Physical Properties and Structure of Solids

INTRODUCTION:

Depending on whether the kind of bonding in a pure substance is primarily ionic, covalent or metallic in character, a substance may be described as ionic, molecular, macromolecular or metallic. These terms, ionic, molecular, macromolecular and metallic, represent ideal models and some substances have properties that would classify them as borderline, somewhere intermediate between two groups. In general however, it is useful to classify substances to better understand the properties of matter.

IONIC SUBSTANCES:

Ionic substances are all solids at room temperature. They are typically crystalline, but may exist as fine powders as well as clearly defined crystals. Ionic substances have high melting points, usually above 300^{o}C but below 1000^{o}C. When molten, ionic substances conduct an electric current because the ions can move freely, but in the solid state, they do not conduct electricity due to the rigid structure and strong bonding in the crystal lattice.

Ionic substances are frequently (but not always) soluble in water. The solutions produced conduct electricity rather well. Ionic substances are usually not nearly as soluble in other liquids as they are in water. For a liquid to be a good solvent for ionic substance, it must be highly polar, containing molecules with well defined positive and negative regions with which the ions can interact.

MOLECULAR SUBSTANCES

All gases and almost all liquids at room temperature are molecular in nature. In addition, many solids, especially organic solids, are molecular, but the melting points of molecular substance are usually below 300^{o}C. Molecular substances do not conduct electricity in either the solid of liquid state. Molecular substances can be polar or non polar-- the properties of the two are contrasted below:

Physical Property	***Non-polar Molecular***	***Polar Molecular***
Melting points	below 100^{o}C	below 300^{o}C
Electrical Conductivity:		
In solution	None	Poor
In the melt	None	None
Solubility:		
In polar solvents (water)	None	Good
In nonpolar solvents (xylene)	Good	None

MACROMOLECULAR SUBSTANCES (NETWORK COVALENT SOLIDS)

Macromolecular substances are all solids at room temperature. They have very high melting points, usually above 1000^{o}C, and low volatility. They are typically very resistant to thermal decomposition. They do not conduct an electric current and are often good insulators. One notable exception to this is graphite, one form of carbon, which due to its structure, will conduct electricity along one axis. They are not soluble in any solvent.

METALLIC SUBSTANCES

The properties of metallic solids are mainly the result from the freedom of movement of the bonding electrons. Most metallic solids are solids at room temperature. Most have high melting points, although mercury does melt at 0 ^{o}C. Metallic solids are very good conductor in the solid and molten state. They are not soluble in any solvent, although many metals will chemically react with polar solvents like water to form solutions. The properties of metallic substances are listed below;

PHYSICAL PROPERTIES & CLASSIFICATION

Classification (Example)	Solubility		Melting Points	Conductivity		
	H_2O (Polar)	Xylene (Non-polar)		Solid	Melt	Aqueous Solution
Ionic (NaCl)	Often Good	Poor	Often 300^{o}C to 1000^{o}C	None	Good	Good
Non-polar Molecular (Mothballs)	Poor	Good	<100^{o}C	None	None	_____
Polar Molecular (Sugar)	Good	Poor	100^{o}C to 300^{o}C	None	None	None*
Macromolecular (C, diamond)	Poor	Poor	>1000^{o}C	None	None	_____
Metallic (Cu)	Poor	Poor	0^{o}C to >1000^{o}C	Good	Good	_____

* Poor - Good, if solute chemically reacts with H_2O to form ions.

EXPERIMENTAL PROCEDURE

SAFETY NOTE: Xylene is a flammable liquid. Keep it away from open flames. Dispose of any mixtures containing xylene or dichlorobenzene in the appropriate waste container.

In this experiment you will determine the classification (ionic, polar molecular, nonpolar molecular, metallic, and network covalent) of a group of solids based on observations you make about each solids melting point, electrical conductivity and solubility. Fill in the data table, following the directions below, then classify each solid. Explain your reasoning for each classification, being sure to include in your reasoning for eliminating the classifications you did not choose.

Solubility is a measure of how well a solid dissolves in a liquid. You will test the solubility of each solid in water (polar solvent) and xylene (nonpolar solvent). It is important that this test be done in a consistent manner in order to accurately determine solubility. Crush any larger crystals into a powder before testing. Be sure to use clean, dry test tubes, especially when testing the solubility in xylene. Mix approximately a match head size quantity of solid with 2 mL of liquid (one pipet full). Stir using a clean, dry stirring rod. If all of the solid dissolves, the liquid will remain clear after mixing. Look for signs of dissolving such as decreased amount of solid present or lines of light diffraction present in the liquid. Cloudiness that does not clear up with continued stirring indicates insolubility. Note: use deionized water.

Approximate **melting points** of substances can be determined rather easily by determining the temperature at which a solid starts to melt. Adjust the Bunsen burner to its maximum temperature before starting this procedure. Substances with low melting points, less than 100^{o}C, for example, will start to melt almost immediately when heated in a test tube over a Bunsen burner. A test tube heated to about 300^{o}C will impart a yellow-orange color to the Bunsen flame. This color becomes more pronounced between 300^{o} and 700^{o}C, at which temperature the Pyrex tube will begin to soften. Solids that start to melt in this region have a melting point between 300^{o} and 700^{o}C; solids that do not start to melt have melting points above 700^{o}C. When heating substances whose properties are unknown, always assume they are toxic. Heat the p-dichlorobenzene and unknown samples in a fume hood. Allow the test tubes to cool, and use your solubility data to determine which solvent to use to clean them. Dispose of the waste substances in the appropriate containers.

Electrical conductivities of your substances in the solid and solutions phase will be measured using a portable test meter. Shine up the electrodes of the test meter before each test. The needle will deflect if the solid or solution conducts electricity. The only solids which you will test in the solution phase will be those that dissolve in water. Add a match head size quantity of solid to a small test tube and fill the test tube to the top with deionized water. Place the electrode in the solution.

Physical Properties and Molecular Structure:

Name_____

Substance	Solubility (good, poor, or none)		Melting Point	Conductivity		Classification and Reasons	
	Water (polar)	Xylene (nonpolar)	(<100, 100–300, 300–700, >700)	Solid	Solution in water	Classification (see instructions)	Reasoning (see instructions)
Urea							
Aluminum							
Silica							
Potassium Iodide							
p-dichlorobenzene							
Unknown _____							
Unknown _____							

QUESTION:

Given the following observations, classify the solids described below as ionic, metallic, polar molecular, or nonpolar molecular. Provide a clear reason why you choose that classification for each solid. Be sure to explain why the other classifications were eliminated. There may be a solid that cannot be classified based on the information provided. If this is the case, also include what other observations you might need to do as well as the reasons for which classifications can be eliminated.

(A) Melts at 120 ºC, soluble in water, doesn't conduct electricity in the solid state.

Classification: _____

Reasoning:

(B) Melts at 500ºC, conducts electricity in the solid state.

Classification: _____

Reasoning:

(C) Melts at 65 ºC, soluble in xylene, doesn't conduct electricity in the solid state.

Classification: _____

Reasoning:

(D) Soluble in nothing, doesn't conduct electricity.

Classification: _____

Reasoning: