

PERIODIC TRENDS

The periodic table is arranged in order of increasing atomic number.

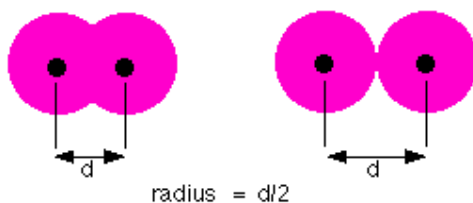
A group is a vertical column of the periodic table. Elements with similar physical and chemical properties belong in a group. The group number gives the number of valence electrons in an element. For example, the Alkali Metals are in Group 1 (one valence electron), and the Halogens are in Group 7 (7 valence electrons). However, depending on which periodic table you are looking at, the Groups may be numbered 0-17 instead of 0-7 if the 10 d-block elements are included. In this case the halogens would be group 17 and you would subtract 10 to get the number of valence electrons in the element.

A period is a horizontal row of the periodic table. Physical and chemical properties change gradually going across a period. The period number indicates the number of energy levels surrounding the nucleus. For example, phosphorus is in Period 3 and therefore has three energy levels for electrons. The repeating pattern of physical and chemical properties shown by the different periods is known as periodicity.

These periodic trends can clearly be seen in atomic radii, ionic radii, ionization energies and electronegativities. These specific trends will be investigated in this activity.

Atomic Radius:

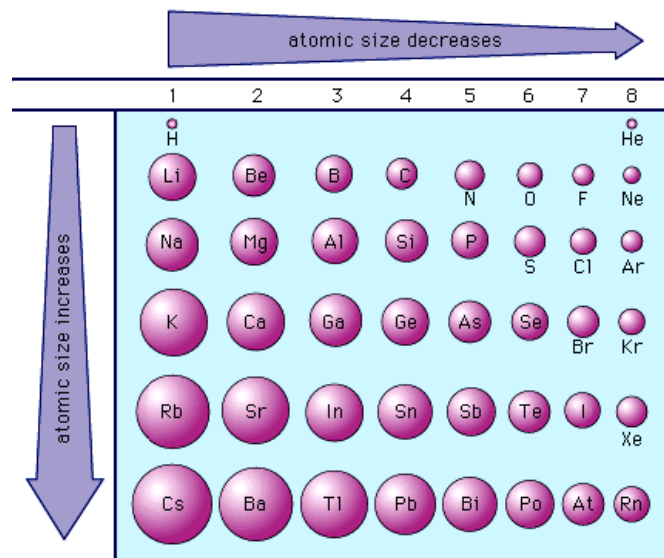
The atomic radius is simply the distance from the nucleus to the outermost electron. Since the position of the outermost electron can never be known precisely, the atomic radius is usually defined as half the distance between the nuclei of two bonded atoms of the same element:



As a group is descended, the outermost electron is in a higher energy level which is further from the nucleus so the radius increases.

Across a period, electrons are being added to the same energy level, but the number of protons in the nucleus increases. This attracts the energy level closer to the nucleus and the atomic radius decreases across a period.

The following graphic shows the trend in atomic radius:



Ionic Radius:

Similar to atomic radius, the ionic radius of an element increases in size down a group as the number of electron shells increase.

However, going across a period, the ionic radius decreases from Group 1 to Group 3 as with atomic radius, but then increases and decreases again as the large negative ions are formed from Groups 5 to 7. (Recall that Group 4 elements do not typically form ions). An example showing the relative ion sizes from Period 3 are shown below:



The cations (Na^+ , Mg^{2+} and Al^{3+}) contain fewer electrons than protons so the electrostatic attraction between the nucleus and the outermost electron is greater and the ion is smaller than the parent atom. It is also smaller because the number of electron shells has decreased by one. Across the period the ions contain the same number of electrons but an increasing number of protons so the ionic radius decreases in size.

The anions (P^{3-} , S^{2-} and Cl^-) contain more electrons than protons and therefore are larger than the parent atom. Across a period, the ionic size decreases because the number of electrons remains the same but the numbers of protons increase, pulling the outer shell closer to the nucleus.

***Note:** The size of an atom always decreases when being converted to a positive ion because it loses an electron and therefore there is less electron repulsion. The size of an atom always increases when being converted to a negative ion because since there is an increase in repulsion between electrons.

Tutorial on atomic radius with animation and audio:

<http://www.mhhe.com/physsci/chemistry/essentialchemistry/flash/atomic4.swf>

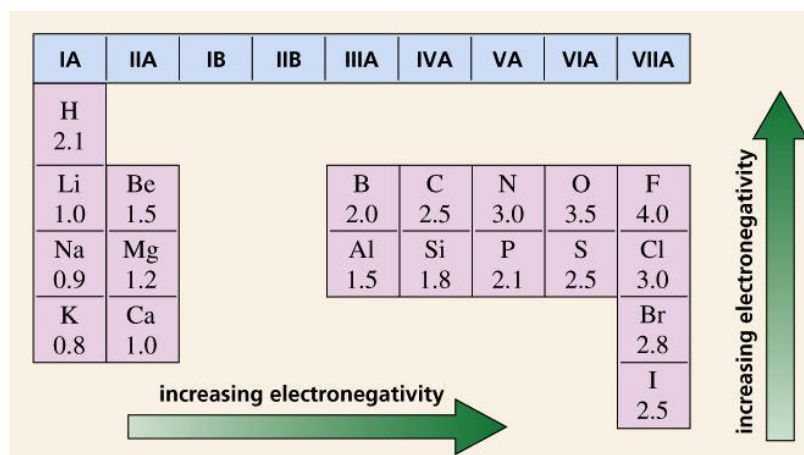
Electronegativity:

Electronegativity is a relative measure of the attraction that an atom has for a shared pair of electrons when it is covalently bonded to another atom.

The electronegativity decreases as you go down a group. This is due to the shielding effect where electrons in lower energy levels shield the positive charge of the nucleus from outer electrons resulting in those outer electrons not being as tightly bound to the atom.

Electronegativity increases as you go from left to right across a period. This is because there is more electron-attracting power of the nucleus with the increasing nuclear charge as the number of protons increase from left to right across the periodic table.

The graphics below show the trend in electronegativity and the specific electronegativity values:



Ionization Energy:

Ionization energy is the amount of energy required to remove the outmost electron. It is closely related to electronegativity.

Ionization energy decreases as you go down a group. This is because the shielding effect makes it easier to remove the outer most electrons from those atoms that have many electrons (those near the bottom of the periodic table).

Ionization energy increases as you go from left to right across a period. This is because of the increased nuclear charge (as the number of protons increase) which holds the electrons more strongly. It will be more difficult to remove a more strongly held electron.

The following graphic shows the trend in ionization energy:

IA										VIIA		VIII	
H										H	He		
1312.0	IIA		IIIA	IVA	VA	VIA				1312.0	2372.3		
Li	Be		B	C	N	O				F	Ne		
520.2	899.4		800.6	1086.4	1420.3	1313.9				1681.0	2080.6		
Na	Mg		Al	Si	P	S				Cl	Ar		
495.8	737.7		577.6	786.4	1011.7	999.6				1251.1	1520.5		
K	Ca		Ga	Ge	As	Se				B	Kr		
418.8	589.8		578.8	762.1	947	940.9				1139.9	1360.7		
Rb	Sr		In	Sn	Sb	Te				I	Xe		
403.0	549.5		558.3	708.6	833.7	869.2				1008.4	1170.4		
Cs	Ba		Tl	Pb	Bi	Po				At	Rn		
375.7	508.1		595.4	722.9	710.6	821				--	1047.8		
Fr	Ra												
--	514.6												

Periodic Table Songs:

The Element Song – Tom Lehrer (animation):

<http://www.privatehand.com/flash/elements.html>

The Hydrogen Song:

<http://www.josephlimbaugh.com/songs/hydrogen.htm>

The Zinc Song:

<http://www.josephlimbaugh.com/songs/zinc.htm>

Periodic Table Tutorial:

http://www.wwnorton.com/college/chemistry/gilbert/tutorials/interface.swf?chapter=chapter_06&folder=periodic_table

An Excellent Periodic Table site:

<http://www.chem1.com/acad/webtext/atoms/atpt-6.html>

Interactive periodic table:

<http://www.chemistrycoach.com.au/chemtutorials.htm>

Periodic Trends Graphing Activity

The periodic table is arranged according to the periodic law. The periodic law states that when elements are arranged in order of increasing atomic number, their physical and chemical properties show a periodic pattern. Students can discover these patterns by examining the changes in properties of elements on the periodic table. The properties that will be examined in this activity are: atomic radius, ionic radius, electronegativity and ionization energy.

Purpose:

The purpose of this activity is to graph the physical properties of the elements in the periodic table and discover the relationship between these properties and their location on the periodic table. Your teacher may assign you to a group of seven whereby you will each contribute one graph to the overall result.

Materials:

- 10 sheets of graph paper
- Ruler
- Pencil
- Data tables for Atomic Radii, Ionic Radii, Electronegativity and Ionization Energy (provided)

Part 1: Group Trends:

- a) On separate sheets of graph paper plot Group 1 atomic symbol (Li → Fr; x-axis) vs.
- Atomic or ionic radius
 - Electronegativity
 - Ionization energy
- b) On separate sheets of graph paper plot Group 7 atomic symbol (F → At; x-axis) vs.
- Atomic or ionic radius
 - Electronegativity
 - Ionization energy

Part 2: Period Trends:

- On separate sheets of graph paper plot Period 3 atomic symbol (Na → Ar; x-axis) vs.
- Atomic radius
 - Ionic radius
 - Electronegativity
 - Ionization energy

Each graph should be neatly drawn with proper titles and labeled axes. On each graph, clearly state the trend observed. Also, try to explain the trend based on your knowledge of electron orbitals and electron configuration.

Analyzing the Periodic Trends

General Periodic Table:

1. State the periodic law in your own words.

2. How do the properties analyzed in this activity show periodicity of the chemical elements? That is, as the atomic number increases, when do the trends repeat?

3. Which of the following is most important in determining the periodic trends across a period? Why?
 - Nuclear charge
 - Shielding
 - Increasing numbers of electrons
 - Increasing energy levels

4. Which of the following is (are) important in determining the trend going down a group? Why?
 - Nuclear charge
 - Shielding
 - Increasing numbers of electrons
 - Increasing energy levels

5. List, by number, both the period and group of each of these elements.

	<u>Symbol</u>	<u>Period</u>	<u>Group</u>
a) Beryllium	Be		
b) Iron	Fe		
c) Lead	Pb		

6. How does an element's period number relate to the number of the energy level of its valence electrons?

Atomic and Ionic Radius:

7. Define atomic and ionic radius.

8. What happens to the atomic radius as the atomic number increases across a period? Down a group? Why do these trends occur?

9. What is the shielding effect?

10. How are the shielding effect and the size of an atom related?

11. Why is a negatively charged ion larger than its corresponding neutral atom?

12. Nitrogen can occur in a variety of oxidation states. Rank these ions in different oxidation states from highest to lowest radius and explain your answer. N^{3+} , N^{5+} , N, N^{3-} .

13. Which ion is larger, Fe^{2+} or Fe^{3+} ? Explain your choice.

14. Ions, like neutral atoms, have characteristic spectra that are generated by the transitions of electrons between energy levels. Since ions have different radii compared to their neutral atoms, explain how the spectra of an ion would compare to that of the corresponding neutral atom.

15. When an atom gains electrons to form a negative ion, the increased repulsion between the electrons causes the radius of the atom to increase. When an atom loses electrons the decreased repulsion between electrons due to the loss of one causes the radius to decrease. What happens to the atomic radii when
- An anion forms?
 - A cation forms?
16. For each of the following pairs, circle the atom or ion having the larger radius. You should be able to justify your choice.
- S or O
 - Ca or Ca^{2+}
 - Na^+ or K^+
 - Na or K
 - S^{2-} or O^{2-}
 - F or F^-
17. For each of the following pairs, identify the smaller ion. You should be able to justify your choice.
- K^+ or Ca^{2+}
 - F^- or Cl^-
 - P^{3-} or S^{2-}
 - S^{2-} or F^-
 - O^{2-} or F^-
 - Fe^{2+} or Fe^{3+}

Electronegativity:

- What is electronegativity?
- What is the most electronegative element and where is it found on the periodic table? (Top, bottom, left, right?)
- Where are the least electronegative elements found? (Top, bottom, left, right?)
- What appears to be the trend in electronegativity as you move from left to right in a row?
- What appears to be the trend in electronegativity as you move from top to bottom in a column?
- List the following atoms in order of increasing electronegativity: O, Al, Ca
- List the following atoms in order of decreasing electronegativity: Cl, K, Cu
- The Pauling Electronegativity Scale is provided with this document. Determine the type of bond between the following compounds if values between:
 - 4.0-1.7 indicates an ionic bond
 - 1.7-0.3 indicates a polar covalent bond
 - 0.3-0.0 indicates a non-polar covalent bond

*Subtract the electronegativities (using absolute value).

For Example: H-F molecule: $4.00 - 2.2 = 1.8$, therefore, ionic bond.

- $\text{N}\equiv\text{N}$
- C-H bond in CH_4 :
- H-Cl

- d) F₂
- e) H-O bond in H₂O
- f) NaCl
- g) B-H bond in BH

Ionization Energy:

26. Define Ionization energy.

27. What happens to the energy needed to remove an electron as the atomic number increases across a period? Down a group?

28. Why does the energy required to remove an electron change as it does?

29. In each of the following pairs, circle the species with the higher first ionization energy:

- a) Li or Cs b) Cl⁻ or Ar c) Ca or Br d) Na⁺ or Ne e) B or Be

30. Summarize the trends you uncovered in this activity. For each of the atomic properties listed in the table below, indicate whether, in general, the property increases or decreases across or down the periodic table.

Property	Across the periodic table	Down the Periodic Table
Atomic Radius		
Ionic Radius		
Electronegativity		
Ionization Energy		

Summary:

Properties such as atomic and ionic radius, ionization energy, electronegativity, etc. repeat regularly throughout the periodic table because the electron configurations repeat regularly.

After uncovering the trends in the above properties, you will have learned the reasons why each trend is observed. The shielding effect and nuclear charge are the two main concepts used to explain the periodic trends down a group or across a period.

Periodicity Data Tables

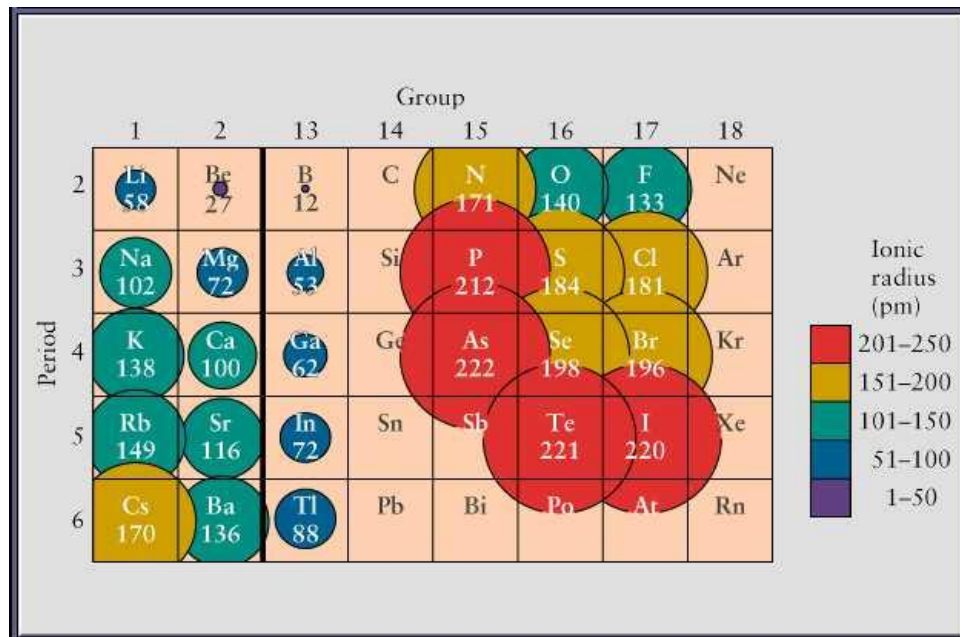
Or use: [Web Elements](http://www.webelements.com/periodicity/) (for online periodicity data)

<http://www.webelements.com/periodicity/>

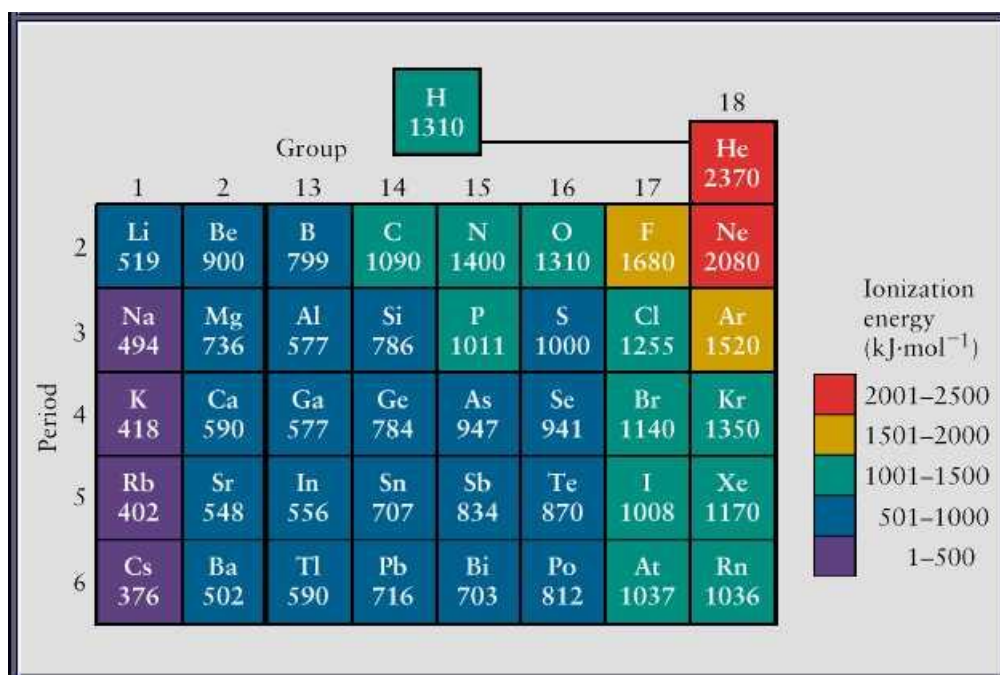
Atomic Radii (pm)

1A	2A	3A	4A	5A	6A	7A	8A
Li 152	Be 112	B 85	C 77	N 75	O 73	F 72	Ne 71
Na 186	Mg 160	Al 143	Si 118	P 110	S 103	Cl 100	Ar 98
K 227	Ca 197	Ga 135	Ge 122	As 120	Se 119	Br 114	Kr 112
Rb 248	Sr 215	In 167	Sn 140	Sb 140	Te 142	I 133	Xe 131
Cs 265	Ba 222	Tl 170	Pb 146	Bi 150	Po 168	At (140)	Rn (141)

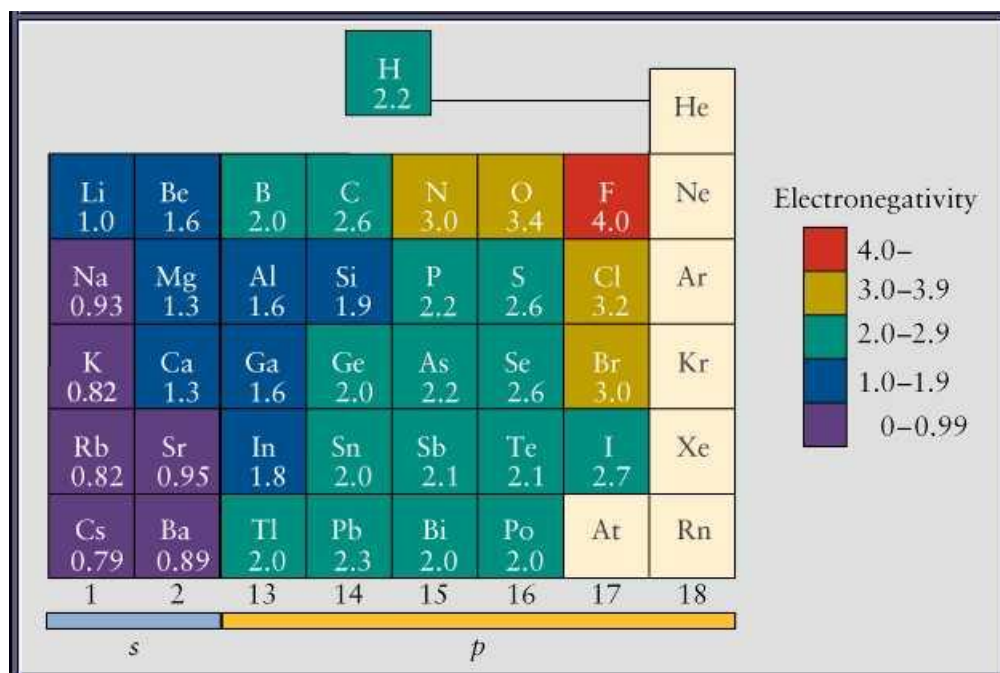
Ionic Radii



Ionization Energies



Pauling Electronegativity Values



Following are two additional Periodic Table activities:

(Source Unknown)

Mystery Periodic Table

Construct a periodic table of the representative elements of the first four rows from the clues provided. See if you understand the patterns. The following sets of elements belong together:

ZRD, PSIF, JXBE, LHT, QKA, WOV, GUN, YMC

Here are the clues:

- ◆ U has a total of six electrons
- ◆ I_2A is the simple formula of an oxide
- ◆ P is less dense than S
- ◆ S is an alkali metal
- ◆ E is a noble gas
- ◆ W is a liquid
- ◆ Z has the smallest atomic mass in its group
- ◆ B has ten protons
- ◆ O has an atomic number larger than V
- ◆ D has the largest atomic mass of its group
- ◆ C has five electrons in its outer energy level
- ◆ F is a gas
- ◆ X has an atomic number one higher than F
- ◆ Y is a metalloid
- ◆ O is a halogen
- ◆ The mass of T is more than that of H
- ◆ J has an atomic number three times that of T
- ◆ Q has an atomic mass 2 times that of A
- ◆ Atoms of I are larger than those of S
- ◆ M has an atomic number one less than that of A
- ◆ The electrons of atom N are distributed over three energy levels
- ◆ The atomic radius of K is the largest of the group

Another Similar Periodic Table Activity

You are a part of a collection of scientists who have been chosen to assist a group of alien scientists. In order to be able to converse scientifically, you must learn their language, and most importantly, you must arrange their elements according to the trends that exist in the periodic table. Below are clues for the alien's elements. So far, the aliens have only discovered elements in groups 1, 2, and 13-18, and periods 1-5. Although the names of the elements are different, they must correspond to our elements if our belief of universal elements holds true. Read each clue carefully, and then place the symbol for that clue's element in the blank periodic table provided.

1. Livium (Lv): This element is responsible for life. It has 2 electron energy levels and 4 electrons available for bonding in the outermost energy level.
2. Computerchipium (Cc): This element is important for its use as a semiconductor in computers.
3. Lightium (L): This is the lightest of elements; aliens previously used it in their aircraft until their aircraft caught fire in a horrific accident.
4. Breathium(Br): When combined with Lightium (L), it makes the alien's most common liquid whose formula is $L_2 Br$.
5. Francium (F): A metal found in period 4 group 13.
6. Moonium (Mo): An element with an atomic number of 34.
7. Explodium (Ex): This element is the most reactive metal on the alien's table.
8. Violetium(V): This element is found as part of a compound in bananas. When burned, it has a violet colored flame.
9. Sparkium (Sp) and Burnium (Bu) are members of the alkali metal group, along with Violetium(V) and Explodium (Ex). Their reactivity, from least to greatest, is Sp, Bu, V, Ex.
10. Balloonium (Ba): A noble gas used to fill balloons.
11. Toothium (To): This element is added to juices to help build strong bones and teeth.
12. Metalloidium (M) and Poisonium (Po): Two metalloids found in period 4. Po is more massive than M.
13. Lowigium (Lo): A period 4 halogen.
14. Darkbluium(Dk): Has an atomic mass of 115.
15. Hugium (Hu): The element on the alien's periodic table that has the most mass.
16. Glucinium (Gl): The element found in period 2, group 2.
17. Reactinium (Re): The most reactive non-metal on the periodic table.
18. Balloonium (Ba), Signium(Si), Stableium(Sb), Supermanium (Sm), and Hugium (Hu) are all noble gases. They are arranged above from least to most massive.
19. Cannium (Cn): This element helps to preserve foods; it is used in can manufacturing.
20. Burnium (Bu), Blue-whitium (Bw), Bauxitium (Xi), Computerchipsium (Cc), Bringer-of-lightium (Bl), Stinkium (Sk), Purium (P), and Stableium (Sb) are all found in period 3. Bu has 1 electron in its outer energy level, Bw has 2, Xi has 3, Cc has 4, Bl has 5, Sk has 6, P has 7 and Sb has 8.
21. Scottishium (Sc): A metal element found in group 2.
22. Infectium (If): This element, mixed with alcohol, is used on cuts.
23. Abundantcium(Ab): One of the most abundant gasses in the universe. It has 7 protons, 7 neutrons, and 7 electrons.
24. Some additional clues: The number after the symbol indicates the number of electrons in the outer energy level: Notalonium(Na): 5, Earthium (E): 6, Boracium (B): 3.