

# **Heat and Energy Transfer**

## **Energy of Phase Change**

# Temperature

- Measure of hotness
- Celsius
  - 0° freezing point of pure water at standard pressure
  - 100° boiling point at standard pressure
- Fahrenheit
  - 0° was lowest attained
  - 32 was his age when he performed experiments
  - 212 is boiling point in those increments

# Temperature

- **Convert with equations**

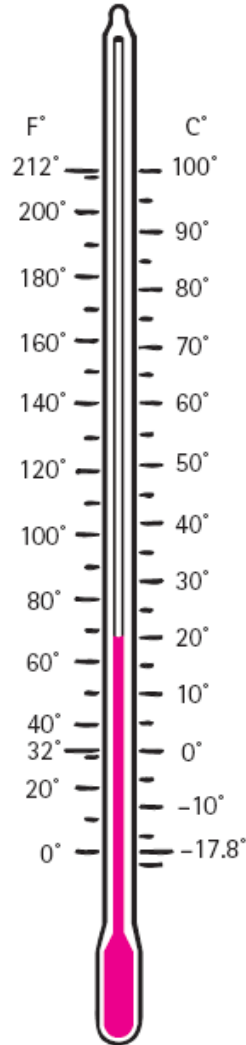
- Order of operations

- Parentheses first
    - Then multiply or divide
    - Add or subtract last

- **Or use adjacent scales**  
such as p. 142 of  
*Conceptual Physical*  
*Science* textbook

$$C = \frac{5}{9} (F - 32)$$

$$F = \frac{9}{5} C + 32$$



# Temperature

- Kelvin same size as degree Celsius
- 'Absolute Zero' is 0 K
  - (notice no degree symbol on K)
- $0^{\circ} \text{C} = 273 \text{ K}$
- Molecular motion ceases at absolute zero

# Heat

- Calorie
  - Amount of heat required to raise the temperature of 1 gram of pure water 1° C
  - Food 'Calories' are kilocalories
- Joule ~  $\frac{1}{4}$  of calorie
  - 1 cal. = 4.184 J

# Laws of Thermodynamics

1. Heat added = increase in thermal energy + external work done by the system
2. Heat never spontaneously flows from a cold substance to a hot substance
3. No system can reach absolute zero

# Specific Heat Capacity

- Quantity of heat needed to change the temperature of given amount of a substance  $1^{\circ}\text{C}$
- Water—very high specific heat capacity
  - Maritime areas more mild temperature than continental areas
  - Takes  $1/8$  calorie to raise temperature of iron  $1^{\circ}\text{C}$

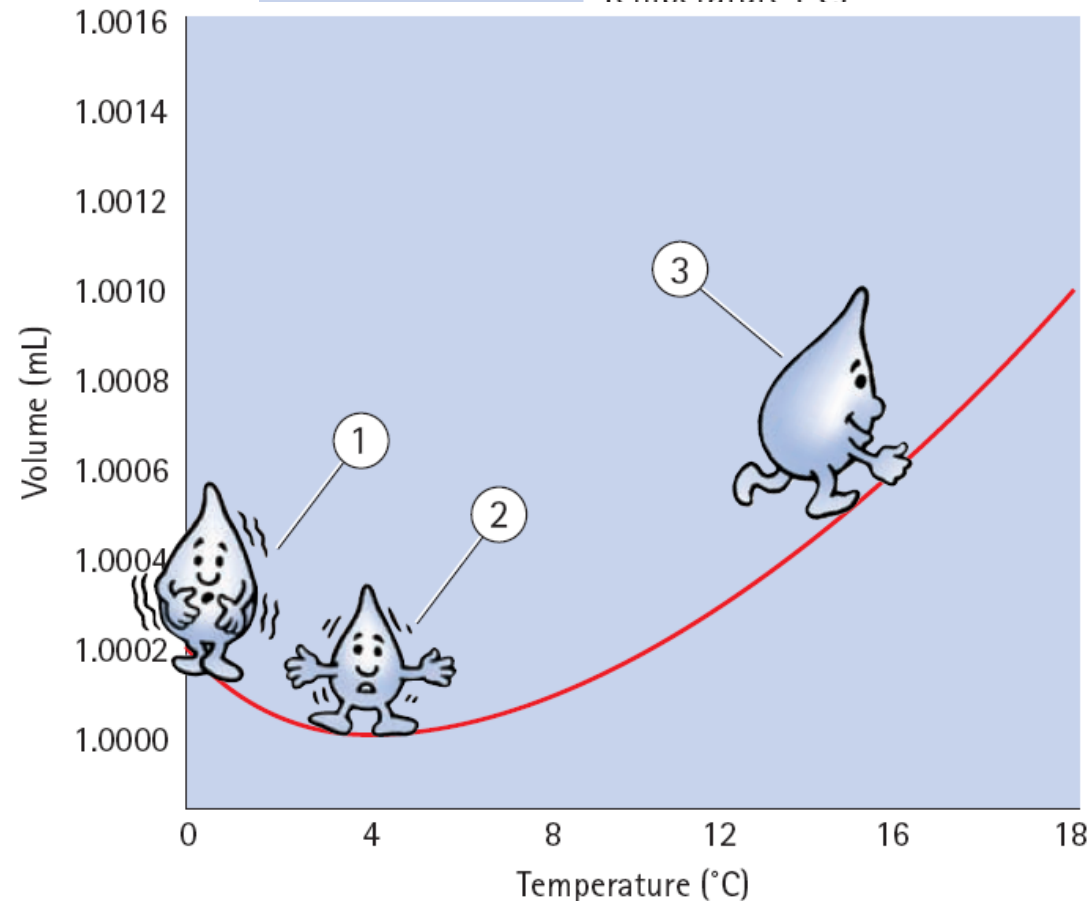
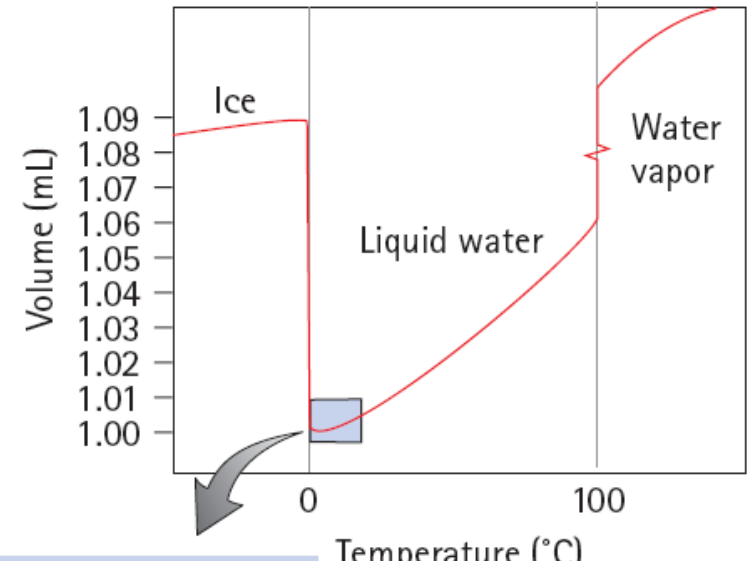
# Heat Expansion

- Random motion causes substance to be bigger
- Liquids usually have greater heat expansion than solids
- Thermostats use different expansion of different type of metals



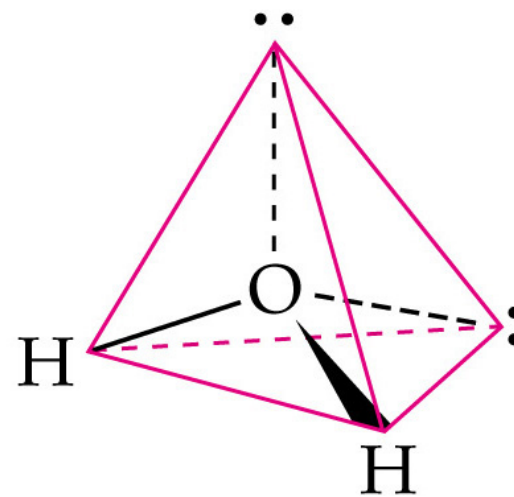
# Water Expansion

- Unusual response to cooling
- Contracts until reaching 4° C
- Expands slightly upon further cooling to 0° C
- Expands 9% upon freezing

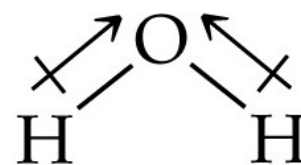


# Water Molecule

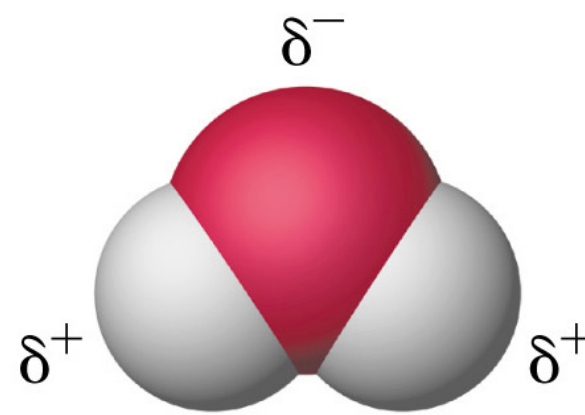
- Bent
- Polar



(a)



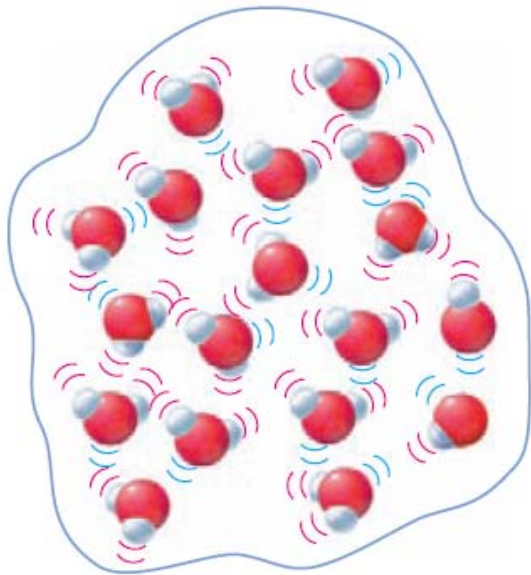
(b)



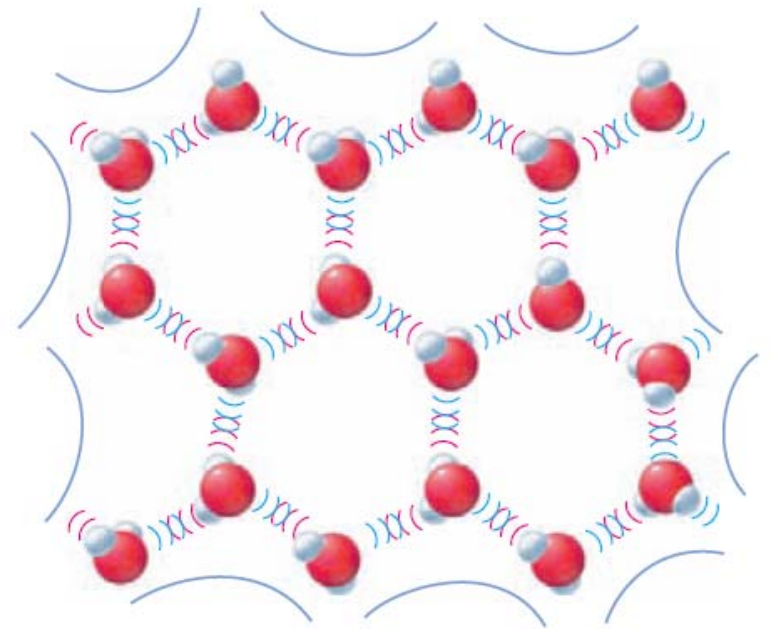
(c)

# Water Expansion

- Molecule shape fit together closer in liquid
- Open structured crystal due to hydrogen bonding of polar molecules upon freezing



Liquid water  
(dense)



Ice  
(less dense)

# Heat Transfer: conduction

- Tile is a better conductor of heat than the wood floor



# Heat Transfer: convection

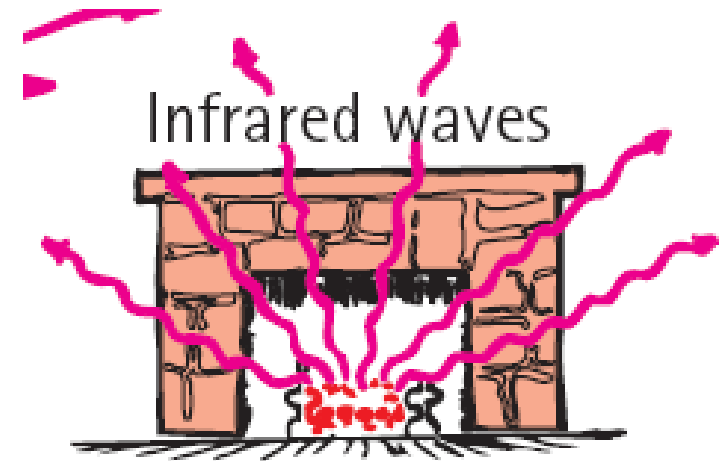


- Currents from heater shown by shadows



# Heat Transfer: radiation

- Does not need material to transfer radiant energy
- Dark bodies absorb it better than light-colored ones



# Radiant Energy

- All objects emit thermal energy
  - Visible light above  $\sim 500^{\circ}\text{C}$
  - Re-emit absorbed radiation at wavelength according to temperature
- Good absorbers are good emitters
- Poor absorbers are poor emitters



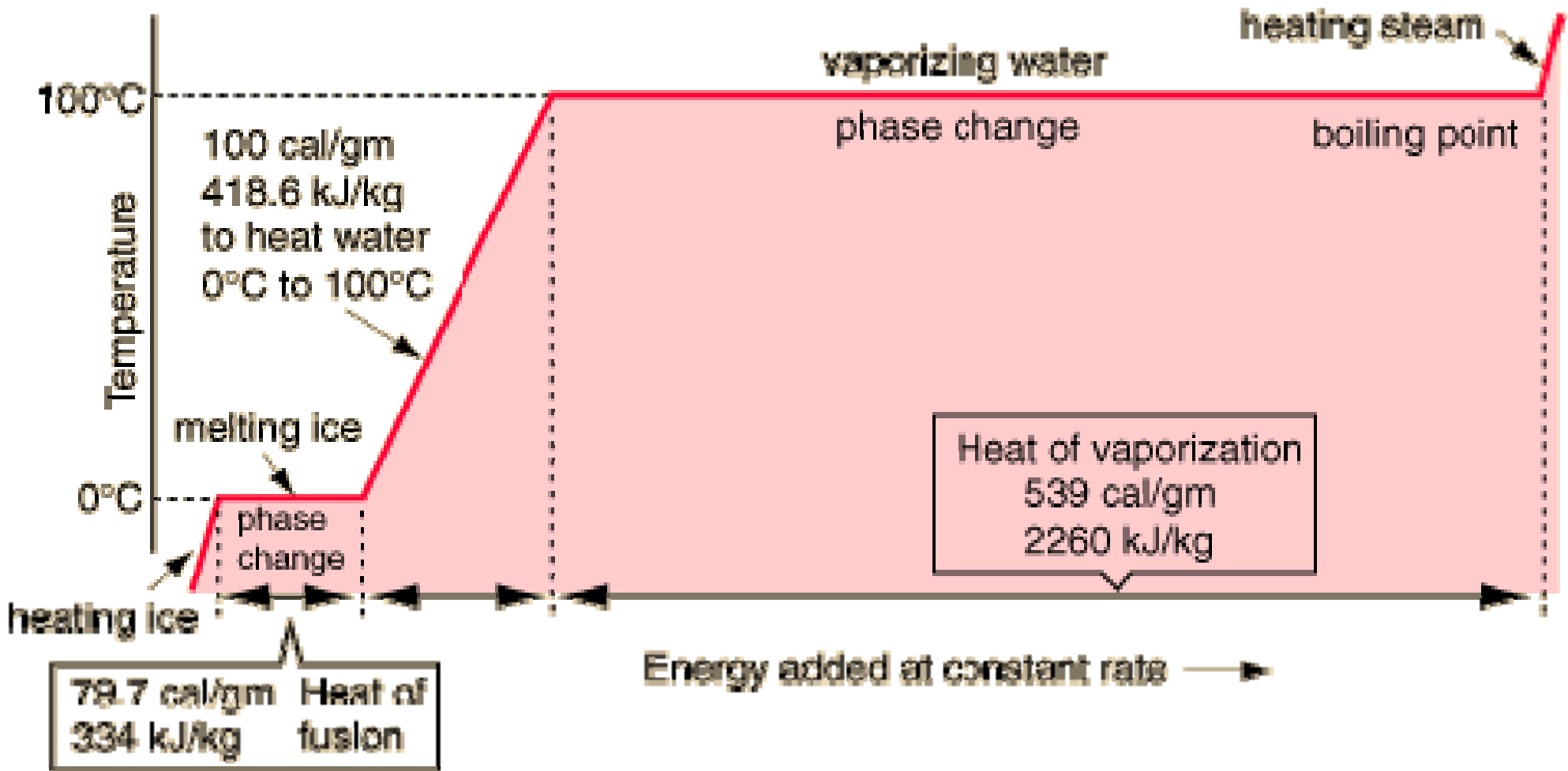
# Heat Transfer

- Conduction
  - Direct molecule interaction
  - Transferring energy to next molecule
- Convection
  - Movement of fluid: liquid or gas
- Radiation
  - Through open space
  - Electromagnetic radiation

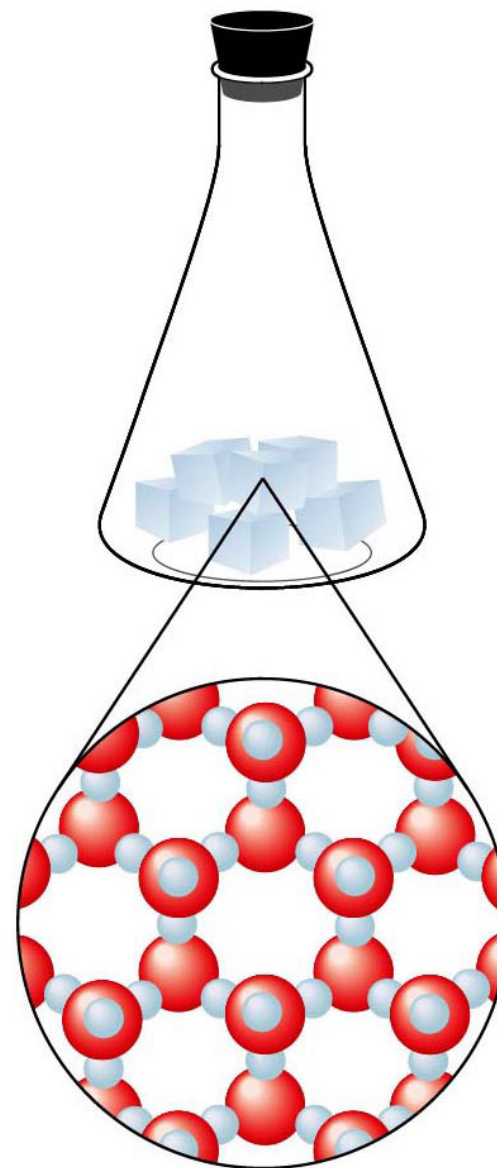
# Energy of Water Phase Change

- Calorie:  
energy to change 1 g water 1 K or 1 °C
- Also need energy to change to different state of matter
- Energy of vaporization/condensation
  - 540 calories per gram of water = 2256 J/g
- Energy of melting/freezing
  - 80 calories per gram = 334 J/g

# Energy of phase change for water

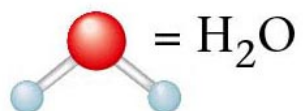
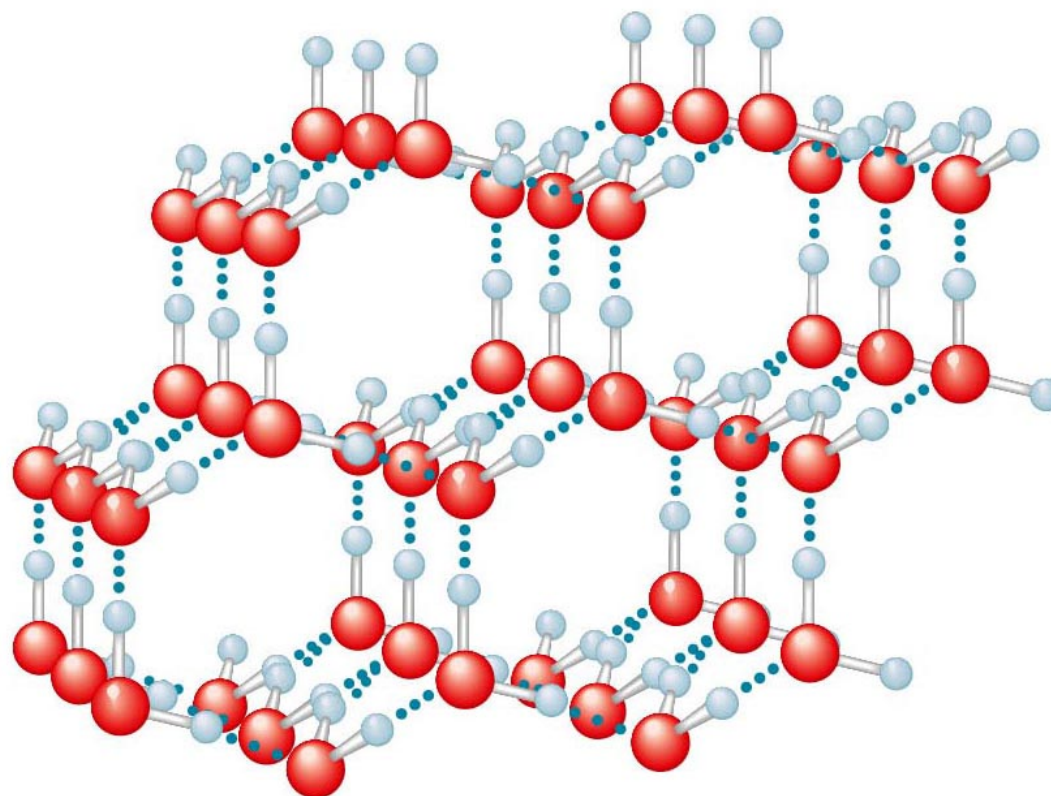


# Solid Ice



$\text{H}_2\text{O}(\text{s})$  Ice

# Molecular Structure of Ice



Ice



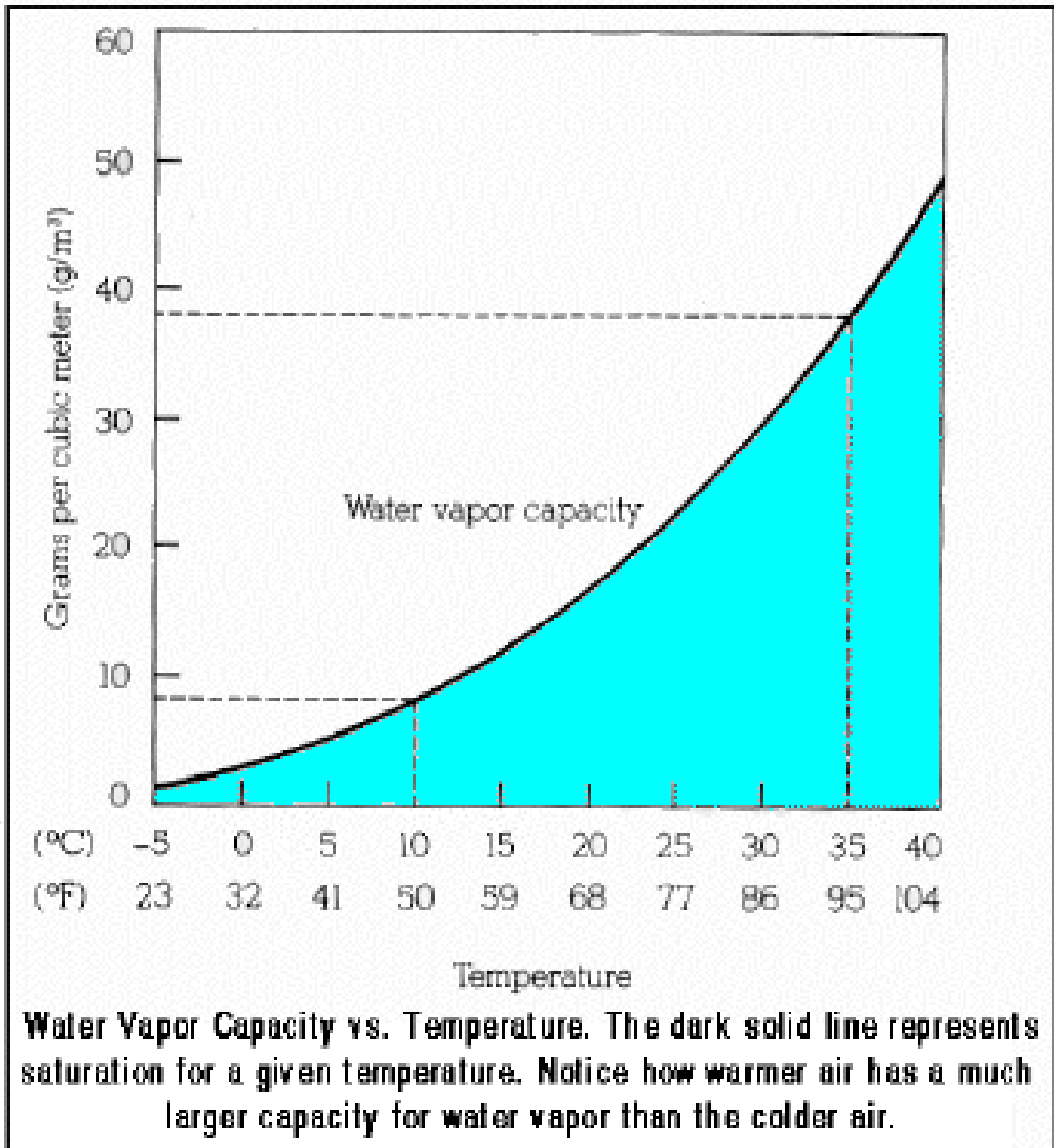
# Three phases of water

# Atmosphere

- Evaporation
  - Energy goes into air
  - Cools remaining water
- Condensation
  - Energy goes from air to surface
  - Warms local environment

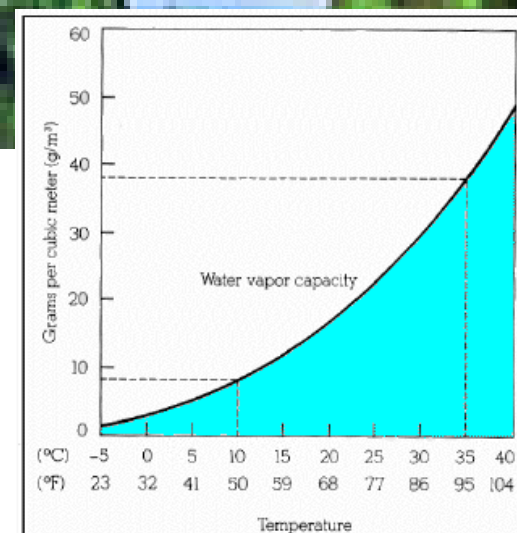
# Atmosphere

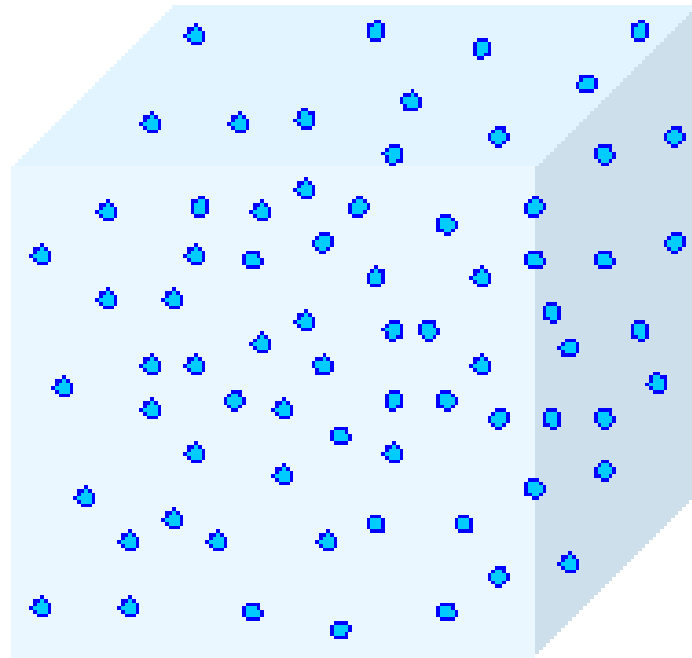
- Warm air has greater capacity for holding water in the vapor phase
- Saturation = at capacity
- Relative Humidity—percent of water contained compared to saturated amount at that temperature



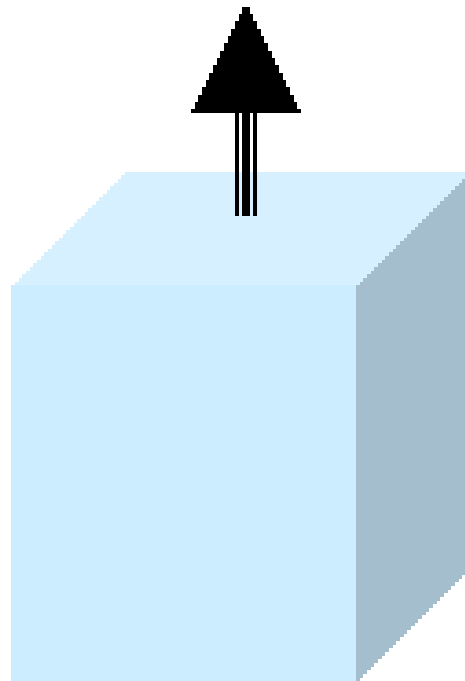
**WARM AIR RISES**

As air rises, it expands and cools  
Condensation of water vapor occurs



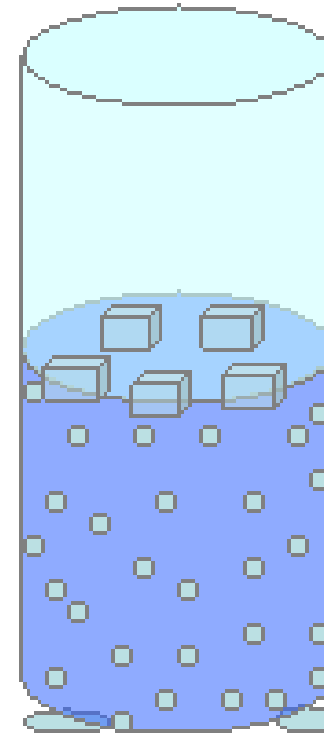


**Condensation**  
**due to the**  
**expansion of air**  
Some of the water vapor in a rising air parcel turns into liquid water droplets as the air parcel expands and cools.



**Condensation due direct**  
**cooling of air**

Some of the water vapor in air next to a cold surface turns into liquid water droplets.







# Homework Assignment

- Handout available today
- Also posted on web page for class  
<http://www.wou.edu/~brownk> go to ES 106 page and look for today's date (April 9)
- Due in one week, April 16
  - If you won't be here that day, get it in early or have someone else bring it
  - If you weren't here April 9, it is **STILL DUE** on April 16