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More Periodic Table Trends

Many properties of the elements change in a predictable way as you move through the periodic table. We have already examined one such property: periodic trends in reactivity. We will now Predict, Observe and Explain several other periodic trends…

Atomic Radius

atomic radius: distance between the center of the nucleus of an atom and the outermost electrons

Thought POE: How does atomic radius vary within groups (going down the periodic table) and within periods (going across the periodic table)?

Trend Down a Group	**P**	**O** **increases**	**E** There are more electrons as you go down so they will fill up more shells which will make the atomic radius bigger
Trend Across a Period	**P**	**O** **decreases**	**E** The more protons there is, the stronger the nuclear force; so the more protons there are, the more they can pull the electrons closer towards the nucleus

Ionic Size

ion: an atom that has a positive or negative charge because it has lost or gained electrons

Thought POE: How does the size of an atom change when it becomes an ion?

Electrons are Removed	**P**	**O** **decreases**	**E** The proton charge is greater, so they are better able to pull the electrons closer to themselves
Electrons are Added	**P**	**O** **increases**	**E** The electrons outnumber the protons, so the protons have a less effective nuclear force which make it harder to pull the electrons closer

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Ionization Energy

ionization energy: energy required to remove the most loosely held electron from an atom

Thought POE: How does ionization energy vary within groups and periods?

Trend Down a Group	**P**	**O** **Less energy**	**E** As you go down, there are more shells, therefore the last electron is farther away from the nucleus and it is not held as tightly with the nucleus; therefore it is easier to remove
Trend Across a Period	**P**	**O** **More energy**	**E** There are more protons so the electrons are closer to the nucleus and held more tightly; therefore it is harder to remove them

The energy required to remove the first electron from an atom is called the 'first ionization energy' (or simply the 'ionization energy'). The successive ionization energies are the energies required to remove electrons beyond the first electron.

$Li \rightarrow Li^+ + e^-$ 1^{st} ionization energy = 521 kJ
$Li^+ \rightarrow Li^{2+} + e^-$ 2^{nd} ionization energy = 7304 kJ
$Li^{2+} \rightarrow Li^{3+} + e^-$ 3^{rd} ionization energy = 11 752 kJ

As you might predict, ionization energy increases with the removal of each additional electron. Examine the following chart to identify any further trends in ionization energies.

Successive Ionization Energies of Period 3 Elements

Element	First	Second	Third	Fourth	Fifth	Sixth	Seventh
Na	496	4560					
Mg	738	1450	7730				
Al	577	1816	2744	11600			
Si	786	1577	3228	4354	16100		
P	1060	1890	2905	4950	6270	21200	
S	999	2260	3375	4565	6950	8490	27000
Cl	1256	2296	3850	5160	6560	9360	11000
Ar	1520	2665	3945	5770	7230	8780	12000

For each element you can find one very large increase between a different pair of ionization energies. For sodium, this large increase is between the first and second ionization energies. For magnesium, the large increase is between the second and third ionization energies. Where is the large increase for aluminum?

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Thinking Question: Why are these LARGE increases in ionization energy observed?

It loses an electron from a full shell

Recall: Atoms tend to gain or lose electrons so that they will have a full valence orbital.

Thought POE: What are the probable electron gains/losses for elements in groups 1, 2, 13, 15, 16, 17 and 18? What are the predicted charges on the resulting ions?

	Electron Gains/Losses		**Charges on Ions**		
Group 1 (1A)	**P**	**O Lose 1**	**P**	**O +1**	**E** Atoms gain or lose electrons in order to achieve full valence shells
Group 2 (2A)	**P**	**O Lose 2**	**P**	**O +2**	
Group 13 (3A)	**P**	**O Lose 3**	**P**	**O +3**	
Group 15 (5A)	**P**	**O Gain 3**	**P**	**O -3**	
Group 16 (6A)	**P**	**O Gain 2**	**P**	**O -2**	
Group 17 (7A)	**P**	**O Gain 1**	**P**	**O -1**	
Group 18 (8A)	**P**	**O – stay the same**	**P**	**O 0**	

open shell: a shell containing less than its maximum number of electrons*
closed shell: a shell containing its maximum number of electrons*

*Note: for the purposes of this section, the transition metals, lanthanides and actinides are ignored. Therefore…

Shell	Maximum Number of Electrons
Shell 1	2
Shell 2	8
Shell 3	8

Ions form in such a way that the outermost shell of an atom will become a **closed** shell.

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Electronegativity

electronegativity: indicates how strongly an atom attracts electrons in a chemical bond

Thought POE: How does electronegativity vary within groups and periods?

Trend Down a Group	**P**	**O** **decreases**	**E** The further down you go, the greater the distance between the electrons on the outermost shell, so the hold on the nucleus is decreasing
Trend Across a Period	**P**	**O** **increases**	**E** The electrons are held closer to the nucleus, so any shared electrons are going to have a stronger pull towards the nucleus than if the electrons were held farther from the nucleus

Unlike ionization energy, electronegativity is not an amount of energy. Nor is it a property of an atom that can be directly measured.

Fluorine is the most electronegative element, with an electronegativity of 4.0. All other electronegativity values are assigned relative to fluorine's. The least electronegative elements are in the lower left corner of the periodic table. Both cesium and francium have electronegativities of 0.7. If a cesium atom and a fluorine atom were to form a chemical bond, the atom with the higher electronegativity–the fluorine atom-would more strongly attract the bond's electrons.

Conductivity

Thought POE: How does conductivity vary within groups and periods?

Trend Down a Group	**P**	**O** **increases**	**E** Conductivity is a metallic property, it increases down a table
Trend Across a Period	**P**	**O** **decreases**	**E** it is a metallic property, it decreases as you go across