Learning Goals Unit 3: Atomic structure

I will be able to:

**KNOW (define)**

- Atom, neutron, proton, electron, atomic mass, atomic number
- Define ions, cations, anions,
- Define isotopes
- Periodic, periodic table, groups (families), periods, alkali metals, alkaline earth metals, halogens, noble gases, transition metals, non-metals, metalloids, diatomic elements (HONClBrIF)
- Define valence electrons, oxidation number

**UNDERSTAND**

1. Explain the difference between science and pseudoscience
2. Describe what are indirect measurements and their importance in science
3. Explain when do scientific models change over time
4. Describe sub atomic structure per the following: protons, neutrons, electrons, and the charges of these particles.
5. Describe the structure of the atom as nucleus made of protons and neutrons with electrons orbiting in the electron cloud.
6. Describe, in general, why elements lose or gain electrons to become ions, while some elements prefer not to gain or lose electrons and remain neutral.
7. Describe what are sublevels and list the sublevels
8. Describe how elements are organized on the periodic table based on their properties
9. Describe the terms Period and Groups as they apply to the periodic table
10. Describe the main characteristics of different types of elements (metals, metalloids, non-metals)

**DO**

1. Identify whether a text is scientific or pseudoscientific
2. Find the number of protons, electrons and neutrons for an element given its atomic mass and atomic number
3. Write the electron configuration for any element (sublevel notation) by reading the periodic table
4. Write the electron configuration using the noble gas short hand
5. Find the oxidation number of elements by a) drawing the atomic sketch of the element, b) looking at groups in the periodic table, and c) using a list of common oxidation numbers.
6. Draw the atomic sketch using sublevel notation and electron dot symbol of an element given the atomic number and atomic mass
7. Recognize patterns in the periodic table of the following properties: atomic radius and ionization energy.
8. Use these patterns to predict the placement of other elements into their organization
The Structure of Matter: A Historical Perspective

Prehistoric times

- Before 1000 B.C.E.
- They thought: “This could make a nice arrowhead,” not, “I wonder what makes this rock hard and shiny?”

Greek Theories

- The Greeks were ________________, not scientists.
- Because they had become “civilized,” they had more time to sit around, ___________ about, and ___________ what matter was.
- They did not do experiments.

Thales – 600 B.C.E.

- Thought that the simplest form of matter was __________.
- He thought: Everything comes from water and depends on water; therefore water must be the most basic of substances.

Anaximenes – 550 B.C.E.

- Thought that the simplest form of matter was __________.
- He thought: Air can be condensed to form solids like the earth or can exist as we know it.

Heraclitus – 500 B.C.E.

- Thought that the simplest form of matter was __________.
- He thought: All things are composed of fire and are again resolved into fire.
Empedocles – 450 B.C.E.
• __________________ the ideas of the Greeks before him but added _________ as a component.
• Developed the ______________ ______________ ______________:
  • All matter is made of 4 basic substances:
    • ___________, ___________, ___________, and ___________.

Leucippus (the teacher) & Democritus (the student) – 450 B.C.E.
• Something cannot come from nothing.
• All matter is made of indivisible, indestructible ______________ (________)
• They thought: “The properties of a material are due to the arrangements of its atoms in space.”

Democritus added:
• Atoms are in ______________ ______________.
• The ______________ of atoms determine their properties:
  • Ex)
    • Sour foods have sharp atoms.
    • Sweet foods have large and round atoms.

Aristotle – 350 B.C.E.
• Disagreed with the atomic theory.
• Supported the 4 element theory and added the __________ ______________:
  __________, __________, __________, and __________.
• Because he was known as the ______________ ______________ in many things, people had to believe him, and did so for 2000 yrs!!!

Alchemy
• “_________________ ________________”
*Studied in many cultures from 5000 B.C.E. to present.
• It is a ____________________: ______________________________

• They develop models that do not fit the 3 criteria of a good model.

• Very secretive

The Philosopher's Stone

• The alchemists thought if they could find or create this substance, they could find or create their three main goals:

1) ______________________ __________
   • The ______________________ _______ ________ ________ that allows you to live forever
   • This would be worth __________.

2) ______________________ __________
   • A liquid that would __________________________
   • This would be worth __________.

3) ______________________ __________
   • ____________ cheap __________ into silver and gold (Ag and Au).
   • This would be worth __________.

Alchemists' Contributions to Science

1) Discovered five ________________: P, As, Sb, Bi, and Zn
   The "ancients" already knew about: Au, Ag, Hg, Pb, Fe, Cu, Sn, and C
2) Produced a variety of ________________: test tubes, flasks, etc.
3) Refined and discovered ways of making things ___________: distillation, crystallization
4) Discovered ways of working with ____________: alloying
Science and Pseudoscience

Remember the work you did in middle school with a black box? The purpose of that activity was to define what scientific models are and how to assess their validity. Let us refresh our memories. Answer the following questions:

A. Explain what is meant by a scientific model. Give an example.

____________________________________________________________________________________________________

____________________________________________________________________________________________________

B. What are the three characteristics used for evaluating models?

____________________________________________________________________________________________________

____________________________________________________________________________________________________

C. Explain why models are often revised.

____________________________________________________________________________________________________

____________________________________________________________________________________________________

The three characteristics for evaluating models can be summarized in what is known as Falsifiability. The predictions made through the model need to be able to be proven wrong. If the model cannot be proven wrong, then it is not a scientific model. “No number of positive outcomes at the level of experimental testing can confirm a scientific theory, but a single counterexample is logically decisive”.

But, as they say, not everything that shines is gold. There are a lot of models out there that sound like scientific models that do not satisfy these criteria. Some people use them for their own convenience as if they were scientific models, but they are not. These models are part of what we call Pseudoscience (pseudo means false or untrue).

By the end of this activity you should be able to evaluate a model and determine if it is truly a scientific model or pseudoscience.

A pseudoscience can be defined as a belief or process which pretends to be science in an attempt to claim a legitimacy that it would not be able to achieve on its own terms.

Read the following text and write down below whether you think it is scientific or pseudoscientific:
Note that there were a lot of earthquakes and volcanoes in 2009-2011. For example, on April 13-14 2010, Iceland Eyjafjallajokull volcano erupted again, and its volcanic ash went over Europe over the next few days and grounded airplanes at airports across Northern Europe. There is a concern that a larger volcano Katla near it could erupt soon. Iceland has more than 100 volcanoes, many could erupt soon, and volcanoes have been erupting in Indonesia and other countries in 2010. This could be a beginning to major volcano eruptions in Iceland, Indonesia, and elsewhere that could cool off the earth, ground air traffic, cause no summer and severe winters.

Could these volcanoes and earthquakes be related to the CERN LHC particle accelerator experiments in France - either because a Black Hole has already been created by the CERN LHC and is eating earth's core, and could cause increasing earthquakes and volcanos around the world, leading up to December 2012 Doomsday, or because the CERN LHC experiments may directly affect earth's core and cause quakes and volcanoes. Note that 70,000 years ago the Toba supervolcano erupted in Indonesia and nearly caused the extinction of mankind then. Volcanos can be a major problem for man's survival on earth.

There is a Nostradamus prophecy on this possibility. The CERN LHC was turned on again in November 2009, and on March 30 2010 the more dangerous high energy collisions at 7 TeV began that could create Black Holes. And on Nov. 4-10 2010 the LHC switched to doing lead nucleus collisions rather than proton collisions, this could result in the creation of an earth-eating Strangelet star. And if a Black Hole is created and goes to the center of the earth, there may be no sign of it for a year or two, until it gets large enough to start causing giant earthquakes and volcanoes, possibly eating earth from the inside on December 21 2012. Also, could the LHC actually be causing earthquakes and volcanos directly by creating gravity waves or particle beams, such as the Chile earthquake in Feb. 2010, which occurred just as the LHC was turned on again, and the Iceland volcano.

In this site Revelation 13, my method of prophecy combines Astrology and other New Age Schools, mythology, religion, the prophecies of Nostradamus, Bible Code in the King James Bible, Bible prophecy, and numerical analysis. In particular, the Book of Revelation of the King James Bible is discussed.

Now it is your turn to evaluate the text:

I believe this text is Scientific / pseudoscientific because: ____________________________________________________________

Compare your thoughts with your partner and write a description of how you could identify pseudoscience:

__________________________________________________________

__________________________________________________________
Characteristic to identify Pseudoscience

Here are some typical characteristics that pseudoscientific claims proven wrong in terms of their predictions (science) or not.

Use of vague, exaggerated or untestable claims

- Declaration of scientific claims that are unclear rather than precise, and that lack specific measurement.
- Failure to make use of simple definitions of the variables, terms, or objects of interest so that other people can reproduce the experiment.
- Use of a more complicated explanation when there is a possible simpler explanation
- Misuse of apparently technical words in an effort to give claims the superficial trappings of science.

Over-reliance on confirmation rather than contradiction

- Cannot be shown to be false by observation or physical experiment.
- Claims that a theory predicts something that it has not been shown to predict.
- Assertion that claims which have not been proven false must be true, and vice versa.
- Over-reliance on testimonials.
- Presentation of data that seems to support its claims while suppressing or refusing to consider data that conflict with its claims. A distortion of evidence or data that arises from the way that the data is collected.

Lack of openness to testing by other experts

- Avoidance to subjecting ideas to peer review. By not going through the peer review process, these proponents forgo the opportunity of corrective feedback from informed colleagues.
- Some agencies, institutions, and publications that fund scientific research require authors to share data so that others can evaluate a paper independently. Failure to provide adequate information for other researchers to reproduce the claims contributes to a lack of openness.
- Claims of secrecy or proprietary knowledge in response to requests for review of data or methodology.

Absence of progress

- Failure to progress towards additional evidence of its claims.
- These ideas rarely change over several millennia.
- Theories may be accused of being pseudoscientific because they have remained unaltered despite contradictory evidence.

Personalization of issues

- Tight social groups enhance the adoption of beliefs that have no rational basis.
- In attempting to confirm their beliefs, the group tends to identify their critics as enemies.
- Claims of a conspiracy on the part of the scientific community to suppress the results.
- Attacking the motives or character of anyone who questions the claims.

Use of misleading language

- Creating scientific-sounding terms in order to add weight to claims and persuade non-experts to believe statements that may be false or meaningless.
- Using established terms in peculiar ways, thereby demonstrating unfamiliarity with mainstream work in the discipline.
Remember to always assess whether a model:

1. Explains *all* data available

2. Can make predictions that can be proven wrong (not the same as *predictable*).

Your teacher will give your team a piece of paper with one of the most common characteristics of pseudoscience that might help you identify it as such. Write the characteristic in the table on the next page, discuss in your group whether this particular characteristic was useful for determining if the previous reading is pseudoscience, and be prepared to share with your classmates where you can see that characteristic on the text.

Table I. Useful characteristics for identifying pseudoscience

<table>
<thead>
<tr>
<th>Use of vague, exaggerated or untestable claims</th>
<th>Over-reliance on confirmation rather than contradiction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of openness to testing by other experts</td>
<td>Absence of progress</td>
</tr>
<tr>
<td>Personalization of issues</td>
<td>Use of misleading language</td>
</tr>
</tbody>
</table>
At the beginning of the last century, Dr. Wilhelm Fliess noticed identical rhythms in the case histories of his patients. He observed active and passive phases in the physical, emotional and mental aspects of humans. From these observations he derived the principle of the biorhythms, which state that a person's life is affected by rhythmic biological cycles which affect one's ability in various domains, such as mental, physical, and emotional activity. These cycles begin at birth and oscillate in a steady sine wave fashion throughout life; thus, by modeling them mathematically, a person's level of ability in each of these domains can be predicted from day to day.

Most biorhythm models use three cycles: a 23-day "physical" cycle, a 28-day "emotional" cycle, and a 33-day "intellectual" cycle. Although the 28-day cycle is the same length as the average woman's menstrual cycle and was originally described as a "female" cycle, the two are not necessarily in any particular synchronization. Each of these cycles varies between high and low extremes sinusoidally, with days where the cycle crosses the zero line described as "critical days" of greater risk or uncertainty. In addition to the three popular cycles, various other cycles have been proposed, based on linear combination of the three, or on longer or shorter rhythms.

The belief in biorhythms is based on numerology, testimonials and the Forer effect. Biorhythms can't predict or explain events, they can only suggest how we may deal with them. For example, some doctors plan operations around them or sports coaches use them in their individual training programs.

At the moment of birth, the biorhythmic cycles are set to zero. Knowing your birthday, the number of days you have lived and where in each cycle you are can be determined for any given day. A biorhythmic chart for July 24, 1998, for someone born four days earlier would look like this:

The line going through the middle is the zero line. A cycle is said to be in a positive phase when above the zero line and in a negative phase when below the zero line. A cycle begins in an ascent for the first fourth of a cycle, then half of the cycle is in descent, then the last quarter of the cycle ascends back to the zero line. The cycles repeat until you die. Should you live to be something like 58 years and 66 days old, you will reach the point at which the physical, emotional and intellectual cycles return to the same point on the zero line. For some, this is a moment of "rebirth."

Explain why you think the previous text is scientific or why you think it is pseudoscientific. You must use the three criteria that validate a model, as well as at least three of the six characteristics we studied before that help identify pseudoscientific texts:

I believe the text is ____________________________________________, because:

Criteria for scientific models:

1. __________________________________________________________

2. __________________________________________________________

3. __________________________________________________________

One way to identify a pseudoscience:

Another way to identify a pseudoscience:

Describe how your chosen pseudoscience can be identified by the method above:

Describe how your chosen pseudoscience can be identified by the method above:
History of the atomic model

Around 460 B.C., the Greek philosopher Democritus asked: If you break a piece of matter in half, and then do so again and again, how many breaks will you have to make until you can break the matter no more? Democritus reasoned that one would eventually end up with the smallest possible bits of matter that could not be broken any more. He named these basic matter particles atomos, or atoms. The idea that matter is made up of fundamental particles called atoms is known as the Atomic Theory of Matter. Democritus’ ideas were opposed by Aristotle and were not commonly considered until more than 2,000 years later.

1. Describe Democritus model of matter (I.16.3)

__________________________________________________________________________

__________________________________________________________________________

2. Did the model match the data available at that time? __________________________

3. Was the model able to predict a testable future outcome? ______________________

John Dalton, a meteorologist in the 1800’s, performed experiments in which he performed experiments and calculated the mass of elements that went through chemical combinations and the mass of their products. The patterns found in his data led him to propose that:

a) All elements are composed of tiny indivisible particles called atoms
b) Atoms of the same element are identical, particularly in mass. Atoms of anyone element are different from those of any other element.
c) Atoms combine chemically with each other in definite whole number ratios to form compounds.

1. Describe Dalton’s model of matter (I.16.3)

__________________________________________________________________________

__________________________________________________________________________

2. Did the model match the data available at that time? (E.20.2) __________________

3. Was the model able to predict a testable future outcome? (E.20.2) ____________

Identify how these two models are similar (E.20.4)

__________________________________________________________________________

__________________________________________________________________________

4. Identify how the models are different(E.20.4)

__________________________________________________________________________

__________________________________________________________________________
In 1987 J.J. Thompson, performed the following experiment: He passed an electric current through a glass tube containing a gas at low pressure and found a glowing beam inside the tube. He found that he could change the direction in which the glowing beam moved using a magnet or an electric field. Thompson proposed that the beam was formed by small pieces of the gas atoms, called electrons, and that these pieces had a negative charge. In his model the atom consists of electrons embedded in a positively charged sphere of stuff, like raisins are embedded in a muffin.

1. Describe Thompson’s model of matter (I.16.3)

___________________________________________________

___________________________________________________

2. Did the model match the data available at that time? (E.20.2)

3. Identify similarities between Thompson’s and Dalton’s models (E.20.4)

___________________________________________________

___________________________________________________

4. Identify difference between Thompson’s and Dalton’s model (E.20.4)

___________________________________________________

___________________________________________________

5. Explain how the discovery of the electrons strengthen or weaken Democritus’ model (E.28.2)

___________________________________________________

___________________________________________________

Ernest Rutherford, a physicist from New Zealand, discovered the existence of the nucleus of the atom in 1911. Rutherford performed an experiment in which he aimed atomic particles at a thin sheet of gold foil. He found that most particles passed right through the foil, but some bounced back. These results suggested a model that most of an atom is empty space. The data also suggested that almost all of the mass of an atom is contained in a tiny nucleus. Rutherford affirmed the idea that the nucleus was positively charged, and offered that the positive charge was a result of the subatomic particles called protons, which he had discovered. Rutherford’s model is similar to a planetary system. The tiny negatively charged electrons orbit the positively charged massive nucleus, leaving a lot of empty space between electrons and nucleus.

1. Describe Rutherford’s model of matter (I.16.3)

___________________________________________________

6. Did the model match the data available at that time? (I.16.3)

___________________________________________________

___________________________________________________
2. Identify similarities between Rutherford’s and Thompson’s models (E.20.4)

3. Identify difference between Rutherford’s and Thompson’s model (E.20.4)

4. Explain how does the discovery of the proton strengthen or weaken Dalton’s model (E.28.2)

5. Use this sequence of events to explain when do models need to be revised

Many more scientists have revised the atomic model. In fact, we are still far from fully understanding what matter is, and many scientists are working towards improving our understanding. One of the biggest questions is how do subatomic particles acquire their mass. We have many years ahead of exciting discoveries!
1. Basic Subatomic Particles and their Characteristics:

<table>
<thead>
<tr>
<th>Subatomic Particle Name</th>
<th>Proton</th>
<th>Neutron</th>
<th>Electron</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symbol</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Charge</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location in the atom</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discoverer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date of discovery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass in grams</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass in amu (mass number)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2. Overall Structure of Atom

A. Nucleus

B. Electron orbits, shells, or energy levels

   i. Elliptical path

   ii. Electron cloud motion

   iii. Relative distances

3. Size and Weight of the Atom – Need for new atomic size units

A. Mass

   i. The atomic mass unit (amu)

      • \( \_\_\_\_\_\_ g = \_\_\_\_\_ amu \)
      • \( \_\_\_\_\_ amu = \_\_\_\_\_ g \)

   ii. Range of masses
iii. Location of atomic mass

iv. Density of the nucleus

B. Length – the Angstrom unit (Å)

i. Diameter

   a. Range of sizes

   b. Diameter of nucleus

4. Visual Evidence for the Existence of Atom
Indirect Measurement

When scientists wanted to find out what an atom was, they were not able to look directly at what an atom was made of since they are very small. Scientists have needed to estimate most of the atomic properties based on certain mathematical calculations of things they can actually measure.

Atoms are not the only things that scientists have studied that cannot directly measure. How do we know the temperature of the sun, if we cannot place a thermometer on it? How do we know what stars that are millions of light years away are made of if we cannot go and sample them?

VIEW “INDIRECT MEASUREMENT” POWERPOINT

Indirect measurement (def.) ___________________________________________ _________________________
___________________________________________________ __________________________________________

Think of other things for which scientists might have had to estimate because direct measurements are not possible and list them here:

________________________________

________________________________

________________________________

________________________________
IPS – Indirect Measurement - Nuclear Marbles Lab

Purpose: To determine the diameter of a marble by indirect measurement.

Procedure:
1. Work in groups of three (Recorder, Roller, and Returner)
2. Place nuclear marbles along wall
3. Without looking, roll the rolling marble at the nuclear marbles
4. Count and record how many trials and how many times a nuclear marble is hit by the rolling marble.
5. You must have 150 trials!

Data:

<table>
<thead>
<tr>
<th>Trials</th>
<th>Hits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Nuclear marbles_______ Rolling marble ___1____

Calculations:

\[ D = \frac{HL}{2TN} \]

Use this formula to calculate your marble diameter:

Show your calculations here:
The number of protons determines the \textit{atomic number} of an atom, and the number of protons also determines to which \textit{element} that atom corresponds. This means that atoms of the same elements will have the same number of protons and the same atomic number, but atoms of different elements will always have different atomic number.

Atoms of every element will tend to have the same number of electrons as protons. We will see later that there are exceptions to this rule, but for the moment we will assume that every atom has the same number of electrons as protons. The smallest atom is hydrogen. It consists of one proton and one electron. The next atom is helium. It contains two protons and two electrons. Remember that in our current model for the atom, electrons orbit the nucleus in different shells. The electrons in the outermost shell determine the chemical properties of each atom.

In addition to the protons and electrons, of course, are the neutrons. They have no effect on the chemical properties of the atom, but they contribute to mass, and in the case of radioactive elements, which we will study later on in the course, the decay rates. For hydrogen, there are three different \textit{isotopes} of this element. An isotope is an atom of any element that has the same number of protons, but a different number of neutrons. Each is still hydrogen because each has the same number of protons, and each has the same chemical properties. The difference is that for the first isotope, there are no neutrons in the nucleus, for the second (deuterium) there is one, and for the third (tritium) there are two neutrons.

The \textit{atomic mass} is equal to the number of protons + neutrons (because the electron essentially has no mass). For hydrogen, there are three isotopes, one with mass 1 (one proton, no neutrons), one with mass 2 (one proton, one neutron) and one with mass 3 (one proton and two neutrons) mass three. For hydrogen, the different isotopes have names: protium, deuterium and tritium.

As you already know, each element has a symbol. For hydrogen, it is H, for helium it is He, uranium is U. Some are not so obvious; iron, for example, is Fe (however, consider that iron is ‘\textit{ferrum}’ in Latin). The isotope of a given element is given by a superscripted atomic mass preceding the element. That is, for hydrogen of mass 1, the notation is $^1\text{H}$, for mass two, it is $^2\text{H}$ and for hydrogen of mass three (one proton, two neutrons) it is $^3\text{H}$.

Likewise, for helium, there are two isotopes. Both have 2 protons and 2 electrons, of course. But one has only one neutron (mass 3, or $^3\text{He}$) and the other has two neutrons (mass 4, or $^4\text{He}$). Oxygen has 8 protons. Its atomic number is 8. It has three different naturally occurring isotopes: $^{16}\text{O}$, $^{17}\text{O}$, $^{18}\text{O}$.

\textbf{Important Terms:} Write any important words or definitions here!
Atomic Structure

You now know that the atom is made out of Protons, neutrons and electrons; that the protons and neutrons are found in the nucleus, and that the electrons orbit the nucleus.

You also know that the elements are organized in the periodic table according to their properties… but if all atoms are made of the same “stuff”, what determines the properties of each atom?

In the following lessons you will discover what determines the properties of an atom. You will begin by learning important terms to describe an atom. If you look at a periodic table you will see that each element has a square with a bunch of numbers. Let us find out what does each of these numbers represent

![19 K 39.098]

- **Atomic number** - tells the # of protons in the nucleus of an atom. The number of protons determines the element.
- **Atomic mass** - the total n# of protons (p) and neutrons (n) in the nucleus. Tells the mass of an atom (electrons are so small that practically do not contribute to the mass)
- **Number of electrons**: Atoms have no charge most of the time, which means that they have the same number of protons as the same number of electrons

By looking at the periodic table you can determine the number of protons, neutrons and electrons.

- Number of protons given by atomic number
- Number of electrons equals number of protons (when the atom has no charge)
- Number of neutrons: round up or down the atomic mass and subtract number of protons

![19 K 39.098]

<table>
<thead>
<tr>
<th>Atomic symbol</th>
<th>Number of protons</th>
<th>Number of electrons</th>
<th>Number of neutrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>K</td>
<td>19</td>
<td>19</td>
<td>20</td>
</tr>
</tbody>
</table>

19 protons therefore, 19 electrons
39 – 19 = 20 neutrons
We have not answered the question: “what determines the properties of an element if they are all made of protons, electrons and neutrons?” The properties of the atoms that we will study in this unit depend on how are the electrons distributed within the atom. We know they orbit the nucleus in energy levels, but how exactly do they do this? In order to understand this we need to know more terms…

d) **electron shells or energy levels** - the location outside the nucleus where the electrons are found. Electrons are found in different energy levels. These energy levels are labeled starting closest to the nucleus and then outward by number \((n=1,2,3,4)\).

The energy levels correspond to the row the element is in on the periodic table. The energy levels are also called orbitals.

e) **valence electrons** - the electrons that are in the outermost shell from the nucleus. The number of valence electrons corresponds with the group number on the periodic table. (Group 1,2,3,4,5,6,7 or 8 going across the table). The **maximum** number of outer shell electrons is 8, therefore the maximum # of dots a dot symbol can have is 8.

<table>
<thead>
<tr>
<th>Energy levels</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>n=1</td>
<td>H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Li</td>
<td>Be</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Na</td>
<td>Mg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n=2</td>
<td>K</td>
<td>Ca</td>
<td>Sc</td>
<td>Ti</td>
<td>V</td>
<td>Cr</td>
<td>Mn</td>
<td>Fe</td>
</tr>
<tr>
<td></td>
<td>Si</td>
<td>P</td>
<td>S</td>
<td>Cl</td>
<td>Ar</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n=3</td>
<td>Rb</td>
<td>Sr</td>
<td>Y</td>
<td>Zr</td>
<td>Nb</td>
<td>Mo</td>
<td>Tc</td>
<td>Ru</td>
</tr>
<tr>
<td></td>
<td>Ru</td>
<td>Rh</td>
<td>Pd</td>
<td>Ag</td>
<td>Cd</td>
<td>In</td>
<td>Sn</td>
<td>Sb</td>
</tr>
<tr>
<td>n=4</td>
<td>Cs</td>
<td>Ba</td>
<td>La</td>
<td>Hf</td>
<td>Ta</td>
<td>W</td>
<td>Re</td>
<td>Os</td>
</tr>
<tr>
<td></td>
<td>Ir</td>
<td>Pt</td>
<td>Au</td>
<td>Ha</td>
<td>Tl</td>
<td>Pb</td>
<td>Bi</td>
<td>Po</td>
</tr>
<tr>
<td>n=5</td>
<td>Fr</td>
<td>Ra</td>
<td>Ac</td>
<td>Ry</td>
<td>Db</td>
<td>Sg</td>
<td>Bh</td>
<td>Hs</td>
</tr>
<tr>
<td></td>
<td>Mt</td>
<td>110</td>
<td>111</td>
<td>112</td>
<td>113</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Lanthanides** *  
**Actinides** **

![Periodic Table of Elements](link)
f) **atomic sketch** - a drawing of an atom showing the protons and neutrons in the nucleus and the electrons in the shells/energy levels outside the nucleus.

Atomic sketch example for K:

<table>
<thead>
<tr>
<th>nucleus</th>
<th>shells</th>
<th>e^+</th>
<th>e^-</th>
</tr>
</thead>
<tbody>
<tr>
<td>n= 1</td>
<td>2</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

# of p = 19

# of e^- = 19

f) **order of electrons filling the shells** - For the moment we will say that the **maximum # of electrons** that can fill a shell, when this shell is the last shell, is: 1 = 2 electrons, 2 = 8 electrons, 3 = 8 electrons, 4 = 8 electrons. We will see later that this is not the case. The electrons fill the 1st shell first, when that is full, 8 more will fill the 2nd shell, then 8 can fit into the 3rd shell (as long as this is the last shell), and if there are more electrons, up to 8 will fill the 4th shell when it is the last shell (notice the Potassium example above). This is valid for the first 20 elements on the periodic table. You will see how it works for other elements in a later course.

g) **electron dot symbol** - shows the element symbol and the number of valence (outer shell) electrons. Potassium has one outer shell electron, so the dot symbol looks like: K

other elements’ dot symbols are: Ca, N, Ar, O, C.
Fluffy Atoms

Now is your turn to do all this using small fluffy particles as positive protons, neutral neutrons and negative electrons according to the following code:

- Protons - red fluffy balls
- Neutrons - black fluffy balls
- Electrons - hole punches

Work on a lab bench. Use the chalk to draw a circle that will represent the nucleus, and circles around it that represent the energy levels. You will place the subatomic particles for the corresponding atom, and your teacher will verify that you have done it well. Also write with chalk, next to the atom, the number of protons, neutrons and electrons that you placed. Place the subatomic particles in the atom according to the following:

Draw here the atomic sketch after your teacher has verified each atom.

a. Atom with atomic number of 5 and atomic mass of 11.

b. Atom with atomic number of 4 and atomic mass of 11

  i. Do these atoms belong to the same element? ________________ Explain our answer

  ______________________________________________________
  ______________________________________________________

  ii. Explain your answer

  ______________________________________________________
  ______________________________________________________

  c. Atom with 6 protons and 6 neutrons

  d. Atom with 6 protons and 8 neutrons

    i. Do the last two atoms belong to the same element? Explain your answer: ________________ Explain our answer

    ______________________________________________________
    ______________________________________________________

  ii. Explain your answer

    ______________________________________________________
    ______________________________________________________

  e. Atom with 3 electrons in the energy level n=2
Atomic Structure and Sketch Practice

1a) How many protons, neutrons, and electrons are in this element?

\[
\begin{array}{c}
20 \\
Ca \\
40.078
\end{array}
\]

protons = 
electrons = 
neutrons = 

1b) Draw the atomic sketch for this element:

\[
\begin{array}{c}
p = 12 \\
N = 13 \quad 2 \quad 8 \quad 2
\end{array}
\]

represents the atomic sketch of an element.

a) How many valence electrons does this element have? ________
b) Write the electron dot symbol for the element ____________
c) How many total electrons does this element have? ________
d) Name the element ___________

3) The atomic number of an element is 14. The atom weighs 28 amu.

a) Draw the atomic sketch of the atom:

b) Write the electron dot symbol ______________

c) Name the element ___________

4) A certain element has 8 electrons in its last shell. The last shell is the shell 2.

a) Draw the atomic sketch:

b) Write the electron dot symbol ______________

c) Name the element _________________
5) An element has 7 electrons in its last shell. The last shell is shell 3. The atomic mass is 35 amu.

a) How many protons does this element have? _______

b) How many electrons does this element have? _______

c) Calculate how many neutrons there are _____________

d) Draw the atomic sketch for the atom:

e) Name this element _____________

Draw the electron dot symbol for the following:

6) atomic number = 5       atomic weight = 11

7) The total # of e⁻ is 7 and number of neutrons is 8

8) protons = 9       neutrons = 10

Tell how many valence electrons are in the following:

9) X

10) oxygen

11) Ne

12) an element in group 3

13) carbon
More Atomic Structure and Sketch Practice

1a) How many protons, neutrons, and electrons are in this element?

\[
\begin{array}{c}
15 \\
P \\
30.974
\end{array}
\]

protons = 15

electrons =

neutrons =

1b) Draw the atomic sketch for this element:

2) \[\begin{array}{c}
p = 16 \\
N = 16 \\
2 \\
8 \\
6
\end{array}\]

represents the atomic sketch of an element.

a) How many valence electrons does this element have? ______

b) Write the electron dot symbol for the element ___________

c) How many total electrons does this element have? ________

d) Name the element ___________

3) The atomic number of an element is 2. The atom weighs 4 amu.

a) Draw the atomic sketch of the atom:

b) Write the electron dot symbol ______________

c) Name the element ______________

4) A certain element has 1 electron in its last shell. The last shell is the 2 shell.

a) Draw the atomic sketch:

b) Write the electron dot symbol ____________

c) Name the element ________________
5) \( \bullet \) is the electron dot symbol for a mystery element. The outer orbit is the 2 orbit. The atomic mass is 12 amu.

a) How many protons does this element have? _______

b) How many electrons does this element have? _______

c) Calculate how many neutrons there are.

d) Draw the atomic sketch for the atom:

e) Name this element _____________

Draw the electron dot symbol for the following:

6) atomic number = 4    atomic weight = 9

7) The total # of e\(^{-}\) is 10 and number of neutrons is 10

8) protons = 5    neutrons = 6

Tell how many valence electrons are in the following:

9) \( \bullet \) \( \bullet \)

10) sodium

11) Cl

12) an element in group 5

13) hydrogen
Atoms in a Bag Exploration

Problems: What is the relationship between the number of protons, neutrons, and electrons in an atom of a given element?

What patterns can be seen between the numbers of subatomic particles and the mass number, atomic number, the atomic charge, and the isotopic number?

How do all these numbers of particle relate to the numbers you see on the Periodic Table?

Procedure: Look closely at each of the bags identified with an element. There are patterns within each bag associated with specific information about a particular atom of the given element. Investigate these patterns. Count the numbers of protons, electrons, and neutrons in each bag, and place the information in the data chart. Compare these numbers to the numbers on your periodic table. Corn kernels will represent the electrons, the black beans will be the neutrons, and the red pinto beans will be the protons.

Please DO NOT open the bags!

Data Table for the “known” elements.

<table>
<thead>
<tr>
<th>Name</th>
<th>Protons</th>
<th>Electrons</th>
<th>Neutrons</th>
<th>Atomic number</th>
<th>Atomic Mass (amu)</th>
<th>Isotopic Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helium</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxygen</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon – 12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isotope</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon – 14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isotope</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium Ion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fluorine</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fluorine Ion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Questions  (Note: Use complete sentences, and be specific!)

1. What is the difference between a sodium atom and a sodium ion?

2. What is the difference between a fluorine atom and a fluorine ion?

3. What is the difference between carbon–12 and carbon–14?

4. What do the 12 and 14 represent in the two isotopes of carbon?

5. Name the two particles that account for the mass of an atom.

6. What do the numbers in the table above correspond to in the periodic table?


8. Which subatomic particle makes a given heavier or lighter?

9. Which subatomic particle determines whether or not an atom will have a positive or negative charge?

10. How is the charge of an atom related to the number of electrons lost or gained?

Now, look at the following table of ‘unknown’ elements. Use what you’ve learned from above to identify these elements.

<table>
<thead>
<tr>
<th>Unknown</th>
<th>Protons</th>
<th>Electrons</th>
<th>Neutrons</th>
<th>Element Name</th>
<th>Isotopic Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
More on ions

Last class you discovered the difference between ions and atoms. By the end of the lesson you should be able to describe why ions are formed, and predict the charge of the ion of a given element based on its atomic structure. Let us begin by rewriting in your own words the definition of an ion:

An ion is:

________________________________________________________________________________________
________________________________________________________________________________________

As you also discovered last class, there are two types of ions, positive ions (Na\(^{+1}\)) and negative ions (F\(^{-1}\)). It is cumbersome to keep saying positive ions and negative ions, so scientists decided to give them a unique name:

- **Cations (ca+ions): are positive (+) ions**
- **Anions (A negative ion) are negative (-) ions.**

  - Write the definition of ca+ions and anions based on whether they lose or gain electrons:

    An atom turns into a ca+ion when: ____________________________________________________________ and another atom turns into an anion when ____________________________________________________________

You now know what is an ion and the definition of ca+ions and anions. But why do neutral atoms become ions to begin with? Why would a perfectly neutral atom lose or gain electrons? Do the following to discover this:

A. Draw the atomic sketch for elements Sodium (atomic number =11) and Chlorine (atomic number =17)

   Na    Cl

B. Determine the number of valence electrons for each of these atoms:

   Valence electrons for Na: _______________ Electron dot symbol for Na: __________
   Valence electrons for Cl: _______________ Electron dot symbols for Cl: __________

The key to understanding ions is that atoms are more stable when their last energy level has 8 electrons (except the first energy level, which can only hold 2 electrons).
C. Look at the atomic sketches. Discuss with your partner what might Na and Cl atoms do to become more stable:

___________________________________________________
___________________________________________________
___________________________________________________
___________________________________________________

Class statement:________________________________________
___________________________________________________
___________________________________________________

D. Redraw the atomic sketches of Na and Cl atoms:

Na
Cl

E. Now draw the sketches of the stable forms of Na and Cl (their ions).

Na ion
Cl ion

F. Label the type of ion (ca+ion or anion) that each of these atoms becomes to be stable

Na becomes a(n): _________________________________
Cl becomes a(n): _________________________________

G. Determine the number of valence electrons for each of these stable ions:

Valence electrons for Na\(^{+1}\): ____________  Electron dot symbol for Na\(^{+1}\): _________
Valence electrons for Cl\(^{-1}\): ____________  Electron dot symbol for Cl\(^{-1}\): _________

H. The charge of an ion is known as the **Oxidation number** of the element. Write the oxidation numbers for Na and Cl:

Oxidation number for Na is: ______________
Oxidation number for Cl is: ______________
I. Indicate whether As lost or gain electrons, and how many, based on the fact that its oxidation number is -3


J. Based on all this information, generalize and write down why do atoms become ions, and when do they become cations and when do they become anions.


Back to those fluffy atoms.

You are asked to create atomic sketches for different elements. You can draw them on your worksheet, or create them with the fluffy subatomic particles.

A. Atomic sketch for Beryllium

   a. Would Be gain or lose electrons to gain stability? _______________   How many? __________
   b. Draw the atomic sketch of the **stable** Be atom

   c. What is Be oxidation number ______________
   d. Is this a cation, anion or none? ____________ Draw the electron dot symbol for the stable Be
      ______________

B. Atomic sketch for Nitrogen

   a. Would N gain or lose electrons to gain stability? _______________   How many? __________
   b. Draw the atomic sketch of the **stable** Be atom

   c. What is N oxidation number ______________
   d. Is this a cation, anion or none? ____________ Draw the electron dot symbol for the stable N
      ______________

C. You cannot draw the atomic sketch for Bismuth, but you can figure out:

   a. Would Bi gain or lose electrons to gain stability? _______________   How many? __________
   b. What is Bi oxidation number ______________
   c. Is this a cation, anion or none? ____________ Draw the electron dot symbol for the stable Bi
      ______________
D. Draw the Atomic sketch for Neon
   a. Would Ne gain or lose electrons to gain stability? _______________  How many? _________
   b. Draw the atomic sketch of the stable Ne atom

c. What is Ne oxidation number ______________
d. Is this a cation, anion or none? ____________  Draw the electron dot symbol for the stable Ne ____________

E. Draw the Atomic sketch for Helium
   a. Would He gain or lose electrons to gain stability? _______________  How many? _________
   b. Draw the atomic sketch of the stable He atom

c. What is He oxidation number ______________
d. Is this a cation, anion or none? ____________  Draw the electron dot symbol for the stable He ____________
e. Propose an explanation for why we place He on the 8th column of the periodic table and not the 2nd column

___________________________________________________
___________________________________________________
___________________________________________________
___________________________________________________
___________________________________________________

Learning goals:

- Define ions, and label them according to their charge as cations and anions
- Define oxidation number
- Explain why and how ions are produced, and predict the oxidation number of an element based on its atomic structure
One strange apartment building.

Imagine a strange college dorm in which the number and size of apartments change according to the floor. Every apartment has double occupancy bedrooms, but some have more bedrooms than others. Apartments are labelled with letters s, p, d, and f according to the number of rooms. Here is how it looks:

- 1st floor: 1 one-bedroom apartment (s)
- 2nd floor: 1 one-bedroom apartment (s) and 1 three-bedroom apartment (p)
- 3rd floor: 1 one-bedroom apartment (s), 1 three-bedroom apartment (p) and 1 five-bedroom apartment (d)
- 4th floor: 1 one-bedroom apartment (s) and 1 three-bedroom apartment (p), 1 five-bedroom apartment (d) and 1 seven-bedroom apartment (f)

The apartments can be labelled using a number for the floor and a letter for the type of apartment, like this:

<table>
<thead>
<tr>
<th>Floor</th>
<th>Apartments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>1s</td>
</tr>
<tr>
<td>2nd</td>
<td>2s, 2p</td>
</tr>
<tr>
<td>3rd</td>
<td>3s, 3p, 3d</td>
</tr>
<tr>
<td>4th</td>
<td>4s, 4p, 4d, 4f</td>
</tr>
</tbody>
</table>

There is no elevator in the building, so the most sought after apartment is the first floor apartment. The first two students to sign up always get this one. It is easier to keep clean a small apartment than a big one, so the next student always prefers to live in the double apartment of the second floor (2s) rather than the three-bedroom (2p). The fourth student fills the same apartment.

Students like to spread out, so they begin to move into the three-bedroom apartment (2p) by treating each room as a single (1 person per room). Once the fourth student arrives to that apartment, then they begin to fill each room as a double. The two-people and six-people apartments in the third level are filled in the same way when needed.

Here is how the building’s occupancy looks like when there are eight students:

- 3rd floor
- 2nd floor: 2 2 1 1
- 1st floor: 2

Total students 3rd floor = 0
Total students 2nd floor = 6
Total students 1st floor = 2

Sketch the building’s occupancy for the following number of students and write the number of students per floor:

a. Three students
- 3rd floor
- 2nd floor
- 1st floor

Total students 3rd floor =
Total students 2nd floor =
Total students 1st floor =

b. Nine students
- 3rd floor
- 2nd floor

Total students 3rd floor =
Total students 2nd floor =
c. Eighteen students

<table>
<thead>
<tr>
<th>3rd floor</th>
<th>1st floor</th>
</tr>
</thead>
</table>

Total students 3rd floor =
Total students 1st floor =

Things begin to get tricky with 19 students. You might think they would begin to fill the very large apartment on the third floor, but students prefer to walk one more flight of stairs and be in a double (4s) in the fourth level rather than live in a very large apartment in the third (3d). Here is how the building looks like with 20 students:

<table>
<thead>
<tr>
<th>4th floor</th>
<th>3rd floor</th>
<th>2nd floor</th>
<th>1st floor</th>
</tr>
</thead>
</table>

Total 4th floor = 2
Total 3rd floor = 8
Total 2nd floor = 8
Total 1st floor = 2

Student 21 arrives and decides that the difference between a three bedroom suite and a five bedroom one is not worth the extra set of stairs, so he moves into the five bedroom apartment in the third floor (3d) instead of the three bedrooms on the fourth floor (4p). From then on, students treat each room on 3d as a single until the need arises to fill them.

<table>
<thead>
<tr>
<th>4th floor</th>
<th>3rd floor</th>
<th>2nd floor</th>
<th>1st floor</th>
</tr>
</thead>
</table>

Total 4th floor =
Total 3rd floor =
Total 2nd floor =
Total 1st floor =

The apartment manager decides to use a different system to show the occupancy that does not involve drawing boxes. She labels them with a number by the floor in which they are found, a letter (s, p, d, p or f) according to the number of rooms, and a superscript to indicate how many students are in each apartment.

\[ 2d^5 = \text{five students in the three bedroom apartment of the second floor} \]

She now writes the occupancy of the building as follows. 8 students: 1s^2 2s^2 2p^4

Use this notation to indicate the building occupancy for the examples you did above:
<table>
<thead>
<tr>
<th>Number of students</th>
<th>Apartment occupancy</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td></td>
</tr>
</tbody>
</table>

**But**, what does all this have to do with chemistry, you might ask? Everything! As we are about to see, electrons fill in the atomic energy levels in the same way as the strange apartment building is filled with students. Instead of floors, there are atomic levels, and instead apartments there are sublevels. Each sublevel is divided into “bedrooms” as well, but we will worry about them later. Check how the analogy with the apartment works:

**Table 2. Analogy between atom and apartment building**

<table>
<thead>
<tr>
<th>Apartment / Atom</th>
<th>Apartments / Sublevels</th>
</tr>
</thead>
<tbody>
<tr>
<td>1\textsuperscript{st} floor / level</td>
<td>1s</td>
</tr>
<tr>
<td>2\textsuperscript{nd} floor / level</td>
<td>2s, 2p</td>
</tr>
<tr>
<td>3\textsuperscript{rd} floor / level</td>
<td>3s, 3p, 3d</td>
</tr>
<tr>
<td>4\textsuperscript{th} floor / level</td>
<td>4s, 4p, 4d, 4f</td>
</tr>
</tbody>
</table>

The atomic energy levels have the same rules for filling with electrons, so the sublevel notation for Calcium (\textit{20}Ca), is:

\[
\text{Ca}: 1s^2 2s^2 2p^6 3s^2 3p^6 4s^2
\]

Notice that this is compatible with Calcium’s atomic sketch the way we were doing them before. The difference is that each level now has sublevels.

How are you going to remember how the apartments / sublevels are filled? Those rules do not have to be memorized, as long as you know how to read the periodic table. \textit{It is much easier to understand than memorize.} Here is what you need to remember:
1. The columns on the periodic table correspond to the sublevels.
   a. The first two columns are sublevels s.
   b. The last six columns, except for He, are sublevels p.
   c. The ten columns in between are the sublevels d.
   d. And the 14 columns in the bottom are the sublevels f.

2. The rows on the periodic table correspond to the energy levels.
   This is trickier than it looks, since one row can have sublevels of more than one level. Remember the
   apartment analogy in which students occupy the apartment 4s before the 3d? It is the same here, but you will
   have no problem writing the sublevel notation once you know where to look in the periodic table for that
   information.

Label the rows and columns of the following periodic table as indicated by your teacher

Remember that the d sublevels are in the row of one higher energy: 3d is in the fourth row, not on the third as would
be expected, and 4d is on the fifth row, not on the fourth.

The f sublevels are two rows above their corresponding level. 4f is in the sixth row, not on the fourth, and 5f is on the
seventh row, not in the fifth as we would expect.

Now color the following periodic tables to have this information in a different form.
### Periodic table by sublevels

<table>
<thead>
<tr>
<th>Periodic Table</th>
<th>Atomic #</th>
<th>Symbol</th>
<th>Element Name</th>
<th>Average Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mercury</strong></td>
<td>80</td>
<td>Hg</td>
<td><strong>Mercury</strong></td>
<td>200.59</td>
</tr>
</tbody>
</table>

**Periodic table by levels**

<table>
<thead>
<tr>
<th>Periodic Table</th>
<th>Atomic #</th>
<th>Symbol</th>
<th>Element Name</th>
<th>Average Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mercury</strong></td>
<td>80</td>
<td>Hg</td>
<td><strong>Mercury</strong></td>
<td>200.59</td>
</tr>
</tbody>
</table>
Sublevel notation

Let us practice writing sublevel notation and relating this to atomic sketches. You need to know which sublevels exist for each level, and what is the maximum number of electrons that a sublevel can have:

<table>
<thead>
<tr>
<th>Level</th>
<th>Sublevels</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1s</td>
</tr>
<tr>
<td>2</td>
<td>2s, 2p</td>
</tr>
<tr>
<td>3</td>
<td>3s, 3p, 3d</td>
</tr>
<tr>
<td>4</td>
<td>4s, 4p, 4d, 4f</td>
</tr>
</tbody>
</table>

Remember that when you draw atomic sketches you draw all of the levels that have electrons. Take the example of Silicon

You have to do the same with the sublevel notation. You have to write all of the sublevels that have electrons. The atom of silicon has:

- 2 electrons in the first level, which only has one s sublevel: \( 1s^2 \)
- 8 electrons in the second level, distributed with 2 in the s sublevel and 6 on the p sublevel: \( 2s^2 2p^6 \)
- 4 electrons in the third level, distributed with 2 electrons in the s sublevel and 2 on p sublevel: \( 3s^2 3p^2 \)

So the complete sublevel notation becomes: \( 1s^2 2s^2 2p^6 3s^2 3p^2 \)

Looking at the section of the periodic table we see that in order to get to silicon, starting from the upper left corner, we need to go through both of the s columns of the first energy level so we write \( 1s^2 \). We then need to go through both of the s columns of the second energy level, all six columns of the p block in the second energy level, both columns of s block on the third energy level and only two columns of the p block in the third energy level.

Your turn to write sublevel notations:

1. Draw the atomic sketch for Hydrogen (atomic # 1)

Write the sublevel notation:
2. Draw the atomic sketch for Lithium (atomic # 3)

Write the sublevel notation:

3. Draw the atomic sketch for Magnesium (atomic # 12)

Write the sublevel notation:

Now write the sublevel notation for the following elements, without drawing the atomic sketch. Circle the sublevel(s) that hold the valence electrons and write the valence electrons.

4. Argon (atomic # 18)

Valence electrons for Ar:

5. Calcium (atomic # 20)

Valence electrons for Ca:

6. Scandium (atomic # 21). Refer to your colored periodic tables.

Valence electrons for Sc:

7. Xenon (atomic # 54).

Valence electrons for Xe:

8. Tungsten (W, atomic # 74).

Valence electrons for W:

From the following sublevel notations, give the atomic sketch, identify the element and write the electron dot symbol:

a) 

\[ 1s^2 \, 2s^2 \, 2p^6 \, 3s^2 \, 3p^6 \, 4s^2 \, 3d^3 \]
b) $1s^2 \ 2s^2 \ 2p^6 \ 3s^2 \ 3p^6 \ 4s^2 \ 3d^{10} \ 4p^6 \ 5s^2 \ 4d^{10} \ 5p^6 \ 6s^1$

c) $1s^2 \ 2s^2 \ 2p^6 \ 3s^2 \ 3p^6 \ 4s^2 \ 3d^{10} \ 4p^6 \ 5s^2 \ 4d^{10} \ 5p^6 \ 6s^2 \ 4f^3$

d) $1s^2 \ 2s^2 \ 2p^6 \ 3s^2 \ 3p^6 \ 4s^2 \ 3d^{10} \ 4p^6 \ 5s^2 \ 4d^{10} \ 5p^6 \ 6s^2 \ 4f^{14} \ 5d^5$

e) $1s^2 \ 2s^2 \ 2p^6 \ 3s^2 \ 3p^6 \ 4s^2 \ 3d^{10} \ 4p^6 \ 5s^2 \ 4d^{10} \ 5p^6 \ 6s^2 \ 4f^{14} \ 5d^{14} \ 6p^8 \ 7s^2 \ 5f^{14} \ 6d^{10} \ 7p^2$

f) Look at the pattern in which sublevels appear on the periodic table and their capacity, and write the sublevel notation for the unknown element with atomic number 121
Sublevel notation and ions

What happens to the ions as we know them?

The sublevel notation is even better at explaining ions than the atomic sketch approach. Remember the reason for why do atoms form ions? We have said that atoms are more stable by gaining or losing electrons in order to have 8 electrons on their last level or shell.

With sublevel notation we can see that all they need to become stable is to have all of their s and p sublevels full. Atoms do not need to have all the levels full to be stable; the d and f sublevels can be partially full and still be stable, like some of the noble gases.

The stability condition can now be written as: atoms are more stable when their s and p sublevels are full. It is all about getting to an s^2p^6 configuration! This configuration will lower energy and provide stability.

Let us see how ions work with Na and Cl in sublevel notation (we already saw their atoms with atomic sketches). Remember that elements are more stable when they have the configuration of a noble gas.

Take a look at sodium:

- Na - 1s^22s^22p^63s^1 it is not stable
- But the Neon is, Ne - 1s^22s^22p^6 stable
- So sodium's goal is to lose that one outer electron to have the s^2p^6 configuration that neon has.
- Na^+ - 1s^22s^22p^6 is stable

Take a look at chlorine:

- Cl - 1s^22s^22p^63s^23p^5 it is not stable
- But Argon is, Ar - 1s^22s^22p^63s^13p^6 stable
- So chlorine's goal is to gain one electron so it can be like Ar and have the s^2p^6 configuration.
- Cl^- - 1s^22s^22p^63s^23p^6 is stable

How about Bromine?

- Br - 1s^22s^22p^63s^23p^64s^23d^104p^5 it is not stable
- But Krypton is, Kr 1s^22s^22p^63s^23p^64s^23d^104p^6
- So Bromine's goal is to gain one electron so it can be like Kr and have the 4s^24p^6 configuration, even if 3d^10 is in between.
- Be^- - 1s^22s^22p^63s^23p^64s^23d^104p^6

Your turn: Which noble gas would Gallium (atomic number # 31) would want to be?

- Sublevel notation for Ga:
- Sublevel notation for the noble gas it wants to be:
- Ga goal is to:
- Sublevel notation for the Ga ion:
It’s in the cards activity

Your teacher will provide you with the handout for the activity.
Periodic Table Notes

Dmitri Mendeleev (1834-1907) -

1) Metals (Find them on your periodic table)

   Characteristics

2) Non-Metals (Find them on your periodic table)

   Characteristics

   Diatomic Elements-

3) Metalloids (Find them on your periodic table)

   Characteristics

4) Noble Gases (Find them on your periodic table)
Color the periodic table according to Metals, Non-Metals, Metalloids and Noble Gases

The synthesized elements begin with element # ______. This element is ____________. Just like the alchemists were trying to do, these synthesized elements have been transmutated.

Currently, the total number of elements is:

The percentages by weight of each element on the Earth are as follows:

<table>
<thead>
<tr>
<th>Element</th>
<th>Abundance</th>
<th>Element</th>
<th>Abundance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen</td>
<td>46.1%</td>
<td>Sodium</td>
<td>2.36%</td>
</tr>
<tr>
<td>Silicon</td>
<td>28.2%</td>
<td>Magnesium</td>
<td>2.33%</td>
</tr>
<tr>
<td>Aluminum</td>
<td>8.23%</td>
<td>Potassium</td>
<td>2.09%</td>
</tr>
<tr>
<td>Iron</td>
<td>5.63%</td>
<td>Titanium</td>
<td>0.56%</td>
</tr>
<tr>
<td>Calcium</td>
<td>4.15%</td>
<td>Hydrogen</td>
<td>0.14%</td>
</tr>
</tbody>
</table>
The periodic table is organized according to element’s properties. The question is how? Your teacher will place small pieces of certain elements in water and you will record the observations. Sounds exciting, doesn’t it?

Let us begin by describing the appearance in terms of color, shininess, and state of matter of the recently exposed surface of the piece below. Indicate if you think these elements are metal, non-metal, metalloids or noble gases.

Lithium (Li):
Sodium (Na):
Potassium (K):
Magnesium (Mg):
Calcium (Ca):

Your teacher will place each of the pieces in a container with water. We will add a clear liquid called phenolphthalein as indicator to the water to identify whether a chemical reaction occurred or not. Describe your observations.

Water with phenolphthalein:
Lithium (Li):
Sodium (Na):
Potassium (K):
Magnesium (Mg):

Look for patterns:

1. Describe differences and similarities among your observations. Which elements behave similarly? Which behave different?

2. Propose an explanation for the similarities and differences:

3. Write the **abbreviated sublevel notation** using the previous noble gas
   a. Li
   b. Na
   c. K
   d. Mg
   e. Al

4. Describe differences and similarities among the sublevel notation for each element.

5. Compare the similarities and differences among the sublevel notations and the similarities and differences of the elements’ reaction with water. What can you conclude?
Practice quiz: Atomic Structures (30 pts)  
Name __________________________
Teacher/Hr _______________________

1. An atom has 1 valence electrons in the 4th shell. This atom has 19 neutrons.

   a) (2 pts) Draw the atomic sketch for an atom of this element.

   b) (1 pt) How many protons does an atom of this element have? ____________

   c) (2 pts) Write the name of the element ______________ and the symbol ________

   d) (1 pt) How many total electrons does an atom of this element have? ____________

   e) (1 pt) Write the electron dot symbol ______

2. \[ \text{X} \] is the electron dot symbol for a mystery element. The outer orbit is the 3rd orbit. The atomic mass is 32.066 amu.

   a) (2 pts) Draw the atomic sketch for the atom:

   b) (1 pt) How many protons does this element have? ______

   c) (1 pt) The name of this element is: ______________

   d) (1 pt) Calculate how many neutrons there are__________________________

   e) (1 pt) How many electrons does this element have? ______

3. \[ p = 14 \]
   
   \[ n = 15 \]
   
   \[ \text{represents the atomic sketch of an atom.} \]

   a) (1 pt) How many total electrons does this atom have? ______

   b) (1 pt) Name the element ______________

   c) (1 pt) Write the electron dot symbol for this element _____________
4. (2 pts) How many valence electrons does an atom of thallium (Tl) at # = 81 have? ____________ Explain how you know.

(5-7, 1 pt each) Choose the correct term for each statement. Answers can be used more than once.

A. Neutral  B. Positive  C. Negative

_____ 5. An atom has a(n) ___ charge.

_____ 6. A cation has a(n) ___ charge.

_____ 7. A compound has a(n) ___ charge.

(8-13, 1 pt each) Match the items to the statement. Some items can be used more than once, and some statements have two correct answers. Fill in all answers that apply!

8. Has/have more electrons than protons. _________________

9. Has/have less electrons than protons. _________________

10. Cation(s) _________________

11. Anion(s) _________________

12. Has/have gained electrons. _________________

13. Has/have lost electrons. _________________
14. Determine the following

   a. (1 pt) Write the electron dot symbol for Phosphorous, with 5 valence electrons. ______________

   b. (1 pt) Would P gain or lose electrons? ______ Explain why. ________________________________

15. (1 pt) Explain why the oxidation number of N is –3.

   ___________________________________________________________________________________

   ___________________________________________________________________________________

16. This question will take some detective work on your part. (extra credit)

   I have less than 3 valence electrons. The total number of valence electrons I have is an odd number. If you double my number of protons you would have the atomic number of a noble gas (an element with a completely filled outer shell). What element am I? __________________