Classification of Chemical Substances

INTRODUCTION:

Depending on the kind of bonding present in a chemical substance, the substance may be called ionic, molecular or metallic.

In a **solid ionic compound** there are ions and the large electrostatic forces between the positively and negatively charged ions are responsible for the bonding which holds these particles together.

In a molecular substance the bonding is caused by the sharing of electrons by atoms. When the stable particles resulting from covalent bonding contain relatively small numbers of atoms, they are called **molecules**. If the particles are very large and include essentially all the atoms in a macroscopic particle, the substance is called **macromolecular.**

Metals are characterized by a kind of bonding in which the electrons are much freer to move than in other kinds of substances. The metallic bond is stable but it is probably less localized than other bonds.

The terms ionic, molecular, macromolecular and metallic are somewhat arbitrary, and some substances have properties that would place them in a borderline category, somewhere in between one group and another. It is useful, however, to consider some of the general characteristics of typical ionic, molecular, macromolecular and metallic substances, since many very common substances can be readily assigned to one category or another.

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. While many ionic substances are stable up to their melting points, some decompose on heating. It is very common for an ionic crystal to release loosely bound water of hydration at temperatures below 200°C. Anhydrous (dehydrated) ionic compounds have high melting points, usually above 300°C but below 1000°C. They are not readily volatilized and boil at only very high temperatures.

Molecular Substances:

All gases and essentially all liquids at room temperature are molecular in nature. If the molecular weight of a substance is over about 100, it may be a solid at room temperature. The melting points of molecular substances are usually below 300°C; these substances are relatively volatile, but several will decompose before they boil. Most molecular substances do not conduct electric current when solid or when molten (melted).

Organic compounds, which contain primarily carbon and hydrogen, often in combination with other non-metals, are essentially molecular in nature. Since there are a great many organic substances, it is true that most compounds are molecular. If an organic compound decomposes on heating, the residue is frequently a black carbonaceous material. Reasonably large numbers

PHYSICAL PROPERTIES of SOME REPRESENTATIVE CHEMICAL SUBSTANCES

Substance	M.P. (°C)	B.P. (°C)	Solubility in water	Solubility in CCl_4	Electrical Conductance	Classification
NaCl	801	1413	Sol	Insol	High in melt and in sol'n.	Ionic
MgO	2800		Sl sol	Insol	Low in sat'd sol'n	Ionic
$CoCl_2$	Sublimes	1049	Sol	Insol	High in sol'n	Ionic
$CoCl_2 \cdot 6H_2O$	86	Dec	Sol	Insol	High in sol'n	Ionic hydrate, loses H_2O at 110°C
$C_{10}H_8$	70	255	Insol	Sol	Zero in melt	Molecular
C_6H_5COOH	122	249	Sl sol	Sol	Low in sat'd sol'n	Molecular-ionic
$FeCl_3$	282	315	Sol	Insol	High in sol'n	Molecular-ionic
SnI_4	144	341	Dec	Sol	Zero in melt	Molecular
SiO_2	1600	2590	Insol	Insol	Zero in melt	Macro-molecular
Fe	1535	3000	Insol	Insol	High in solid	Metallic

Key: Sol = at least 0.1 mole / L; Sl sol = appreciable solubility but < 0.1 mol / L
Insol = essentially insoluble; Dec = decomposes.

of inorganic substances are also molecular; those which are solids at room temperature include some of the binary compounds of elements in Groups IV A, V A, VI A and VII A.

Molecular substances are frequently soluble in at least a few organic solvents, with the solubility being increased if the substances and the solvent are similar in molecular structure.

Some molecular compounds are markedly polar, which tends to increase their solubility in water and other polar solvents. Such substances may ionize appreciably in water, or even in the melt, so that they become conductors of electricity. Often the conductivity is considerably lower than that of an ionic material. Most polar molecular compounds in this category are organic, but a few, including some of the salts of the transition elements, are inorganic.

Macromolecular Substances:

Macromolecular substances are all solids at room temperature. They have very high melting points, usually above 1000°C, and low volatility. They are typically very resistant to thermal decomposition. They do not conduct electric current and are often good insulators. They are not soluble in water or any organic solvents. They are frequently chemically inert and may be used as abrasives or refractories.

Metallic Substances:

The properties of metals appear to derive mainly from the freedom of movement of their bonding electrons. Metals are good electrical conductors in the solid form, and have characteristic luster and malleability. Most metals are solid at room temperature and have melting points that range from below 0°C to over 2000°C. They are not soluble in water or organic solvents. Some metals are prepared as black powders, which may not appear to be electrical conductors; if such powders are heated, the particles will coalesce to give good electrical conductivity.

EXPERIMENTAL PROCEDURE

1. Take a dime-sized amount of one of the substances and place it on a clean, dry watch glass. If there are large pieces available, take one of them.

2. Test the conductivity of the solid on the apparatus demonstrated by the instructor. If the solid is a powder, make sure that both "feet" of the conductivity apparatus are in contact with it. If the solid consists of large, sturdy pieces clamp one with the alligator clips. Record the value of the conductivity in volts (0 - 25 V).

3. Place the watch glass with the solid on it on the hot plate marked LOW. If the solid melts, the approximate melting point is <100°C. If it does not melt after a couple of minutes, transfer the watch glass using your crucible tongs and wire gauze to the hot plate marked MEDIUM. If it melts, the approximate melting point is 100 - 300°C. If it does not melt after a couple of minutes, transfer the watch glass to the hot plate marked HIGH. If it melts, the approximate melting point is 300 - 600°C. If it does not melt, the approximate melting point is >600°C.

4. If the solid melts, test the conductivity of the melt. Make sure that the substance is a liquid at this point. If it has resolidified, remelt it. Record the voltage. If the solid did <u>not</u> melt in step 3, do not test the conductivity of the melt. Simply put an X in the box.
5. Discard the solid in the proper place.

6. Take a pea-sized amount of the same solid. Put it in 10 mL of distilled water. Stir. Does the solid dissolve?

7. If the solid has dissolved, test the conductivity of the solution. Record the voltage. If the solid did <u>not</u> dissolve in step 6, do not test the conductivity. Simply put an X in the box.

8. Discard the solution in the appropriate place.

9. Repeat steps 1 through 8 with the other five solids.

10. Classify each of the six substances and see the instructor.

11. Pick two unknowns and check with the instructor for disposal directions.

12. Perform steps 1 through 8 with each unknown.

Lab #12

DATA SHEET

NAME _____ SECTION_____

Classification of Chemical Substances

Substance #	Conduct as a solid (V)	Approx. Melting Point, °C	Conduct. as a melt (V)	Solubility in water	Conduct. as a solution (V)	Classification	Waste
		(<100, 100-300 300-600 600)					
I							
II							
III							
IV							
V							
VI							
Unknown No. _____							
Unknown No. _____							

Lab #12

PRESTUDY

A

NAME_____ SECTION_____

CLASSIFICATION of SUBSTANCES

1.(3 points) List three properties of a substance which would definitely establish that the material is macro-molecular.

2.(2 points) A powdery material has melting point of 625°C, does not conduct electricity in the solid state but does conduct electricity in the molten state and in aqueous solution. What would the classification of this substance be?

3.(2 points) A white solid melts at 120°C, does not conduct electricity in the solid or molten state and is not soluble in H_2O but is soluble in toluene, C_7H_8. What would the classification of the substance be?

4.(3 points) A white solid has a melting point of 60°C, is soluble in H_2O and in polar organic solvents. It does not conduct electricity in the solid or molten state, but does conduct in an aqueous solution. What would the classification of this substance be?

Lab #12

PRESTUDY

B

NAME_____ SECTION_____

CLASSIFICATION of SUBSTANCES

1.(3 points) List 3 differences between metallic and macro-molecular substances.

2.(2 points) A substance is a white, crystalline solid at 25°C. The solid does not conduct a current. It melts at 350°C without decomposing and the melt conducts an electric current. What would be the classification of the substance?

3.(2 points) A substance conducts electricity in the solid and molten state. It has a melting point of 40°C. It is insoluble in H_2O and in non-polar solvents. What would be the classification of this substance?

4.(3 points) A lustrous material does not conduct electricity in both the solid and molten state. It has a very high melting point. What would be the classification of this substance?