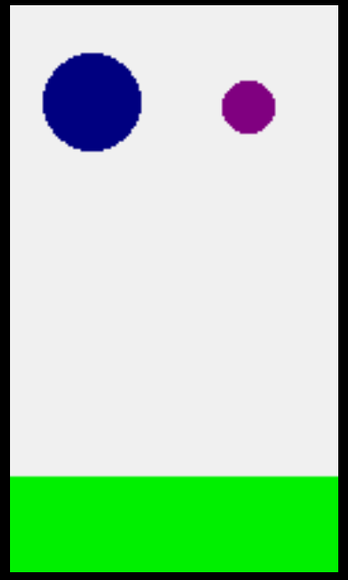
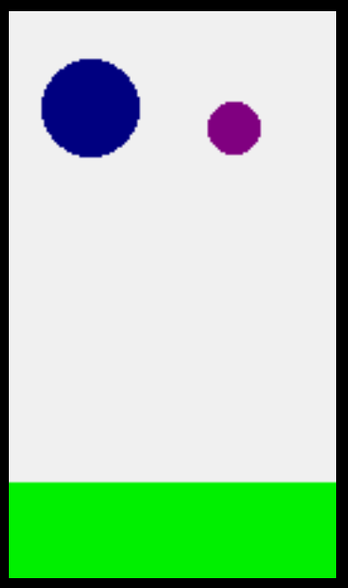
In the center of the `School of Athens' by Raphael are Aristotle and Plato, Aristotle's hand level to the Earth symbolizing his realism view of Nature; Plato's hand pointed towards the heaven symbolizing the mystical nature to his view of the Universe. This image symbols the sharp change in the meaning of how `natural philosophy' or physics will be done for the 2,200 years.

Aristotle also provides a good example of the way in which what one knows or believes influences the way one understands new information. His theory of motion flows from his understanding of matter as constituted of four elements: air, earth, fire, and water. Each element exists in its own sphere around the Earth. Objects, being solid like earth, would tend to clump together with other solids (earth), so objects tend to fall to earth, their natural place. Thus, falling is a natural motion. Hot objects, like a hot air balloon, would rise towards its sphere of Fire.



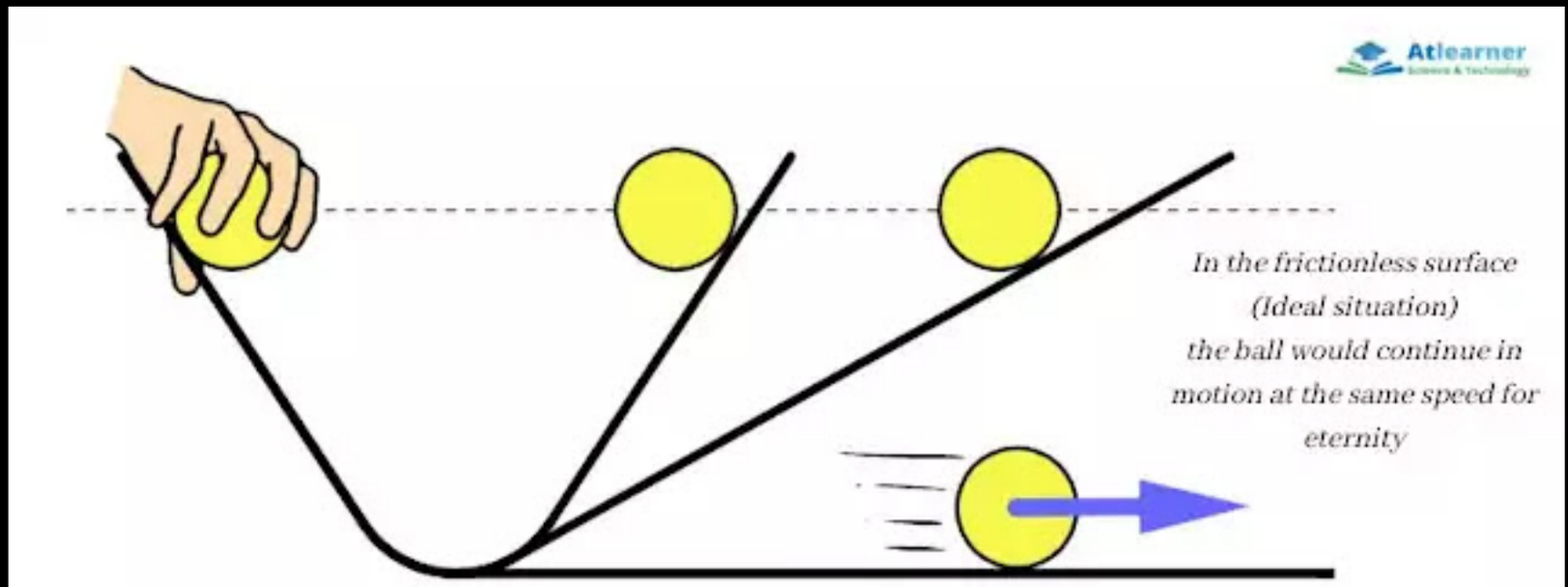
The way Aristotle believed objects to fall on the Earth



The way objects actually fall to Earth

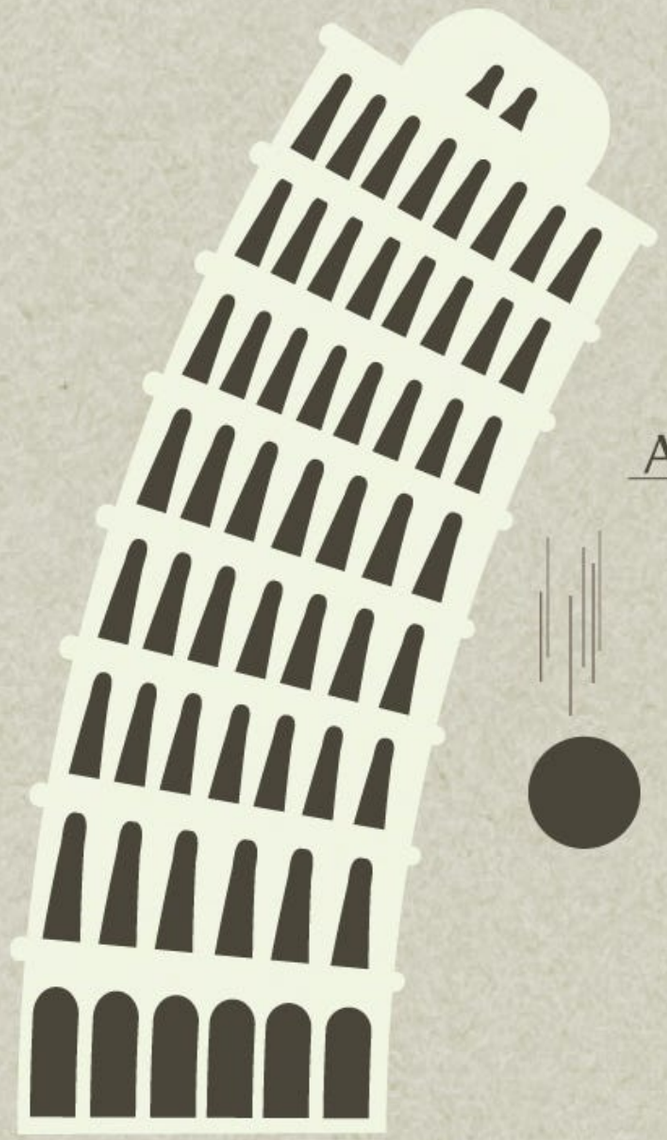
Galileo’s laws of motion:

- developed the concept of motion in terms of velocity (speed and direction) through the use of inclined planes.
- developed the idea of force, as a cause for motion.
- determined that the natural state of an object is rest or uniform motion, i.e. objects always have a velocity, sometimes that velocity has a magnitude of zero = rest.
- objects resist change in motion, which is called inertia.



Galileo inferred the law of inertia from observing the motion of a ball in a double enclided plane.

Galileo's Leaning Tower of Pisa experiment



Aristotle's theory of gravity
(which states that objects
fall at speed
relative to their mass)
proved false

Apollo 15 astronaut David Scott
re-created the famous experiment
on the Moon by dropping
a hammer and a feather.

Newton’s laws of motion:

- The three root quantities in mechanics are velocity, time and distance. The three are related by the formula; distance = velocity x time

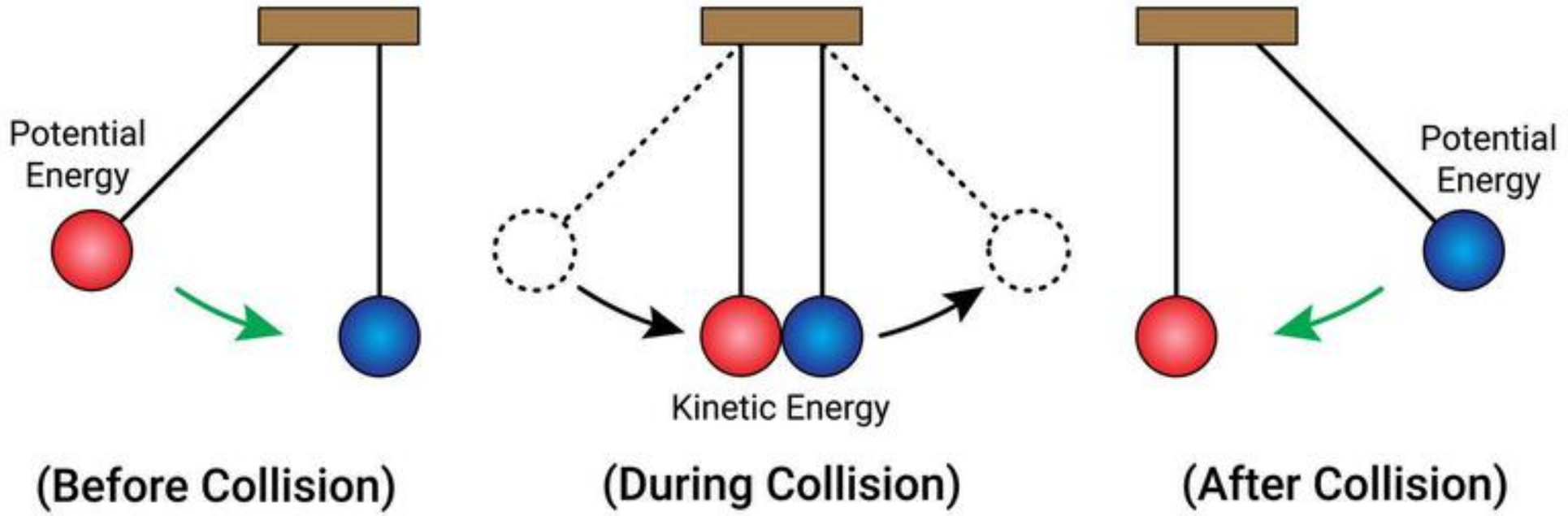
- change in velocity = acceleration -> caused by force

- inertia = resistance to change in velocity and is proportional to the mass of the object

With respect to the energy of motion we follow Newton's formulation of the concept of momentum. A quantity that is used to describe the energy of motion and is expressed as the mass of an object times its velocity.

Newton also found that there is a law of the conservation of momentum that states the total momentum of a system is conserved. In other words, the sum of the momentum before must equal the sum of the momentums afterword. Conservation laws are extremely powerful in physics since they allow one to derive the future from the present conditions.

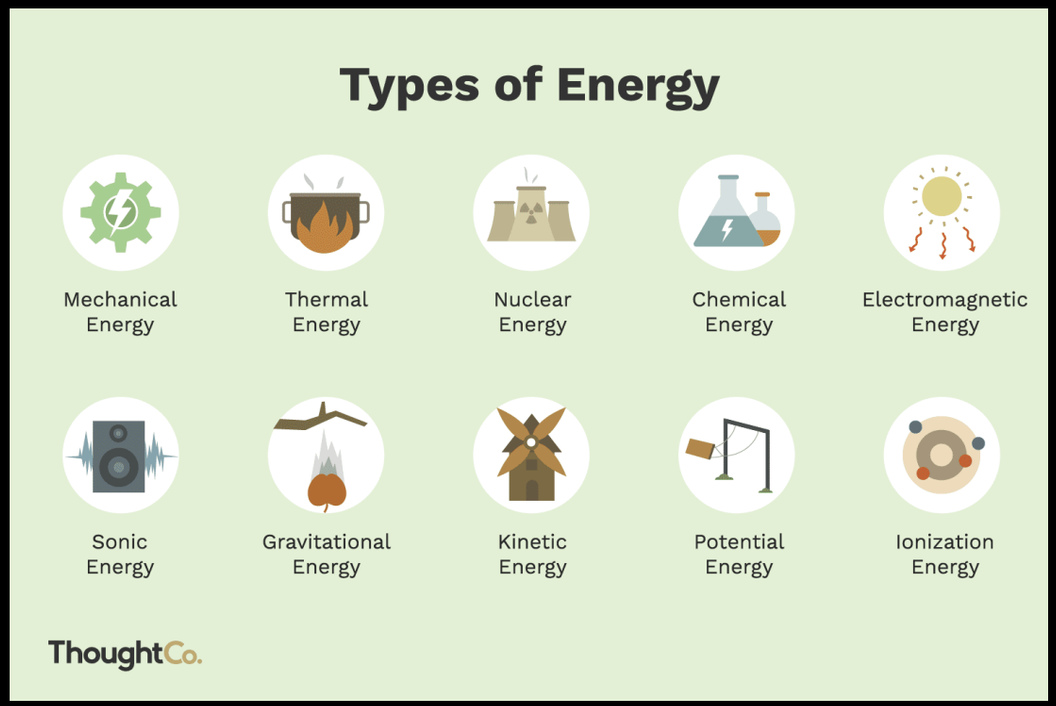
Conservation of Momentum

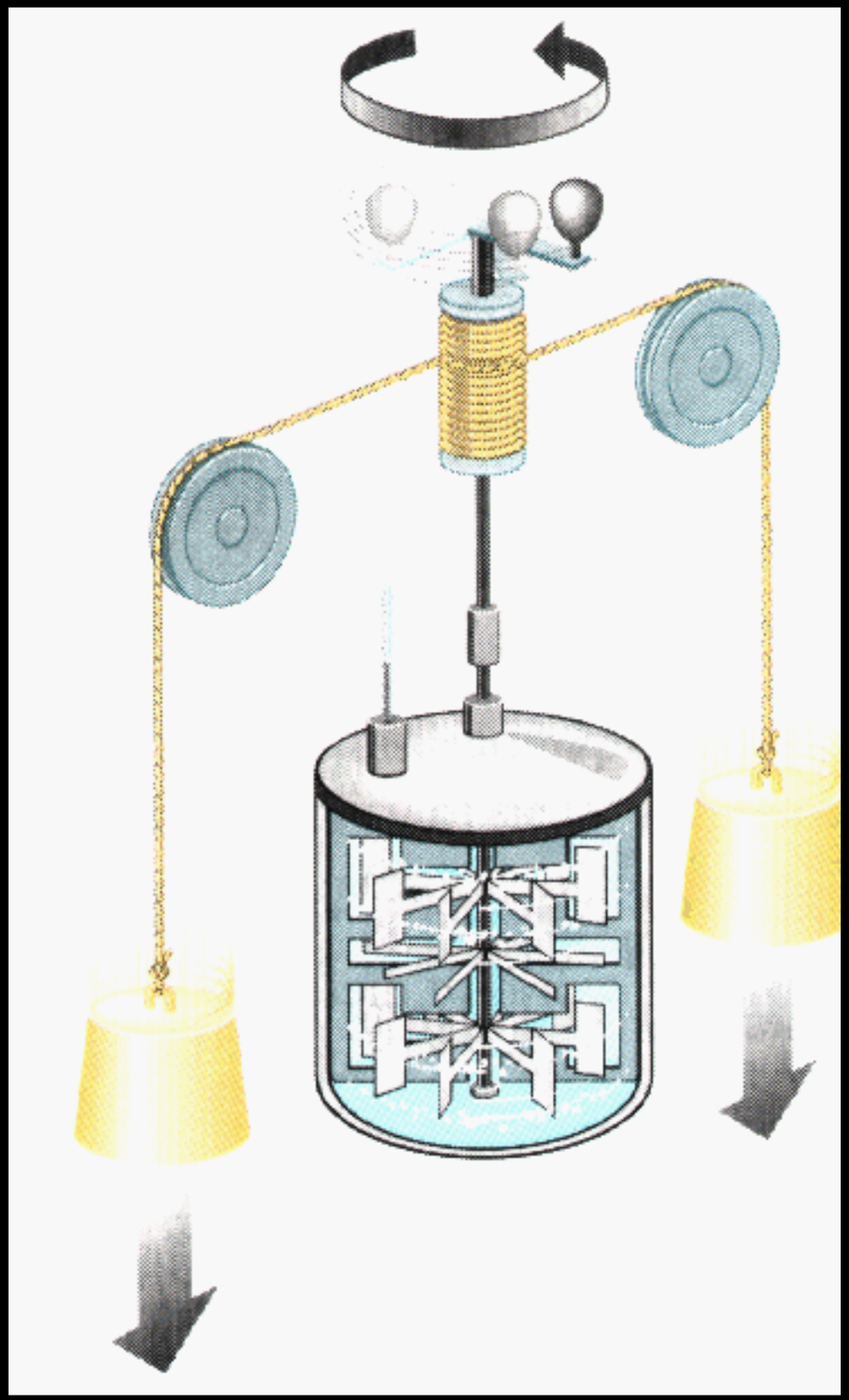


Energy can not be created or destroyed, only transferred from place to place. Energy is defined to be force times distance and is expressed in units of ergs (grams centimeter per second).

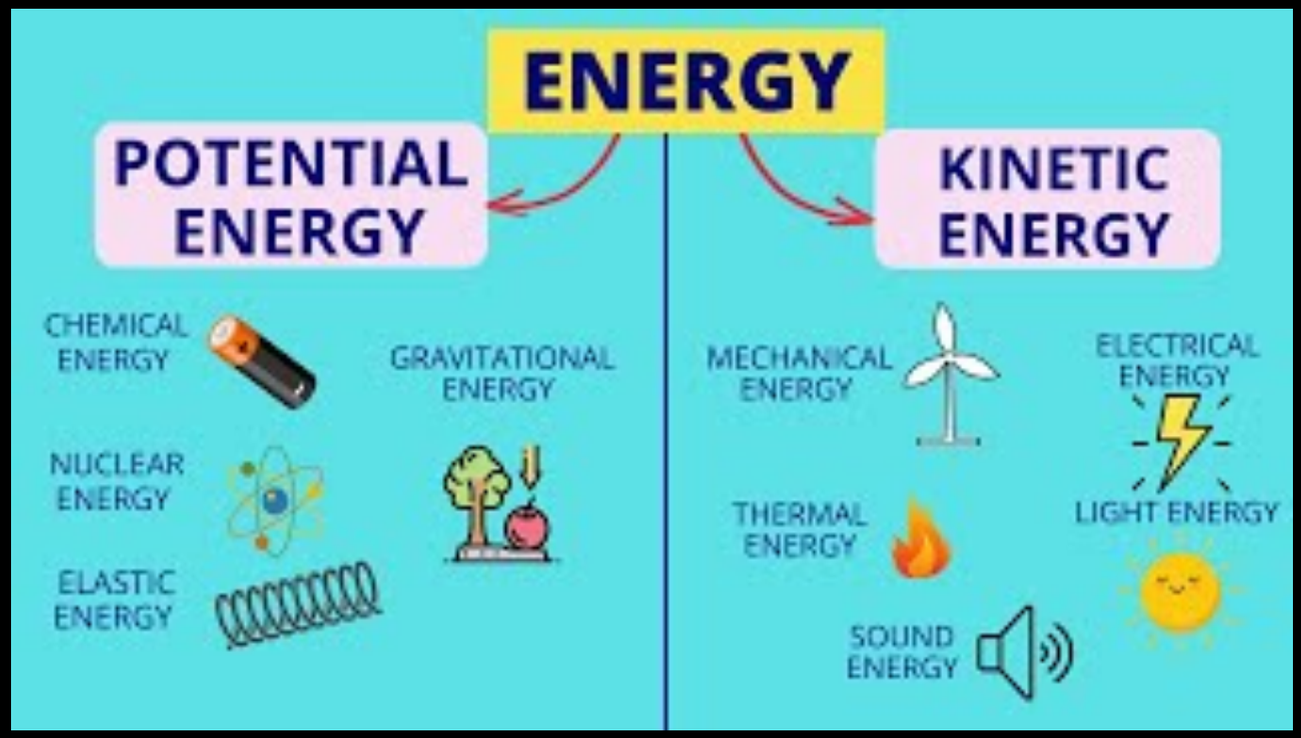
- energy is not like matter
- energy does not have size, shape or occupy space
- energy does not have inertia

Energy is a measure of the ability of a physical system to perform work (i.e. to change the system).





The law of the conservation of energy means that energy can neither be created or destroyed, only transformed from one form to another.



FORMS OF ENERGY

All forms of energy fall under two categories

POTENTIAL

Potential energy is stored energy
and
the energy of position (gravitational)

CHEMICAL ENERGY

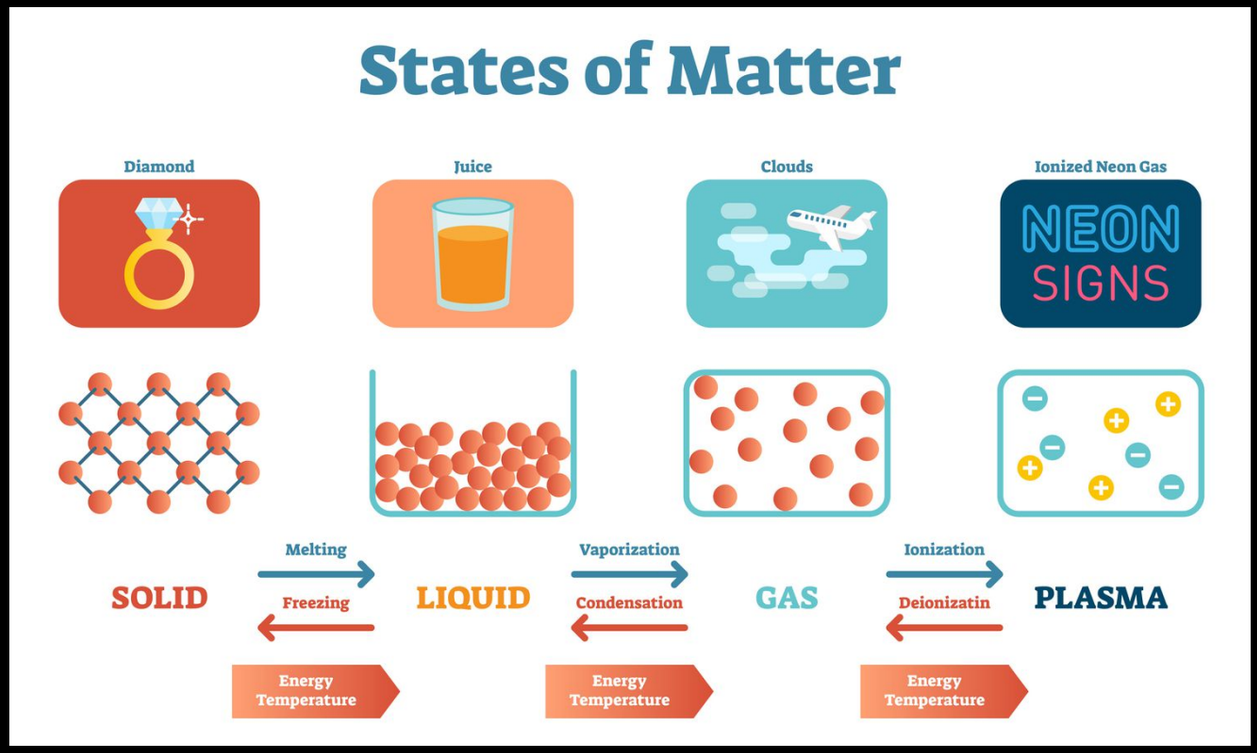
Chemical energy is the energy stored in the bonds of atoms and molecules. Biomass, petroleum, natural gas, propane and coal are examples of stored chemical energy.

KINETIC

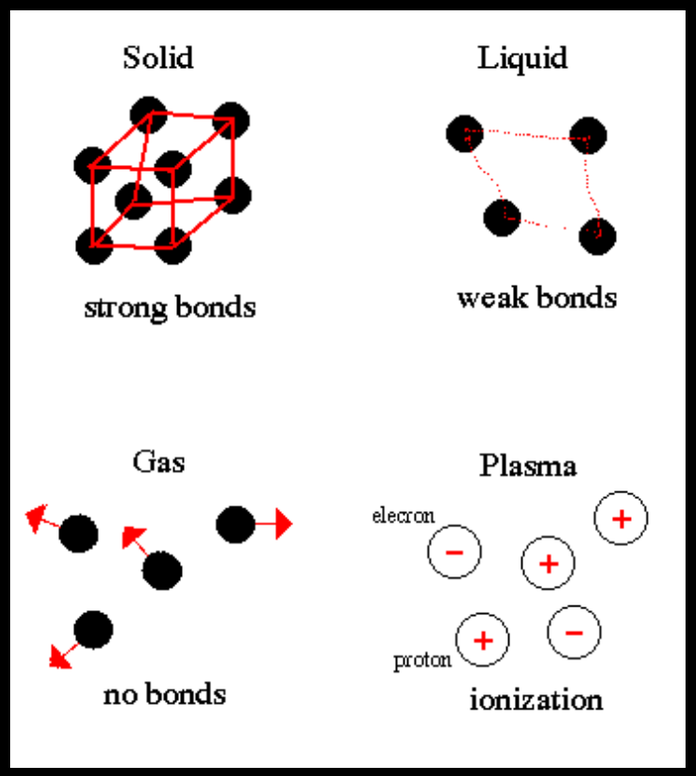
Kinetic energy is energy in motion.
It is the motion of waves, electrons, atoms, molecules and substances

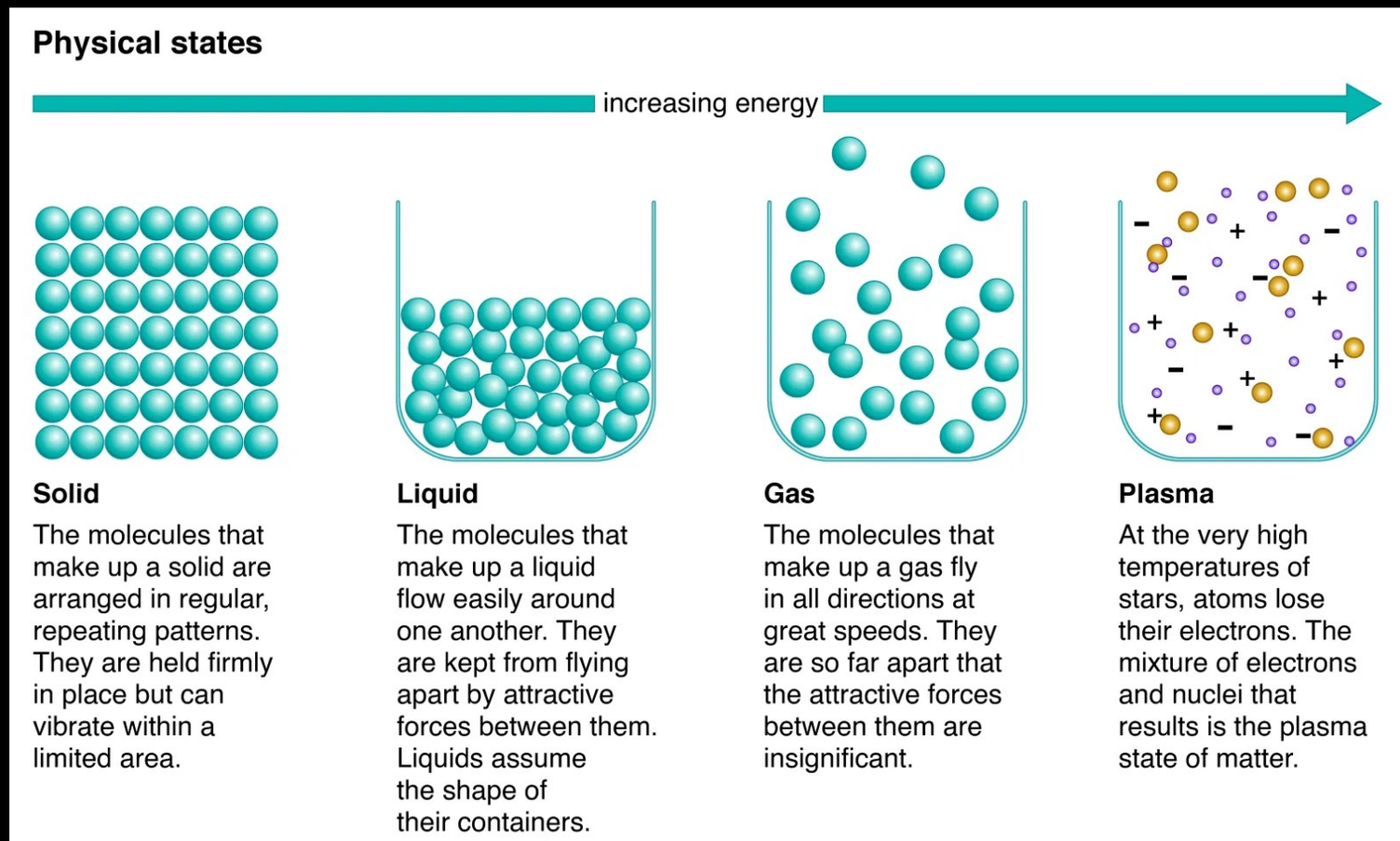
RADIANT ENERGY

Radiant energy is electromagnetic energy that travels in transverse waves. Radiant energy includes visible light, x-rays, gamma rays and radio waves. Solar energy is an example of radiant energy.



Matter consists of atoms held together by electromagnetic forces. How tight these bonds are determines which of the four states: solid, liquid, gas and plasma, matter exists as.





Atomic theory is the field of physics that describes the characteristics and properties of atoms that make up matter. The key point to note about atomic theory is the relationship between the macroscopic world (us) and the microscopic world of atoms. For example, the macroscopic world deals with concepts such as temperature and pressure to describe matter. The microscopic world of atomic theory deals with the kinetic motion of atoms to explain macroscopic quantities.

Pressure and Temperature (Gay-Lussac' Law)

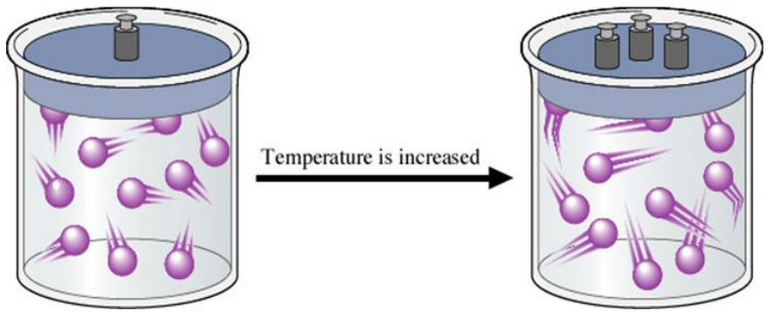
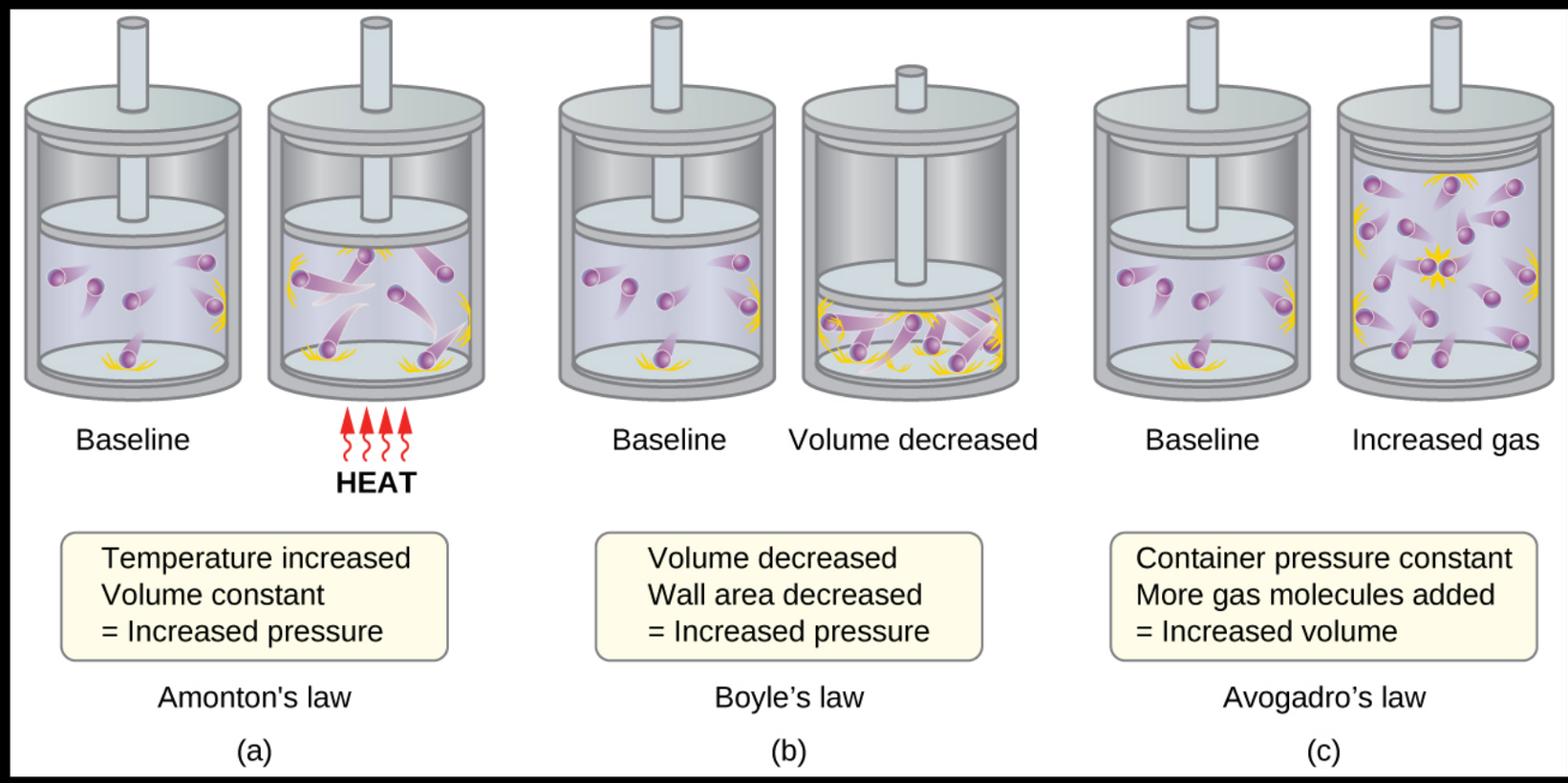
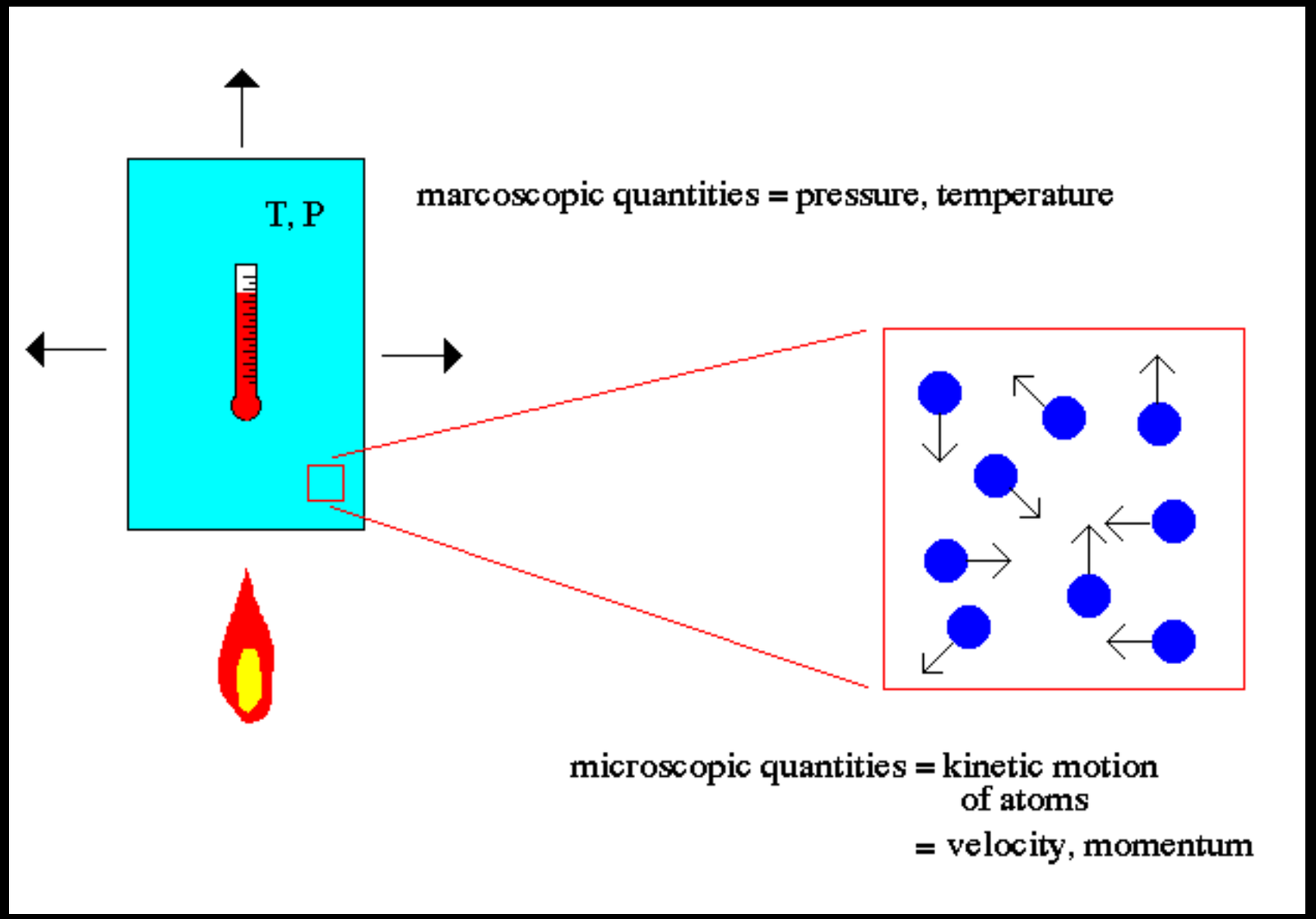


Figure 5.15
The Effects of Increasing the Temperature of a Sample of Gas at Constant Volume

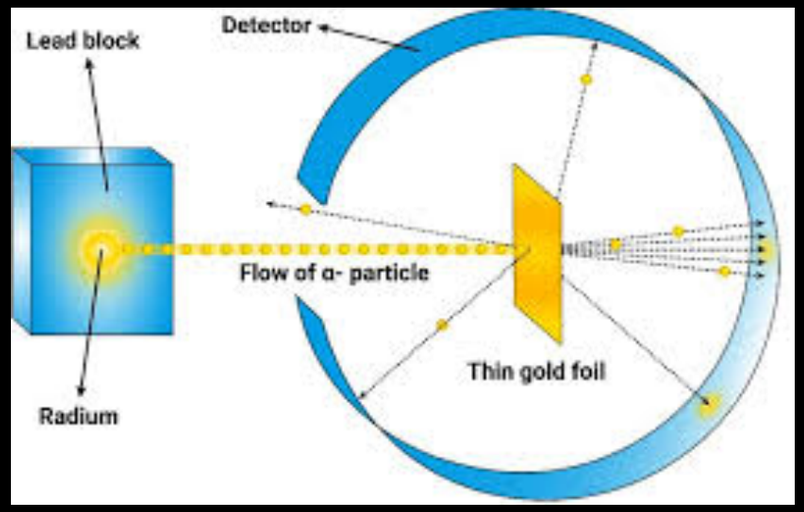
Increasing the temperature causes the particles to move faster increasing the frequency of collision with the walls of the container. If the volume is constant this results in and increase in pressure

Macroscopic properties of matter are governed by the Ideal Gas Law of chemistry (a combined form of the 4 laws shown here).

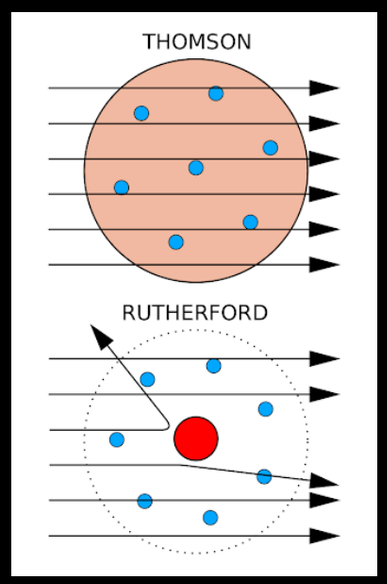


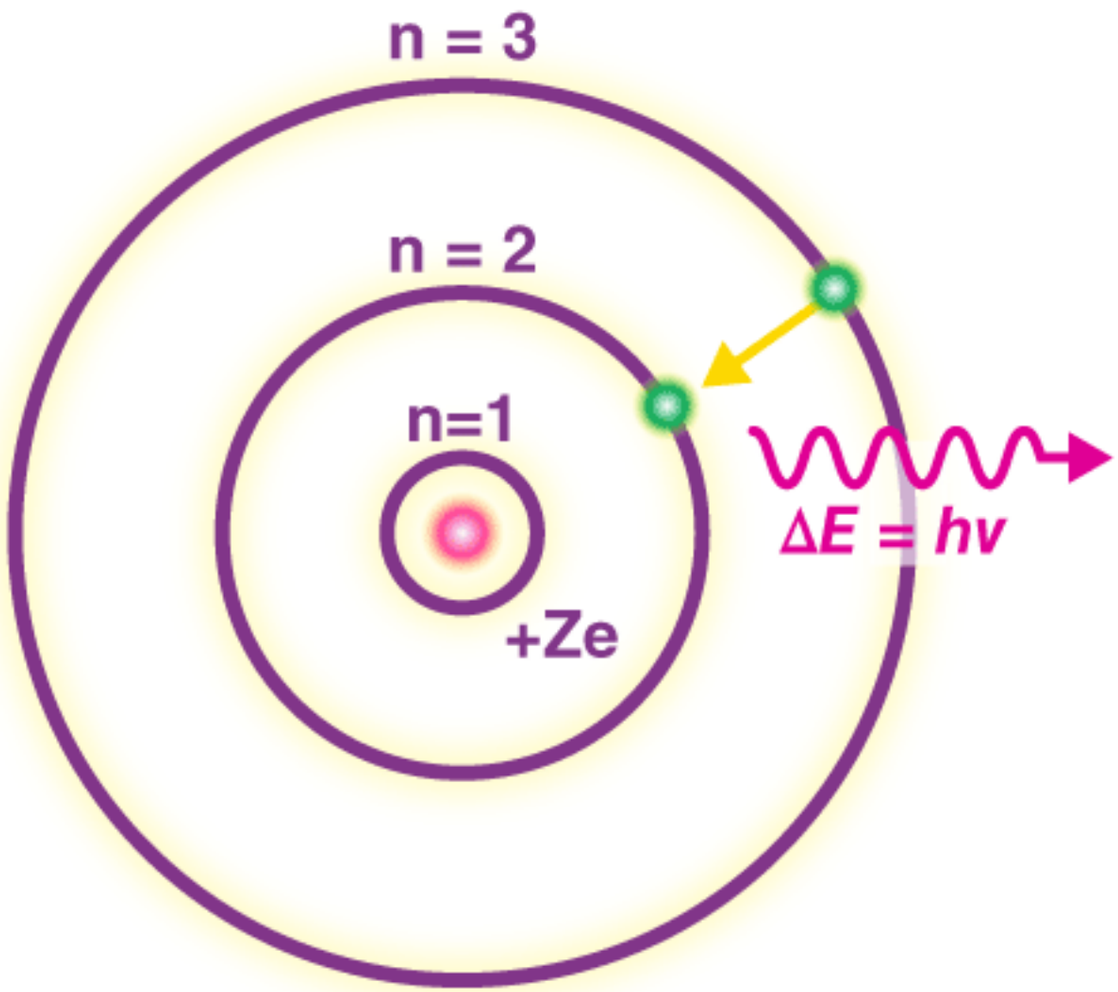


Temperature is explained in atomic theory as the motion of the atoms (faster = hotter). Pressure is explained as the momentum transfer of those moving atoms on the walls of the container (faster atoms = higher temperature = more momentum/hits = higher pressure).

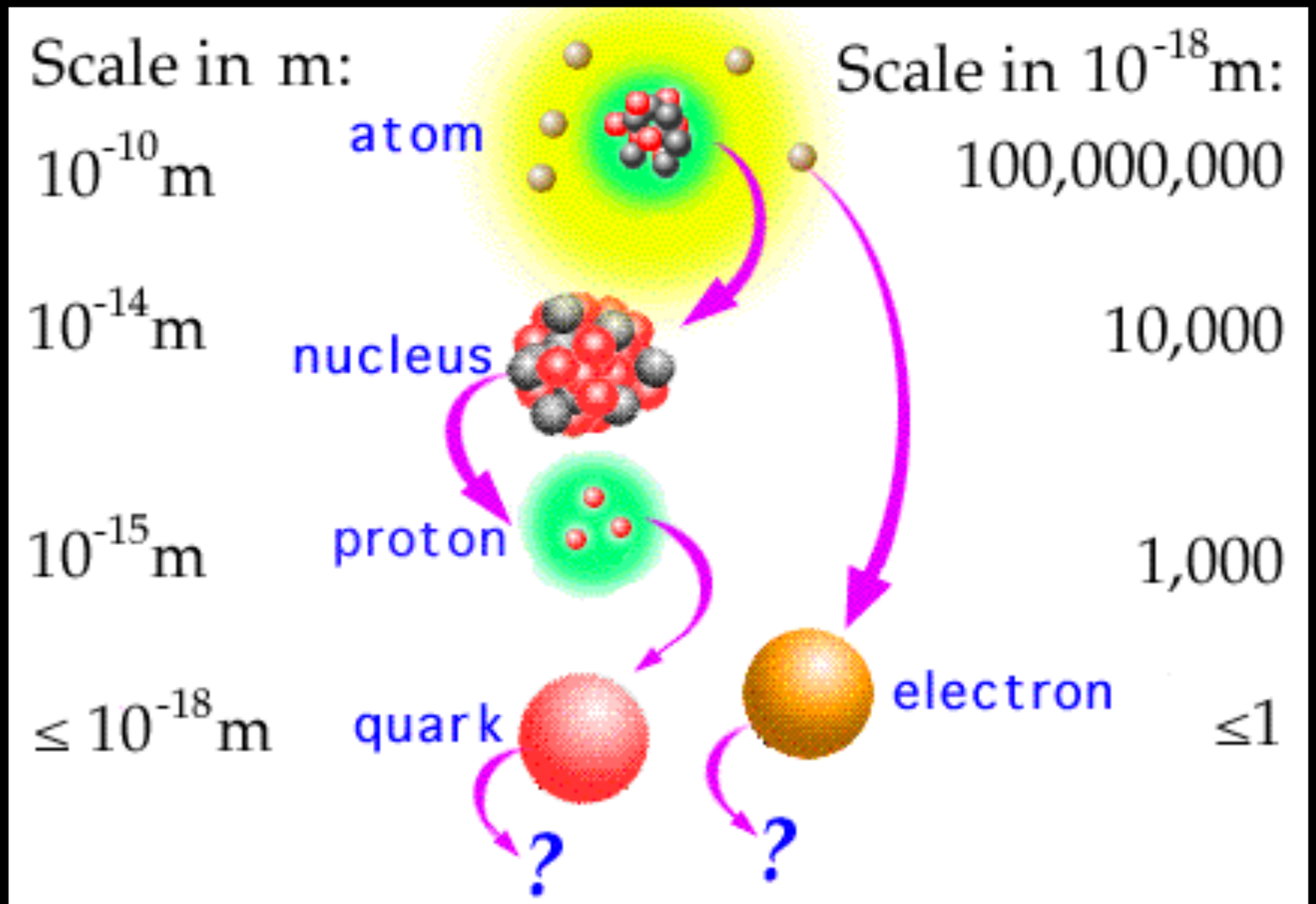


For the ideal gas law, atoms appear to operate as tiny billiard balls, having no structure. Rutherford performed early experiments of shooting alpha particles (helium nuclei) at sheets of gold to show that atoms were, in fact, mostly empty space. Rutherford's model of an atom has a small nucleus containing protons (positive charged particles) and neutrons (particles with no electric charge) surrounded by electrons (small particles of negative charge).

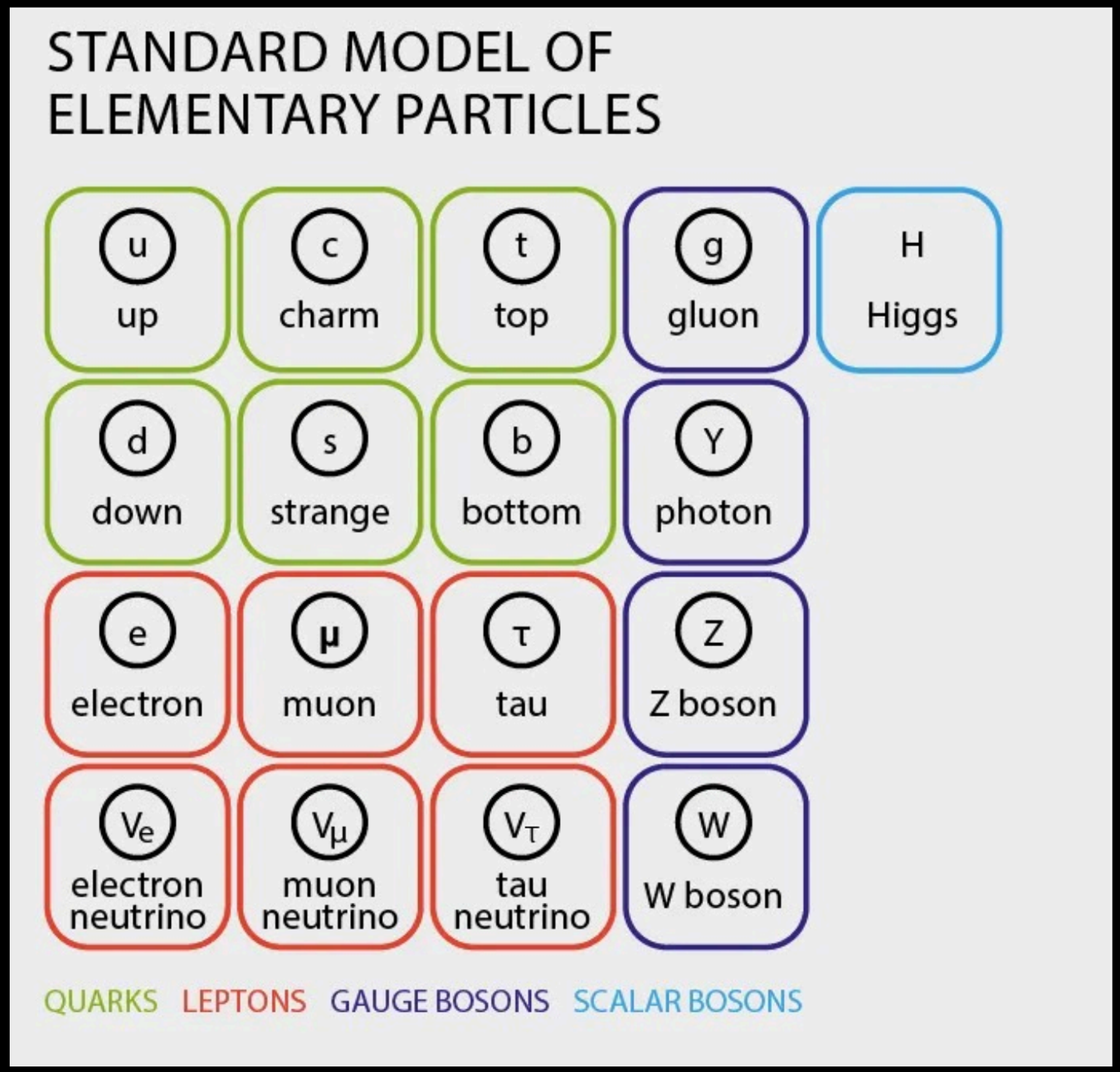




Bohr developed a different model of the atom to explain the absorption and emission line spectrum that could not be understood by the Rutherford atom model. The Bohr atom is similar to Rutherford atom, except the electrons can only move in fixed or quantized orbits.



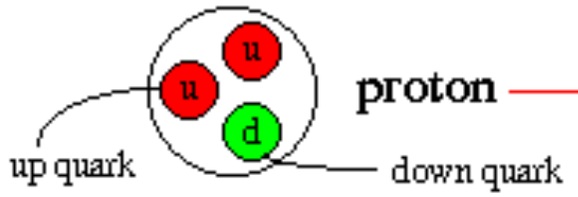
The search for the origin of matter means the understanding of elementary particles. The understanding of elementary particles requires an understanding of not only their characteristics, but how they interact and relate to other particles and forces of Nature, the field of physics called particle physics.



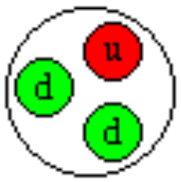
The two most fundamental types of particles are quarks and leptons, where each class is divided into 6 flavors corresponding to three generations of matter. Quarks (and antiquarks) have electric charges in units of 1/3 or 2/3's. Leptons have charges in units of 1 or 0.

Atomic Nuclei = Combinations of Quarks

Baryons = particles made of 3 quarks

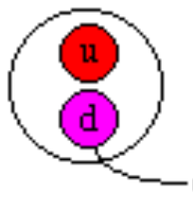


proton —— charge = +1 (2/3+2/3−1/3)



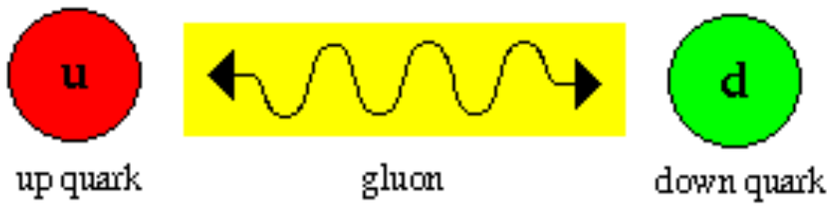
neutron —— charge = 0 (2/3−1/3−1/3)

Mesons = particles made of 2 quarks



pion —— charge = +1 (2/3+1/3)

What binds quarks together?



the strong force carried by gluons