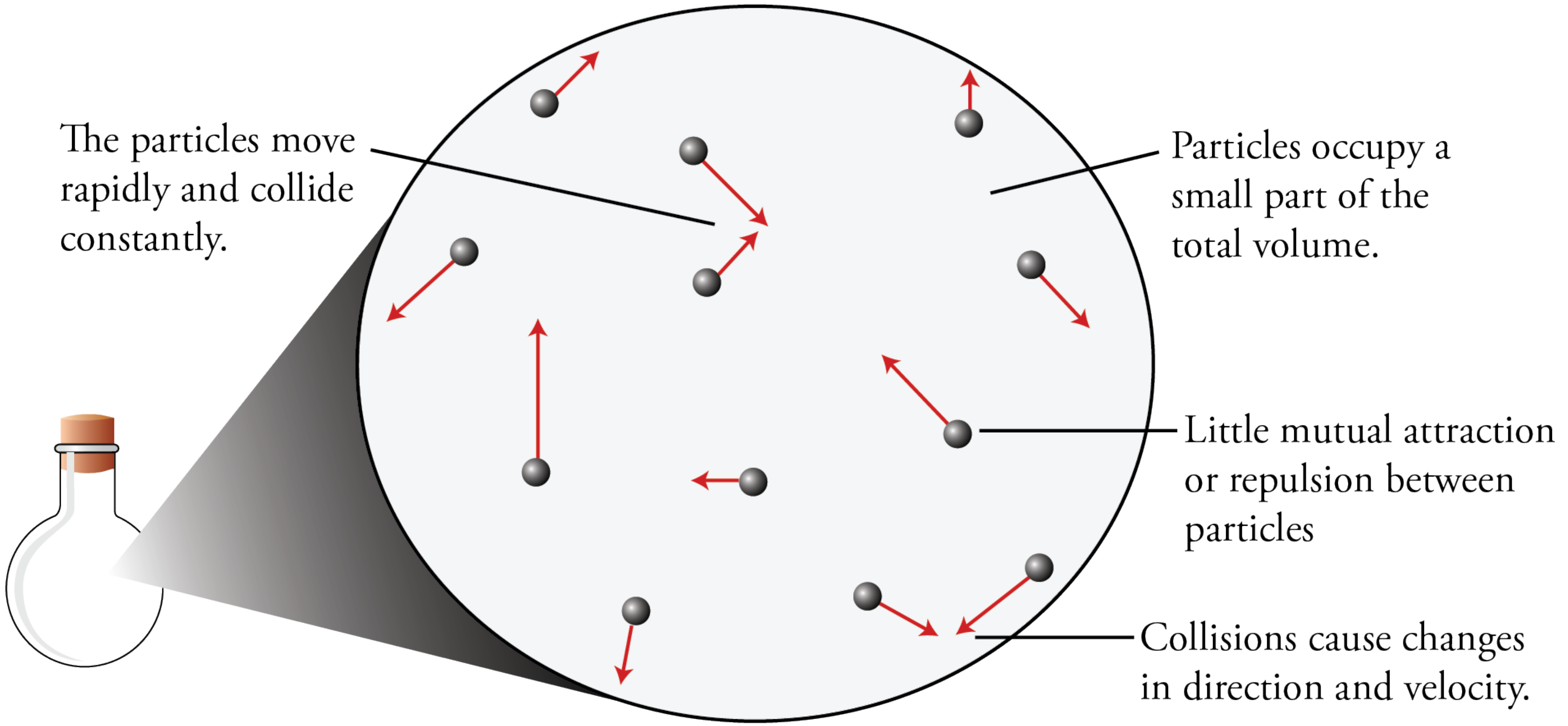
Gas



The particles move rapidly and collide constantly.
Particles occupy a small part of the total volume.
Little mutual attraction or repulsion between particles
Collisions cause changes in direction and velocity.

Gas Model

- Gases are composed of tiny, widely-spaced particles.
  - For a typical gas, the average distance between particles is about ten times their diameter.

Gas Model (cont.)

- Because of the large distance between the particles, the volume occupied by the particles themselves is negligible (approximately zero).
  – For a typical gas at room temperature and pressure, the gas particles themselves occupy about 0.1% of the total volume. The other 99.9% of the total volume is empty space. This is very different than for a liquid for which about 70% of the volume is occupied by particles.

Gas Model (cont.)

- The particles have rapid and continuous motion.
  - For example, the average velocity of a helium atom, He, at room temperature is over 1000 m/s (or over 2000 mi/hr). The average velocity of the more massive nitrogen molecules, N_2, at room temperature is about 500 m/s.
  - Increased temperature means increased average velocity of the particles.

Gas Model (cont.)

- The particles are constantly colliding with the walls of the container and with each other.
  - In a typical situation, a gas particle moves a very short distance between collisions. Oxygen, O_2, molecules at normal temperatures and pressures move an average of 10^{-7} m between collisions.

Gas Model (cont.)

- There is no net loss of energy in the collisions. A collision between two particles may lead to each particle changing its velocity and thus its energy, but the increase in energy by one particle is balanced by an equal decrease in energy by the other particle.

Ideal Gas Assumptions

- The particles are assumed to be point-masses, that is, particles that have a mass but occupy no volume.
- There are no attractive or repulsive forces at all between the particles.

Gas Pressure

- Pressure (P) = Force/Area
- Gas particles are constantly colliding with the walls of their container, and each time a particle hits a wall, it exerts a force against the wall.
- This force is proportional to its momentum, which is mass times velocity.
  – A more massive particle moving at a given velocity will exert more force against the wall.
  – A faster moving particle exerts more force against the wall than a slower moving particle of the same mass.

$$\text{Gas pressure} = \frac{\text{Force due to particle collisions with the walls}}{\text{Area of the walls}}$$

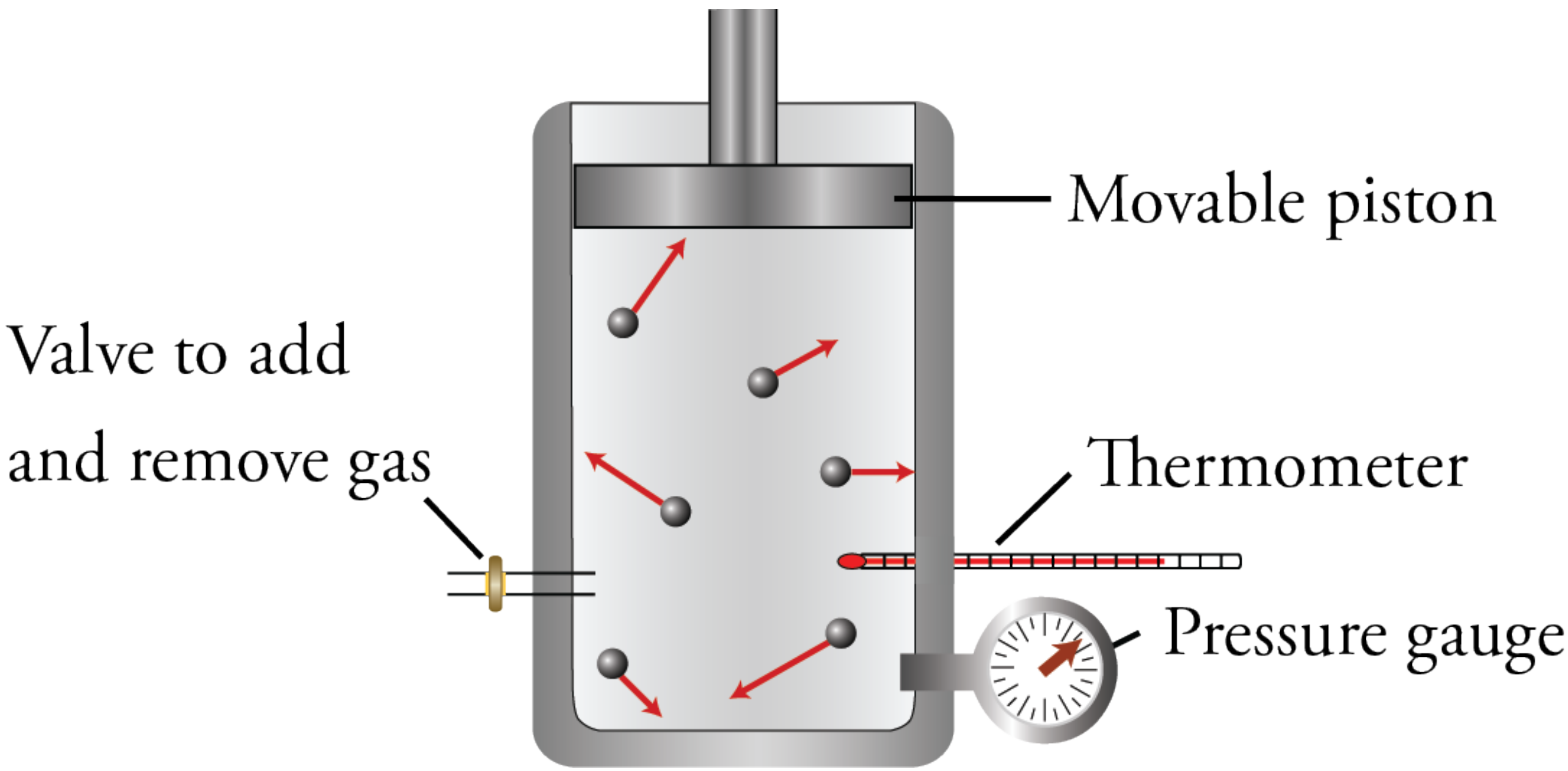
Gas Properties and their Units

- 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)

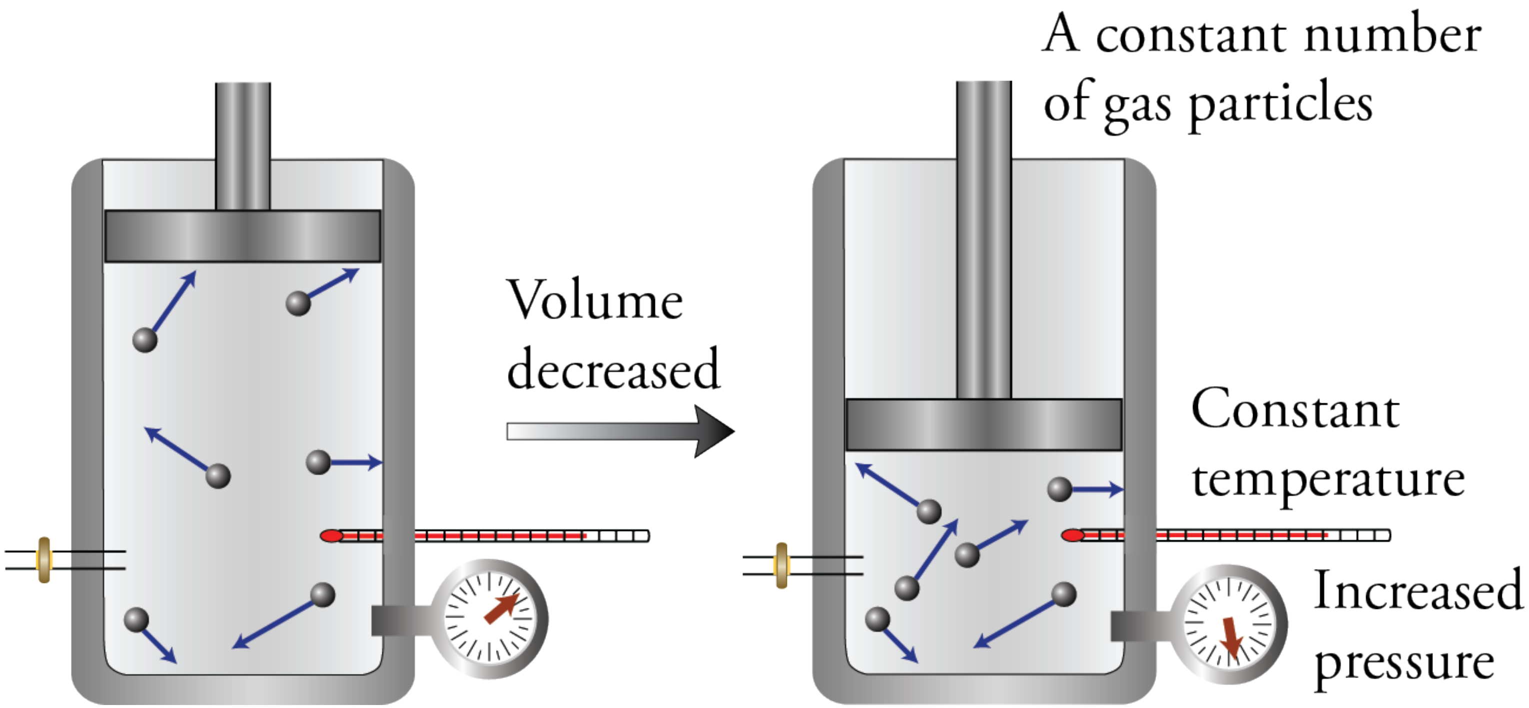
Gas Law Objectives

- For each of the following pairs of gas properties, (1) describe the relationship between them, (2) describe a simple system that could be used to demonstrate the relationship, and (3) explain the reason for the relationship.
    - V and P when n and T are constant
    - P and T when n and V are constant
    - V and T when n and P are constant
    - n and P when V and T are constant
    - n and V when P and T are constant

Apparatus for Demonstrating Relationships Between Properties of Gases



Decreased Volume Leads to Increased Pressure



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

https://preparatorychemistry.com/Boyles_Law_Canvas.html

Relationship between P and V

Decreased volume

↓

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

↓

Increased number of particles close to any area of wall

↓

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

↓

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

↓

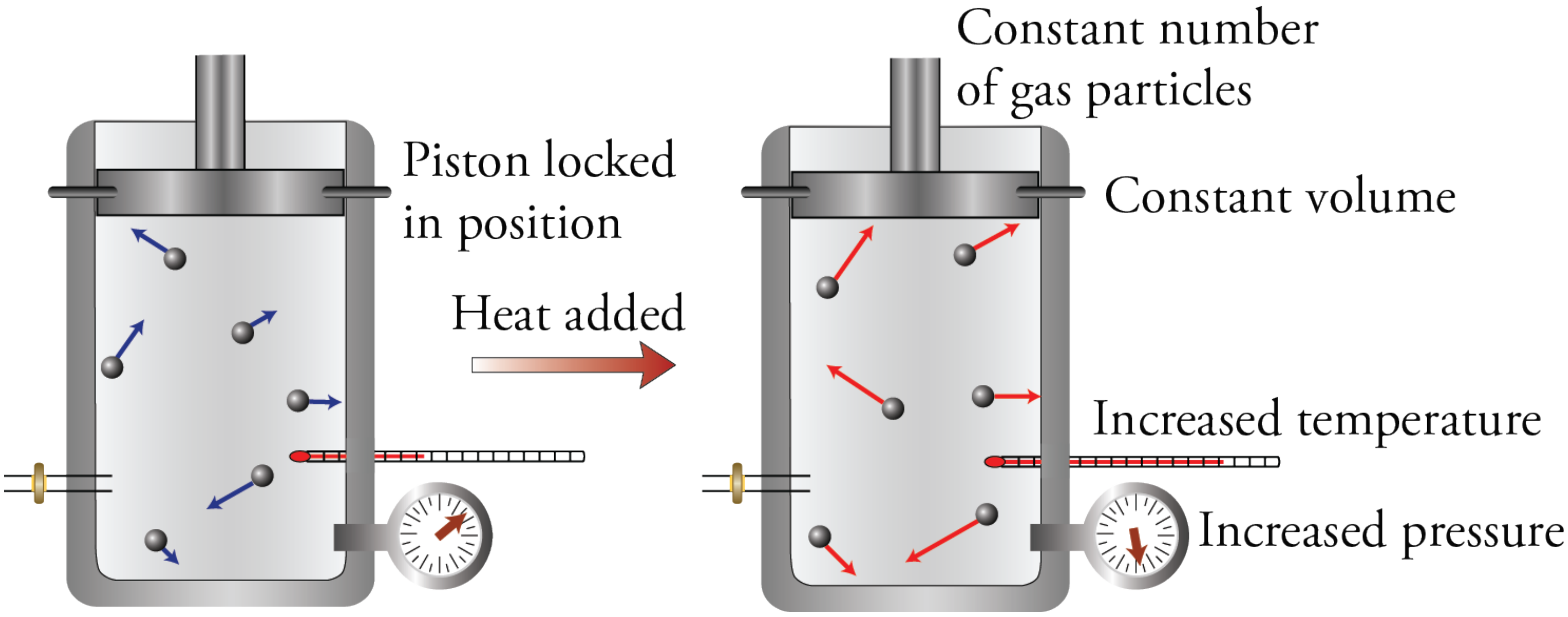
Increased gas pressure

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.

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

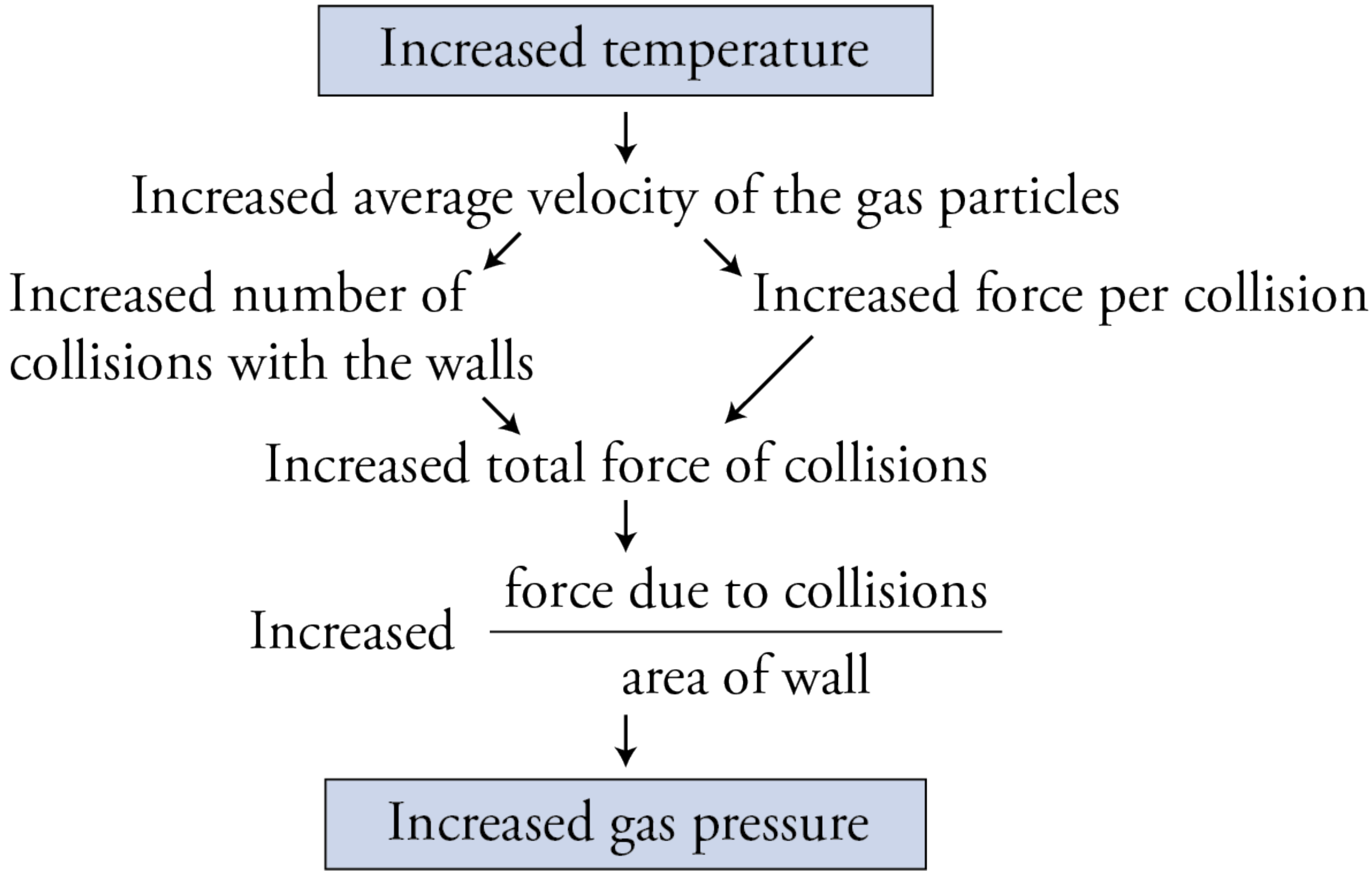
Increased Temperature Leads to Increased Pressure



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

https://preparatorychemistry.com/Gay_Lussacs_Law_Canvas.html

Relationship between P and T

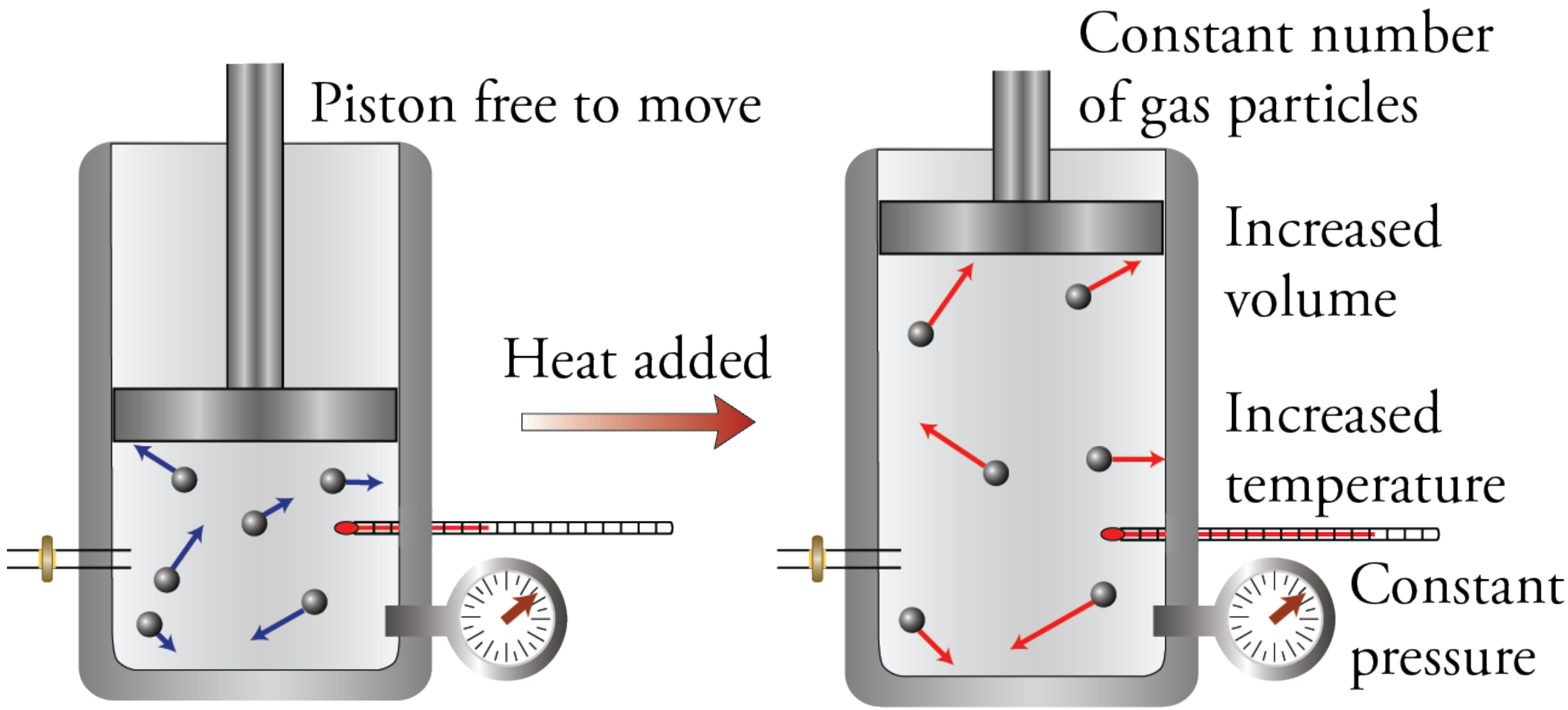


Gay-Lussac's Law

- 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.

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

Increased Temperature Leads to Increased Volume



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

https://preparatorychemistry.com/Charles_Law_Canvas.html

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**

↓

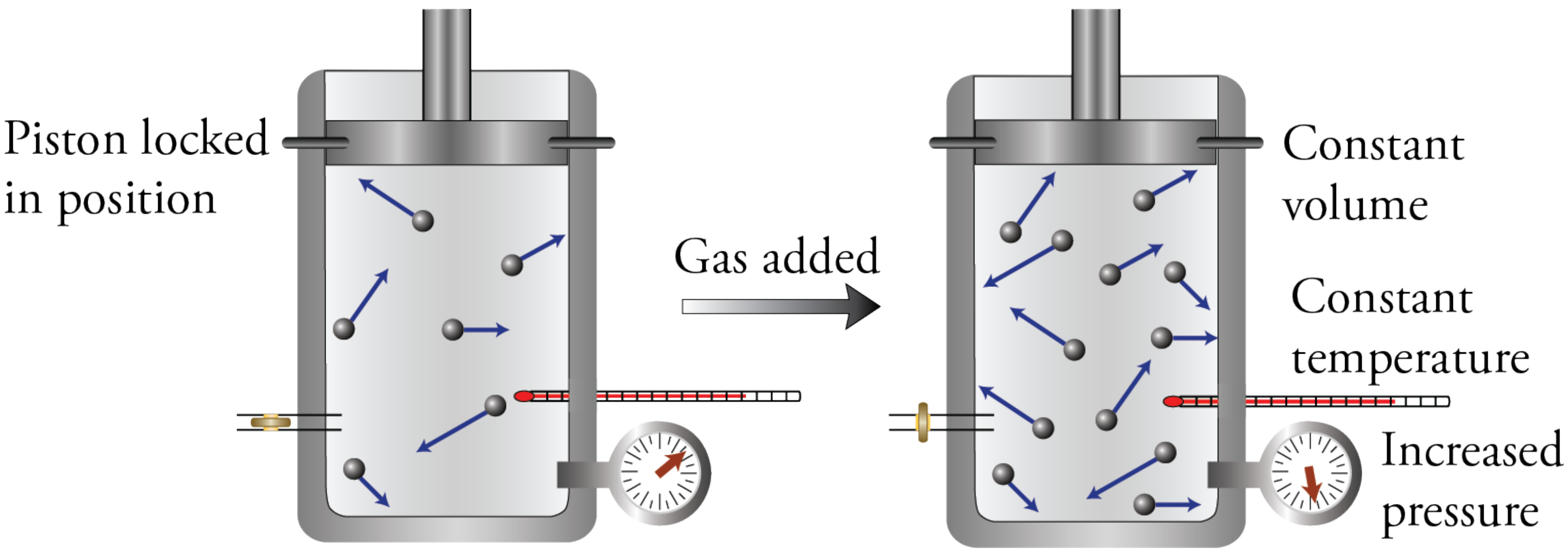
Decreased pressure until the inside pressure equals the external pressure

Charles' Law

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

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

Increased Moles of Gas Leads to Increased Pressure



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

https://preparatorychemistry.com/Moles_Pressure_Law_Canvas.html

Relationship between n and P

Increased number of gas particles

↓

Increased number of collisions with the walls

↓

Increased total force of collisions

↓

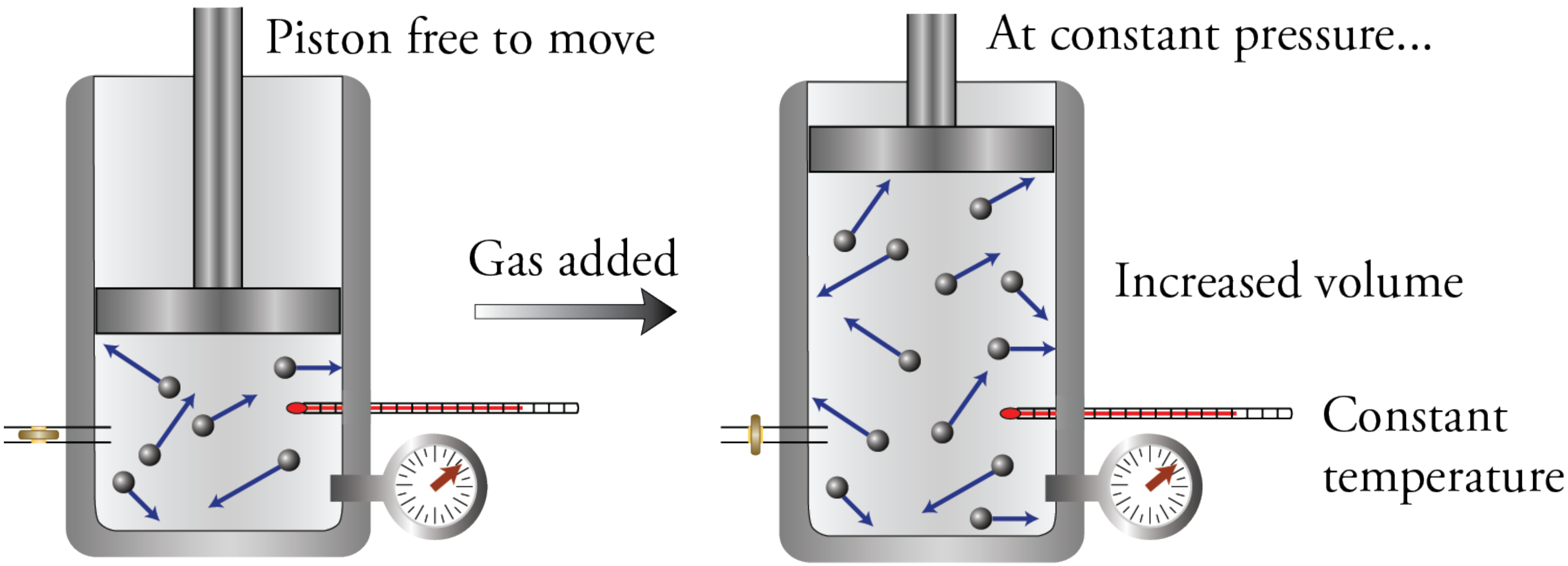
Increased gas pressure

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.

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

Increased Moles of Gas Leads to Increased Volume



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

https://preparatorychemistry.com/Avogadros_Law_Canvas.html

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

↓

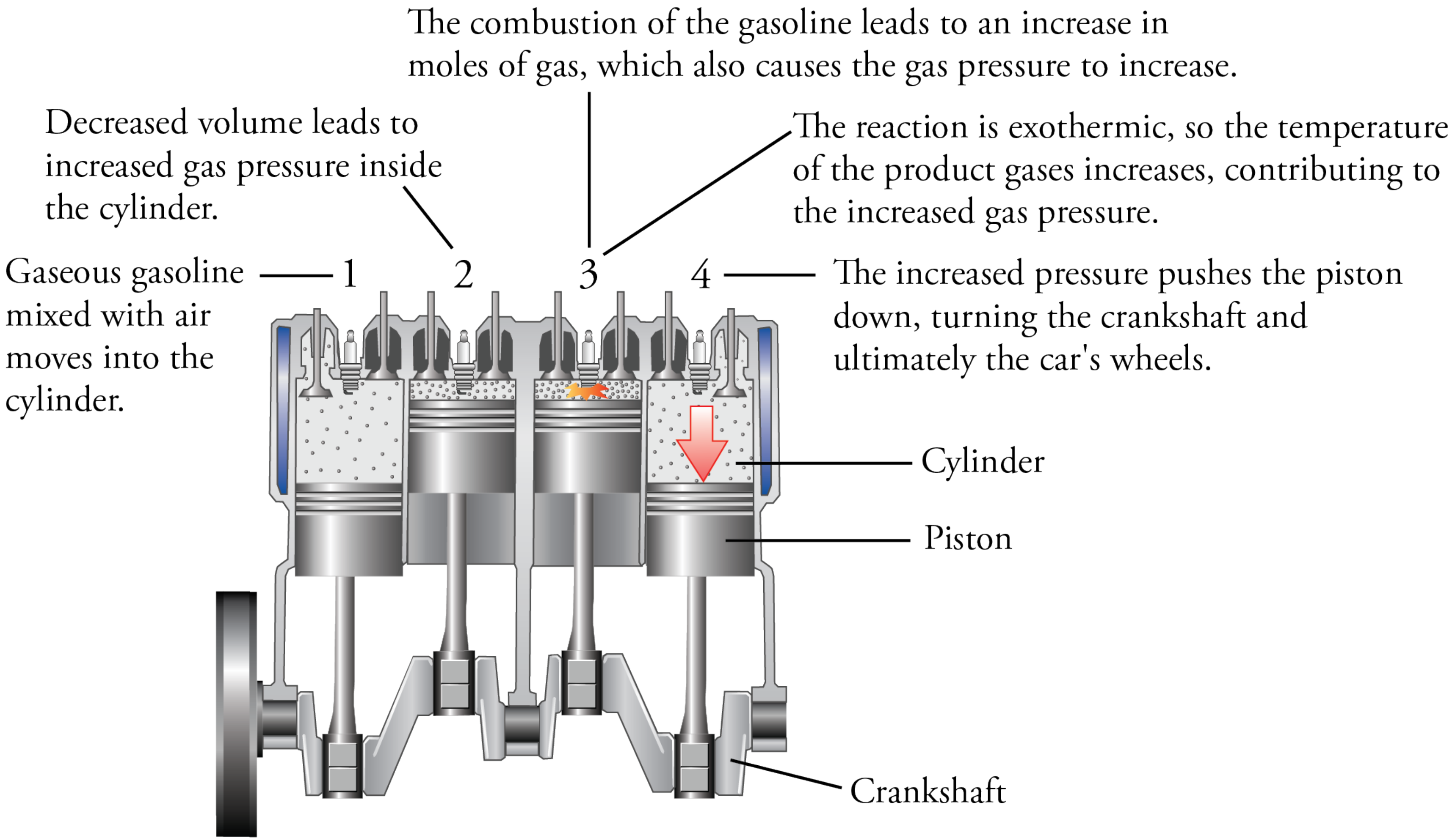
Decreased pressure until the inside pressure equals the external pressure

Avogadro's Law

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

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

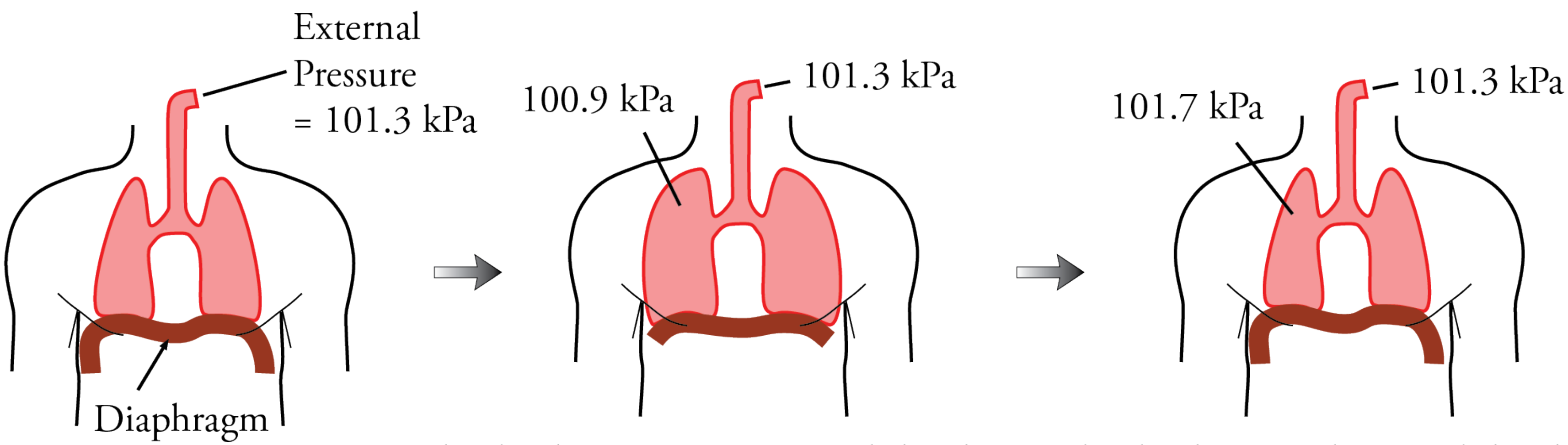
Engines and Pressure



Sample reaction: $2C_8H_{18}(g) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(g)$ + energy

27 moles of gas $\rightarrow$ 34 moles of gas

Breathing



The diaphragm contracts, and the chest expands, causing the lungs to expand. The increased volume decreases the pressure in the lungs to below the external pressure, causing air to move into the lungs faster than it moves out.

The diaphragm relaxes and the chest returns to its original volume, causing the lung volume to decrease. This increases the pressure in the lungs, causing air to move out of the lungs faster than it moves in.