

Experiment 26: TLC of Reactions

- Step 1 is called an “initiation step.” Bromine (Br_2) undergoes homolytic photochemical dissociation into two bromine radicals. Mechanistically, the use of fishhook arrows are used to show the movement of one electron (Figure 26-2).



Figure 26-2: The initiation step.

- Step 2 is called a “propagation step”: the bromine radical adds to the double bond of dimethyl maleate to form an intermediate carbon radical (Figure 26-3). In the free radical intermediate, free rotation about the newly formed carbon-carbon single bond is possible, and is energetically favorable.

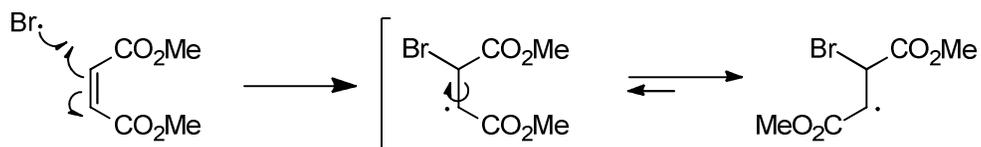


Figure 26-3: The first propagation step.

- Step 3, a second “propagation step”, is the loss of the bromine radical and the regeneration of the carbon-carbon double bond (Figure 26-4). Since the carbon radical intermediate in step 2 can freely rotate, regeneration of the dimethyl maleate is possible. However, since dimethyl fumarate is lower in energy than dimethyl maleate, the *trans* product is favored.



Figure 26-4: The second propagation step.

- Step 4 is a “termination step,” in which two bromine radicals come together to regenerate Br_2 (Figure 26-5).

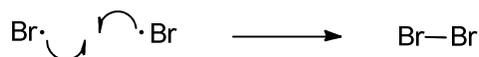


Figure 26-5: The termination step.

Note that since bromine is regenerated at the end of the reaction without being consumed, it is serving as a catalyst.

At the end of the reaction period, both dimethyl maleate and dimethyl fumarate are likely to be present in the crude reaction. The two compounds, however, can be easily separated by concentrating the reaction mixture and then adding hexanes, a non-polar solvent. Under these conditions, dimethyl maleate is soluble and dimethyl fumarate is insoluble, thus the newly formed dimethyl fumarate precipitates out of the solution. Typically, we think of solubility as a product of similar polarities, and in general the old adage “like dissolves like” holds true. In this case, however, polarity is not the determining factor. In fact, dimethyl maleate is *more* polar than dimethyl fumarate because it has a dipole moment. In this case, another solubility factor takes precedence, crystal lattice forces. The *trans* configuration of the dimethyl fumarate enables it to pack more readily into a crystal lattice structure than the *cis* configuration of the dimethyl maleate. This results in the precipitation of dimethyl fumarate while dimethyl maleate remains a liquid in

solution. (This also explains why dimethyl fumarate is a solid at room temperature while dimethyl maleate is a liquid; the difference in lattice forces mean that dimethyl maleate has a lower melting point.)

Safety Precautions

Bromine is a poison, an oxidizer, and corrosive. The bromine solution you will work with in this experiment is dilute and therefore less harmful, but still must be handled with care. If you spill the bromine solution, tell your TA immediately. Wear protective clothes and gloves and avoid inhaling any vapors. Dichloromethane, hexanes and ethyl acetate are moderate health hazards, hexanes and ethyl acetate are flammable.

Procedure

You will work in pairs for this experiment.

You will use bromine as a reagent for this experiment. Since acetone reacts with bromine (in fact, it creates a lachrymator which releases fumes that will irritate your eyes), be sure your reaction glassware has no traces of acetone in it when you start adding reagents. If you need to clean your glassware before you begin, you should rinse it with DCM, not acetone.

Prepare a TLC standard of pure dimethyl maleate by dissolving 1 drop of the compound in approximately 1 mL of DCM in a vial. Cap the vial and label it "TLC Standard – Dimethyl Maleate." Do the same thing for dimethyl fumarate by mixing ~10 mg of the compound in 1 mL of DCM, and again cap and label it.

You will use a solvent system of hexanes and ethyl acetate. From least to most polar, the options are:

1. pure hexanes
2. 75:25 hexanes/ethyl acetate
3. 50:50 hexanes/ethyl acetate
4. 25:75 hexanes/ethyl acetate
5. pure ethyl acetate.

Choose one of the available solvents, mix up 20 mL of it in a stoppered flask (you can share solvents with the people in other hoods around you), and prepare a TLC plate as shown in Figure 26-6. You may wish to prepare several plates at once to cut down on effort. Each plate should have a label at the bottom for DM (dimethyl maleate standard) and DF (dimethyl fumarate standard). At the top of the plate, write which solvent you are trying out. Spot both the standards onto the plate. Use three microcapillary TLC spotters during this experiment – one for DM, one for DF, and one for the reaction mixture that you will run later.



Figure 26-6: An example of the TLC plates you will use to find a good TLC solvent.

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You will use the same method to develop your TLC plates that you used in the previous TLC lab. Afterwards, calculate the R_f of each spot. You should aim to find the solvent mixture that gives you the biggest difference in R_f s between your two spots (written as ΔR_f). To keep track of R_f s, you should compile a table like the one shown below.

Solvent	DM R_f	DF R_f	ΔR_f
Hexanes			
75:25 Hex/EA			
50:50 Hex/EA			
25:75 Hex/EA			
Ethyl acetate			

Once you have found the best solvent choice, you are ready to use it for monitoring a reaction. Prepare a series of TLC plates, as shown in Figure 26-7. Each one should have a label at the bottom for DM (dimethyl maleate standard), DF (dimethyl fumarate standard), and RXN (your reaction). At the top, lightly label the plates with the reaction time at which they will be collected. You should have plates for 0, 5, 10, and 15 minutes. You can save some time by spotting the standards onto all the plates now, so you don't have to go through and spot each plate individually later.

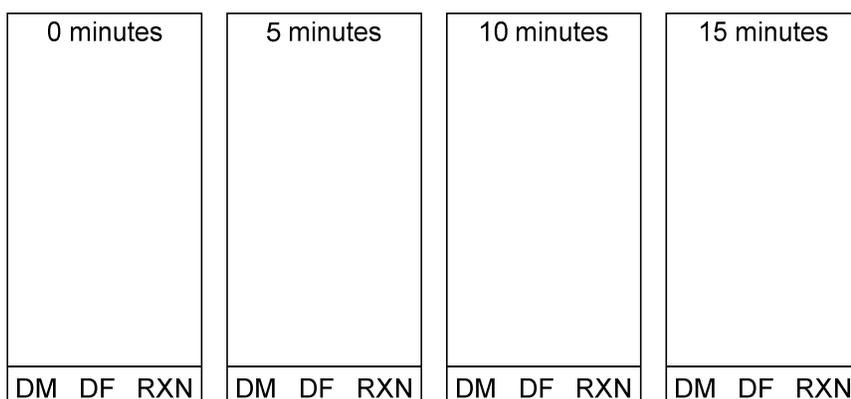


Figure 26-7: An example of the TLC plates you will use to monitor the reaction.

Place your magnetic stir bar in your 25 mL round-bottom flask, and add 4 mL of DCM and 15 drops of dimethyl maleate. Spot the first plate (0 minutes) with the reaction mixture and with both standards. Since the reaction mixture is more concentrated than the standards, you may have to spot it lightly – touch the tip of the spotter to the TLC plate and remove it as quickly as possible. You can examine your undeveloped TLC plate under a UV lamp to see how dark each of the spots is – they should all be approximately the same. Alternatively, if you are finding it hard to spot the reaction mixture lightly enough, you can dilute each reaction sample down. To do so, withdraw a few drops of the reaction mixture with a clean pipet (take enough liquid to fill the narrow “neck” at the bottom of the pipet, but no more). Place this into a vial and then add two to three times as much DCM. You can now use this as your RXN spotter for this TLC plate. You will have to repeat this process each time you want to take a TLC sample from the reaction.

Note the time, then begin the actual reaction by adding 10 drops of 1.0 M Br_2 /DCM solution to the maleate mixture. Stopper and swirl the flask. The ambient light in your fume hood is enough to promote

this reaction, so you do not need a special light source. While the reaction proceeds, you can start developing the first TLC plate in your chosen solvent. You will need a UV lamp to visualize the spots.

Once five minutes have elapsed, dip the spotter back into the reaction mixture and spot the second plate – the one that says 5 minutes. Again, spot the plate with both standards (if you haven't already done so) and develop it.

Continue to take TLC samples every five minutes, until the relative intensity of the spots on your TLC stops changing. At this point your reaction is considered complete. You may need to make up more plates for 20 minutes, 25 minutes, and so forth, depending on how slowly your reaction proceeds. If the reaction mixture decolorizes during the reaction period, add a few additional drops of 0.5M Br₂/DCM solution.

Once the reaction is complete, add a boiling chip to the reaction flask and then reduce the volume by about half by heating it on a hotplate for a few minutes. You should notice most of the bromine being boiled off as well. Once the solution has been concentrated, add 6 mL of cold hexanes, chill the flask in an ice bath, and continue chilling in the ice bath until crystal formation is no longer apparent (about 5 min). Collect the crystals by vacuum filtration, rinse them with a little cold hexanes, and air dry the crystals.

Make up a TLC sample of your final product by dissolving 0.01 g in 1 mL DCM, and then spot this mixture on a TLC plate labeled with "Final product" at the top. Again, spot the plate with both standards and develop it in your chosen solvent.

Determine the yield and melting point of the crystals. Place the product into the Product Recovery Jar.

Wastes

Organic Waste: Reaction mixture filtrates, and used TLC eluting solvents.

Solid Chemical Waste: Used TLC plates, filter paper, pipets, etc.

Recovery Jar: The recovered compound goes into the product recovery jar in the main hood.

Lab Report

Your conclusions should include:

- Your table of R_f values in various solvents, and which solvent you chose to monitor the reaction.
- How long your reaction took to go to completion, as measured by TLC
- What was the compound which precipitated out of the reaction mixture when the cold hexanes were added? How did you identify this compound?

Study Questions

- 1) Which compound, dimethyl maleate or dimethyl fumarate, should be more strongly adsorbed onto the silica gel? Why is this?
- 2) Which isomer, dimethyl maleate or dimethyl fumarate, should be the more stable isomer? Explain.
- 3) A student is running this reaction and sees a strong TLC spot for dimethyl fumarate, but no crystals form when the student adds hexanes and cools the mixture. What might the student do to recover their product?

