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

IA	IIA	IIIA	IVA	VA	VIA	VIIA
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?

   VIA and VIIA.

   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.

   O and F have the Smallest atomic radius and have a large number of protons, So the effective nuclear charge is greatest.

   c. Do these elements have a high electronegativity or a low electronegativity?

   High 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.

   a. Which columns in Model 1 contain these elements?

   IA and IIA.

   b. 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.

   Rb and Sr have the largest atomic radius and due to e⁻ Shielding the least ionization energy Since effective nuclear charge is weak.

   c. Do these elements have high electronegativities or low electronegativities?

   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 — Li W/K — Neither atom attracts the electron strongly. The electron is free to move about.

   Li with O — F W/ F — Both atoms attract the electron strongly. The electron stays between the atom.

   Li with K — Li W/O — One atom attracts the electron strongly and pulls the electron towards itself.

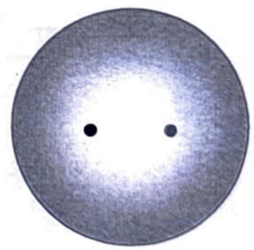
STOP

Model 2 – Types of Bonds

A

F With F
Covalent bond

B



Li With K
Metallic bond

C

Li With O
Ionic bond

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.

   a. Which figure(s) in Model 2 indicates a sharing of electrons? Support your answer with evidence from Model 2.

   A & B. because there is one ring around the two electrons.

   b. Which figure(s) in Model 2 indicates a transfer of electrons? Support your answer with evidence from Model 2.

   C. because there is a ring around only one of the electrons.

   c. 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.

   A.

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.

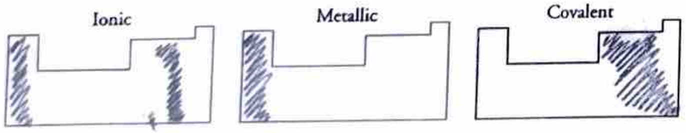
Covalent bonds are formed when both atoms have a strong attraction to the electron, so they share the electron. Neither atom has a charge.

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.

Ionic | Metallic | Covalent



Model 3 – Comparing Electronegativities

Substance	Electronegativity (EN)		AvgEN	ΔEN	Type of Bonding
	First atom	Second atom			
CsF (s)	0.7	4.0	2.35	3.3	Ionic
NaCl (s)	0.9	3.0	1.95	2.1	Ionic
NaI (s)	0.9	2.5	1.70	1.6	Ionic
Cs (s)	0.7	0.7	0.70	0.0	Metallic
Na (s)	0.9	0.9	0.90	0.0	Metallic
Mg (s)	1.2	1.2	1.20	0.0	Metallic
F_2 (g)	4.0	4.0	4.00	0.0	Covalent
HI (g)	2.1	2.5	2.30	0.4	Covalent
C (diamond, s)	2.5	2.5	2.50	0.0	Covalent

9. Calculate the average electronegativity (AvgEN) and the absolute difference in electronegativity (ΔEN) 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 ΔEN values leads to each of the three bond types? Circle the appropriate word in each box.

	AvgEN			ΔEN		
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).

Ionic—Metal and nonmetal fighting for electrons one with high and the other with low electronegativity.
Covalent—Two nonmetals fighting equally hard for electrons.
Metallic—Two metals fighting weakly for electrons.

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

O_2	NaF	KCl	CH_4	Fe
C	I	I	C	M

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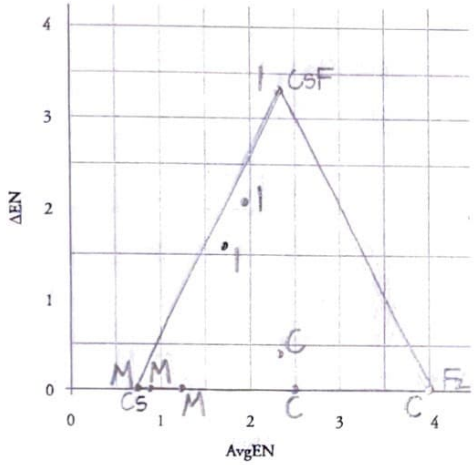
Extension Questions

Model 4 – The Bond-Type Triangle



13. 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.

14. Use the points for the substances CsF, F_2 and Cs to generate a triangle on the graph in Model 4. Why were these points chosen to make the triangle?

Cs, F_2, and CsF all have different bond types and CsF is made up of Cs and F.

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.

The region above the covalent substances due to a higher ΔEN.

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.

The region to the right of the metallic substances toward the bottom due to a higher avgEN.

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	ΔEN	Type of Bonding
	First atom	Second atom			
ICl (s)	2.5	3.0	2.75	0.5	C
MgO (s)	1.2	3.5	1.85	2.3	I
GaAs (s)	1.6	2.0	1.8	0.4	SM
Si (s)	1.8	1.8	1.8	0.0	SM
Cd_3Mg (s)	1.7	1.2	1.45	0.5	M
P_4O_7 (s)	2.1	3.5	2.8	1.4	PC
NCl_3 (l)	3.0	3.0	3.0	0.0	C