Gases

(CH-3)

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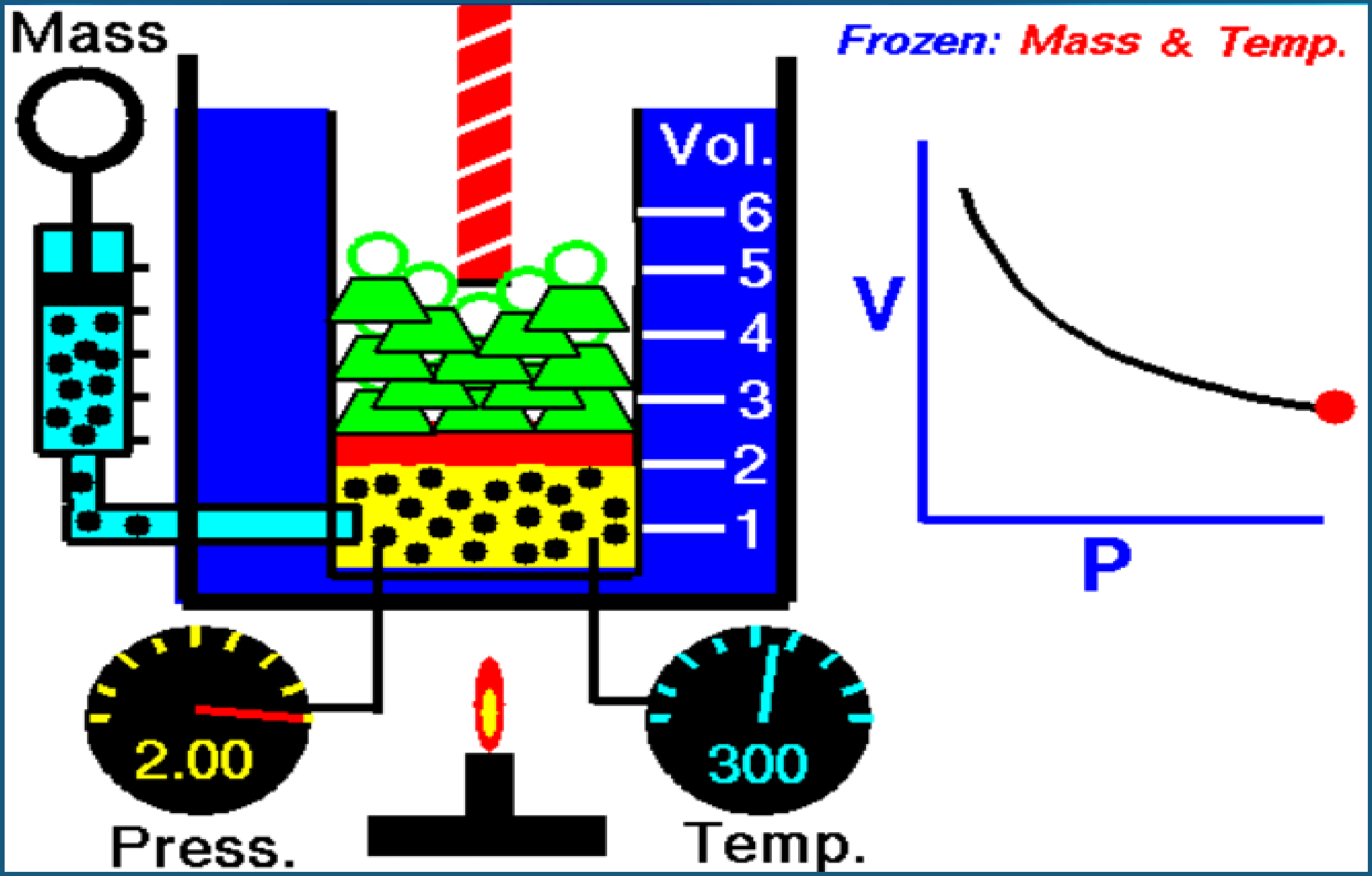
16-9-2014

Gas Laws



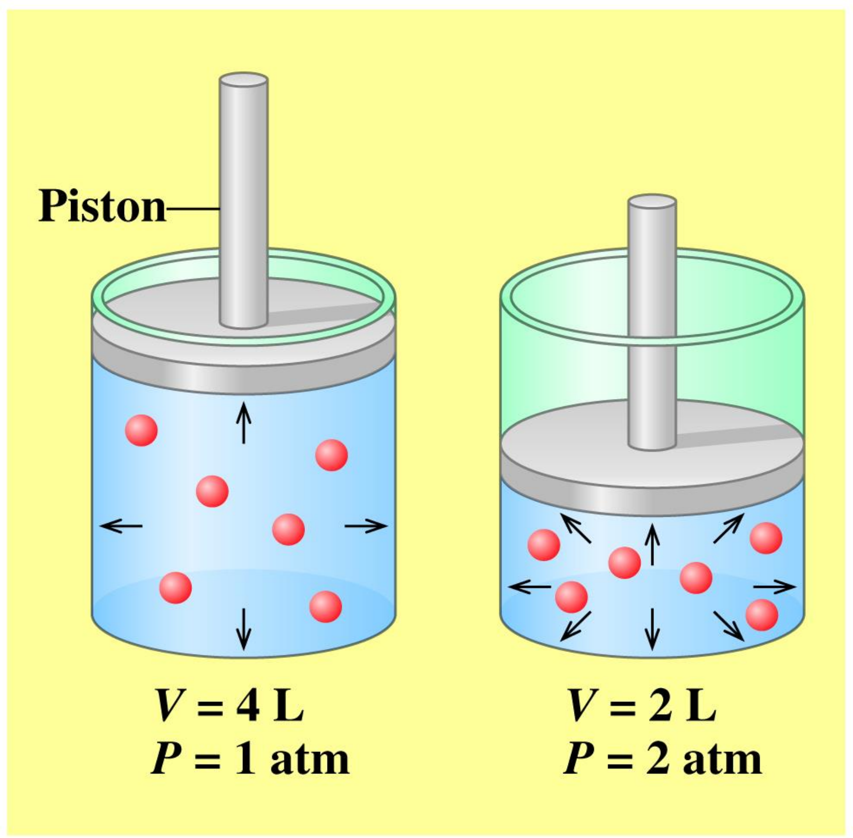
Boyle's Law

The product of pressure and volume for a gas is a constant for a fixed amount of gas at fixed temperature.

$$P \propto \frac{1}{V}$$

PV = constant

$P_i V_i = P_f V_f$ (T, n constant)



Boyle's Law

In Boyle's Law, the product *PV* is constant as long as *T* and *n* do not change.

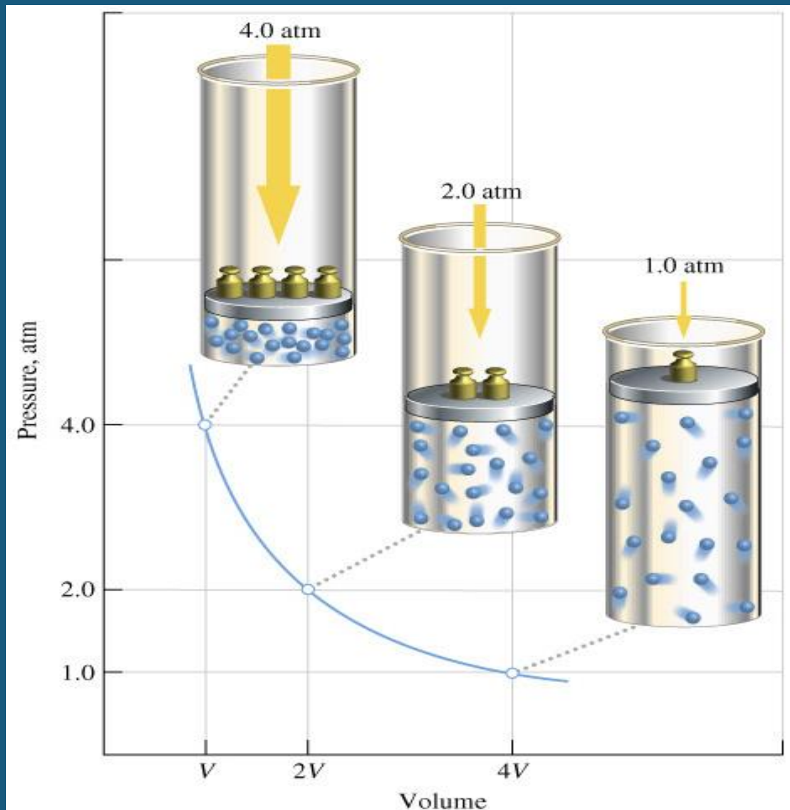
$P_1V_1 =$ 10.0 atm x 4.0 L = 40.0 atm L

$P_1V_1 =$ 8.0 atm x 5.0 L = 40.0 atm L

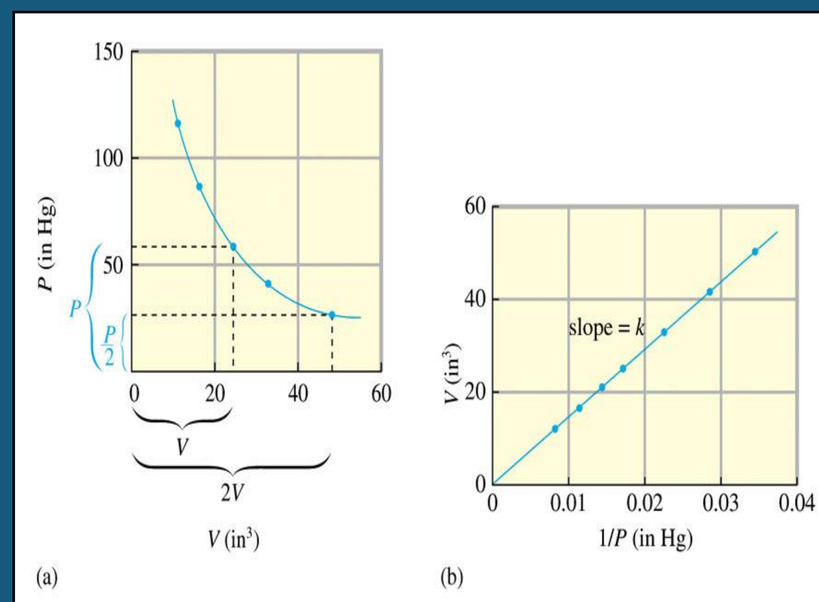
$P_1V_1 =$ 4.0 atm x 10.0 L = 40.0 atm L

$P_1V_1 =$ 2.0 atm x ??? L = 40.0 atm L

Boyle's Law



4.0 atm
2.0 atm
1.0 atm
Pressure, atm
4.0
2.0
1.0
V
2V
4V
Volume

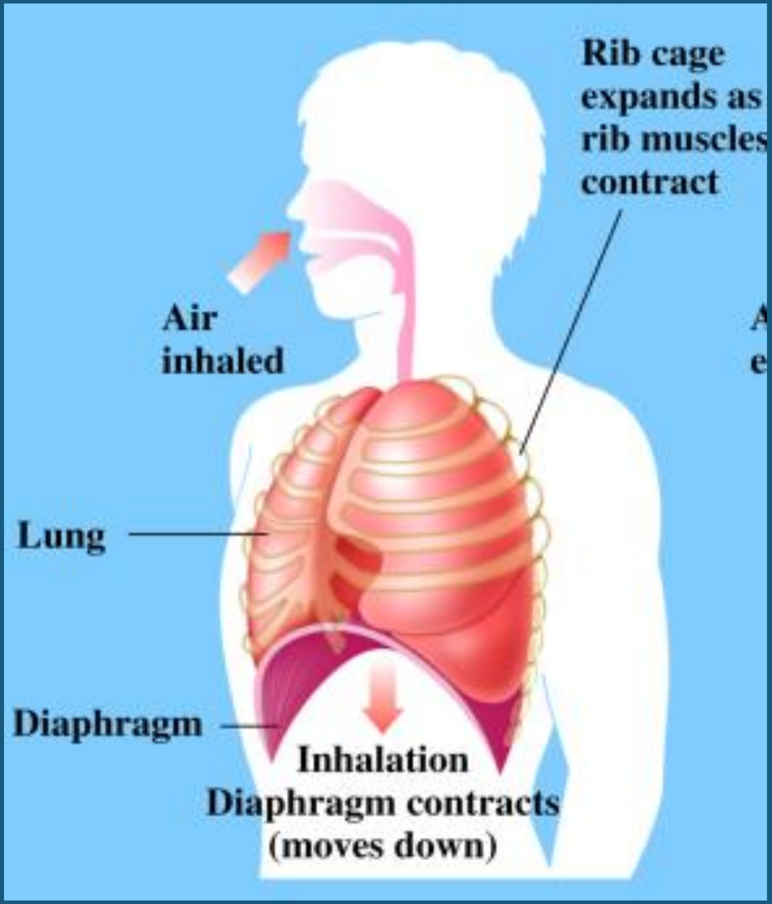


150
100
50
P (in Hg)
P
P/2
0
20
40
60
V
2V
V (in³)
(a)
60
40
20
0
V (in³)
slope = k
0
0.01
0.02
0.03
0.04
1/P (in Hg)
(b)

Boyle's Law

During an inhalation:

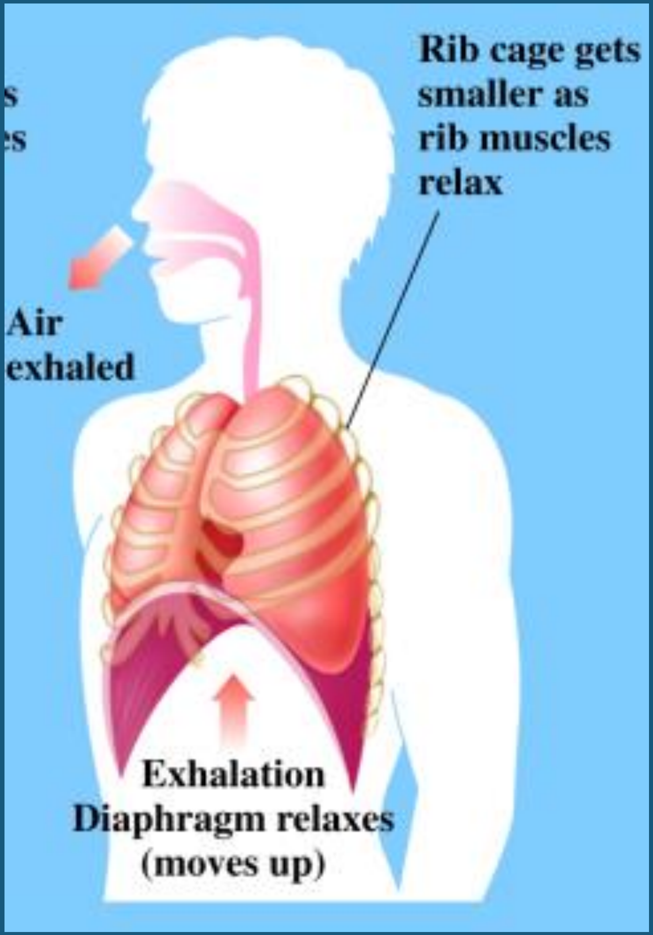
- The lungs expand.
- The pressure in the lungs decreases.
- Air flows towards the lower pressure in the lungs.



Boyle's Law

During an exhalation:

- Lung volume decreases.
- Pressure within the lungs increases.
- Air flows from the higher pressure in the lungs to the outside.



Charles Law

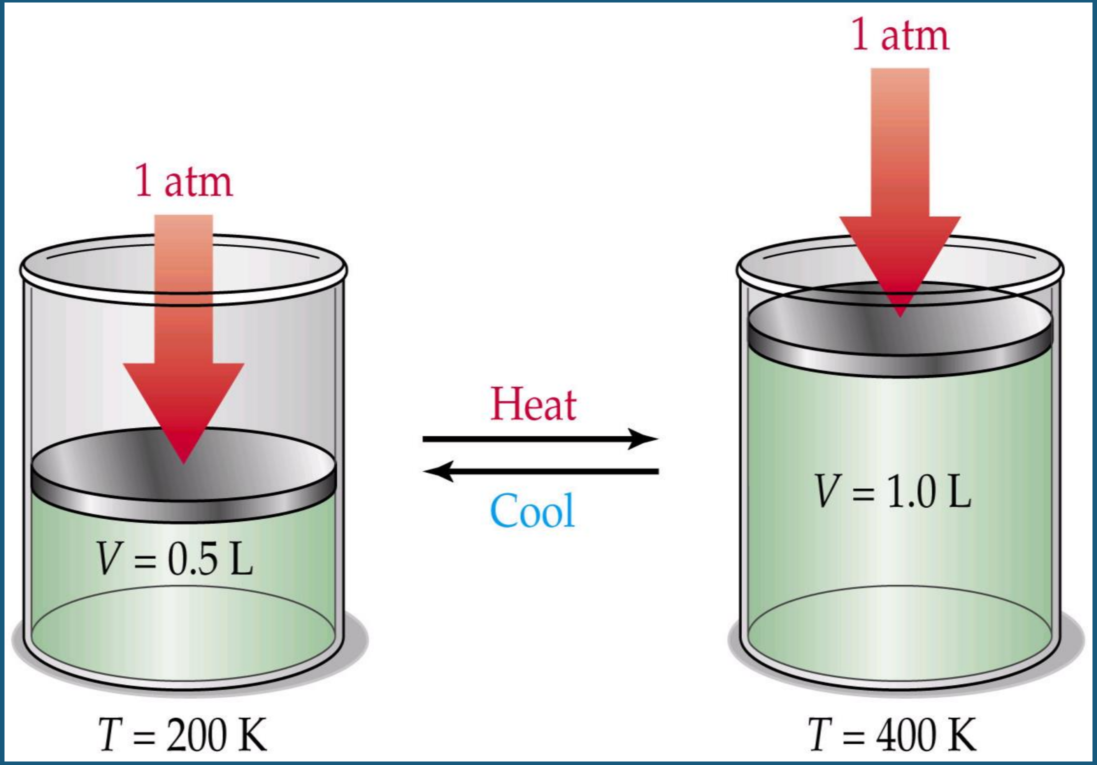
Volume of a gas varies directly with the absolute temperature at constant pressure.

$$V \propto T$$

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

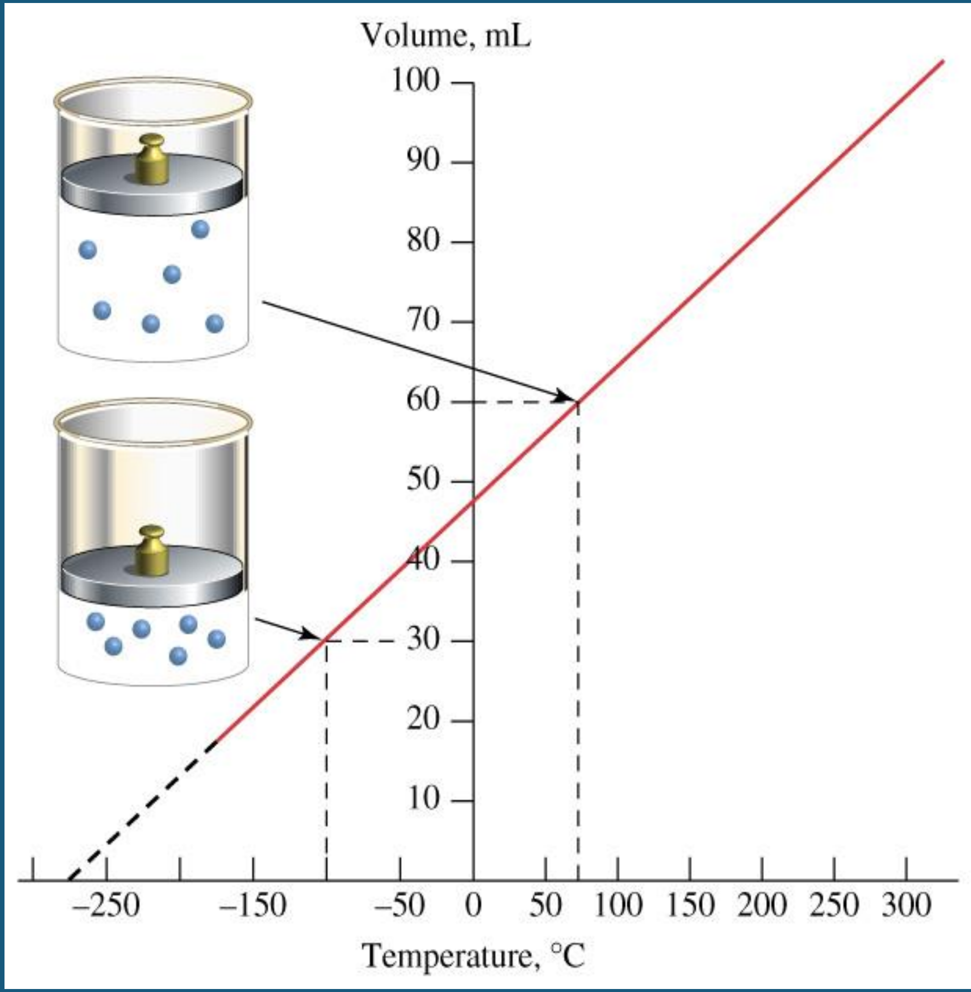
$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\frac{V_1}{V_2} = \frac{T_1}{T_2}$$



Charles Law

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$



Avogadro's Law

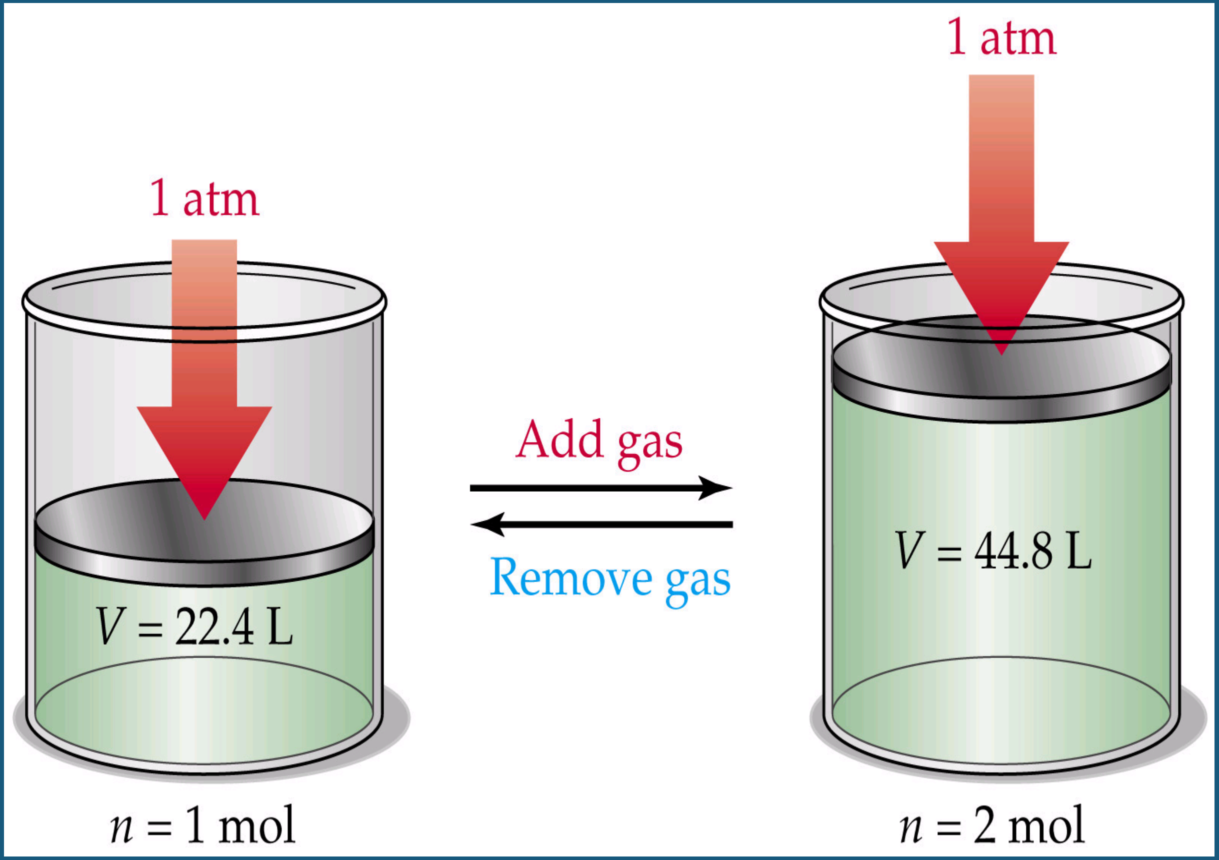
At constant temperature and pressure, the volume of a gas is directly related to the number of moles.

$V \propto n$

$\frac{V}{n} = \text{constant}$

$$\frac{V_1}{n_1} = \frac{V_2}{n_2}$$

$$\frac{V_1}{V_2} = \frac{n_1}{n_2}$$



Gay-Lussac's Law

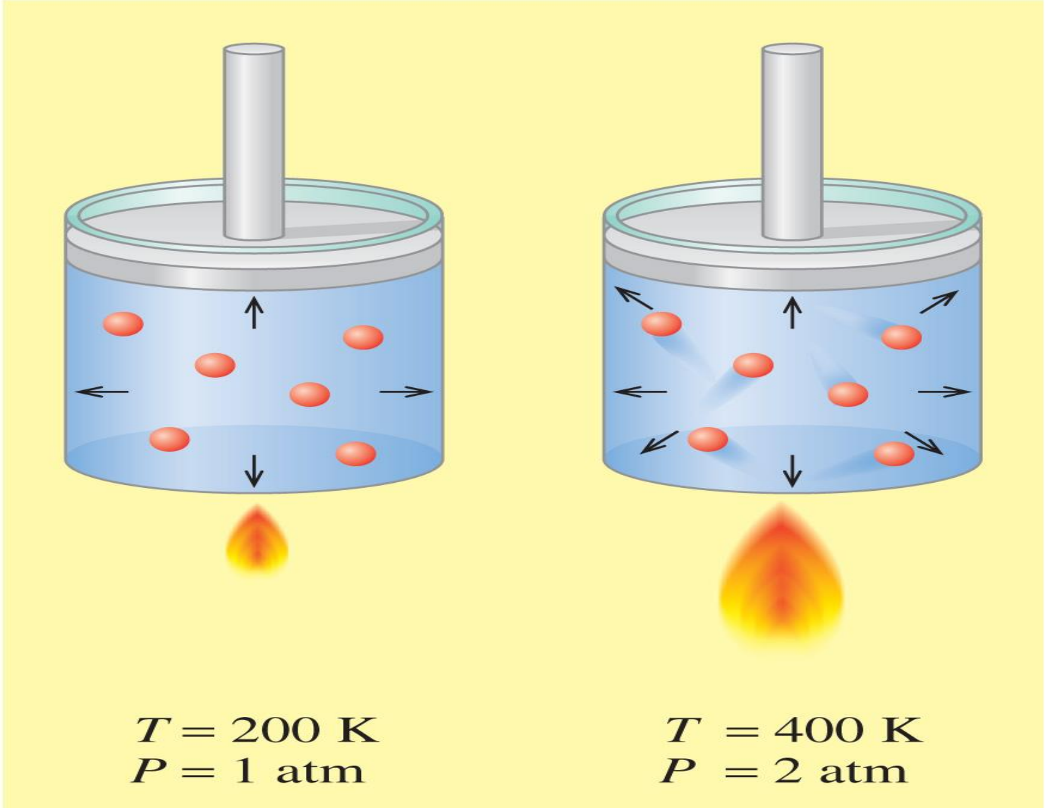
At constant volume, pressure and absolute temperature are directly related.

$$P \propto T$$

$$\frac{P}{T} = \text{constant}$$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

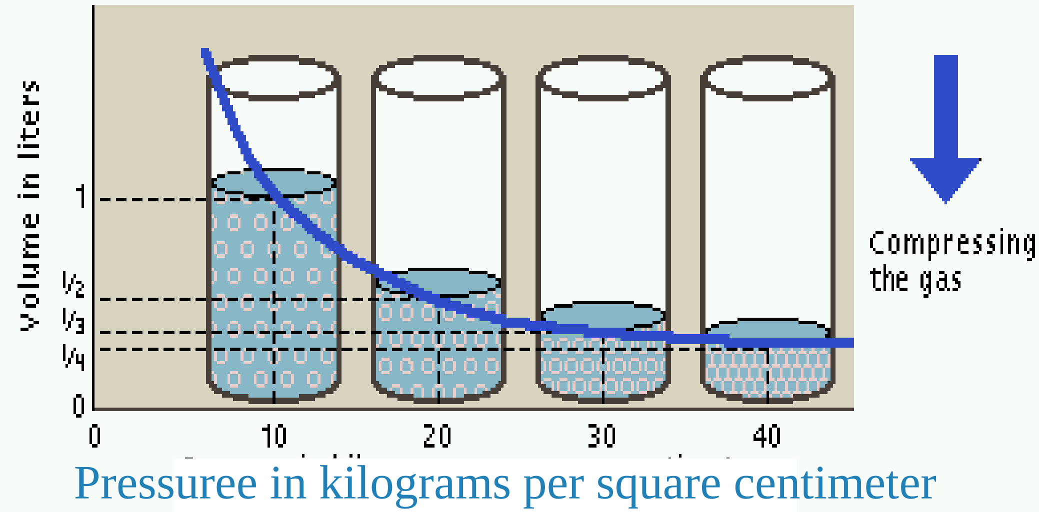
$$\frac{P_1}{P_2} = \frac{T_1}{T_2}$$



Combined Law

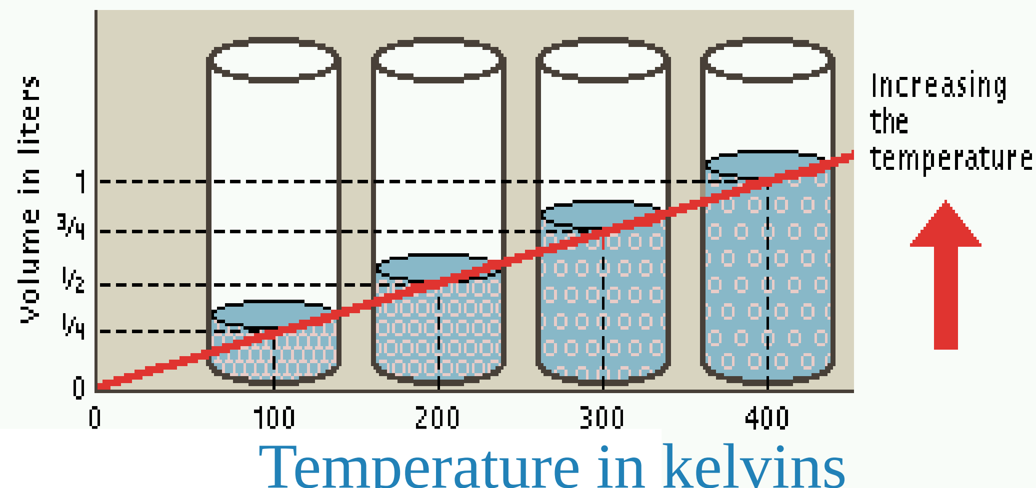
Boyle's Law

If a gas is held at a **constant temperature**, the volume is inversely proportional to the pressure. Compressing a gas to half of its initial volume doubles its pressure.



Charles' Law

If a gas is held at a **constant pressure**, the volume is directly proportional to the absolute temperature. Heating a gas to double its original temperature doubles its volume.



Combined Law

Boyle's Law	$V = kP^{-1}$	$P_1V_1 = P_2V_2$ (at a fixed temperature)
Charles' Law	$V = bT$	$V_1 / V_2 = T_1 / T_2$ (at a fixed pressure)
Avogadro	$V = an$ n = number of moles	(at a fixed pressure and temperature)
$V = nRTP^{-1}$	$PV = nRT$ ideal gas law	an empirical law

Ideal and Real Gases

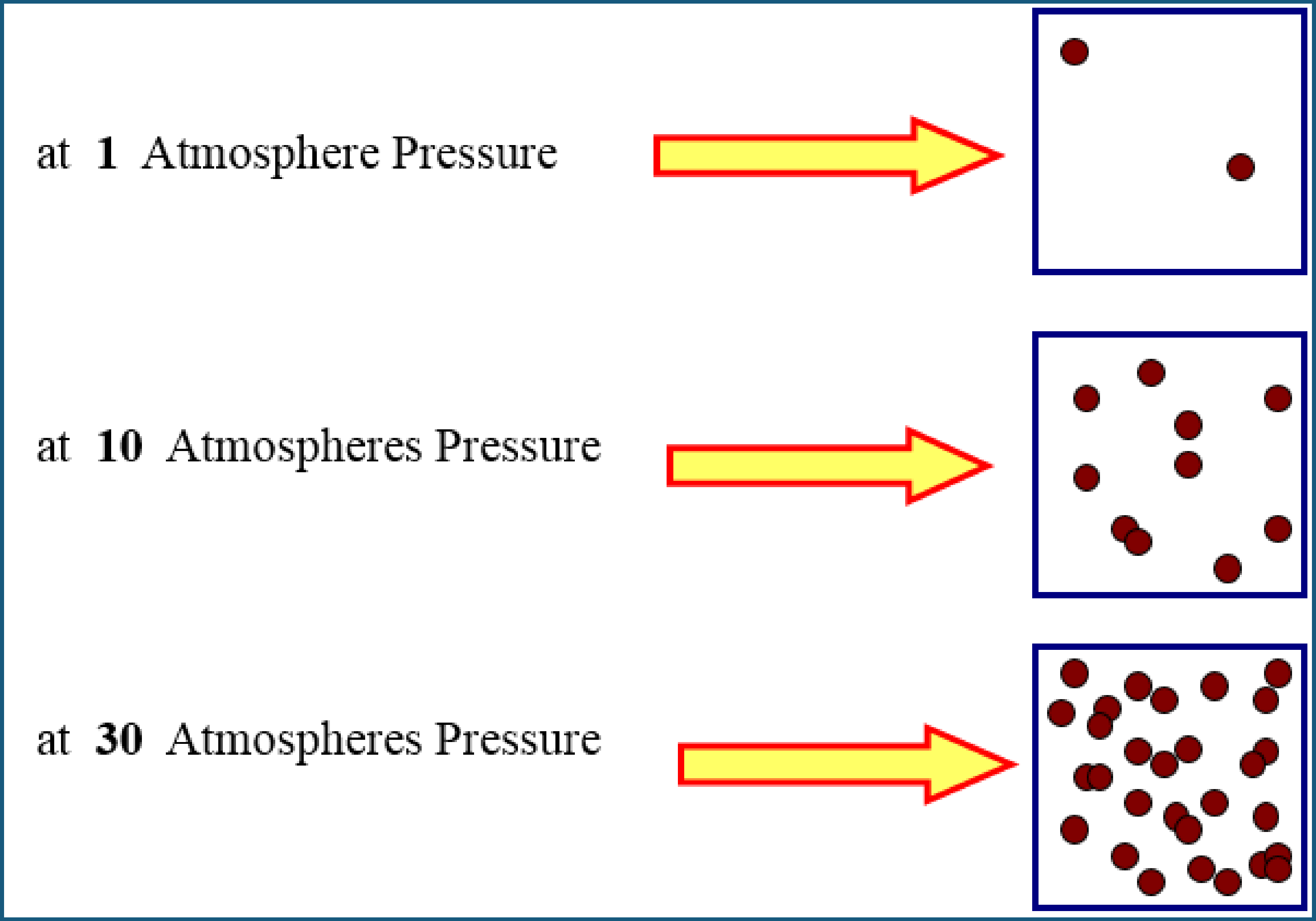
	Ideal Gas	Real Gas
Obey PV=nRT	Always	Only at very low P and high T
Molecular volume	Zero	Small but nonzero
Molecular attractions	Zero	Small
Molecular repulsions	Zero	Small

Real Gases

- Real molecules do take up space and do interact with each other (especially polar molecules).
- Need to add correction factors to the ideal gas law to account for these.

Real Gases

Ideally, the volume of the molecules was neglected



Real Gases

But since real gases do have volume, we need:

Volume Correction

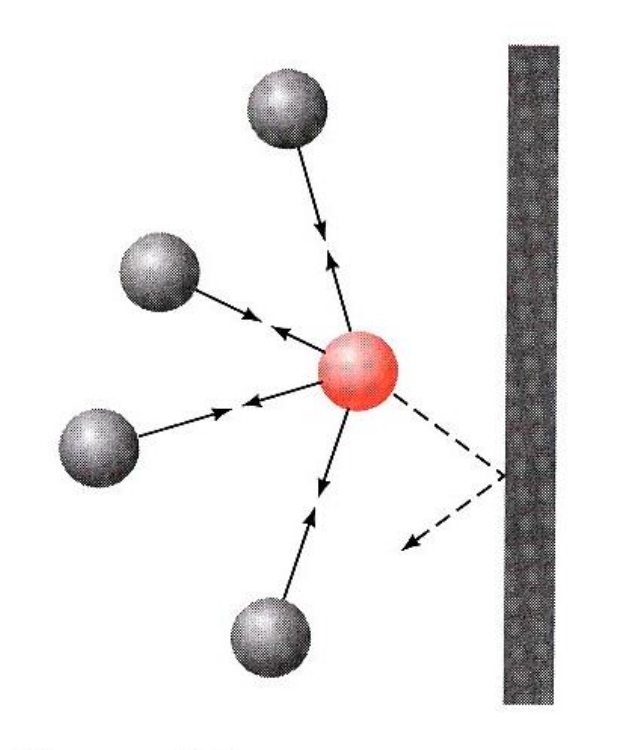
- The actual volume free to move in is less because of particle size.
- More molecules will have more effect.
- Corrected volume $V' = V - nb$
- "b" is a constant that differs for each gas.

Real Gases

Pressure Correction

- Because the molecules are attracted to each other, the pressure on the container will be less than ideal.
- Pressure depends on the number of molecules per liter.
- Since two molecules interact, the effect must be squared

$$P_{observed} = P - a\left(\frac{n}{V}\right)^2$$



Van der Waal's equation

$$[P_{obs} + a\left(\frac{n}{V}\right)^2](V - nb) = nRT$$

Corrected Pressure — Corrected Volume

- "a" and "b" are determined by experiment
- "a" and "b" are different for each gas
- bigger molecules have larger "b"
- "a" depends on both size and polarity

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