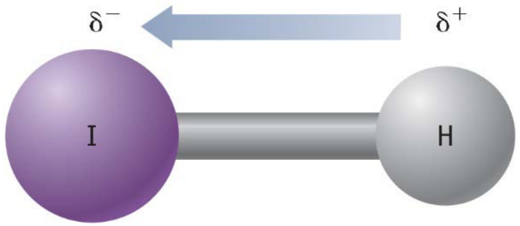
Molecular Polarity

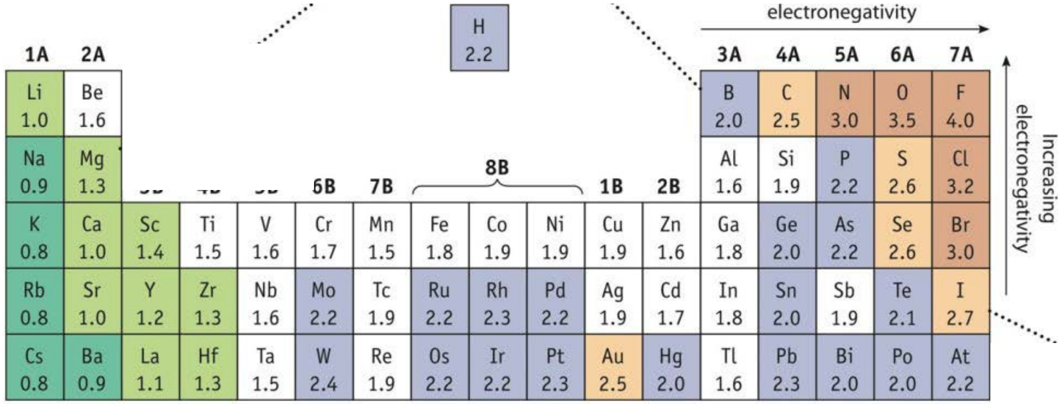
For a molecule to be polar it must

1. have a polar bond (bond between atoms of different electronegativities)
2. bond polarities must add to give a net polarity (dipole) for the molecule
3. a dipole moment is a vector

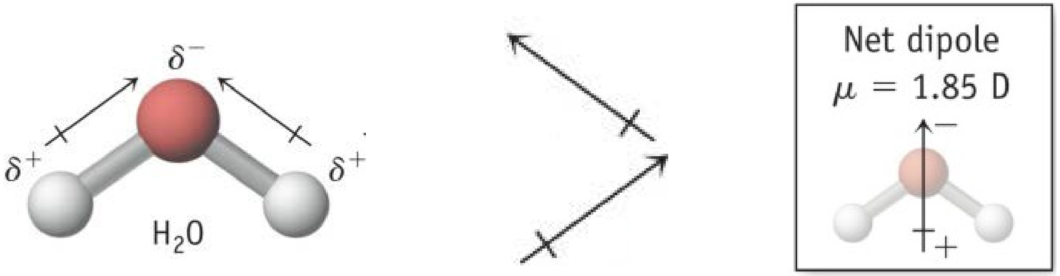
$$\mu = \Sigma\, Q_i \boldsymbol{r}_i$$

Consider HI: I is more electronegative than H so the dipole points from H (δ+) to I (δ-)





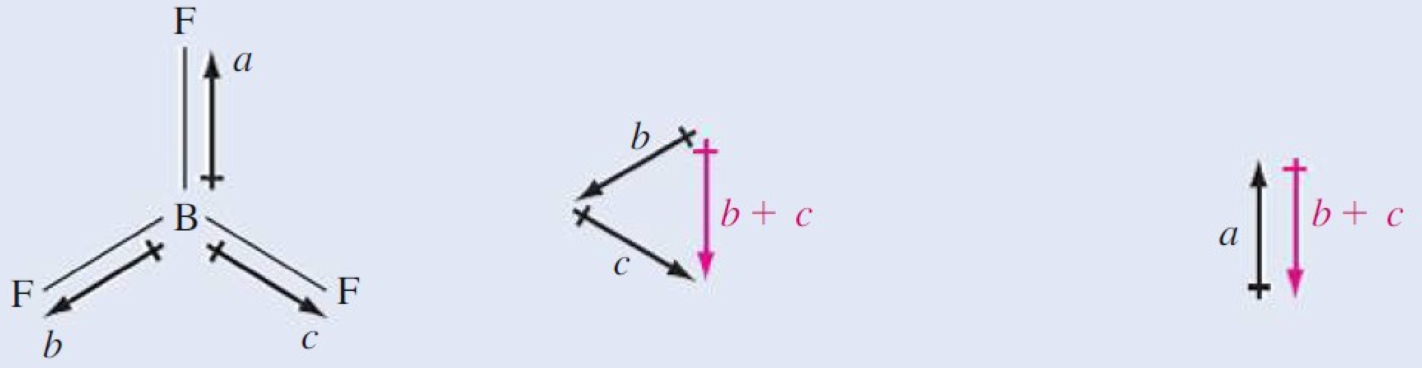
In water each O – H bond is polar with the dipole pointing from H (δ+) to O (δ-). Then the two bond dipoles need to be vectorially added to give the net dipole for the molecule



Molecule with Polar Bonds May Not be Polar

The addition of bond dipoles can be extended to more than two. Consider BF_3

1. draw the Lewis structure
2. determine the electronic geometry and then the molecular geometry (determines bond dipoles)
3. sketch the structure (three dimensional if needed
4. vectorially add the bond dipoles



The bond dipoles are labeled *a*, *b*, and *c*.

Add *b* and *c* "head-to-tail" to form the vector sum *b* + *c*.

The vector sum of *a* and *b* + *c* is a vector of zero length (no dipole).

REVIEW FROM WEDNESDAY

Electronegativity and Atomic Size Effects

EX 1. Determine the stronger acid in the following pairs and explain why.

a) H_3PO_3 or H_3PO_4 — more lone O atoms

b) CH_4 or NH_3 — N more electronegative

c) $H_2AsO_4^-$ or $HAsO_4^{2-}$ — easier to remove H^+ from singly charged anion

d) HIO or HClO — Cl more electronegative

e) H_2Se or H_2Te — Te larger

Gases

Z Ch 5

"The particles of the air are in contact with each other, yet they do not fit closely in every part, but void spaces are left between them, as in the sand on the sea shore: the grains of sand must be imagined to correspond to the particles of air, and the air between the grains of sand to the void spaces between the particles of air. Hence, when any force is applied to it, the air is compressed, and, contrary to its nature, falls into the vacant spaces from the pressure exerted on its particles: but when the force is withdrawn, the air returns again to its former position from the elasticity of its particles, as is the ease with horn shavings and sponge, which, when compressed and set free again, return to the same position and exhibit the same bulk." **Hero of Alexandria, ~ AD 60**

Physical States of Matter

solid	rigid	fixed volume, fixed shape
liquid	fluid	fixed volume, conforms to container
gas	fluid	no fixed volume, no fixed shape **SIMPLE**

while gases are simple they still do have chemistry, e.g.,

$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$ and $NH_4Cl(s) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l) + NH_3(g)$

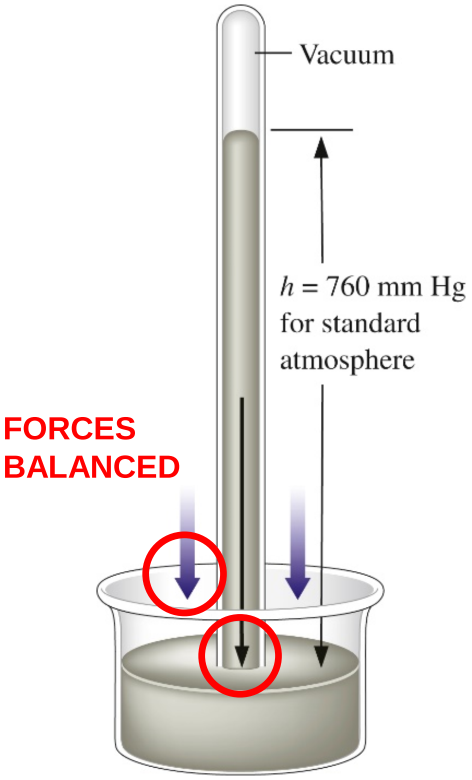
5.1 Early Experiments
5.2 Gas Laws
5.3 Ideal Gas Law

NEXT FRIDAY quiz

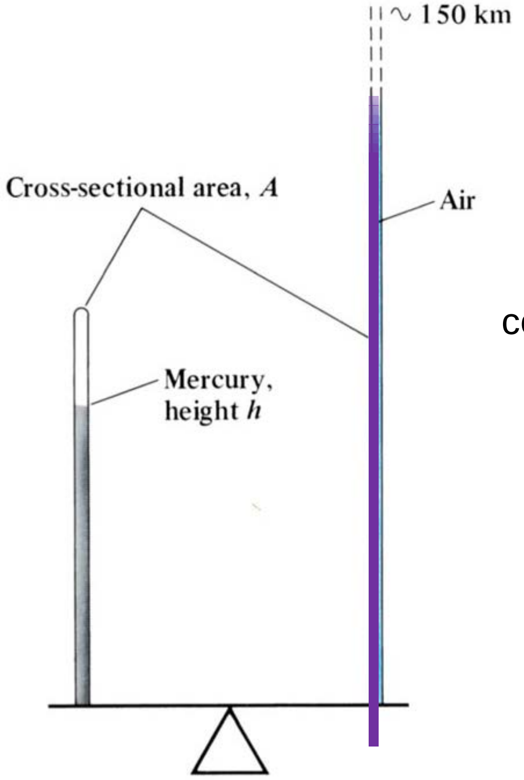
Toricelli's Barometer

How is pressure measured? How do you measure atmospheric pressure, i.e., how does a barometer work? Consider a mercury barometer. Invert a glass tube that is completely filled with mercury in a dish of mercury. The mercury will flow out of the the glass tube until a certain height is reached.

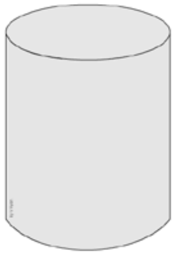
Evangelista Torricelli, 1608-1648



The height achieved is due to a balancing of forces on the surface of mercury, the weight of a column of air and the weight of the mercury column.

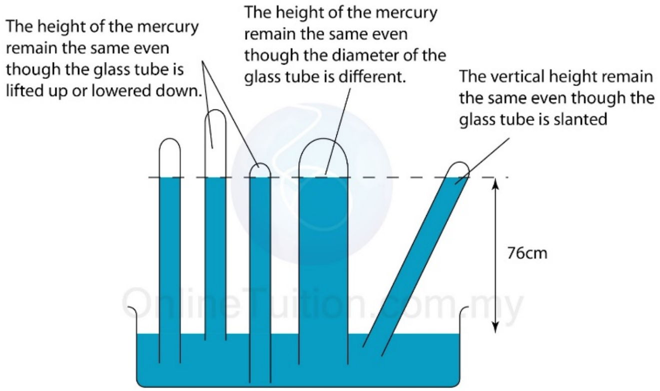


$P_{Hg} = F_{Hg}/A$ $\quad F_{air}/A = P_{air}$



column cross section of area A

$P = F/A$
$= mg/A$
$= dVg/A$
$= dAhg/A$
$\Rightarrow \mathbf{P = dgh}$



How is force related to height?

Toricelli's Barometer

1 **atm** = 760 **torr**
= 760 mm Hg (0°C)
= 29.92 in Hg (0°C)
= 101.325 kPa
= 14.69595 psi

Units Used to Measure Pressure	
Unit Name and Abbreviation	**Definition or Equivalency**
Pascal (Pa)	$1\ \mathrm{kg\ m^{-1}\ s^{-2}} = 1\ \mathrm{N\ m^{-2}}$ (the SI unit)
Standard atmosphere (atm)	101,325 Pa exactly
Bar (bar)	100,000 Pa exactly or 0.986923 atm
Torr (torr)	(101,325/760) Pa or (1/760) atm
Millimeter of mercury at 0°C (mm Hg)	(101,325/760) Pa or (1/760) atm
Pound of force per square inch (lbf in^{-2}, or psi)	6894.757 Pa or (1/14.69595) atm

EX 1. What is the pressure when the height of a column of mercury is 76.0000 cm? (d_{Hg} = 13.5951 g crn^{-3}, g = 9. 80665 m s^{-2})

$$P = dgh = (13.5951\ \mathrm{g} / \mathrm{cm}^{-3})\ (9.80665\ \mathrm{m} / \mathrm{s}^{2})\ (76.0000\ \mathrm{cm})$$

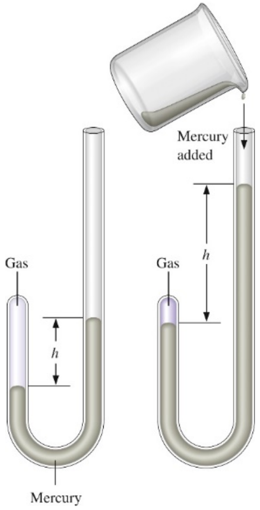
$$= (1.01325 \times 10^{4})\ (100\ \mathrm{cm} / \mathrm{m})^{2}\ (1\ \mathrm{kg} / 1000\ \mathrm{g})$$

$$= 1.01325 \times 10^{5}\ \mathrm{kg\ m^{-1}\ s^{-2}} = 101{,}325\ \mathrm{Pa} = \mathbf{101.325\ kPa}$$

$$P = F / A = ma / A = \mathrm{kg\ m\ s^{-2} / m^{2}} = \mathrm{kg\ m^{-1}\ s^{-2}}$$

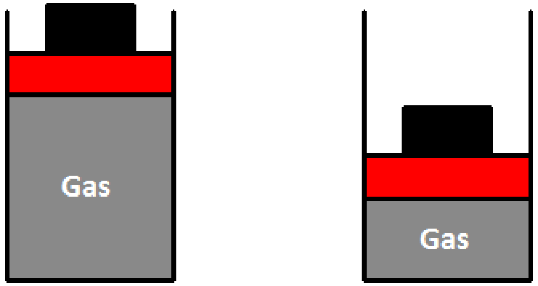
Gas Laws (Avogadro, Boyle, Charles – ABC)

Robert Boyle, 1627-1691



V ∼ 1/P

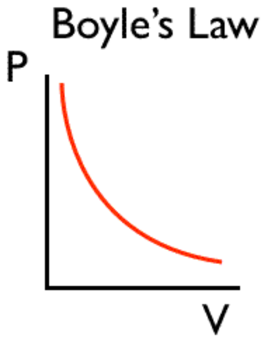
$T_1 = T_2 = 100\ K$



$p_1 = 2$
$v_1 = 5$

$p_2 = 5$
$v_2 = 2$

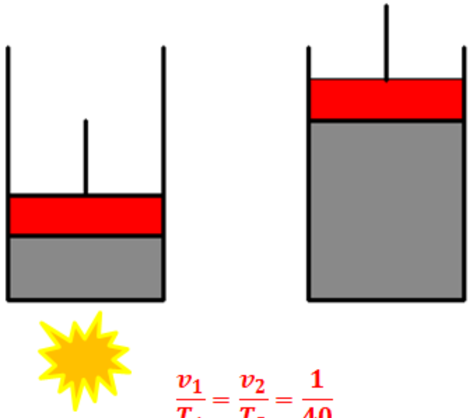
$p_1 v_1 = p_2 v_2 = 10$



$PV = constant$

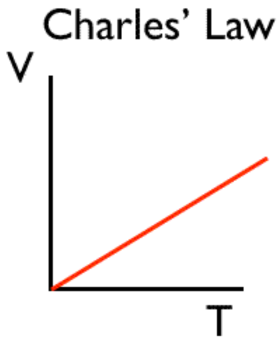
$p_1 = p_2 = 1\ atm$

$v_1 = 5\ L$
$T_1 = 200\ K$



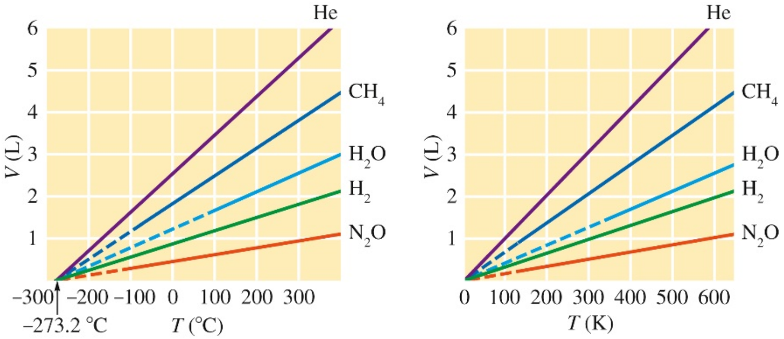
$v_1 = 10\ L$
$T_1 = 400\ K$

$\frac{v_1}{T_1} = \frac{v_2}{T_2} = \frac{1}{40}$



$\frac{V}{T} = constant$

V ∼ T



Jacques Alexandre César Charles, 1746-1823

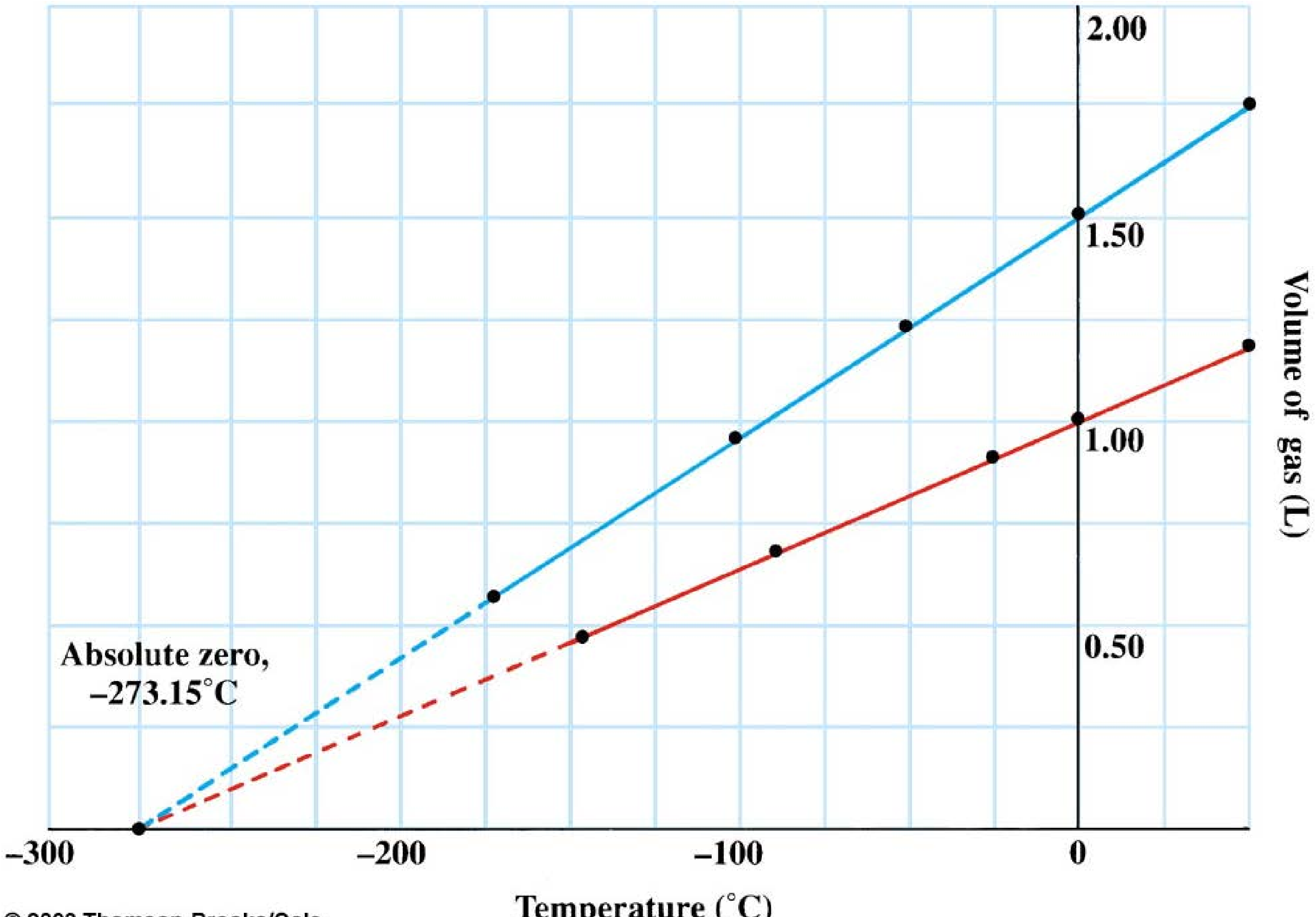
Charles Law and Absolute Zero

$$V = V_0 + \alpha V_0 t$$

experimentally:

$$\alpha = 1/273.15\ (^{o}C)^{-1}$$

$$= V_0\left[1 + \frac{t}{273.15^{o}C}\right]$$



V = volume at 0^{o}C

α = coefficient of thermal expansion

Ideal Gas Law

Boyle: $V \sim 1 / P$

Charles: $V \sim T$ $\quad\quad V = CnT / P$ or $PV = nCT = nRT$

Gay-Lussac/Avogadro: $V \sim n$

EX 2. What is the volume occupied by one mole of an ideal gas at STP conditions?

$$PV = nRT \Rightarrow V = nRT / P = (1.00)(0.0820574)(273.15) / (1 \text{ atm}) = 22.414 \text{ L}$$

Ideal Gas Law

EX 4. Hydrogen fills a 250-L reaction vessel at 100°C and 1.00 atm pressure. Determine the volume of the same quantity of hydrogen at 0°C and 1.50 atm.

P_1 = 1.00 atm	P_2 = 1.50 atm	n constant
T_1 = 100 ^{o}C	T_2 = 0^{o}C	
V_1 = 250 L	V_2 = ?	

$$PV = nRT \Rightarrow P_1V_1 / T_1 = nR = P_2V_2 / T_2$$

$$V_2 = P_1V_1T_2 / P_2T_1$$

$$V_2 = (1.00)(250)(273.15) / (1.50)(273.15 + 100)$$

= **122 L**