THE UNIVERSITY OF UTAH

Meteorology 3510

Lecture 4

Equation of State of Moist Air

- Ideal Gas Law for water vapor
- Mixing ratio and specific humidity
- Virtual Temperature

CLASS Presentation

- Form group of 2 students
- Present ~20 minute presentation (~ 10 minute each person)
- Focus on topics found within “In Practice” section of your textbook.
- Your research should go beyond the textbook.
- Be Creative!   Props

Examples of material to present

- Hygrometer
- Wind Chill
- Radiosonde
- Skew-T diagram
- Psychrometer
- Heat Index
- Aneroid Barometer
- Altimeter
- Subsidence inversion

Suggestions for effective display

- **Keep it simple!** Fancy designs or color shifts make important material hard to read. Less is more.
- Use at least a 24-point font so everyone in the room can read your material.
- Try to limit the material to eight lines per slide, and keep the number of words to a minimum. **Keep it simple**.
- Limit the tables to four rows/columns for readability. Sacrifice content for legibility. Large tables can be displayed more effectively as a graph.
- Use easily read fonts.
- Don't fill up the slide - the peripheral material may not make it onto the display screen.
- **Identify the journal when you give references.**
- Finally, always preview your presentation. You will look foolish if symbols that looked OK in a WORD document didn't translate into anything readable in POWERPOINT.

Definitions

Vapor Pressure (*e*) *= The pressure exhibited by vapor present above a liquid surface.*

Water vapor density = Absolute humidity (ρ_v) = *measure of the actual amount of water vapor in a sample of air (i.e., mixing ratio)*

Ideal Gas Law for Water Vapor / Absolute Humidity

$$e = \rho_v R_v T$$

$$Rv = \frac{R^*}{m_w}$$

$$Rv = 461.5\ Jkg^{-1}K^{-1}$$

Partial Pressure
(Dalton's Law)

$$p = p_d + e$$

$$p = (\rho_d R_d + \rho_v R_v)T$$

Mixing ratio

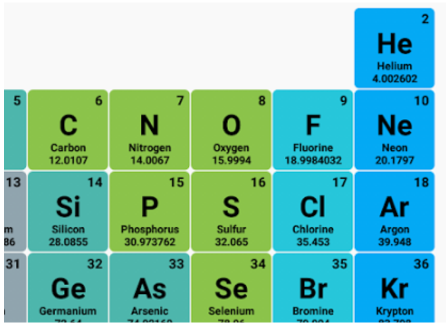
Mixing Ratio = $w = \frac{M_v}{M_d} = \frac{\rho_v}{\rho_d}$

Where:
M_v = mass of water vapor
M_d = mass of dry air

Typically measured in g/kg in meteorology (mass mixing ratio)

Atmospheric Chemists using a mole mixing ratio!

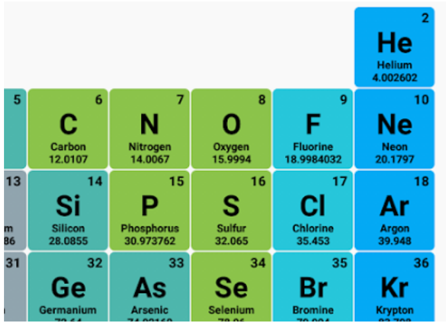
In Class problem



Currently global CO_2 is approximately 400 ppm.

What is the mass mixing ratio of CO_2?

In Class problem



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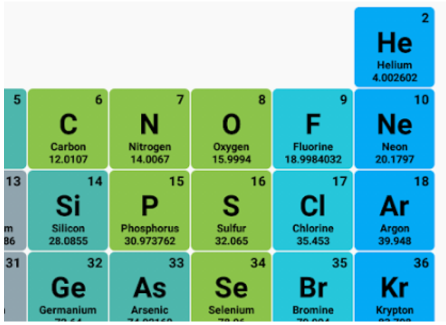

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Hint 2: Molecular mass of dry air = 28.8 g/mole

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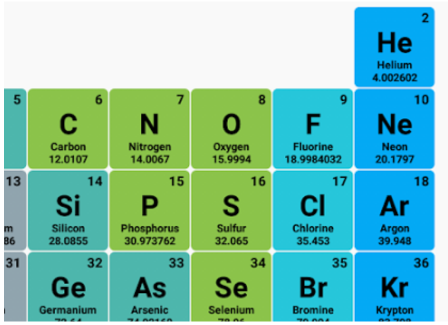

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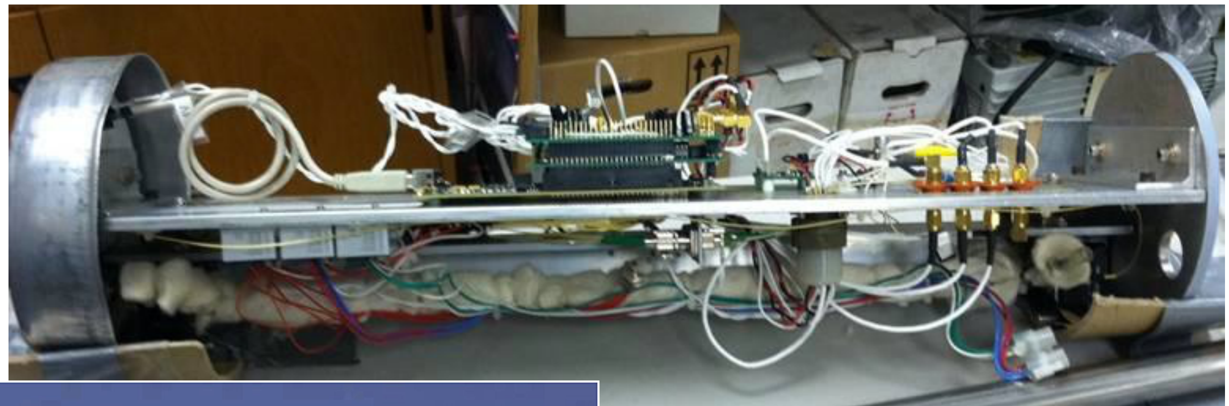
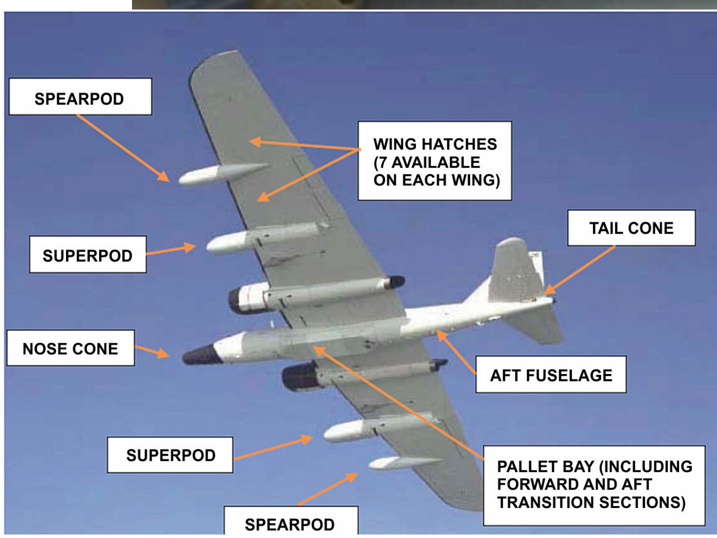
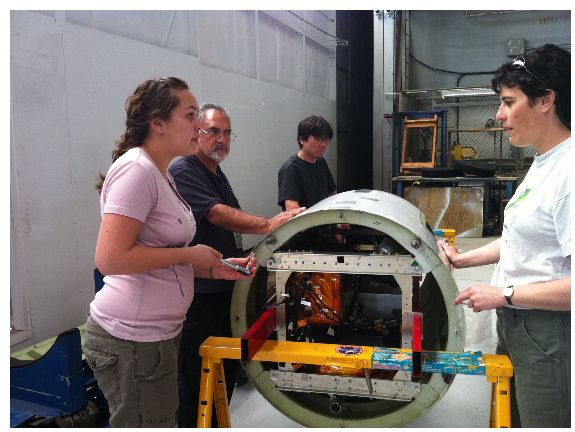
Answer: Mass mixing ratio of CO_2 is 400 ppb x 44/28.8 = 611 ppm by mass

Techniques to measure the mixing ratio of water







Specific Humidity =q $= \frac{M_v}{M_v+M_d} = \frac{\rho_v}{\rho_v+\rho_d}$

Converting between mixing ratio and vapor pressure:

In class show that:

Mixing ratio = $w = \frac{\rho_v}{\rho_d} = \frac{\varepsilon e}{p-e} \approx \frac{\varepsilon e}{p}$

Where: $\varepsilon = \frac{R_d}{R_v} = \frac{m_w}{m_d}$ = 0.622

Virtual Temperature

$$T_v \approx (1 + 0.61q)T$$

HW Problem 3.9 – Derive this equation

- Virtual temperature of a moist air parcel is the temperature at which a theoretical dry air parcel would have a total pressure and density equal to the moist parcel of air.
- Logically, as the moisture content of the air increases, the virtual temperature increases since an increase of moisture decreases density.
- **You may ask the purpose in needing to know virtual temperature. It is important since it makes meteorological equations MUCH less complicated. If virtual temperature is used, the moisture in the air can be ignored.**

Virtual Temperature

$$T_v \approx (1 + 0.61q)T$$

Why is T_v warmer than T?

- Water vapor has lighter molecular weight (18) than that of dry air (~29)
- Moist air is less dense than dry air. Therefore, air which is perfectly dry needs to have a higher temperature in order to have the same density as the less dense moist air.