Chapter 3 Atoms and Elements
Atomic Theory

Atoms are tiny particles of matter.

Atoms are made up of subatomic particles: protons, neutrons and electrons.

**Protons** have a positive (+) charge.

**Electrons** have a negative (−) charge.

**Neutrons** are neutral.

Like charges *repel*, and unlike charges *attract*.

\[
\text{size of atom/size of nucleus} = 100000/1
\]

roughly a football to a football field in area

\[
\text{Atomic diameter } 10^{-10}
\]
### TABLE 3.6 Particles in the Atom

<table>
<thead>
<tr>
<th>Subatomic Particle</th>
<th>Symbol</th>
<th>Electrical Charge</th>
<th>Approximate Mass (amu)</th>
<th>Location in Atom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proton</td>
<td>$p$ or $p^+$</td>
<td>1+</td>
<td>1</td>
<td>Nucleus</td>
</tr>
<tr>
<td>Neutron</td>
<td>$n$ or $n^0$</td>
<td>0</td>
<td>1</td>
<td>Nucleus</td>
</tr>
<tr>
<td>Electron</td>
<td>$e^-$</td>
<td>1−</td>
<td>0.0005 ($\frac{1}{2000}$)</td>
<td>Outside nucleus</td>
</tr>
</tbody>
</table>

- Mass of a proton ($p$) = $1.672 \times 10^{-24}$ g
- Mass of a neutron ($n$) = $1.674 \times 10^{-24}$ g
- Mass of an electron ($e$) = $9.1 \times 10^{-28}$ g

Mass proton/electron = $\frac{1.672 \times 10^{-24}}{9.1 \times 10^{-28}} = 1840/1$
Chapter 3 Element and Symbols

copper Cu
Elements are pure substances that cannot be separated into simpler substances by ordinary laboratory processes; they are the building blocks of matter.

- Gold
- Aluminum
- Carbon

Many elements can be found in different forms; the arrangement in of the atoms are different in these different forms; diamond and graphite (lead in your pencil) are different forms of carbon.
Do I need to know the symbols of all these elements?
The heavy zigzag line separates metals and nonmetals.  
**Metals** are located to the left.  
**Nonmetals** are located to the right. 
**Metalloids** are located along the heavy zigzag line between the metals and nonmetals.

Why is the distinction made between metals and non-metals?

Metals are generally found combined with non-metals in the compounds they form.
Alkali metals

Group 1A (1)

3 Li
11 Na
19 K

Lithium (Li)
Sodium (Na)
Potassium (K)

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Halogens

Group 7A (17)

9 F
17 Cl
35 Br
53 I

Chlorine (Cl₂)
Bromine (Br₂)
Iodine (I₂)

Fay: alkali metals

Fay: halogens

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**Metals** are shiny and ductile; are good conductors of heat and electricity

**Nonmetals** are dull, brittle, and poor conductors of heat and electricity; are good insulators

**Metalloids** are better conductors than nonmetals, but not as good as metals; are used as semiconductors and insulators
Atomic number and mass number

sulfur \( S \)

The **atomic number** is specific for each element; is the same for all atoms of an element is equal to the number of protons in an atom

The **mass number** represents the number of particles in the nucleus; is equal to the sum of the number of protons and number of neutrons

sulfur \( ^{16}S_{32} \) \( ^{32}S_{16} \)

Atoms of the same element always have the same atomic number but may have different atomic masses; the mass number is always equal or larger than the atomic number

<table>
<thead>
<tr>
<th>Element</th>
<th>Symbol</th>
<th>Atomic Number</th>
<th>Mass Number</th>
<th>Number of Protons</th>
<th>Number of Neutrons</th>
<th>Number of Electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>H</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>N</td>
<td>7</td>
<td>14</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Chlorine</td>
<td>Cl</td>
<td>17</td>
<td>35</td>
<td>17</td>
<td>18</td>
<td>17</td>
</tr>
<tr>
<td>Chlorine</td>
<td>Cl</td>
<td>17</td>
<td>37</td>
<td>17</td>
<td>20</td>
<td>17</td>
</tr>
<tr>
<td>Iron</td>
<td>Fe</td>
<td>26</td>
<td>57</td>
<td>26</td>
<td>31</td>
<td>26</td>
</tr>
<tr>
<td>Gold</td>
<td>Au</td>
<td>79</td>
<td>197</td>
<td>79</td>
<td>118</td>
<td>79</td>
</tr>
</tbody>
</table>

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$^{3}\text{Li}_7$

$^{3}\text{Li}_6$

$^{6}\text{C}_{12}$

$^{6}\text{C}_{13}$

$^{6}\text{C}_{14}$
Isotopes and atomic mass (weight)

**Isotopes** are atoms of the same element that have different mass numbers; they have the same number of protons but different numbers of neutrons.

**Isotopes** are difficult to separate from each other, therefore they occur in any sample of the element in their natural abundance which remains relatively constant, regardless of the source of the element.

Most but not all isotopes are stable. Those that are unstable are referred to as being radioactive.
This is what is found on a periodic table for Cl

Since atomic mass is equal to the sum of the number of protons and neutrons, how can you have a fractional number?

How was an atomic mass value of 35.45 arrived at?

Since in a “handful” of Cl there is a mixture of two isotopes in the abundances shown on the left, an average atomic mass has been defined

Average Atomic Mass Cl = 0.7576(Cl_{35}) + 0.2434(Cl_{37})

= 0.7576(35) + 0.2434(37)

= 35.45

Since most elements in the periodic table have stable isotopes, most atomic masses are not whole numbers but rather averages of the atomic masses of their isotopes adjusted for their natural abundances

An exception is ^9_F_{19} which consists of only one isotope
Which of the isotopes listed above for each element do you think is most abundant?

Most of the isotopes listed above are stable; carbon 14 is an exception.
The electrons which are negatively charged are believed to be distributed around the nucleus since it is possible to remove an electron by various means and form new species which are positively charged. Furthermore, there are experiments that suggest that most of the mass of the atom is located in only a very small portion of the atom and that most of the atom is relatively empty space. Remember that the size of atom/size of nucleus = 100000/1
Light: What is it?

Everything we know about our universe comes from the study of how light interacts with matter

![Light Spectrum Diagram](https://example.com/light_spectrum.png)

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Light is referred to as electromagnetic radiation

Light has both wave properties and particle properties

All light, whether radiowaves or visible light, travels as the same speed, $3 \times 10^8$ meters/sec

As a result, since the length of each wave decreases from left to right, the frequency of the peaks and troughs of the waves shown above must increase from left to right

Referring to light as a particle, known as a photon of light, the energy of each particle of light is also known to increase from left to right

The total energy of course depends on the frequency of the light and the number of particles
Light also has a magnetic field associated with it. It varies in the same fashion as the electric field, traveling at the same speed but perpendicular to the electric field. Both the electric and magnetic fields are used in medicine and science. A MRI (magnetic resonance image) of a heart and lungs using radiowave frequencies in the presence of a strong external magnetic field.
White light that passes through a prism is separated into all colors that together are called a continuous spectrum gives the colors of a rainbow.

When an element is heated, it gives off light. However the entire rainbow of colors is absent and only certain colors are present. Each element gives it own spectrum of color. Not all of the light is in the visible region. Depending on the temperature, the element, some light covering a large portion of the electromagnetic spectrum can be observed.
A model has been devised to explain this phenomena

Think of the model as a bookcase with each succeeding shelf getting closer and closer

Depending on the element, different electronic transitions can be observed. The emphasis here is electronic, the electrons are being excited to different levels
The periodic table is named periodic because it has been known for a long time that many of the chemical properties of the elements are very similar but very different from others. This is why they are lumped into groups.

The theory that has been developed, therefore, has been developed to explain this periodicity. Since it is mathematical in origin, we will simply look at it as a model.
Also on closer inspection of the different n levels, additional fine structure is observed within each n level and these are assigned different letters of the alphabet.

According to the mathematics each s, p, d level can accommodate 2 electrons. There is one s level for each shelf, three equivalent p levels for shelf 2 and above and 5 equivalent d levels for the third shelf and above. The difference between the three equivalent 2p levels is their arrangement in space. Otherwise they are equivalent in shape. Similarly for the d levels.
These orbitals according to theory is the region in space one is likely to encounter an electron; volumes of highest probability.
\[ {}^1\text{H} \quad {}^3\text{Li} \quad {}^7\text{N} \quad {}^{11}\text{Na} \]

\[ {}^2\text{He} \quad {}^4\text{Be} \quad {}^8\text{O} \]

\[ {}^6\text{C} \quad {}^9\text{F} \]

\[ {}^5\text{B} \quad {}^{10}\text{Ne} \]
Valence electrons determine the chemical properties of the elements; they are the electrons in the outermost, highest energy level and are related to the Group number of the element.

How many valence electrons does this neutral atom have and what is the element?
A summary of the periodic table and electron orbitals