Background for HW 2

IPOL 8512

Mole

- A ***mole*** (mol) is an amount of substance that contains the same number of particles as there are atoms in 12 g of carbon-12.
- To four significant figures, there are 6.022×10^{23} atoms in 12 g of carbon-12.
- Thus a mole of natural carbon is the amount of carbon that contains 6.022×10^{23} carbon atoms.
- The number 6.022×10^{23} is often called ***Avogadro's number***.

Avogadro’s Number

If the extremely tiny atoms in just 12 grams of carbon are arranged in the line, the line would extend over 500 times the distance between earth and the sun.

Molar Mass For Elements

- Atomic Mass from the Periodic Table

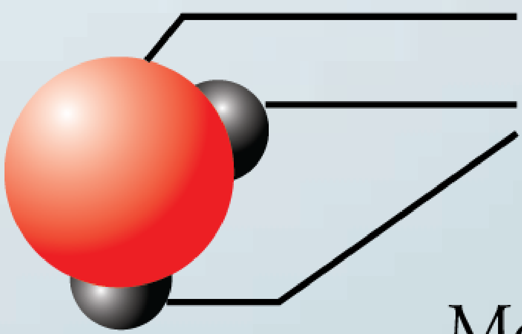
$$\left(\frac{(\text{atomic mass})\ \text{g element}}{1\,\text{mol element}}\right)$$

Molar Mass Calculation for Carbon

$$? \text{ mol C} = 0.55 \cancel{\text{carat C}} \left(\frac{1 \cancel{\text{g}}}{5 \cancel{\text{carat}}}\right)\left(\frac{1 \text{ mol C}}{12.011 \cancel{\text{g C}}}\right) = \mathbf{9.2 \times 10^{-3} \text{ mol C}}$$

Molecular Mass

- Whole = sum of parts
- mass of a molecule = sum of the masses of the atoms in the molecule
- **molecular mass** = the sum of the atomic masses of the atoms in the molecule



Molar mass O: 15.9994 g/mol
Molar mass H: 1.00794 g/mol
1.00794 g/mol

Molar mass H_2O: 18.0153 g/mol

Molar Mass For Molecular Compounds

- ***Molecular Mass*** = Sum of the atomic masses of atoms in one molecule

$$\left(\frac{(\text{molecular mass})\,\text{g molecular compound}}{1\,\text{mol molecular compound}} \right)$$

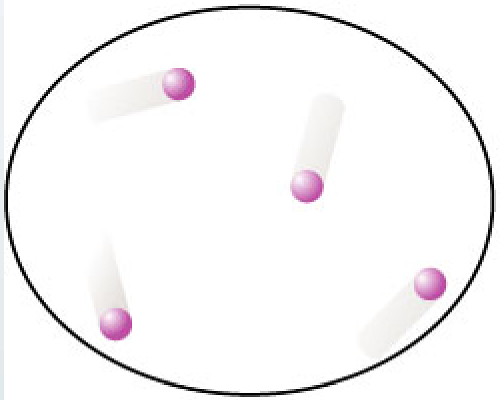
- The average molar mass of air is 29 g/mol.

Formula Units

- A ***formula unit*** of a substance is the group represented by the substance's chemical formula, that is, a group containing the kinds and numbers of atoms or ions listed in the chemical formula.
- Formula unit is a general term that can be used in reference to elements, molecular compounds, or ionic compounds.

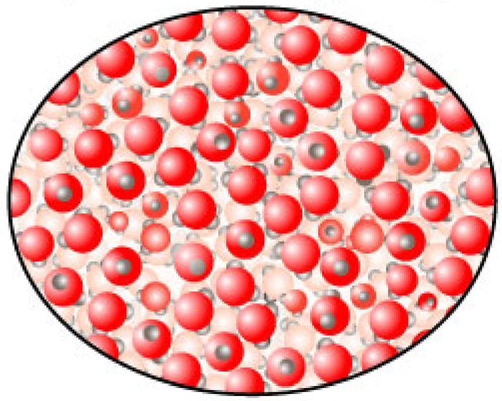
Formula Unit Examples

neon gas
(element)



A formula unit of neon contains one Ne atom.

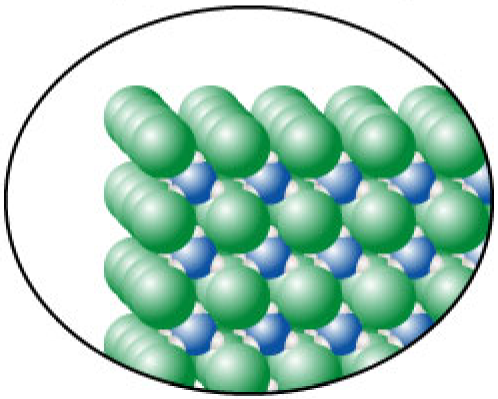
liquid water
(molecular compound)



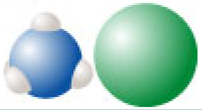
Liquid water is composed of discrete H_2O molecules.

A formula unit of water contains one oxygen atom and two hydrogen atoms.

ammonium chloride
(ionic compound)

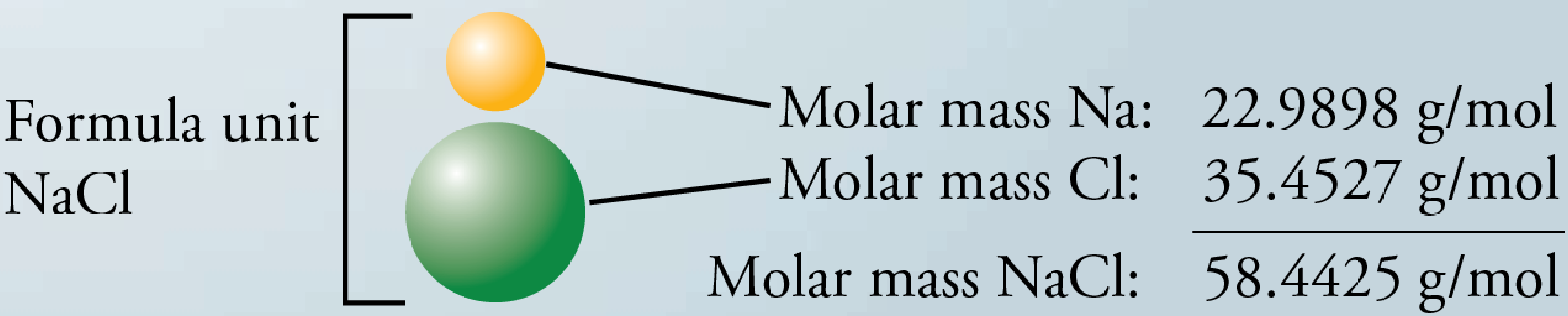


There are no separate ammonium chloride, NH_4Cl, molecules. Each ion is equally attracted to eight others.
A formula unit of ammonium chloride contains one ammonium ion, NH_4^+, and one chloride ion, Cl^-, (or one nitrogen atom, four hydrogen atoms, and one chloride ion).



Formula Mass for Ionic Compounds

- Whole = sum of parts
- Mass of a formula unit = sum of the masses of the atoms in the formula unit
- ***Formula mass*** = the sum of the atomic masses of the atoms in the formula



Molar Mass For Ionic Compounds

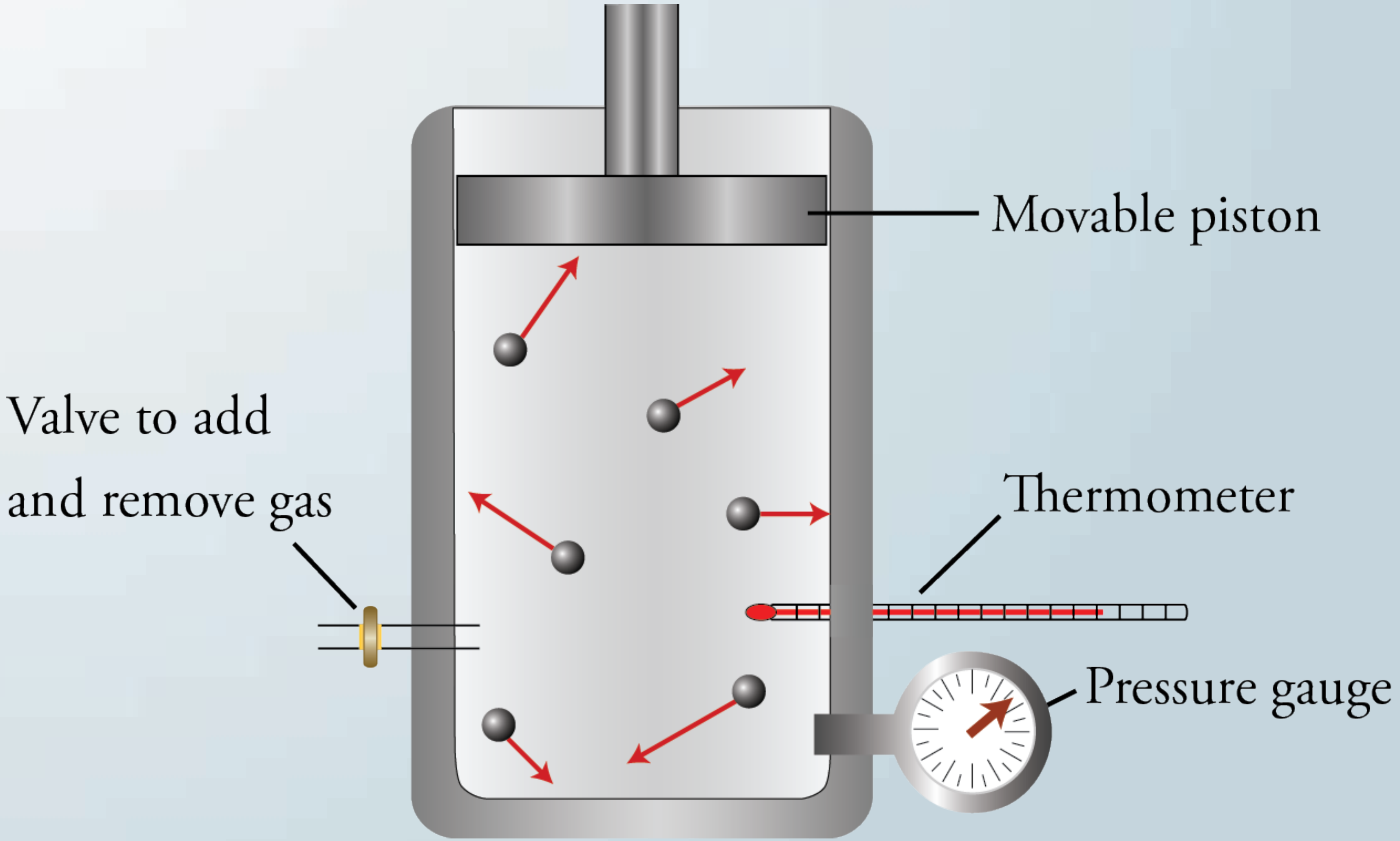
- ***Formula Mass*** = Sum of the atomic masses of the atoms in a formula unit

$$\left(\frac{\text{(formula mass) g ionic compound}}{\text{1 mol ionic compound}}\right)$$

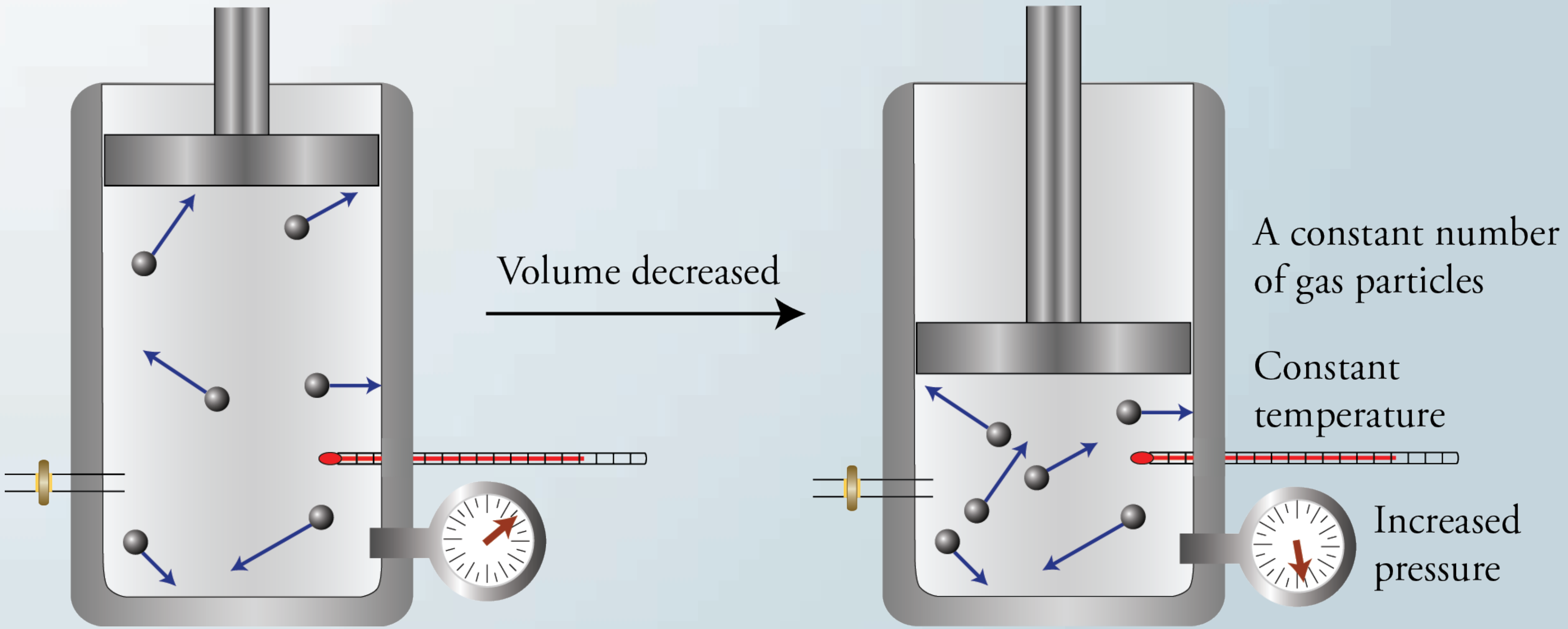
Gas Properties and their Units

- Pressure (P) = Force/Area
  - units
    - 1 atm = 101.325 kPa = 760 mmHg = 760 torr
    - 1 bar = 100 kPa = 0.9869 atm = 750.1 mmHg
- Volume (V)
  - unit usually liters (L)
- Temperature (T)
  - ? K = --- °C + 273.15
- Number of gas particles expressed in moles (n)

Apparatus for Demonstrating Relationships Between Properties of Gases



Decreased Volume Leads to Increased Pressure



$P \alpha 1/V$ if n and T are constant

http://preparatorychemistry.com/Bishop_Boyles_Law_Flash1.htm

Relationship Between P and V

Decreased volume

↓

$$\text{Increased } \frac{\text{number of gas particles}}{\text{volume of container}}$$

↓

Increased number of particles close to any area of wall

↓

$$\text{Increased } \frac{\text{number of collisions per second}}{\text{area of wall}}$$

↓

$$\text{Increased } \frac{\text{force due to collisions}}{\text{area of wall}}$$

↓

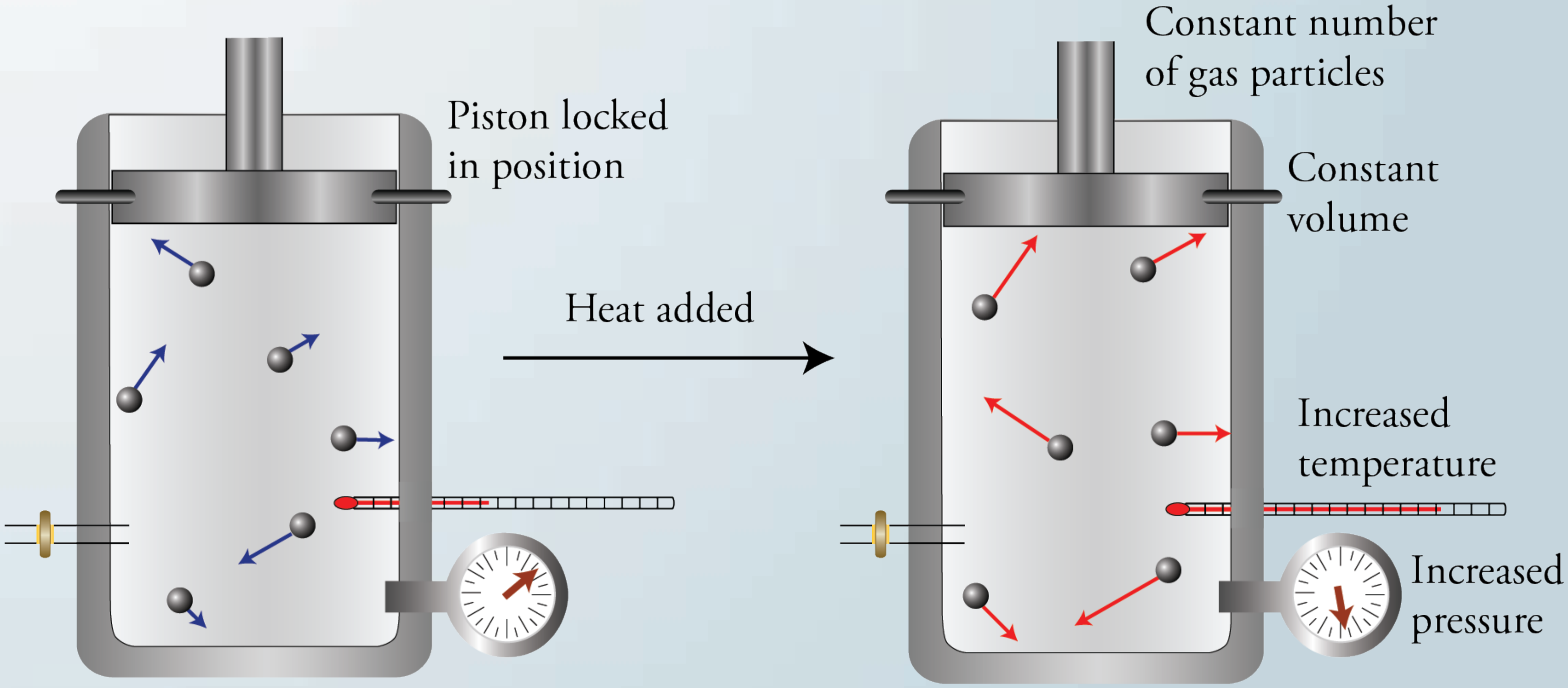
Increased gas pressure

Boyle's Law

- The pressure of an ideal gas is inversely proportional to the volume it occupies if the moles of gas and the temperature are constant.

$$P \propto \frac{1}{V} \quad \text{if n and T are constant}$$

Increased Temperature Leads to Increased Pressure



P α T   if n and V are constant

http://preparatorychemistry.com/Bishop_Gay_Lussac_Law_Flash1.htm

Relationship Between P and T

Increased temperature

Increased average velocity of the gas particles

Increased number of collisions with the walls

Increased force per collision

Increased total force of collisions

Increased $\dfrac{\text{force due to collisions}}{\text{area of wall}}$

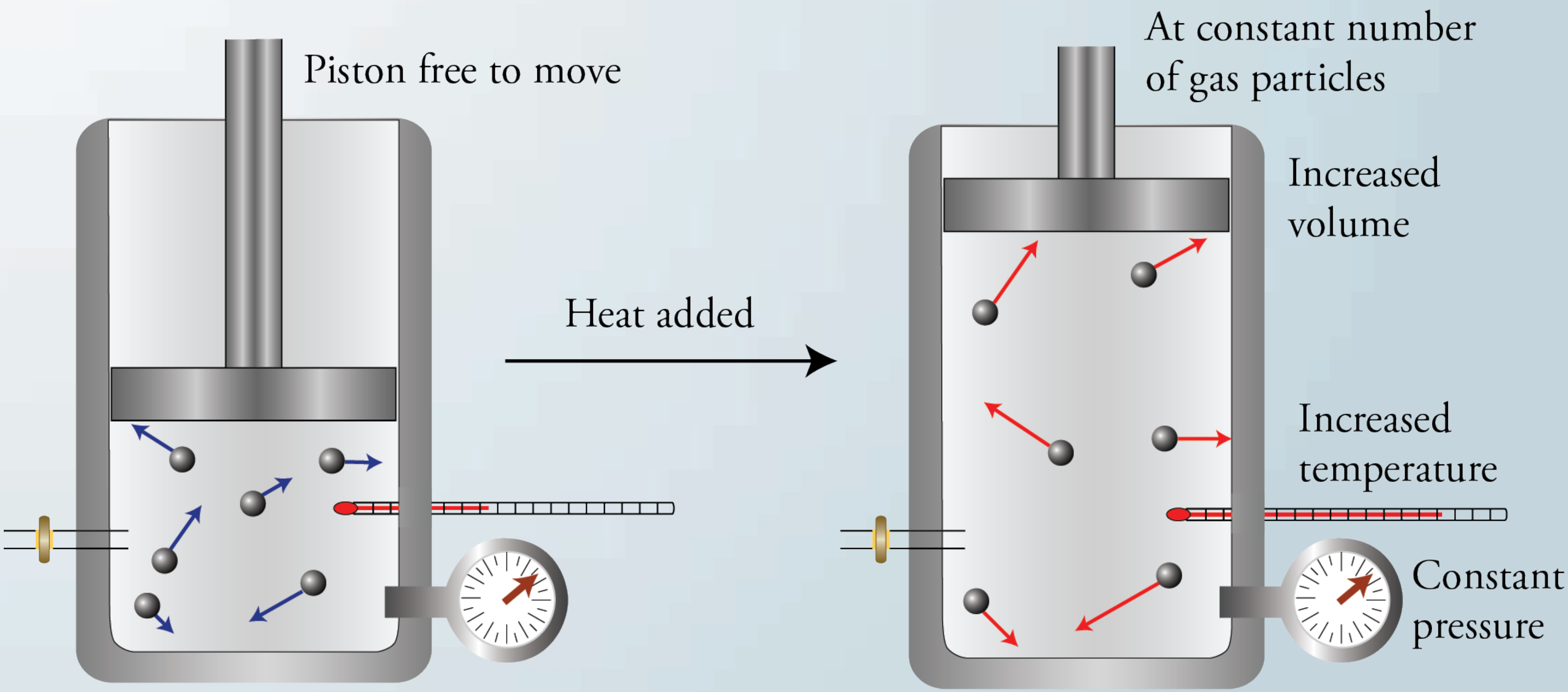
Increased gas pressure

Gay-Lussac’s Law

- The pressure of an ideal gas is directly proportional to the Kelvin temperature of the gas if the volume and moles of gas are constant.

$P \propto T$ if V and n are constant

Increased Temperature Leads to Increased Volume



V α T   if n and P are constant

http://preparatorychemistry.com/Bishop_Charles_Law_Flash1.htm

Relationship Between T and V

Increased temperature

↓

Increased average velocity of the gas particles

↙ ↘

Increased number of collisions with the walls

Increased force per collision

↘ ↙

Initial increase in force per area−that is, in pressure

↓

Inside pressure is greater than external pressure

↓

Container expands → **Increased volume**

↓

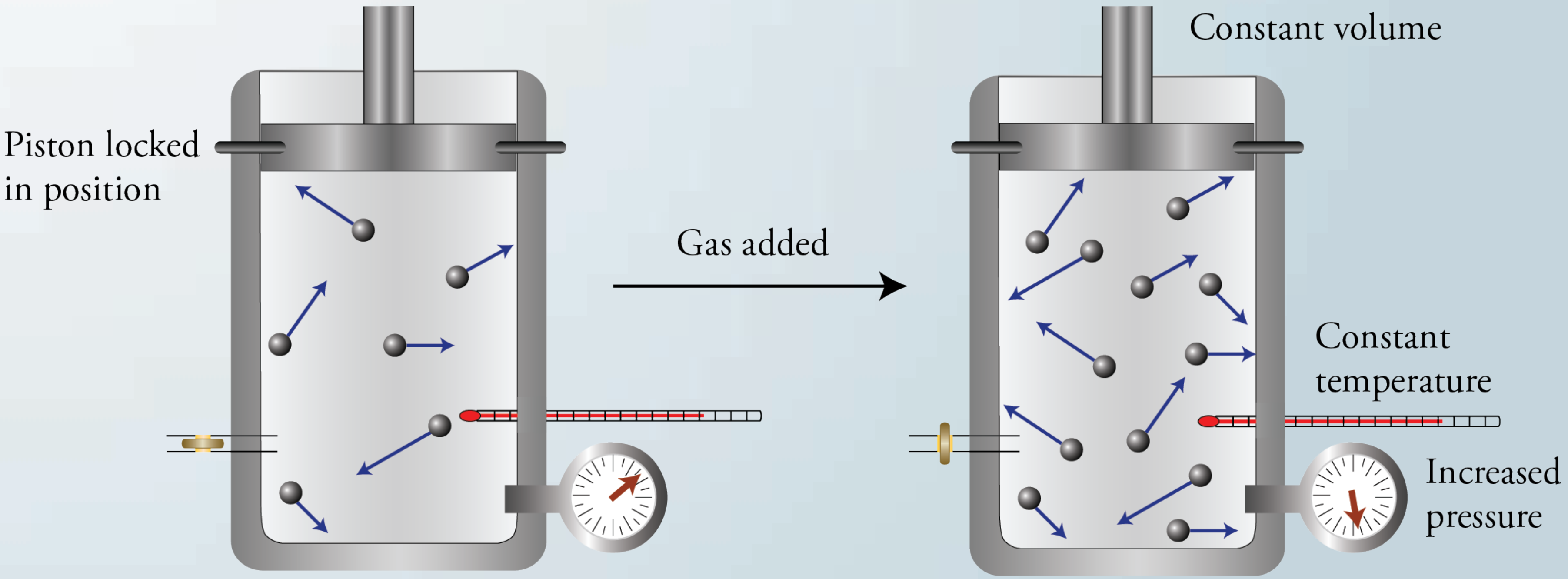
Decreased pressure until the inside pressure equals the external pressure

Charles' Law

- For an ideal gas, volume and temperature described in kelvins are directly proportional if moles of gas and pressure are constant.

$$P \propto T \quad \text{if } V \text{ and } n \text{ are constant}$$

Increased Moles of Gas Leads to Increased Pressure



P α n if T and V are constant

http://preparatorychemistry.com/Bishop_Moles_Pressure_Law_Flash1.htm

Relationship Between n and P

Increased number of gas particles

$\downarrow$

Increased number of collisions with the walls

$\downarrow$

Increased total force of collisions

$\downarrow$

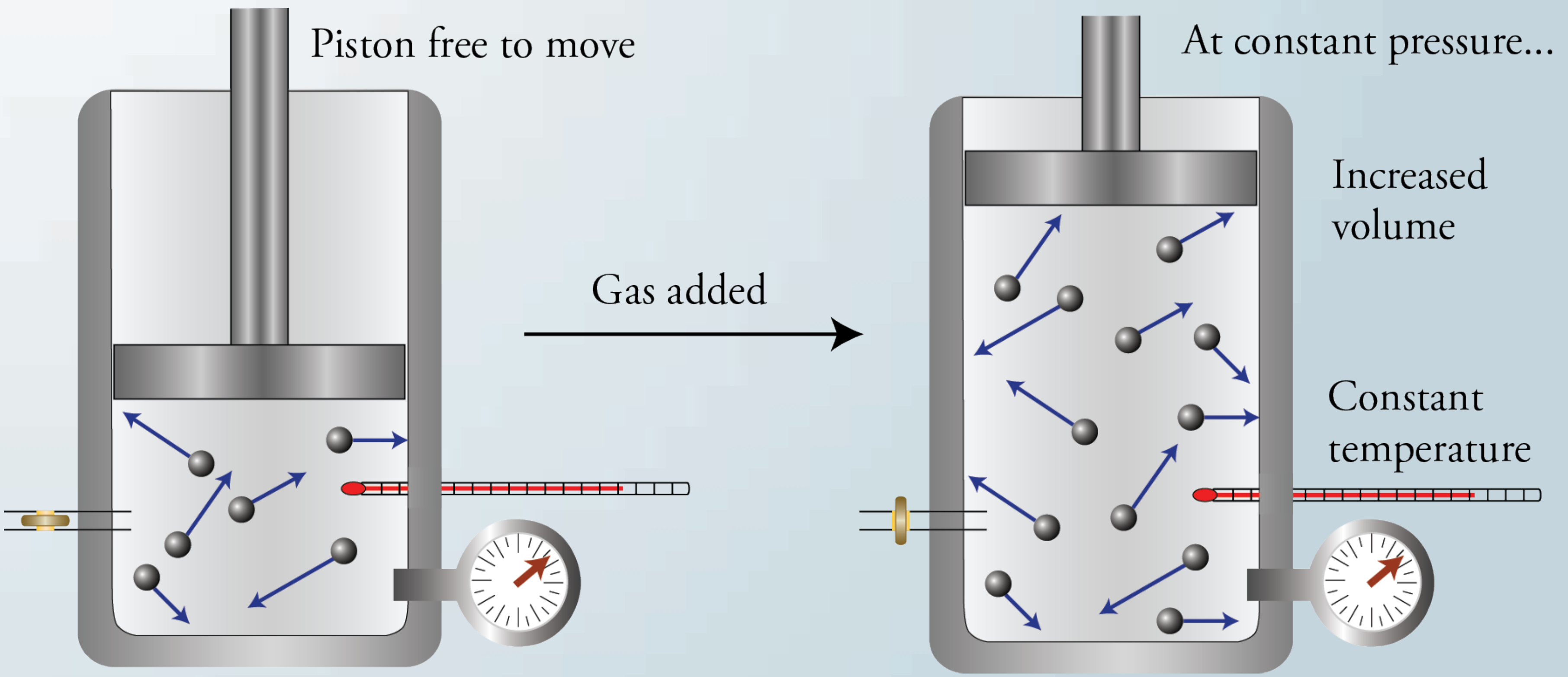
Increased gas pressure

Relationship Between Moles of Gas and Pressure

- If the temperature and the volume of an ideal gas are held constant, the moles of gas in a container and the gas pressure are directly proportional.

$P \propto n$ if T and V are constant

Increased Moles of Gas Leads to Increased Volume



V α n   if T and P are constant

http://preparatorychemistry.com/Bishop_Avogadros_Law_Flash1.htm

Relationship Between n and V

Increased number of gas particles

↓

Increased number of collisions with the walls

↓

Increased total force of collisions

↓

Initial increased in force per area - that is, in pressure

↓

Inside pressure is greater than external pressure

↓

Container expands ⟶ Increased volume

↓

Decreased pressure until the inside pressure equals the external pressure

Avogadro's Law

- For an ideal gas, the volume and moles of gas are directly proportional if the temperature and pressure are constant.

$$V \propto n \quad \text{if T and P are constant}$$

Ideal Gas Equation Derivation

$P \propto n$ if T and V are constant

$P \propto T$ if n and V are constant

$P \propto \dfrac{1}{V}$ if n and T are constant

or $P \propto \dfrac{nT}{V}$

so $P = \text{(a constant)}\ \dfrac{nT}{V}$

$$\boldsymbol{PV = nRT} \quad \frac{0.082058\ \text{L} \bullet \text{atm}}{\text{K} \bullet \text{mol}} \ \text{or}\ \frac{8.3145\ \text{L} \bullet \text{kPa}}{\text{K} \bullet \text{mol}}$$

Standard Temperature and Pressure

- **Standard Temperature and Pressure (STP)** = the standard sets of conditions for experimental measurements established to allow comparisons to be made between different sets of data. (There are no universally accepted standards.)
  - International Union of Pure and Applied Chemistry (IUPAC) uses 273.15 K (0 °C, 32 °F) and 100 kPa (14.504 psi, 0.986 atm, 1 bar)
  - An unofficial, but commonly used standard is **standard ambient temperature and pressure** (**SATP**) of 298.15 K (25 °C, 77 °F) and 100 kPa (14.504 psi, 0.986 atm). This is the most useful set of values for us.
  - National Institute of Standards and Technology (NIST) uses 20 °C (293.15 K, 68 °F) and 101.325 kPa (14.696 psi, 1 atm)

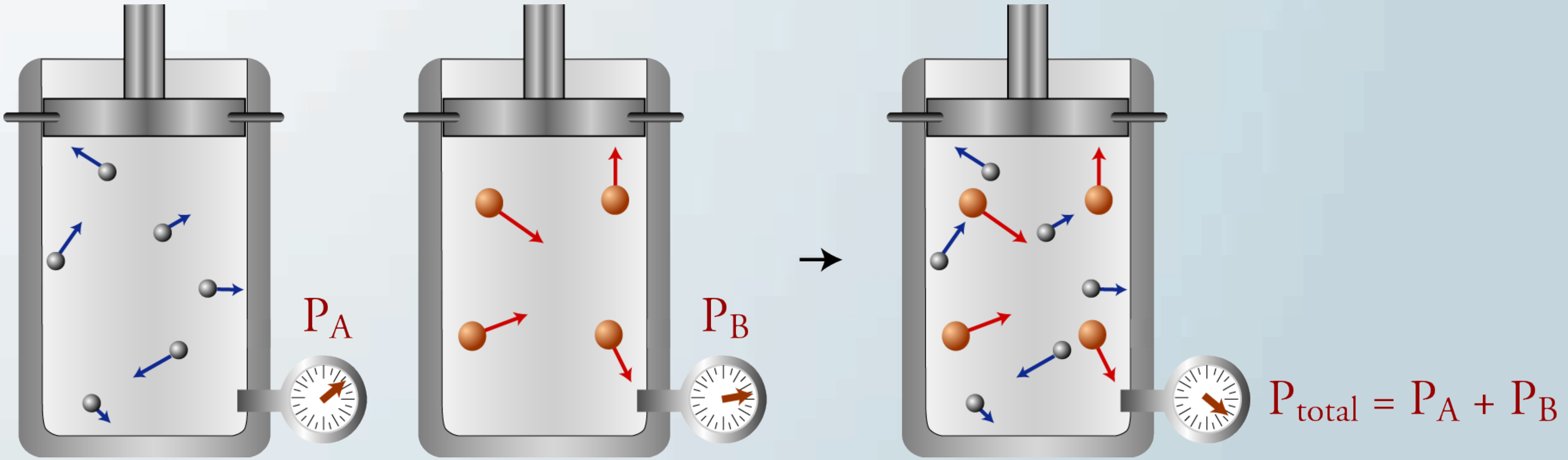
Molar Volume at STP

- You will find the following derived conversion factor useful for converting between volume and moles of gas.

$$PV = nRT$$

$$\frac{V}{n} = \frac{RT}{P} = \frac{\left(\frac{8.3145\ \text{L}\cdot\cancel{\text{kPa}}}{\cancel{\text{K}}\cdot\text{mol}}\right)(298.15\ \cancel{\text{K}})}{100\ \cancel{\text{kPa}}} = \left(\frac{24.790\ \text{L}}{1\ \text{mol}}\right)_{\text{SATP}}$$

Dalton's Law of Partial Pressures



$$P_{\text{total}} = \Sigma P_{\text{partial}} \quad \text{or} \quad P_{\text{total}} = (\Sigma n_{\text{each gas}})\frac{RT}{V}$$

Partial Pressures and Constant T and P

$$V_A = n_A \frac{RT_A}{P_A} \qquad V_t = n_t \frac{RT_t}{P_t}$$

$$\frac{V_A}{V_t} = \frac{n_A \dfrac{RT_A}{P_A}}{n_t \dfrac{RT_t}{P_t}}$$

for gases at the same T and P

$$\frac{V_A}{V_t} = \frac{n_A \dfrac{RT}{P}}{n_t \dfrac{RT}{P}} = \frac{n_A}{n_t}$$

Partial Pressures and Constant T and V

$$P_A = n_A \frac{RT_A}{V_A} \qquad P_t = n_t \frac{RT_t}{V_t}$$

$$\frac{P_A}{P_t} = \frac{n_A \dfrac{RT_A}{V_A}}{n_t \dfrac{RT_t}{V_t}}$$

for gases at the same T and V

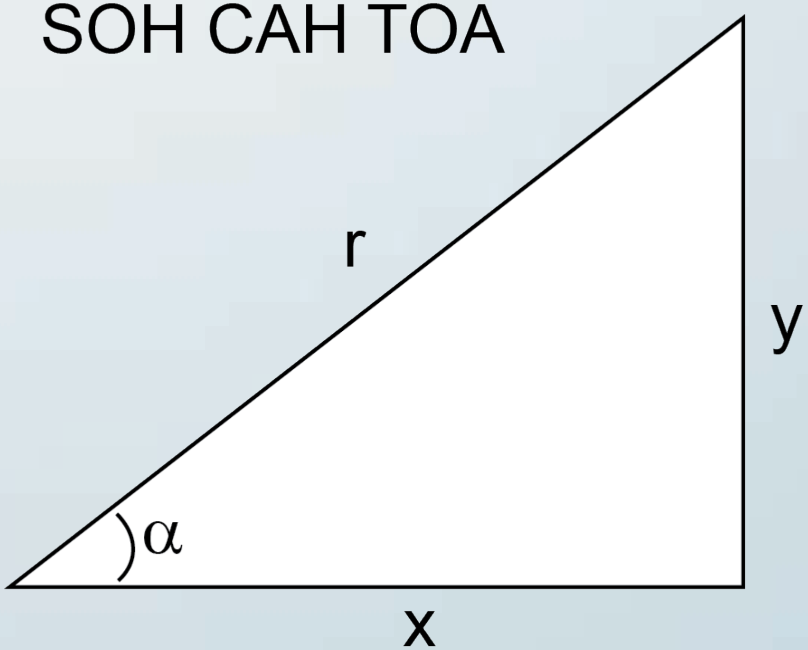
$$\frac{P_A}{P_t} = \frac{n_A \dfrac{RT}{V}}{n_t \dfrac{RT}{V}} = \frac{n_A}{n_t} = \text{mole fraction} = X_A$$

$$P_A = X_A P_t$$

A Little Trig Stuff

- One of the following relationships and your calculator will help you to do one of the homework problems.

SOH CAH TOA



$$\sin\alpha = \frac{\text{opposite}}{\text{hypotenuse}} = \frac{y}{r}$$

$$\cos\alpha = \frac{\text{adjacent}}{\text{hypotenuse}} = \frac{x}{r}$$

$$\tan\alpha = \frac{\text{opposite}}{\text{adjacent}} = \frac{y}{x}$$

Fractal Units and Lengths of Uneven Surfaces

- If the coastline of Britain is measured using the fractal unit of 200 km, then the value derived for the length of the coastline is 2400 km (approx.).

- If we use the fractal unit of 50 km, the value derived for the length of the coastline is 3400 km (1000 km more).