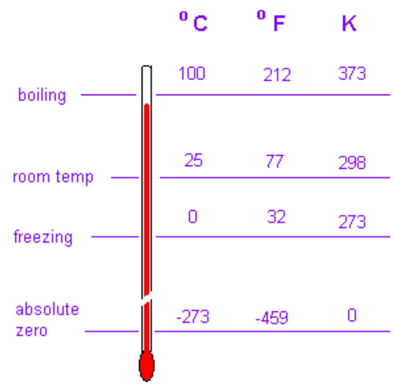
PSC1341 Chapter 6
Thermal Energy & Gas Laws

Chapter 6: Thermal Energy & Gas Laws

A. Temperature
B. Phases: Solid, Liquid, Gas
C. Phase Changes, the heating cooling curve
D. Kinetic Molecular Theory
E. Gas Behavior
F. Gas Laws

### Temperature




- Temperature is a measure of the average kinetic energy of the molecules.
- Kinetic Energy is $\frac{1}{2}mv^2$.
- As temperature increases, the velocity of the molecules increases.

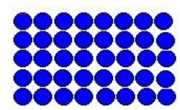
### Temperature Conversions

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

K=C+273

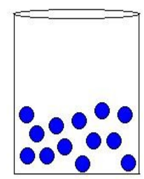
## Phases

### Solid



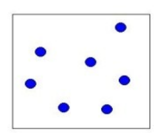
- Attractive forces overcome the kinetic energy so neighbors do not change.
- Definite shape and definite volume
- Are generally the most dense of the three phases

### Liquid



- Attractive forces and kinetic energy both play a role
- The attractive forces keep a definite volume but the kinetic energy allows the molecules to move past each other.
- Takes the shape of the container.

### Gas



- kinetic energy has overcome any attractive forces so the molecules do not stick together.
- Take the shape and volume of the container
- Generally are less dense than liquids

### Attractive forces

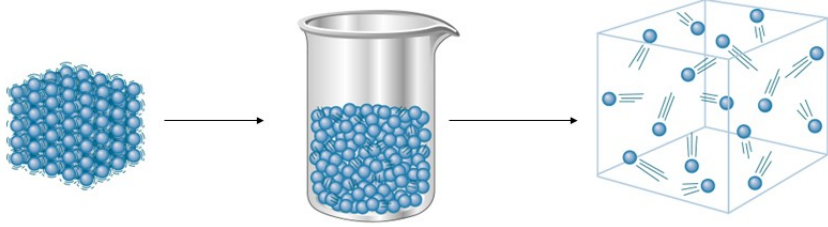
- Water's attractive forces are hydrogen bonds. Ice (mp = 0 $^{o}$C, bp 100 $^{o}$C) is a molecular solid.
- Salt (Ionic solid) and diamonds (covalent solid) have high melting points.

- Propane's attractive forces are London forces. Propane has a very low mp and boiling point. It is a gas at room temperature.

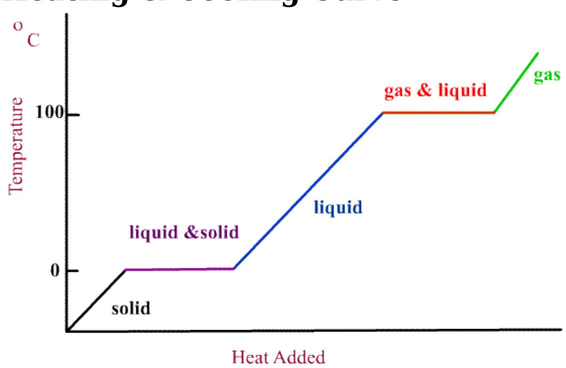
| Very Very Strong | Strong | Weak |
|---|---|---|
| Ionic and covalent | Hydrogen bonds | London forces |

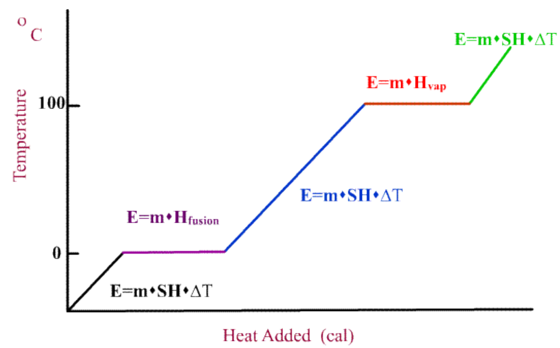
**What is happening to water during a phase change?**

- When there are temperature changes, the molecules move faster.
- During melting some of H-bonds break.
- During vaporization, all the rest of the H-bonds break.



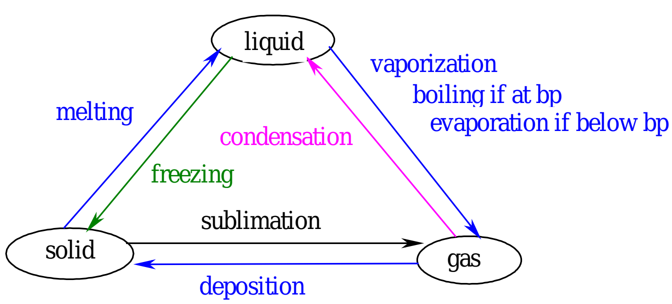
**Heating & Cooling Curve**




**Sample: How much heat is required to vaporize 100. g of water from 37°C ?**

**Names of phase changes**
(Increasing elevation lowers atmospheric pressure which lowers boiling point)



**Kinetic Molecular Theory (Ideal Gas)**

1. Gas molecules moving in straight lines in constant random motion
2. Temperature related to KE(1/2 $mv^2$)
3. Molecules act like billiard balls, collisions are elastic.
4. Volume of molecules small compared to volume of the gas. An ideal gas molecule has no volume.
5. Gas molecules do not stick to each other. Ideal gases have no attraction.
6. Pressure is related to collisions with the side wall of the container.

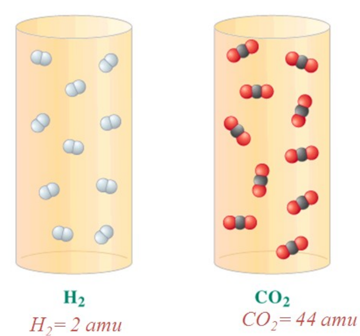
**Properties of Gases**

- Volume, V: measured in liters (L)
- Amount, n: measured in moles
- Temperature, T: measures in Kelvin (K)
    - K = C+273.15
- Pressure, P: measured in atmospheres (atm)
    - 760 torr= 760 mm Hg = 1 atm
    - 14.70 $lb/in^2$ = 1 atm

**Pressure in a closed system**

- P=force/area
- in a closed system, the force is the molecules hitting the sidewall of the container.
- The area is the area of the walls of the container.

Cool demo
A better demo



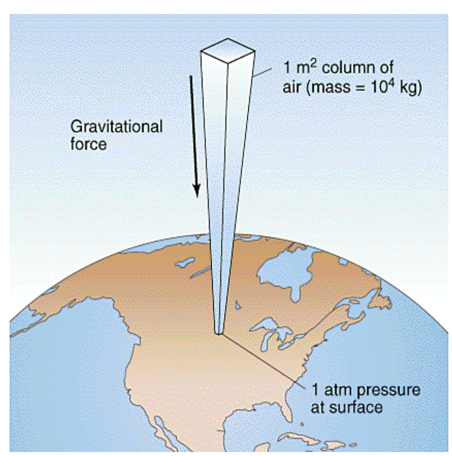

**2 tanks, equal T, V, P and n**

All gases tend to act the same. There are no attractive forces to differentiate a $H_2$ and a $CO_2$.

**Pressure in an open system**

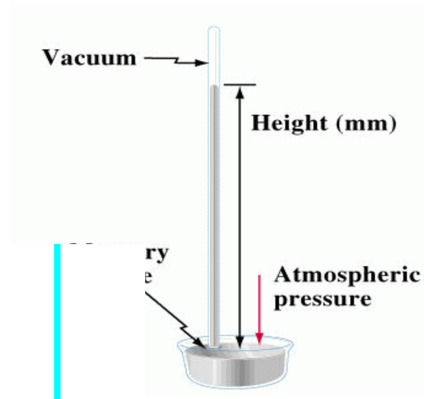
What is the pressure of the atmosphere on your book sitting on your desk?

- Pressure=force/area.
- The area is the areas of the top of the book.
- Imagine a column of gas extending from your book to the top of the stratosphere. The force comes from the weight of that gas pushing down. (F=mg where g= 9.8$m/s^2$).

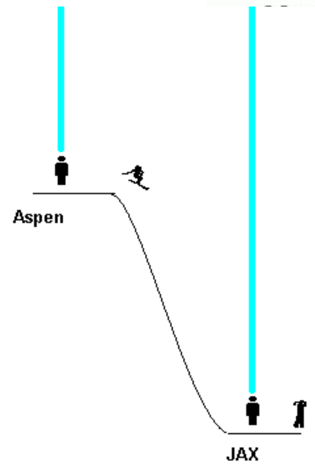


**Barometer**

- An instrument that measures atmospheric pressure
- Hg in tub feels weight of 1 atm
- Hg in bottom of tube feels weight of 760 mm Hg
- Which is denser air or Hg?




**Pressure in Aspen vs. Jacksonville**




**Effects on Pressure**

- Increasing temperature, increasing the number of moles and decreasing volume all increase pressure.
- These observations along with a mathematical model based on an ideal gas lead to the ideal gas equation:

**Describing Gases**

- Since all gases act mostly like ideal gases, they follow the same behavior, described by

$$PV=nRT$$

- R= 0.08206 L atm/mole K.

**What is the volume of one mole of air at STP, 1.00 atm and 0 ºC?**

**Combined Gas Law**

$$\frac{PV}{nT}=R \quad \text{so} \quad \frac{P_1V_1}{n_1T_1}=\frac{P_2V_2}{n_2T_2}$$

*At times 1 and 2.*

Generally we worked with closed or sealed systems so $n_1 = n_2$ .
The number of moles stays the same.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

**A sample of 23.0 L of $NH_3$ gas at 10 ºC is heated at a constant pressure until it fills a volume of 50.0 L. What is the new temperature in ºC?**

***Note that constant pressure means that $P_1 = P_2$***

**How do I know which equation to use?**

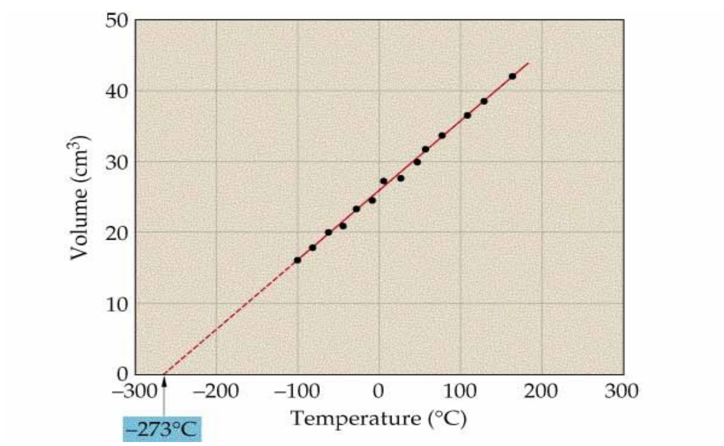
- If you see “changing”, “moved”, “compressed”, use the combined gas law equation.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

- If you are asked about a single situation, use the ideal gas equation.

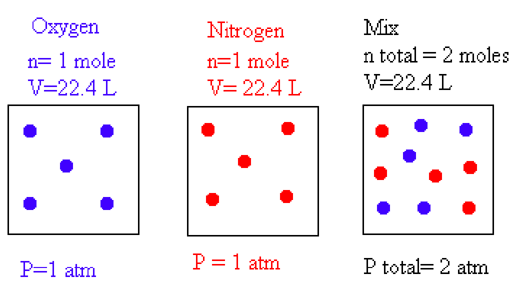
PV = nRT

**Determining absolute zero**




**Partial Pressure Defined**

- The partial pressure of a single gas in a mixture is defined as the pressure the gas would exert if it were alone in the container.
- PV=nRT holds for each individual gas in a mixture, as well as for the total mixture.



**Air**

| | | |
|---|---|---|
| Air | 100% | 1.00 atm |
| Nitrogen ($N_2$) | 78% | 0.78 atm *(partial pressure of $N_2$)* |
| Oxygen ($O_2$) | 21% | 0.21 atm *(partial pressure of $O_2$)* |
| Other stuff | 1% | 0.01 atm |

**Sample**: A piston is squished from 20.0 mL to 5.0 mL. If the starting pressure is 1.00 atm, what is the final pressure? Assume temperature is constant.

**Sample**: How many moles of gas are in a balloon that has a pressure of 1.11 atm, a temperature of 25 °C and a volume of 4.00 L?

**Sample:** A rigid metal container contains a gas at temperature of 298K and a pressure of 2.34 atm. This gas is heated to a temperature of 398K. What is the final pressure?

**Homework**

1) Molecules are, in general, farthest apart from one another in
   (A) gases (B) liquids (C) solids

2) The temperature of a gas sample in a rigid container is raised. The pressure the gas exerts on the container walls increases because
   a) the molecules are in contact with the walls for briefer intervals
   b) the molecular masses increase
   c) the molecules have higher average speeds and so strike the walls more often and with greater momentum
   d) the molecules lose more kinetic energy each time they strike the wall

3) Molecular motion in a gas is the minimum possible at
   a) 0°F
   b) 0°C
   c) 0 K
   d) -273 K

4) Which of the following statements about gases are true? Provide the best answer.
   a) Gas molecules are small compared with the average distance between them.
   b) Gas molecules collide without loss of kinetic energy.
   c) Gas molecules exert almost no forces on one another, except when they collide.
   d) All these statements are true.
   e) All these statements are not true.

5) The average human body temperature is 98.6°F. What is the equivalent temperature on the Celsius scale?
   a) 22.8°C
   b) 37.0°C
   c) 51.2°C
   d) 209.4°C

6) A rigid container initially at 1 atm and 27°C is heated to 327°C. The volume of the container remains 1 liter. What is the final presure?
   a) 0.0826 atm
   b) 0.500 atm
   c) 2.00 atm
   d) 12.1 atm

7) A piston with a volume of gas of 70.0 ml at 1.35 atm is compressed to a final volume of 22.5 ml. What is the final pressure?

Answer
1. A 2. C 3. C 4. D (They are all true, see kinetic molecular theory) 5. B 6. C( The trick here is to remember to convert temperatures to Kelvin) 7. $(P_1V_1)/V_2= P_2 = (1.35 \text{ atm} * 70 \text{ mL})/22.5\text{mL}= 4.2 \text{ atm}$