

Lab # 12 - 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 that 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 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 waters 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. They may or may not be soluble in water. If they are water soluble, the resulting solution carries a strong electric current. As solids, they do not conduct electricity but when molten (melted) they do.

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 g/mol, 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.

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 of inorganic substances are also molecular; those which are solids at room temperature include some of the binary compounds of elements in Groups IVA, VA, VIA and VIIIA (all transition metals). 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

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organic, but a few, including some of the salts of the transition elements, are inorganic. Such substances belong to the subcategory called **molecular-ionic**.

Macromolecular Substances

Macromolecular, or network covalent, 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 usually do not conduct an 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.

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. All metals but one, mercury, 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.

Physical Properties of Some Representative Solids

Substance	Melting Pt (°C)	Boiling Pt (°C)	Solubility in H₂O	Electrical Conductivity	Classification
NaCl	801	1413	sol	high in melt and in soln	ionic
MgO	2800		sl sol	low in sat'd soln	ionic
CoCl ₂	sublimes	1049	sol	high in soln	ionic
CoCl ₂ ·6H ₂ O	86	dec	sol	high in soln	ionic (hydrate, loses H ₂ O at 110°C)
C ₁₀ H ₈	70	255	insol	zero in melt	molecular
SnI ₄	144	341	dec	zero in melt	molecular
C ₆ H ₅ COOH	122	249	sl sol	low in sat'd soln	molecular-ionic
FeCl ₃	282	315	sol	high in soln	molecular-ionic
SiO ₂	1600	2590	insol	zero in melt	macromolecular
B ₄ C	2350	>3500	insol	zero in melt	macromolecular
Fe	1535	3000	insol	high in solid	metallic
W	3422	5555	insol	high in solid	metallic

sol – soluble (at least 0.1 mol/L), sl sol – slightly soluble (appreciable solubility but <0.1 mol/L), soln – solution, sat'd – saturated, dec – decomposes, insol – essentially insoluble

Lab # 12 - Classification of Chemical Substances**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 $<300^{\circ}\text{C}$. 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 $300 - 600^{\circ}\text{C}$. If it does not melt, the approximate melting point is $>600^{\circ}\text{C}$ (HIGH).
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 not 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 not 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.

NAME _____

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Lab # 12 - Classification of Chemical Substances**DATA**

Substance #	Conductivity as solid (V)	Approx. Melting Point (°C) (<300, 300-600, >600)	Conductivity as melt (V)	Solubility in water	Conductivity as solution (V)	Classification	Waste
I							
II							
III							
IV							
V							
VI							
unknown # _____							
unknown # _____							

Instructor's Initials _____

