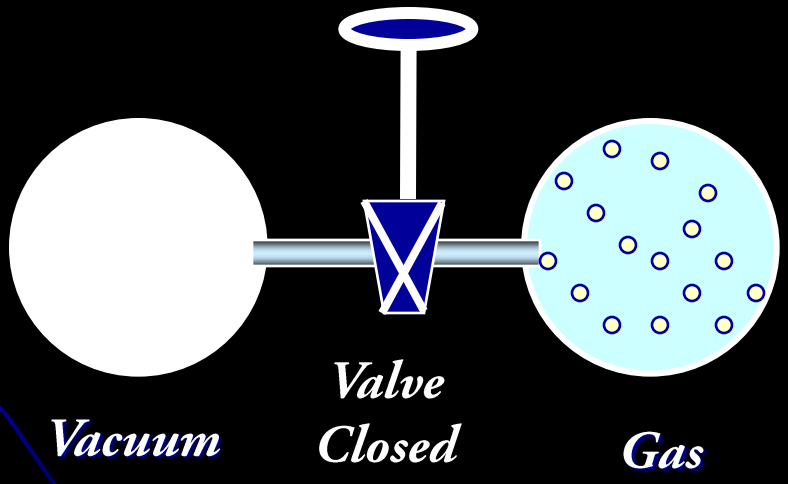
Natural (or Irreversible) Process

- *Physical Processes That Proceed in One Direction But Not The Other*

- *Tends Towards Equilibrium*
  - *Equilibrium Only At End of Process*

Natural (or Irreversible) Process

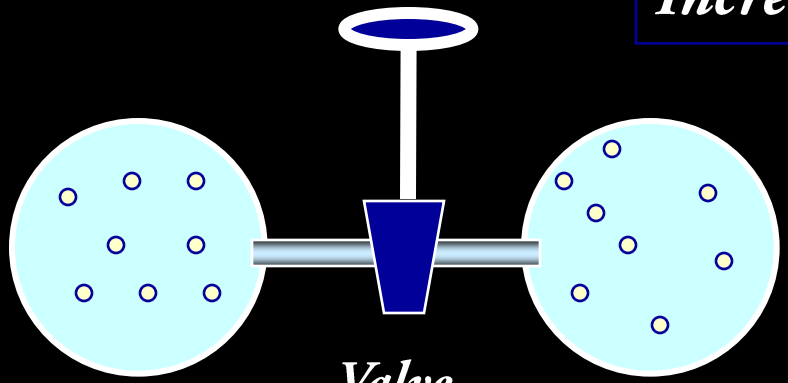
- *Examples*
  - *Free Expansion of Gas*



Natural (or Irreversible) Process

- *Examples*
  - *Free Expansion of Gas*

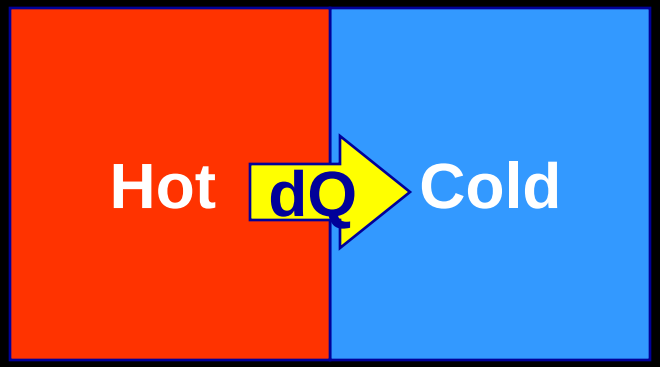
Equilibrium



Increase in Entropy

Natural (or Irreversible) Process

- *Examples*
  - *Thermal Conduction*



Natural (or Irreversible) Process

- *Examples*
  - *Thermal Conduction*

Increase in Entropy

Equilibrium

Warm

Pseudo Adiabatic Process فرآیند بی دررو وار

Consider a saturated parcel of air.

Expand parcel from $T, p, r_s \ldots$

$\ldots$*to* $T+dT, p+dp, r_s+dr_s$

(note: dT, dp, dr_s *are all negative)*

This releases latent heat = $-Ldr_s$

Assume this all goes to heating dry air

Not water vapor, liquid, or solid.

Assume

all condensation products fall out of parcel immediately.

$$-L dr_s = dq = c_{p_d} dT - \alpha_d dp_d$$

$$dp_d = d(p - e_s) \cong dp$$

$$\alpha_d \cong \alpha = \frac{RT}{p}$$

$$-L dr_s = c_{pd} dT - RT \frac{dp}{p}$$

$$or \quad \frac{dT}{T} = \frac{R}{c_{pd}} \frac{dp}{p} - \frac{L}{c_{pd} T} dr_s$$

Remember t hat $\frac{T}{\theta} = \left(\frac{p}{p_o}\right)^{R/c_p}$; $p_o = 1000\,mb$

$$\ln T - \ln \theta = k \ln p - k \ln p_o$$

$$or \quad \frac{dT}{T} - \frac{d\theta}{\theta} = k\frac{dp}{p} \qquad (k = R/c_p)$$

$$\text{using} \quad \frac{dT}{T} = \frac{R}{c_{pd}}\frac{dp}{p} - \frac{L}{c_{pd}T}dr_s$$

we get $\frac{d\theta}{\theta} = -\frac{L}{c_{pd}T}dr_s$ for a pseudo adiabatic process.

Since $dr_s < 0$, θ *increases* for a pseudoadiabatic process.