

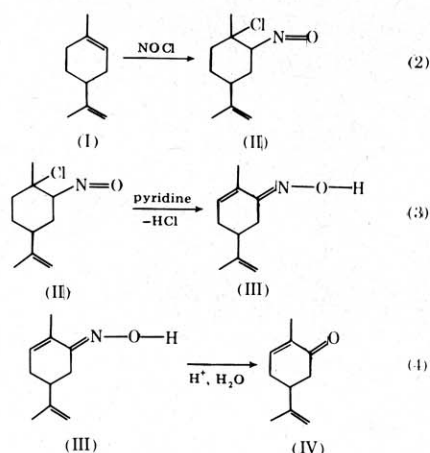
Conversion of (+)-Limonene to (-)-Carvone

An organic laboratory sequence of local interest

Disposal of orange peels resulting from the processing of oranges into orange juice represents a potentially formidable problem. This problem is solved by drying and pelletizing the peels for use as animal feed. A by-product of this process is (+)-limonene(I). A portion of the (+)-limonene so generated finds its way into the flavoring industry where it is converted into (-)-carvone(IV).

In an attempt to incorporate chemistry of local interest into our organic chemistry program, we have developed a nine-hour experiment based on the method of E. E. Royals and S. E. Horne (1) that involves isolation of (+)-limonene from orange peels and conversion of this product into (-)-carvone. The steps of this experiment are summarized below:

Steam distillation and isolation of (+)-limonene (I) (1)



Several aspects of this experiment are particularly suited to the second semester of organic chemistry. These include the use of a large number of basic techniques, the inclusion of several reaction types, and the presence of a high degree of student interest. This interest stems from the fact that "or-

ange oil" (I) is converted to one of the components of spearmint oil, (-)-carvone (IV). The enantiomer of (-)-carvone is one of the components of caraway oil. The odor difference is caused by stereochemical factors (2). The isolation of (+)-carvone from caraway oil is described by Pavia, Lapman, and Kriz (3) and is one of the experiments done by our students prior to the synthesis of (-)-carvone.

The first step in this sequence illustrates the isolation of a natural product by steam distillation. Isolation of the 10 g of (+)-limonene required for the second step demands approximately 25 oranges. Since this quantity is impractical, even in sunny Florida, the students' meager supply of (+)-limonene obtained from three oranges is augmented after IR and GC analysis.¹ Better students are encouraged to complete the sequence with the small quantity of (+)-limonene obtained by steam distillation, but the overall yield falls considerably below the class average of twenty per cent (20%).²

The second step of the sequence, conversion of (+)-limonene into the limonene nitrosochloride (II), is an excellent example of regiospecific addition to a double bond. The addition is selective to the ring double bond and occurs in Markownikoff fashion. The formation of the nitroso isomer is evident from the IR spectrum. In addition, the *in situ* generation of NOCl requires the synthesis of ethyl nitrite and hence the use of a gas generation technique.

The third step of the sequence, conversion of the limonene nitrosochloride (II) into the carvoxime (III), is an example of an elimination. The reaction is run under reflux, and it is quite facile. That the carvoxime exists as the oxime tautomer is evident from the —OH stretch in the IR spectrum. Isolation of the carvoxime (III) is a challenging exercise in obtaining first crystals.

The synthesis is completed by the conversion of the carvoxime into (-)-carvone (IV). This reaction is an example of the hydrolysis of a ketone derivative. The final product, (-)-carvone, is steam distilled from the reaction mixture and isolated by extraction with methylene chloride.

With samples of both enantiomers of carvone in hand, students are asked to compare various physical and chemical properties and contrast these similarities with olfactory differences. Students are referred to literature documentation

¹ Crude limonene is available through Eastman Organic Chemicals.

² Reported yields represent a typical class (12) average, and they are representative.

of these differences (2–5) as well as to a general review of the stereochemical theory of odor (6). A provocative alternative olfaction theory presented by Callahan (7) to explain insect detection of pheromones is also of interest to students.

Experimental (1)

(+)-Limonene (I)

(+)-Limonene is prepared by the steam distillation of the peels of three oranges. Since the boiling point of (+)-limonene is 177°C, it is not necessary to use live steam. Steam distillation from a simple distillation apparatus equipped with a Claisen adapter and separatory funnel (water reservoir), followed by CH₂Cl₂ extraction, yields about 1 g of oil (90% (+)-limonene) bp 173°C (Siwoloboff technique) (8); ν^{neat} , NaCl plates 3110; 2980; 2940; 1640; 1430; 1365; 880 cm⁻¹.

Limonene Nitrosochloride (II)

Ethyl nitrite is generated by dropping a mixture of 4.7 g (0.1 mole) of ethanol, 5.7 ml of concentrated H₂SO₄, and enough water to make 60 ml into a mixture of 14.0 g (0.20 mole) NaNO₂, 4.7 g (0.10 mole) of ethanol, and enough water to make 60 ml. The gas is delivered to a mixture of 10 g (0.073 mole) of (+)-limonene and 12.5 ml of ethanol. The reaction vessel (150-ml Erlenmeyer flask), equipped with a gas inlet tube, a magnetic stirrer, and a gas outlet tube (aspirator trap), is immersed in an ice-salt mixture to maintain a -5°C reaction temperature. When all of the ethyl nitrite has been evolved, 17 ml (0.22 mole) of concentrated HCl is added, dropwise, to the mixture while stirring vigorously. The reaction mixture is then stirred for 30 min. The white precipitate is filtered, washed with cold ethanol, and allowed to air dry; yield of limonene nitrosochloride is 7.8 g (56%). Recrystallization from ether affords white crystals, mp 111–112°C; ν^{KBr} 3100; 2960; 2650; 1190 cm⁻¹.

Carvoxime (III)

A slurry of 6 g (0.025 mole) of crude limonene nitrosochloride, 2.6 ml (0.032 mole) of pyridine, and 50 ml of acetone is refluxed for 10 min. The reaction mixture is reduced to an oil which is crystallized from ethanol to give 4.4 g (90%) of caroxime. Recrystallization from ethanol affords white crystals, mp 68–72°C; ν^{KBr} 3300; 2920; 1640; 1430; 1370; 920; 880.

(-)-Carvone

A mixture of 4 g of carvoxime and 40 ml of 5% oxalic acid is heated under reflux for 30 min. Steam distillation followed by CH₂Cl₂ extraction yields 1.6 g (44%) of (-)-carvone, ν^{neat} , NaCl plates 3110; 2950; 1670; 1440; 1360; 1110; 980 cm⁻¹.

Acknowledgment

The authors gratefully acknowledge the suggestions and support of Dr. James M. Bonnell of Tropicana Products, Inc., in the development of this experiment. The valuable suggestions of Dr. Tom Newton from the Chemistry Department, Colby College, are also acknowledged.

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