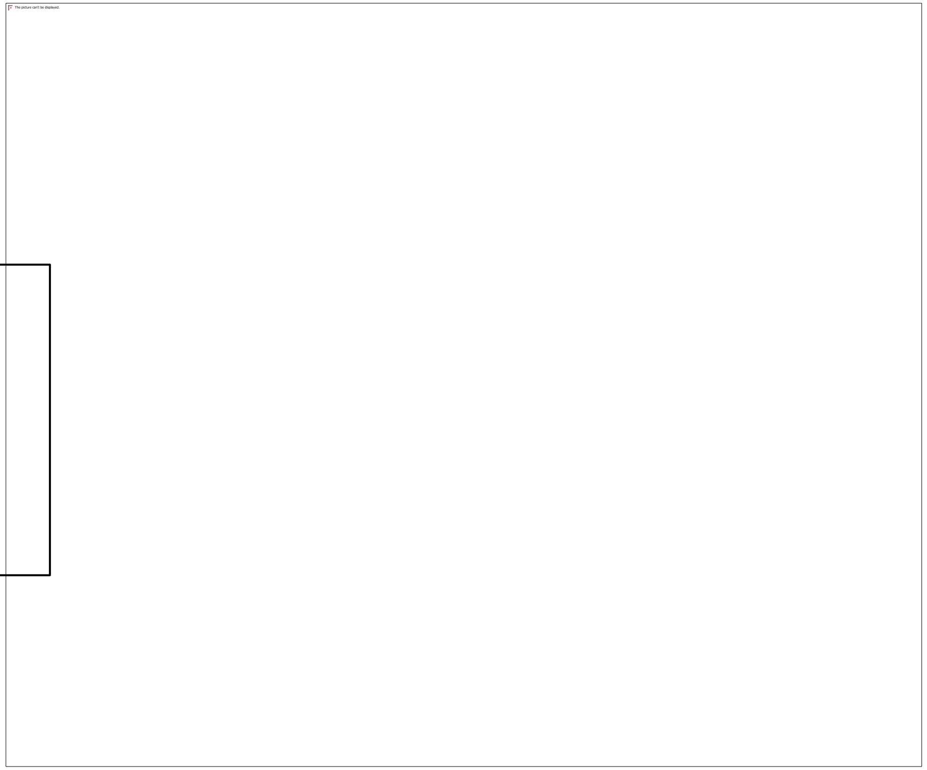
The History & Make-Up of Atoms

Atoms

Atoms are the basic building blocks for all objects in universe, and all elements discovered (or made) are made of different atoms (by elements, I mean “Carbon”, Helium”, Aluminum”, etc.) The atom was originally thought to be smallest particle around, but then, discoveries of sub-atomic particles were made! We have:

1. Proton (+) = Defines the element!, positively charged, mass = 1.7×10^{-27} kilograms
2. Electron (-) = negatively charged, mass = 9.1×10^{-31} kilograms
3. Neutron = no charge, same mass as proton



Math Problem!

The electron’s mass is considered negligible relative to the proton. Why? Show with examples or a proof.

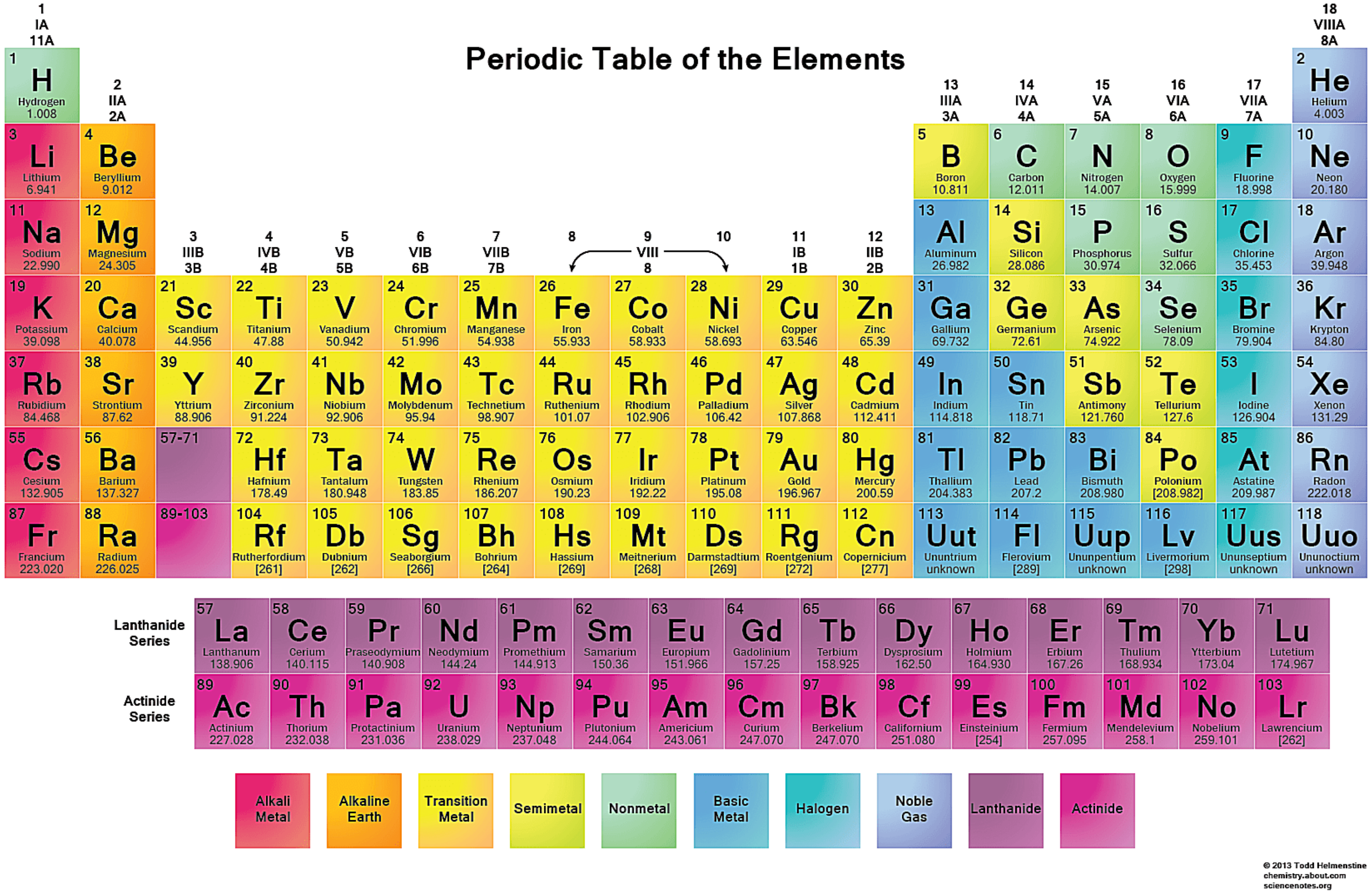
This is a COMPARATIVE size question, so we just use the exponents as a ratio to compare!
10^{-27} vs 10^{-31} → $10^{-27} / 10^{-31}$ → 10 (-27-(-31)) =
10^(-27+31) = 10^4 = 10000. The proton is ten thousand times more massive then the electron!

Atom Make-up

Protons & Neutron = exist in nucleus
Electron = exist outside of the nucleus (more on this later)

The Periodic Table

Elements are organized into the Periodic Table of Elements. They are organized into columns by their similarities in chemical properties:

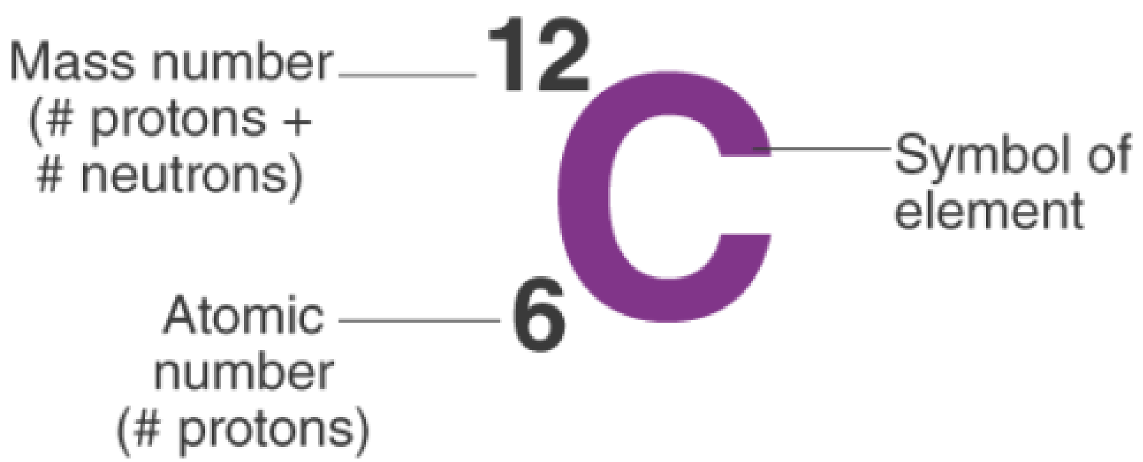


For each element, we can directly relate the amount of protons, electrons and neutrons that exist.
But first, we need to learn some terms!

Symbol of Element
1 or 2 letter abbreviation for each element

Mass Number
- Not always a whole number (more on this later!)
- #protons + #neutrons

Atomic Number
#protons (defines the element!)



Thus,

# of protons = atomic number (defines the element!)
# of electrons = # of protons (if neutral)
# of neutrons = Mass Number - Atomic number

Math Problem!

Using the provided periodic table, calculate the number of protons, electrons, and neutrons for each of the following:

1. Fluorine (F)
2. Iron (Fe)
3. Charged Oxygen (O^{-2})
4. Chlorine (Cl)

1	2											3	4	5	6	7	0
				Key			1 **H** hydrogen 1										4 **He** helium 2
7 **Li** lithium 3	9 **Be** beryllium 4			relative atomic mass **atomic symbol** name atomic (proton) number								11 **B** boron 5	12 **C** carbon 6	14 **N** nitrogen 7	16 **O** oxygen 8	19 **F** fluorine 9	20 **Ne** neon 10
23 **Na** sodium 11	24 **Mg** magnesium 12											27 **Al** aluminium 13	28 **Si** silicon 14	31 **P** phosphorus 15	32 **S** sulfur 16	35.5 **Cl** chlorine 17	40 **Ar** argon 18
39 **K** potassium 19	40 **Ca** calcium 20	45 **Sc** scandium 21	48 **Ti** titanium 22	51 **V** vanadium 23	52 **Cr** chromium 24	55 **Mn** manganese 25	56 **Fe** iron 26	59 **Co** cobalt 27	59 **Ni** nickel 28	63.5 **Cu** copper 29	65 **Zn** zinc 30	70 **Ga** gallium 31	73 **Ge** germanium 32	75 **As** arsenic 33	79 **Se** selenium 34	80 **Br** bromine 35	84 **Kr** krypton 36
85 **Rb** rubidium 37	88 **Sr** strontium 38	89 **Y** yttrium 39	91 **Zr** zirconium 40	93 **Nb** niobium 41	96 **Mo** molybdenum 42	[98] **Tc** technetium 43	101 **Ru** ruthenium 44	103 **Rh** rhodium 45	106 **Pd** palladium 46	108 **Ag** silver 47	112 **Cd** cadmium 48	115 **In** indium 49	119 **Sn** tin 50	122 **Sb** antimony 51	128 **Te** tellurium 52	127 **I** iodine 53	131 **Xe** xenon 54
133 **Cs** caesium 55	137 **Ba** barium 56	139 **La*** lanthanum 57	178 **Hf** hafnium 72	181 **Ta** tantalum 73	184 **W** tungsten 74	186 **Re** rhenium 75	190 **Os** osmium 76	192 **Ir** iridium 77	195 **Pt** platinum 78	197 **Au** gold 79	201 **Hg** mercury 80	204 **Tl** thallium 81	207 **Pb** lead 82	209 **Bi** bismuth 83	[209] **Po** polonium 84	[210] **At** astatine 85	[222] **Rn** radon 86
[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac*** actinium 89	[261] **Rf** rutherfordium 104	[262] **Db** dubnium 105	[266] **Sg** seaborgium 106	[264] **Bh** bohrium 107	[277] **Hs** hassium 108	[268] **Mt** meitnerium 109	[271] **Ds** darmstadtium 110	[272] **Rg** roentgenium 111	Elements with atomic numbers 112 – 116 have been reported but not fully authenticated						

* The Lanthanides (atomic numbers 58 – 71) and the Actinides (atomic numbers 90 – 103) have been omitted.

Relative atomic masses for **Cu** and **Cl** have not been rounded to the nearest whole number.

Solutions

Fluorine (F)

Protons = atm # = 9

Neutrons = 19 – 9 = 10

Electrons = protons = 9

Iron (Fe)

Protons = atm # = 26

Neutrons = 56 – 26 = 30

Electrons = protons = 26

Charged Oxygen (O^{-2})

Protons = atm # = 8

Neutrons = 16 – 8 = 8

2 more electrons = 10 electrons

Chlorine (Cl)

Protons = atm # = 17

Neutrons = 35.5 – 17 = 18.5

Electrons = protons = 17

Is their more than one answer possible for #3? Why or Why not?

Mathematically yes, BUT if the proton number changes, then we no longer have Oxygen, so there is only the one answer possible (above).

What do you notice about Chlorine?

½ neutron! ½ neutron! Is that possible? No, so see next page ;)

The Truth About The Atomic Mass Number!

Many elements occur naturally in different varieties. As we saw with problem 3, electrons may be added or taken away to create charged elements called **ions** (positively charged = cations; negatively charged = anions).

But we can also vary the number of neutrons in the nucleus while NOT changing the number of protons (why is this?). This creates the same element with different masses and thus different atomic mass numbers. These are referred to as **isotopes** of an element.

Isotopes = Different version of the same element due to its neutrons. They are found in nature in specified %'s (done so experimentally).

For example:

C-12 = Carbon 12 features 6 protons + 6 neutrons in its nucleus; It's Percentage Abundance is 98.90%
C-13 = Carbon 13 features 6 protons + 7 neutrons in its nucleus; It's Percentage Abundance is 1.10%

Carbon's listed and PT table mass is **12.011**. How did that number get calculated?

Via **Weighted Average** Calculations!

(Mass of X isotope x % abundance**) + (**Mass of Y isotope x % abundance**) + ... = avg mass** (also referred to as amu)

Math Problems!

1) Set-up the equation to calculate the average atomic mass of Nitrogen (N) based on the information given:

Isotope	**Mass**	**% Abundance**
N-14	14.003074	99.63%
N-15	15.000108	0.37%

2) The final grade for "Math Taught the Right Way (MTRW)" is calculated via weighted averages. What is final grade if the following were true?

Homework	**Attendance**	**Final**
20% of grade	20% of grade	60% of grade
800 points out of 1000 total points available	16 classes attended out of 20 classes given	90% on test

Answers!

1)

(14.003074)(.9963) + (15.000108)(.0037) = 14.007

2)

.20 (800/1000) + .20 (16/20) + .6 (90/100)

.20 (4/5) + .20 (4/5) + .6 (9/10)

.20 (.8) + .20 (.8) + .6 (.9)

.16 + .16 + .54

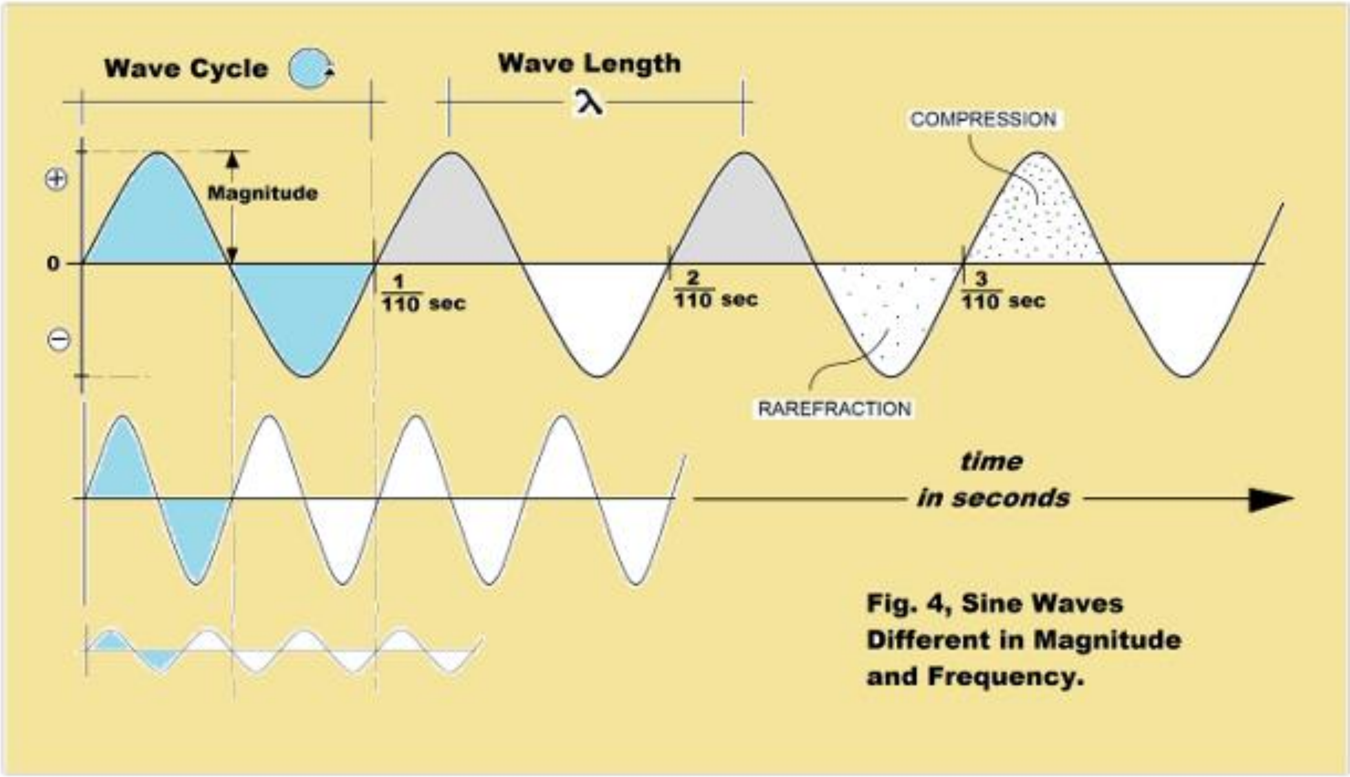
.86 = 86%

Let’s transition to light and PHOTONS! We will relate this soon to Electrons ;)

Light is defined as both a WAVE and a PARTICLE!

As a PARTICLE, light exists in defined quantities known as Light Quanta or Photons, and these photons have energy associated with them (same is true for ANY moving object – think physics!). A photon is considered to be massless with no electric charge.

As a WAVE, light has properties of waves, including frequency (how often the cycle occurs) and wavelength (the length of each cycle). Mathematically, it looks like this:



Because light travels and has energy, we can calculate it's energy and properties!

$E = hf$

E = Energy of the Photon (Joules)
h = Planck's Constant = 6.626×10^{-34} J-s = 6.6×10^{-34} J-s
f = frequency of photon (hertz, cycles/second = 1/s))

BUT, for waves, we can relate the frequency to the wavelength via it's speed (true for any constant wave)!
Speed = frequency (f) x wavelength (λ)
(wavelength = λ (lambda), measured in meters)

For **light** then:
Speed of light = **frequency** (f) x **wavelength** (λ)
c = frequency (f) x wavelength (λ)

$c = f \times \lambda$

Where c = speed of light = 3×10^8 meters/second – Super fast!

Therefore, combining this equation with the equation above:

$E = hf = hc/\lambda$

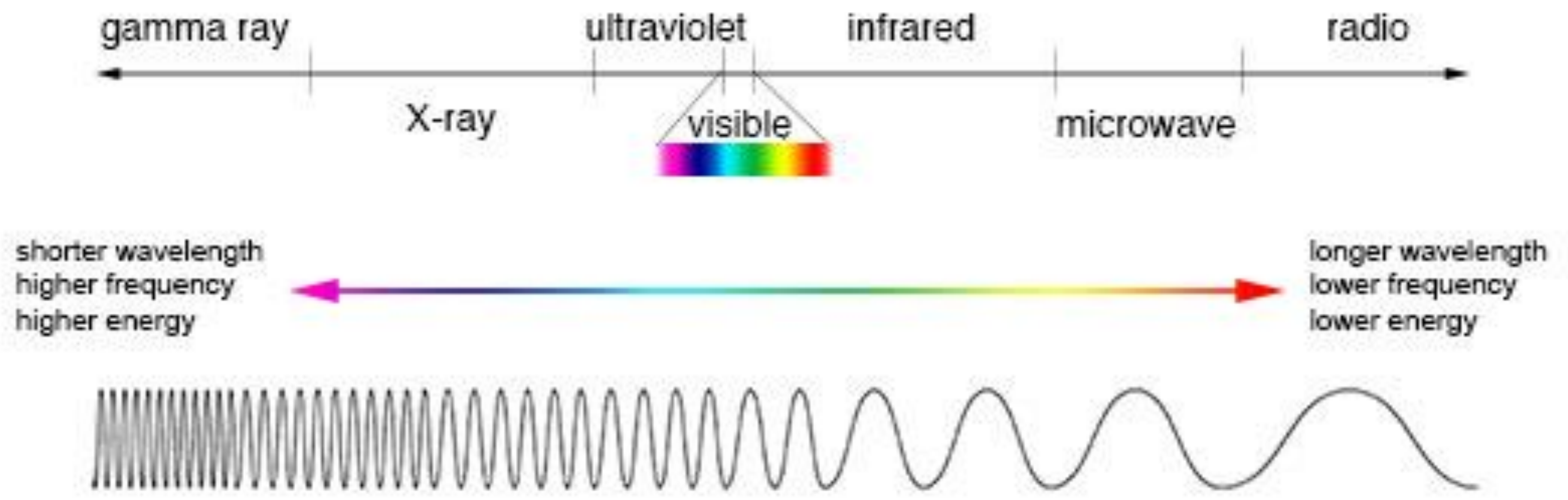
Why does this matter?

1. Properties of different light types can be studied!
2. Fun with exponent math!

$E = hf = hc/\lambda$

Energy and frequency are DIRECTLY related
Energy and wavelength are INVERSELY related

↑ Energy = ↑ frequency = ↓ wavelength
↓ Energy = ↓ frequency = ↑ wavelength



All light types have specified ranges for frequency and wavelength. Commonly, wavelength is used to describe light. The light we see, **visible light**, has wavelengths of 4×10^{-7} meters to 7×10^{-7} meters.

To measure visible light, we normally use nanometers:

1 meter = 1×10^{9} nanometers