The Molar Mass Trap Lab

Chemistry | Teacher Preparation Guide

Intermolecular forces lab for Chemistry and Honors Chemistry (Unit 4: Covalent Bonding). Everything you need to set up, run, and assess it in one period.

At a Glance

Students test four liquids that share a surprise: the lightest molecule, water, does not lose every contest. They compare **cohesion** (bead or spread), **viscosity** (a steel shot falling through each liquid), and **miscibility** (five liquid pairs), then use the type and strength of the IMFs to explain what they saw. No liquid in the lab is flammable, and no heat source is used.

- **Time:** Pre-lab as homework or a 5-minute bell ringer. Three tests at about 8 minutes each. About 10 minutes for cleanup and debrief. Lab quiz the next class.
- **Groups:** 3 to 4 students. The three tests can be done in any order, so groups rotate through shared viscosity stations without a queue.
- **Students will:** rank London dispersion, dipole-dipole, and hydrogen bonding by strength, identify the IMFs present from polarity, composition, and Lewis structures, and relate LDF strength to molecular size.
- **Hook:** Water is 18 g/mol and mineral oil is more than 15 times heavier, yet water beads up tall and mineral oil spreads flat. Molar mass alone predicts the wrong answer.

Materials

Per group

- 4 dropper bottles, labeled W, G, O, and M: water tinted blue, glycerin, 1-octanol, mineral oil tinted red
- Wax paper, about 15 cm by 15 cm, and a ruler
- Marker, stopwatch or phone, and a magnet
- 5 small test tubes with stoppers and a rack
- Waste beaker, paper towels, goggles, and gloves

Per viscosity station (3 or 4 for the room)

- 4 sealed tubes, one per liquid, labeled W, G, O, and M
- 1 steel shot in each tube
- Stopper and parafilm on every tube

One time

- FD&C Blue 1 and Sudan III dyes
- Labeled container for waste

How Much to Prepare

A drop is about 0.05 mL. Each group uses the amounts below once per period.

Liquid	Test 1 (3 drops)	Test 3	Per group	Dropper bottle fill
Water, blue	0.15 mL	3 mL (tubes 1, 2, 3)	about 3.2 mL	5 mL
Glycerin	0.15 mL	2 mL (tubes 1, 5)	about 2.2 mL	5 mL
1-Octanol	0.15 mL	1 mL (0.5 mL in tubes 3, 4)	about 1.2 mL	3 mL
Mineral oil, red	0.15 mL	3 mL (tubes 2, 4, 5)	about 3.2 mL	5 mL

1-Octanol is the limiting chemical. Example for 8 groups, 5 periods, and 3 viscosity stations with tubes filled to 8 mL: 8 groups use 9.6 mL per period. The bottles start with 24 mL (8 x 3 mL) and are topped off 4 times (4 x 9.6 = 38.4 mL), which is 62.4 mL. The 3 octanol viscosity tubes take 24 mL. The total is about **90 mL**. Order more before a second unit. For the same plan, prepare about 200 mL each of blue water and red mineral oil and about 150 mL of glycerin.

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Prep: Do Once for the Whole Day

1. **Tint two liquids.** Add a few grains of FD&C Blue 1 to about 200 mL of water. Stir a few grains of Sudan III into about 200 mL of mineral oil until it is clearly red. Let any undissolved grains settle and pour off the clear red oil.
2. **Fill and label the dropper bottles.** Use the fill amounts in the table. Label each bottle with its letter. Keep glycerin capped, because it absorbs water from the air and its viscosity drops.
3. **Build 3 or 4 viscosity sets.** Fill four identical test tubes to the same height, one per liquid. Leave a small air gap at the top. Add one steel shot to each, stopper tightly, and wrap each stopper in parafilm. Label them W, G, O, and M. These can be reused all year.
4. **Time one set yourself.** Glycerin is slowest by a wide margin. Water is often too fast to time, and students then record "less than 0.5 s". Your tube size and fill height set the actual numbers, so write your reference times on your printed copy.
5. **Run a full dry run.** Mix all five Test 3 pairs and check that tubes 1 and 4 give one layer and tubes 2, 3, and 5 give two. Confirm the results before students arrive.
6. **Set each group's table.** Bottles, wax paper, ruler, marker, rack with 5 tubes, stopwatch, magnet, towels, and a waste beaker. Gloves at every table.

What Students Should See

Test	Expected result
Cohesion	Water and glycerin form tall beads. 1-Octanol and mineral oil spread into wide, flat puddles.
Viscosity	Slowest to fastest: glycerin, mineral oil, 1-octanol, water. This ranking is the main discussion point. Water hydrogen bonds but is tiny. Mineral oil has no hydrogen bonds, but its very large molecules have strong LDF.
Miscibility	Tube 1 (water + glycerin) one layer. Tube 2 (water + oil) two layers. Tube 3 (water + 1-octanol) two layers. Tube 4 (oil + 1-octanol) one layer. Tube 5 (glycerin + oil) two layers.

Common Misconceptions to Listen For

- **"Bigger molar mass means stronger IMFs."** This is the trap. It works only for molecules with the same type of IMF. Hydrogen bonding in water beats the LDF of a small molecule, but the very large molecules in mineral oil have LDF strong enough to slow the shot.
- **"Hydrogen bonds are bonds."** A hydrogen bond is an attraction between molecules, much weaker than a covalent bond. When water evaporates, hydrogen bonds break but the O-H covalent bonds stay intact.
- **"Oil and water repel each other."** They do not repel. Water molecules attract each other so strongly that they leave out molecules that cannot join the hydrogen-bond network.

Safety, Disposal, and Cleanup

Chemical	Main hazards	Notes for you
Water, tinted blue	Low hazard	The dye stains. Wipe up spills.
Glycerin	Irritant. Slippery.	Not flammable. Keep capped.
1-Octanol	Irritates skin and eyes	Combustible. Store in a flammable cabinet and keep away from heat. Dispense it yourself if you prefer.
Mineral oil, tinted red	Low hazard. Slippery.	Sudan III stains skin and clothing.
Steel shot	Low hazard while sealed	Tubes stay sealed. Students move the shot with a magnet.

- **Disposal:** Collect all Test 3 mixtures in a labeled container for licensed waste pickup, and follow your district's chemical hygiene plan and the SDS for 1-octanol. Wax paper and paper towels go in the trash. Nothing goes down the sink. The viscosity tubes can be reused all year. Review the current SDS for each chemical before the lab, and keep a spill kit handy, since glycerin and oil make floors slippery.

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Lab Quiz and Key

Give next class. About 10 minutes. Copy the quiz section for students.

1. Rank the three IMFs (London dispersion, dipole-dipole, hydrogen bonding) from weakest to strongest for molecules of similar size.

2. Ethylene glycol ($HOCH_2CH_2OH$) and decane ($C_{10}H_{22}$) were tested the same way as in lab. Identify each unknown, then justify each identification using **both** the IMFs present **and** the data.

Unknown	Puddle on wax paper	Steel shot fall time (s)	Mixes with water?	Mixes with mineral oil?
A	Tall bead	2.8	Yes	No
B	Spreads flat	0.6	No	Yes

3. A classmate says, "Mineral oil flows slower than water, so mineral oil must have stronger hydrogen bonds." Explain what is wrong with this statement.

4. 1-Butanol (C_4H_9OH) mixes partly with water, but 1-octanol does not. Explain the difference in terms of IMFs.

5. A drop of water and a drop of glycerin are left on a bench. Predict which evaporates faster, and explain using IMFs.

Quiz Answer Key

> **1.** London dispersion < dipole-dipole < hydrogen bonding.

> **2. A is ethylene glycol.** Its two OH groups give hydrogen bonding, so it beads, flows slowly, and mixes with water but not with nonpolar oil. **B is decane.** It is nonpolar with only LDF, so it spreads, flows quickly, and mixes with oil but not with water. Full credit needs one IMF statement and one data point for each unknown.

> **3.** Mineral oil has no hydrogen bonding, because it has no H bonded to N, O, or F. Its slow flow comes from strong LDF between very large molecules and from long chains tangling.

> **4.** Both can hydrogen bond with water through one OH group. Octanol's 8-carbon chain is much larger and nonpolar, so LDF dominates and it behaves more like an oil. Butanol's 4-carbon chain is small enough that the OH group still wins.

> **5.** Water evaporates faster. Glycerin has three OH groups and a larger molecule, so it has more hydrogen bonding and stronger LDF per molecule, and its molecules escape less easily.

Optional Extension

Evaporation link. This lab does not measure evaporation, so quiz question 5 covers it conceptually. For a 3-minute teacher demo, compare evaporative cooling of water and 70% isopropyl alcohol on a temperature probe. Keep the alcohol, which is flammable, in your hands and use a small volume.

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