

## 6. A CHEMISTRY MYSTERY: NAME THAT UNKNOWN!

### Introduction

How do atoms join together? Do these forces dictate how matter looks and behaves in nature? Understanding bonding forces will help you understand the patterns in the properties of matter. In this lab, you will assume the role of an investigator studying the properties of unknown substances. You will be testing a number of parameters to determine the nature of chemical bonding and unmask the identity of your unknown solids.

### Concepts

- Chemical bonding
- Ionic bond
- Polar covalent bond
- Nonpolar covalent bond
- Physical and chemical properties
- Solubility

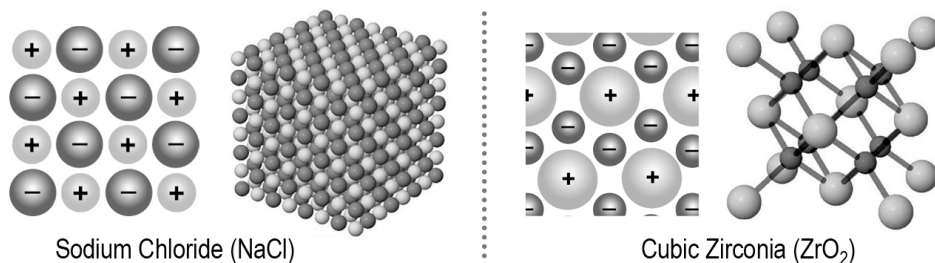
### Background

Did you ever have that chemist's nightmare where you enter your lab and all the labels to your chemicals have fallen off? If you have, then you know that it will take some serious sleuthing to figure out the identities of your chemicals! Every chemical in your inventory has intrinsic properties that make it distinct from all others. Its unique nature is the result of the types of bonds that hold its atoms together.

Indeed, atoms bond together in different ways as exemplified in the diversity of matter. A bond is a force that holds groups of two or more atoms together and makes them function as a unit. It is the electrons in atoms and forces of attraction between atoms that dictate the type of bonds that are formed. Energy is released when bonds form and absorbed when bonds are broken.

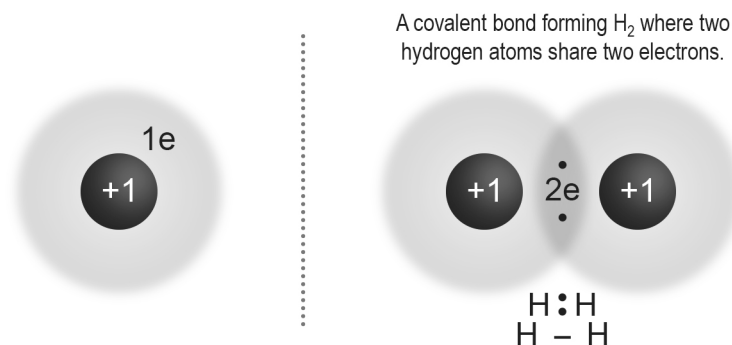
Ionic bonds are formed between metals and nonmetals when one atom that loses its electrons relatively easily (metal) reacts with an atom that has a high affinity for electrons (nonmetal). Ionic compounds are sturdy aggregates, crystalline in nature with high melting points. The strong bonding forces in ionic compounds result from the attraction between closely packed, oppositely charged ions as shown for sodium chloride and cubic zirconia on the figure below.

#### IONIC COMPOUNDS OFTEN FORM CRYSTALS



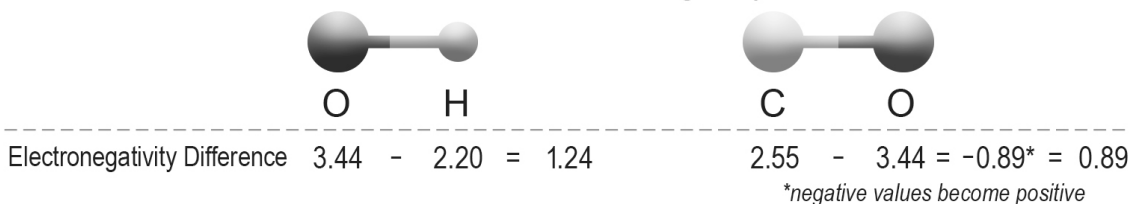
Covalent bonds are found in molecules where electrons are shared by nuclei instead of being transferred. In covalently bonded molecules, electrons reside primarily in the space between the two nuclei. Thus, for hydrogen, electrons are shared in the space between two single H atoms and are

attracted simultaneously and equally by the two protons. This leads to the formation of molecular hydrogen, H<sub>2</sub>. When the covalent bond is formed, the resulting H<sub>2</sub> molecule is more stable in nature than the two separated hydrogen atoms.

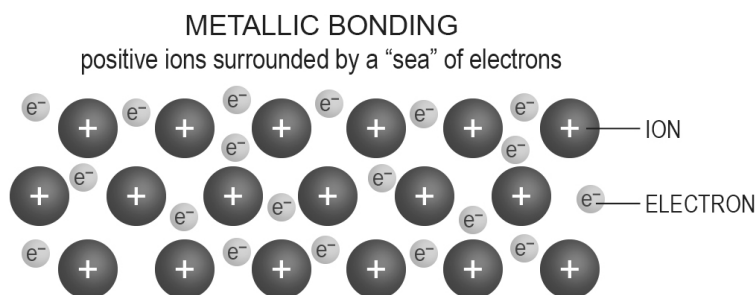


Between these two extremes of bonding: ionic bonding where participating atoms are so different that one or more electrons are transferred to form oppositely charged ions, and covalent bonding where two identical atoms share electrons equally (non-polar covalent), exist intermediate cases in which electrons are unequally shared between atoms. These types of bonds are formed between atoms that have different degrees of electronegativity. The term refers to the relative ability of an atom in a molecule to attract shared electrons to itself and because of the uneven distribution of charges between atoms, the bond formed is called a polar covalent bond.

Polar covalent bonds have an electronegativity difference of 0.5 to 2.1



Metal bonds are characterized by a “sea” of valence electrons that are shared among atoms in a strong but non-directional way. They are quite mobile in the metal crystal. Mobile electrons can conduct heat and electricity and because metal atoms can be moved easily, they have the unique properties of malleability and ductility; that is, they can be hammered into sheets and pulled into wires.



In this lab, you will evaluate a series of compounds based on their physical and chemical properties and classify them by the nature of chemical bonding. You might even identify them by name. Happy sleuthing!

## Pre-Lab Questions

1. Draw pictures that illustrate how particles are arranged for each bond type at the atomic level.

IONIC SOLID	POLAR-COVALENT SOLID	NONPOLAR COVALENT SOLID

2. Using text or online sources, research the properties of the following solids and fill in the table below. Bond types represented are ionic, polar covalent, nonpolar covalent and metallic.

SOLID	BOND TYPE	MELTING POINT (°C)	COLOR/APPEARANCE	SOLUBILITY IN WATER (25 °C)
Potassium Iodide (KI)				
Dextrose (C <sub>6</sub> H <sub>12</sub> O <sub>6</sub> )				
Iodine (I <sub>2</sub> )				
Aluminum (Al)				

3. Explain the difference in melting points of iodine and potassium iodide.
4. Explain the difference in solubility of dextrose and iodine in water at 25°C.

## Materials and Equipment

Use the following materials to complete the initial investigation. For conducting an experiment of your own design, check with your teacher to see what materials and equipment are available.

- Data collection system
- Wireless conductivity sensor
- Wireless pH sensor
- Hotplate
- Beaker, 250-mL
- Beakers, 100-mL
- Graduated cylinder, 100-mL
- Stirring rod
- Spatula
- Tongs
- Aluminum foil squares (8), 5 cm x 5 cm
- Masking tape
- 
- Wash bottle with distilled water
- Table salt
- Table sugar
- Paraffin wax
- 0.1 M Sodium hydroxide (NaOH)
- 0.1 M Hydrochloric acid (HCl)
- Unknown A
- Unknown B
- Unknown C
- Unknown D
- Unknown E

## Safety

Follow these important safety precautions in addition to your regular classroom procedures:

- Wear safety goggles and gloves at all times.
- The hot plate gets very hot. Handle with care.
- Avoid direct contact with and handle all samples in heat-proof containers using tongs.
- Handle hot plate only when it has cooled.
- Keep all materials and electrical cords from the hot plate.
- Wash hands thoroughly with soap and water before leaving laboratory.
- Dispose of solutions as directed by Material Safety Data Sheet.

## Disposal

If your drain system is connected to a sanitary sewer system, the following instructions apply. Dilute acid and base solutions may be rinsed down the drain with an excess of water. Solid waste is safe to dispose of as solid trash.

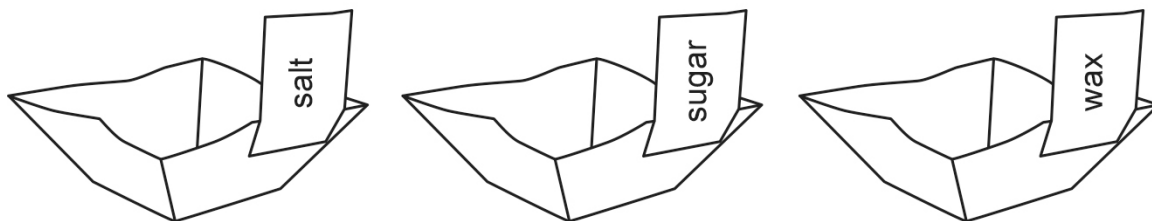
## Initial Investigation

### Sample Testing Procedures

Property	Testing Protocol
Color or Appearance	Record visual and textural observations of the solid
Solubility in Water (25oC)	Mix 2.0 mL of distilled water and a pea-sized sample (1/4 tsp) of solid in a test tube. Record results.
Conductivity in Solution	Mix 50 mL of distilled water and a pea-sized sample (1/4 tsp) of solid in a beaker. Record conductivity using a wireless conductivity sensor as $\mu\text{S}/\text{cm}$ divided by conductivity of distilled water (blank).
pH in Aqueous Solution	Following conductivity determination, rinse and calibrate pH probe (Reference Guide 013-14662A at pasco.com). Measure and record the pH of your test solution. Rinse probe between test samples.
Melting Point	<p>Low Temperature Melting Solids (&lt;100°C): Fold a 5 cm x 5 cm piece of aluminum foil into a “boat” and place a pea-sized sample (1/4 tsp) of sold in it. Float the dish on a boiling water bath for 1-2 minutes. If the substance melts, record melting temperature as “low”.</p> <p>Medium Temperature Melting Solids (100-301°C): For a solid that does not melt above boiling water, transfer aluminum boat directly onto hot plate surface and allow to heat for 1-2 minutes. If it melts, record melting temperature as “medium”.</p> <p>High Temperature Melting Solids (&gt;301°C): If sample does not melt over the hot plate, record melting temperature as “high”.</p>
Reaction with 0.1 M HCl	Mix 2.0 ml 0.1 M HCl and a pea-sized sample (1/4 tsp) of solid in a test tube. Record observations. If no reaction, record as “no reaction”.
Reaction with 0.1 M NaOH	Mix 2.0 ml 0.1 M NaOH and a pea-sized sample (1/4 tsp) of solid in a test tube. Record results. If no reaction, record as “no reaction”.

### Characteristics of Ionic and Covalent Compounds

1. Turn on hot plate to highest setting. PASCO PS-3401 reaches a maximum temperature of 301°C.
2. Fill a 250-mL beaker with 125 mL of distilled water and set it on the hot plate to boil. Do not handle heated instruments without proper protective equipment.
3. Start a new experiment on the data collection system on your Chromebook, computer or mobile device.
4. Connect the conductivity sensor and pH sensor to your data collection system.
5. Fold pieces of aluminum foil into sample “boats” as shown in Figure 1, for your “known” samples.



Use tape to create labels for 3 foil dishes.

6. Conduct testing procedures as specified above for each known sample and record observations in Table 1 below.

**Table 1: Properties of Known Samples**

SOLID	COLOR OR APPEARANCE	SOLUBILITY IN WATER	SOLUTION CONDUCTIVITY	SOLUTION pH	MELTING POINT	REACTION WITH ACID	REACTION WITH BASE	TYPE OF BONDING
Sodium chloride								
Sucrose								
Paraffin Wax								

7. Based on the information obtained above, predict the type of chemical bonding found in each of your known samples. Justify your predictions.

## Advanced Investigation

### A Chemistry Mystery: Characteristics of Unknown Compounds

1. Obtain samples of 5 unknowns from your teacher. You will note that they are all white in color. Your task is to examine the properties of each sample and perform sample testing procedures as detailed in the Initial Activity section. Record your data in Table 2:

Table 2: Properties of Unknown Samples

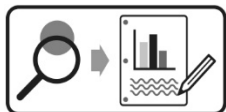
Unknown Solid	Color or Appearance	Solubility in Water	Solution Conductivity	pH	Melting Point	Reaction with Acid	Reaction with Base	BOND TYPE
A								
B								
C								
D								
E								

2. Predict the nature of chemical bonding in each of your unknown samples. Justify your predictions. Obtain the names of your unknowns from your instructor. They will be given as a random list. Using your data and predictions, match the correct name with your unknown samples in Table 3.

Table 3: Solving the Chemistry Mystery

	Name	Type of Bonding	Justification
A			
B			
C			
D			
E			

## Extended Inquiry Investigation



### Case Study

The local fire department responded to a call to handle a small fire in a private residence. No one wanted to fuss up about the fire's origin so the fire investigator (your instructor) obtained a sample of residue from the site and took it to the lab for analysis. You are the chemist who has been given the job of identifying the residue. Design a protocol to solve this mystery. You may use any of the data tables from this lab as a guide.

### Synthesis Question

- Ethanol and acetone are two compounds that are liquids at room temperature. Their formulas and properties are listed in the table below.

Properties	$\begin{array}{c} \text{O} \\    \\ \text{CH}_3-\text{C}-\text{CH}_3 \\ \text{Acetone} \end{array}$	$\text{CH}_3-\text{CH}_2-\text{OH} \\ \text{Ethanol}$
Possible interactions	London-type of dispersion	Hydrogen bond
Strength of strongest interactions	Weak	Strong
Formula weight (g/mol)	58.0	46.0
Boiling point (°C)	56.5	78.4

Using your understanding of bond strength and intermolecular forces, formulate an explanation for the properties of both liquids.

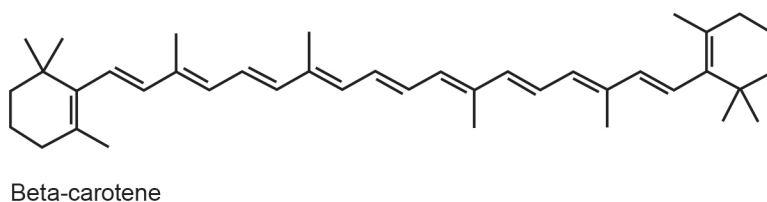
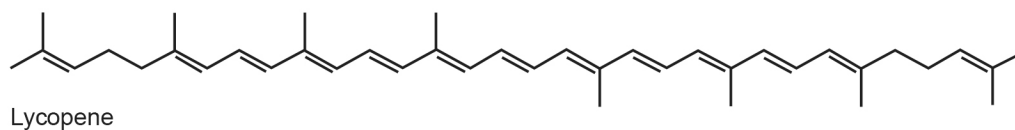
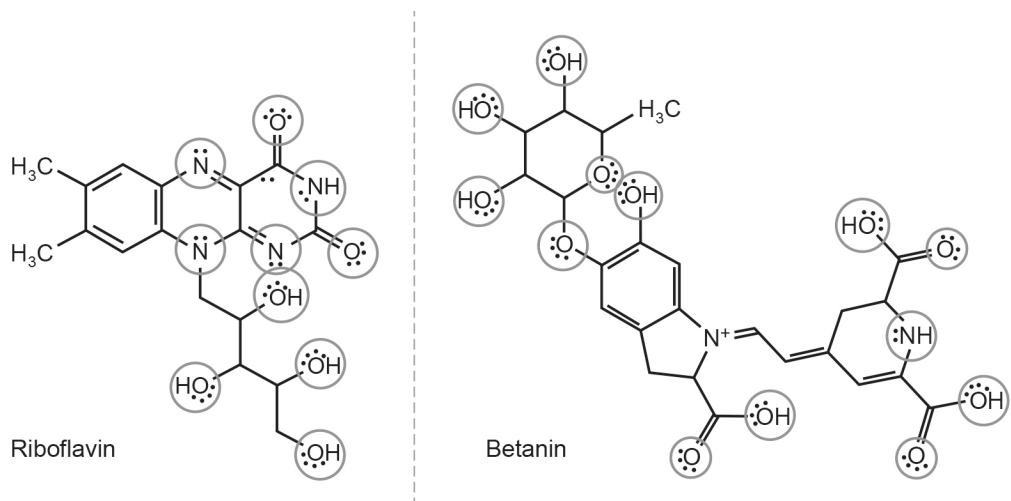


## AP® Chemistry Review Questions

1. One way to think about which molecular compounds will dissolve in water and which will dissolve in oil is to determine which molecules are able to form hydrogen bonds with the water molecules.

- a. What atoms must be present for a molecule to form a hydrogen bond with water?

Refer to these skeleton structures of four compounds:



- b. Can riboflavin form a hydrogen bond with water? If so, circle the places on the molecule that could form a hydrogen bond with water.
- c. Can beta-carotene form a hydrogen bond with water? If so, circle the places on the molecule that could form a hydrogen bond with water.
- d. Are all of the molecules that dissolved in water able to form hydrogen bonds with water?