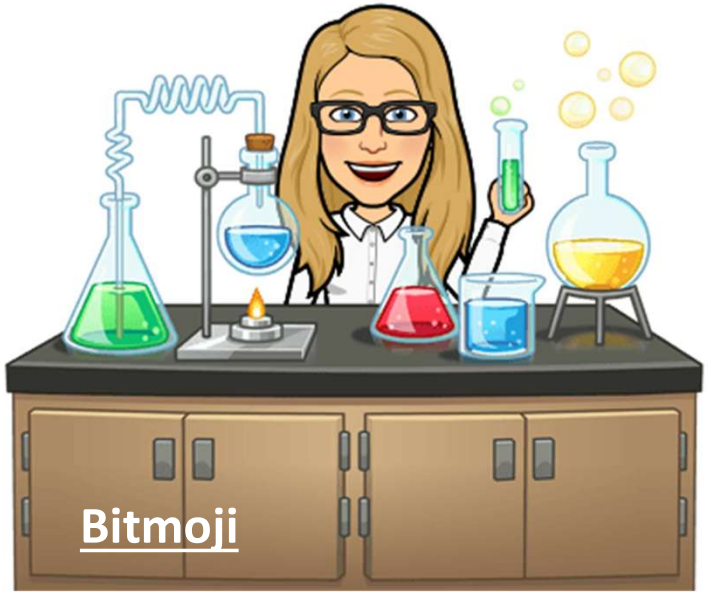
Interactive, Web-Based Resources to Teach TLC and Liquid-Liquid Extraction



Laurie S. Starkey

Cal Poly Pomona

lsstarkey@cpp.edu

BCCE 2026

chemistryconnected.com

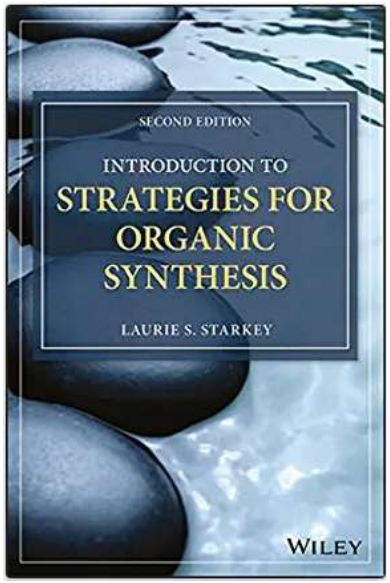
About me…

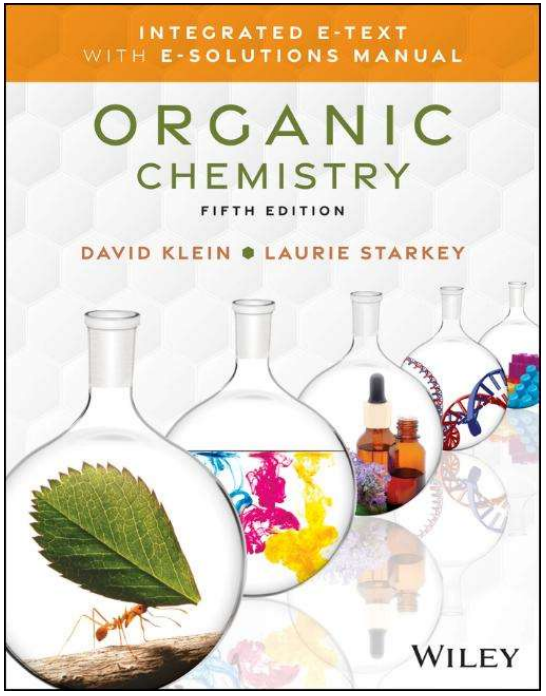
Cal Poly Pomona

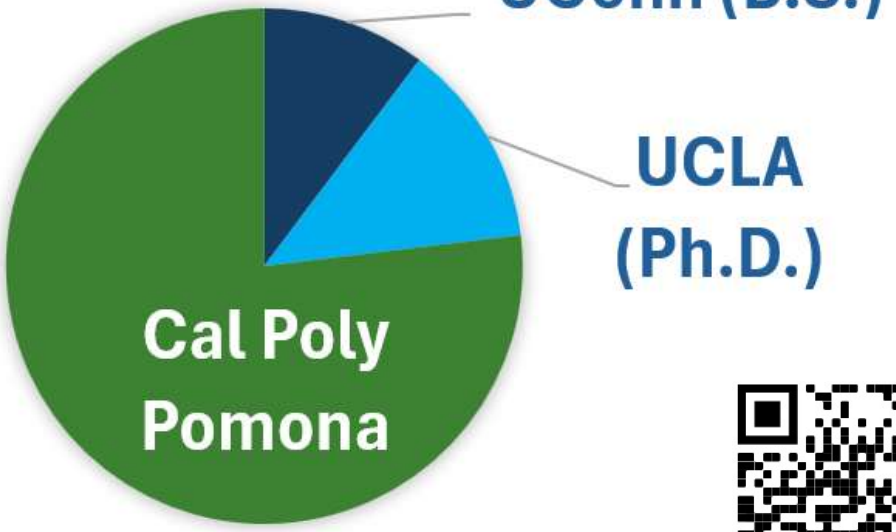
30 miles east of Los Angeles

Est. 1996

Felix Winkelnkemper Wikimedia cc-by-2.0







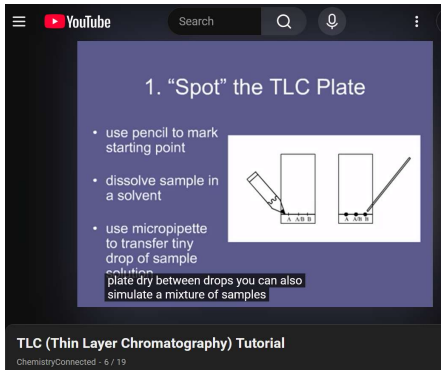
chemistryconnected.com

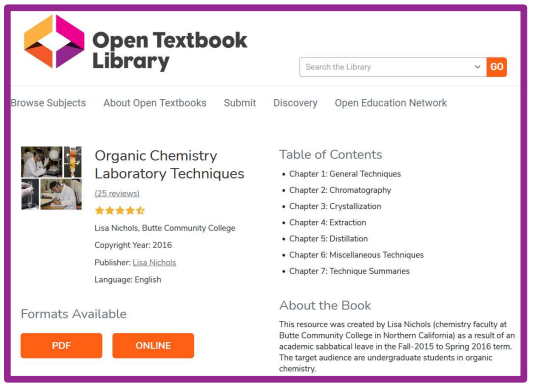
The Challenge of Teaching/Learning TLC: TLC is a complex system …in Orgo 1 Lab!

Interpret Results	**Did your reaction work?**	**What is in your sample?**	**More polar = *lower* R_f?**	**More polar = *higher* R_f?**
Hands-on Techniques	prepare chamber	develop plate	visualize & mark spots	calculate R_f
	making spotters	label plates	spot plates	measure solvents
New Vocabulary	TLC chamber	eluent	solvent front	R_f
	TLC plate	micropipette spotter	co-spotting	silica gel
Chromatography Theory	stationary phase	mobile phase	partitioning	polarity

Traditional Teaching Methods Fell Short

- ✓ Read lab manual Lab Techniques FREE eBook
- ✓ Watch tutorial video
- ✓ Take online quiz (multiple attempts allowed)
- ✓ Take in-person prelab quiz*





*Deficiencies noted in Organic 1 & 2 Labs

TLC Weakness Persisted at All Levels

Senior-level **Organic Synthesis Lab** (CHM 422L)
Final exam was a **mock job interview** (1999 – 2016)

http://www.amtec.us.com/ *via Flickr cc-by-sa-2.0*

"Using a 50:50 mixture of ethyl acetate and hexane, your spot has an R_f of 0.5.

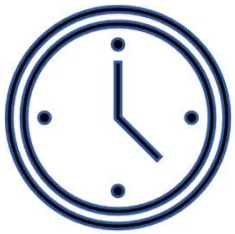
How would you adjust the solvent mixture to get an R_f of 0.3? Explain."

< 10% of students gave perfect answers to all TLC questions

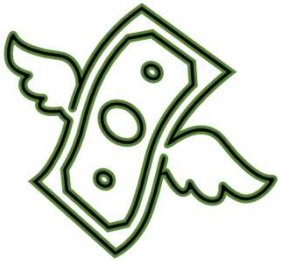
~ 0% of students were confident in TLC answers!

Learning Goal: Inquiry-Driven Exploration

Students need to explore solvent effects by running lots of TLC experiments, but…

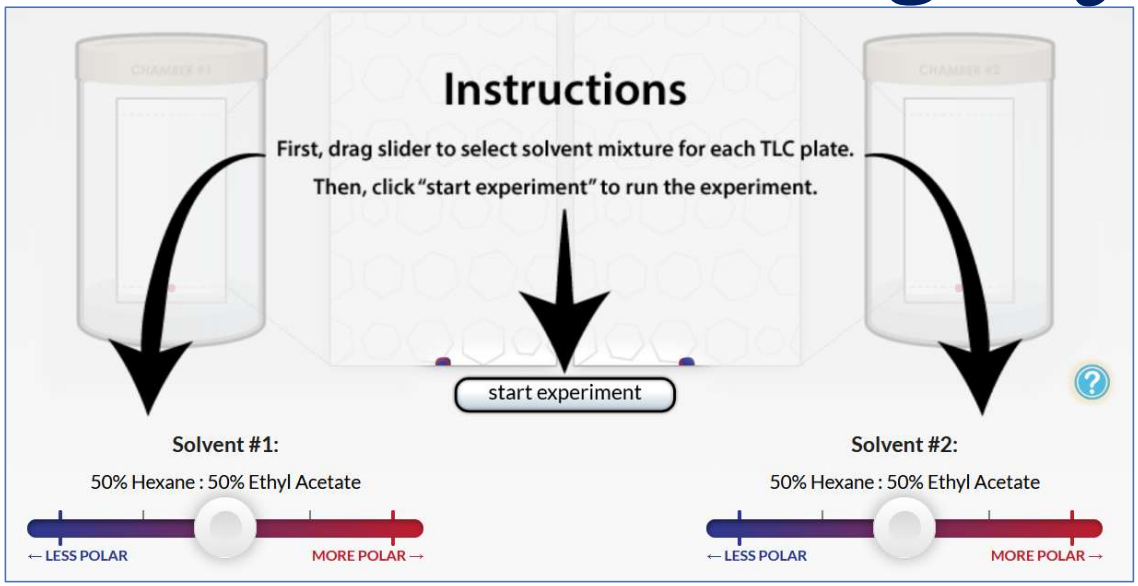


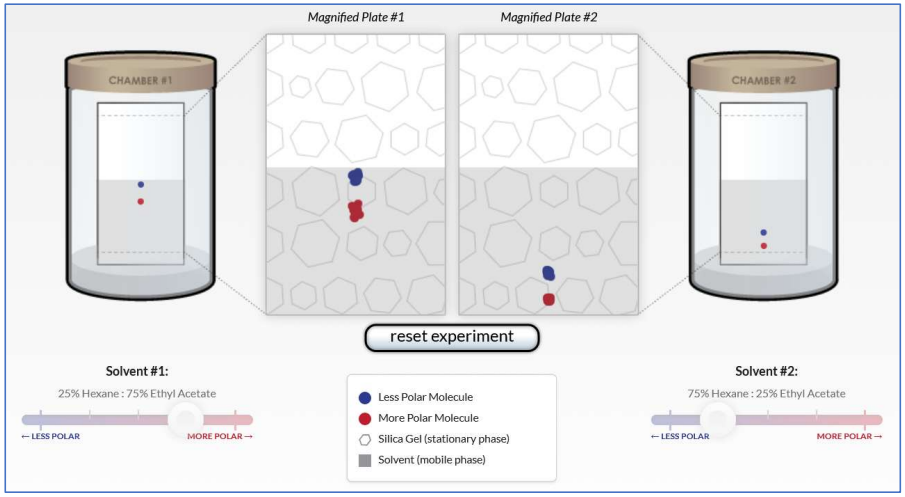
- **Time** in lab is severely limited
- Increased trials = **increased costs**, **waste**

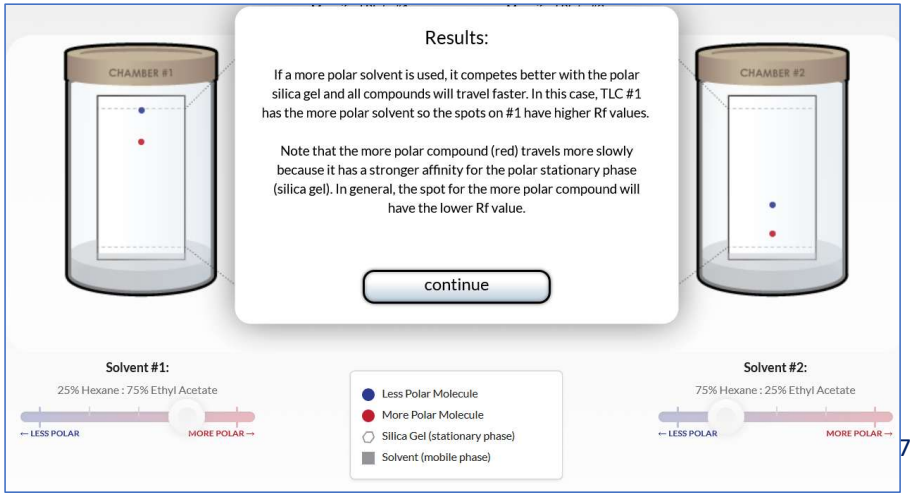


- Who is analyzing/interpreting results?
  - Prof./TA grading increases significantly
  - **Coaching is needed!**
  - Practice makes ~~perfect~~ permanent!

Solution: Multimedia Learning Object (MLO)



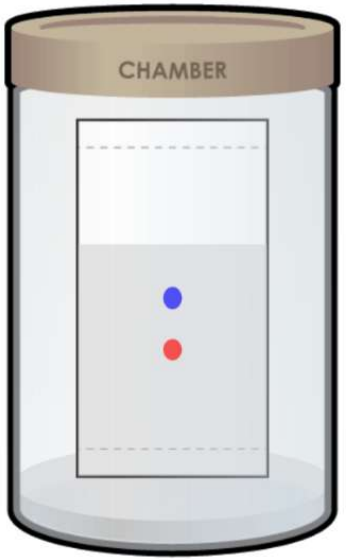




Advantages of TLC Simulator MLO

- Asynchronous activity does not use lab time
- Enables unlimited experimentation (now & later)
  - Run multiple trials = quick, easy, and free
  - Review for final, Orgo 2 Lab, research
- Feedback provided along the way

Initial launch was…underwhelming.



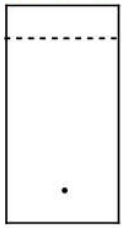
Provide Worksheet to Maximize Learning

TLC Simulator Worksheet **Dr. Laurie Starkey, Cal Poly Pomona**

Follow instructions to explore the TLC simulator and answer the questions below.

http://goo.gl/PZSCpb

1) Click "Start Experiment" to run the simulator with a **50:50 mixture** of Hexane and Ethyl Acetate. Sketch the plate below (label the spots red and blue)

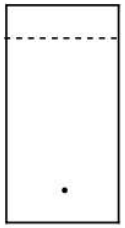


Is silica gel polar?

Which compound is more polar, red or blue? Explain brie

Draw the structures for ethyl acetate (EtOAc):

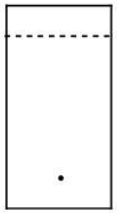
2) Click on "reset experiment" and change the solvent system on one of **75% Ethyl Acetate**. Sketch the plate below (label spots) and answer th



Is the new solvent (compared to 50:50) more or less pola

What happened to the R_f of the spots in the new solvent?

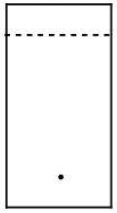
3) Click on "reset experiment" and change the solvent system on one of the plates to be **25% Ethyl Acetate**. Sketch the plate below (label spots) and answer the given questions.



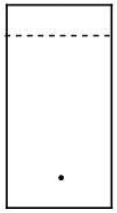
Is the new solvent (compared to 50:50) more or less polar? Explain briefly.

What happened to the R_f of the spots in the new solvent? Explain briefly.

4) Click on "reset experiment" and change the solvent systems to be **100% Ethyl Acetate** on one plate and **100% Hexane** on the other. Sketch the plates below and describe the R_f of the spots.



100% EtOAc
R_f =



100% hexane
R_f =

Conclusions about silica gel TLC (circle the correct answers)

A **more polar compound** has a higher/lower R_f.

A **less polar compound** has a higher/lower R_f.

A **more polar solvent** causes a higher/lower R_f.

A **less polar solvent** causes a higher/lower R_f.

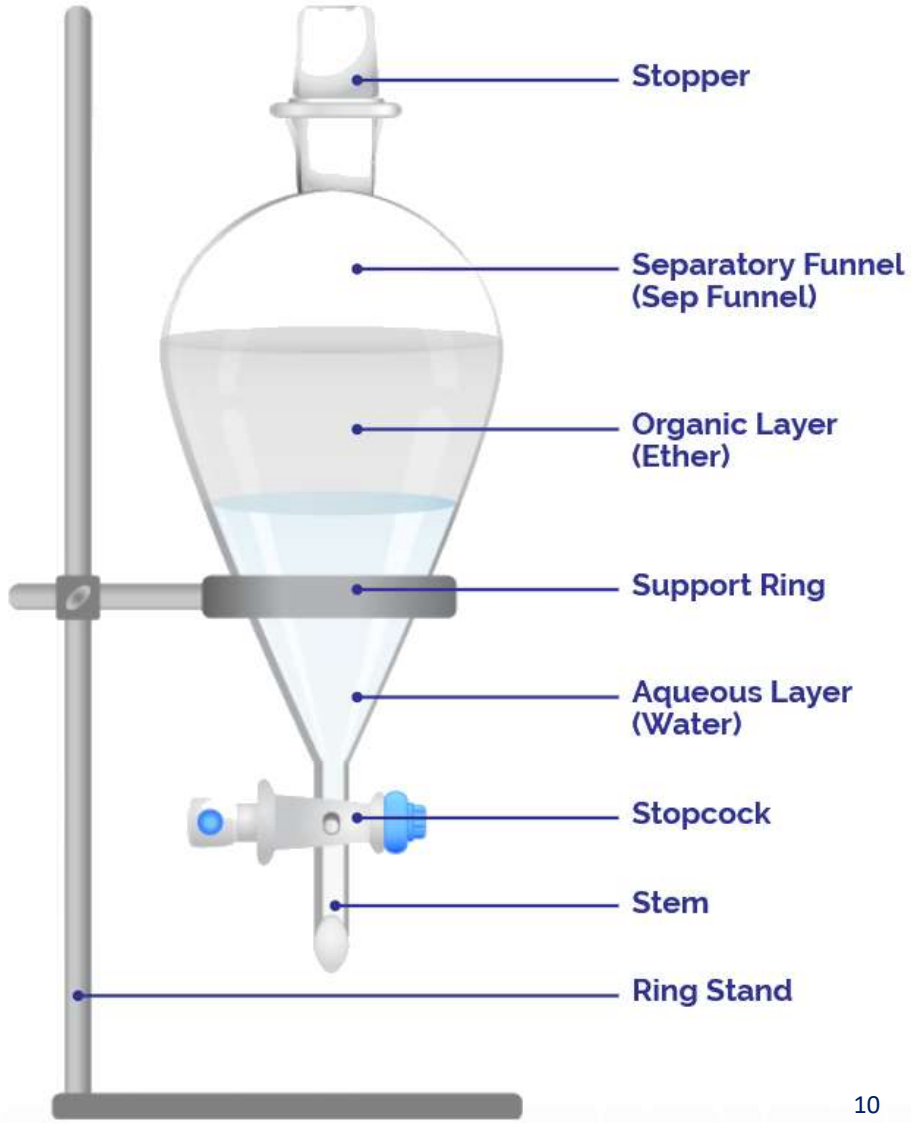
To increase the Rf of a spot, you should add more hexane/EtOAc.

Guided inquiry is efficient, provides structure

Student comes away with study guide

Challenge #2

Extraction is a complex *and dynamic* system… in Orgo 1 Lab!

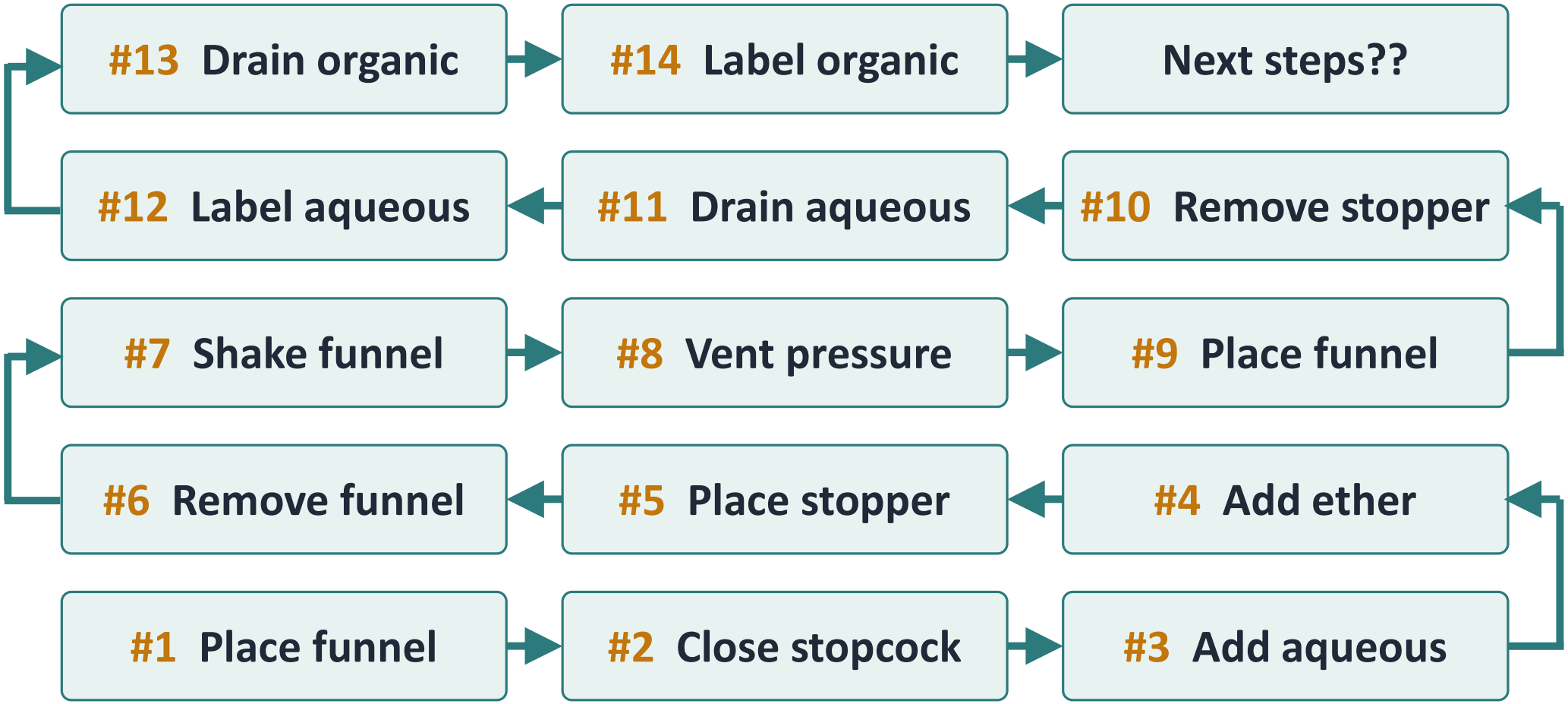


Raise your hand if you've witnessed:

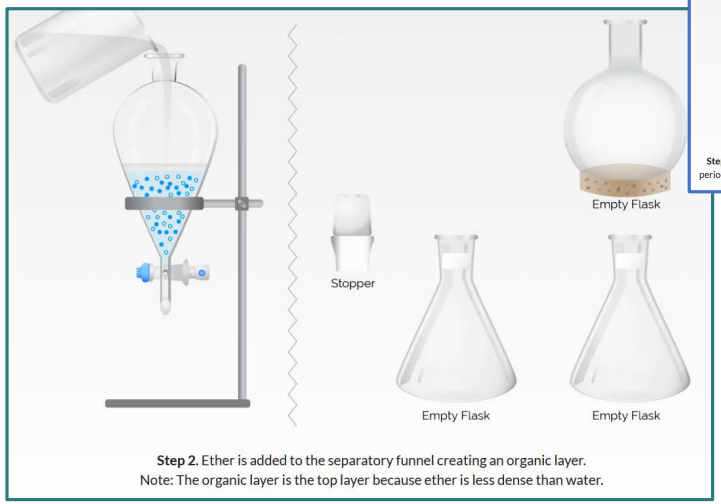
- Student tries to drain stoppered funnel 😅
- Student has discarded the wrong layer 😫
- A sep funnel does not have two layers 🤔
- Student has added drying agent to the combined aqueous layers 😱

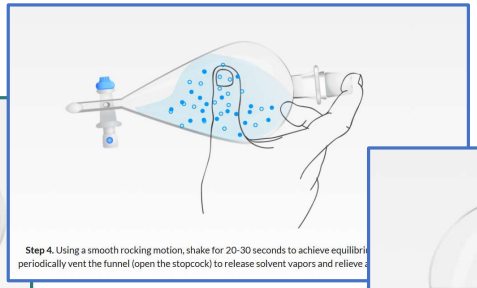
If "Extract with Ether" is in Procedure…

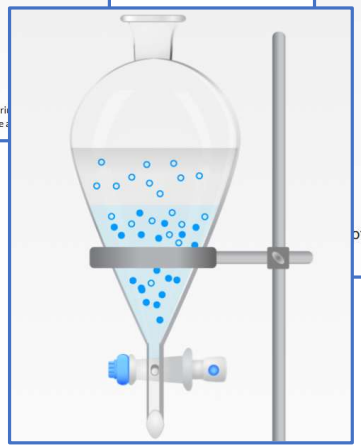
First extraction requires an ***exact sequence of 14 steps!***

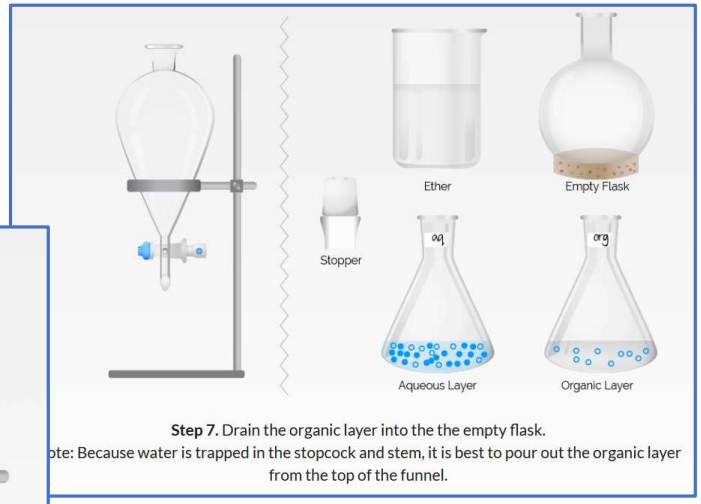


Pre-lab Prep: Extraction Simulator MLO







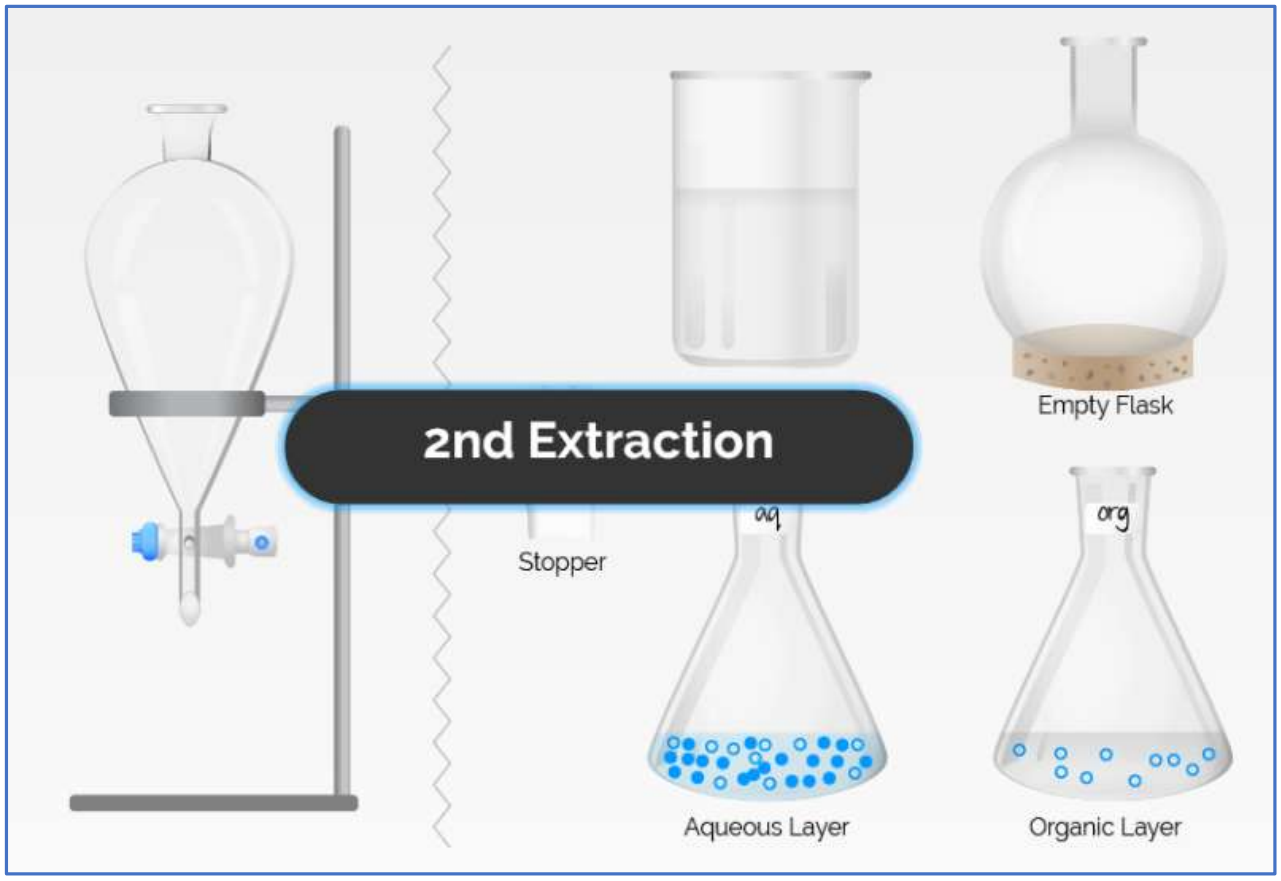


Step 5. Remove the stopper and wait as the layers fully separate.

Note: If the layers fail to separate, an **emulsion** has formed. After thorough mixing, each solute will be partitioned (divided) between the aqueous and organic layers. In general, organic compounds prefer the organic layer. Salts and highly polar organic compounds prefer the aqueous layer. Learn more about **solubility**.

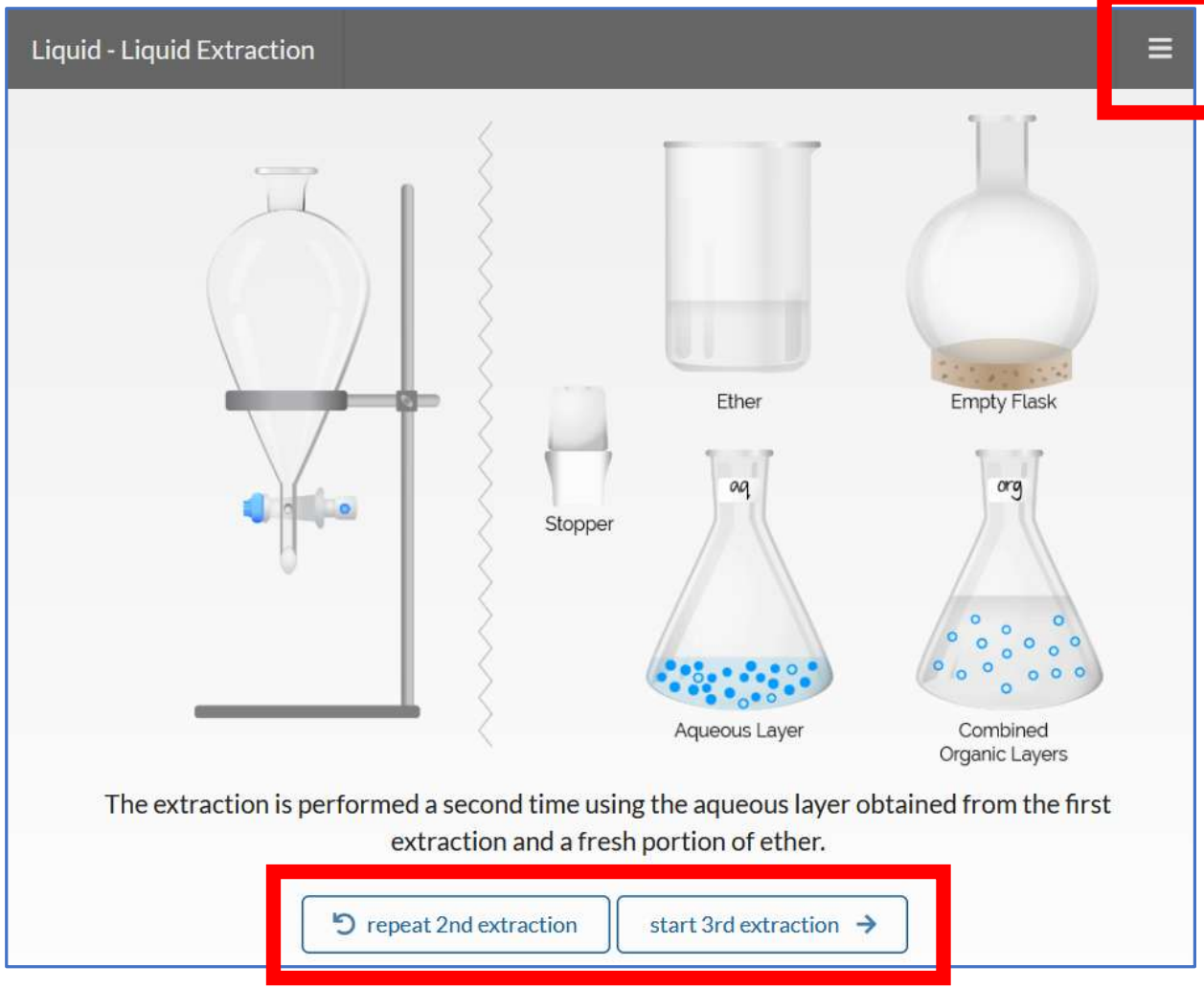
- Student clicks to step through the extraction sequence
- Each step is animated with cartoon graphics
- Each step includes an explanation (what's happening?)

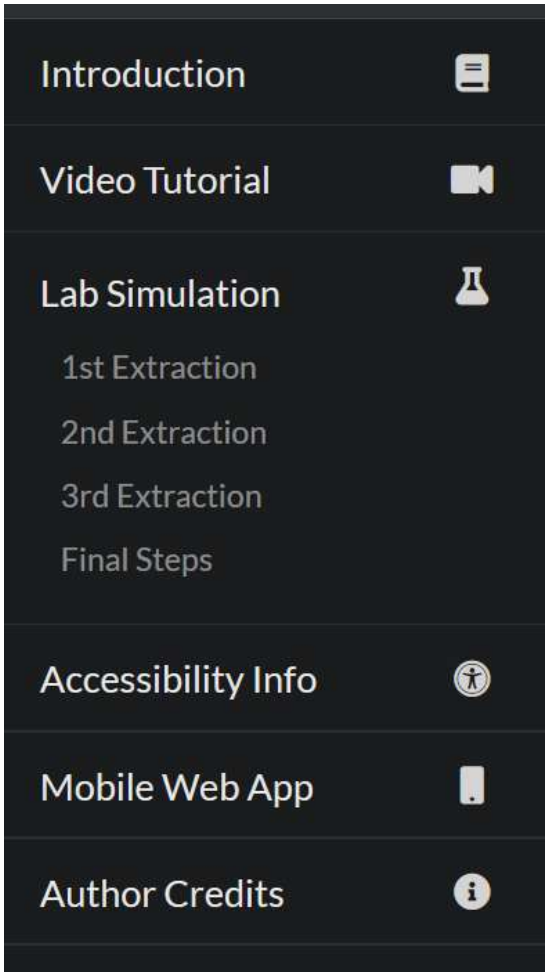
“Extract Three Times with Ether” Animation Continues



A single click by the student launches entire 2nd extraction sequence.

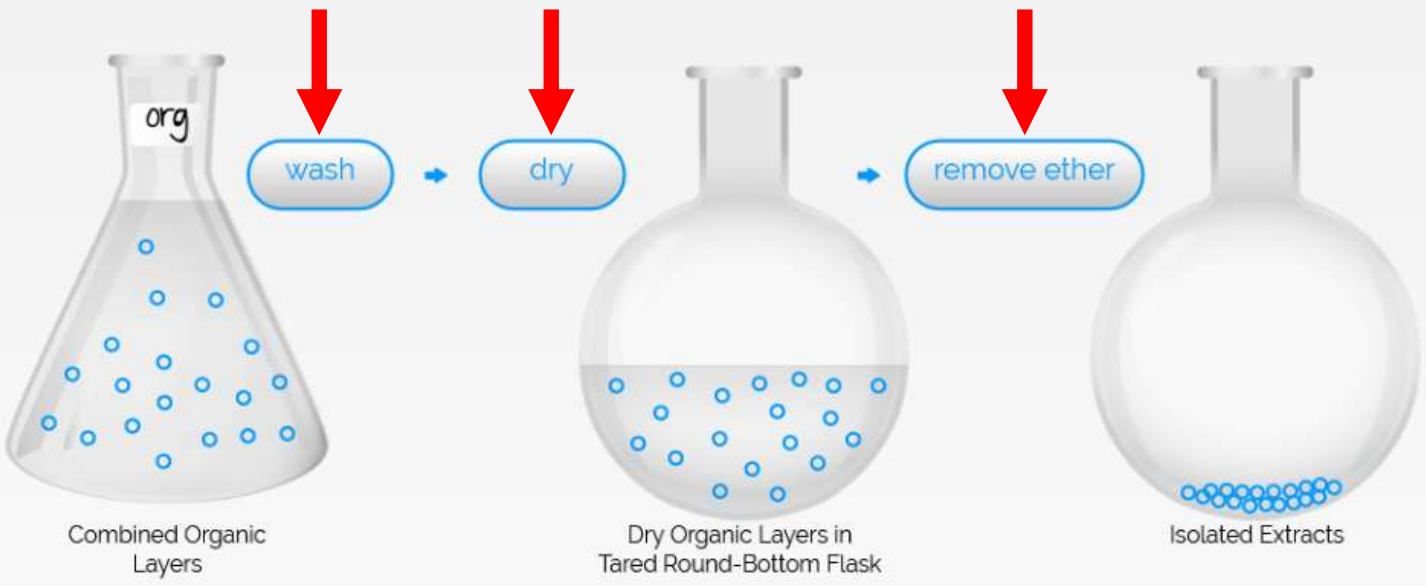
3rd Extraction Sequence





Navigation options

Overview of Final Workup Steps



After washing the organic layers to remove residual impurities (such as acids, bases and salts), a solid drying agent is used to remove water, and the ether is evaporated to afford the extracted organic compounds. The isolated solid or liquid organic compounds are now ready to be **weighed**, **analyzed** (IR, NMR, TLC, GC, etc.) and **purified**, if needed (recrystallized, column chromatography, etc.). Click on each button to learn more about the final steps taken in an extraction procedure.

Click on each to learn more

- Wash
- Dry
- Rotovap

Worksheet = Guidance + Skeleton Notes

Extraction Animation Worksheet **Dr. Laurie Starkey, Cal Poly Pomo**

goo.gl/4X5Ws4

Follow the given instructions to explore the "**extracting three times with ether**" animation, and answer the questions below. After the animation pauses, please read the onscreen notes provided before clicking "**continue.**" You may click on any **blue text** to learn more. This animation represents some of the steps you are likely to take after quenching an organic reaction with water (perhaps aq. acid or aq. base), so the reaction mixture will be the aqueous phase in the separatory funnel. It is colored blue to make it visible, and the blue circles and blue dots represent solutes.

1) Sketch a separatory ("sep") funnel and label the following parts:

ring stand
stopcock
stopper
stem
support ring

2) Please begin the animation with "**Click Here to Start Experiment**," and click "**continue**" to proceed through **Steps 1 through 4**. Answer the questions below.

a) Ether is the organic solvent used in the animation. In a laboratory setting, the name "ether" is short for "diethyl ether." Provide a structure for diethyl ether:

b) Which is the upper layer? (circle one) aqueous or organic

c) Why is it necessary to mix the layers for at least 20-30 seconds?

d) Why is it necessary to periodically vent the separatory funnel, and how is it done?

3) Read about **Step 5** and answer the questions below.

e) After mixing, solutes will be _____ between aq. and org. layers. *starts with "P"*

f) Salts prefer the _____ layer; organic solutes prefer the _____ layer.

g) In your own words, describe what an **emulsion** is, and provide four possible solutions to the problem.

h) Why are 2-3 extractions with ether usually performed? *hint: read more about* ***solubility***

4) Proceed to **Steps 6** and **7** and answer the questions below.

j) When draining the separatory funnel, should the stopper be: on or off ? (circle one)

k) True or False (circle one): *All* of the organic compound (blue open circles) moved to the organic layer after the first extraction.

l) The animation shows the organic layer being drained through the stopcock. Why is it a better practice to instead pour it out from the top of the separatory funnel?

m) True or False (circle one): It is more efficient to do two extractions with 10-mL portions of ether than a single extraction with a 20-mL portion of ether.

5) Click on "**Start 2nd extraction**" and watch the entire process before answering the question below.

n) What are the seven steps involved in the extraction procedure? *Try to recall steps on your own.*

1.
2.
3.
4.
5.
6.
7.

6) Note that at this point, very little of the organic solute (blue open circles) remains in the aqueous layer. Click on "**start 3rd extraction**" to continue, and then "**complete extraction process.**" Click on the **wash**, **dry** and **remove ether** buttons to learn more before answering the questions below.

o) Which layer is involved in the washing and drying steps? aqueous or organic (circle one)

p) What is the difference between "washing" and "extracting" steps in an extraction procedure?

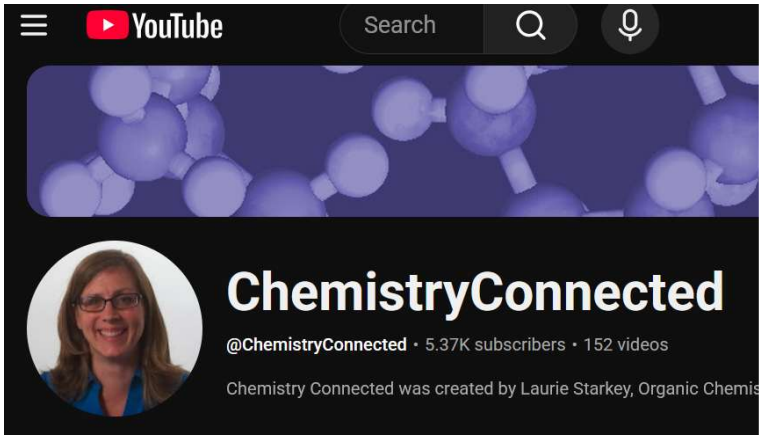
q) How could a washing step remove residual acid?

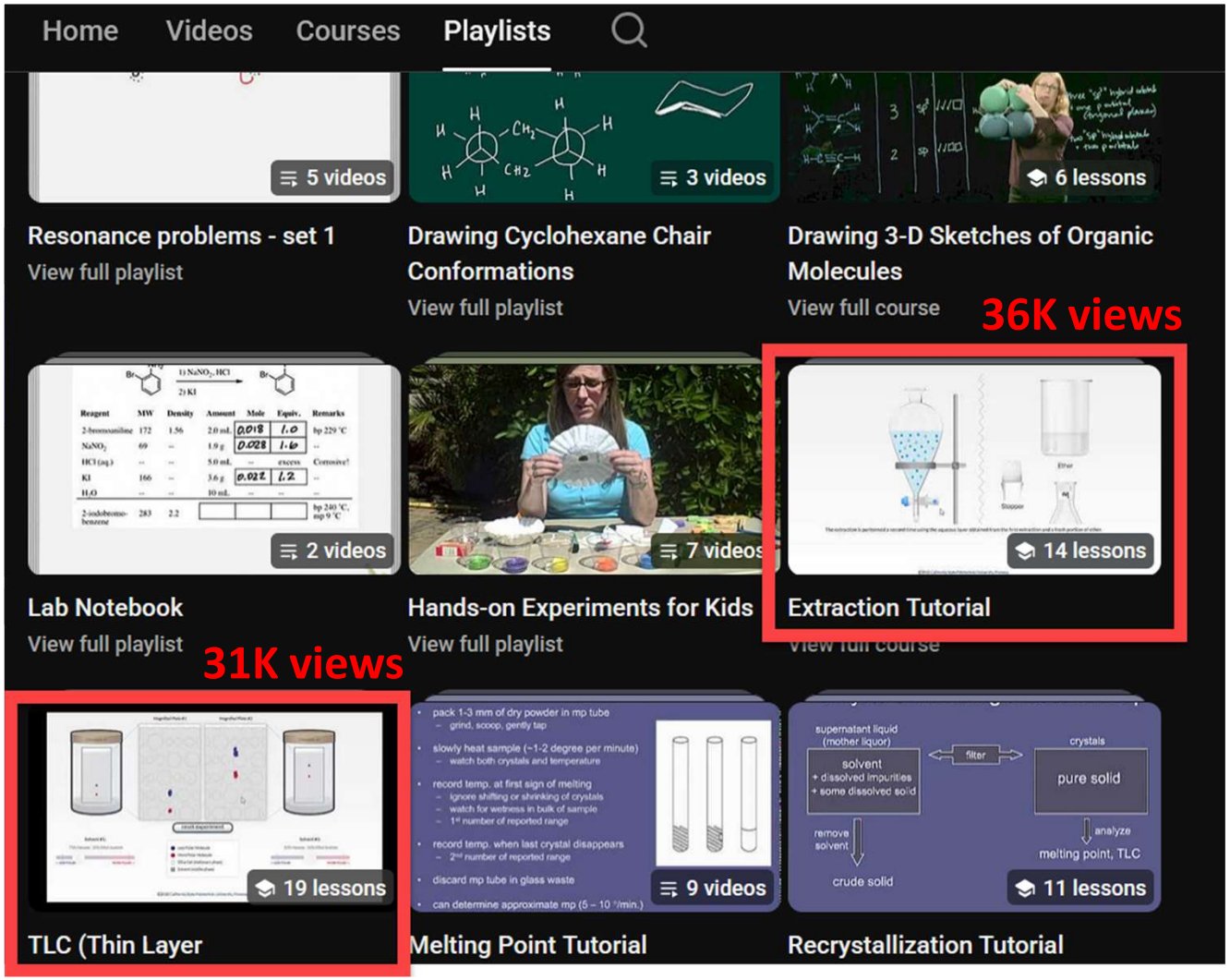
r) In your own words, describe the "dry" step(s) – what is the purpose and how is it done?

s) Name three commonly used solid drying agents.

t) After removing the solvent, what is likely to be done with the isolated reaction products?

Walk-through Videos on YouTube





https://www.youtube.com/@ChemistryConnected/playlists

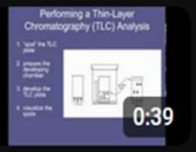
TLC Tutorial (YouTube playlist)

TLC Thin Layer Chromatography
Click here to visit the TLC simulator: https://elearning.cpp.edu/learning-object...

1. Introduction to TLC (Thin-Layer C...
First video in a playlist exploring Thin-Layer Chromatography (TLC). Explore TLC with...

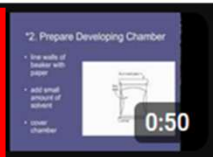
2. Chromatography
What is chromatography used for and what are some common types? Explore TLC...

3. Theory of Chromatography
How does chromatorgraphy work? Discussion of stationary and mobile...



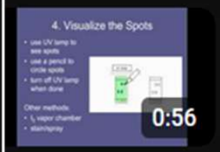
4. Performing a Thin-Layer Chroma...
An overview of the steps involved in a TLC (Thin-Layer Chromatography) analysis....

5. 1) Spot the TLC Plate
How do you add your sample to the TLC plate? This is called "spotting" the plate....

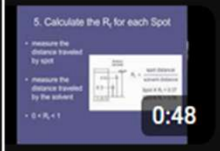


6. 2) Prepare Developing Chamber
How to prepare the chamber used to develop the TLC plate. Try this interactive...

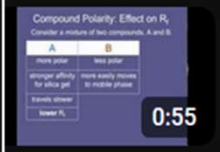
7. 3) Develop the TLC Plate
This shows how a TLC plate is developed. Try this interactive TLC simulator: http://...



8. 4) Visualize the Spots
After running a TLC, how can we see the spots? Try this interactive TLC simulator:...

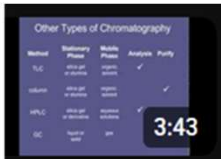


9. 5) Calculate the Rf for each Spot
How to calculate the Rf of a spot, based on the distance it traveled. Explore TLC with...

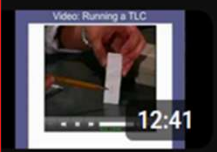


10. Compound Polarity- Effect on Rf
What does the Rf tell us about a compound's polarity? Explore TLC with an...

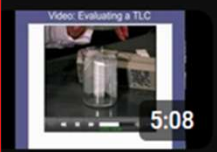
11. Solvent Polarity- Effect on Rf
Explore TLC with an interactive simulator: https://elearning.cpp.edu/learning-object...



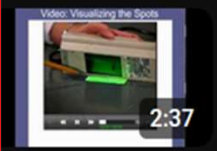
12. Other Types of Chromatography
What are some other kinds of chromatography besides TLC? Try this...



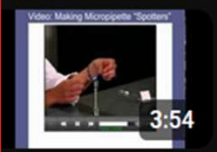
13. Lab demonstration - Running a ...
See a demonstration of running a TLC. Explore TLC with an interactive simulator:...



14. Lab demonstration - Evaluating ...
See how Rf is calculated. For online organic chemistry lessons, visit Dr....



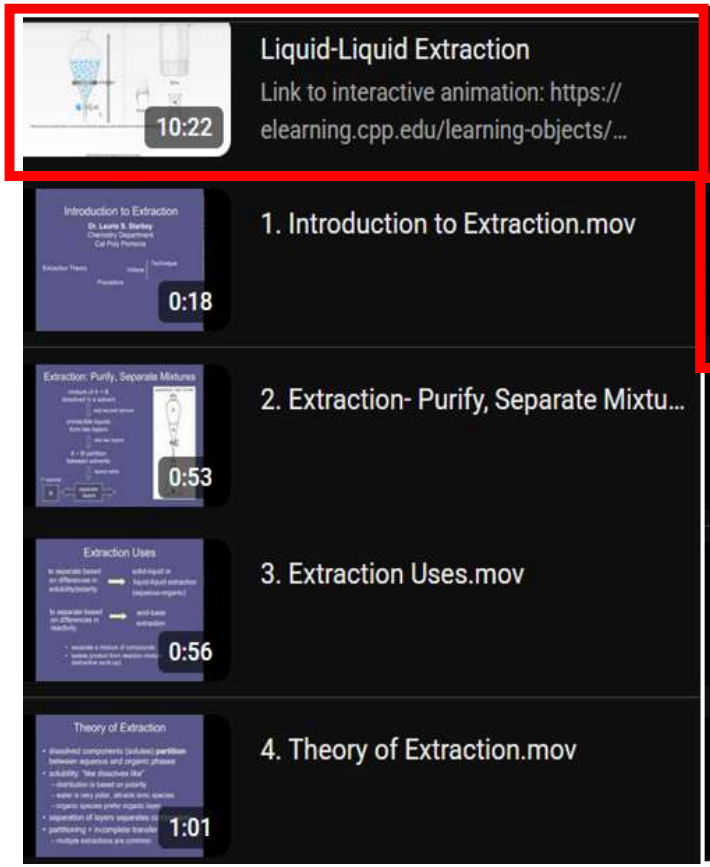
15. Lab demonstration - Visualizing...
visualizing spots on a TLC plate For online organic chemistry lessons, visit Dr....

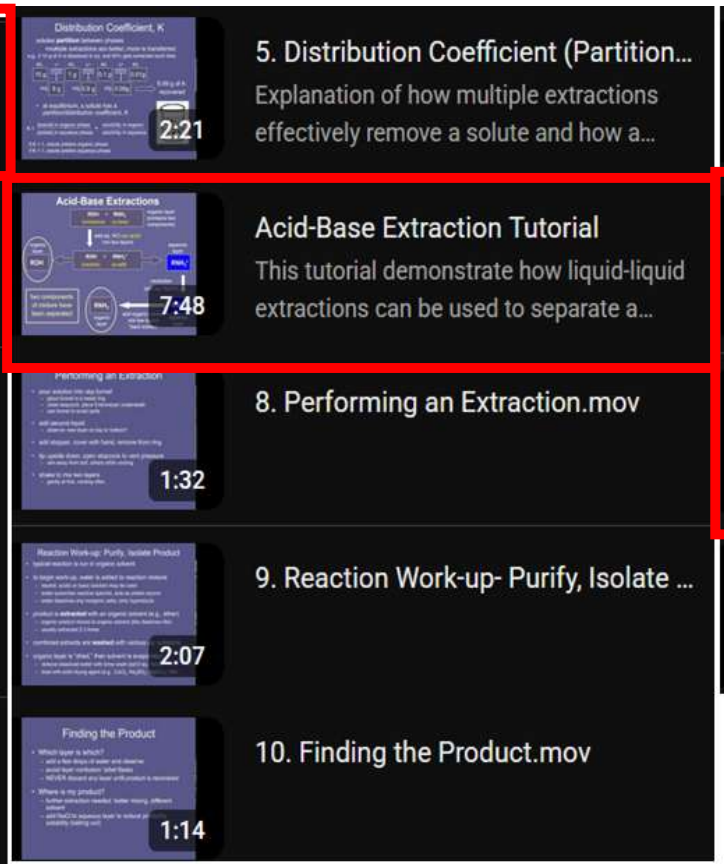


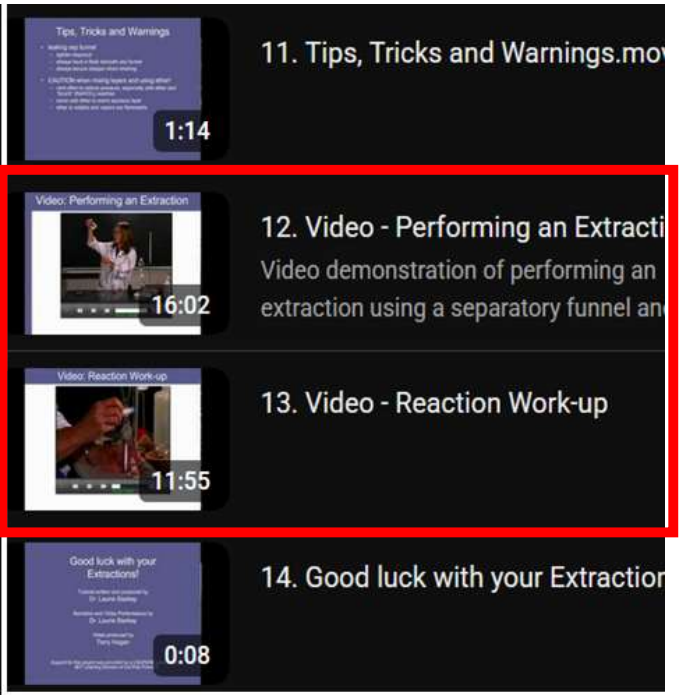
16. Lab demonstration - Making Mi...
See how to make micropipette spotters using capillary tubes and a Bunsen burner...

17. Lab demonstration - Column Ch...
Video demonstration of column chromatography. For online organic...

Extraction Tutorial (YouTube playlist)







Acid-Base Extraction Tutorial

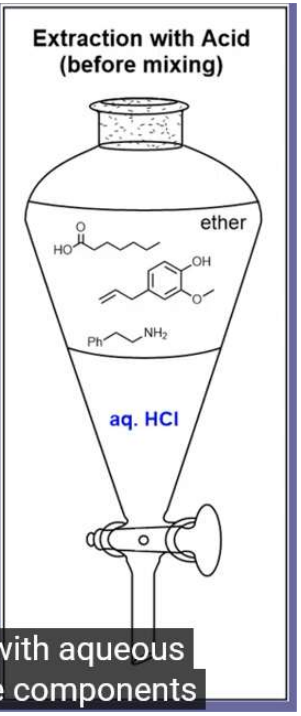
Planning an Acid-Base Extraction

solute → type (in org.) ↓ aq. soln.	"neutral" alkane, ROH ketone, RX, ester, ether	basic amine (RNH_2)	weakly acidic phenol (ArOH)	acidic carb. acid (RCO_2H)
water	N.R. (stays in org.)	N.R.	N.R.	N.R.
aq. acid (10% HCl)	N.R.	RNH_3^+ (moves to aq.)	N.R.	
strong base (10% NaOH)	N.R.	N.R.	ArO^- (moves to aq.)	
mild base (aq. $NaHCO_3$)	N.R.	N.R.	N.R.	

The resulting phenoxide ion is water-soluble and would be extracted into the aqueous layer.

Extraction with Aqueous HCl

Which component moves to the Aqueous Layer?



Now if we mixed that organic layer with aqueous hydrochloric acid, would any of these components

Thank you!

Any Questions?

lsstarkey@cpp.edu

TLC video
(YouTube)

Cal Poly Pomona MLO Library

THANK YOU to CPP
eLearning & CAFE

Extraction video
(YouTube)