A Thin Layer Chromatography Prelaboratory Activity Using a 3D-Printed Model to Address Student Misconceptions about Polarity and Intermolecular Forces

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1 Introduction and Motivation

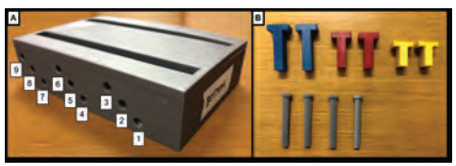
Normal phase thin layer chromatography (TLC) is a commonly taught technique in introductory organic chemistry laboratory courses. Before students can apply the technique, they need to understand how polarity and intermolecular forces (IMFs) affect the separation of compounds on a TLC plate. Unfortunately students are prone to misconceptions about TLC. Two of the most common are:

1) Trends in solvent polarity mirror those of compound polarity.
2) Misapplication of the "like-dissolves-like" heuristic.

To address these misconceptions, we designed and implemented a prelaboratory activity using a 3D-printed model of a TLC plate. We anticipated that the visual and tactile components of the model would help students to better understand how polarity and IMFs affect the separation of compounds via TLC.

2 Design of the Model and Activity

Three main pieces: a base plate, T-pins, and cylindrical pins.
The base plate (A) represents the TLC plate.
The T-pins (B) may be inserted into and slide up the lanes of the base plate and represent different chemical compounds.
The cylindrical pins (B) may be inserted into the holes on the sides of the base plate and represent solvents of different polarities that halt the movement of particular T-pins at different points along the plate.



The activity covered during class has three scenarios that evaluate student understanding of polarity and IMFs as they relate to the separation of compounds via TLC. Each scenario is covered using the predict-observe-explain technique (as described below).

PREDICT:
- A question is posed to the students.
- Students predict the outcome.

OBSERVE:
- An answer to the question is given by instructor or instructions for how to set up the model to see the outcome are given.

EXPLAIN:
- Students evaluate if the outcome supports their prediction.
- If the outcome is inconsistent with their prediction, students discuss to rationalize the outcome.

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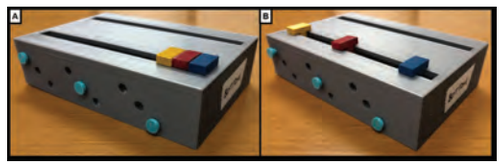
3 Scenario #1: Compound Polarity and IMFs

INSTRUCTIONS:
- Insert one of each T-pin and add circular pins to holes 1, 5, and 9. (A)
- Push the T-pins up as far as they will go. (B)
- Predict which T-pin represents the most polar compound.
- T-pins represent the compounds ethylbenzene, benzyl alcohol, and anisole. Predict which T-pin represents each compound.

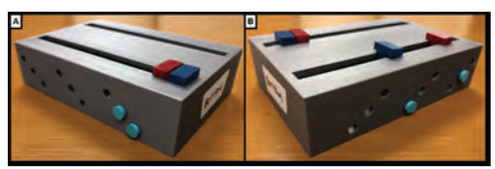


4 Scenario #2: Solvent Polarity and IMFs

INSTRUCTIONS:
- Remove the red T-pin and the circular pin in position 5. (A)
- Predict how far the compounds would move in a more polar solvent.
- Put another set of the blue and yellow T-pins, along with circular pins in positions 4 and 9, in the right lane and push the T-pins up as far as they will go. (B)
- Reset the right lane and predict how far the compounds would move in a more nonpolar solvent.
- Put circular pins in positions 1 and 6 and push the T-pins up. (C)

5 Scenario #3: Application of Concepts

INSTRUCTIONS:
- Insert one red and one blue T-pin and add circular pins to holes 1 and 2.
- Push the T-pins up as far as they will go. (A)
- Predict the polarity of the solvent based on how far the T-pins moved.
- Determine whether the polarity of the solvent should be increased or decreased to improve the separation of the compounds.
- Put another set of the red and blue T-pins, along with circular pins in positions 4 and 8, in the right lane and push the T-pins up as far as they will go. (B)



6 Effects on Short- and Long-Term Understanding

Survey Question	Summer (N = 49)		Fall (N = 161)	
	Pre-survey	Post-survey	Pre-survey	Post-survey
Q1. If we have a polar solvent with one polar compound and one nonpolar compound, which compound will move higher up on the plate?	59.2%	81.6%	60.9%	86.3%
Q2. If we have a nonpolar solvent and relatively polar compounds, where will the compounds be on the plate?	77.6%	98.0%	81.4%	89.4%
Q3. If we have a polar solvent and relatively nonpolar compounds, where will the compounds be on the plate?	67.3 %	91.8%	46.7%	85.7%
Q4. You are trying to separate a mixture of benzyl alcohol and benzylamine by TLC. You initially use a solvent of 6:4 hexanes:ethyl acetate, but after developing the plate, you observe two overlapping spots near the base of the plate. What solvent system should be used to improve the separation?	65.3%	95.9%	75.8%	88.8%
Q5. You are trying to separate a mixture of ethylbenzene and benzyl bromide by TLC. You initially use a solvent of 6:4 hexanes:ethyl acetate, but after developing the plate, you observe two overlapping spots near the top of the plate. What solvent system should be used to improve the separation?	57.1%	95.9%	63.4%	82.6%

Understanding improves both short- and long-term. Short-term understanding was evaluated using pre- and post-activity surveys (above). Long-term understanding was evaluated based on performance on a TLC technique final (below)

70.5% (Spring Before Activity) **87.8% (Summer with Activity)** **80.8% (Fall with Activity)**

7 Acknowledgements and Citations

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For more information, please read the following article:
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