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 = \(1.7 \times 10^{-27}\) kilograms
2. Electron (-) = negatively charged, mass = \(9.1 \times 10^{-31}\) 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!

\[
10^{-27} \text{ vs } 10^{-31} \rightarrow 10^{-27} / 10^{-31} \rightarrow 10^{-27+31} = 10^4 = 10000. \text{ The proton is ten thousand times more massive than the electron!}
\]

Atom Make-up
Protons & Neutron = exist in nucleus
Electron = exist outside of the nucleus (more on this later)
Elements are organized into the Periodic Table of Elements. They are organized into columns by their similarities in chemical properties:

<table>
<thead>
<tr>
<th>Element</th>
<th>Symbol</th>
<th>Atomic Number</th>
<th>Period</th>
<th>Group</th>
<th>Block</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>H</td>
<td>1</td>
<td>1</td>
<td>1A</td>
<td>S</td>
</tr>
<tr>
<td>Helium</td>
<td>He</td>
<td>2</td>
<td>1</td>
<td>18</td>
<td>S</td>
</tr>
<tr>
<td>Lithium</td>
<td>Li</td>
<td>3</td>
<td>2</td>
<td>1A</td>
<td>S</td>
</tr>
<tr>
<td>Beryllium</td>
<td>Be</td>
<td>4</td>
<td>2</td>
<td>2A</td>
<td>S</td>
</tr>
<tr>
<td>Boron</td>
<td>B</td>
<td>5</td>
<td>2</td>
<td>2A</td>
<td>S</td>
</tr>
<tr>
<td>Carbon</td>
<td>C</td>
<td>6</td>
<td>2</td>
<td>14</td>
<td>P</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>N</td>
<td>7</td>
<td>2</td>
<td>15</td>
<td>P</td>
</tr>
<tr>
<td>Oxygen</td>
<td>O</td>
<td>8</td>
<td>2</td>
<td>16</td>
<td>P</td>
</tr>
<tr>
<td>Fluorine</td>
<td>F</td>
<td>9</td>
<td>2</td>
<td>17</td>
<td>P</td>
</tr>
<tr>
<td>Neon</td>
<td>Ne</td>
<td>10</td>
<td>2</td>
<td>18</td>
<td>S</td>
</tr>
<tr>
<td>Sodium</td>
<td>Na</td>
<td>11</td>
<td>3</td>
<td>1A</td>
<td>S</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Mg</td>
<td>12</td>
<td>3</td>
<td>2A</td>
<td>S</td>
</tr>
<tr>
<td>Aluminum</td>
<td>Al</td>
<td>13</td>
<td>3</td>
<td>13</td>
<td>S</td>
</tr>
<tr>
<td>Silicon</td>
<td>Si</td>
<td>14</td>
<td>3</td>
<td>14</td>
<td>S</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>P</td>
<td>15</td>
<td>3</td>
<td>15</td>
<td>S</td>
</tr>
<tr>
<td>Sulfur</td>
<td>S</td>
<td>16</td>
<td>3</td>
<td>16</td>
<td>S</td>
</tr>
<tr>
<td>Chlorine</td>
<td>Cl</td>
<td>17</td>
<td>3</td>
<td>17</td>
<td>S</td>
</tr>
<tr>
<td>Argon</td>
<td>Ar</td>
<td>18</td>
<td>3</td>
<td>18</td>
<td>S</td>
</tr>
</tbody>
</table>

The Periodic Table

- **Lanthanide Series**: Lanthanide (La-Lu) elements are found on the right side of the table.
- **Actinide Series**: Actinide (Ac-Lr) elements are found on the bottom of the table.

**Legend**:
- Alkaline Metal
- Alkaline Earth
- Transition Metal
- Semimetal
- Nonmetal
- Basic Metal
- Halogen
- Noble Gas
- Lanthanide
- Actinide

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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
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)

<table>
<thead>
<tr>
<th>Atomic Number</th>
<th>Element</th>
<th>Protons</th>
<th>Neutrons</th>
<th>Electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Fluorine (F)</td>
<td>9</td>
<td>9 - 10</td>
<td>9</td>
</tr>
<tr>
<td>26</td>
<td>Iron (Fe)</td>
<td>26</td>
<td>32 - 33</td>
<td>26</td>
</tr>
<tr>
<td>8</td>
<td>Oxygen (O)</td>
<td>8</td>
<td>8 - 10</td>
<td>8</td>
</tr>
<tr>
<td>17</td>
<td>Chlorine (Cl)</td>
<td>17</td>
<td>17 - 18</td>
<td>17</td>
</tr>
</tbody>
</table>

* 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 there 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!

\[
(Mass \text{ of } X \text{ isotope } \times \% \text{ abundance}) + (Mass \text{ of } Y \text{ isotope } \times \% \text{ abundance}) + \ldots = \text{ avg mass} \quad \text{(also referred to as amu)}
\]

**Math Problems!**

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

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Mass</th>
<th>% Abundance</th>
</tr>
</thead>
<tbody>
<tr>
<td>N-14</td>
<td>14.003074</td>
<td>99.63%</td>
</tr>
<tr>
<td>N-15</td>
<td>15.000108</td>
<td>0.37%</td>
</tr>
</tbody>
</table>

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?

<table>
<thead>
<tr>
<th>Homework</th>
<th>Attendance</th>
<th>Final</th>
</tr>
</thead>
<tbody>
<tr>
<td>20% of grade</td>
<td>20% of grade</td>
<td>60% of grade</td>
</tr>
<tr>
<td>800 points out of 1000 total points available</td>
<td>16 classes attended out of 20 classes given</td>
<td>90% on test</td>
</tr>
</tbody>
</table>
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 its energy and properties!

\[ E = hf \]

**E** = Energy of the Photon (Joules)
\( h = \) Planck’s Constant = 6.626 x 10\(^{-34}\) J-s = 6.6 x 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 its speed (true for any constant wave)!

Speed = frequency (f) x wavelength (\( \lambda \))
(wavelength = \( \lambda \) (lambda), measured in meters)

For light then:

**Speed of light** = **frequency** (f) x **wavelength** (\( \lambda \))

\[ c = f \times \lambda \]

Where \( c = \) speed of light = 3 x 10\(^8\) meters/second – Super fast!

Therefore, combining this equation with the equation above:

\[ E = hf = \frac{hc}{\lambda} \]
Why does this matter?

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

\[ E = hf = \frac{hc}{\lambda} \]

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 $4 \times 10^{-7}$ meters to $7 \times 10^{-7}$ meters.

To measure visible light, we normally use nanometers:

1 meter = $1 \times 10^9$ nanometers