TEACHER INFORMATION

Evaporation and Intermolecular Attractions

1. Editable Microsoft Word versions of the student pages and pre-configured TI-Nspire files can be found on the CD that accompanies this book. See *Appendix A* for more information.

2. This experiment, as written, is not intended for use with Easy or Go! products since data from two sensors must be collected at the same time. A single, multi-channel interface is preferred.

3. If you are using Easy or Go! products, or if you have a limited number of temperature probes, you can do this experiment with only a single sensor, testing a single alcohol with each run. Similarly, you can use more than two temperature probes if you have a multi-channel interface.

4. We recommend wrapping the probes with paper as described in the procedure. Wrapped probes provide more uniform liquid amounts, and generally greater Δt values, than bare probes. Chromatography paper, filter paper, and various other paper types work well.

5. Snug-fitting rubber bands can be made by cutting short sections from a small rubber hose. Surgical tubing works well. Orthodontist's rubber bands are also a good size.

6. Other liquids can be substituted. Although it has a somewhat larger Δt, 2-propanol can be substituted for 1-propanol. Some petroleum ethers have a high percentage of hexane and can be used in its place. Other alkanes of relatively high purity, such as n-heptane or n-octane can be used. Water, with a Δt value of about 5°C, emphasizes the effect of hydrogen bonding on a low-molecular weight liquid. However, students might have difficulty comparing its hydrogen bonding capability with that of the alcohols used.

7. Sets of the liquids can be supplied in 13 × 100 mm test tubes stationed in stable test-tube racks. This method uses very small amounts of the liquids. Alternatively, the liquids can be supplied in sets of small bottles kept for future use. Adjust the level of the liquids in the containers so it will be above the top edge of the filter paper.

8. Because several of these liquids are highly volatile, keep the room well-ventilated. Cap the test tubes or bottles at times when the experiment is not being performed. The experiment should not be performed near any open flames.

9. Other properties, besides Δt values, vary with molecular size and consequent size of intermolecular forces of attraction. Viscosity increases noticeably from methanol through 1-butanol. The boiling temperatures of methanol, ethanol, 1-propanol, and 1-butanol are 65°C, 78°C, 97°C, and 117°C, respectively.

10. **HAZARD ALERTS:**

    n-Hexane: Flammable liquid: dangerous fire risk; may be irritating to respiratory tract. Hazard Code: B—Hazardous.

    Methanol: Flammable; dangerous fire risk; toxic by ingestion (ingestion may cause blindness). Hazard Code: B—Hazardous.

Ethanol: Dangerous fire risk; flammable; addition of denaturant makes the product poisonous—it cannot be made non-poisonous; store in a dedicated flammables cabinet or safety cans. If a flammables cabinet or safety cans are not available, store in a Flinn *Saf-Stor*® Can. Hazard Code: C—Somewhat hazardous.

n-Pentane: Flammable liquid; narcotic in high concentrations. Hazard Code: B—Hazardous.

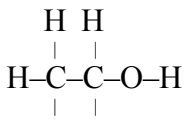
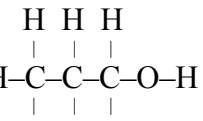
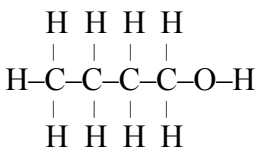
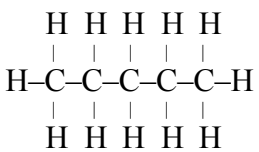
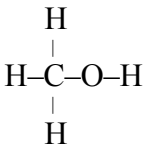
1-Propanol: Flammable liquid; dangerous fire risk; harmful to eyes and respiratory tract. Hazard Code: B—Hazardous.

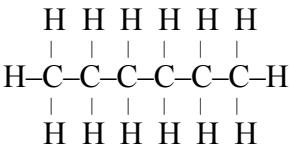
1-Butanol: Moderate fire risk; toxic on prolonged inhalation; eye irritant; absorbed by skin. Hazard Code: B—Hazardous.

The hazard information reference is: Flinn Scientific, Inc., *Chemical & Biological Catalog Reference Manual*, 1-800-452-1261, www.flinnsci.com. See *Appendix F* for more information.

11. Piping which can be purchased at a yard goods or sewing store can serve as an appropriate sleeve for the temperature probe. You have to cut it pieces and remove the "rope".

ANSWERS TO PRE-LAB QUESTIONS

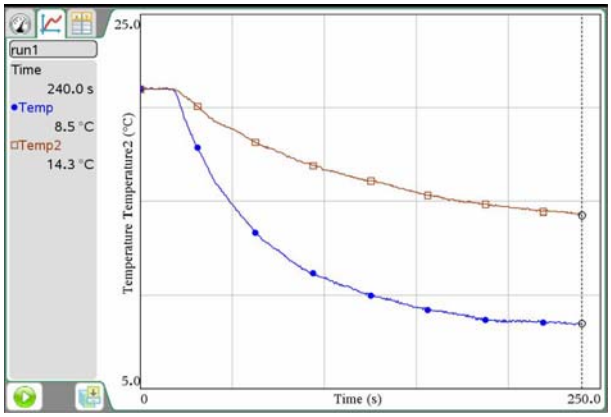
Substance	Formula	Structural Formulas	Molecular Weight	Hydrogen Bond (Yes or No)
ethanol	C_2H_5OH		46	yes
1-propanol	C_3H_7OH		60	yes
1-butanol	C_4H_9OH		74	yes
n-pentane	C_5H_{12}		72	no
methanol	CH_3OH		32	yes

n-hexane	C_6H_{14}		86	no

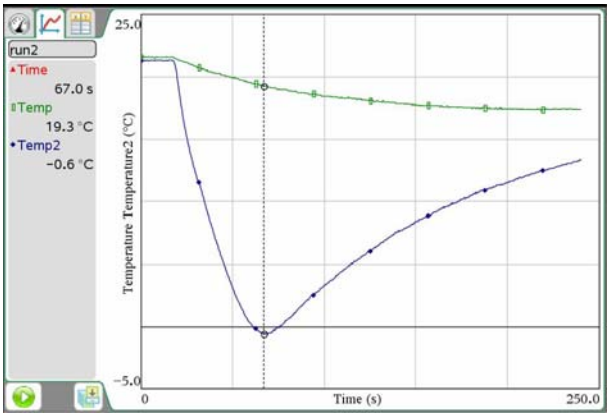
SAMPLE RESULTS

Substance	t_1 (°C)	t_2 (°C)	Δt (t_1–t_2) (°C)
ethanol	21.0	8.5	12.5
1-propanol	21.1	14.3	6.8
1-butanol	21.5	17.4	4.1
n-pentane	21.3	-0.6	21.9
Methanol	21.0	1.3	19.7
n-hexane	22.8	6.7	16.1

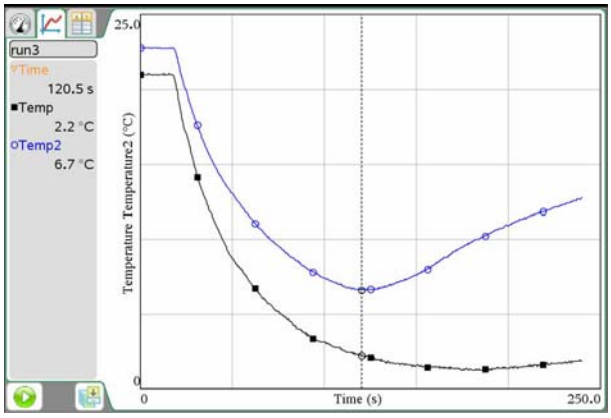
Predicted Δt (°C)	Explanation
varies (< 4.9°C)	It has a higher molecular wt. than 1-propanol (both have H-bonds).
varies (> 8.3°C)	It has a higher molecular wt. than either, but no H-bonding.
varies (> 8.3°C)	It has a lower molecular wt. than ethanol (both have H-bonds).
varies (< 16.1°C)	It has a higher molecular wt. than n-pentane; also no H-bonding.



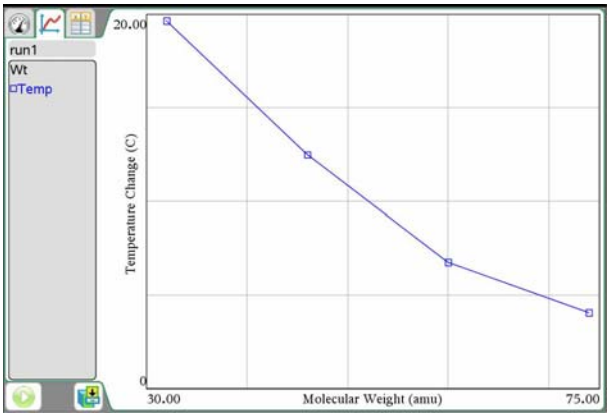
Evaporation of ethanol (●) *and 1-propanol* (□).



Evaporation of 1-butanol (▯) *and n-pentane* (♦)



Evaporation of methanol (■) *and n-hexane* (○).



Temperature change vs. *alcohol molecular weight.*

ANSWERS TO QUESTIONS

1. Even though n-pentane and 1-butanol have molecular weights of 72 and 74, respectively, 1-butanol has a much smaller Δ*t* due to the presence of hydrogen bonding between its molecules. This results in a stronger attraction, and a slower rate of evaporation.

2. The 1-butanol has the strongest attractions between its molecules. Methanol has the weakest attractions. The 1-butanol has the largest molecules and resulting strongest dispersion forces. This gives it the lowest evaporation rate and the smallest Δt.

3. The n-hexane has the stronger attractions between its molecules. The n-pentane has the weaker attractions. The n-hexane has the larger molecules and the resulting stronger dispersion forces. This gives it a lower evaporation rate and the smallest Δt.