The Bohr Model of the Atom

The colors for several compounds are provided in Figure 1. Take a moment to examine the data. What patterns do you notice?

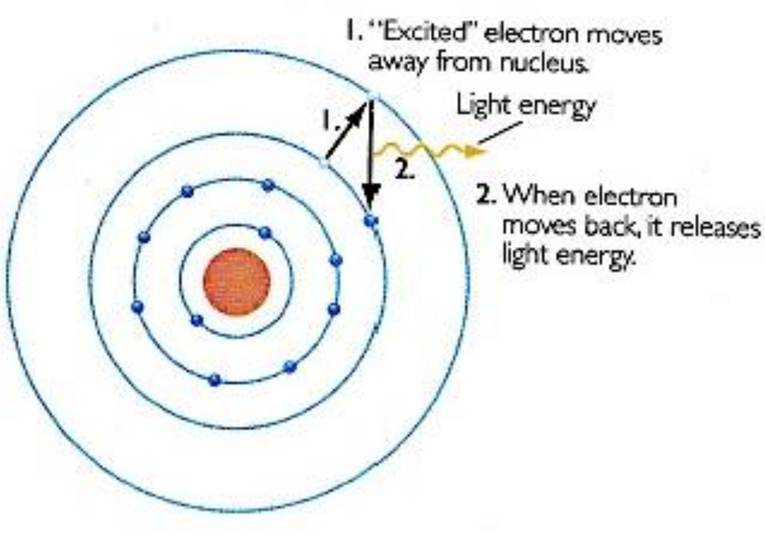
Red	Orange	Yellow-orange	Green	Blue-green	Pink-lilac
lithium nitrate $LiNO_3$	calcium nitrate $Ca(NO_3)_2$	sodium nitrate $NaNO_3$	barium nitrate $Ba(NO_3)_2$	copper nitrate $Cu(NO_3)_2$	potassium nitrate KNO_3
lithium chloride $LiCl$	calcium chloride $CaCl_2$	sodium chloride $NaCl$	barium chloride $BaCl_2$	copper chloride $CuCl_2$	potassium chloride KCl
lithium sulfate Li_2SO_4	calcium sulfate $CaSO_4$	sodium sulfate Na_2SO_4	barium sulfate $BaSO_4$	copper sulfate $CuSO_4$	potassium sulfate K_2SO_4
lithium Li	calcium Ca	sodium Na	barium Ba	copper wire Cu	potassium K

Figure 1: This table shows what color different elements are associated with. For example, all compounds with lithium will be red when excited.

Notice that each metal atom, Li, Ca, Na, and so on, is associated with a specific flame color. Lithium compounds all make a red flame, while the barium compounds all make a green flame. The nonmetal atoms in these compounds do not seem to affect the color of the compound. So $CaSO_4$, $CaCl_2$, and $Ca(NO_3)_2$ all have the same color flame, but $CaCl_2$, $NaCl$, and $CuCl_2$ do not. The metal atom must somehow be responsible for the color of the flame.

Chemists have found these flame color patterns to be quite helpful. A flame test can be used to quickly confirm the presence of certain metal atoms in an unknown sample. So a potassium compound can quickly be distinguished from a calcium compound by heating samples of the compounds.

***Figure 2**: A Bohr model of a Sodium (Na) atom.*



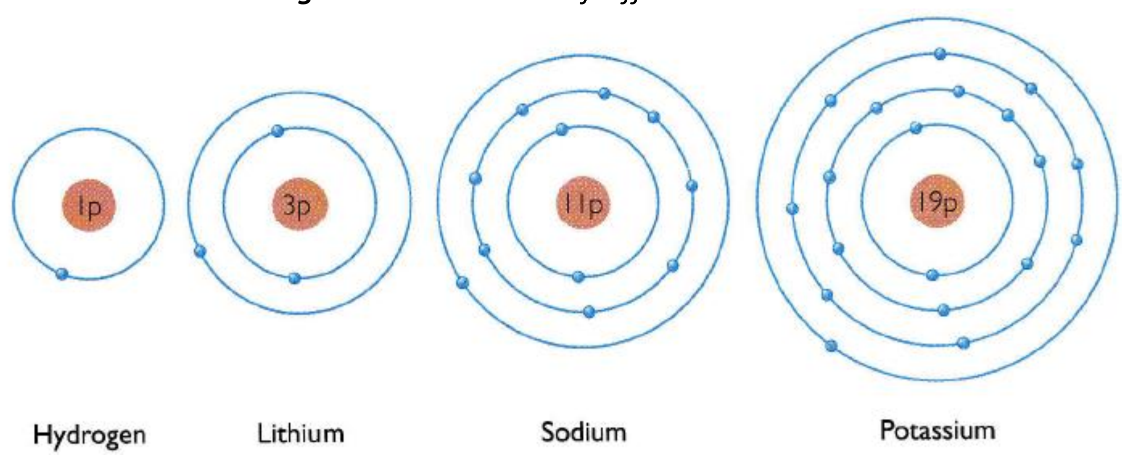
Electrons are located at different average distances from the nucleus of an atom. Each level is called a "shell". When heated, the outer electrons (**valence electrons**) of metal atoms get "excited" and move to shells farther from the nucleus (see figure 2). This move is only temporary. When the electrons move back to their original shell from the nucleus, they release energy in the form of colored light. This is what you see during a flame test. The exact color emitted varies from atom to atom since all atoms are different sizes and have different numbers of electrons. Atoms that have the same number of valence electrons tend to react in similar ways.

How to draw a Bohr Model of an Atom:

In the Bohr Model different shells or energy levels hold different amount of electrons. Start from the shell closest to the nucleus in the middle and go outward when filling the electrons. The electrons on the last shell farthest from the nucleus are called **valence electrons.** In chemistry, valence electrons are very important in an atom because they can participate in chemical bonds with other atoms and thus are the cause for chemical reactions.

	Maximum number of electrons in shell
1st shell	2 electrons
2nd shell	8 electrons
3rd shell	8 electrons

Figure 3: *Bohr models of different elements.*



Salt Power: Watt's Next in Rechargeable Batteries?

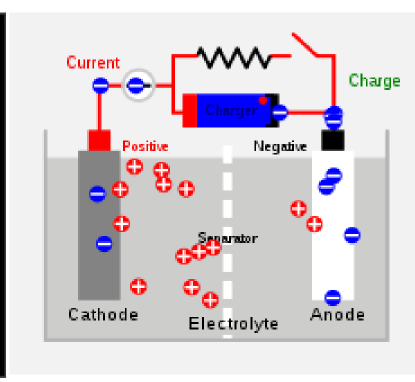
Oct. 18, 2012 — Reza Shahbazian-Yassar thinks sodium might be the next big thing in rechargeable batteries.

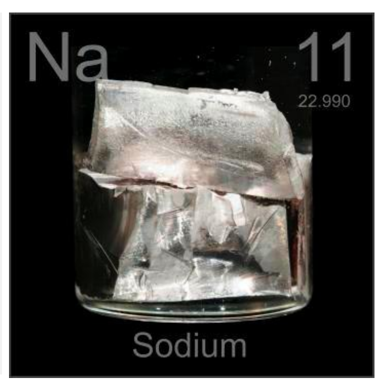
Now, the gold standard in the industry is the lithium ion battery, which can be recharged hundreds of times and works really well. Its only problem is that it is made with lithium, which is not cheap. It could get even more expensive if more electric vehicles powered with lithium ion batteries hit the road and drive up demand. "Some people think lithium will be the next oil," says Shahbazian-Yassar, an associate professor of mechanical engineering-engineering mechanics at Michigan Technological University.

Sodium may be a good alternative. "After lithium, it's the most attractive element to be used in batteries," Shahbazian-Yassar said. It's also cheap and abundant; seawater is full of it. It has just one drawback: sodium atoms are big, about 70 percent larger in size than lithium atoms. "When the atoms are too big, that's problematic," says Shahbazian-Yassar, because they can cause a battery's electrodes to wear out faster. "Imagine bringing an elephant through the door into my office. It's going to break down the walls."

Before a long-lasting rechargeable sodium battery can be developed, scientists need to better understand these challenges and develop solutions. With a $417,000 National Science Foundation grant, Shahbazian-Yassar is leading that effort at Michigan Tech. "We have an opportunity to tackle some of the fundamental issues relating to charging and discharging of batteries right here," he said. "We have a unique tool that lets us observe the inside of a battery." Using a transmission electron microscope, Shahbazian-Yassar and his team can peer inside and see how a battery is charging and discharging at the atomic level. "We will study these fundamental reactions and find out what materials and electrodes will do a better job hosting the sodium."

Sodium ion batteries would not have to be as good as lithium ion batteries to be competitive, Shahbazian-Yassar notes. They would just need to be good enough to satisfy the consumer. And they could make electric cars more affordable, and thus more attractive. Plus, they could reduce our dependence on fossil fuels, particularly if the batteries were charged using renewable energy sources. That would lead to two laudable goals: greater energy independence and less pollution worldwide.





Questions for "Salt power: Watt's Next in Rechargeable Batteries?"

1) What are the advantages of using lithium over sodium when producing rechargeable batteries?

2) What are the advantages of using sodium over lithium when producing rechargeable batteries?

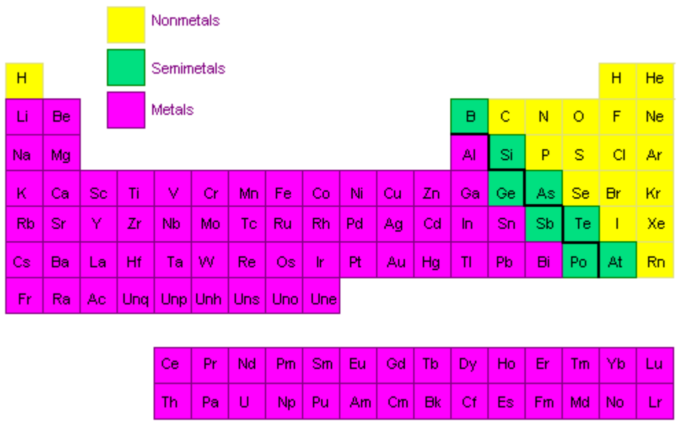
3) Interpret what Mr. Shahbazian-Yassar means when he states "Some people think lithium will be the next oil."

4) Potassium is another salt with atoms larger than that of Sodium and Lithium. Would Potassium be a good alternative for producing rechargeable batteries? Explain your answer.

Metals, Nonmetals, Semi-Metals, and Family Names

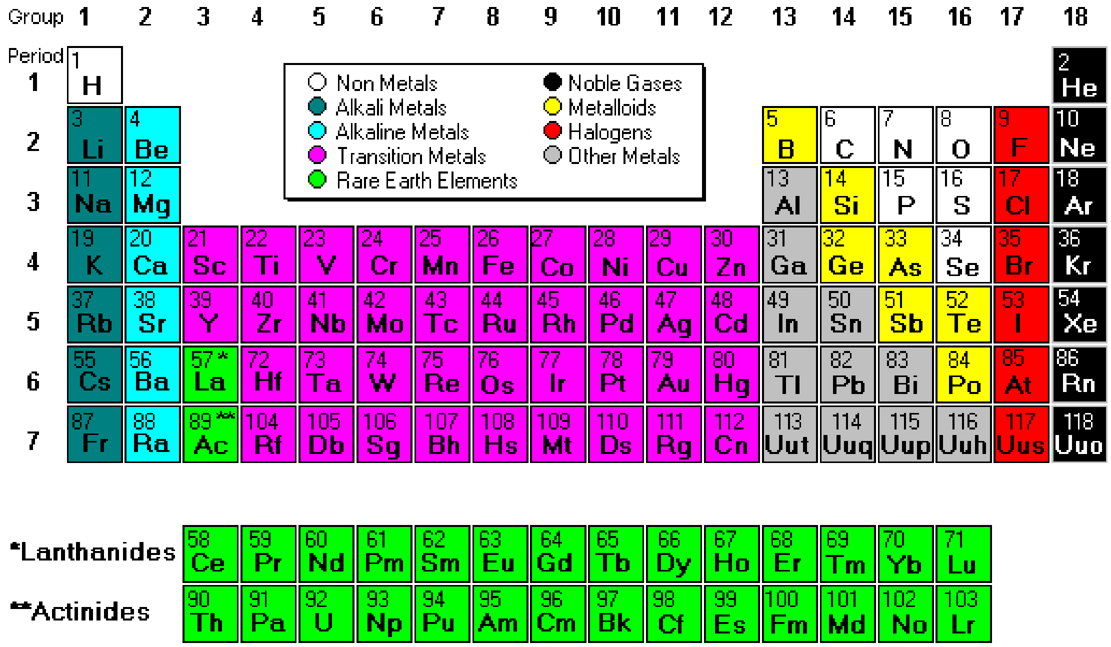
There are three main types of elements in the world: metals, semi-metals, and nonmetals. Metals are shiny elements that can conduct electricity. They are also ***malleable***, which means they are easy to bend. Metals can be found on the left side of the periodic table. Nonmetals are the opposite of metals. They are called ***insulators***, which means they cannot conduct electricity. Nonmetals are dull and ***brittle***, which means they snap instead of bending when enough force is applied. Nonmetals are found on the right side of the periodic table. Found on the steps in-between nonmetals and metals are the semi-metals. As their name suggests, these elements share properties that are in-between nonmetals and metals. Figure one shows the distribution of metals, semi-metals, and nonmetals on the periodic table.

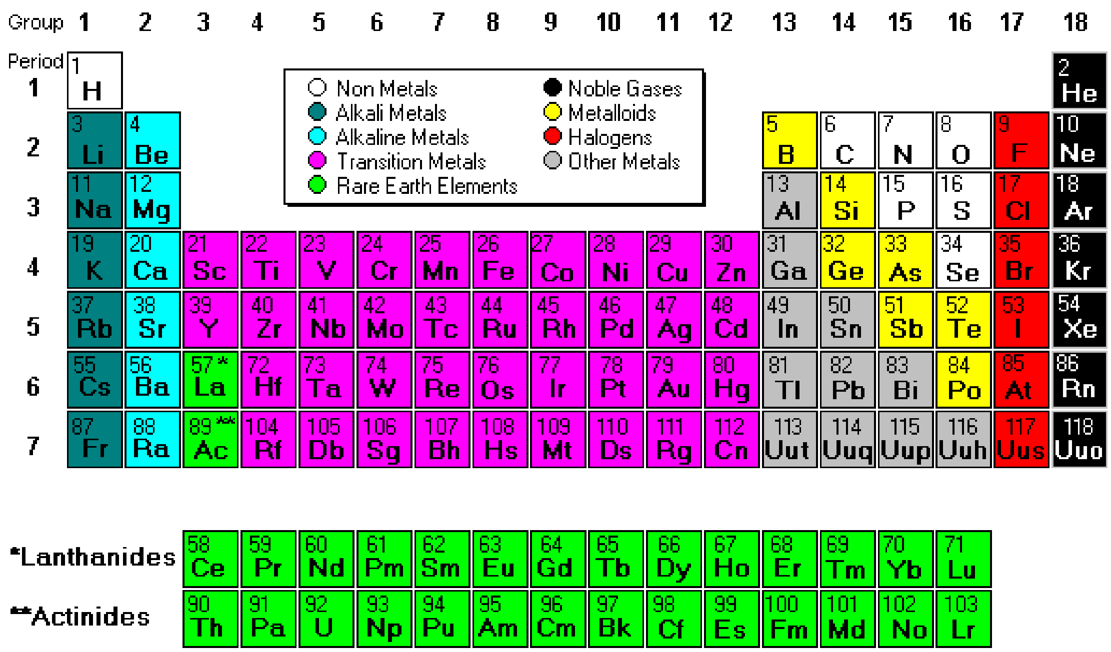
Figure 1: Metals, semi-metals, and nonmetals on the periodic table.



Within the general categories of metals, semi-metals, and non-metals, there are specific names for some families (groups). Because groups all have the same number of valence electrons, they tend to react in very similar ways (like a family in real life might). Since group 1 all have 1 valence electron and react similarly, they are called a “family”. Figure 2 has the names of each family labeled.

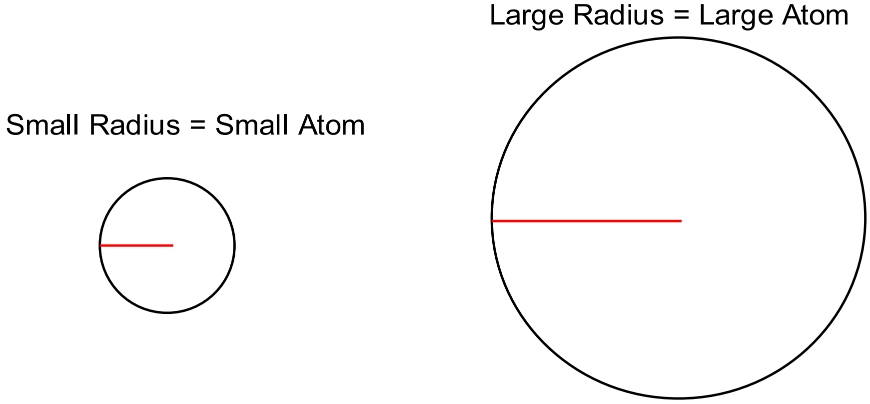
Figure 2: Families of the periodic table.



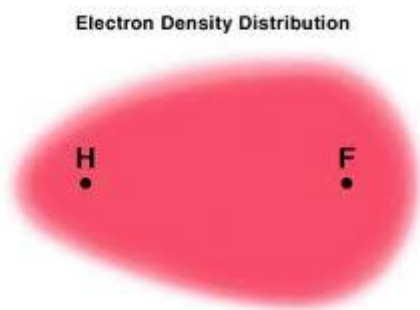

Group 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Period
Non Metals
Alkali Metals
Alkaline Metals
Transition Metals
Rare Earth Elements
Noble Gases
Metalloids
Halogens
Other Metals
1 1 H 2 He
2 3 Li 4 Be 5 B 6 C 7 N 8 O 9 F 10 Ne
3 11 Na 12 Mg 13 Al 14 Si 15 P 16 S 17 Cl 18 Ar
4 19 K 20 Ca 21 Sc 22 Ti 23 V 24 Cr 25 Mn 26 Fe 27 Co 28 Ni 29 Cu 30 Zn 31 Ga 32 Ge 33 As 34 Se 35 Br 36 Kr
5 37 Rb 38 Sr 39 Y 40 Zr 41 Nb 42 Mo 43 Tc 44 Ru 45 Rh 46 Pd 47 Ag 48 Cd 49 In 50 Sn 51 Sb 52 Te 53 I 54 Xe
6 55 Cs 56 Ba 57* La 72 Hf 73 Ta 74 W 75 Re 76 Os 77 Ir 78 Pt 79 Au 80 Hg 81 Tl 82 Pb 83 Bi 84 Po 85 At 86 Rn
7 87 Fr 88 Ra 89** Ac 104 Rf 105 Db 106 Sg 107 Bh 108 Hs 109 Mt 110 Ds 111 Rg 112 Cn 113 Uut 114 Uuq 115 Uup 116 Uuh 117 Uus 118 Uuo
*Lanthanides 58 Ce 59 Pr 60 Nd 61 Pm 62 Sm 63 Eu 64 Gd 65 Tb 66 Dy 67 Ho 68 Er 69 Tm 70 Yb 71 Lu
**Actinides 90 Th 91 Pa 92 U 93 Np 94 Pu 95 Am 96 Cm 97 Bk 98 Cf 99 Es 100 Fm 101 Md 102 No 103 Lr

Periodic Trends: Atomic Radius, Electronegativity, Ionization Energy

<u>Atomic Radius:</u> The distance from the nucleus of an atom to its valence electrons: the atomic size.



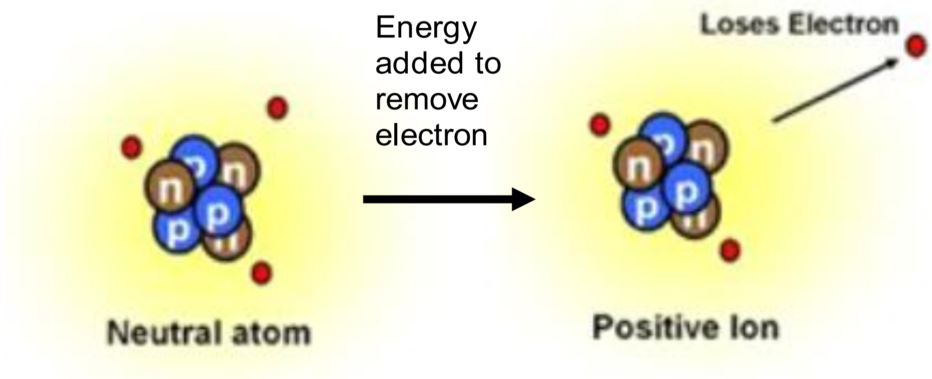
<u>Electronegativity:</u> A measure of how strongly an atom attracts electrons; a higher electronegativity means that the atom attracts electrons more; a lower electronegativity means that the atom attracts electrons less.



The figure above shows that fluorine pulls electrons more towards itself in a bond with hydrogen.

<u>Ionization Energy:</u> How difficult it is to remove an electron from an atom; a higher ionization energy means that is harder to remove an electron from an atom; a lower ionization energy means that it is easier to remove an electron from an atom.

Electrons can be taken away or added to atoms to make **ions**. Ions have an overall positive or negative electric charge.



CHECK YOUR UNDERSTANDING:

1. Data for the atomic radii of the alkali metals is below. Rank them from the largest atom to the smallest atom. Do you notice any pattern on the periodic table?

Element	Atomic radius (nm)
Li	0.152
Cs	0.265
Na	0.185
K	0.227
Rb	0.247

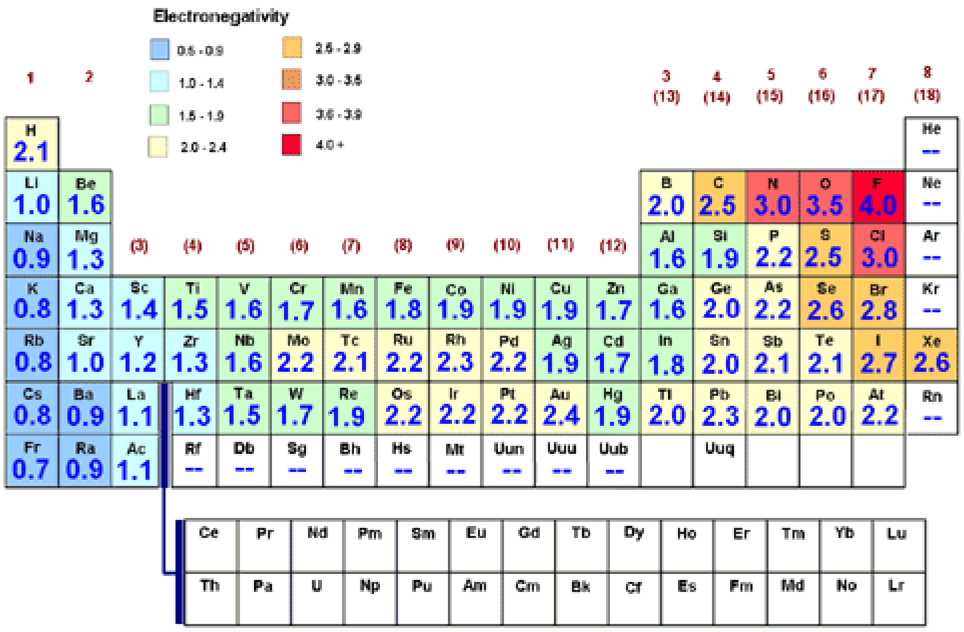
2. If a high electronegativity atom and a low electronegativity atom are both trying to attract an electron, which will most likely attract the electron? Explain.

3. If an atom has a high electronegativity, will it have a high or low ionization energy? Explain.

4. If energy is added to an atom to remove an electron, but the energy is lower than the ionization energy, what will happen?

Read the scenario and answer the remaining questions in complete sentences, using academic language.

Chemical compounds consist of multiple atoms bound together. The only way for atoms to stick together is for their electrons to interact. Sometimes atoms will completely transfer electrons and make something called an ionic bond. At other times, atoms will share electrons and form something called a covalent bond. Each bond has very different properties, and can be predicted by comparing atom's electronegativities. The periodic table below has each atom's electronegativity. A higher number means that the atom has a higher electronegativity.



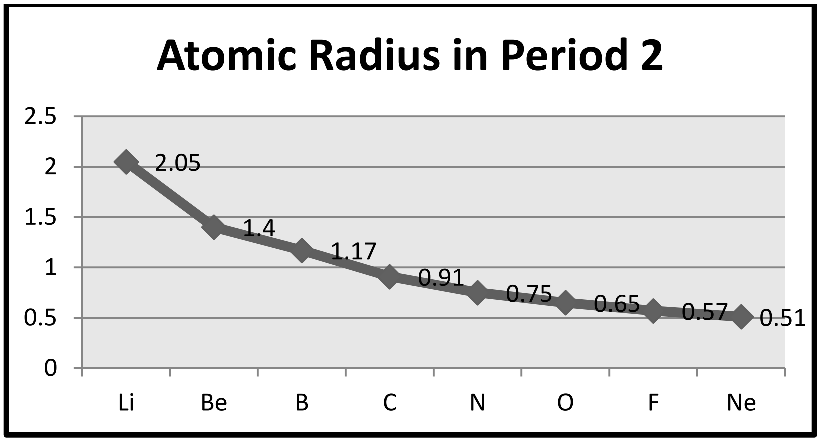
A) Which element on the periodic table has the strongest tendency to attract electrons?

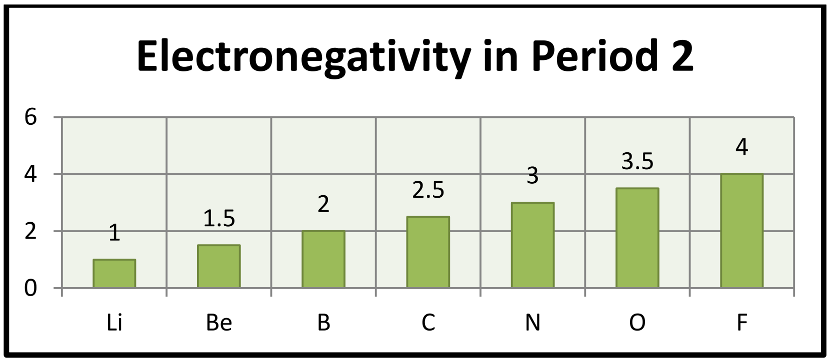
B) When sodium and chlorine bond to form sodium chloride (table salt), an electron is completely transferred. Which atom most likely gains the electron? Explain based on electronegativity.

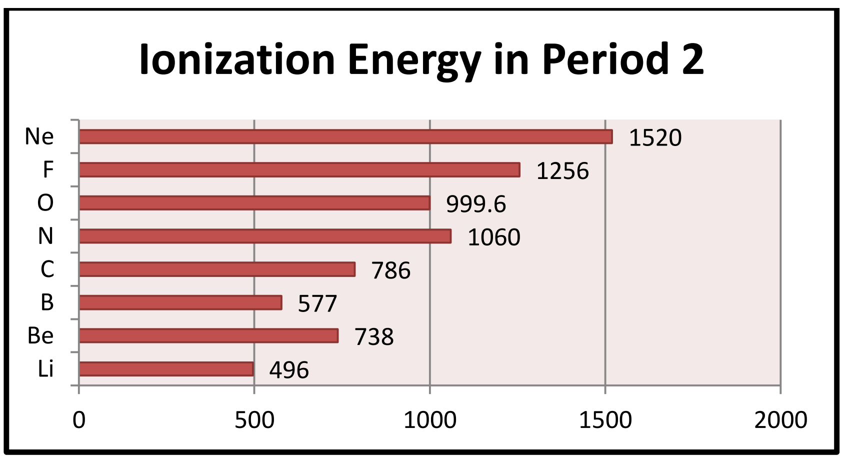
C) Nitrogen and oxygen bond to make nitrous oxide (NO_2), which is sometimes used in street racing to improve engine performance. Would you expect electrons to be completely transferred or shared in this compound? Explain.

D) The period 4 transition metals all have very similar electronegativities. Would you expect them to have similar or different atomic radii? Explain.

Periodic Trends Within a Period







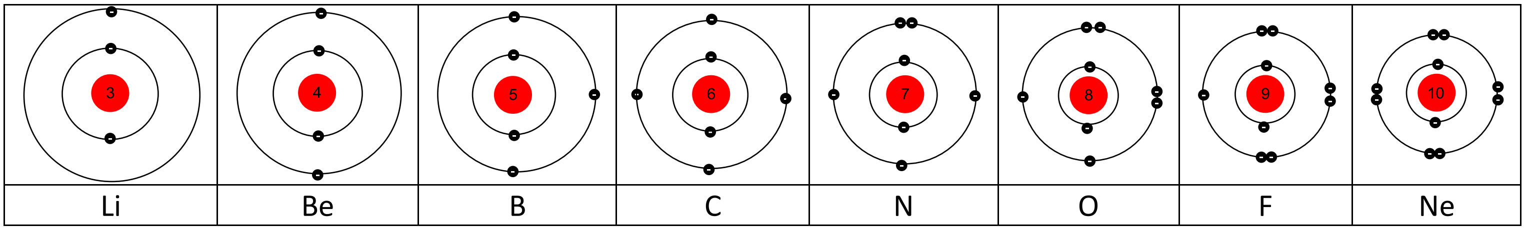
TEST YOUR UNDERSTANDING:

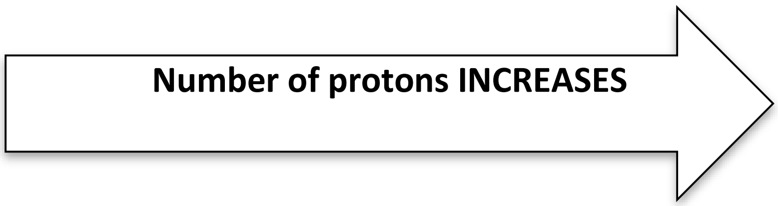
As you **move to the right on the periodic table**, atoms become _______________ (bigger/smaller), and they attract electrons _________ (more/less). This makes it _________________ (easier/harder) to remove an electron.

As you **move to the left on the periodic table**, atoms become _______________ (bigger/smaller), and they attract electrons _________ (more/less). This makes it _________________ (easier/harder) to remove an electron.

Using our knowledge of the atomic nucleus and its surrounding valence shells, we can explain why the trends of atomic radius, electronegativity, and ionization energy look the way they do across a period (side to side). In a single period, all of the atoms have the same outer shell but different numbers of electrons. As you move to the right, more protons are added to the nucleus, even though no more electron shells are added.

Period 2





As you move across a period, each atom has more protons. Because of this:

- Atoms get smaller = **Atomic Radius Decreases**
- Electrons feel more attraction from the nucleus = **Electronegativity Increases**
- It is harder to remove electrons = **Ionization Energy Increases**

From left to right, the atomic number increases, which means that the number of protons also increases. As more protons are added, the attraction between the nucleus and the outer electrons gets stronger. Since the attraction between them is now stronger, the outer electrons are drawn closer to the nucleus, shrinking the atomic radius. With the electrons now closer to the nucleus, they feel more attraction and the electronegativity increases. It is also more difficult to remove electrons, which means the ionization energy increases.

TEST YOUR UNDERSTANDING:

As you **move to the left across the periodic table**:

- Atomic Radius ___________________ because:

- Electronegativity __________________ because:

- Ionization Energy _________________ because:

1. Rank the following atoms by **increasing** atomic radius:
    a. Zn, K, Br, Ca
    b. Sr, Ru, Xe, I
    c. F, Li, N, C
2. Rank the following by **increasing** electronegativity:
    a. S, Cl, Al, Si
    b. Be, F, N, O
    c. K, Co, V
3. Rank the following by **increasing** ionization energy.
    a. Kr, Ge, Fe, Ni
    b. Cl, Ar, P, Na
    c. Ti, Co, Cr, Ca
4. Consider the following two elements: ***Oxygen (O) and Fluorine (F).***

Bohr Models	
	Oxygen:
	Fluorine:

    a. What do these two elements have in common?
    b. Which has a larger atomic radius? Why?
    c. Which has a higher electronegativity? Why?
    d. Which has a higher ionization energy? Why?

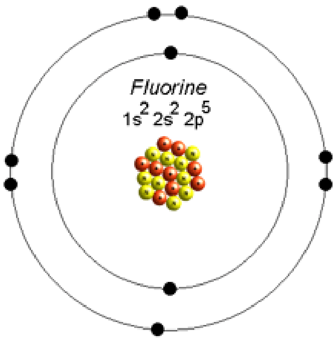
5. Consider the following two elements: ***Sodium (Na) and Magnesium (Mg).***

Bohr Models	
	Sodium:
	Magnesium:

    a. What do these two elements have in common?
    b. Which has a larger atomic radius? Why?
    c. Which has a higher electronegativity? Why?
    d. Which has a higher ionization energy? Why?

Read the scenario and answer the remaining questions in complete sentences, using academic language.

Fluorine was not discovered until 1886, although scientists predicted its existence in 1811. Based on fluorine's position on the periodic table, scientists could predict several of fluorine's properties without ever isolating the element.



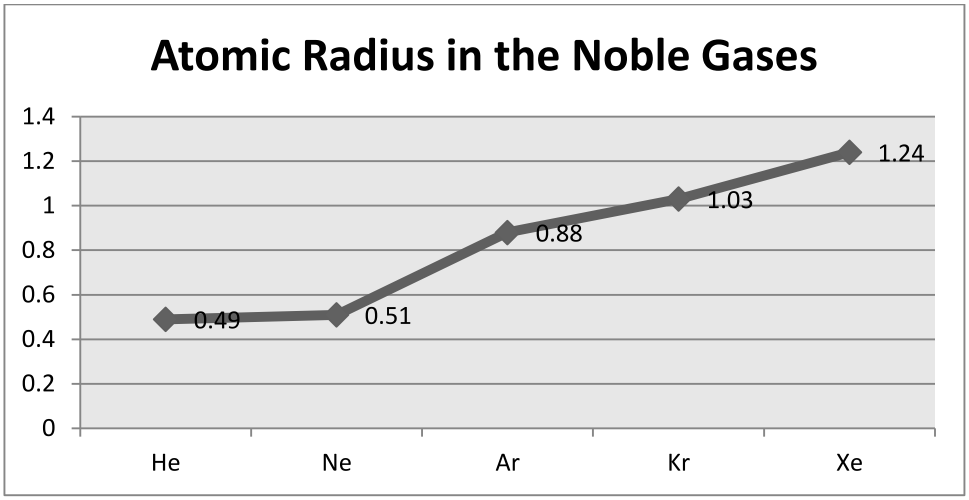
A) Would you expect fluorine to have a higher or lower electronegativity than oxygen? Why?

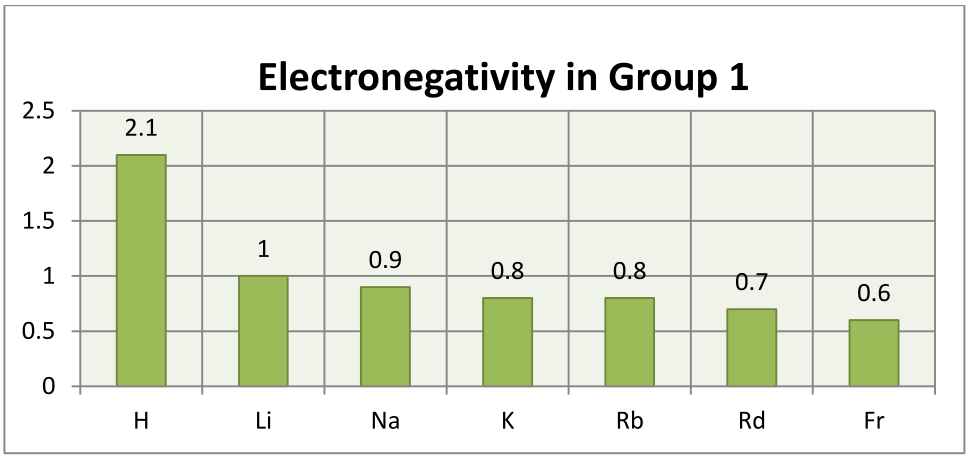
B) Do you expect fluorine to be a large or small atom? Why?

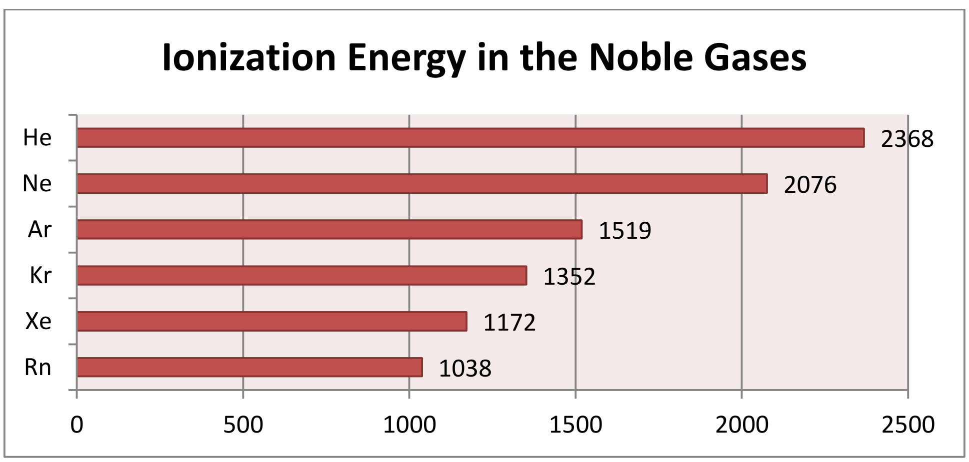
C) If lithium and fluorine form a bond, they will transfer electrons. Do you expect for fluorine to take an electron, or for lithium to take an electron? Explain.

D) For a substance to conduct electricity, charges, usually electrons, must be able to move around. Would fluorine be a good conductor? Explain in terms of its electronegativity.

Periodic Trends Within a Group







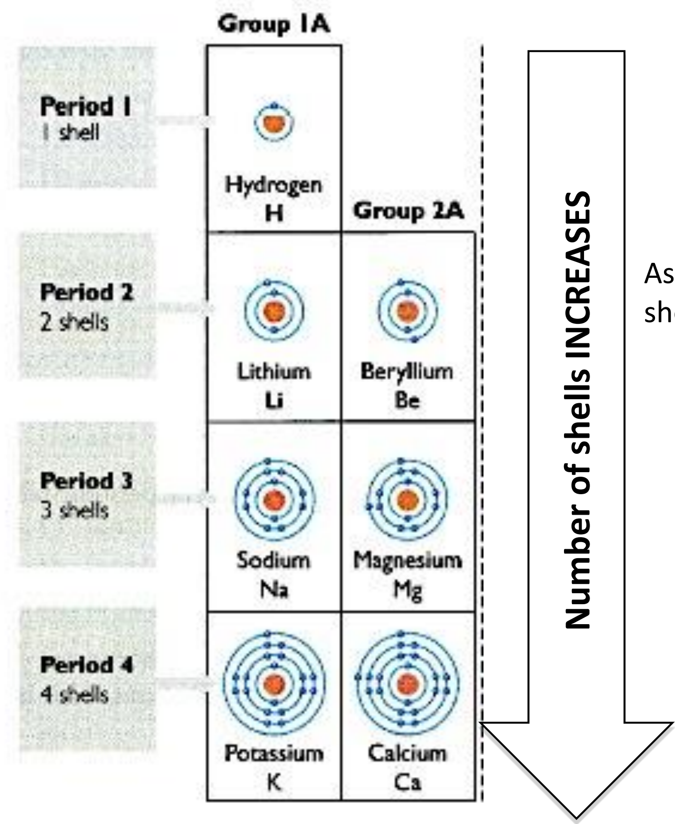
TEST YOUR UNDERSTANDING:

As you **move up the periodic table**, atoms become _______________ (bigger/smaller), and they attract electrons _________ (more/less). This makes it _________________ (easier/harder) to remove an electron.

As you **move down the periodic table**, atoms become _______________ (bigger/smaller), and they attract electrons _________ (more/less). This makes it _________________ (easier/harder) to remove an electron.

How do scientists explain the patterns in atomic radius, electronegativity, and ionization energy that we have observed? As it turns out, scientists have been able to explain these patterns using only basic atomic structure.

Within a group (going up and down) on the periodic table, we can explain these patterns using the **number of shells** that an atom has. As you move down the periodic table, the atoms have more shells.



As you move down the periodic table, each atom has more shells. Because of this:

- Atoms get bigger **= Atomic Radius Increases**
- Electrons are further from nucleus
  - Electrons feel less attraction from the nucleus = **Electronegativity Decreases**
  - It is easier to remove electrons = **Ionization Energy Decreases**

The more shells an atom has, the larger its atomic radius is, since each shell is larger than the previous. As the shells become larger, the electrons on the valence shell are farther and farther from the nucleus, so the electrons feel less attraction from the nucleus. This means that the electronegativity decreases. Since the electrons feel less attraction from the nucleus, it is easier to remove the electrons from the atom, and the ionization energy decreases.

TEST YOUR UNDERSTANDING:

As you **move up the periodic table**:

- Atomic Radius ___________________ because:
- Electronegativity __________________ because:
- Ionization Energy _________________ because:

1. Rank the following atoms by **<u>increasing</u>** atomic radius:
   a. In, Al, B, Ga

   b. Xe, Kr, Ar, Ne, He

   c. K, Li, Na, Rb

2. Rank the following atoms by **<u>increasing</u>** electronegativity:
   a. Be, Mg, Ca

   b. F, Cl, Br

   c. O, S, Te, Se

3. Rank the following atoms by **<u>increasing</u>** ionization energy:
   a. Copper, Gold, Silver

   b. The Halogens

   c. The Alkaline Earth Metals

4. Consider the following two elements: ***Oxygen (O) and Sulfur (S).***

Bohr Models	
	Oxygen:
	Sulfur:

   a. What do these two elements have in common?

   b. Which has a larger atomic radius? Why?

   c. Which has a higher electronegativity? Why?

   d. Which has a higher ionization energy? Why?

5. Consider the following two elements: ***Potassium (K) and Sodium (Na).***

Bohr Models	
	Sodium:
	Potassium:

   a. What do these two elements have in common?

   b. Which has a larger atomic radius? Why?

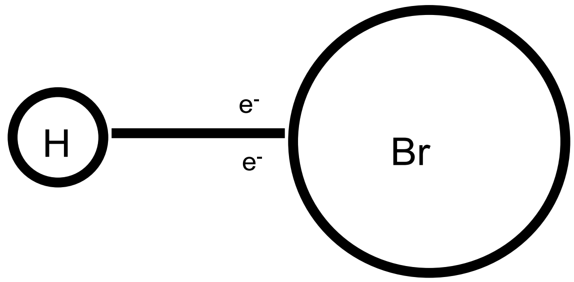
   c. Which has a higher electronegativity? Why?

   d. Which has a higher ionization energy? Why?

Read the scenario and answer the remaining questions in complete sentences, using academic language.

When elements have similar electronegativities, they will share electrons and form something called a covalent bond. However, they will not always share electrons equally. Two such compounds are hydrogen fluoride (HF) and hydrogen bromide (HBr). When elements in a compound do not share electrons equally, the compound is said to be polar. The more unequally electrons are shared, the more polar a compound is.

Unequal sharing of electrons in HBr.
The electrons are closer to Br.



A) What family do bromine and chlorine belong to?: ____________________

B) Bromine is a much larger atom than chlorine. Explain why bromine is larger than chlorine.

C) Why are the electrons in the diagram closer to the Br than the H in HBr?

D) Will HCl likely be more or less polar than HBr? Explain.

E) Make a diagram for HCl like the one above for HBr, showing where the electrons are and how large each atom is.

How do you determine the charge of an ion?

1) Sort your cards by charge. Make as many observations as you can in 4 minutes.

+1	+2	+3	-3	-2	-1

2) Look at the card for Fluorine and form a hypothesis for what the overall charge represents.

The overall charge represents:____

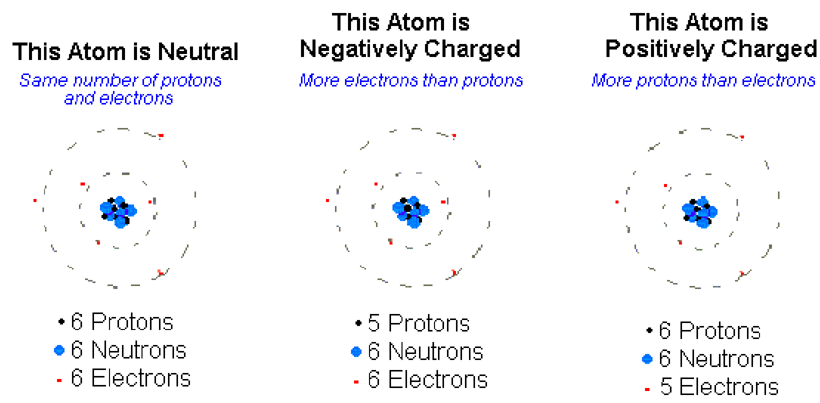
3) Test your hypothesis with each card. If it doesn't hold, than form a new hypothesis and try again.

4) Once you get a working hypothesis, use it to complete the table below.

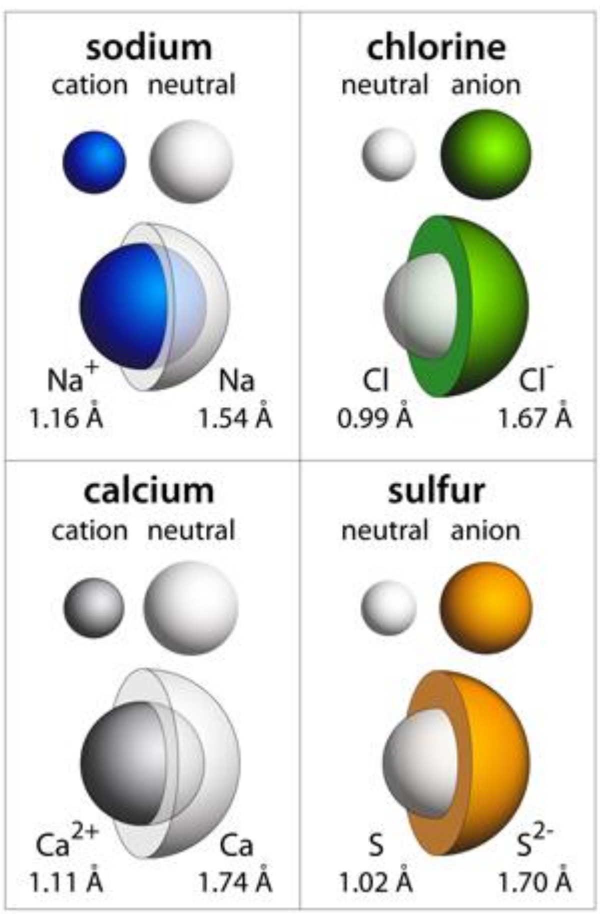
Element Symbol	Protons	Electrons	Overall Charge
Mg	12	10	
C	6	10	
	35		-1
	15	18	
		36	-2
		54	+2
	8		-2
	17		-1

Ions and ionic radius

An atom is technically defined as a neutral particle. When an atom gains a positive or negative charge, it becomes an ion. Atoms consist of protons, neutrons, and electrons. The neutrons do not affect the charge of the ion. Protons contribute +1 positive charge for each proton and electrons contribute -1 negative charge for each electron. Neutral atoms will have the same amount of positive and negative charges; they will have the same number of electrons and protons.



When an ion is formed, the size of the atom changes. Atoms that gain electrons form negative ions and become larger. These negative ions are called anions. The protons can no longer hold onto the electrons very well and the electrons get farther away from the nucleus. Since the electrons are farther away, the atomic radius increases. Atoms that lose electrons actually become positive, because they are losing a negative charge. This double negative makes them end up with a positive charge. These ions are called cations. Since they have more protons than electrons, the electrons get pulled in closer and the atomic radius decreases for cations.



Review Stations

3.f : I can relate the position of an element in the periodic table to its atomic number and atomic mass.

1) What does atomic number tell you about an element?

2) Which subatomic particles contribute to the mass of an atom?

3) If Uranium-234 has an atomic number of 92 and an atomic mass of 234, how many neutrons are there?

4) Is the periodic table organized by atomic number or by atomic mass?

5) Complete the table below

Element Name	Element Symbol	Atomic Number	Atomic Mass	# Protons	# Electrons	# neutrons
Hydrogen						
	Mg					
		35				
				29		

3.g I can use the periodic table to identify metals, semimetals, and nonmetals.
3.h I can use the periodic table to identify alkali metals, alkaline earth metals, halogens, and transition metals,

- Deal out the strips
- The dealer starts by reading one of his cards.
- Whoever has what the dealer asks for reads their card
- And so on
- When finished, shuffle, re-deal and try to do it *faster*!

3.i … trends in ionization energy, electronegativity, and the relative sizes of ions and atoms.

In your notes, explain the following…

1) Why is Bromine smaller than Calcium?

2) Why does it take more energy to remove an electron from Calcium than Barium?

3.j : I can use the periodic table to determine the number of electrons available for bonding.

1) What is a valence electron?

2) Lithium reacts violently with water, producing heat and hydrogen gas. What is one other element that will have a similar reaction and how do you know?

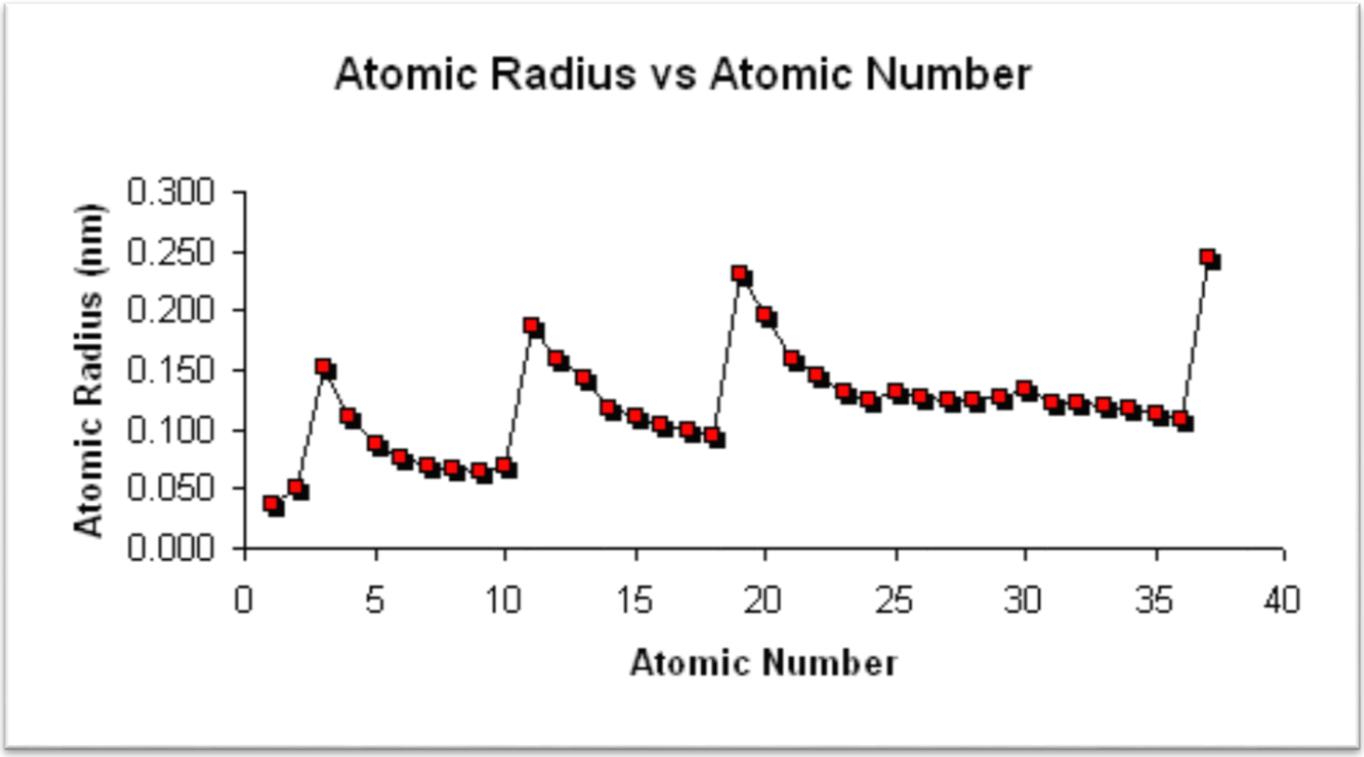
3) How many valence electrons in Carbon, Phosphorus, and Fluorine?

4) If you add the number of valence electrons in Sodium Chloride (NaCl) together, what do you get?

5) Draw the bohr model diagrams for:
   a. Oxygen
   b. Hydrogen
   c. Magnesium

Read the scenario and answer the remaining questions in complete sentences, using academic language.

The figure below shows the first 37 elements on the periodic table and their atomic radii.



1) Circle the elements in period 3.
2) Explain why the atomic radius decreases as the atomic number increases in period 3.

3) Draw a little box around each element that is an alkali metal.

4) What is the trend for atomic radius as atomic number increases in the alkali metals?

5) Why does the trend you identified in question 4 occur?

6) How are atomic radius and electronegativity connected?