

ALE 19. Classification of Solids(Reference: pp. 463 – 464; 470 – 473 of Sec. 12.6 in *Silberberg 5th edition*)***How do inter-particle forces affect the physical properties of a solid?*****The Model: Types of Solids**

Crystals may be classified as one of the following: (1) *molecular*; (2) *Atomic*, (3) *ionic*, (4) *covalent network*; or (5) *metallic*.

Type of Solid	“Building-block” Particles within Crystal
Molecular crystal	Molecules
Atomic crystal	Atoms
Ionic crystal	Cations and Anions
Covalent Network crystal	Atoms
Metallic crystal	Metal Cations and a “Sea” of Electrons

If presented with an unknown crystal, a chemist can classify it by its physical properties. Examples of commonly-tested physical properties include *melting point* and the *ability to conduct electricity* as a solid, as a liquid and dissolved in aqueous solution (if soluble in water).

	Substance	mp (°C)
Molecular	HCl	-114
	H ₂ O ₂	-0.43
	H ₂ O	0.0
	C ₁₄ H ₈ O ₅	374

	Substance	mp (°C)
Atomic	F ₂	-220
	Ar	-189
	Cl ₂	-101
	I ₂	114

	Substance	mp (°C)
Metallic	Ga	30.
	Cu	1083
	Fe	1535
	W	3410

	Substance	mp (°C)
Ionic	LiCl	605
	CuO	1326
	K ₃ PO ₄	1340
	Al ₂ O ₃	2072

	Substance	mp (°C)
Covalent Network	SiO ₂ (quartz)	1610
	WC	2870
	BN	2973
	C(diamond)	3550

Key Questions

- List three types of intermolecular forces that exist between molecules in the condensed phase (i.e. in solids and liquids) of a *molecular compound*.
- What force holds the particles of an *ionic crystal* together?

- 3a. If the atoms within a molecule have a charge, are the atoms fully charged (e.g., +1) or are they partially charged (e.g., +0.2)? (Circle your answer.)
- b. Coulomb's Law may be written as

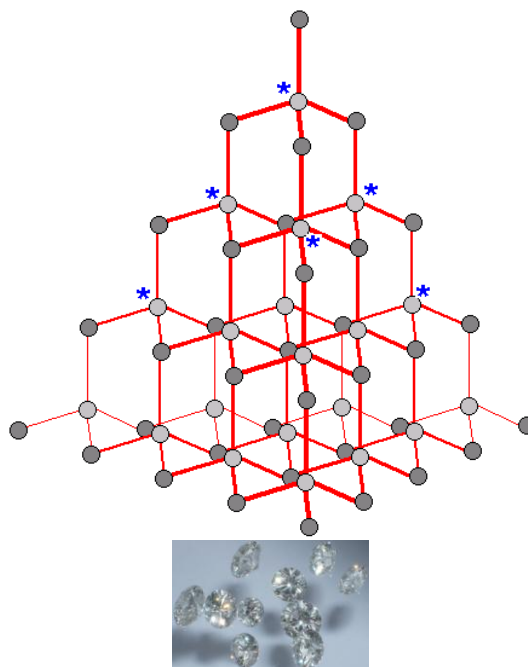
$$F = k \frac{Q_+ Q_-}{r^2}$$

where Q_+ is the positive charge on one particle and Q_- is the negative charge on another particle. Which of the following does Coulomb's Law predict? (Circle your answer.)

- The attractive force between molecules in a molecular solid is weaker than that between cations and anions in an ionic solid.
 - The attractive force between molecules in a molecular solid is greater than that between cations and anions in an ionic solid.
 - The attractive force between molecules in a molecular solid is about the same of that between cations and anions in an ionic solid.
- c. Do the relative melting points of molecular crystals and ionic crystals agree with the answer to part (b)? Yes OR No Circle your answer and explain.

4. Diamond is an example of a covalent network solid. To the right is a ball and stick representation of a *very small* fragment of a diamond—a 1 carat diamond has about 10^{22} carbon atoms! In the figure, the balls marked with an * represent what *every* atom looks like within the structure of diamond. Because of a lack of space on the sheet of paper, not every atom can be drawn the same way.

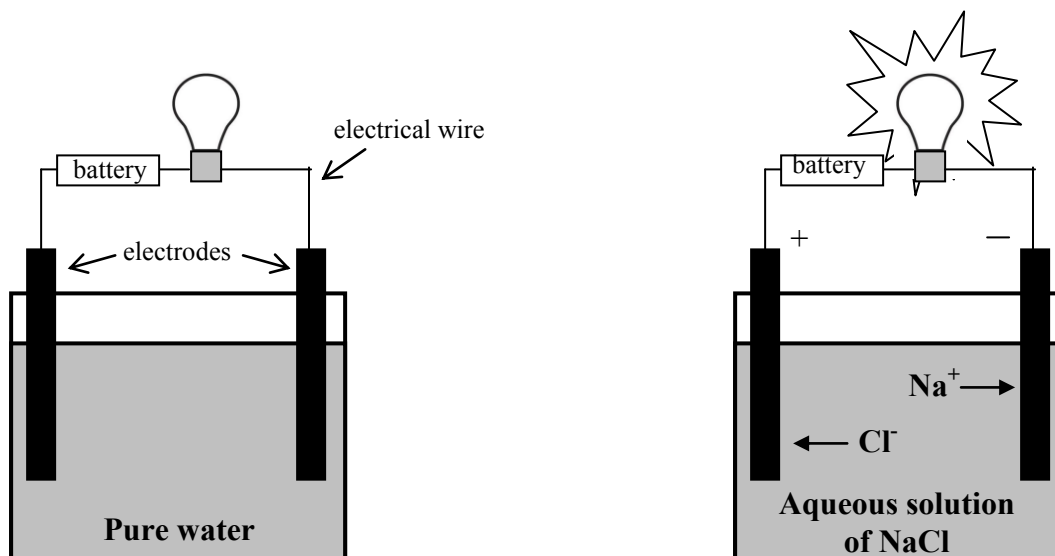
- What kind of bonds are the atoms in a network crystal held together by?
- The bond energy of a C—C bond is 347 kJ/mol. Recall that the enthalpy of fusion of H_2O is about 6 kJ/mol. Use this information to explain why covalent network solids have “very high” melting points (relative to molecular crystals).



5. Explain why one would probably not use an experimentally-determined melting point to classify an unknown solid as a metal. Use specific data from the model, above, to support your response.

The Model: Conduction of Electricity

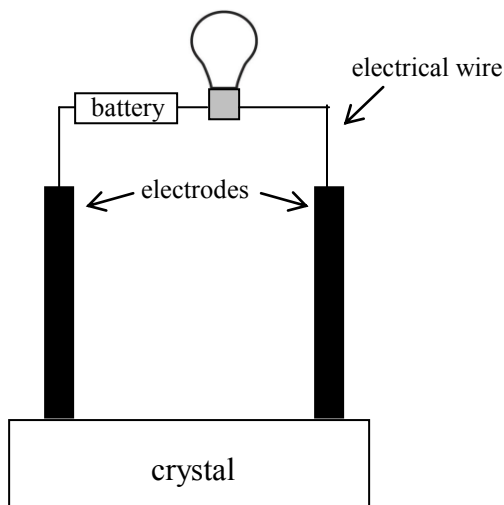
In Chem 140 we defined an electrolyte as a substance that dissociates into ions when dissolved in water and therefore enhances the conductivity of electricity through the water.



Unlike the water molecules, the dissolved ions are *flowing charged particles* that complete the “electrical circuit” in the figure on the right.

Key Questions

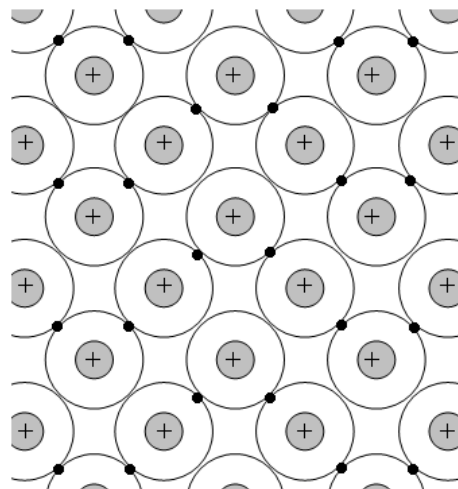
6. Suppose the following figure (obviously, not to scale!) represents the experimental setup to test the electrical conductivity of a crystal. Based on what’s presented in the Model below, what must present in the crystal in order for the “electrical circuit” to be completed and make the light bulb go on?



- 7a. Do molecular crystals have the particles mentioned as the answer to Question 6? Yes OR No (Circle your answer.)
- b. Do molecular crystals conduct electricity? Yes OR No Circle your answer and briefly explain why or why not.
- c. Suppose a molecular compound was first melted and the electrodes of the above proposed experimental apparatus were placed in the liquid. Would the liquid of a molecular compound conduct electricity? Yes OR No Circle your answer and briefly explain why or why not.
- 8a. Do ionic crystals have the particles mentioned as the answer to Question 6? Yes OR No (Circle your answer.)
- b. Do ionic crystals conduct electricity? Yes OR No Circle your answer and briefly explain why or why not.
- c. Suppose an ionic compound was first melted and the electrodes of the above proposed experimental apparatus were placed in the liquid. Would the liquid of an ionic compound conduct electricity? Yes OR No Circle your answer and briefly explain why or why not.
- 9a. Do covalent network crystals have the particles mentioned as the answer to Question 6? Yes OR No (Circle your answer.)
- b. Do covalent network crystals conduct electricity? Yes OR No Circle your answer and briefly explain why or why not.
- c. Suppose a compound that crystallizes as a covalent network was first melted and the electrodes of the above proposed experimental apparatus were placed in the liquid. Would the liquid of a covalent network conduct electricity? Yes OR No Circle your answer and briefly explain why or why not.

10. What is an everyday experience that suggests that metals conduct electricity?

11. The figure to the right represents a 2-D slice through a portion of a crystal of lithium. (The circles represent the valence shells. The black dots represent the $2s$ electrons. The inner shaded circles represent the nuclei and the core shells. The “+” signifies that the resultant charge of 3 protons and 2 core electrons is +1.) (Again, because of the limitations of space, not all atoms can be shown.)



- a. All electrons are indistinguishable from each other. Does an individual electron “belong” to a single lithium atom? Yes OR No
(Circle your answer.)
- b. A metallic crystal is often described as being a collection of metal cations surrounded by a “sea of electrons”. What are the flowing charged particles in a metallic crystal?
- c. When a metal is melted, does it still conduct electricity? Explain your answer.

Exercises

12. A solid has a melting point of $1427\text{ }^{\circ}\text{C}$. It does not conduct electricity as either a solid or a liquid. The solid can be classified as which of the following: (Circle your answer.)
- | | |
|-------------|--------------------|
| ① molecular | ③ covalent network |
| ② ionic | ④ metallic |
13. A solid has a melting point of $321\text{ }^{\circ}\text{C}$. It does conduct electricity as both the solid and as a liquid. The solid can be classified as which of the following: (Circle your answer.)
- | | |
|-------------|--------------------|
| ① molecular | ③ covalent network |
| ② ionic | ④ metallic |
14. A solid has a melting point of $782\text{ }^{\circ}\text{C}$. It does not conduct electricity as either a solid, but it does as a liquid. The solid can be classified as which of the following: (Circle your answer.)
- | | |
|-------------|--------------------|
| ① molecular | ③ covalent network |
| ② ionic | ④ metallic |
15. A solid has a melting point of $114\text{ }^{\circ}\text{C}$. It does not conduct electricity as either a solid or a liquid. The solid can be classified as which of the following: (Circle your answer.)
- | | |
|-------------|--------------------|
| ① molecular | ③ covalent network |
| ② ionic | ④ metallic |