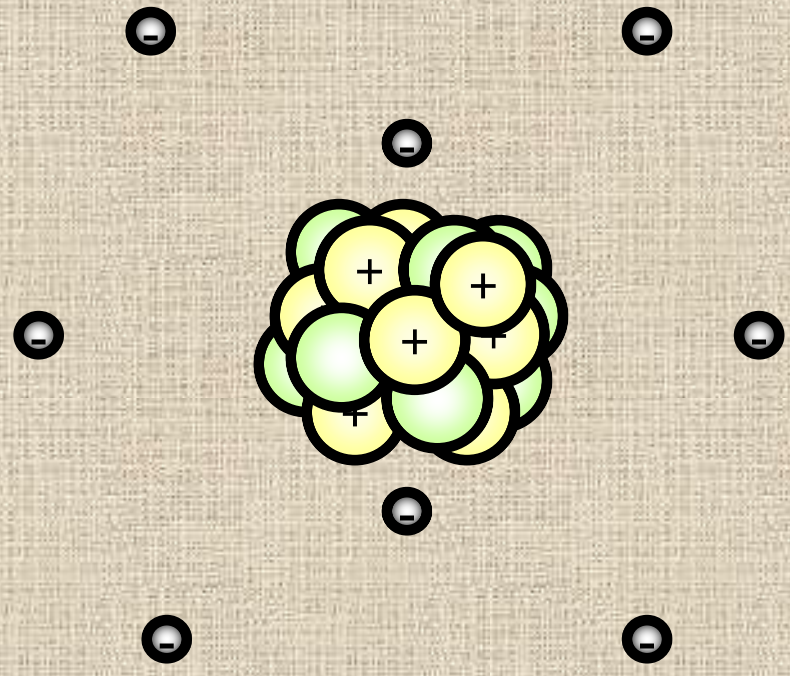
The Building Blocks of Matter: <u>**Atoms**</u>

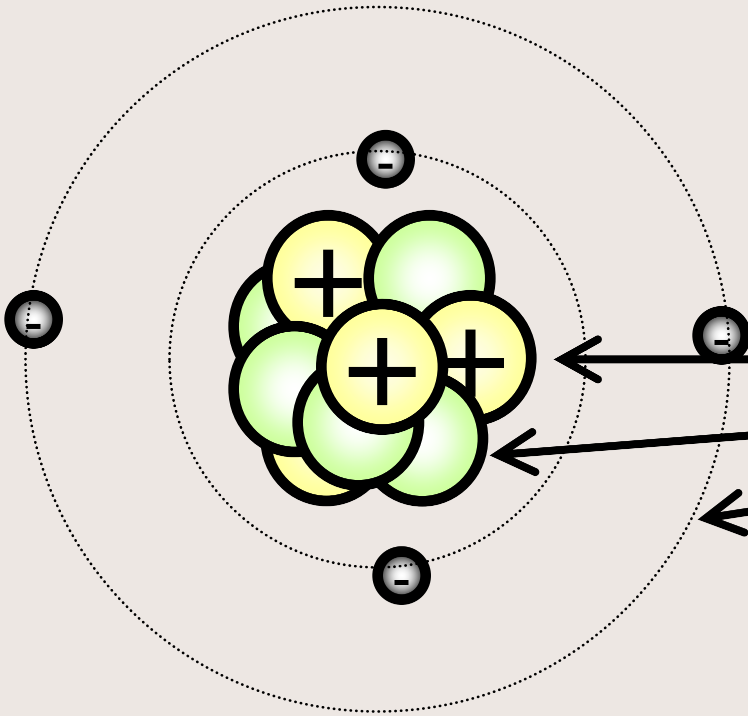


Matter

- Anything that has mass and takes up space (volume)
  - Examples:
    - A brick has <u>mass</u> and <u>takes up space</u>
    - A desk has <u>mass</u> and <u>takes up space</u>
    - A pencil has <u>mass</u> and <u>takes up space</u>
    - Air has <u>mass</u> and <u>takes up space</u>

All of the above examples are considered matter because they have <u>mass</u> and <u>take up space</u>. Can you think of anything that would not be considered matter?

Atoms



- Smallest possible unit into which matter can be divided, while still maintaining its properties.
- Made up of:

For example, what is the smallest possible unit into which a long essay can be divided and still have some meaning?

- The solar system is commonly used as an analogy to describe the structure of an atom

Atoms are so small that…

- it would take a stack of about 50,000 aluminum atoms to equal the thickness of a sheet of aluminum foil from your kitchen.
- if you could enlarge a penny until it was as wide as the US, each of its atoms would be only about 3 cm in diameter – about the size of a ping-pong ball
- a human hair is about 1 million carbon atoms wide.
- a typical human cell contains roughly 1 trillion atoms.
- a speck of dust might contain $3x10^{12}$ (3 trillion) atoms.
- it would take you around 500 years to count the number of atoms in a grain of salt.

www.deckersfoods.com

C-C-C-C-C-… + 999,995 more

1 trillion atoms →

Is made of approximately 3 trillion atoms

Just one of these grains

Let's Experiment

In order to try to gain an idea of how small an atom really is, you will complete the following activity.

1. Cut a strip of 11 in. paper in half.
2. Discard one half.
3. Cut the remaining piece in half.
4. Continue cutting and discarding the strips as many times as you can.
5. Make all cuts parallel to the first one. When the width gets longer than the length, you may cut off the excess, but that does not count as a cut.

Results

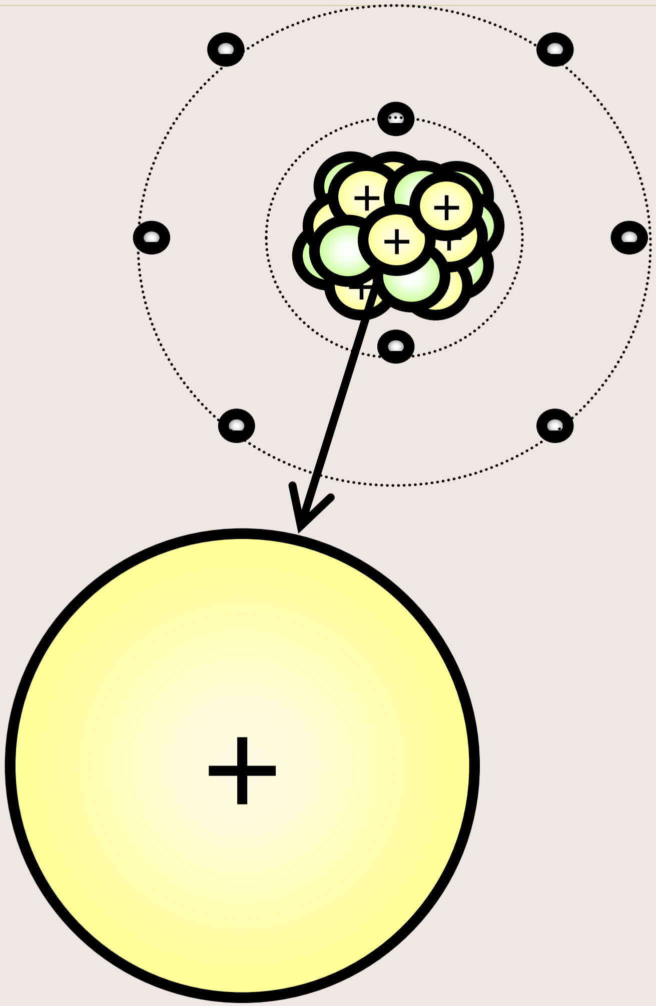
- How many cuts were you able to make?
- Do you think you could keep cutting the paper forever? Why or why not?

You would have to cut the paper in half around thirty-one (31) times to get to the size of any atom.

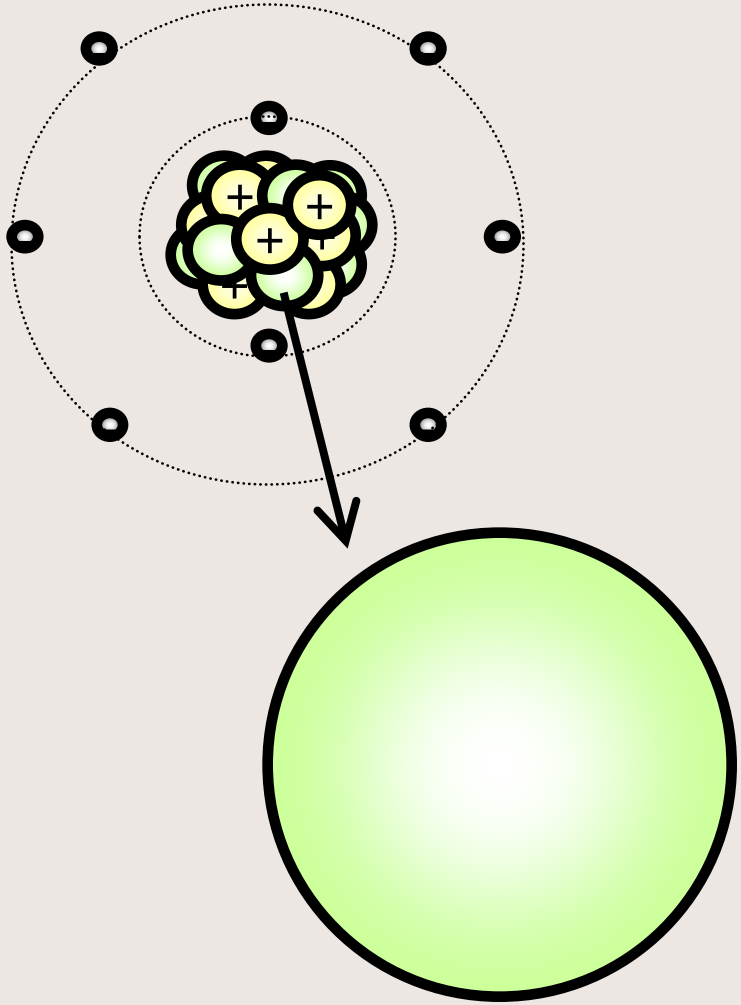
http://www.miamisci.org/af/sln/phantom/papercutting.html

Protons (+)

- Positively charged particles
- Help make up the nucleus of the atom
- Help identify the atom (could be considered an atom's DNA)
- Equal to the atomic number of the atom
- Contribute to the atomic mass
- Equal to the number of electrons



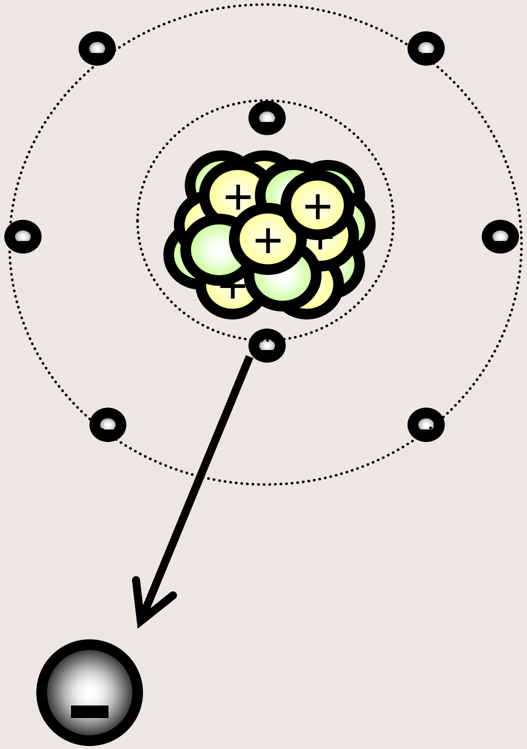
Neutrons



- Neutral particles; have no electric charge
- Help make up the nucleus of the atom
- Contribute to the atomic mass

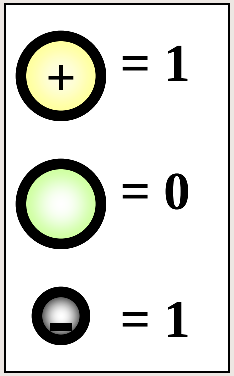
Electrons (-)

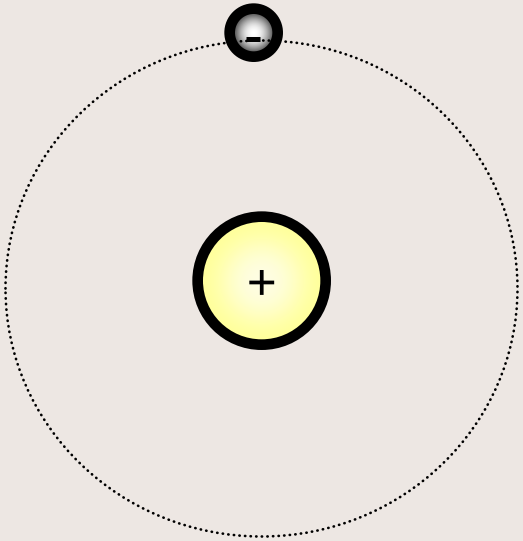
- Negatively charged particles
- Found outside the nucleus of the atom, in the electron orbits/levels; each orbit/level can hold a maximum number of electrons (1^{st} = 2, 2^{nd} = 8, 3^{rd} = 8 or 18, etc…)
- Move so rapidly around the nucleus that they create an electron cloud
- Mass is insignificant when compared to protons and neutrons
- Equal to the number of protons
- Involved in the formation of chemical bonds



Hydrogen (H) Atom

- Notice the one electron in the first orbital



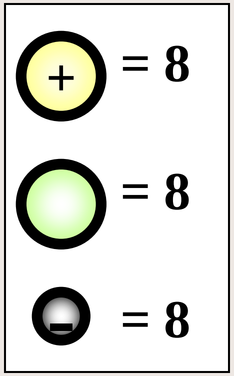


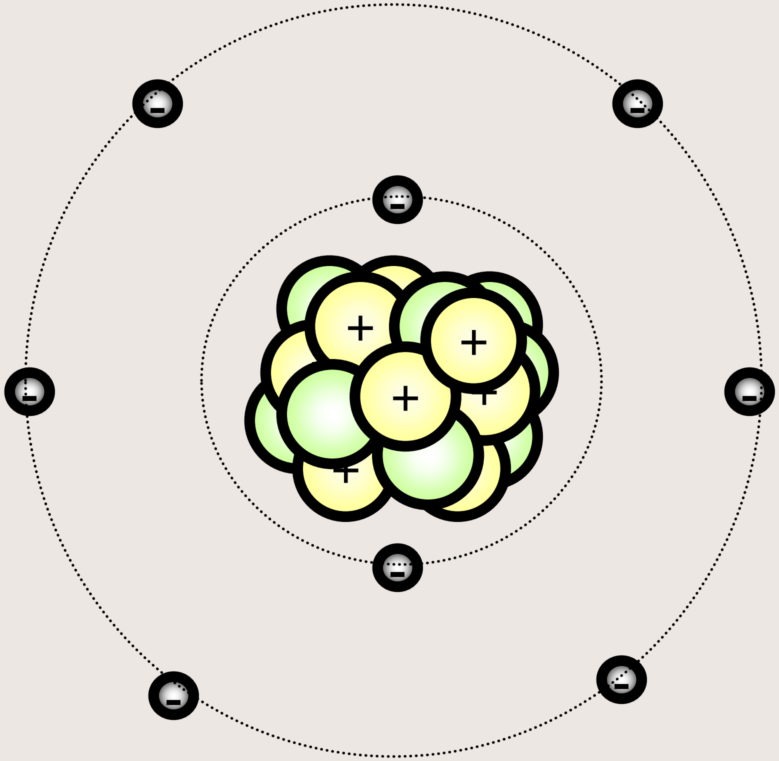
How many more electrons can fit in the 1st orbital/ level?

Even though there are no neutrons present, Hydrogen is still considered an atom

Oxygen (O) Atom

- Notice the two electrons in the first orbital/level and the six in the second

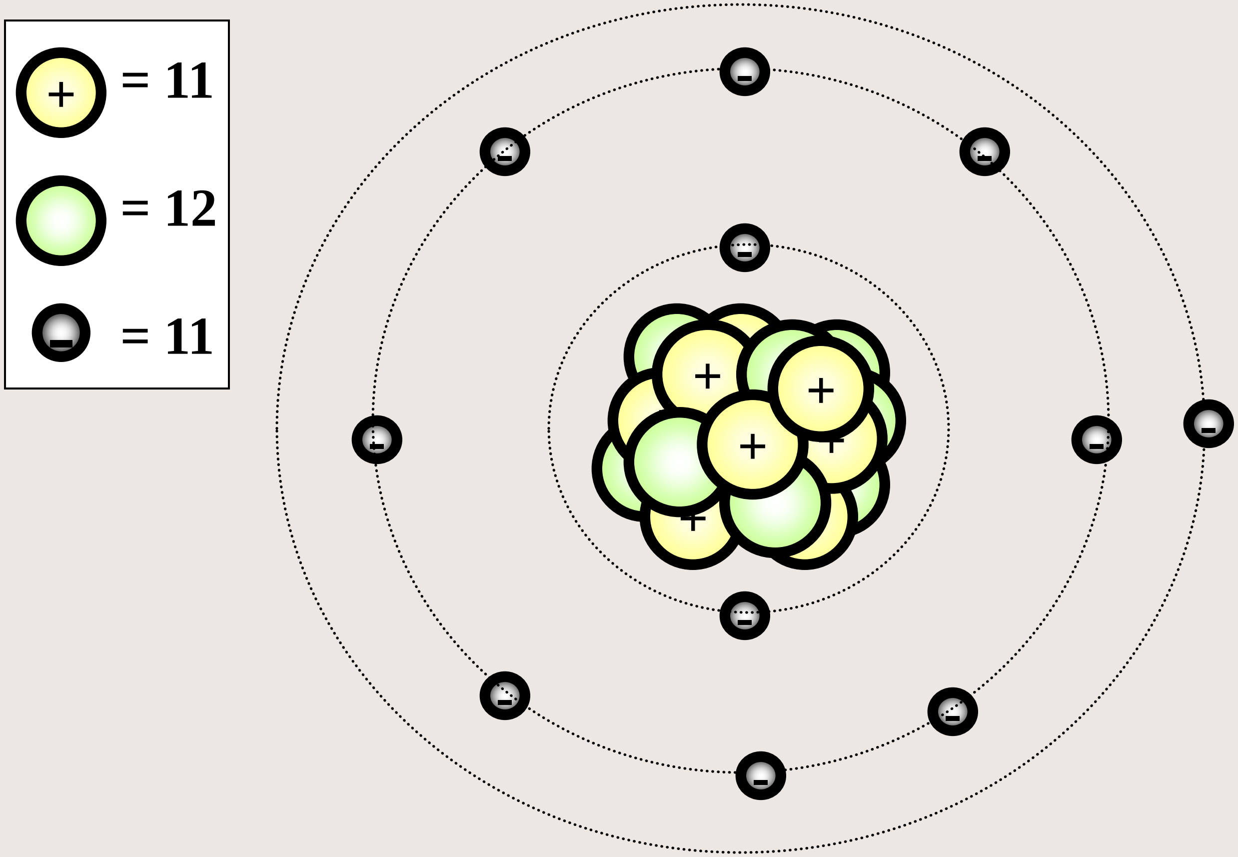




How many more electrons can fit in the 2nd orbital/ level?

Sodium (Na) Atom

- Notice the two electrons in the first orbital/level, eight in the second, and one in the third

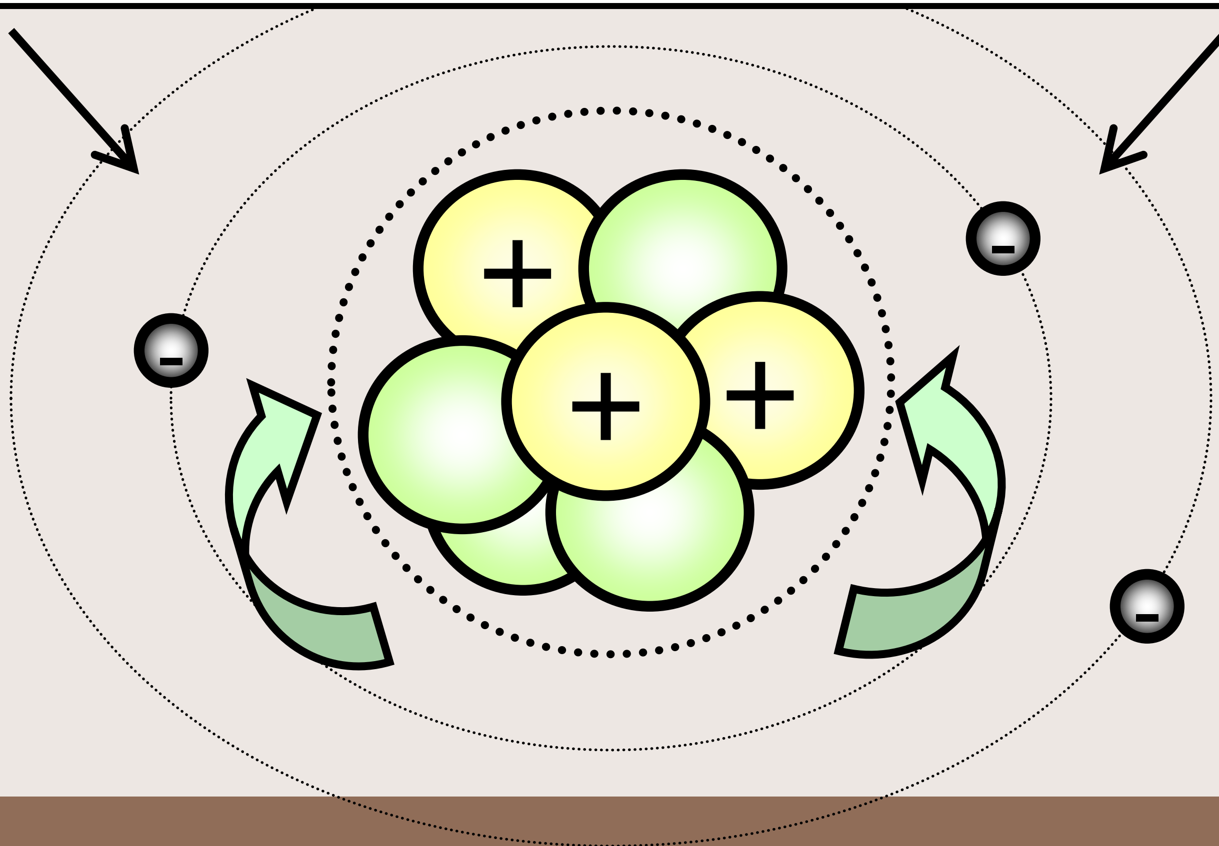


How many more electrons can fit in the 3rd orbital/ level?

The Atom's "Center"

- Protons and neutrons are grouped together to form the "center" or **<u>nucleus</u>** of an atom.

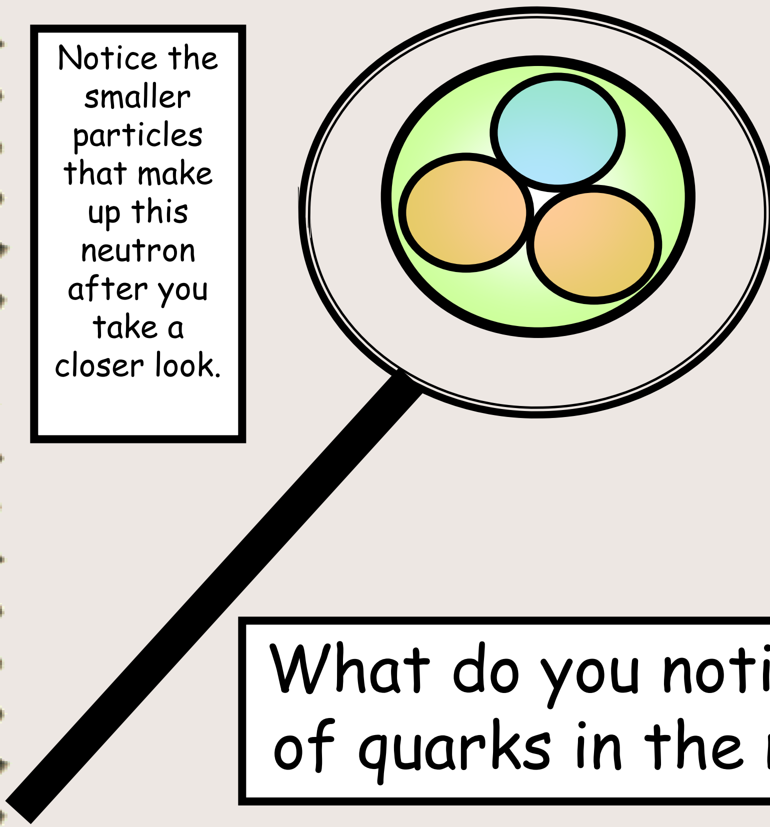
Notice that the electrons are not apart of the nucleus

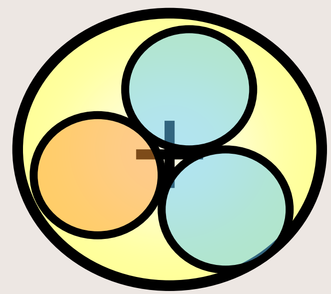


QUARKS

- Particles that make up protons and neutrons

Notice the smaller particles that make up this neutron after you take a closer look.





Notice the smaller particles that make up this proton after you take a closer look.

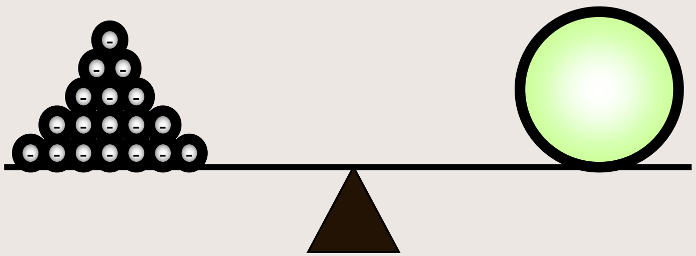
What do you notice about the number of quarks in the neutron and proton?

Sub-Atomic Particles

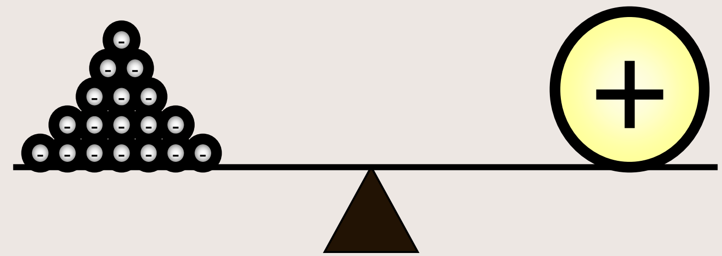
Weight Comparison

(protons, neutrons, electrons)

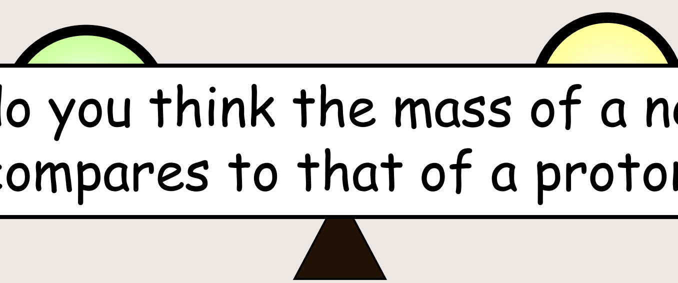
Neutron = 1.6749286 $\times 10^{-27}$ kg
Proton = 1.6726231 $\times 10^{-27}$ kg
Electron = 9.1093897 $\times 10^{-31}$ kg



1839 electrons = 1 neutron



1836 electrons = 1 proton



How do you think the mass of a neutron compares to that of a proton?

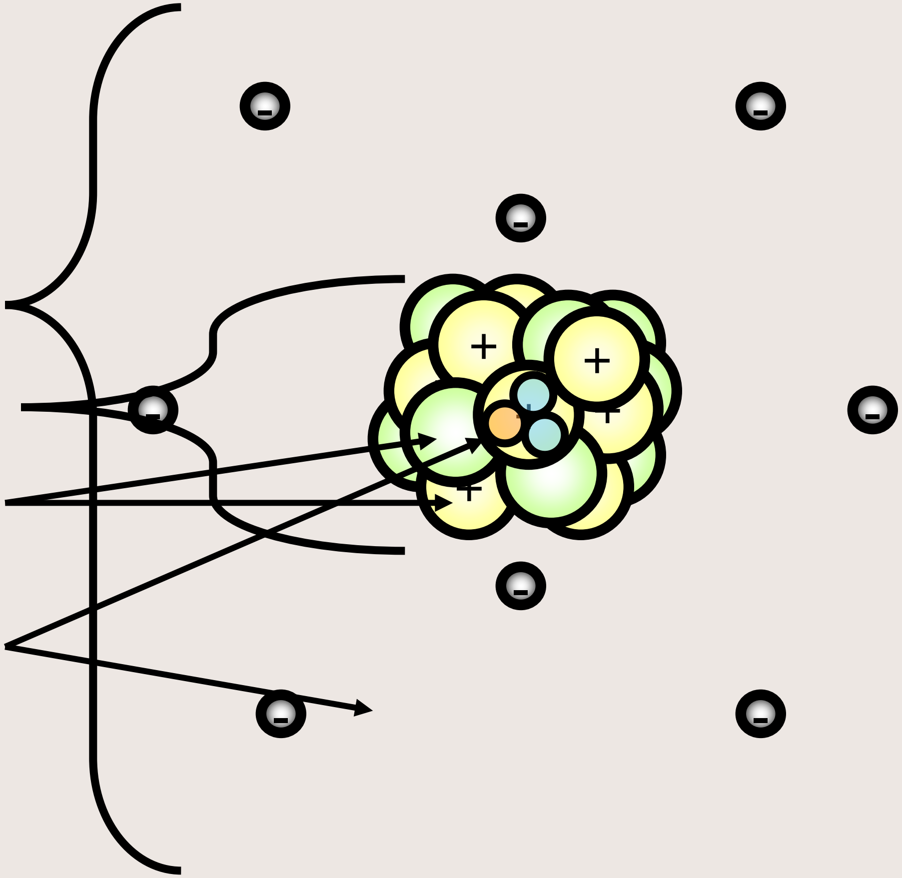
1 neutron ≈ 1 proton

Sub-atomic Particles

Size Comparison

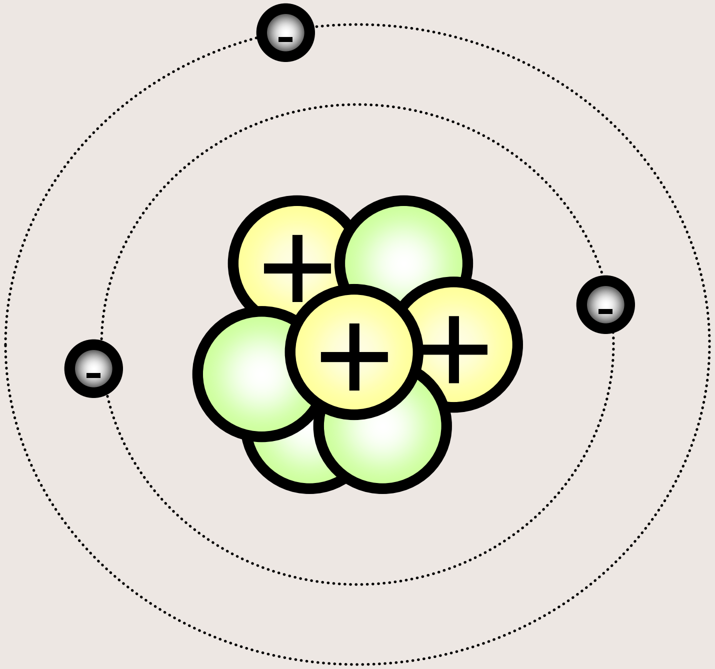
(protons, neutrons, electrons, & quarks)

	Size in atoms	Size in meters (m)
Atom	1	10^{-10}
Nucleus	$\frac{1}{10,000}$	10^{-14}
Proton or Neutron	$\frac{1}{100,000}$	10^{-15}
Electron or Quark	$\frac{1}{100,000,000}$	10^{-18} (at largest)



Atomic Number

- The number of protons in the nucleus of an atom

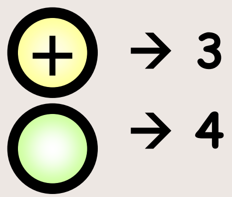


What would be the atomic number of this atom?

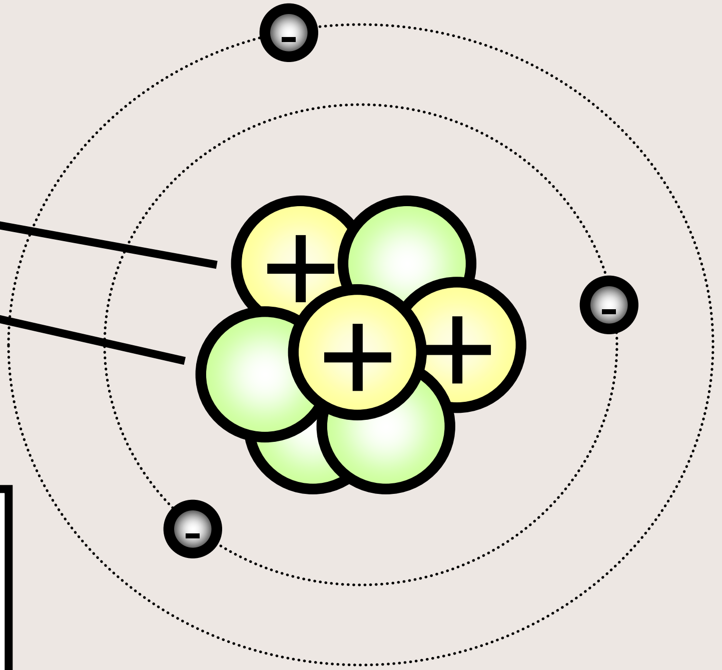
Mass Number

- The total number of protons and neutrons in an atom's nucleus
- Expressed in <u>A</u>tomic <u>M</u>ass <u>U</u>nits (amu)
  - Each proton or neutron has a mass of 1 amu

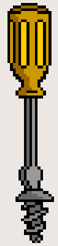
What would be the mass number of this atom?



3 protons + 4 neutrons = a mass number of 7 amu



Why did we not account for the electrons when calculating the mass number?



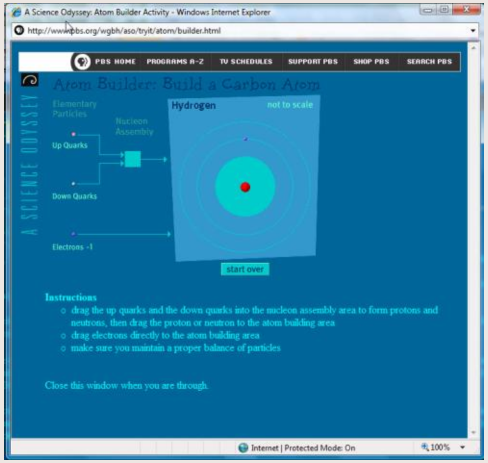
Building Atoms

Using the whiteboard and the proton, neutron, and electron pieces, build the following atoms, and determine their atomic and mass numbers.

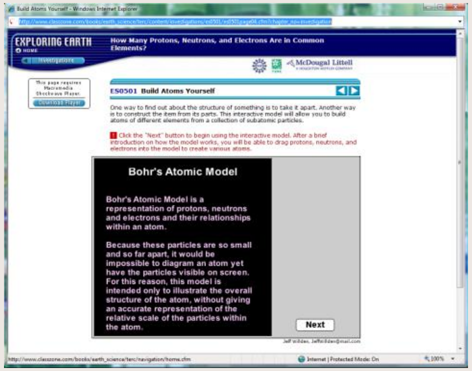
Atoms	Protons	Neutrons	Electrons
Carbon	6	6	6
Beryllium	4	5	4
Oxygen	8	8	8
Lithium	3	4	3
Sodium	11	12	11

Atom Builder

- Using the interactive website link below, practice building atoms.



- http://www.pbs.org/wgbh/aso/tryit/atom/



- Using the classzone.com link below, click on the “Build an Atom” simulation and practice building atoms.

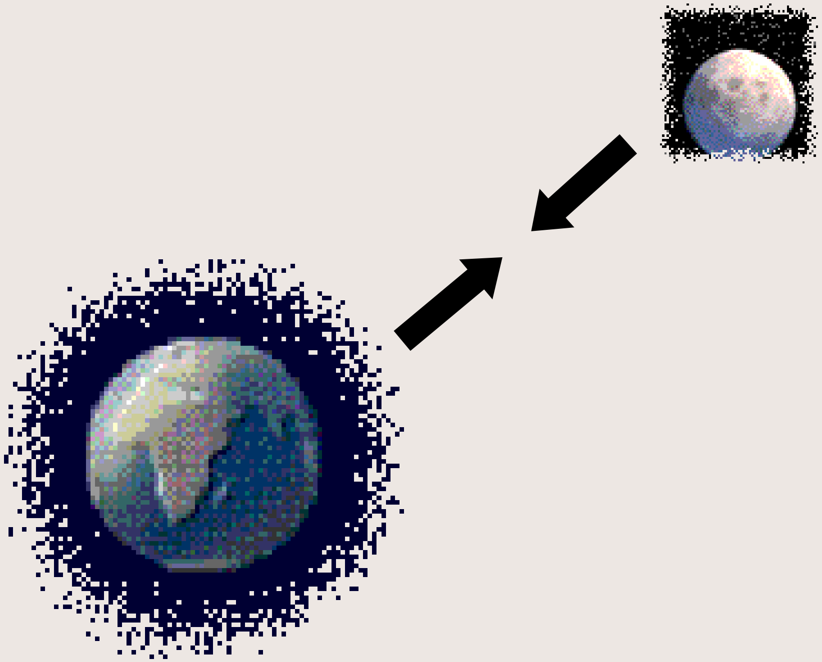
http://www.classzone.com/books/ml_sci_physical/page_build.cfm?id=resour_ch1&u=2##

FORCES IN THE ATOM

- Gravitational Force
- Electromagnetic Force
- Strong Force
- Weak Force

Gravitational Force

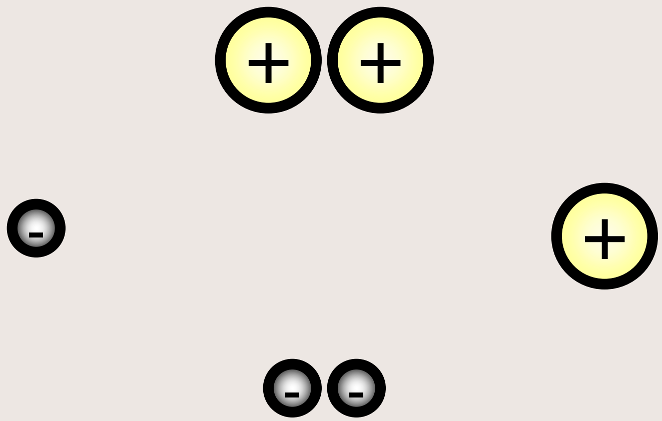
- The force of attraction of objects due to their masses
- The amount of gravity between objects depends on their masses and the distance between them



Do you think this force plays a significant role in holding the atom together?

Electromagnetic Force

- The force that results from the repulsion of like charges and the attraction of opposites
- The force that holds the electrons around the nucleus



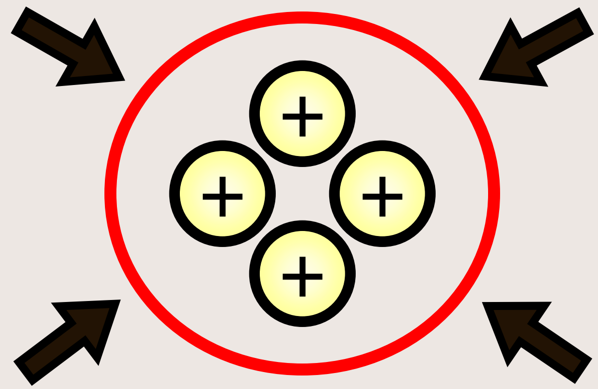
Notice how the particles with the same charge move apart and the particles with different charges move together.

Why are neutrons not pictured above?

Strong Force

- The force that holds the atomic nucleus together
- The force that counteracts the electromagnetic force

Notice how the electromagnetic force causes the protons to repel each other but, the strong force holds them together.



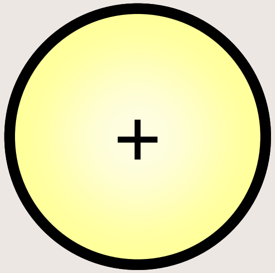
If you need help remembering strong force, just think of…

Would an atom have a nucleus if the strong force did not exist?

Weak Force

- This force plays a key role in the possible change of sub-atomic particles.
  - For example, a neutron can change into a proton(+) and an electron(-)
- The force responsible for radioactive decay.
  - <u>Radioactive decay</u> → process in which the nucleus of a radioactive (unstable) atom releases nuclear radiation.

Notice how the original particle changes to something new.

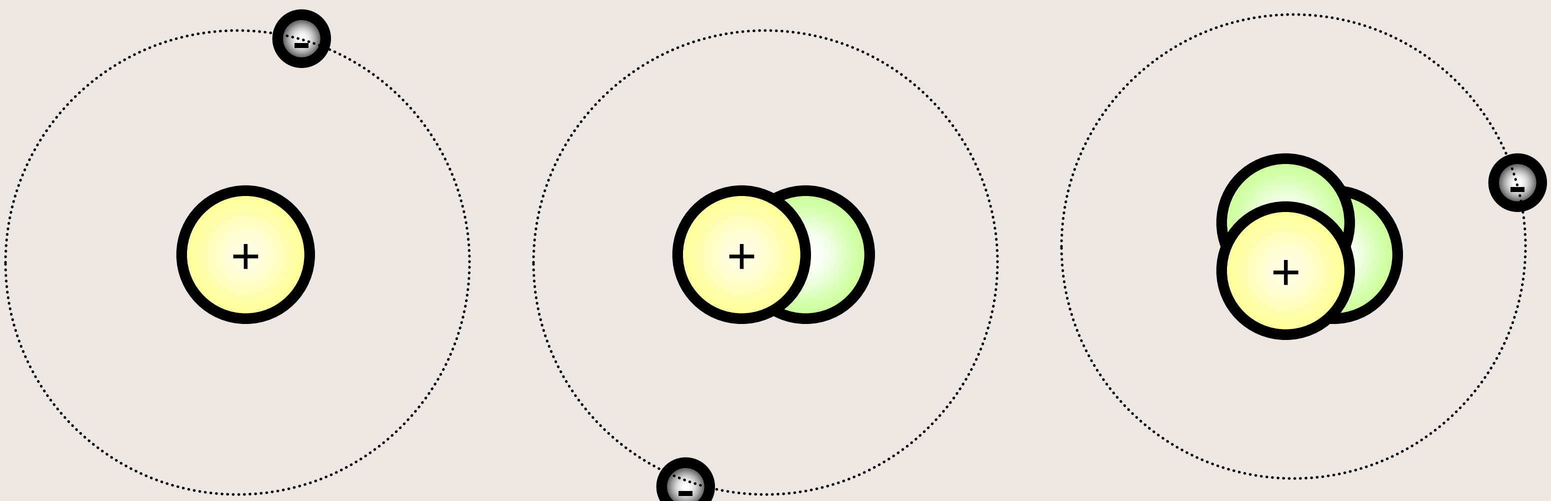


If you need help remembering weak force, just think of…

Isotopes

- Atoms that have the same number of protons, but have different numbers of neutrons
- Examples

Notice that each of these atoms have one proton; therefore they are all types of hydrogen. They just have a different mass number (# of neutrons).

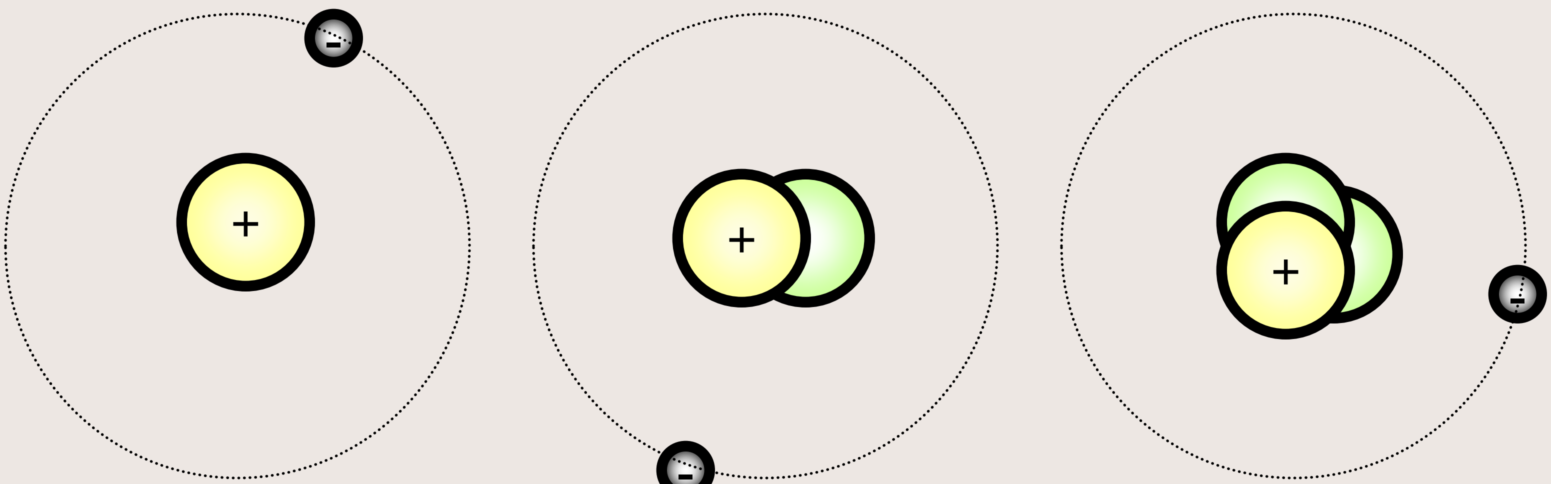


Hydrogen (Protium) Hydrogen (Deuterium) Hydrogen (Tritium)

Atomic Mass

- The weighted average of the masses of all the naturally occurring isotopes of an element
- The average considers the percent abundance of each isotope in nature
- Found on the periodic table of elements
- Example

What would be the atomic mass (≈) of Hydrogen if these three isotopes were found in the following percentages (99.9, 0.015, 0) respectively?



Hydrogen (Protium)
Mass # = 1 amu

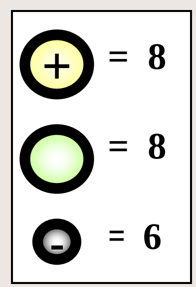
Hydrogen (Deuterium)
Mass # = 2 amu

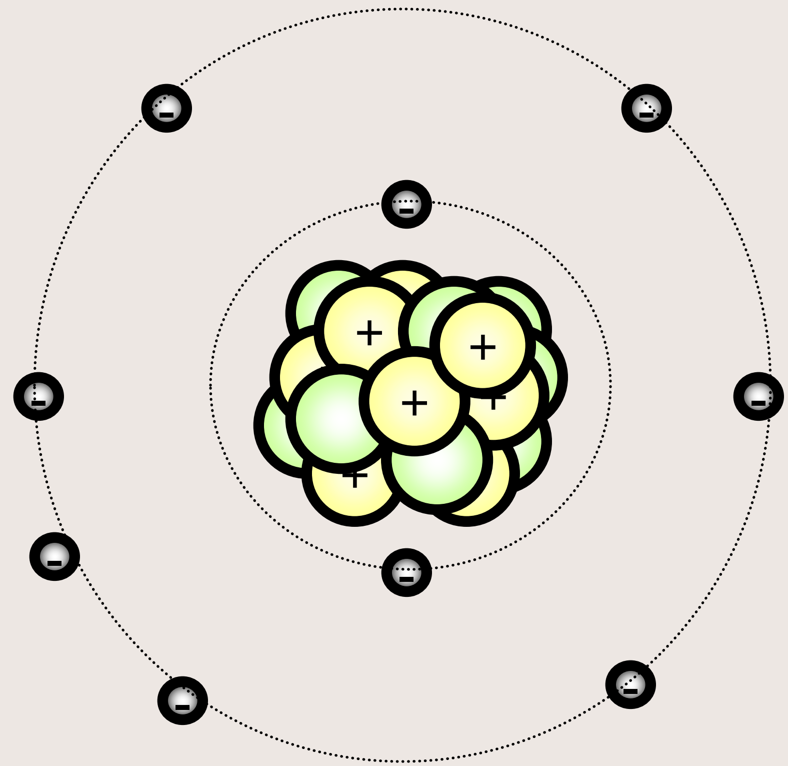
Hydrogen (Tritium)
Mass # = 3 amu

If you simply average the three, 2 amu (1 amu + 2 amu + 3 amu/3) would be the atomic mass, but since 99.9% of the Hydrogen is Protium, the atomic mass is around 1 amu (.999 x 1 amu)

Ion

- Charged particle that typically results from a loss or gain of electrons
- Two types:
  - <u>Anion</u> = negatively charged particle
  - <u>Cation</u> = positively charged particle





Currently, this atom of oxygen is neutral because it has an equal number of electrons (8) and protons (8).

Symbol = O

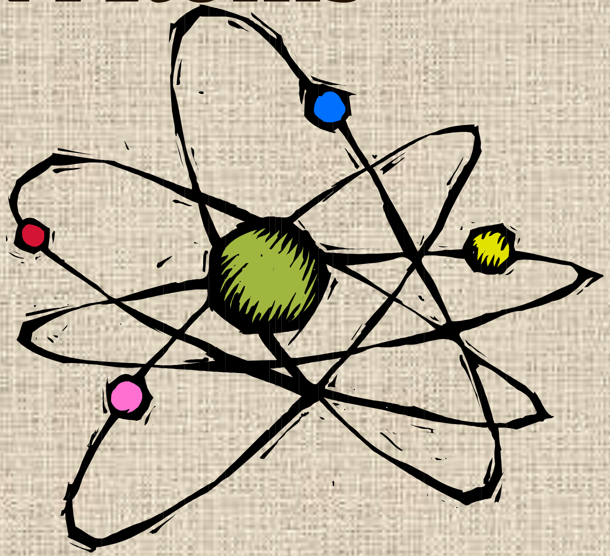
Building Ions

Using the whiteboard and the proton, neutron, and electron pieces, build the following ions, and determine their atomic and mass numbers.

Ions	Protons	Neutrons	Electrons
Carbon (C^{3-})	6	6	9
Hydrogen (H^{1+})	1	0	0
Oxygen (O^{2-})	8	8	10
Lithium (Li^{3+})	3	4	0
Sodium (Na^{1-})	11	12	12

Be aware that the atomic and mass numbers are not impacted by the loss or gain of electrons.

Elements & Atoms



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www.thesciencequeen.net

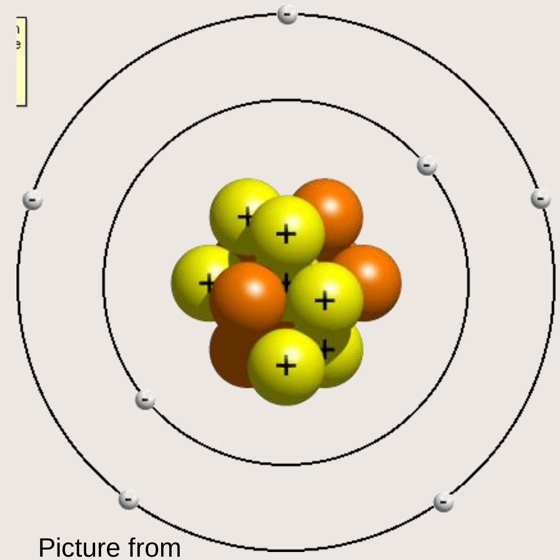
An atom refresher

- **Matter** is anything that takes up space and has mass.
- All matter is made of atoms
- https://pub.dev/packages/advance_pdf_viewer
- Atoms are the building blocks of matter, sort of how bricks are the building blocks of houses.

An atom refresher

- An atom has three parts:
- **Proton** = positive
- **Neutron** = no charge
- **Electron** = negative

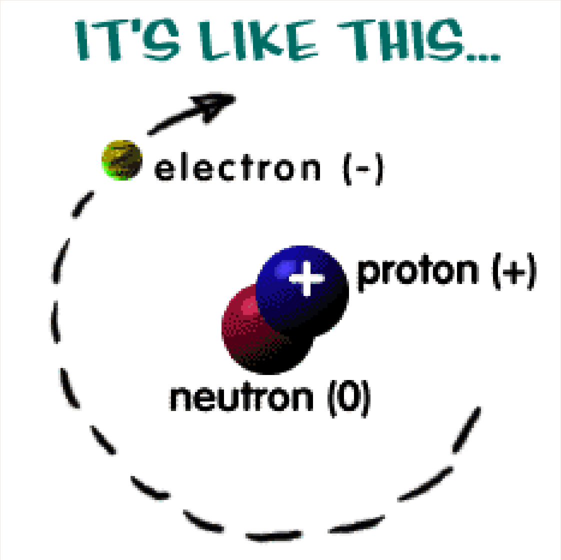
- The proton & neutron are found in the center of the atom, a place called the **nucleus.**
- The *electrons* orbit the



Picture from
http://education.jlab.org/qa/atom_model_03.gif

What are elements?

- Elements are the alphabet to the language of molecules.
- To make molecules, you must have elements.
- Elements are made of atoms. While the atoms may have different weights and



Information & picture from Chem4kids at http://www.chem4kids.com/files/atom_structure.html

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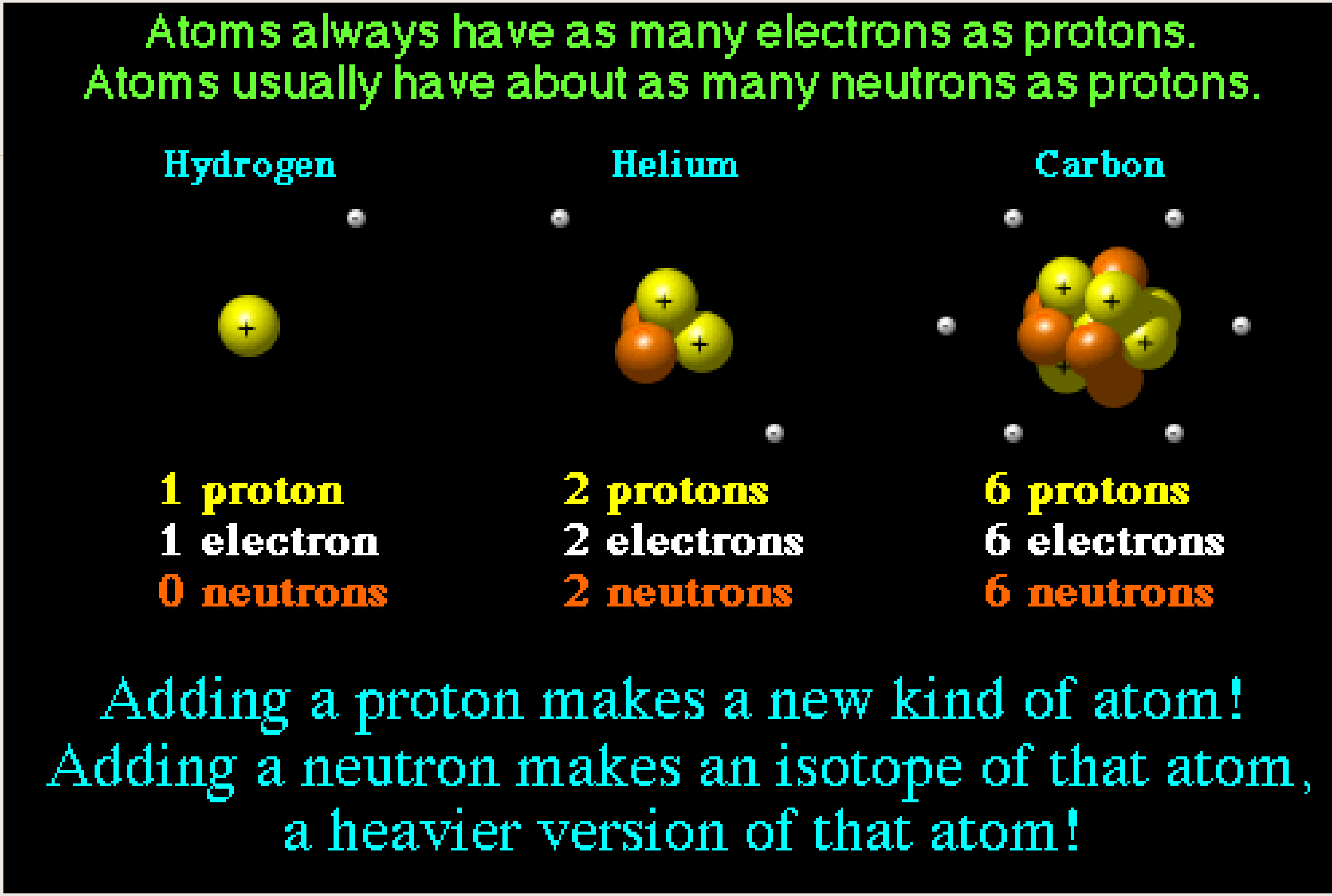

Graphic from http://education.jlab.org/atomtour/fact2.html

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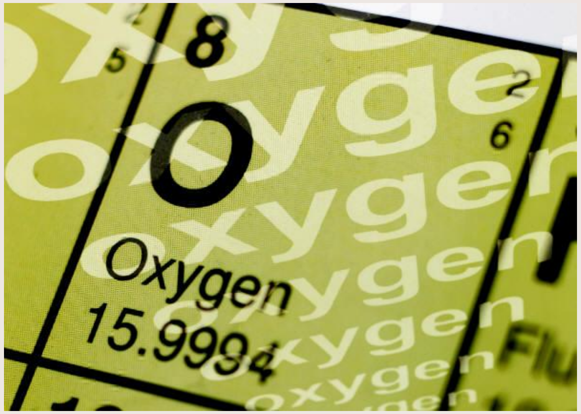
More about Elements..

- **Elements** are the building blocks of all matter.
- The periodic table is a list of all of the elements that can build matter. It's a little like the alphabet of chemistry.



- The periodic table tells us several things

Periodic Table

Atomic Number:

Number of protons and it is also the number of electrons in an atom of an element.

Element's Symbol:

An abbreviation for the element

Elements Name

Atomic Mass/Weight:

Number of protons + neutrons.

8

O

Oxygen

16

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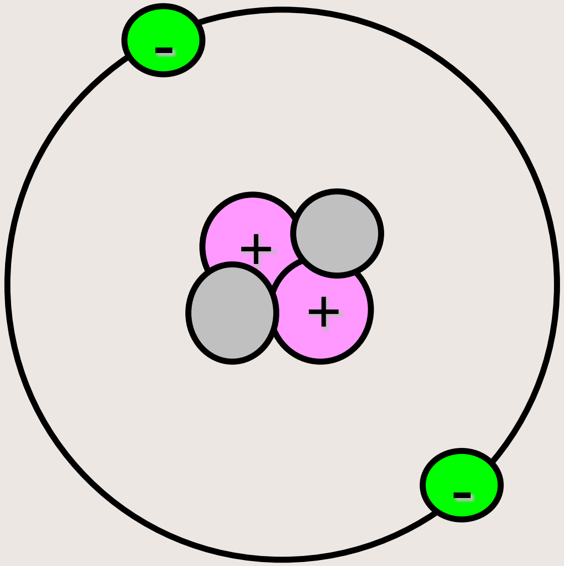
Atom Models

- There are two models of the atoms we will be using in class.
- Bohr Model
- Lewis Dot Structure

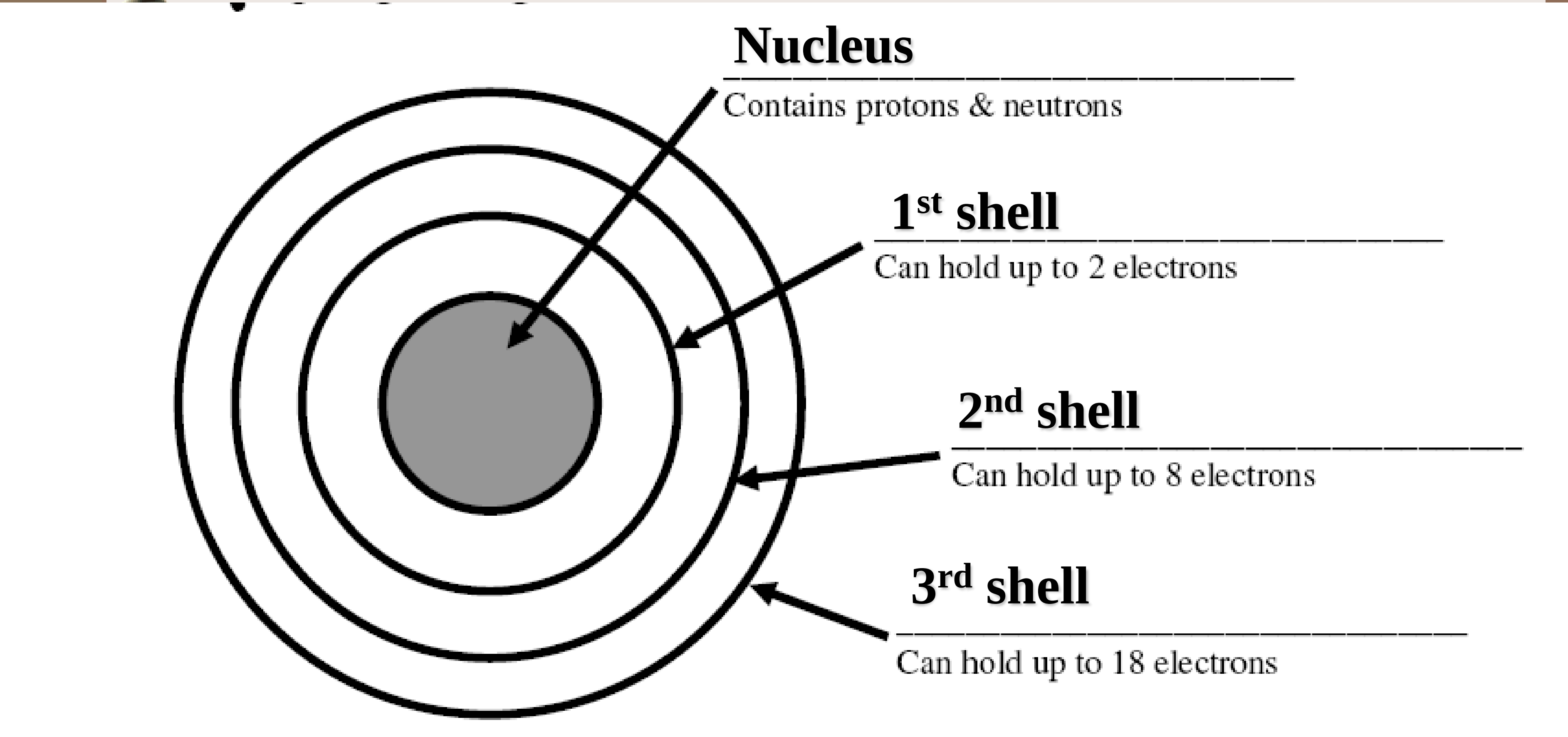
Bohr Model

- The Bohr Model shows all of the particles in the atom.
- In the center is circles. Each circle represents a single neutron or proton. Protons should have a plus or P written on them. Neutrons should be blank or



Electrons have special rules….

- You can’t just shove all of the electrons into the first orbit of an electron.
- Electrons live in something called **shells or energy levels**.
- Only so many can be in any certain shell.



Adapted from http://www.sciencespot.net/Media/atomsfam.pdf

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Electrons have special rules….

- You can’t just shove all of the electrons into the first orbit of an electron.
- Electrons live in something called shells or energy levels.

- Only so many can be in any certain shell.
- The electrons in the outer most shell of any element are called **valance electrons**.

So let's try it….

- How to draw a Lithium atom
- First, look at the Periodic Table
- Second, determine the number of protons (Look @ the atomic number)
- Then determine the number of neutrons (Atomic mass – atomic number)
- Then determine the number of electrons (Look @ the atomic number)

3
Li
Lithium
7

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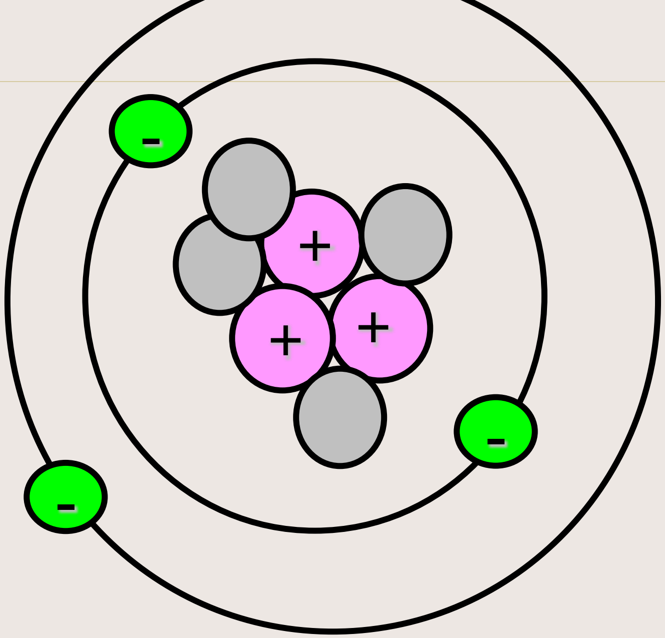
So let's try it….



Protons = 3

3
Li
Lithium
7

Electrons = 3

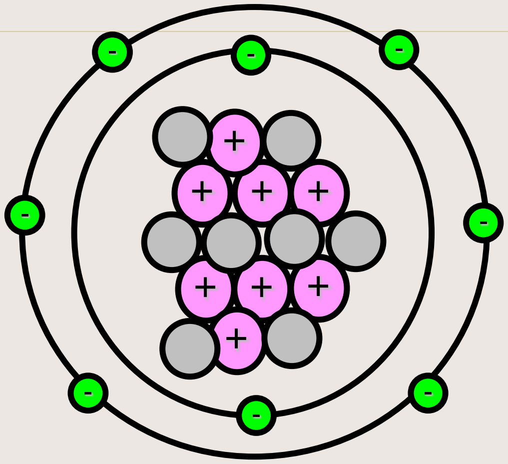
2 in the 1st shell, 1 in the 2nd shell

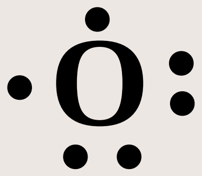
Neutrons = 4

(7-3=4)

Lewis Dot Structure

- The Lewis Dot Structure is a bit different from the Bohr model.
- It only shows the element symbol and it's outer most electron shell.





How to…

1. Write the symbol.
2. Start on the right hand side, working your way clockwise around the symbol.
3. Try Lithium

Your activity…

- Using the beans (Lentils are electrons, Lima Beans are protons, and kidney beans are neutrons), create a Bohr model , and then a Lewis dot structure model of each of the first 20 elements. After you have created each model, draw each model on your chart.
- Hint to make a chart, use a burrito fold, then fold the top down by 1 ½ inches. Unfold, you now have 3 columns. Label the columns: element, Bohr model, Lewis Dot.

2.5 The Modern View of Atomic Structure: An Introduction

The forces that bind the positively charged protons in the nucleus will be discussed in Chapter 19.

In the years since Thomson and Rutherford, a great deal has been learned about atomic structure. Because much of this material will be covered in detail in later chapters, only an introduction will be given here. The simplest view of the atom is that it consists of a tiny nucleus (with a diameter of about 10^{-13} cm) and electrons that move about the nucleus at an average distance of about 10^{-8} cm from it (Fig. 2.14).

As we will see later, the chemistry of an atom mainly results from its electrons. For this reason, chemists can be satisfied with a relatively crude nuclear model. The nucleus is assumed to contain **protons**, which have a positive charge equal in magnitude to the electron's negative charge, and **neutrons**, which have virtually the same mass as a proton but no charge. The masses and charges of the electron, proton, and neutron are shown in Table 2.1.

Two striking things about the nucleus are its small size compared with the overall size of the atom and its extremely high density. The tiny nucleus accounts for almost all the atom's mass. Its great density is dramatically demonstrated by the fact that a piece of nuclear material about the size of a pea would have a mass of 250 million tons!

The *chemistry* of an atom arises from its electrons.

An important question to consider at this point is, *"If all atoms are composed of these same components, why do different atoms have different chemical properties?"* The answer to this question lies in the number and the arrangement of the electrons. The electrons constitute most of the atomic volume and thus are the parts that "intermingle" when atoms combine to form molecules. Therefore, the number of electrons possessed by a given atom greatly affects its ability to interact with other atoms. As a result, the atoms of different elements, which have different numbers of protons and electrons, show different chemical behavior.

If the atomic nucleus were the size of this ball bearing, a typical atom would be the size of this stadium.

A sodium atom has 11 protons in its nucleus. Since atoms have no net charge, the number of electrons must equal the number of protons. Therefore, a sodium atom has 11 electrons moving around its nucleus. It is *always* true that a sodium atom has 11 protons and 11 electrons. However, each sodium atom also has neutrons in its nucleus, and different types of sodium atoms exist that have different numbers of neutrons. For example, consider the sodium atoms represented in Fig. 2.15. These two atoms are **isotopes**, or *atoms with the same number of protons but different numbers of neutrons.* Note that the symbol for one particular type of sodium atom is written

Mass number → $^{A}_{Z}X$ ← Element symbol
Atomic number

Mass number → $^{23}_{11}Na$ ← Element symbol
Atomic number

where the **atomic number** Z (number of protons) is written as a subscript, and the **mass number** A (the total number of protons and neutrons) is written as a superscript. (The particular atom represented here is called "sodium twenty-three." It has 11 electrons, 11 protons, and 12 neutrons.) Because the chemistry of an atom is due to its electrons, isotopes show almost identical chemical properties. In nature most elements contain mixtures of isotopes.

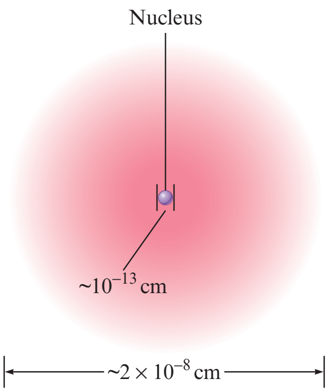


Figure 2.14 | A nuclear atom viewed in cross section. Note that this drawing is not to scale.

Table 2.1 | The Mass and Charge of the Electron, Proton, and Neutron

Particle	Mass	Charge*
Electron	9.109×10^{-31} kg	1−
Proton	1.673×10^{-27} kg	1+
Neutron	1.675×10^{-27} kg	None

*The magnitude of the charge of the electron and the proton is 1.60×10^{-19} C.

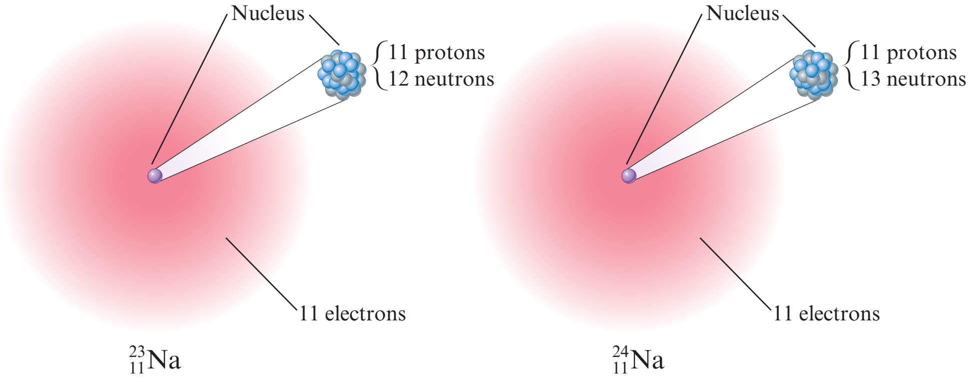


Figure 2.15 | Two isotopes of sodium. Both have 11 protons and 11 electrons, but they differ in the number of neutrons in their nuclei.

Critical Thinking

The average diameter of an atom is 2×10^{-10} m. What if the average diameter of an atom were 1 cm? How tall would you be?

Interactive Example 2.2

Sign in at http://login.cengagebrain.com to try this Interactive Example in **OWL**.

Writing the Symbols for Atoms

Write the symbol for the atom that has an atomic number of 9 and a mass number of 19. How many electrons and how many neutrons does this atom have?

Solution

The atomic number 9 means the atom has 9 protons. This element is called *fluorine,* symbolized by F. The atom is represented as

$$^{19}_{9}F$$

and is called *fluorine nineteen.* Since the atom has 9 protons, it also must have 9 electrons to achieve electrical neutrality. The mass number gives the total number of protons and neutrons, which means that this atom has 10 neutrons.

See Exercises 2.59 through 2.62

2.6 | Molecules and Ions

PowerLecture: Covalent Bonding

From a chemist's viewpoint, the most interesting characteristic of an atom is its ability to combine with other atoms to form compounds. It was John Dalton who first recognized that chemical compounds are collections of atoms, but he could not determine the structure of atoms or their means for binding to each other. During the twentieth century, we learned that atoms have electrons and that these electrons participate in bonding one atom to another. We will discuss bonding thoroughly in Chapters 8 and 9; here, we will introduce some simple bonding ideas that will be useful in the next few chapters.

The forces that hold atoms together in compounds are called **chemical bonds**. One way that atoms can form bonds is by *sharing electrons*. These bonds are called **covalent bonds**, and the resulting collection of atoms is called a **molecule**. Molecules can be represented in several different ways. The simplest method is the **chemical formula**, in which the symbols for the elements are used to indicate the types of atoms present and subscripts are used to indicate the relative numbers of atoms. For example, the formula for carbon dioxide is CO_2, meaning that each molecule contains 1 atom of carbon and 2 atoms of oxygen.