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- Conservation laws: momentum, angular momentum

- Energy (potencial, kinetic, Radiative)

Energy is always conserved

It can change from one form to another, but it doesn't disappear.

Changing gravitational potential energy to kinetic energy

Ball has gravitational potential energy.

Ball has kinetic energy.

Changing gravitational potential energy to kinetic energy

what happen when the rock hits the ground ?

Changing gravitational potential energy to kinetic energy

what happen when the rock hits the ground ?

producing sound and to heating the ground, rock, and surrounding air

Converting gravitational potential energy to kinetic energy

- Why do we care?
- Has many astronomical applications

Converting gravitational potential energy to kinetic energy

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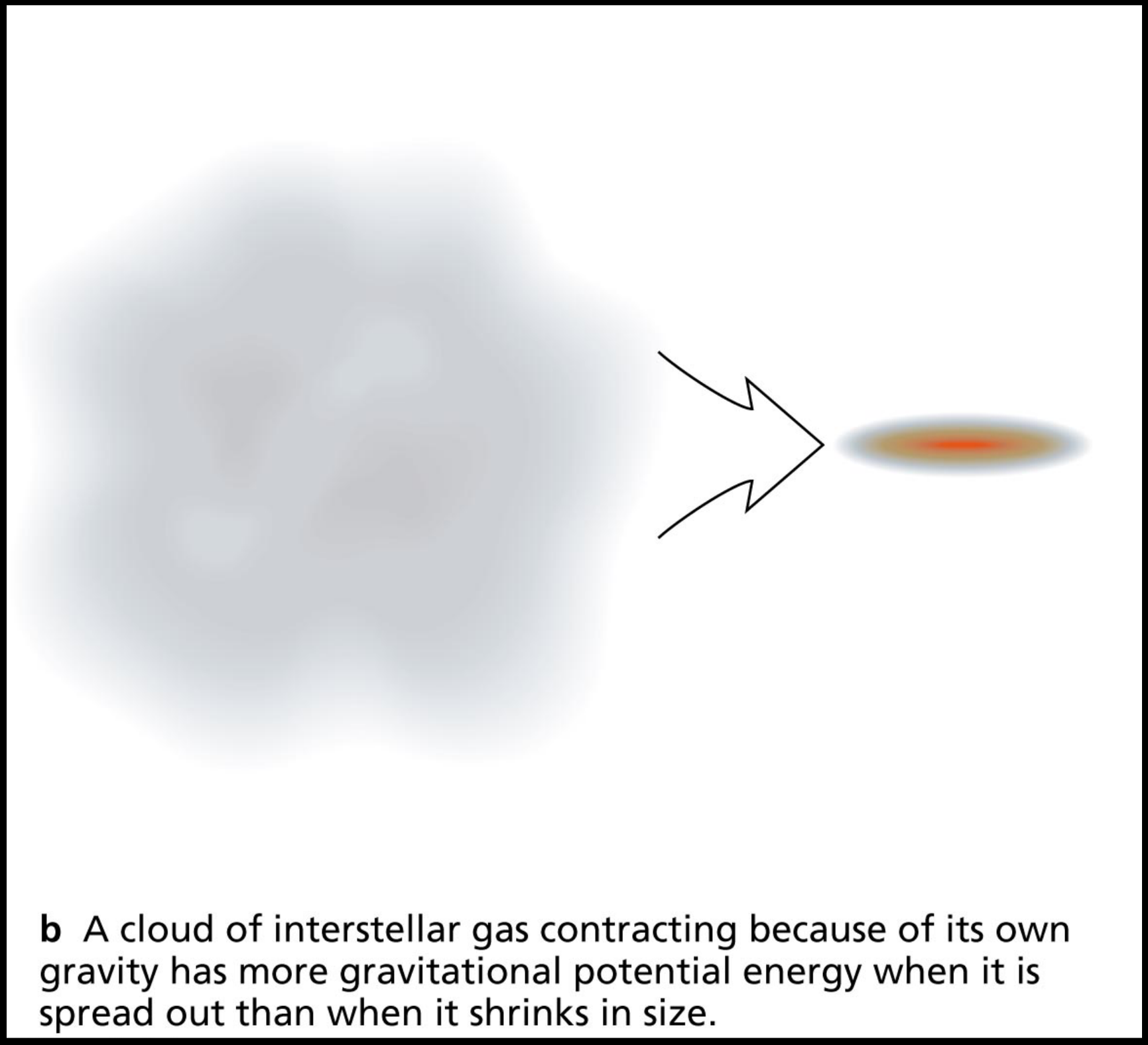
- Has many astronomical applications
  - Understanding orbits (e.g., planets around a star)
  - A star forming from a gas cloud
  - Collapse of the cores of stars near the end of their main sequence lifetimes

Conservation of energy



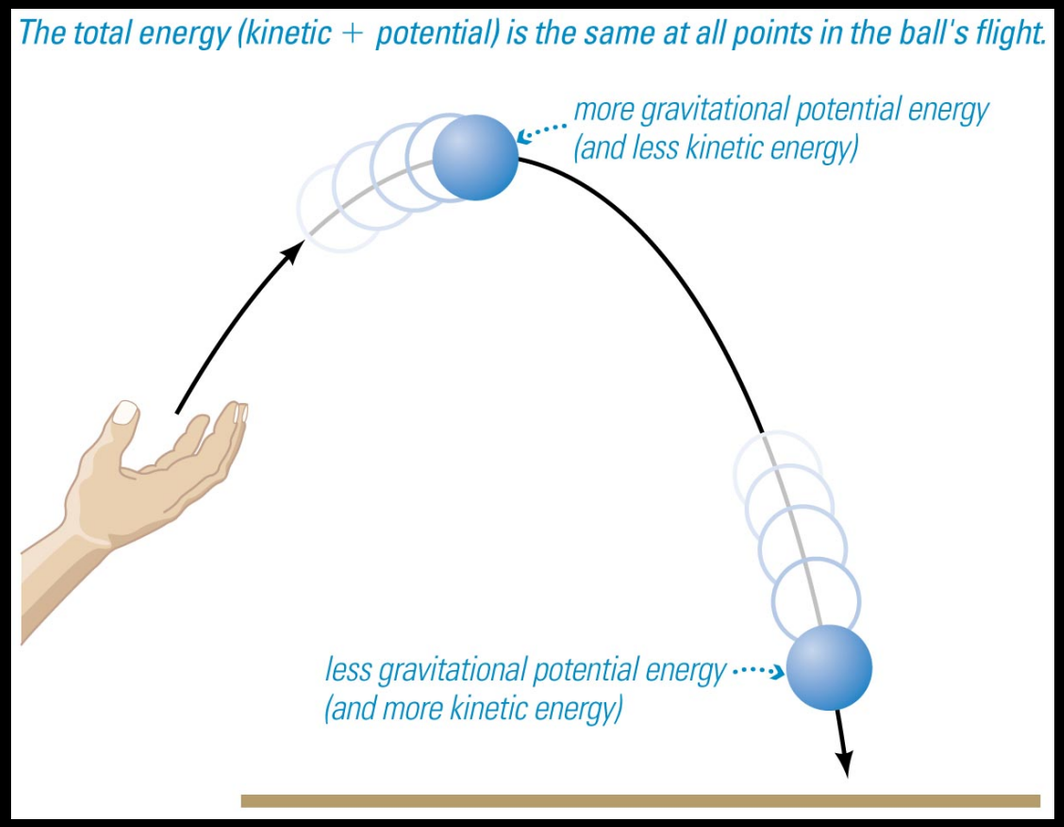
b A cloud of interstellar gas contracting because of its own gravity has more gravitational potential energy when it is spread out than when it shrinks in size.

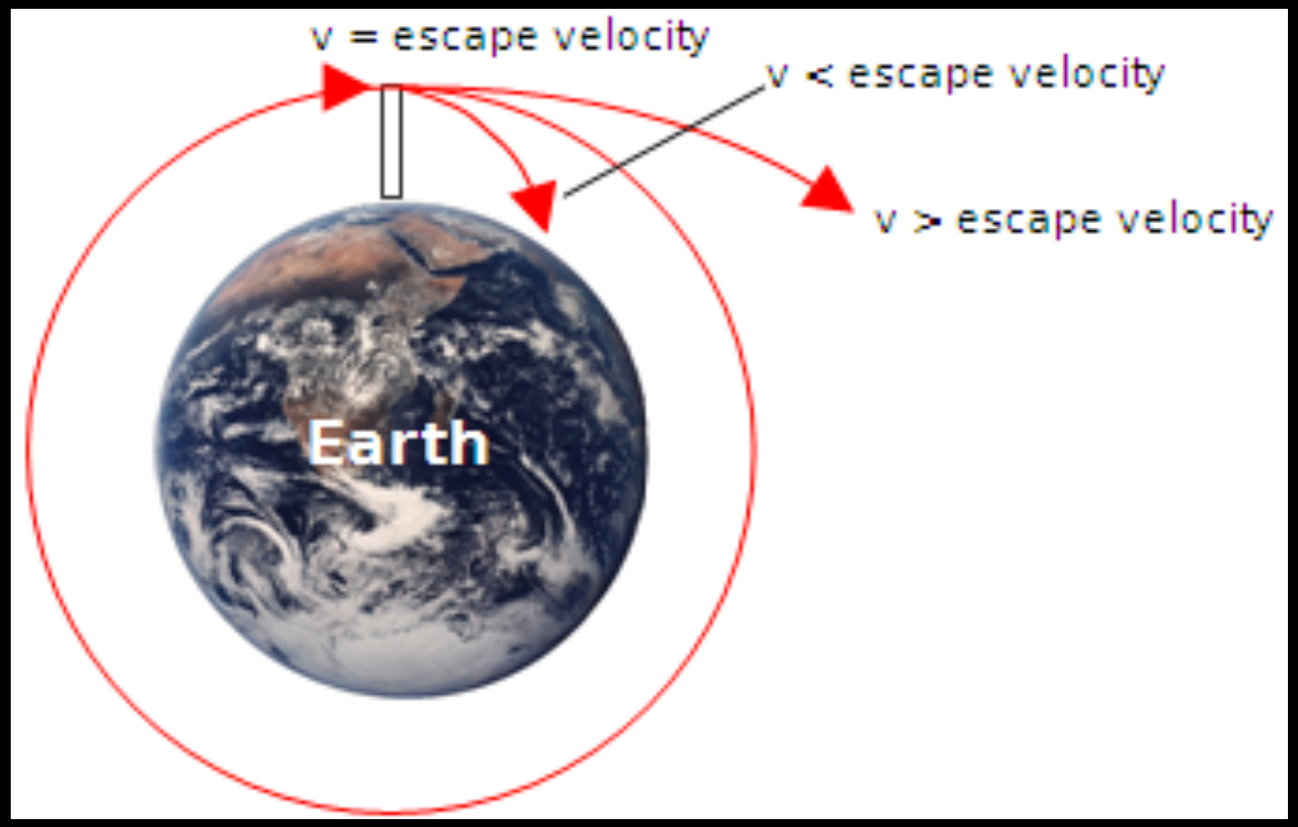
Converting gravitational potential energy to kinetic energy

- Why do we care?
- Has many astronomical applications
  - Understanding orbits (e.g., planets around a star)
  - A star forming from a gas cloud
  - Collapse of the cores of stars near the end of their main sequence lifetimes
  - Gas spiraling into a black hole

Total energy and orbits

- Total energy = Potential + Kinetic
  - If negative: gravitationally bound
  - If positive: object will escape from the gravitational pull of the central object



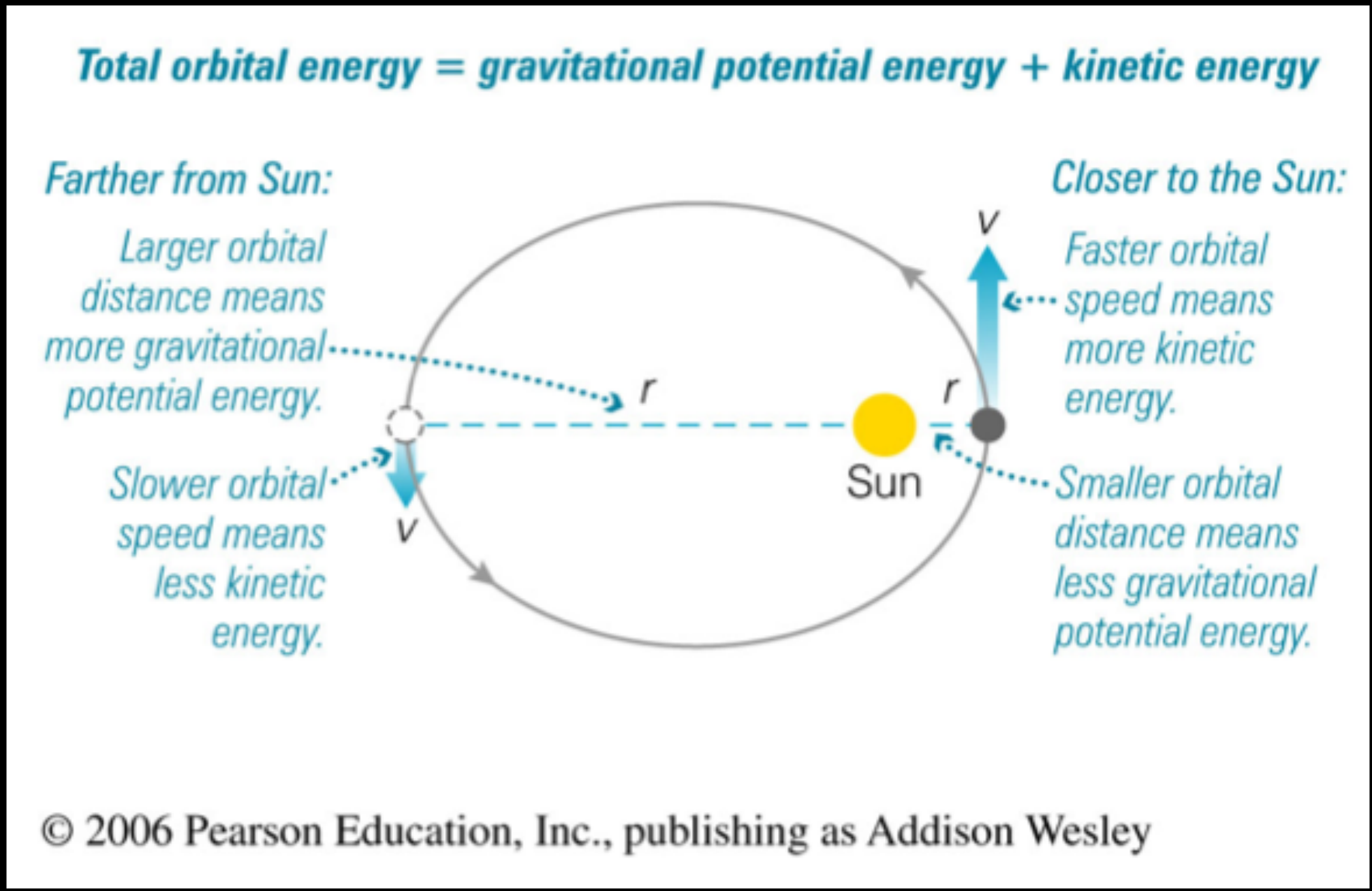


- Potential energy: negative ($-Gm_1m_2/r$)
- Kinetic energy: always positive ($1/2\ mv^2$)

Energy and orbits

- If you roll a ball on an elliptical path, this is analogous to an elliptical orbit due to gravity

Total energy is conserved during the orbit



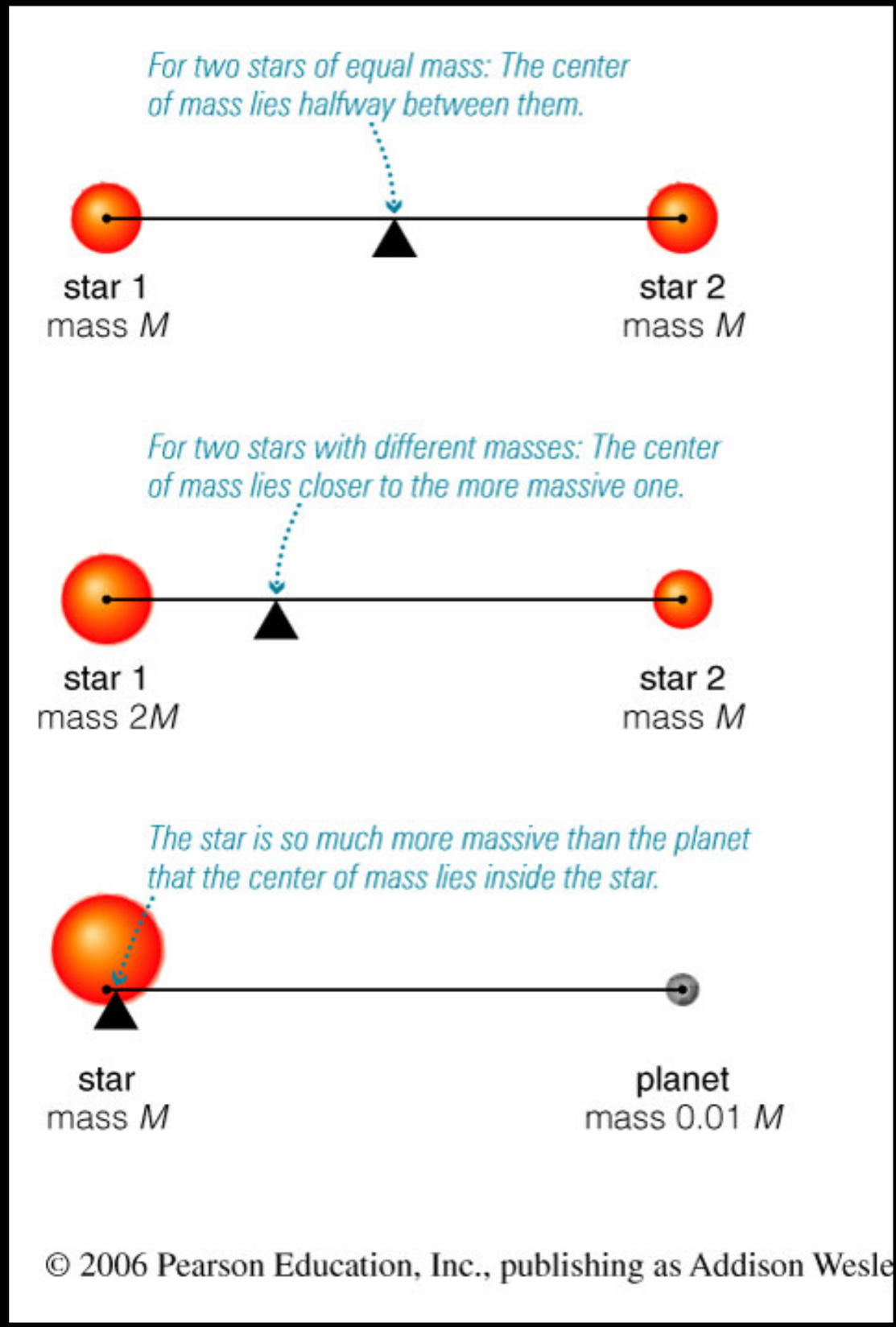
Newton’s version of Kepler’s Laws

Newton's version of Kepler's Laws

- A combination of:
  - Newton's law of gravity
  - Conservation of energy
  - Conservation of angular momentum
- Leads to more explicit version of laws:

Newton's version of Kepler's Laws

- Kepler's first law, revised
  - For a binary system, both objects move about the center of mass on ellipses, with the center of mass at one focus of each ellipse.



Newton's version of Kepler's Laws

Kepler's third law ($P^2=a^3$), revisted

– The square of the period depends on the cube of the semimajor axis, as before, but also on the total mass of the two objects:

$$P^2 = \frac{4\pi^2}{G\left(M_1 + M_2\right)} a^3$$

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– What happens if M_1 is much bigger than M_2?

- Think of the Sun compared to the Earth

$$P^2 \approx \frac{4\pi^2}{GM_1} a^3$$

We can use this to measure mass

- Newton's version of Kepler's laws relates three quantities:
  - The semimajor axis of the orbit (a)
  - The period of the orbit (P)
  - The total mass in the system (M_1+M_2)

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$$M_1+M_2 = 4\pi^2 a^3 / GP^2$$

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- NOTE: if we're talking about a planet that is orbiting a star then the mass of the star is essentially the total mass

Question:

Each of the following lists two facts. Which pair can be used with Newton's version of Kepler's third law to determine the mass of the Sun?

A) Mercury is 0.387 AU from the Sun, and Earth is 1 AU from the Sun.

B) The mass of Earth is 6×10^{24} kg, and Earth orbits the Sun in 1 year.

C) Earth rotates in 1 day and orbits the Sun in 1 year.

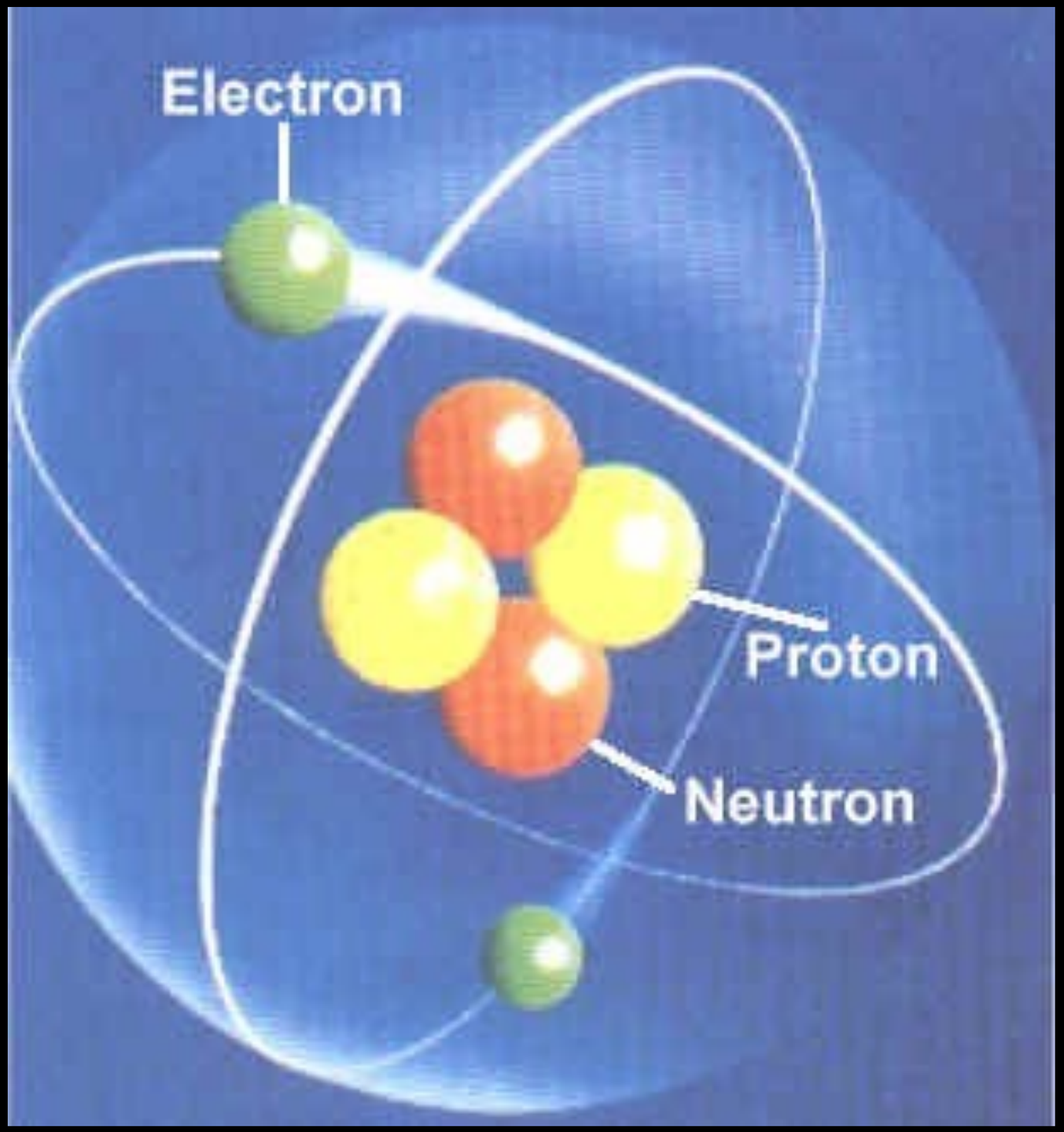
D) Earth is 150 million km from the Sun and orbits the Sun in 1 year.

E) Jupiter is the most massive planet and has a mass of 1.9×10^{27} kg.

Matter in the Universe

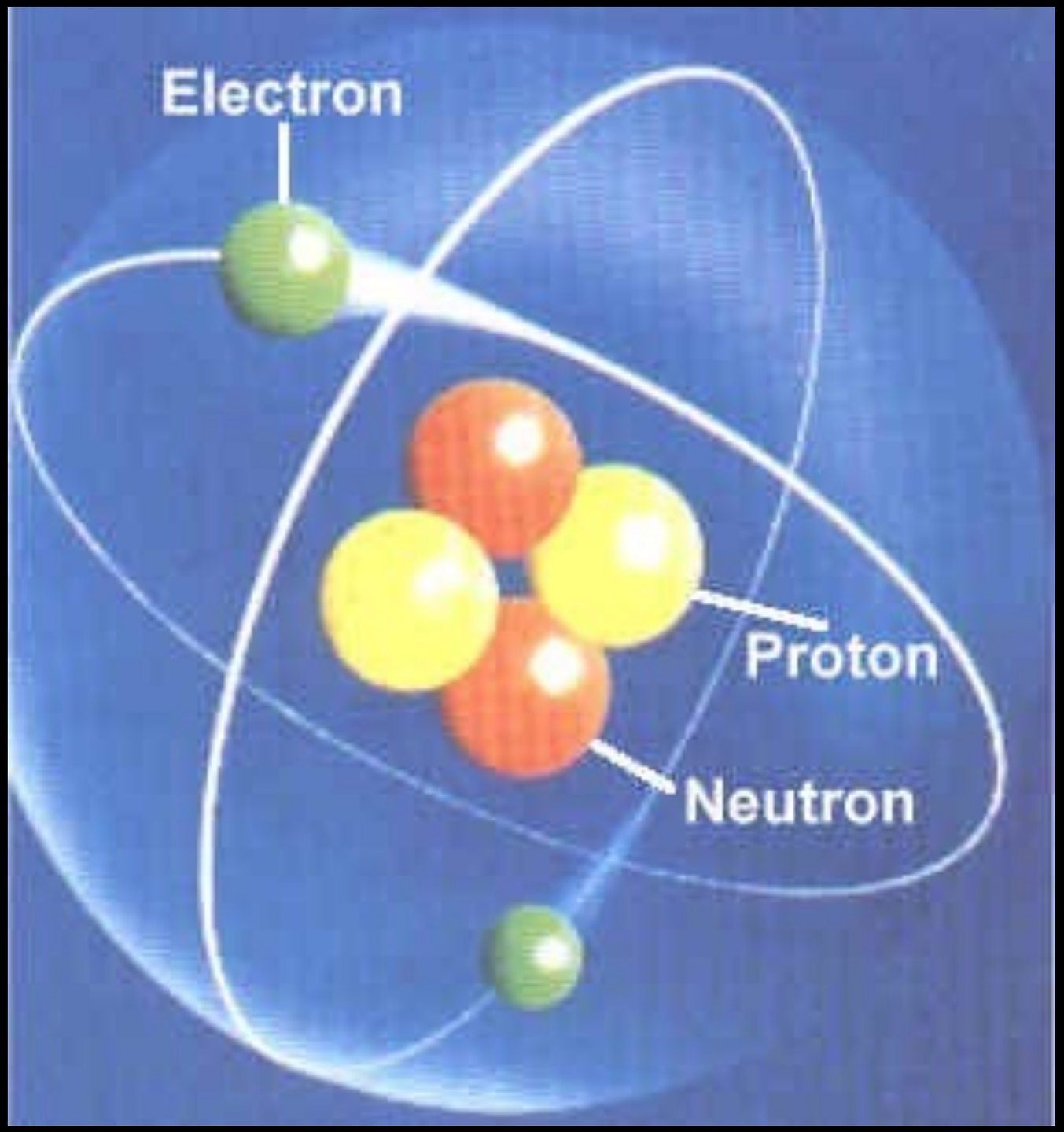
Chapter 5.3

The basic building block of normal (baryonic) matter is the atom



Protons
- Massive
- Positive (+) charge

The basic building block of normal (baryonic) matter is the atom



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  - No charge (neutral)

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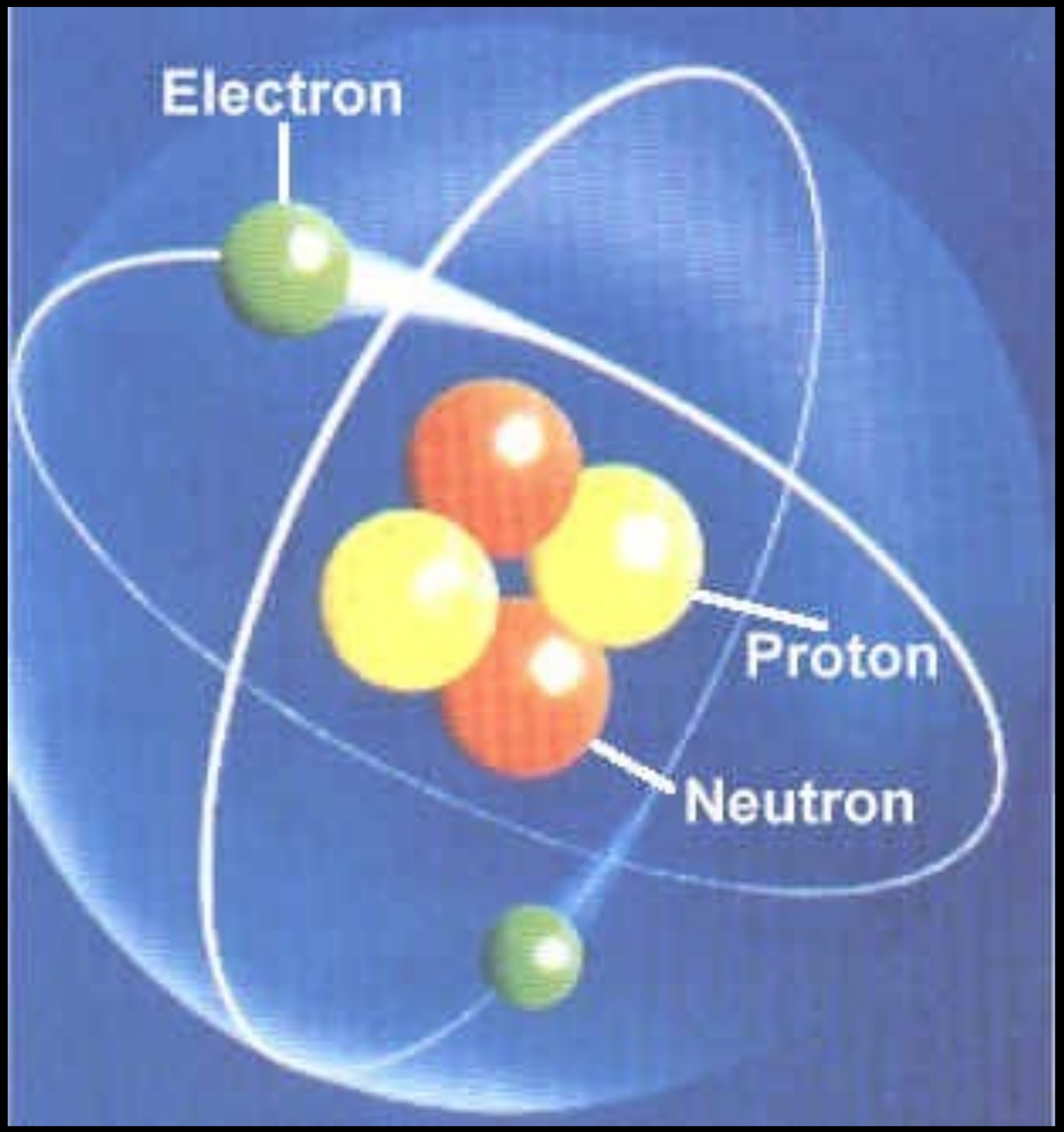
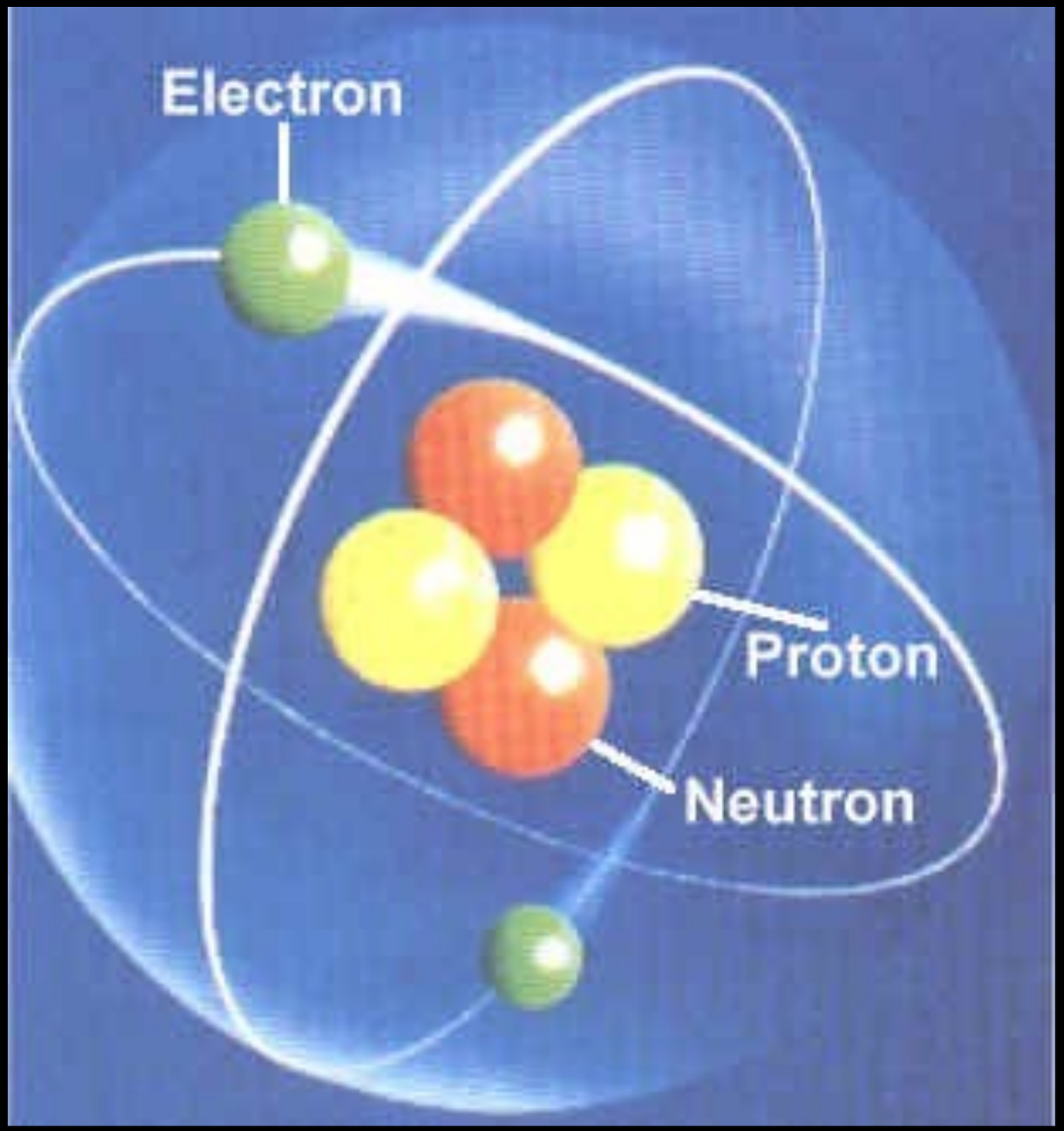


- Protons
  - Massive
  - Positive (+) charge
- Neutrons
  - Massive
  - No charge (neutral)
- Electrons
  - Negligible Mass
    (me = mp / 1830)
  - Negative (-) charge

Which is the force that keep the electron in the atom?



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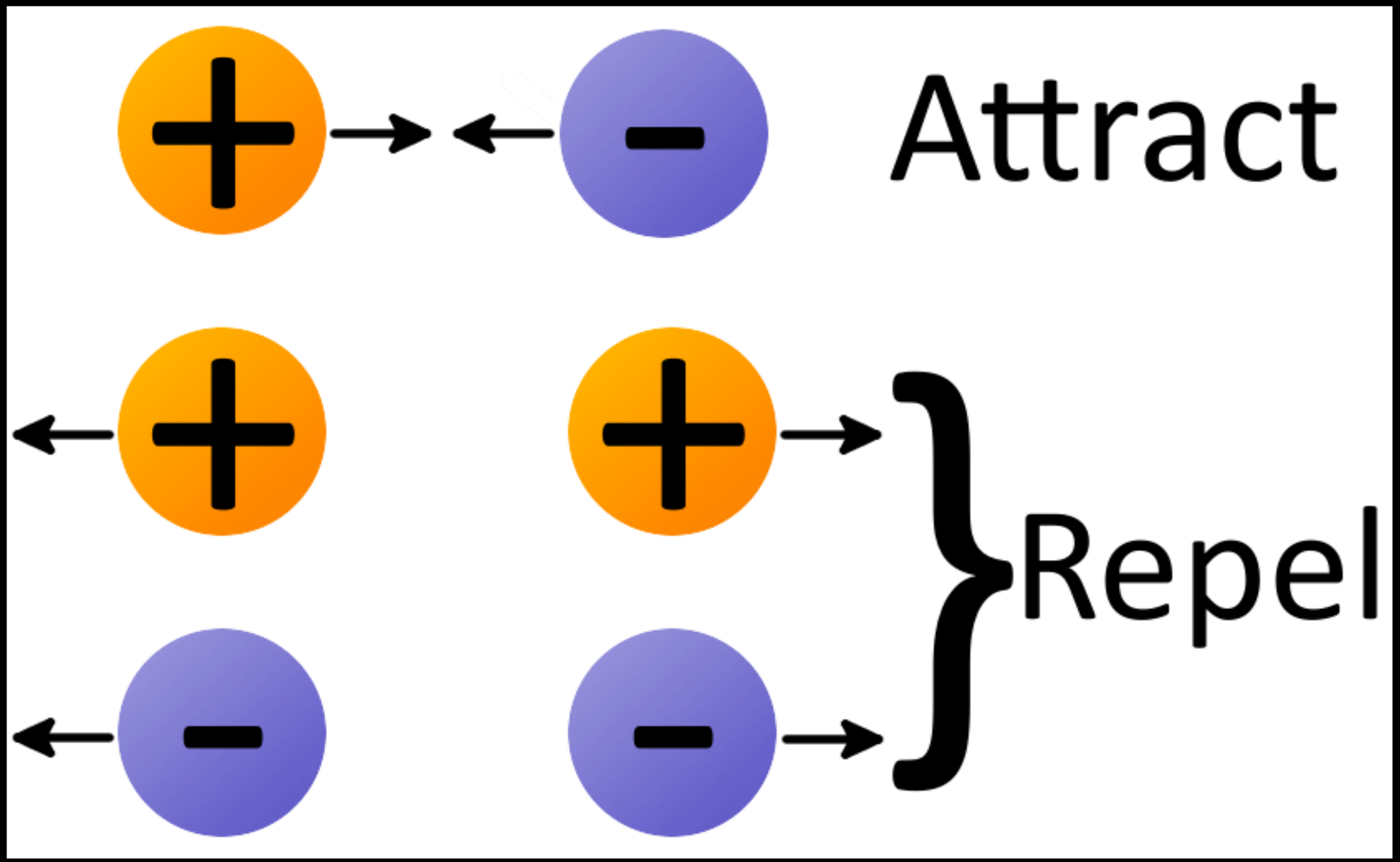
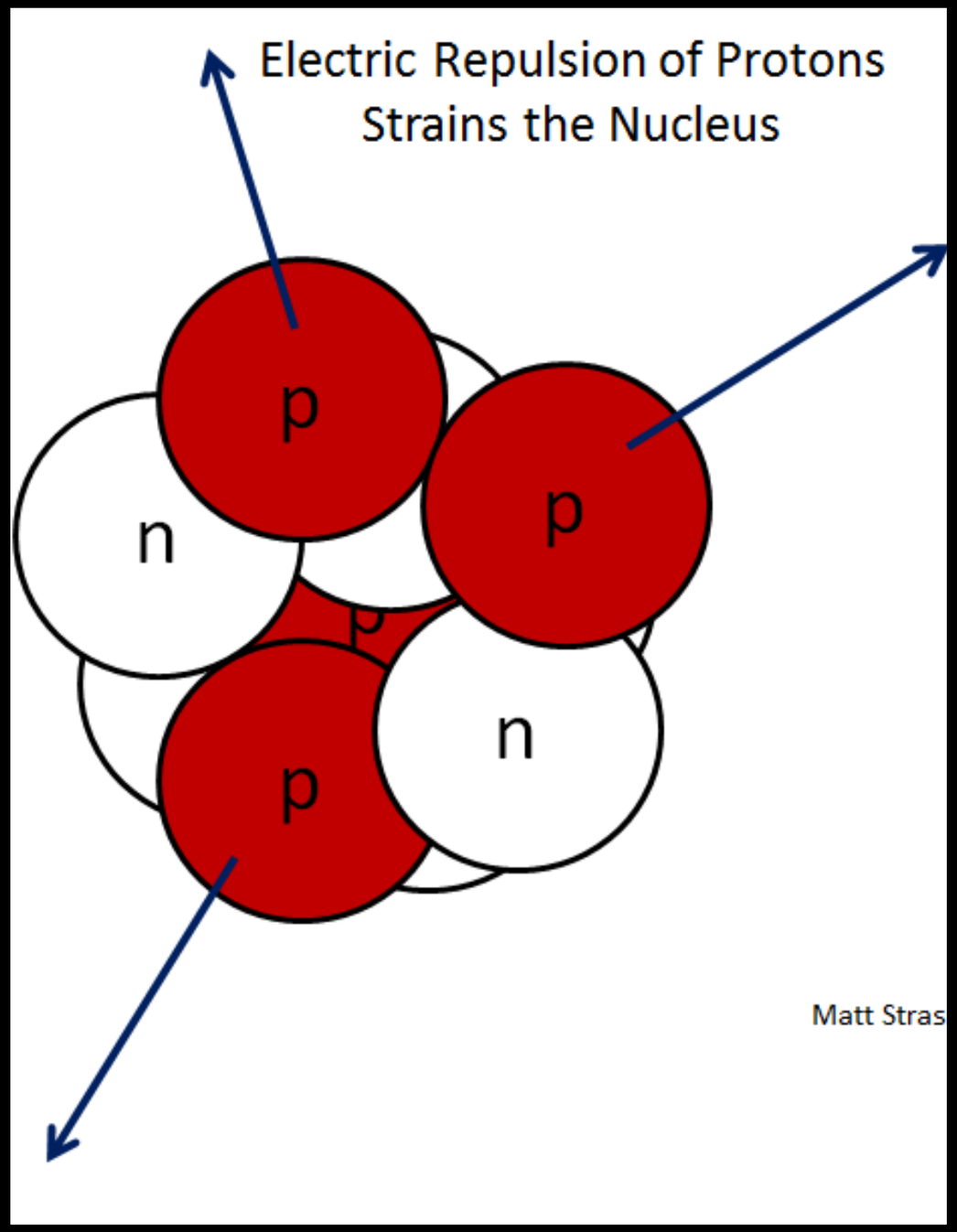
Electromagnetic Force

The electric force try to separate particle with different charge

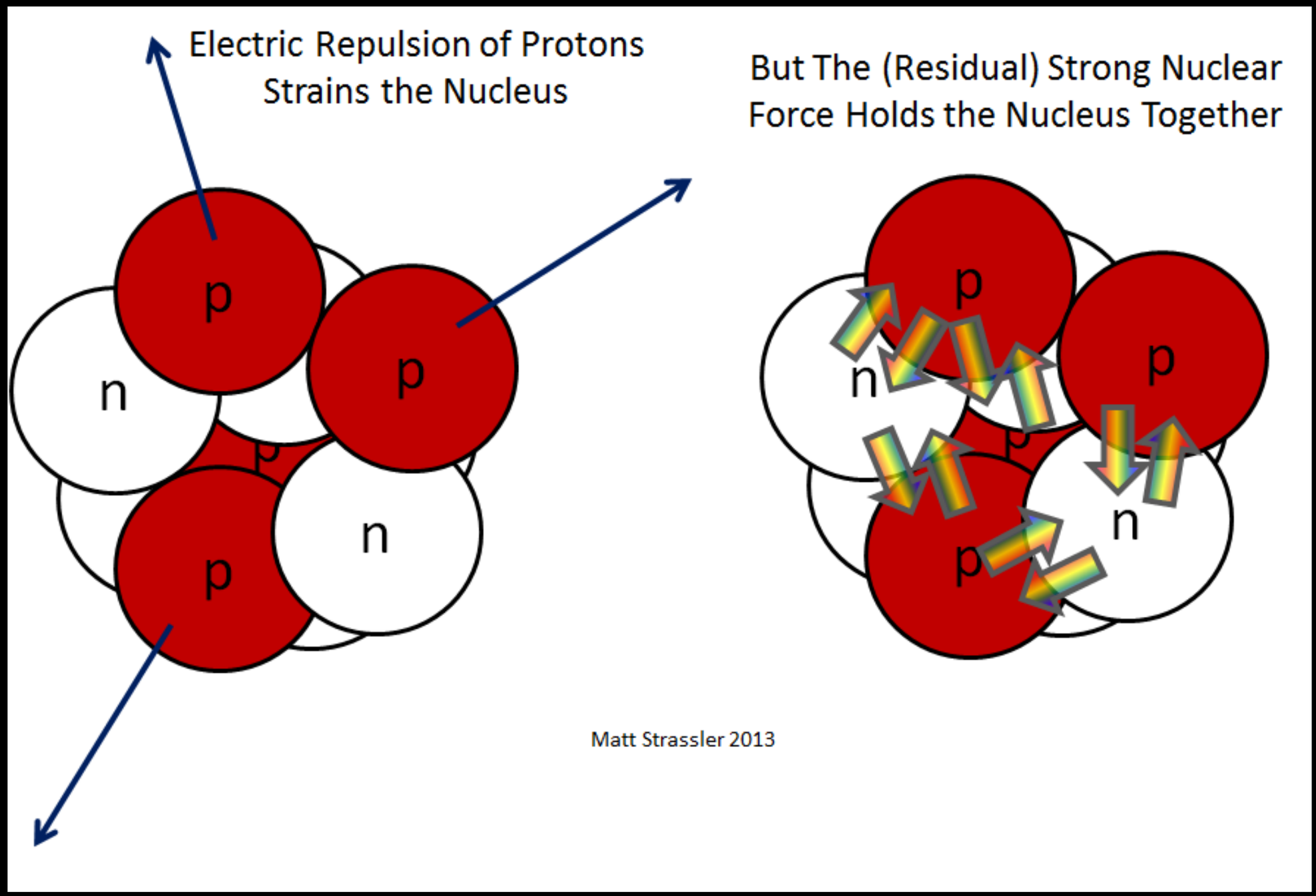


The Nucleus


Electric Repulsion of Protons
Strains the Nucleus
p
p
n
p
n
p
Matt Stras

The Nucleus

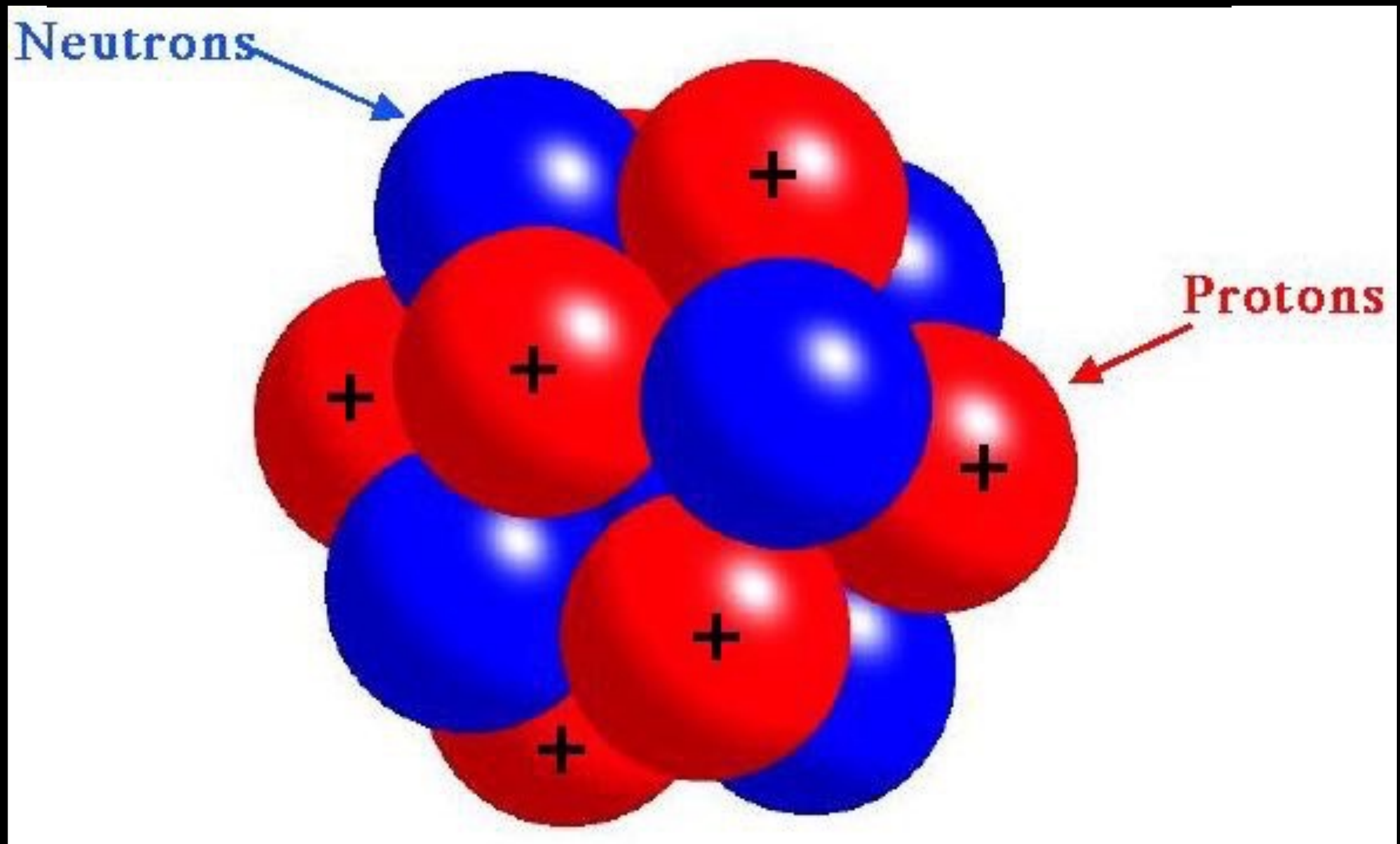
Held together by the strong force



The Nucleus

Held together by the strong force

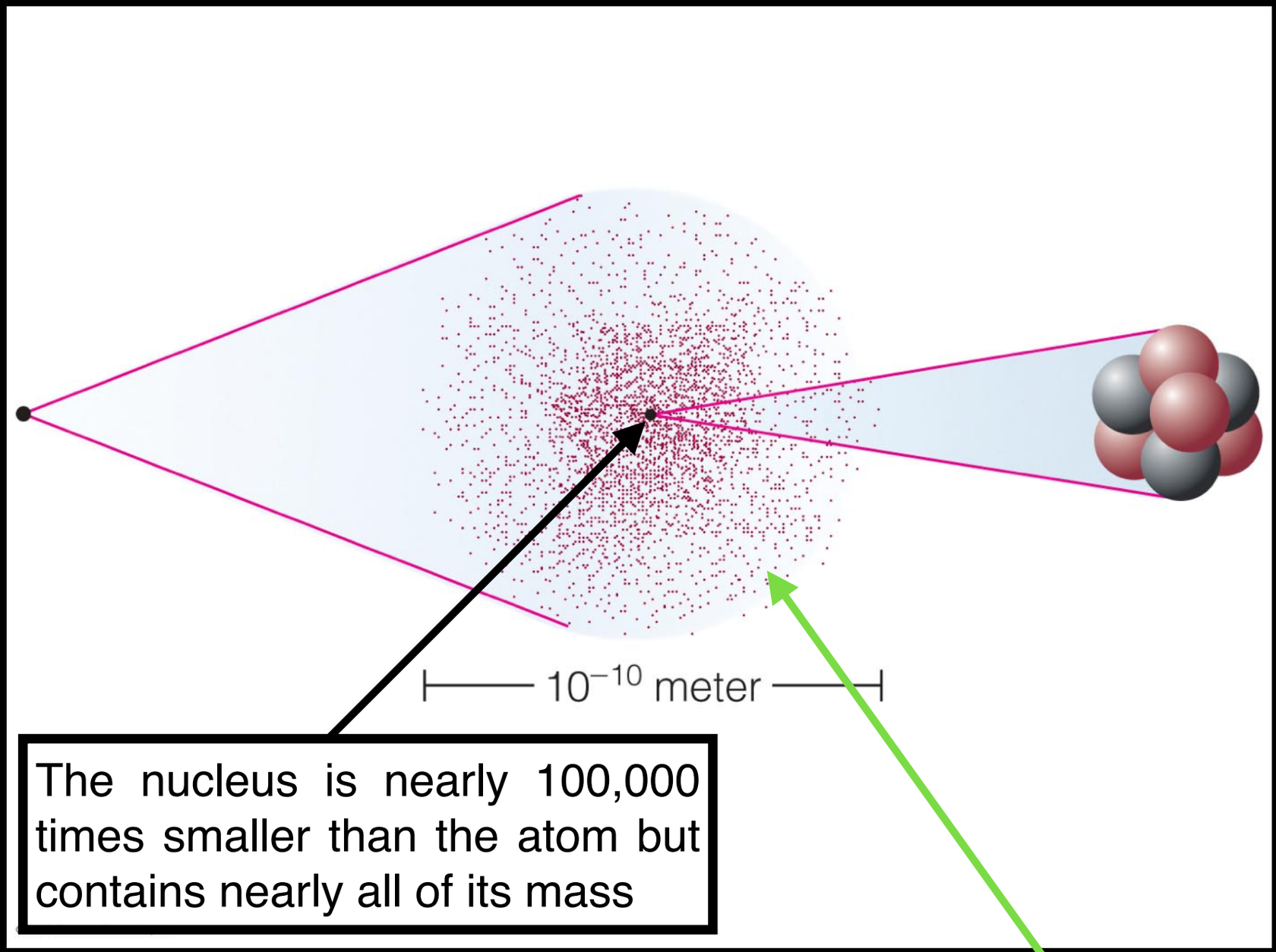
- Tiny in size! (~10^{-15} m)
- Protons and Neutrons have almost the same mass.



The Structure of Atoms

Nuclei have essentially all the mass.

- Electrons travel throughout the volume.



The nucleus is nearly 100,000 times smaller than the atom but contains nearly all of its mass

Each dot does not represent a separate electron! this is a map of where the 4 electrons are likely to spend their time

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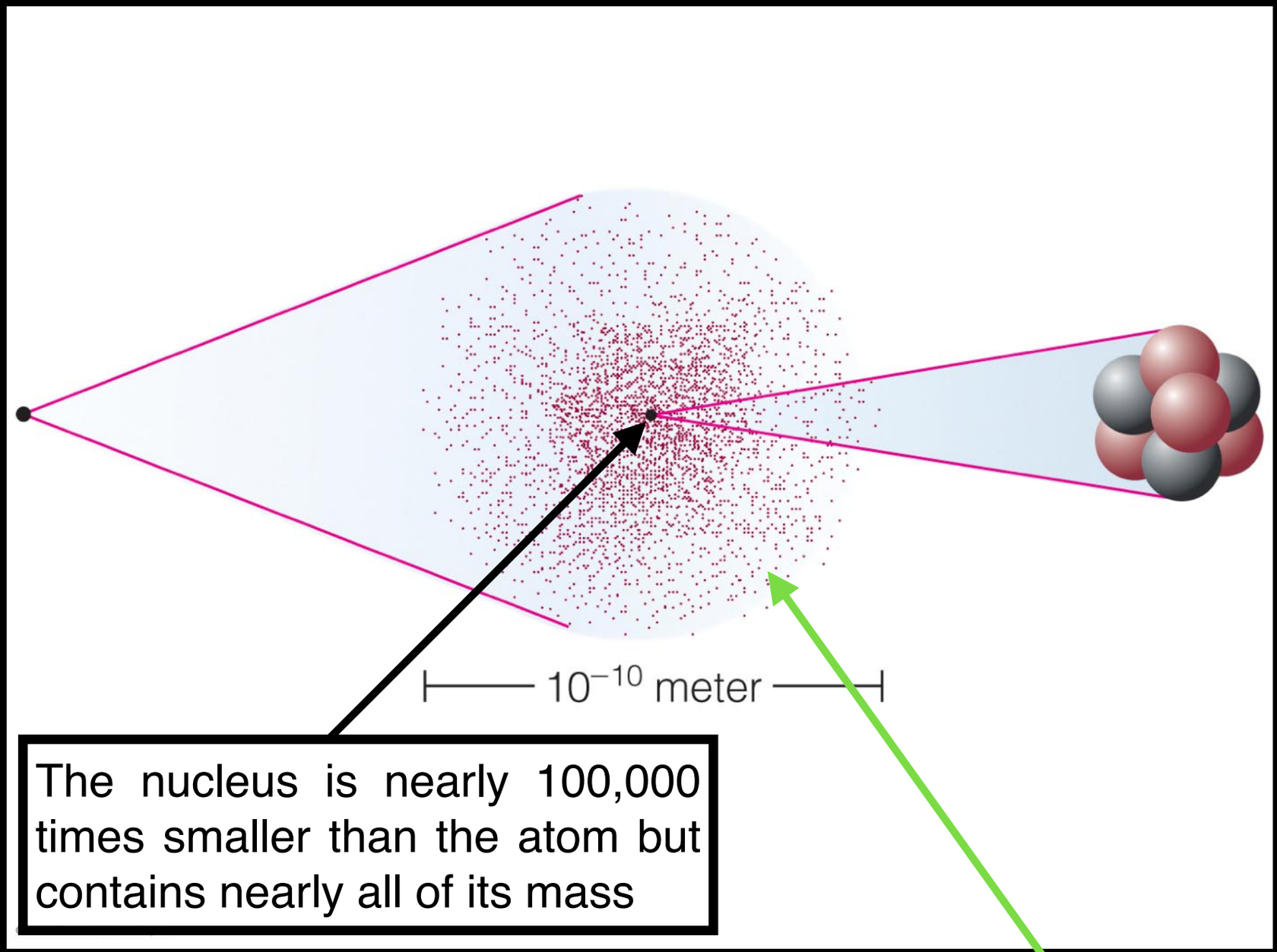

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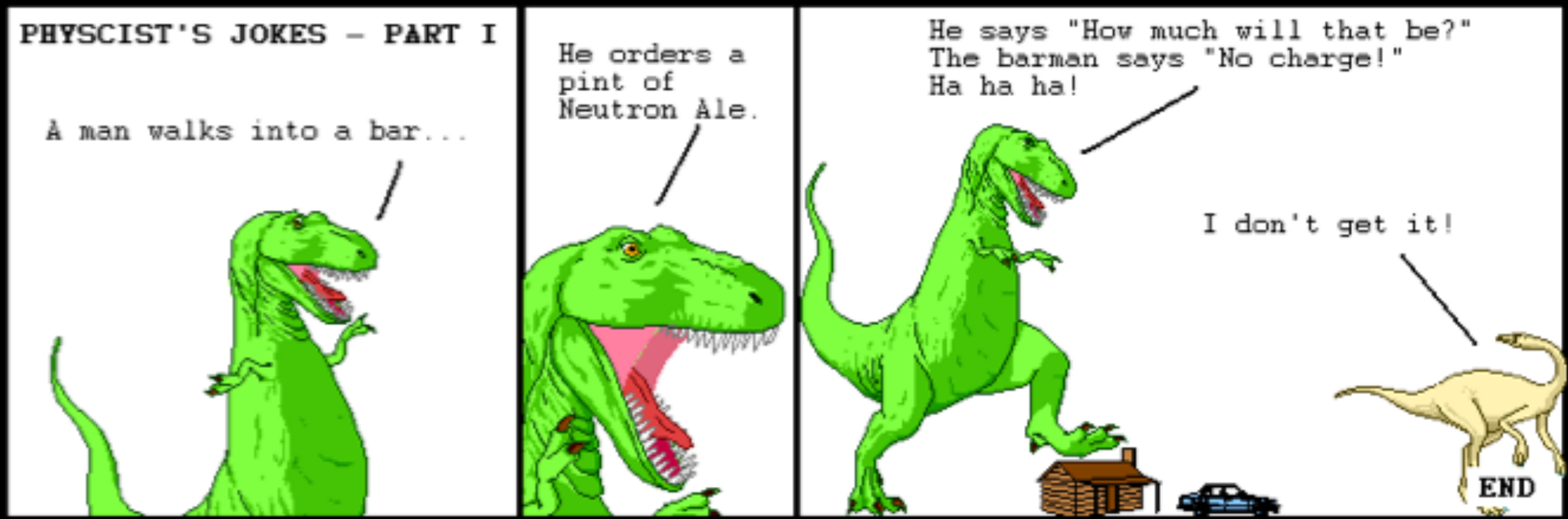

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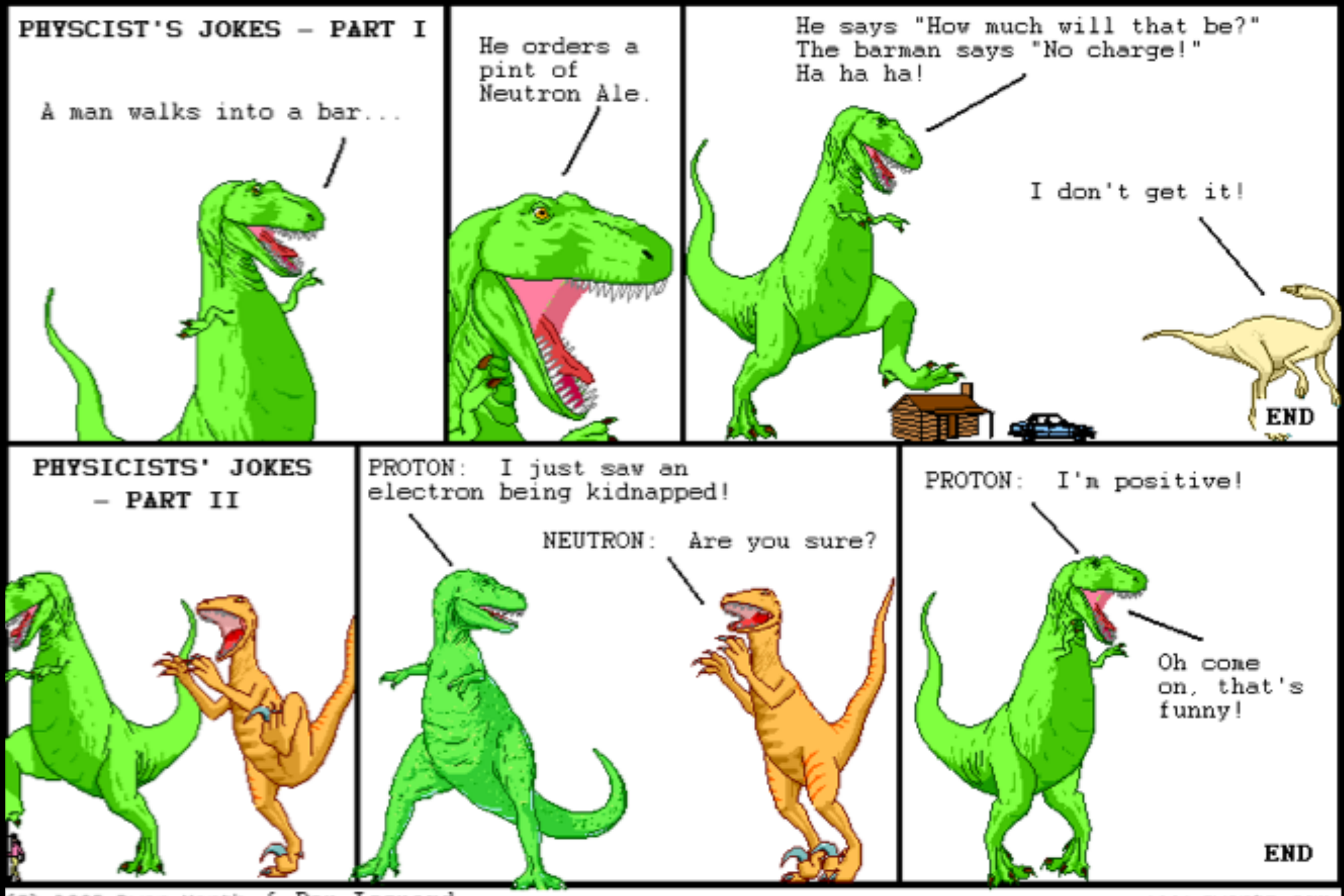
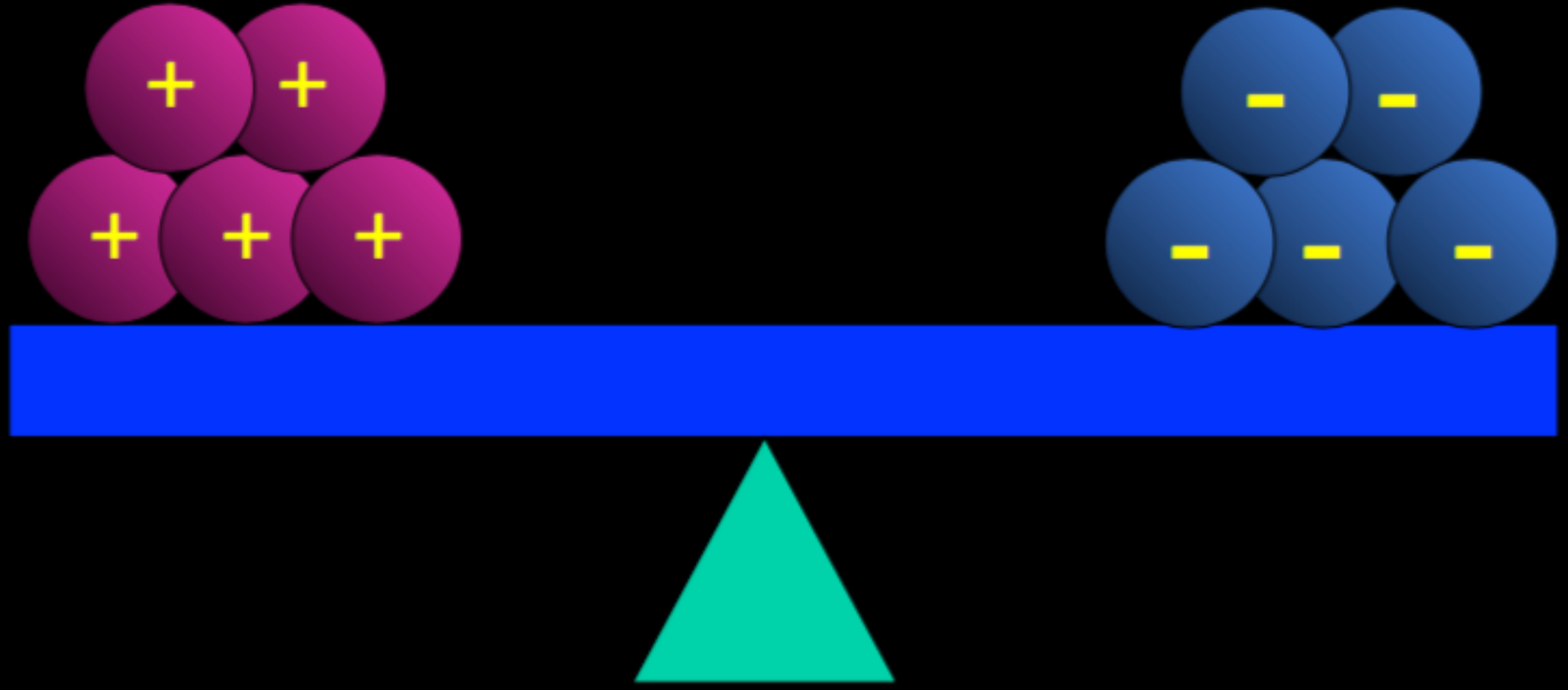


The basic rules of atoms

The basic rules of atoms

An atom wants to have as many electrons as protons (i.e. it wants to be electrically NEUTRAL, with no net charge)



The basic rules of atoms

1 Atoms want: # of Protons = # of Electrons

The number of protons defines the element

# of protons ⟷ **ELEMENT**

1	Hydrogen
2	Helium
6	Carbon
8	Oxygen
26	Iron

Atomic Number

The Periodic Table

	IA	IIA	IIIB	IVB	VB	VIB	VIIB	—	VIIB	—	IB	IIB	IIIA	IVA	VA	VIA	VIIA	0
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	57 *La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	89 +Ac	104 104	105 105	106 106	107 107	108 108	109 109	110 110	111 111	112 112		114 114		116 116		118 118

*Lanthanide Series	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
+Actinide Series	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Each box is a different element, with a different number of protons.

The basic rules of atoms

1 Atoms want: # of Protons = # of Electrons

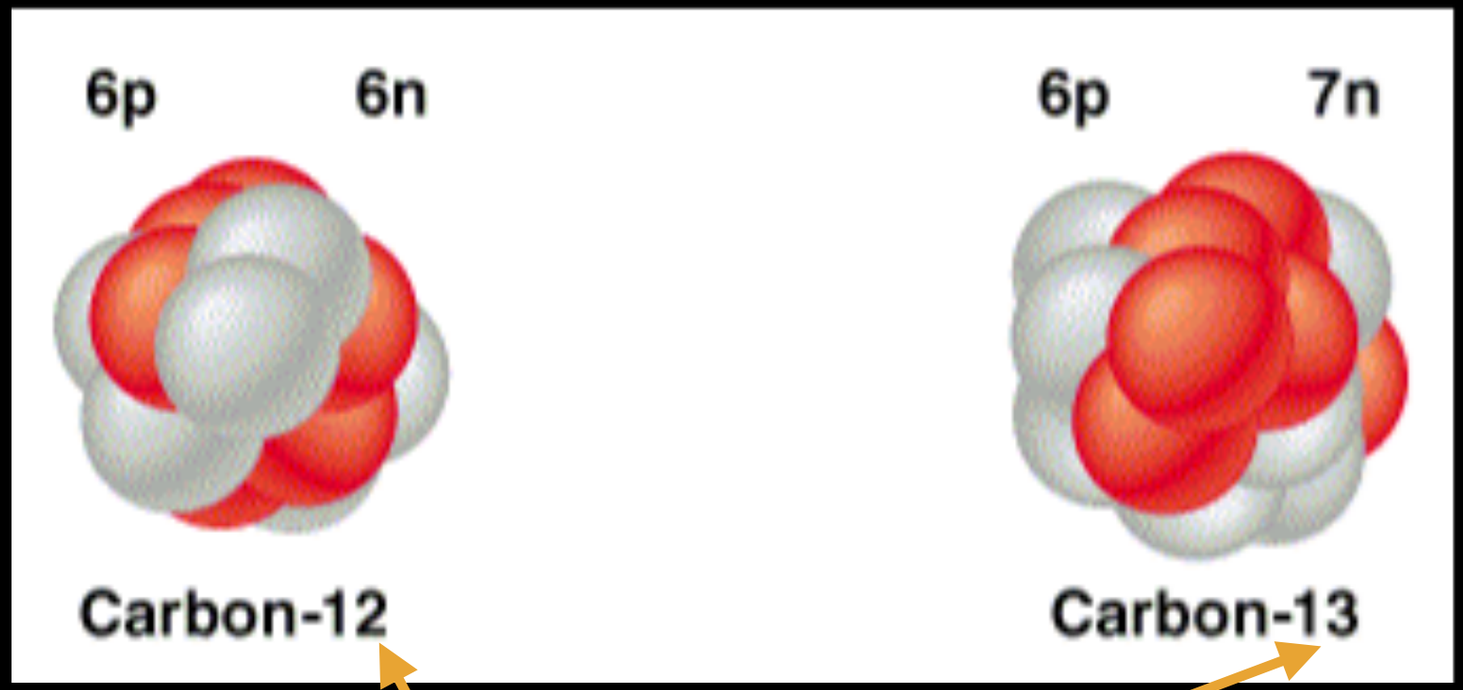
2 The number of protons defines the element

Neutrons add mass, but don't change much about how the atom behaves

# of neutrons ⟷ ISOTOPE

Same element,

but different isotopes!



The basic rules of atoms

1 Atoms want: # of Protons = # of Electrons

2 The number of protons defines the element

3 # of Neutrons ! Isotope, different mass, same chemistry

Question

Oxygen has 8 protons. How many neutrons has the oxygen isotope Oxygen-18 ?

A) 10

B) 8

C) 18

D) 0

E) 1

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Oxygen has 8 protons. How many electrons has the oxygen isotope Oxygen-18 if the atom is electrically neutral?

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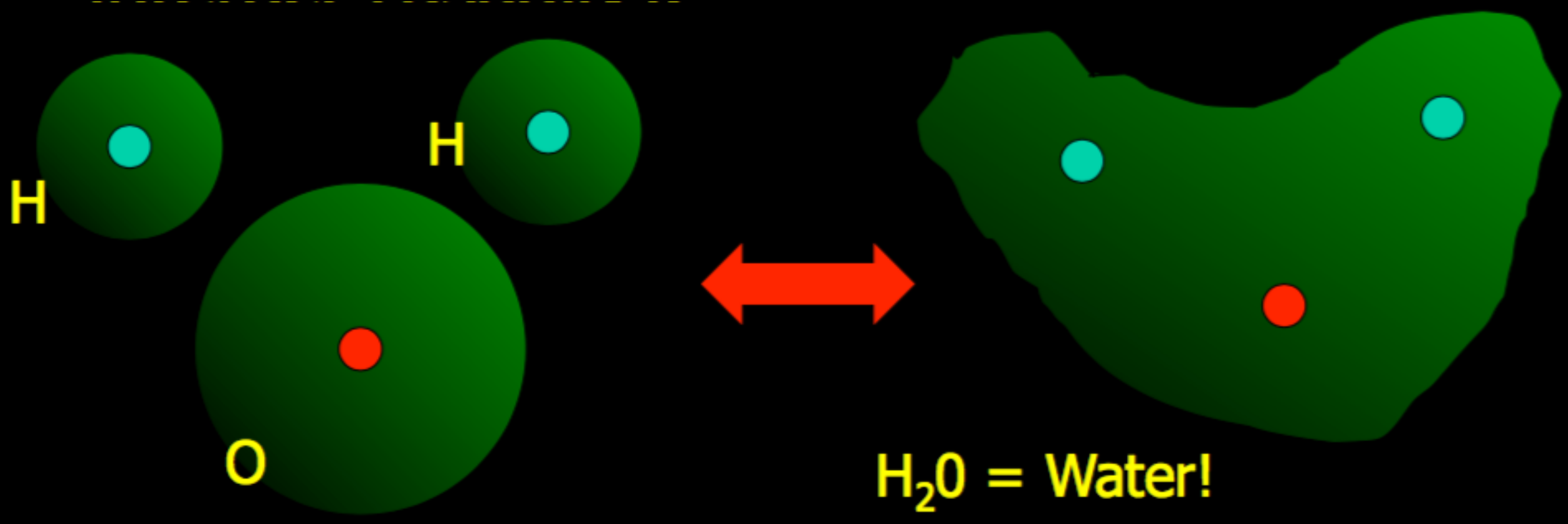
The basic rules of atoms

1 Atoms want: # of Protons = # of Electrons

2 The number of protons defines the element

3 # of Neutrons ! Isotope, different mass, same chemistry

Atoms combine to form molecules by sharing electrons, but the nuclei don't interact (usually).



Elements, Atoms, & Molecules: What's the big deal?

- Universe is made of elements, atoms, and/or molecules raw material for planets, stars, & galaxies

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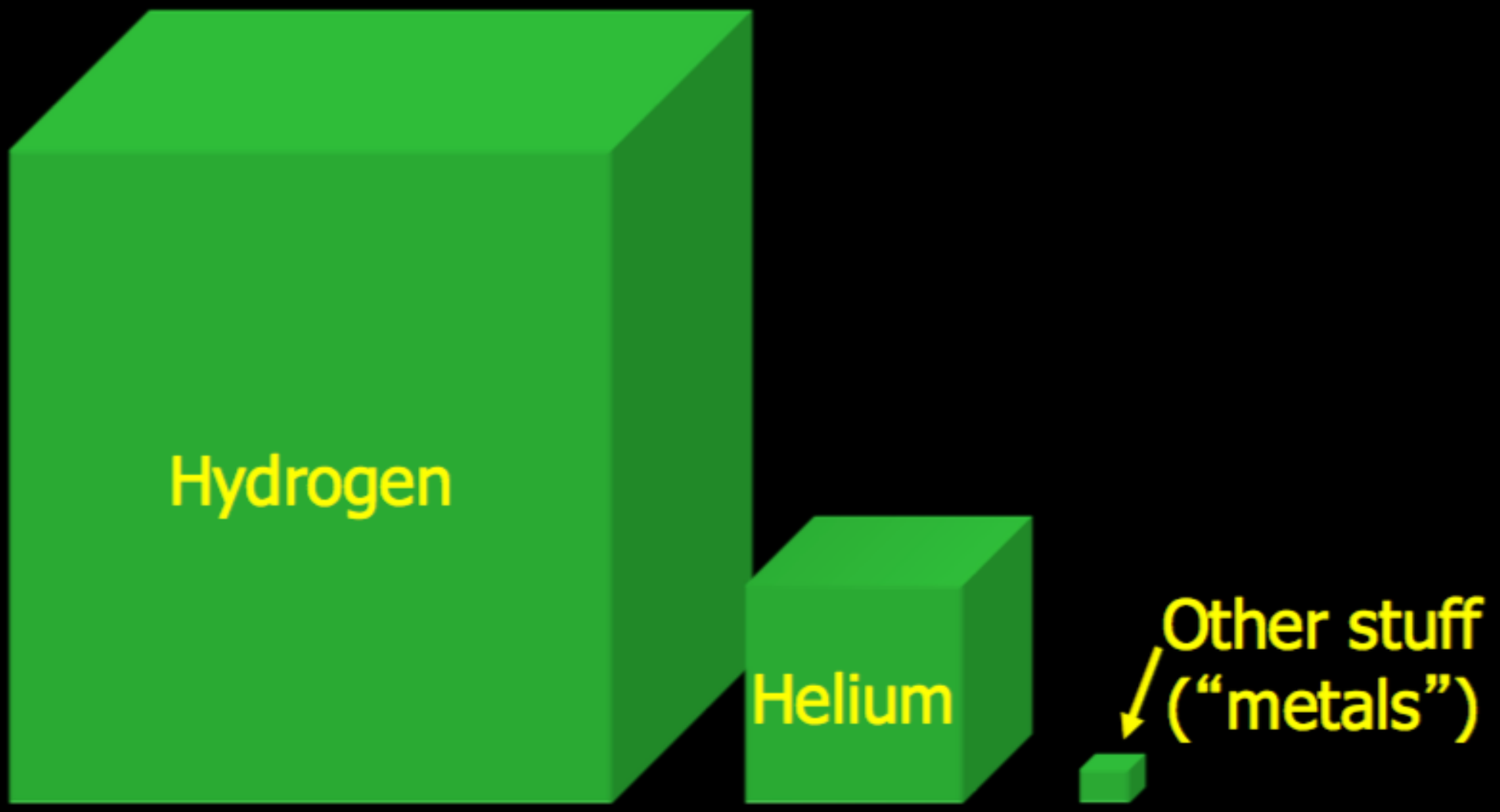
• Space is full of rich **CHEMISTRY**! There are giant cold gas clouds in our own galaxy which form complex molecules (water, sulfuric acid, alcohol, maybe even amino acids???)

Of all the possible elements, the universe is made up almost entirely of Hydrogen and Helium.



Of all the possible elements, the universe is made up almost entirely of Hydrogen and Helium.

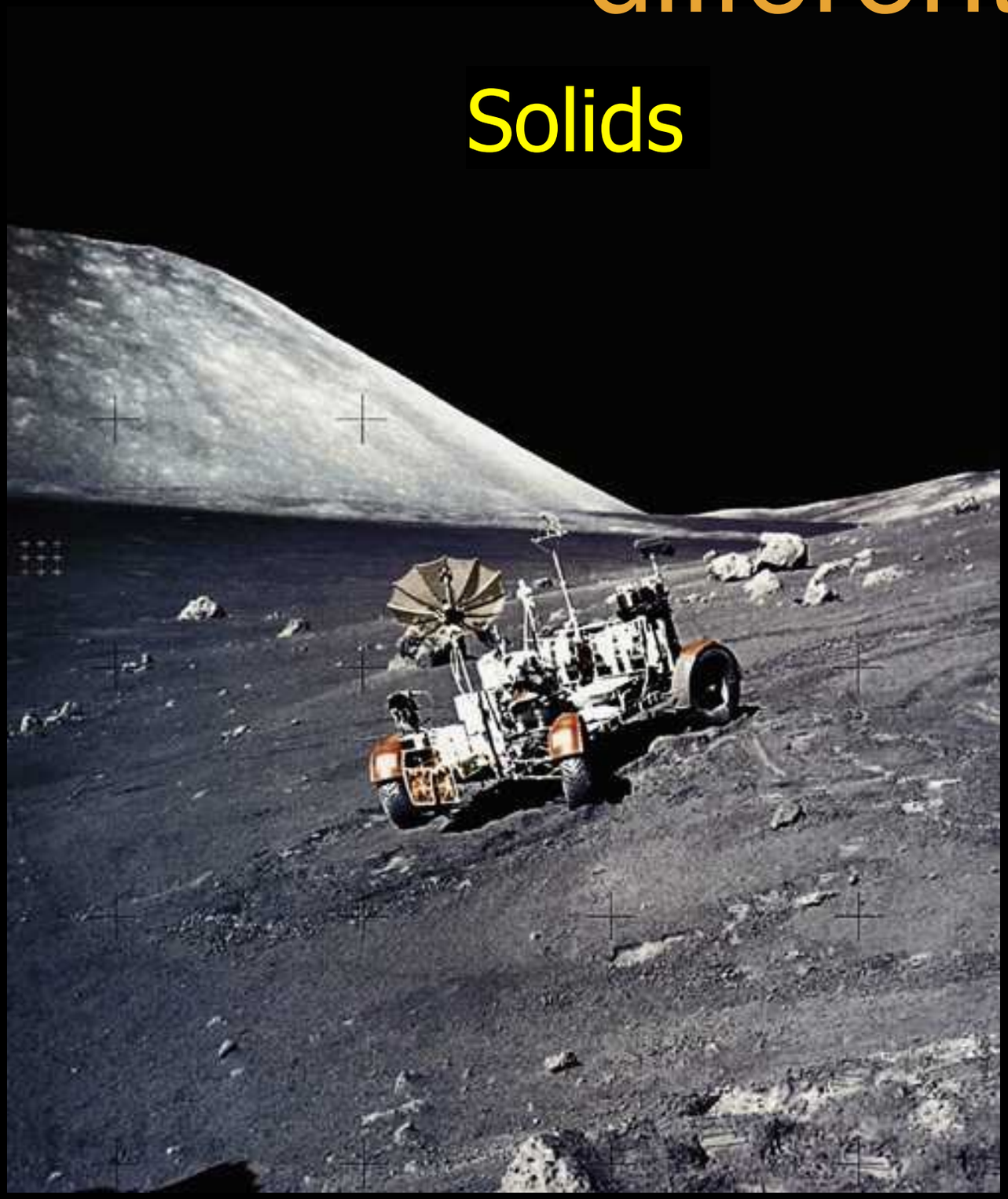
ELEMENT	PERCENTAGE BY NUMBER OF ATOMS	PERCENTAGE BY MASS
Hydrogen	92.0	73.4
Helium	7.8	25.0
Carbon	0.03	0.3
Nitrogen	0.008	0.1
Oxygen	0.06	0.8
Neon	0.008	0.1
Magnesium	0.002	0.05
Silicon	0.003	0.07
Sulfur	0.002	0.04
Iron	0.004	0.2

The states of matter

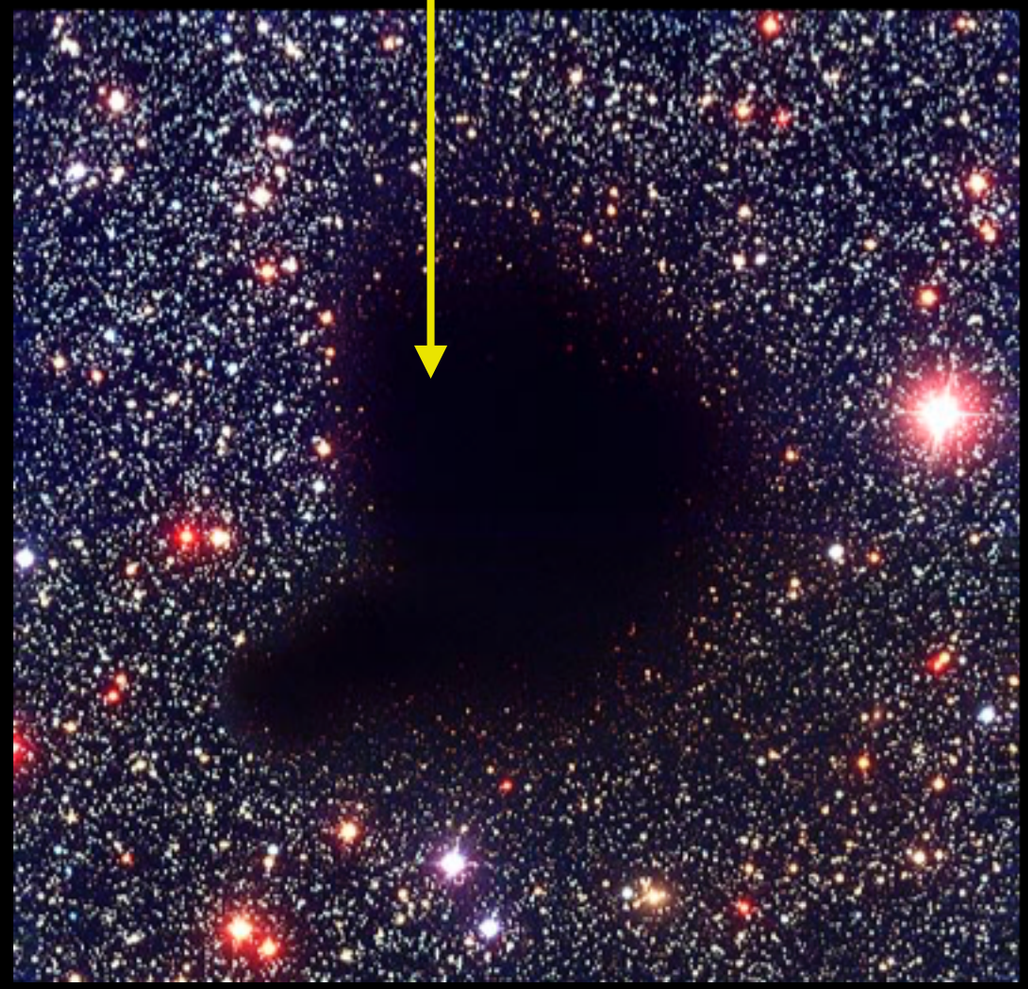
Important for understanding, for example, the formation of the Solar System

These elements occur in many different states.

Solids



Interstellar dust cloud



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Solids

Liquids (not much)

These elements occur in many different states.

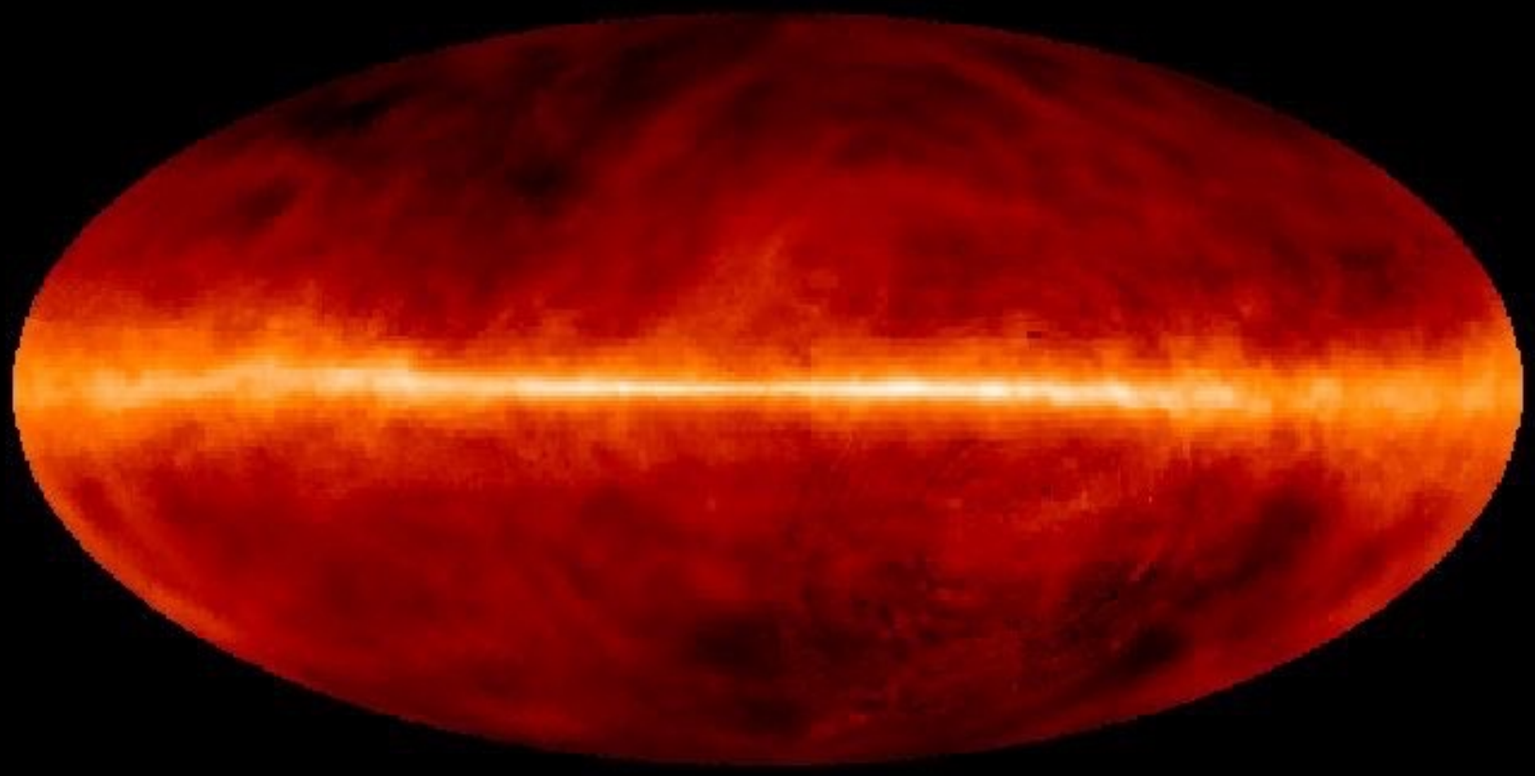
Solids

Liquids (not much)

Gas (lots!)

Optical

Hydrogen Gas



These elements occur in many different states.

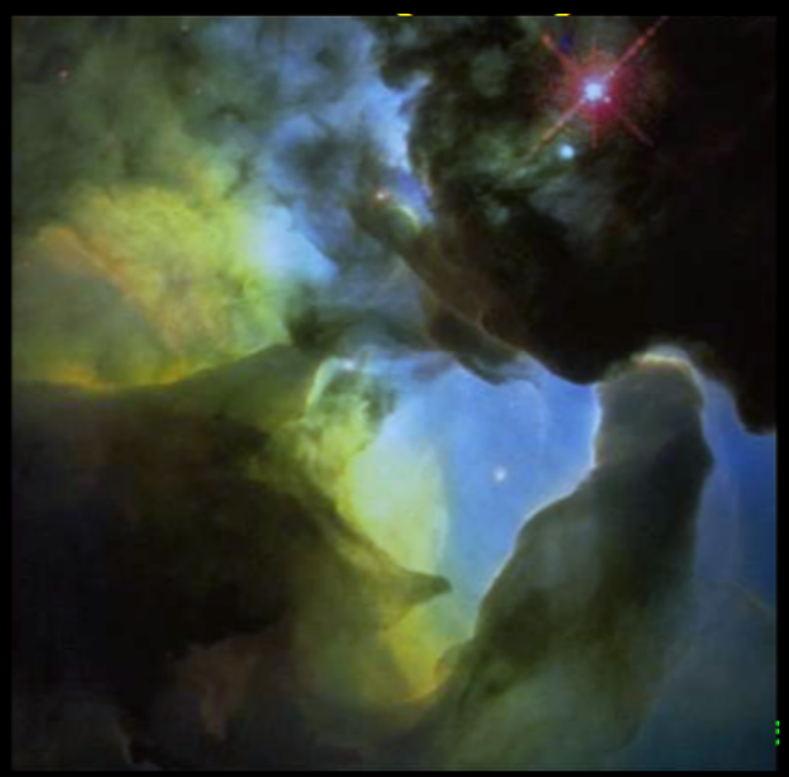
Solids

Liquids (not much)

Gas (lots!)

“Ionized” Gas, or Plasma (lots)

Star formation regions



The same material can exist in many different states

For Example water

What's the difference between these states of matter?

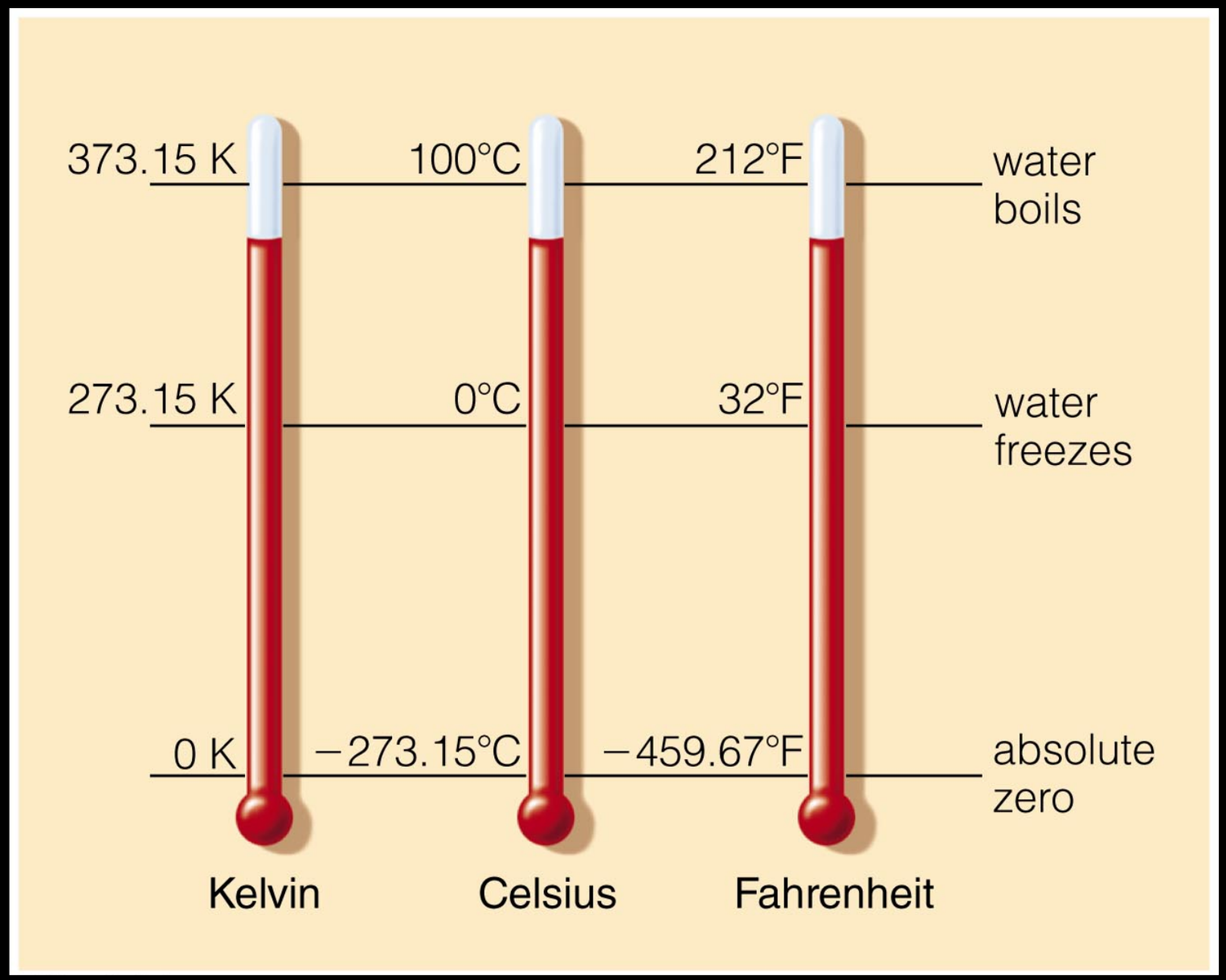
What's the difference between these states of matter?

Temperature alters the structure of the atoms and/or molecules.

Temperature Scales

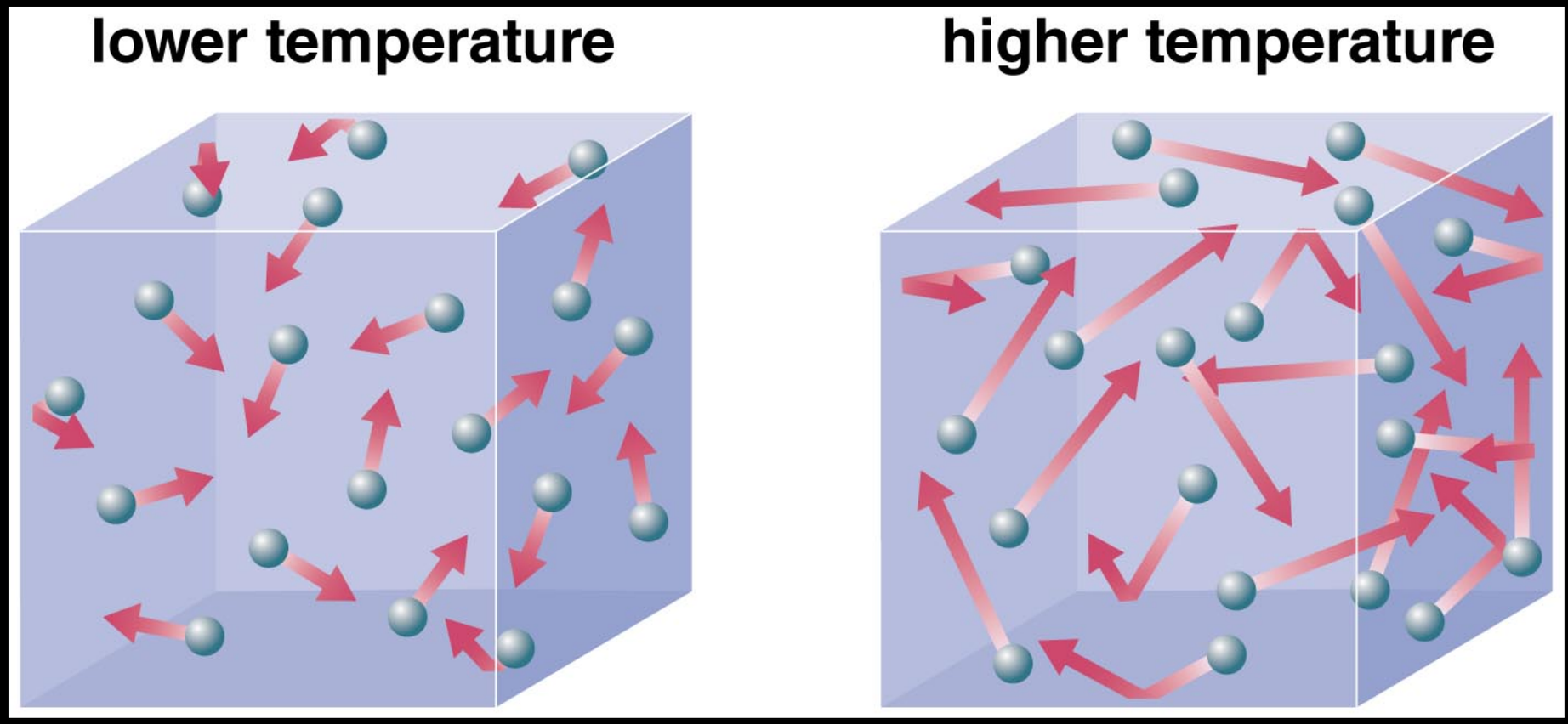
- Astronomers & physicists use "Kelvins".
- Temperature differences are the same as Celsius, but

"zero" corresponds to a different temperature.



"absolute zero" is the coldest that matter can be.

What is temperature, really?



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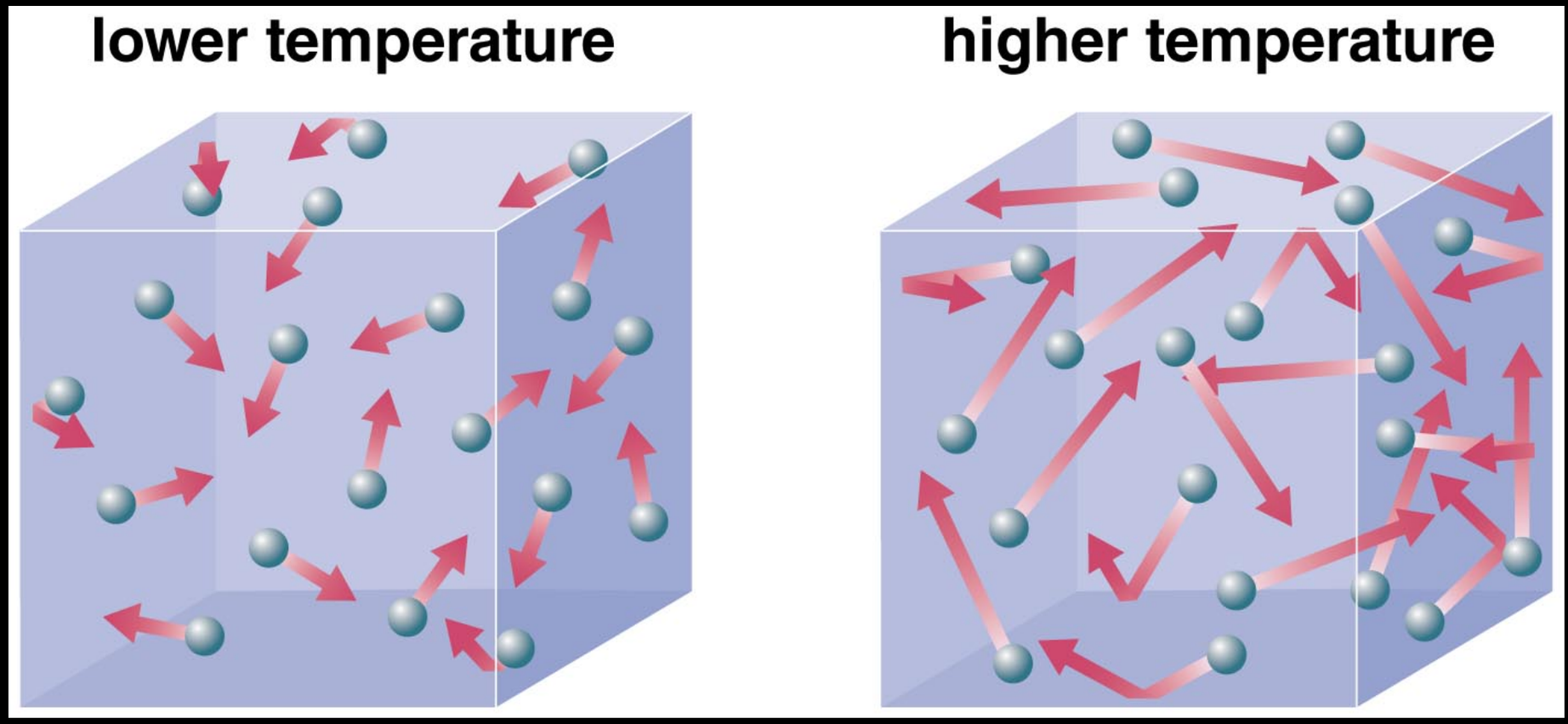
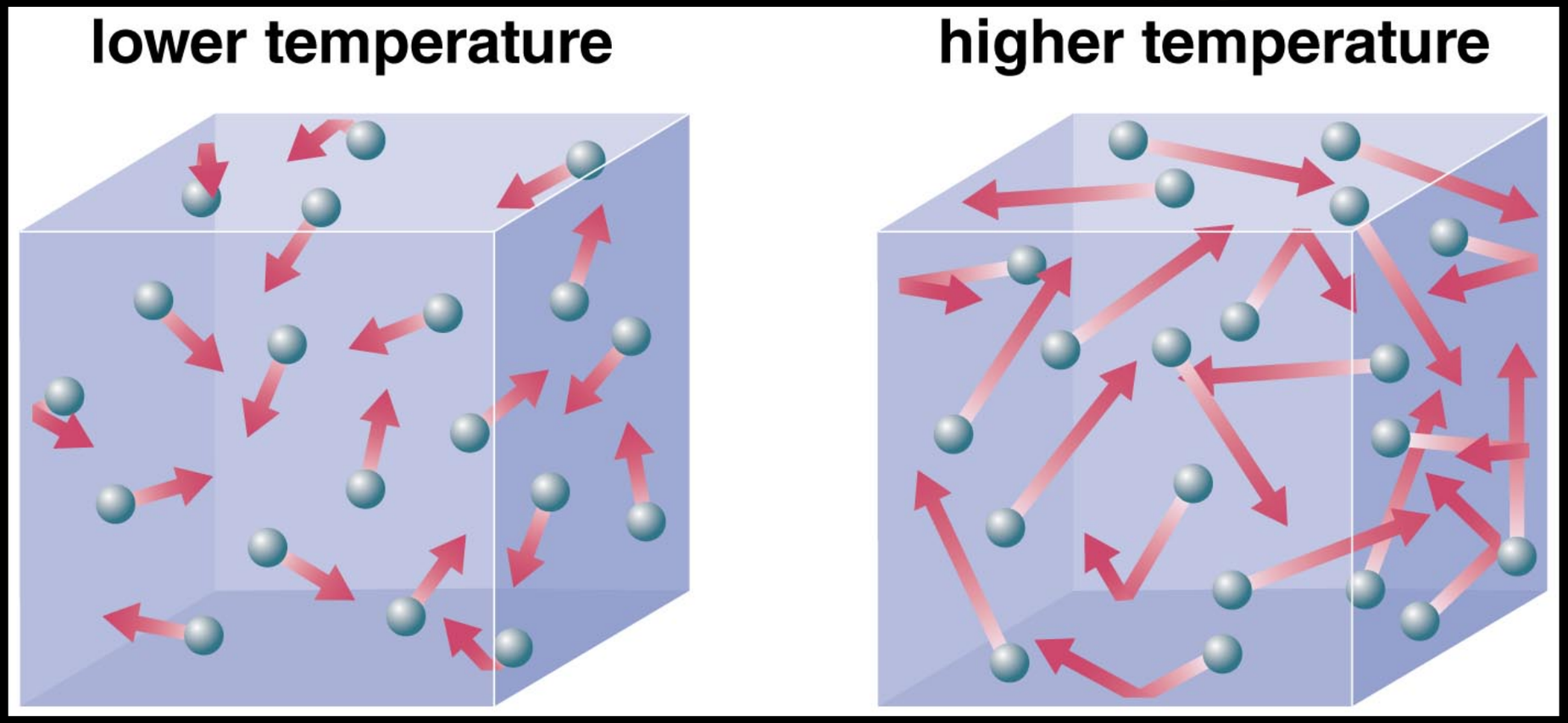


- Temperature represents the average kinetic energy of the particles

  (and thus their average speed)

- Higher Temp! Higher typical speeds
- Absolute Zero is where nothing is moving

Temperature is not the same as Thermal Energy



- Temperature: the average energy per particle (depends on typical particle speed)

- Thermal Energy (Heat): the total energy due to particle motion (depends on both speed & number of particles (mass)).

Temperature can change the phase of matter

- Increasing temperature means increasing speeds of the particles
- Increase particle speeds means more violent motions and collisions
- These can:
  - break up solids

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  - break up molecules into atoms

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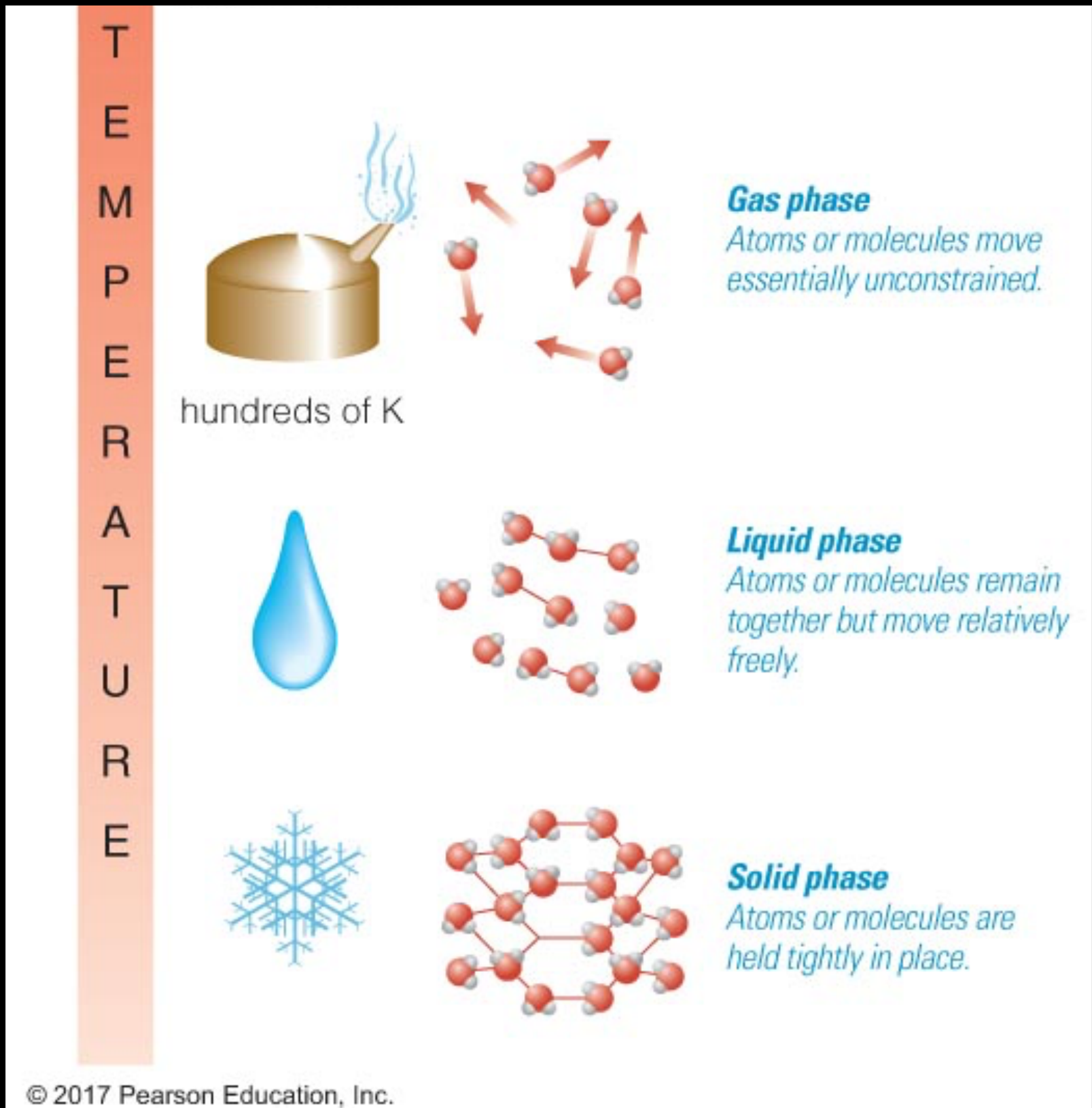
- Increase particle speeds means more violent motions and collisions
- These can:
  - break up solids
  - cause liquids to boil
  - break up molecules into atoms
  - knock electrons off atoms

At high temperatures, the structure of atoms begins to change!

Collisions between atoms convert kinetic energy into electric potential energy

Electrons become so energetic, that they can be easily stripped from their nuclei. The atoms become **IONIZED**. The naked nuclei are called **IONS**.

Phase of the matted (low T)



Phase of the matted (high T)