

Chemistry BC2001x: General Chemistry I



Lecture 7: Tuesday September 29, 2009

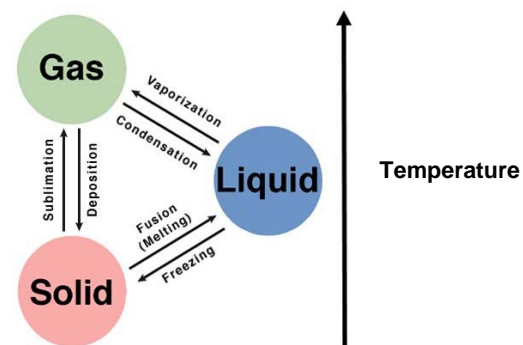
Topic: Gases and the Ideal Gas Law

Pick up the following:

- Graded set 2
- Data on Gases
- Kinetic Theory of Gases
- Hints for studying for Exam I (Tuesday, Oct 6)
Sample exam from 2008 with answers is on course web site (please read the comments).

1

Phases of matter and their transformations



2

Avogadro's hypothesis

Equal **volumes** of gas at the same pressure and temperature contain equal **number of moles**

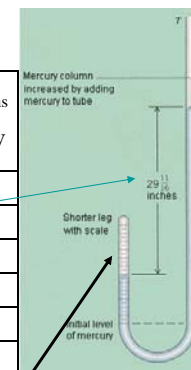
Consequence: volume is proportional to moles
Data below at one atmosphere and 0°C

| Gas | mass (g/mole) | Volume (L/mole) |
|-----------------|---------------|-----------------|
| H ₂ | 2.0 | 22.43 |
| N ₂ | 28.0 | 22.40 |
| O ₂ | 32.0 | 22.39 |
| CH ₄ | 17.0 | 22.09 |

3

Robert Boyle's Original Data for Air (1662)

| (1) Difference in Hg levels, in inches | (2) Difference in Hg levels plus atmospheric pressure; measures pressure of gas | (3) Length of the air column (in arbitrary units); proportional to its volume | (4) Product of columns (2) and (3); proportional to PV |
|---|---|---|--|
| 0 | 29 $\frac{2}{16}$ | 12 | 349.5 |
| 6 $\frac{3}{16}$ | 35 $\frac{5}{16}$ | 10 | 353.1 |
| 15 $\frac{1}{16}$ | 44 $\frac{3}{16}$ | 8 | 353.5 |
| 29 $\frac{11}{16}$ | 58 $\frac{13}{16}$ | 6 | 352.9 |
| 41 $\frac{9}{16}$ | 70 $\frac{11}{16}$ | 5 | 353.4 |
| 88 $\frac{7}{16}$ | 117 $\frac{9}{16}$ | 3 | 352.7 |



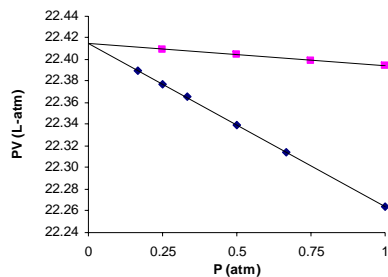
Measure the pressure and volume of the air trapped here in the tube

Boyles Law: for a fixed amount of a gas at fixed temperature, PV is constant

4

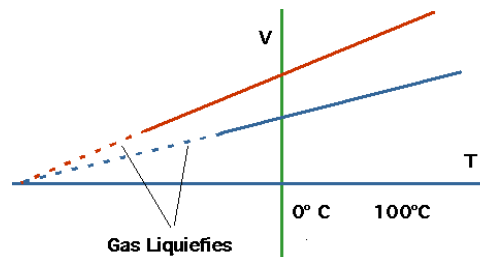
Modern Data:
1.00000 mole of specified gas at 0.000°C

| CO ₂ | | O ₂ | |
|-----------------|------------|----------------|------------|
| P (atm) | PV (L·atm) | P (atm) | PV (L·atm) |
| 1.00000 | 22.2643 | 1.00000 | 22.3939 |
| 0.66667 | 22.3148 | 0.75000 | 22.3987 |
| 0.50000 | 22.3397 | 0.50000 | 22.4045 |
| 0.33333 | 22.3654 | 0.25000 | 22.4096 |
| 0.25000 | 22.3775 | | |
| 0.16667 | 22.3897 | | |



5

Charles' (or Gay-Lussac's) Law
At fixed pressure, the volume of a fixed amount of gas expands linearly with temperature

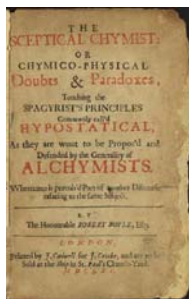


Same amount of gas at two pressures: red line is at larger P than blue line

6

Studies on the behavior of Gases

| who | fixed | studied | result |
|----------|-------|---------|---------------|
| Avogadro | t, P | V, n | $V = k_A n$ |
| Boyle | t, n | P, V | $V = k_B / P$ |
| Charles | n, P | V, t | $V = k_C T$ |



7

Combined: The ideal Gas Law

$$pV = nRT$$

n is number of moles of gas

T is temperature: *must* be in degrees Kelvin!

P is pressure

V is volume

R is universal gas constant

value depends on units for P and V

0.08205746 L·atm/K·mole

8

The density ($\rho = \text{rho}$) of methane gas (CH_4) as a function of pressure at 0°C

| | | | | |
|--------------------------|---------|---------|---------|---------|
| Pressure: P (atm) | 1.00000 | 0.75000 | 0.50000 | 0.25000 |
| Density: ρ (g/L) | 0.71707 | 0.53745 | 0.35808 | 0.17893 |
| Ratio ρ/P (g/L·atm) | 0.71707 | 0.71660 | 0.71616 | 0.71572 |

