

Experiment #7: Gas-Phase Synthesis, Column Chromatography and Visible Spectroscopy of 5,10,15,20 - Tetraphenylporphyrin

Pre-Lab Preparation

1. Read the article by Drain and Gong (*Chem. Commun.* **1997**, 42, 2117) describing this synthetic approach.
2. Study the technique sections in your lab manual regarding column chromatography, TLC, visible spectroscopy, and use of the rotary evaporator.
3. Carry out pre-lab preparations as described in Chapter 11, section 11.6A, or as called for by your instructor.

Experimental Procedure

SAFETY PRECAUTIONS: Ethyl acetate, hexanes, and acetone are flammable; avoid exposure to open flames. Avoid inhalation of silica gel particles or fumes of benzaldehyde or pyrrole. Pyrrole and benzaldehyde can be irritating to the skin – avoid contact. The reaction is effected at a relatively high temperature – take care to avoid thermal burns.

Reaction

1. Cap a 5 mL conical vial with a septum-bearing screw cap. Place the vial in a heating mantle filled with sand so that the bottom 1.5 inches of the vial is submerged in the sand. Apply heat to the sand bath, and when the temperature of the bath reaches 170 °C, use a 20 μ L syringe to inject 10 μ L of benzaldehyde (0.1 mmol) through the septum. (Test the syringe before use to ensure that it is not blocked – try squirting a bit of benzaldehyde onto a piece of tissue. Be sure to clean the syringe after you use it.)

2. Once droplets of benzaldehyde form on the walls of the vial and the temperature has reached approximately 180 °C, use a 10 μL syringe to inject 7 μL of pyrrole [51] (0.1 mmol) through the septum.
3. Raise the temperature of the sand bath to 250°C. After heating the vial for 15 minutes at 250 °C, remove it from the sand bath and allow it to cool to room temperature on the bench top.

Workup

4. After the vial is cool, use 1 mL of CH_2Cl_2 to rinse the cap liner and walls of the vial, affording a solution of the crude product, ready for chromatographic analysis and purification.

Thin Layer Chromatography (TLC)

5. Analyze the product mixture by thin layer chromatography on a silica TLC plate, using a 7:1 hexanes/ethyl acetate mixture to elute the plate. (Remember to make sure all the spotting solvent has evaporated before developing the plate to avoid irreproducible results based on the presence of traces of CH_2Cl_2 .) Tetraphenylporphyrin, easily recognizable by its violet color, should appear as the leading spot on the silica plate, with an R_f value of around 0.46. The remaining impurities appear as a broad band at lower R_f (0 to 0.3).

Purification – Column Chromatography

6. Prepare a silica gel column in a chromatography column (3 – 5 mm inside diameter) fitted with a Teflon stopcock. If the column contains a porous glass disk, add the silica directly, as described below. If not, insert a small plug of glass wool into the bottom of the column. Close the stopcock and add 5 mL of 7:1 hexanes/ethyl acetate, then gently add sand to a depth of about 2 cm. (The presence of the solvent aids in the formation of a uniform sand layer.) Prepare a loose slurry of approximately 6.5 g of silica gel in 7:1 hexanes/ethyl acetate (approximately 30 mL). Swirl the flask to make sure the silica gel is thoroughly suspended in the solvent, then quickly, but carefully,

51. Pyrrole should be passed through a short column of basic alumina (Al_2O_3) prior to use. If protected from light, the purified pyrrole may be stored for several days. Your instructor will provide purified pyrrole for you.

pour the suspension into the column. Open the stopcock and allow the silica gel to settle and the solvent to slowly drain until the level of the top of the silica gel stops lowering. Your column height should be around 30 cm. If it is not, add more slurry to the column. Finally, carefully deposit a 2 cm layer of sand to protect the top surface of the column. The sand should fall through the remaining solvent and make an even layer on the top of the silica gel.

7. Drain the solvent down to the top of the sand. Carefully load the entire solution of the product mixture in CH_2Cl_2 on the top of the column and elute until the solvent level has reached the top of the sand. Stop the flow and carefully add the elution solvent (7:1 hexanes/ethyl acetate). Run the column at a flow rate of approximately 30 drops/min until the leading purple band elutes. Generally, the entire porphyrin band can be collected in approximately 7 – 8 mL of solvent after a total of about 20 – 25 minutes.

Keys to successful column chromatography

- Carry out initial TLC to find the optimal elution solvent.
- Pack a good column – make sure every layer is uniform.
- Add the sample solution in as small a volume of solvent as possible.
- If performing gradient chromatography (you are not in this experiment), start with the least polar solvent and don't change the solvent composition too rapidly.
- If there is no obvious visual cue about the contents of eluted fractions (there is in this experiment – the desired compound is purple), collect fractions and analyze each one before mixing any of them together

Visible Spectroscopy

8. Prepare your sample for visible spectroscopy by placing 1 – 2 drops of the highly colored tetraphenylporphyrin solution in a sample vial and diluting it to 4 mL with additional 7:1 hexanes/ethyl acetate. Add a few drops of triethylamine to the solution to prevent protonation of the porphyrin by any traces of acid. **Note: In order to estimate your yield, you will need to know the volume of tetraphenylporphyrin solution used and the amount of solvent used to dilute the sample. The more carefully you measure and prepare your solutions, the higher the accuracy in your determination of yield.**

9. The UV/visible absorption spectrum of tetraphenylporphyrin shows a strong absorbance at 420 nm (extinction coefficient = $\epsilon = 4.7 \times 10^5$) along with four weaker absorptions at 510 ($\epsilon = 1.87 \times 10^4$), 550 ($\epsilon = 7.7 \times 10^3$), 590 ($\epsilon = 5.4 \times 10^3$), and 645 nm ($\epsilon = 3.4 \times 10^3$). Adjust the concentration of your sample, keeping track of the volume of solvent added in order to permit an estimated yield calculation, until the absorbance at 420 nm is around one absorbance unit. Print a copy of this spectrum, labeling the wavelengths of the absorption maxima if possible. Also print a second copy, with the absorbance axis scaled to half of its original numerical maximum.

Post-Lab Questions and Exercises

1. To the best of your ability based on your spectroscopic analysis, using the extinction coefficients listed above, report the mass and percent of theoretical yield of the product.
2. Describe your TLC results for the reaction mixture. What were the R_f values for the spot(s)?
3. Describe what happened during column chromatography. What bands did you see elute, in what order?
4. Given an absorbance maximum at about 420 nm, what color would you *expect* the porphyrin to be? What color is the porphyrin that you isolated? How do you explain this color?
5. Attach your UV/visible spectra. Be sure to indicate which fraction from the column chromatography you used to obtain these spectra. Label the absorbance and wavelength of each peak in the spectrum.
6. Calculate the atom economy for the reaction.

Experiment Development Notes

This is another experiment taken from the recent primary literature [49]. Very few details were given in the original report, and many modifications were required in order to develop the method and optimize it for reliable use in the teaching laboratory [50]. This experiment is particularly appealing given the single-step formation of a complex organic molecule and the colorful column chromatography.