**ANSWER KEY.** Observations match the simulation readouts for Unknowns 1 to 4.

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# Chemical Bonding Virtual Lab

Chemistry | ANSWER KEY

Open **activities.zornscience.org/chemical-bonding-lab/** and follow each step. Record what the simulation shows.

## Objective

Test the properties of four unknown solids and use the evidence to classify each one as **ionic**, **polar covalent**, **nonpolar covalent**, or **metallic**.

**NGSS alignment:** HS-PS1-3. Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

**Practices and concepts:** Planning and carrying out investigations; Engaging in argument from evidence; Structure and function; Patterns.

## Meet the simulation

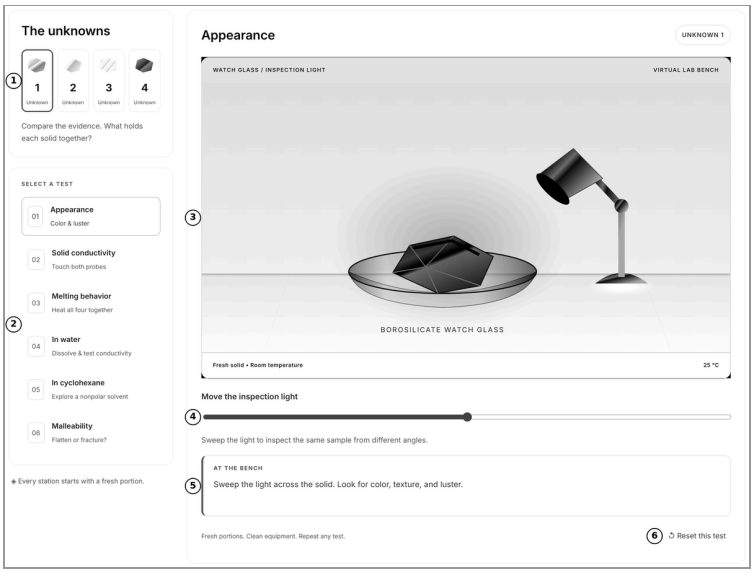



Figure 1. The Chemical Bonding Lab. The dark lab bench is shown inverted for printing.

1. Choose Unknown 1, 2, 3, or 4.
2. Choose one of the six tests.
3. The lab bench for the test you chose.
4. Buttons and sliders for each step of the test.
5. "At the bench" describes what you observe.
6. Reset this test repeats it with a fresh portion.

## Pre-lab

| Substance | Bond type | Melting point (°C) | Color | Solubility in water |
|---|---|---|---|---|
| Sodium iodide, NaI | Ionic | 661 | White | Soluble |
| Lactose, $C_{12}H_{22}O_{11}$ | Polar covalent | 203 | White | Soluble |
| Iodine, $I_2$ | Nonpolar covalent | 114 | Dark gray | Slightly soluble |
| Tin, Sn | Metallic | 232 | Shiny gray | Insoluble |

Table 1. Properties of four known solids.


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**1.** Use Table 1. (a) Why does iodine melt at a much lower temperature than sodium iodide? (b) Why is iodine only slightly soluble in water while lactose is very soluble?

**(a) Melting iodine only overcomes weak London dispersion forces between $I_2$ molecules. Sodium iodide is a lattice of $Na^+$ and $I^-$ ions held by strong attractions between opposite charges, so it takes much more energy.**
**(b) Water is polar. Nonpolar iodine cannot form strong attractions to water, but lactose has many O−H groups that hydrogen bond with water ("like dissolves like").**

**2.** Predict the bond type, melting point (high or low), and solubility in water for each solid.

| Solid | Bond type | Melting point | Solubility in water |
|---|---|---|---|
| Iodine monochloride, ICl | **Polar covalent** | **Low** | **Soluble (polar; it also reacts with water)** |
| Cobalt(II) nitrate, $Co(NO_3)_2$ | **Ionic** | **High** | **Soluble** |
| Sulfur, $S_8$ | **Nonpolar covalent** | **Low** | **Insoluble** |
| Lead, Pb | **Metallic** | **High (327 °C)** | **Insoluble** |

## Procedure

Run every test on all four unknowns (melting tests all four at once). Record results in Table 2 on the next page.

1. **Appearance.** Drag the light slider. Record color, texture, and luster (metallic shine or not).
2. **Solid conductivity.** Click **Touch probes to solid**. Record the reading: NONE, LOW, MEDIUM, HIGH, or VERY HIGH.
3. **Melting behavior.** Click **Load all four portions**, then **Switch on hot plate**. Watch the temperature and record the order in which the unknowns change and the temperature of each change. The plate stops at 300 °C. A solid that has not melted by 300 °C has a high melting point. Then lift the boat with the tongs and dispose of it when cool.
4. **In water.** Click through **Weigh 0.10 g**, **Measure 50.0 mL water**, **Transfer to beaker**, and **Stir with glass rod**. Record the solubility. Then click **Immerse conductivity probe** and record the reading (Figure 3).
5. **In cyclohexane** (a nonpolar solvent). Measure 5.0 mL, add the solid, stir, and click **Advance to 5:00**. Record the solubility.
6. **Malleability.** Press the solid. Record whether it flattens (malleable) or breaks (brittle).


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## Results

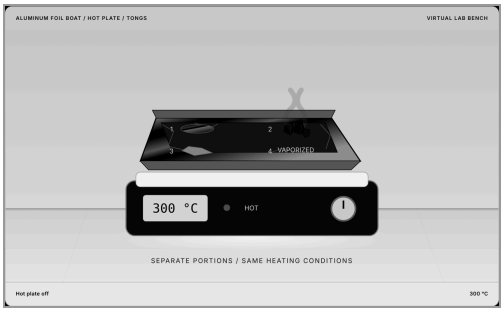



Figure 2. The foil boat at 300 °C. Numbers mark each unknown's portion.

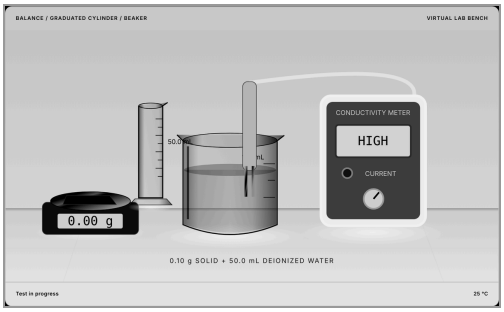



Figure 3. The water test for one unknown. The reading appears on the conductivity meter.

| Test | Unknown 1 | Unknown 2 | Unknown 3 | Unknown 4 |
|---|---|---|---|---|
| Appearance | **Shiny silver-gray, metallic luster** | **White angular crystals, no metallic luster** | **White to off-white granules, dull, powdery** | **Dark gray crystals, violet cast, reflective** |
| Solid conductivity | **Very high** | **None** | **None** | **None** |
| Melting behavior (order and temp.) | **3rd, melts near 232 °C** | **Did not melt by 300 °C (highest)** | **2nd, softens and browns near 203 °C** | **1st, melts near 114 °C, then vaporizes** |
| Solubility in water | **Insoluble** | **Soluble** | **Soluble** | **Slightly soluble (faint yellow-brown)** |
| Conductivity in water | **None** | **High** | **None** | **None** |
| Solubility in cyclohexane | **Insoluble** | **Insoluble** | **Insoluble** | **Soluble (violet solution)** |
| Malleability | **Malleable (flattens)** | **Brittle** | **Brittle** | **Brittle** |

Table 2. Properties of the four unknown solids.

## Analysis

**3.** Which unknown does not conduct as a solid but conducts well once dissolved in water? Explain why, using the word **ions**.

**Unknown 2. In the solid, its ions are locked in place in a crystal lattice, so charge cannot flow. In water, the ions separate and move freely, so the solution conducts.**

**4.** Unknowns 3 and 4 are both molecular and neither conducts. Use the two solvents to explain how you can tell which one is polar.

**Unknown 3 dissolved in polar water but not in nonpolar cyclohexane, so it is polar. Unknown 4 dissolved in cyclohexane but only slightly in water, so it is nonpolar. "Like dissolves like."**


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**5.** Unknown 1 conducts as a solid and flattens when pressed. Explain both properties using the model of metallic bonding.

**Metal cations sit in a "sea" of delocalized electrons. The free electrons move through the solid and carry current. When pressed, layers of cations slide past each other while the electron sea holds them together, so the metal bends instead of breaking.**

**6.** Unknown 4 melted first and Unknown 2 never melted. What does melting order tell you about the strength of the attractions between particles?

**A lower melting point means weaker attractions between particles. Unknown 4 has only weak London dispersion forces between nonpolar molecules. Unknown 2 is held by strong ionic attractions throughout its lattice, so it needs much more energy.**

**7.** Name two possible sources of error in a real version of this lab and how to reduce each one.

**Any two: dirty probes or glassware give false conductivity (rinse with deionized water); tap water adds ions (use only deionized water); unequal portions or uneven heating change melting order (use equal small portions the same distance from the plate center); not stirring or waiting long enough misjudges solubility (stir for a set time and wait the full 5 minutes); uneven force misjudges malleability (press the same way each time).**

## Conclusion

**8.** Classify each unknown as ionic, polar covalent, nonpolar covalent, or metallic. Give at least two pieces of evidence from Table 2 for each one.

| Unknown | Bond type | Evidence |
|---|---|---|
| 1 | **Metallic** | **Metallic luster; very high solid conductivity; malleable; insoluble in both solvents.** |
| 2 | **Ionic** | **No solid conductivity but high in water; did not melt by 300 °C; brittle; soluble in water only.** |
| 3 | **Polar covalent** | **No conductivity as solid or in water; soluble in water, not cyclohexane; changed near 203 °C.** |
| 4 | **Nonpolar covalent** | **Lowest melting point (114 °C); soluble in cyclohexane, slightly in water; no conductivity.** |

*Teacher note: the unknowns are fixed in the simulation (not random). They model 1 = tin, 2 = sodium iodide, 3 = lactose, 4 = iodine, the substances in Table 1. Students only need the bond type.*

**9.** Write a claim that answers the objective. Support it with evidence from one unknown, and explain your reasoning: how does the type of bonding cause the properties you observed?

**Sample: Claim: The type of bonding in a solid can be identified from its properties. Evidence: Unknown 2 did not conduct as a solid, conducted highly in water, and did not melt by 300 °C. Reasoning: These are ionic properties. Strong attractions between oppositely charged ions give a high melting point, and the ions can only carry current when they are free to move in solution. (Any unknown with correct matching evidence and reasoning is acceptable.)**


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