

Types of Bonds

How can one determine if a bond between two atoms is ionic, covalent or metallic?

Why?

Chemical bonding is all about having a full valence shell of electrons. However, there are various ways to accomplish this goal. Atoms can share electrons with other atoms, or steal electrons from other atoms. Linus Pauling used scientific data to devise a numbering system, which quantifies an atom's ability to attract an electron from another atom. These values are shown in Model 1. You can think of these electronegativities as the ranking of members in a prizefighting competition. All contestants are fighting to get the ultimate prize—an electron to fill their shell.

Model 1 – Electronegativities for Selected Elements

H 2.1						
Li 1.0	Be 1.2	B 2.0	C 2.5	N 3.0	O 3.5	F 4.0
Na 0.9	Mg 1.2	Al 1.5	Si 1.8	P 2.1	S 2.5	Cl 3.0
K 0.8	Ca 1.0	Ga 1.6	Ge 1.8	As 2.0	Se 2.4	Br 2.8
Rb 0.8	Sr 1.0	In 1.7	Sn 1.8	Sb 1.9	Te 2.1	I 2.5

1. Label the columns of the table in Model 1 with their group numbers from the periodic table. For example, the column containing hydrogen is group IA.
2. Some of the elements in Model 1 have atoms that need only one or two electrons to fill their valence shell.
 - a. Which columns in Model 1 contain these elements?
 - b. Which of the elements in part *a* have atoms with the most pulling potential for an electron? Describe the subatomic structure in these atoms, which gives them this attractive force.
 - c. Do these elements have a high electronegativity or a low electronegativity?

3. Some of the elements in Model 1 have atoms with only one or two electrons in their valence shells. They can achieve a full valence shell by losing these electrons.
- Which columns in Model 1 contain these elements?
 - Which of the elements in part *a* will require the least amount of energy to remove an electron? Describe the subatomic structure in these atoms that allows an electron to be removed with very little energy.
 - Do these elements have high electronegativities or low electronegativities?



4. Suppose that a free electron was placed between two atoms. Predict the outcome of each contest by matching each set of atoms with a description. Be ready to share your reasoning with the class.

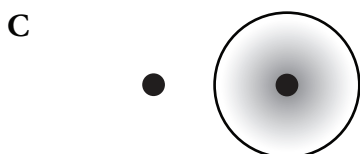
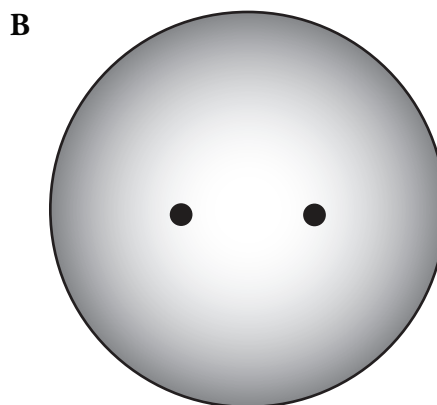
F with F _____ Neither atom attracts the electron strongly. The electron is free to move about.

Li with O _____ Both atoms attract the electron strongly. The electron stays between the atom.

Li with K _____ One atom attracts the electron strongly and pulls the electron towards itself.



Model 2 – Types of Bonds





5. The figures in Model 2 depict the valence electron distribution around bonded atoms. The black dots represent the nuclei of the two atoms that are bonded. The circles and ellipses represent the area where the bonded valence electrons could be. Darker shading indicates a higher probability of finding the electrons in that space.
- Which figure(s) in Model 2 indicates a sharing of electrons? Support your answer with evidence from Model 2.
 - Which figure(s) in Model 2 indicates a transfer of electrons? Support your answer with evidence from Model 2.
 - Compare figures A and B in Model 2. In which case are the electrons more tightly held by the two nuclei of the bonded atoms? Support your answer with evidence from Model 2.
6. These three situations are the results of the battles that took place in Question 4. Label the three figures in Model 2 with the contests from Question 4 and be prepared to explain your reasoning to the class.

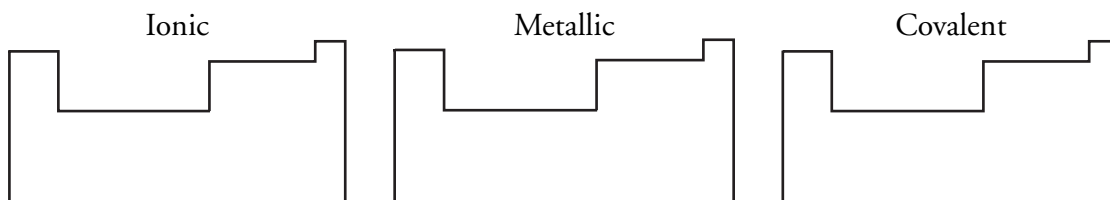
Read This!

Ionic bonds are formed when one atom takes an electron from another atom. Ions are the result (one positive, one negative). They stick together because of opposite charges.

Covalent bonds are formed when both atoms have a strong attraction to the electron, so they share the electron. Neither atom has a charge.

Metallic bonding occurs when neither atom has a strong attraction to the electrons.

-  7. Label the three figures in Model 2 with the three types of bonding described in the *Read This!* box.
-  8. Bonds can be formed between atoms that come from the same region of the periodic table or between atoms that come from two different regions of the periodic table. For each of the bond types below, shade in one or two regions of the periodic table where atoms might come from to form that type of bond.



Model 3 – Comparing Electronegativities

Substance	Electronegativity (EN)		AvgEN	Δ EN	Type of Bonding
	First atom	Second atom			
CsF (s)	0.7	4.0			Ionic
NaCl (s)	0.9	3.0			Ionic
NaI (s)	0.9	2.5			Ionic
Cs (s)	0.7	0.7			Metallic
Na (s)	0.9	0.9			Metallic
Mg (s)	1.2	1.2			Metallic
F ₂ (g)	4.0	4.0			Covalent
HI (g)	2.1	2.5			Covalent
C (diamond, s)	2.5	2.5			Covalent

9. Calculate the average electronegativity (AvgEN) and the absolute difference in electronegativity (Δ EN) for the bonds in the substances listed in Model 3. Record these values in the appropriate columns in Model 3. Divide the work among group members.



10. Based on the data in Model 3, what combination of AvgEN and Δ EN values leads to each of the three bond types? Circle the appropriate word in each box.

	AvgEN			Δ EN		
Ionic	low	medium	high	low	medium	high
Metallic	low	medium	high	low	medium	high
Covalent	low	medium	high	low	medium	high

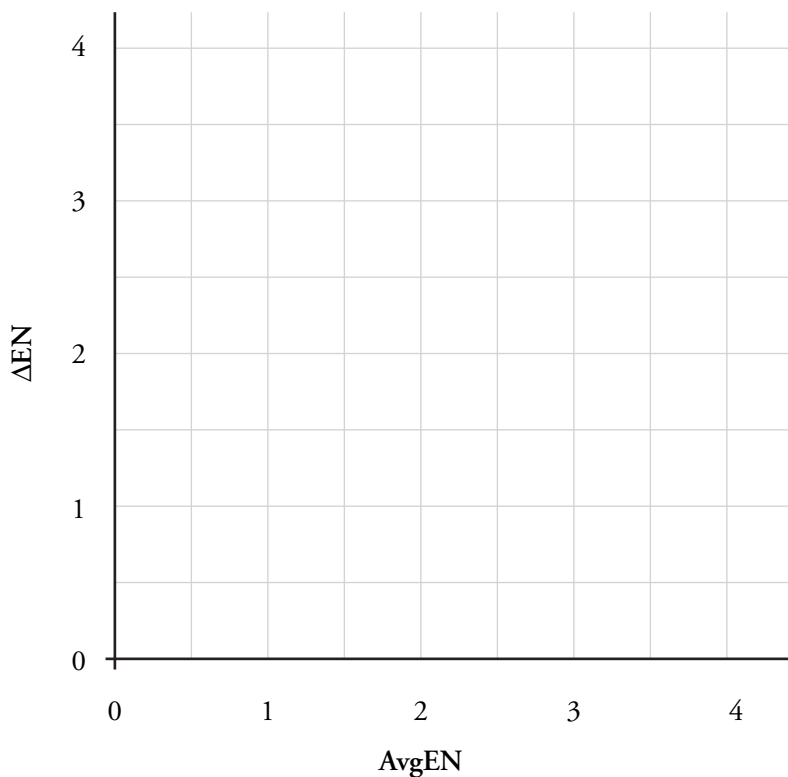
11. Explain your answers in Question 10 in terms of the analogies developed earlier in the activity (i.e., the atoms fighting for electrons).

12. Identify the substances below as having ionic, covalent or metallic bonding based on their AvgEN and Δ EN.



Extension Questions

Model 4 – The Bond-Type Triangle



- Plot each of the substances with known bond types from Model 3 on the graph in Model 4. Label each point with the type of bonding represented by each substance.
- Use the points for the substances CsF, F₂ and Cs to generate a triangle on the graph in Model 4. Why were these points chosen to make the triangle?

Read This!

Although as chemists (and students of chemistry) we would like the divisions between bonding types to be clear, they are more like points on a continuum—a two dimensional continuum. Many compounds have properties that are intermediate between the three bond types.

15. The term **polar covalent** refers to bonds where the electrons are not equally shared—there is a preference for one nucleus over the other. Discuss with your group what region of the Bond-Type Triangle in Model 4 would contain substances with polar covalent bonding.
16. The term **semimetal** refers to metallic bonds where the electrons are more tightly held. These substances will exhibit fewer metallic properties and more covalent properties. Discuss with your group what region of the Bond-Type Triangle in Model 4 would contain semimetallic substances.
17. Use the Bond-Type Triangle in Model 4 to determine the type of bonding of these substances. Use ionic, covalent, metallic, polar covalent and semimetallic as your answers.

Substance	Electronegativity (EN)		AvgEN	Δ EN	Type of Bonding
	First atom	Second atom			
ICl (s)	2.5	3.0			
MgO (s)	1.2	3.5			
GaAs (s)	1.6	2.0			
Si (s)	1.8	1.8			
Cd ₃ Mg (s)	1.7	1.2			
P ₄ O ₇ (s)	2.1	3.5			
NCl ₃ (l)	3.0	3.0			