Properties of Gases

Chapter 1 of “Physical Chemistry - 6th Edition” P.W. Atkins.
Chapter 1 and a little bit of Chapter 24 of 7th Edition.
Chapter 1 and a little bit of Chapter 21 of 8th edition.

The perfect gas

States of gases
Gas laws
Kinetic model of gases (Ch 24.1 7th ed, 21.1 8th ed.)

Real gases

Molecular interactions
van der Waals equation
Principle of corresponding states

Phases of Matter *

Three basic phases of matter:

Gas: Fills a container, taking on the shape of the container. Similar to a liquid, except that particles are very widely spaced from one another, and interparticle interactions are minimal.

Liquid: Does not fill a container, but takes on the shape of the container. Similar to gases, except particles very closely spaced.

Solid: Does not fill a container, and do not conform to the shape of the container. Particles are very closely packed - still much dynamic motion in a solid, which increases with heating.

Perfect Gases *

We shall consider a hypothetical **perfect** or **ideal** gas, which is a form of matter that completely fills any container.

A *perfect gas* is pictured as a collection of molecules or atoms which undergo continuous random motion (or Brownian motion):

- The speeds of the particles increase as the temperature is increased

- The molecules are widely separated from one another, with the only interactions being with the side of the container and other molecules during infrequent collisions

- The molecules are unaffected by intermolecular forces (e.g., dipole-dipole, van der Waals, etc.)

States of gases

The physical **state** of a substance is defined by its physical properties.

The state of a perfect pure gas is defined by:

V	volume
n	amount of substance (moles)
p	pressure
T	temperature

Each substance is described by an **equation of state**, which correlates the variables describing that state. For example, for a perfect gas:

$$p = f(T, V, n) = \frac{nRT}{V}, \qquad R \text{ is constant}$$

Pressure †

Pressure is the amount of equal force applied (measured in N) to a specific area (measured in m^2):

$$p = F/A$$

Pressure from a gas is the result of countless collisions of rapidly moving molecules with the walls of the container.

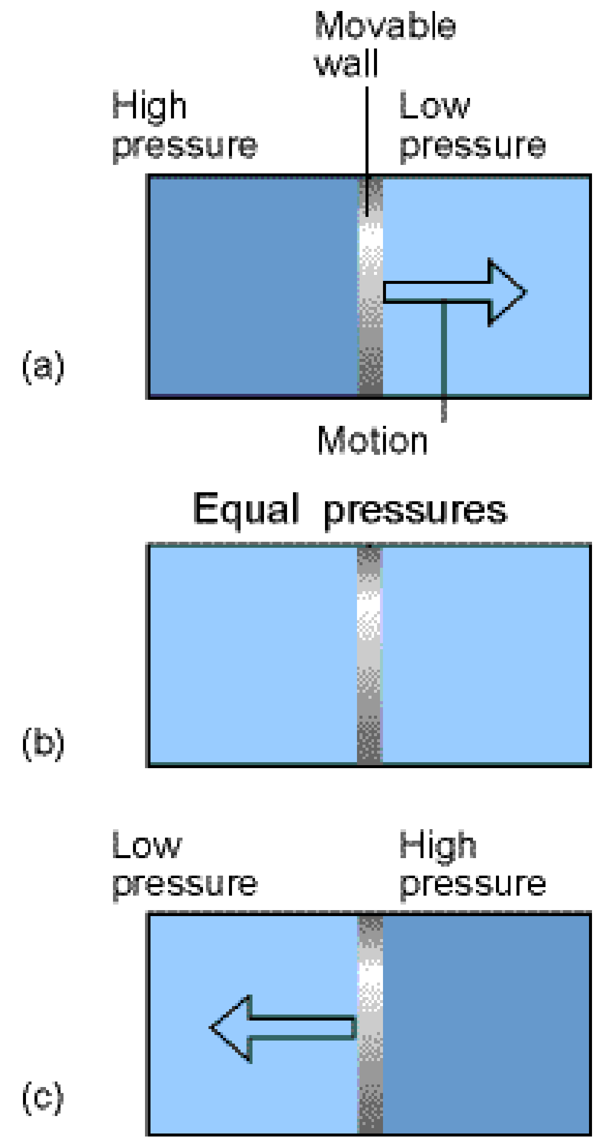
Units of pressure:

Name	***Symbol***	***Value***
pascal	1 Pa	1 N m^{-2}, 1 kg m^{-1} s^{-2}
bar	1 bar	10^5 Pa
atmosphere	1 atm	101325 Pa
torr	1 Torr	101325/760 Pa = 133.32 Pa
mm of mercury	1 mm Hg	133.322 Pa
pound per sq inch	1 psi	6.894 757 kPa

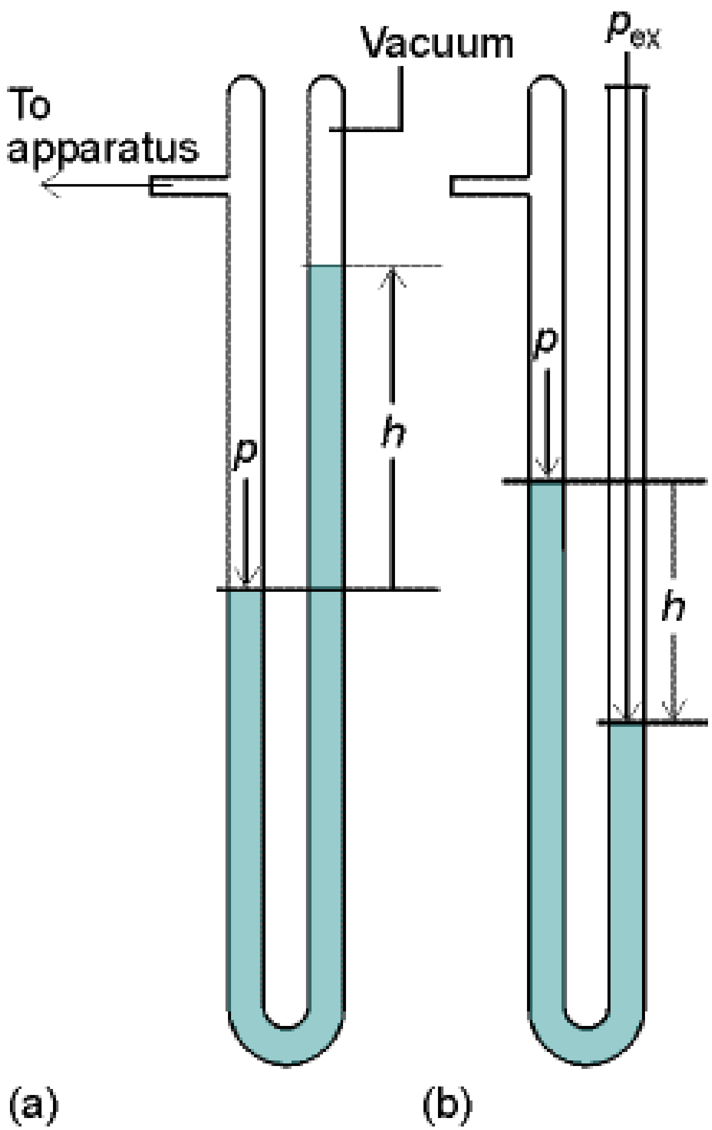
Pressure Exerted by Gases

Gases can be stored in two separate containers separated by a movable wall (i.e., **piston**). The higher pressure gas will move the wall and **compress** the lower pressure gas, until an equilibrium pressure is established. The piston is said to be in **mechanical equilibrium** at this point.

Pressures of the gases in a mechanical system involving a piston can be controlled via gas entry and release valves, that are set or controlled to let gases in and out at certain pressure thresholds.



Measuring Pressure



One device used to measure pressure is a **barometer** (by Torricelli). When the column of mercury is in equilibrium with the atmosphere, the pressure at the base is equal to that from the atmosphere - so the height of the mercury is a measure of the external pressure.

A simple pressure measuring device is a **manometer**, in which a non-volatile viscous fluid is contained in a U-tube

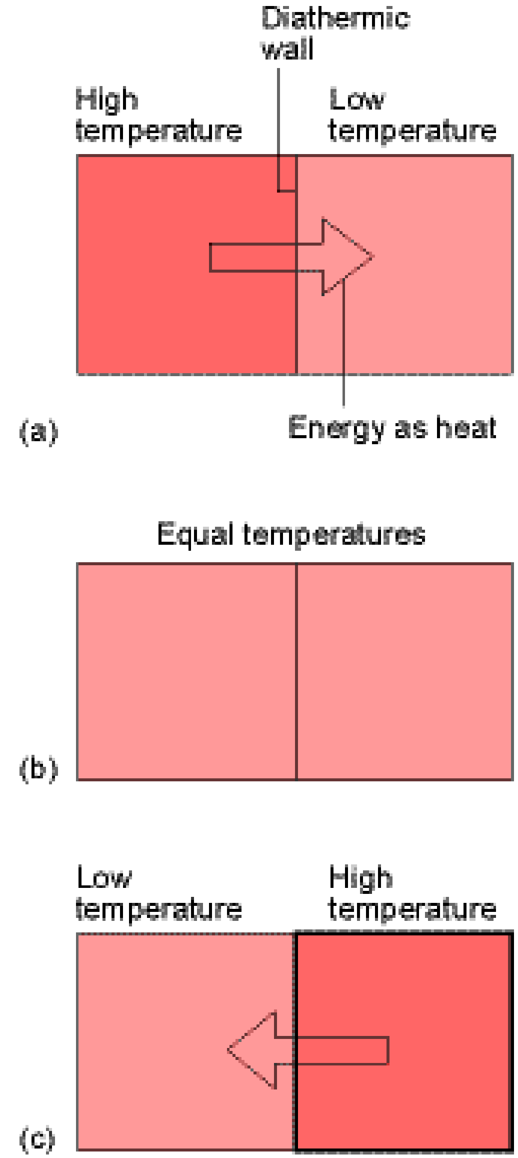
The pressure in the apparatus (a) or from atmosphere (b) is directly proportional to the height difference of the two columns, *h*:

$$p = \rho g h$$

ρ = density of viscous fluid
g = gravitational acceleration, 9.8 m s^{-2}

Temperature

Temperature is a property that describes the flow of energy. Energy will flow between two objects in contact, resulting in **change of state** of these two objects. If objects A and B are touching, and A has a higher temperature than B, energy flows from A to B until some equilibrium condition is established.

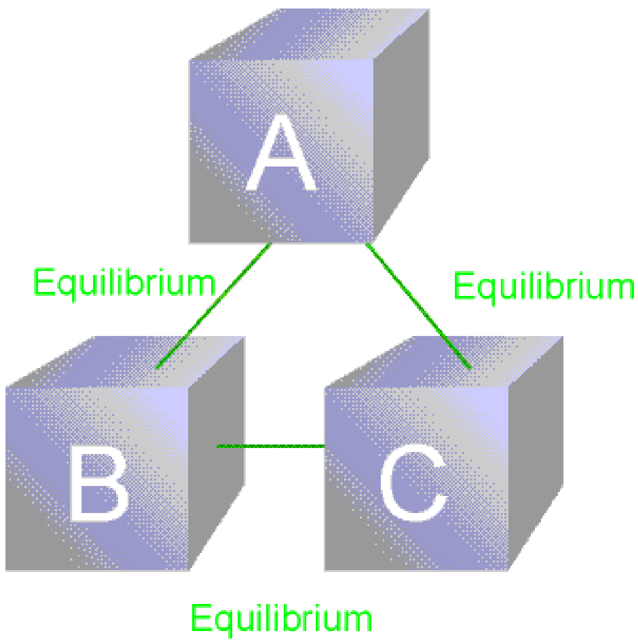


Separatory boundaries:

Diathermic - if a change of state is observed when two bodies are brought into contact with one another (e.g., metal)

Adiabatic - if no energy flow is permitted between the two objects in contact (e.g., styrofoam)

Thermal Equilibrium



Two objects are said to be in **thermal equilibrium** if no change in state occurs when they are in contact with one another.

A: Block of iron
B: Block of copper
C: Flask of water

Zeroth Law of Thermodynamics:
If A is in thermal equilibrium with B, and B is in thermal equilbrium with C, then C is also in thermal equilibrium with A

If B is a **thermometer** (glass capillary with Hg), in contact with A the Hg column has a certain length. If B is placed in contact with another object C, one can predict the change of state when A and C are put in contact. Thus, the Hg column is used to measure the temperatures of A and C.

Thermodynamic temperature scale (Kelvin): $\boldsymbol{T/\mathrm{K} = q/^{o}\mathrm{C} + 273.15}$

Thermometers & Temperature

A system that changes in a regular and observable manner with changes in temperature has the potential to be used as a thermometer.

Examples:
- Height of liquid in a narrow tube (mercury or alcohol)
- Change in gas volume (argon)
- Variation in electrical resistance in a wire (platinum)

Thermometers are **calibrated** by comparison to systems in reproducible states: e.g., H_2O at its **triple point** or Ag at its **melting point**.

Calibration: determination of a base point and graduated scale by comparison to systems with reproducible base points

Temperature is not heat! Temperature is a relative measure of heat between multiple systems - in fact, if you touch a system, and it feels hot, temperature can be defined as the tendency of that system to lose heat! We will make a formal definition of heat later...