BERKELEY MATH CIRCLE

The Math of Chemistry

The Make-up of Atoms I: Protons, Electrons & Neutrons

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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.

+ vs − : 10^{-27} vs 10^{-31}

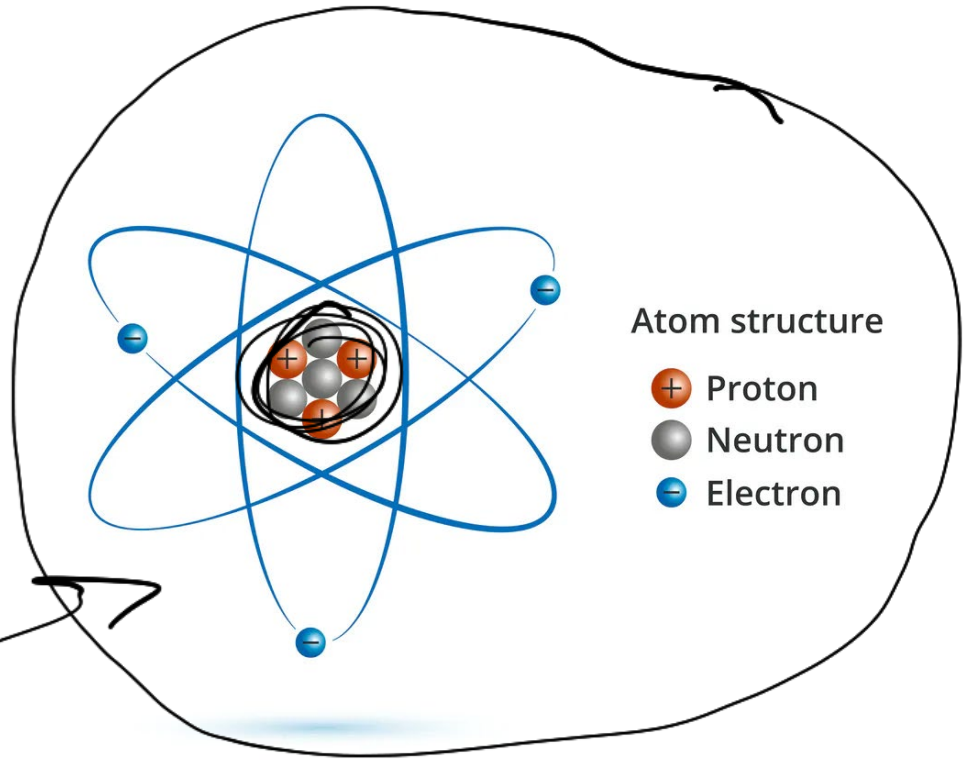
$10^{-27} - (-31) = 10^{4}$

10,000

Atom Make-up

Protons & Neutron = exist in nucleus

Electron = exist outside of the nucleus (more on this later)



The History & Make-Up of Atoms

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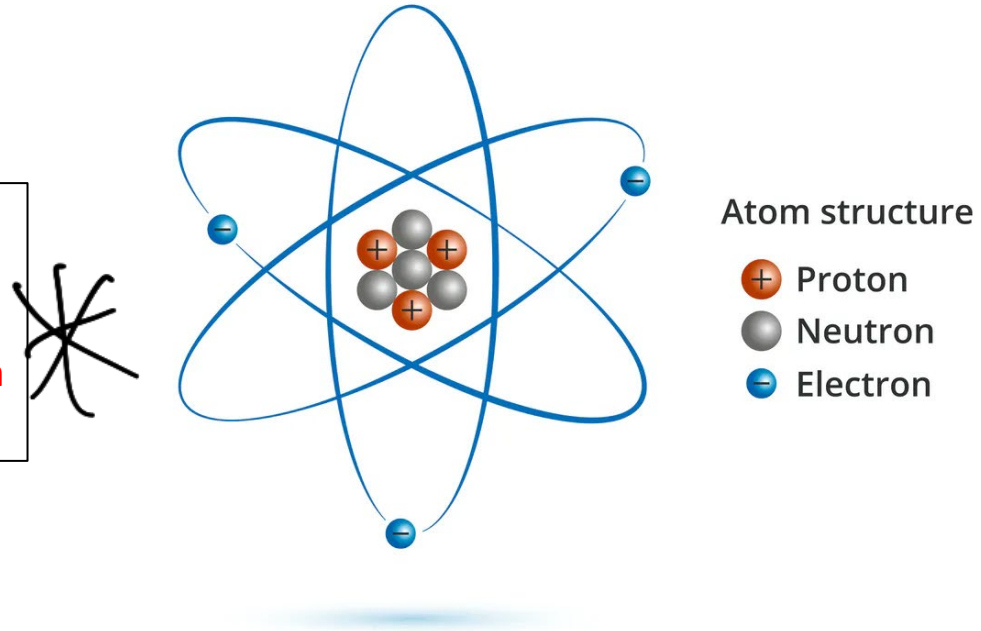
This is a COMPARATIVE size question, so we just use the exponents as a ratio to compare!
10^{-27} vs 10^{-31} → 10^{-27} / 10^{-31} → 10 (-27-(-31)) =
10^(-27+31) = 10^4 = 10000. The proton is ten thousand times more massive then the electron!

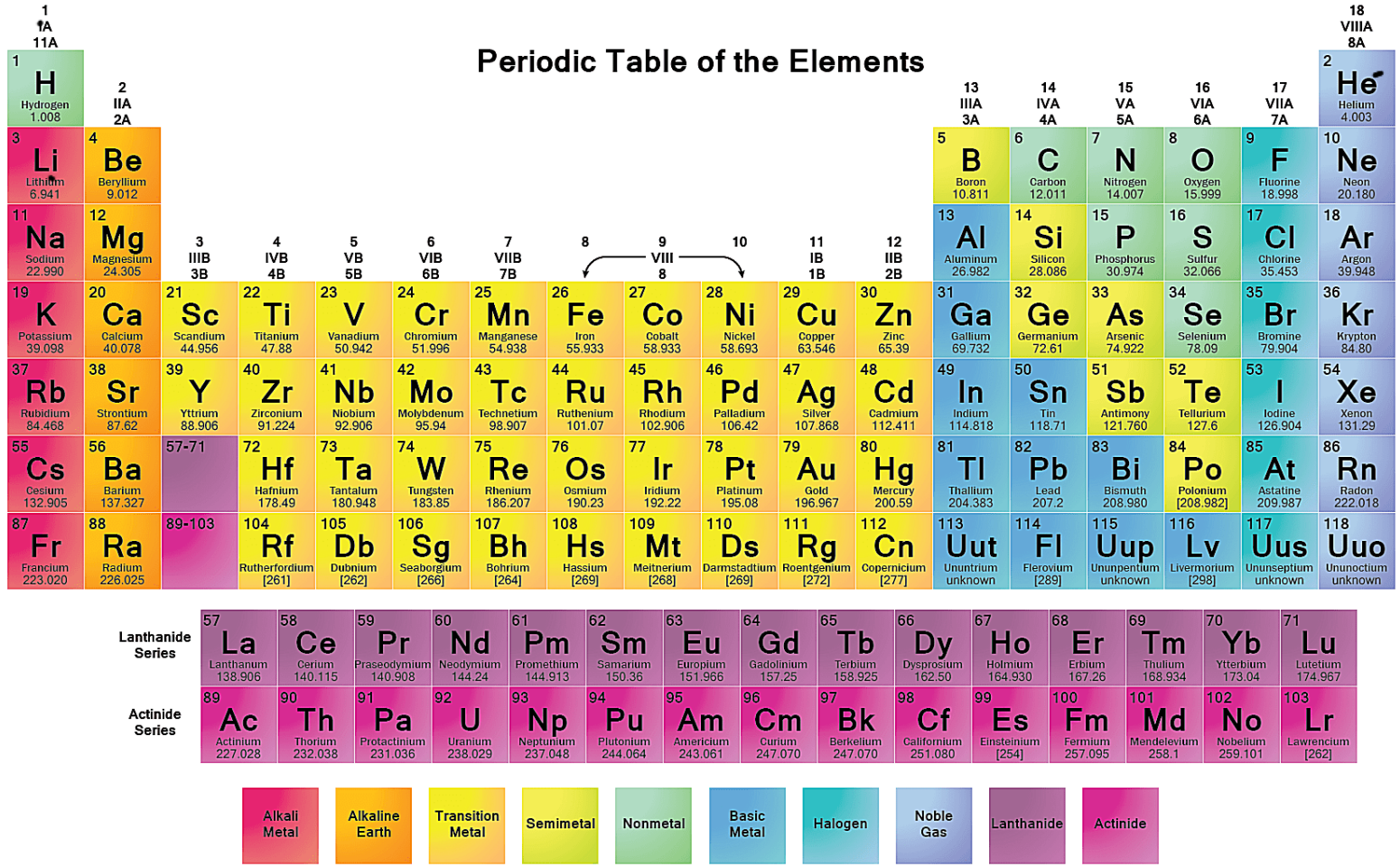


Atom Make-up

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!

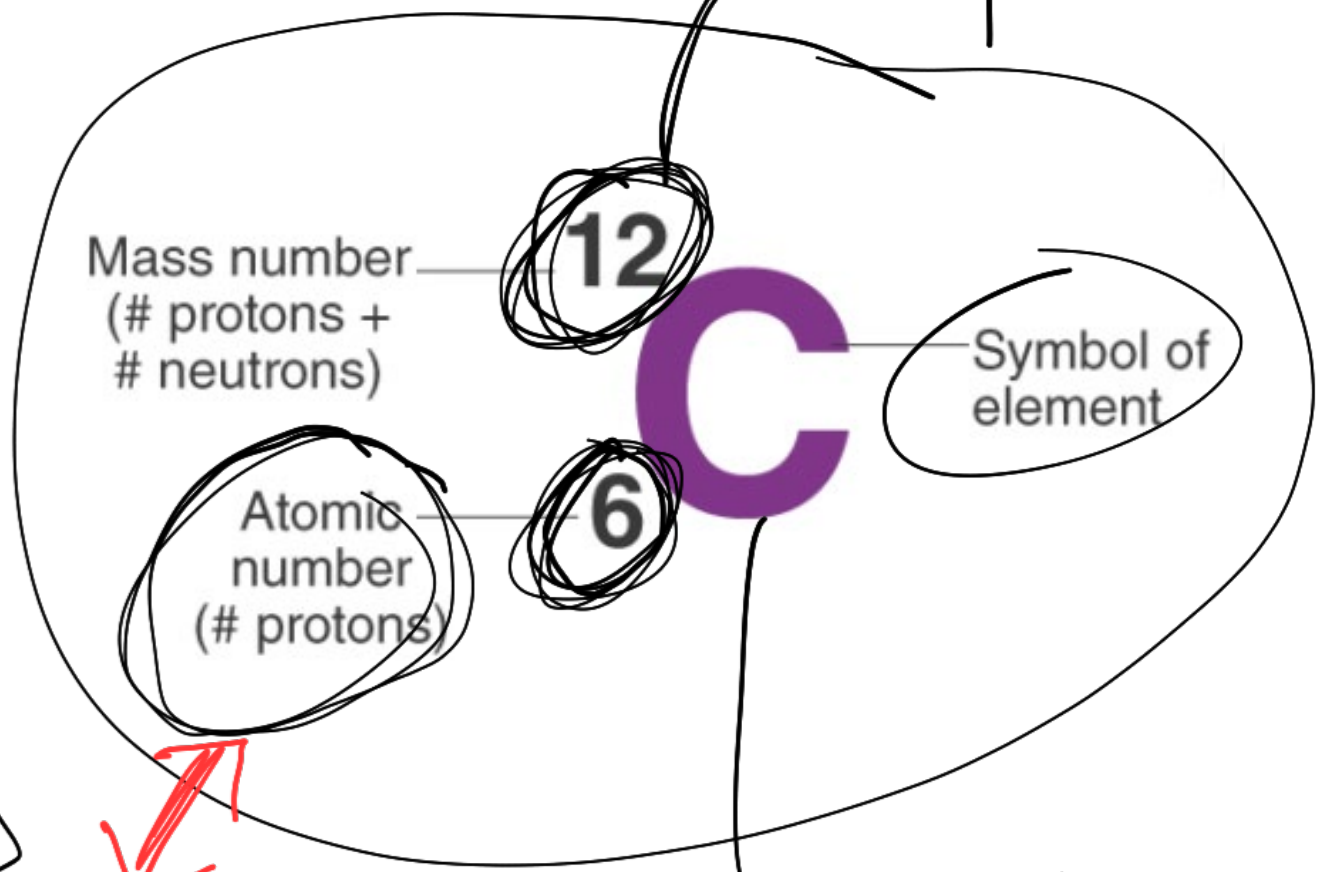
Symbol of Element
1 or 2 letter abbreviation for each element

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



Atm mass
p + n

Carbon
C

Atm # : # of protons
e's : # of protons [− = +]

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 # of protons

② # of electrons

③ # of neutrons

1	2											3	4	5	6	7	0
																	4 **He** helium 2
7 **Li** lithium 3	9 **Be** beryllium 4											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						

Key: relative atomic mass / **atomic symbol** / name / atomic (proton) number

1 **H** hydrogen 1

* 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)

19 = atm mass
9 = atm number

#of protons = 9
#of e's = 9
#of neutrons ⇒ atm mass = p + n
19 = 9 + n
n = 10

# of protons DEFINE the element

Iron (Fe)

Atm # = 26
Atm mass = 56

#of protons = 26 p's
#of electrons = 26 e's
#of neutrons = 56 - 26 = 30 neutrons

Charged Oxygen (O^{-2})

↳ oxygen ⇒ -2 charge

#of protons = 8
#of electrons = 10
#of neutrons ⇒ 16 - 8 = 8

Chlorine (Cl)

protons = 17
electrons = 17

neutrons = 35.5 - 17
= 18.5

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

What do you notice about Chlorine?

½ neutron ???

Solutions

Fluorine (F)
Protons = atm # = 9
Neutrons: 19-9= 10 neutrons
Electrons = protons = 9

Iron (Fe)
Protons = atm # = 26
Neutrons: 56-26 = 30 neutrons
Electrons = protons = 26

Charged Oxygen (O^{-2})
Protons = atm # = 8
Neutrons: 16-8= 8 neutrons
2 more electrons = 10 electrons

Chlorine (Cl)
Protons = 17
Neutrons: 35.5-17 = 18.5 neutrons
Protons = atm # = 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! Is that possible? No, so see next page ;)