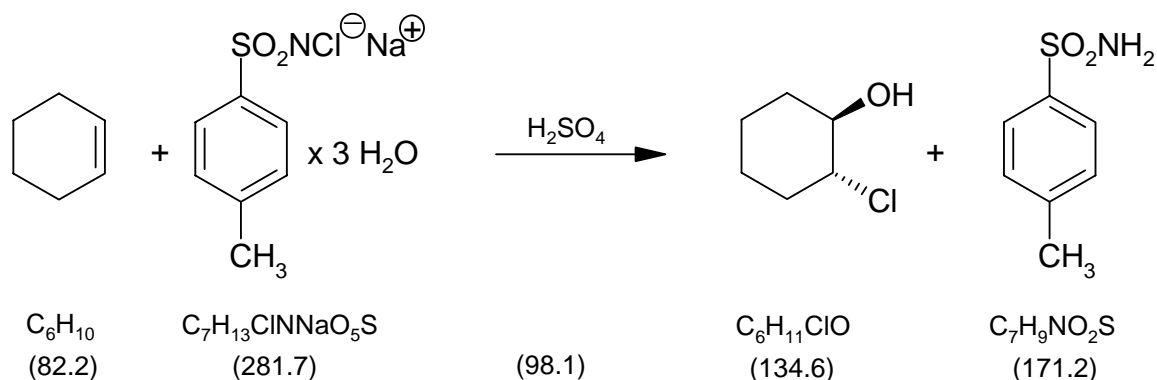


**3003 Synthesis of trans-2-chlorocyclohexanol from cyclohexene****Literature**

B. Damin, J. Garupon, B. Sillon, *Synthesis* **1981**, 362

**Classification****Reaction types and substance classes**

addition to alkenes, stereoselective addition

alkene, halohydrin

**Work methods**

heating under reflux, stirring with magnetic stir bar, adding dropwise with an addition funnel, steam distillation, shaking out, extracting, filtering, evaporating with rotary evaporator, distilling under reduced pressure, heating with oil bath

**Instruction (batch scale 100 mmol)****Equipment**

250 mL two- or three-neck flask, heatable magnetic stirrer, magnetic stir bar, reflux condenser, addition funnel with pressure balance, distillation apparatus, separating funnel, steam distillation apparatus, hot-air dryer, rotary evaporator, vacuum pump, oil bath

**Substances**

cyclohexene (bp 83 °C)	8.22 g (10.1 mL, 100 mmol)
chloramine T trihydrate (mp > 70 °C) (N-chlor-4-toluenesulfonamide, sodium salt)	28.2 g (100 mmol)
conc. sulphuric acid (98%)	9.8 g (5.3 mL, 100 mmol)
acetone (bp 56 °C)	40 mL
<i>tert</i> -butyl methyl ether (bp 55 °C)	75 mL
sodium chloride	about 120 g
sodium sulfate	about 5 g

**Reaction**

28.2 g (100 mmol) chloramine T trihydrate and 80 mL of a 1:1-mixture of acetone and water are filled in a 250 mL two- or three-neck flask with reflux condenser, addition funnel and magnetic stir bar. 8.22 g (10.1 mL, 100 mmol) cyclohexene are added to this suspension and then 9.8 g (5.3 mL, 100 mmol) conc. sulphuric acid is added dropwise under stirring within one hour. The mixture is heated under reflux until no longer iodine is formed, when a 1 mL sample of the reaction solution is mixed with an acidic potassium iodide solution (about 45 minutes).

**Work up**

The reaction mixture, which consists of two phases, is saturated with about 13 g sodium chloride and the acetone is distilled off. The residue is subjected to a steam distillation, at least 250 mL distillate should be collected.

This distillate is saturated with sodium chloride and the colourless oily phase is separated with a separating funnel. The aqueous phase is shaken out three times with 25 mL *tert*-butyl methyl ether each. The previously separated oil is combined with the ether extracts and this organic phase is shaken out two times with 25 mL saturated sodium chloride solution each. The organic phase is dried with sodium sulfate. After filtration of the drying agent the solvent is evaporated at a rotary evaporator. An oily residue remains.

Yield: 8.91 g (66.2 mmol, 66%); GC-purity 98%. For the most purposes this product is pure enough.

For further purification the product can be fractional distilled under reduced pressure. During distillation the product can solidify in the cooler, therefore the cooling water should run very slowly and a hot air dryer should be kept ready for heating solidified substance.

Yield of distillate: 8.20 g (60.9 mmol, 61%), colourless liquid; bp 79 °C (13 hPa), mp 27-29 °C; GC-purity 98%

The aqueous residue of the steam distillation contains 4-toluenesulfonamide as solid, which is filtered off, washed with water and dried in a desiccator over silica gel.

Yield 16.8 g (98.0 mmol, 98%)

**Alternative work up**

An alternative to a normal steam distillation is an extractive steam distillation, if the necessary equipment is available: After the acetone is distilled off, the reaction mixture is filled in this apparatus and extracted for 2 hours with *tert*-butyl methyl ether. The ether phase is dried with sodium sulfate. After filtration of the drying agent the solvent is removed at the rotary evaporator. An oily residue remains.

Yield: 9.16 g (68.1 mmol, 68%); GC-purity 98%. For the most purposes this product is pure enough. A distillation is possible as aforementioned.

The aqueous residue of the steam distillation contains 4-toluenesulfonamide as a solid, which is filtered off, washed with water and dried in a desiccator over silicagel.

Yield: 16.8 g (98.0 mmol, 98%)

**Waste management****Waste disposal**

Waste	Disposal
distilled acetone (might contain cyclohexene)	organic solvents, halogen free
residue from steam distillation, after separation of 4-toluenesulfonamide	solvent water mixtures, containing halogen
aqueous phase of steam distillate	solvent water mixtures, halogen free
evaporated <i>tert</i> -butyl methyl ether (might contain acetone)	organic solvents, halogen free
distillation residue	dissolve in acetone, then: organic solvents, containing halogen
sodium sulfate	solid waste, free from mercury

**Time**

5 hours

**Break**

Before work up

After steam distillation

Before distillation

**Degree of difficulty**

Medium

**Instruction (batch scale 10 mmol)****Equipment**

100 mL two- or three-neck flask, heatable magnetic stirrer, magnetic stir bar, reflux condenser, addition funnel with pressure balance, micro distillation apparatus, separating funnel, steam distillation apparatus, hot-air dryer, rotary evaporator, vacuum pump, oil bath

**Substances**

cyclohexene (bp 83 °C)	0.822 g (1.01 mL, 10.0 mmol)
chloramine T trihydrate (mp > 70 °C) (N-chlor-4-toluenesulfonamide, sodium salt)	2.82 g (10.0 mmol)
conc. sulphuric acid (98%)	0.98 g (0.53 mL, 10 mmol)
acetone (bp 56 °C)	10 mL
<i>tert</i> -butyl methyl ether (bp 55 °C)	45 mL
sodium chloride	about 35 g
sodium sulfate	about 1 g

### Reaction

2.82 g (10.0 mmol) chloramine T trihydrate and 20 mL of a 1:1-mixture of acetone and water are filled in a 100 mL two- or three-neck flask with reflux condenser, addition funnel and magnetic stir bar. 0.822 g (1.01 mL, 10.0 mmol) cyclohexene are added to this suspension and then 0.98 g (0.53 mL, 10 mmol) conc. sulphuric acid is added dropwise under stirring within 10 minutes. The mixture is heated under reflux until no longer iodine is formed, when a 1 mL sample of the reaction solution is mixed with an acidic potassium iodide solution (about 45 minutes).

### Work up

The reaction mixture, which consists of two phases, is saturated with about 5 g sodium chloride and the acetone is distilled off. The residue is subjected to a steam distillation, at least 50 mL distillate should be collected.

This distillate is saturated with sodium chloride and the colourless oily phase is separated in a separating funnel. The aqueous phase is shaken out three times with 15 mL *tert*-butyl methyl ether each. The previously separated oil is combined with the ether extracts and this organic phase is shaken out two times with 15 mL saturated sodium chloride solution each. The organic phase is dried with sodium sulfate. After filtration of the drying agent the solvent is evaporated at a rotary evaporator. An oily residue remains.

Yield: 875 g (6.50 mmol, 65 %); GC-purity 98%. For the most purposes this product is pure enough.

For further purification the product can be fractionally distilled under reduced pressure. During distillation the product can solidify in the cooler, therefore the cooling water should run very slowly and a hot air dryer should be kept ready for heating solidified substance.

Yield of distillate: 790 mg (5.87 mmol, 59%), colourless liquid; bp 79 °C (13 hPa), mp 27-29 °C; GC-purity 98%

The aqueous residue of the steam distillation contains 4-toluenesulfonamide as solid, which is filtered off, washed with water and dried in a desiccator over silica gel.

Yield 1.70 g (9.92 mmol, 99%)

### Alternative work up

An alternative to a normal steam distillation is an extractive steam distillation, if the necessary equipment is available: After the acetone is distilled off, the reaction mixture is filled in this apparatus and extracted for 2 hours with *tert*-butyl methyl ether. The ether phase is dried with sodium sulfate. After filtration of the drying agent the solvent is removed at the rotary evaporator. An oily residue remains.

Yield: 881 mg (6.54 mmol, 65%); GC-purity 98%. For the most purposes this product is pure enough. A distillation is possible as aforementioned.

The aqueous residue of the steam distillation contains 4-toluenesulfonamide as a solid which is filtered off, washed with water and dried in a desiccator over silica gel.

Yield: 1.70g (9.92 mmol, 99%)

**Waste management****Waste disposal**

Waste	Disposal
distilled acetone (might contain cyclohexene)	organic solvents, halogen free
residue from steam distillation, after separation of 4-toluenesulfonamide	solvent water mixtures, containing halogen
aqueous phase of steam distillate	solvent water mixtures, halogen free
evaporated <i>tert</i> -butyl methyl ether (might contain acetone)	organic solvents, halogen free
distillation residue	dissolve in acetone, then: organic solvents, containing halogen
sodium sulfate	solid waste, free from mercury

**Time**

5 hours

**Break**

Before work up

After steam distillation

Before distillation

**Degree of difficulty**

Medium

**Analytcs****GC**

Sample preparation:

A sample of the substance is diluted with 1 mL *tert*-butyl methyl ether from which 1  $\mu$ L is injected.

GC-conditions:

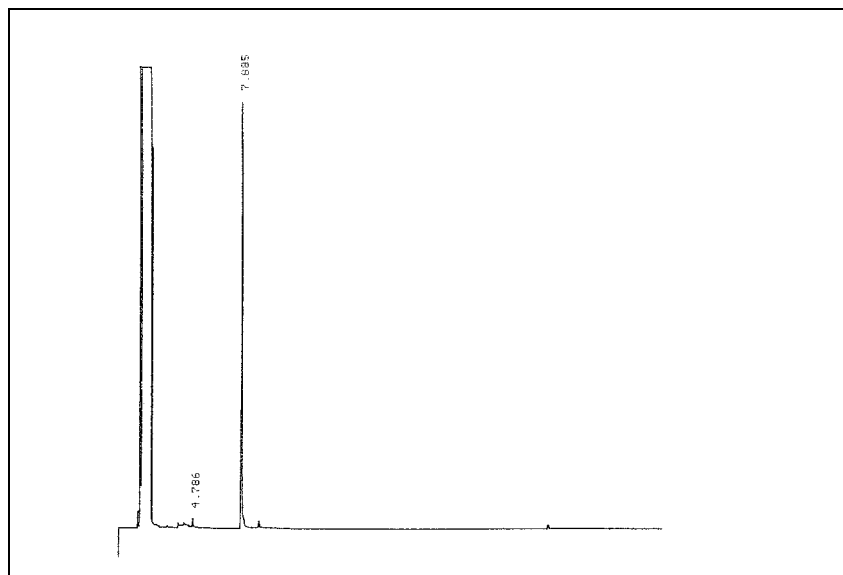
column: Macherey and Nagel, SE-54, 326-MN-30705-9, length 25 m, ID 0.32 mm, DF 0.25  $\mu$ minlet: Gerstel KAS with control unit, injector temperature 250 °C;  
split injection 1:20, injected volume 1  $\mu$ L

carrier gas: nitrogen, pre-column pressure 62 kPa, flow rate 1.04 mL/min

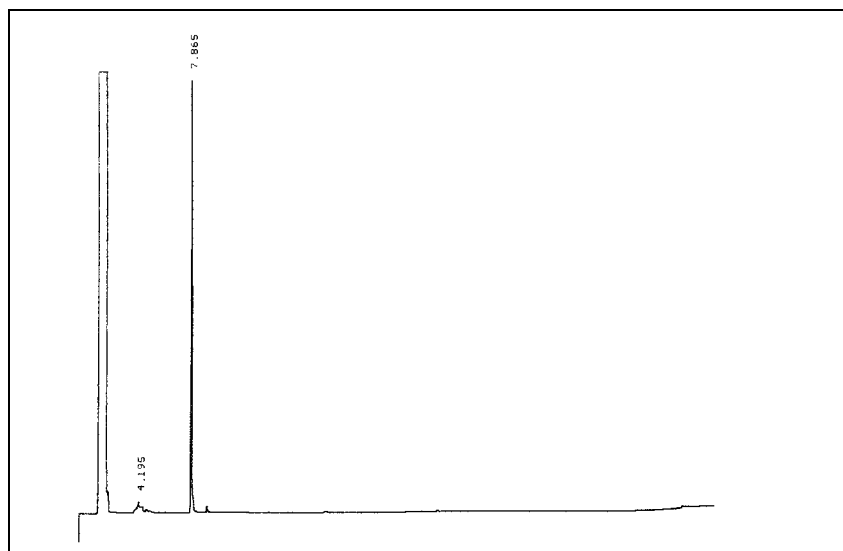
oven: start temperature: 80 °C (1 min), 5 °C/min, final temperature 250 °C (30 min)

detector: FID, 275 °C

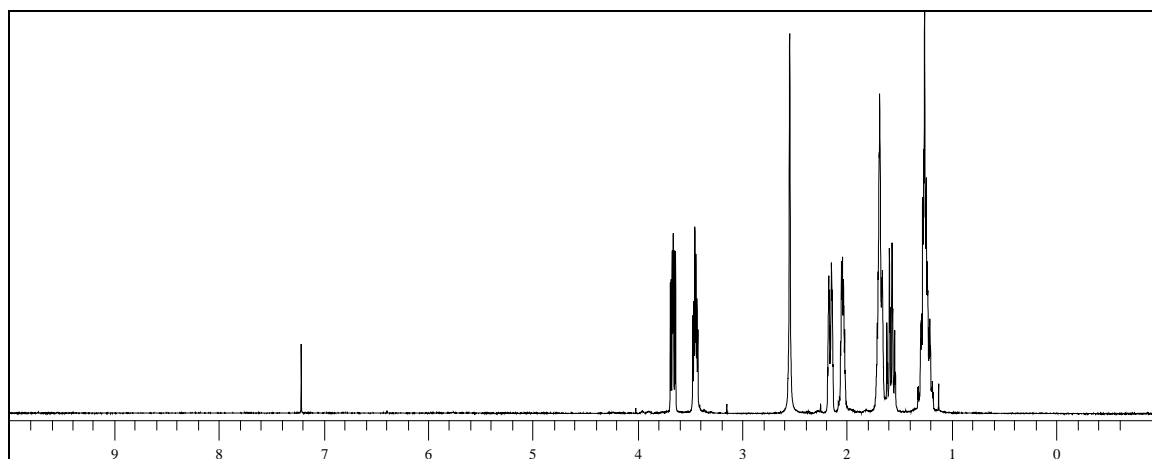
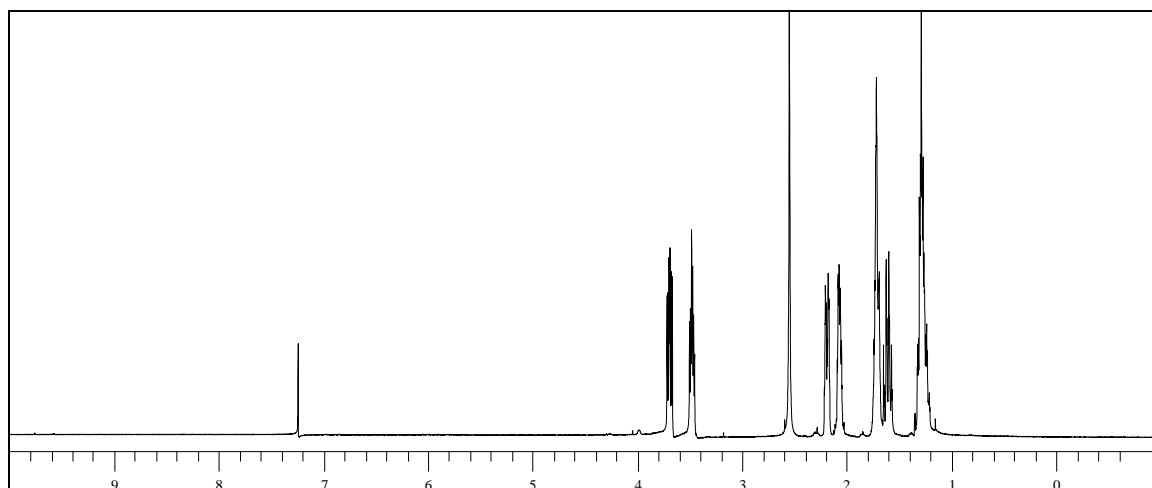
Percent concentration was calculated from peak areas.

**GC of the crude product**

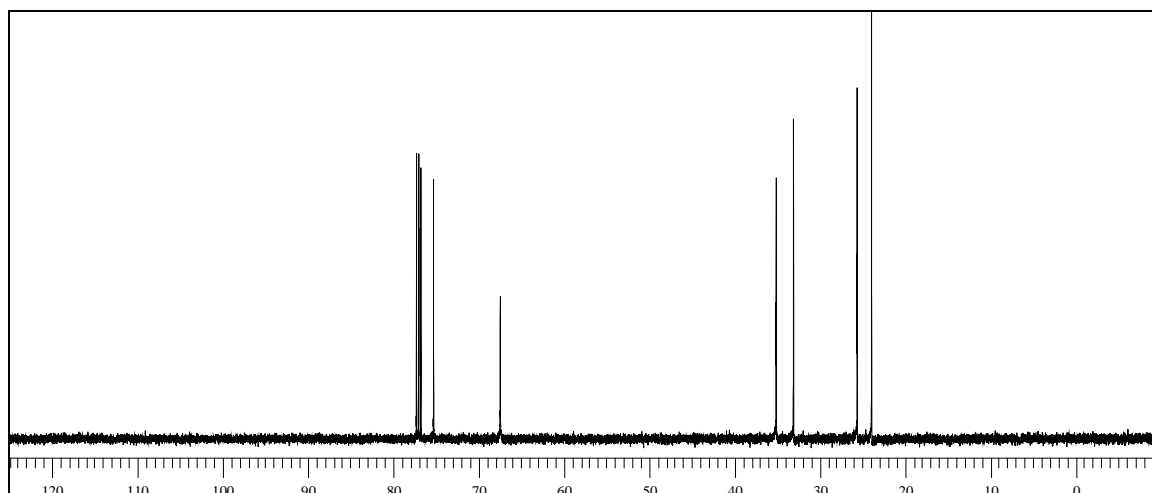
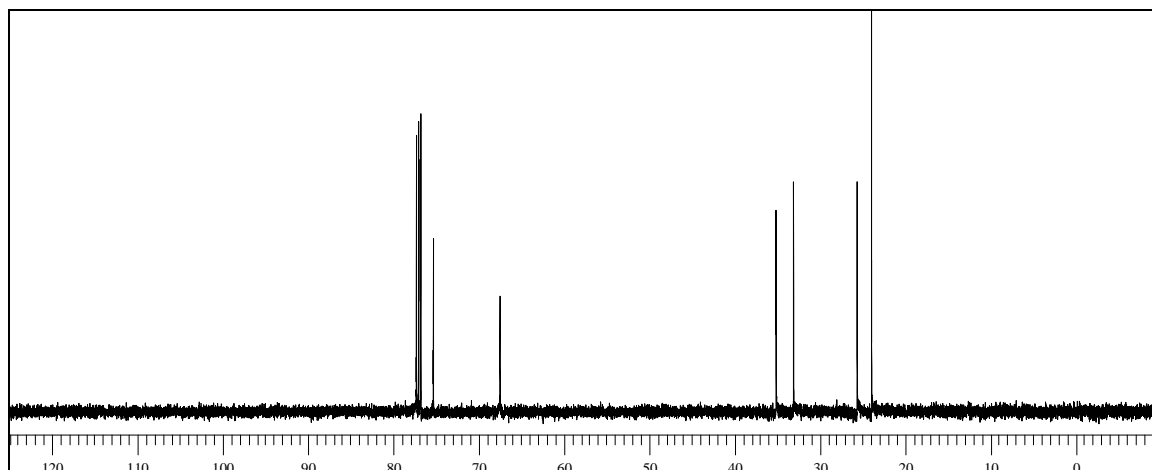
Retention time (min)	Substances	Peak area %
7.8	product ( <i>trans</i> -2-chlorocyclohexanol)	98
4.8	not identified	2

**GC of the pure product**

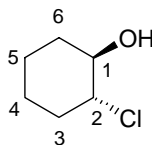
Retention time(min)	Substances	Peak area %
7.8	product ( <i>trans</i> -2-chlorocyclohexanol)	98
4.2	not identified	2

**$^1\text{H}$  NMR spectrum of the crude product (500 MHz,  $\text{CDCl}_3$ )** **$^1\text{H}$  NMR spectrum of the pure product (500 MHz,  $\text{CDCl}_3$ )**

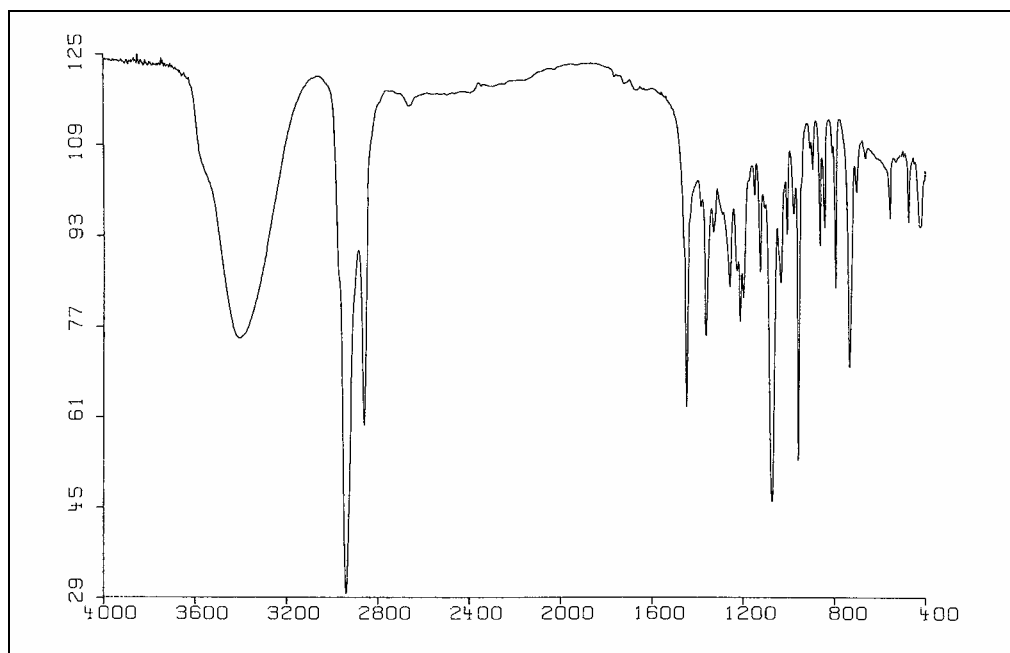
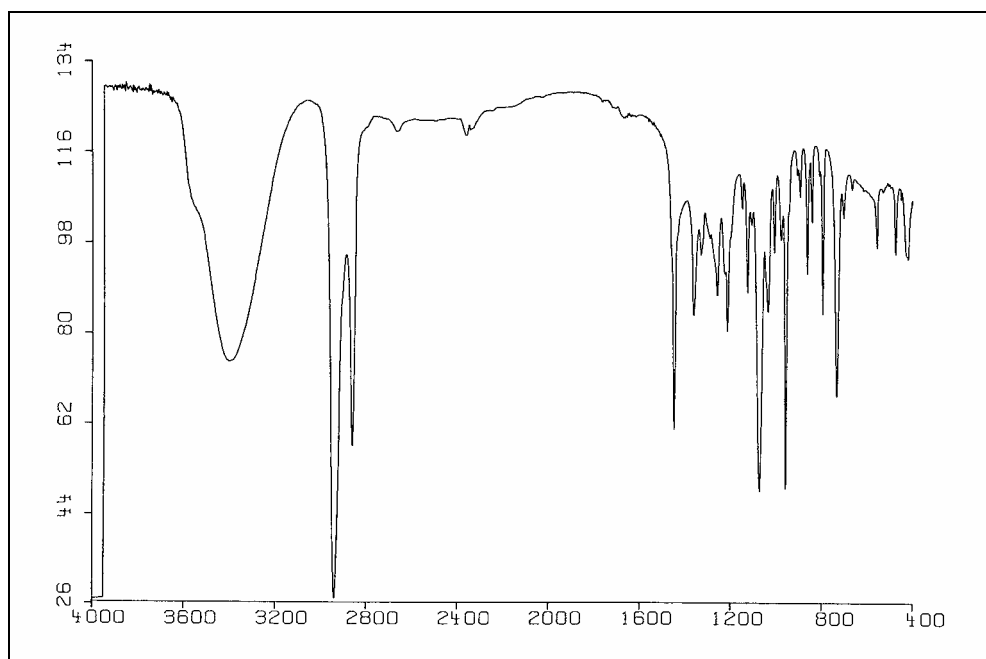
$\delta$ (ppm)	Multiplicity	Number of H	Assignment
1.20 - 1.36	M	3	$\text{CH}_2$
1.56 - 1.65	m	3	$\text{CH}_2$
2.04 - 2.10	m	1	$\text{CH}_2$
2.16 - 2.22	m	1	$\text{CH}_2$
2.55	s	1	OH
3.45 - 3.56	m	1	CH-OH
3.66 - 3.72	m	1	CH-Cl
7.26			solvent

**$^{13}\text{C}$  NMR spectrum of the crude product (125 MHz,  $\text{CDCl}_3$ )** **$^{13}\text{C}$  NMR spectrum of the pure product (125 MHz,  $\text{CDCl}_3$ )**

$\delta$ (ppm)	Assignment
24.0	C-5
25.6	C-4
33.2	C-3
35.2	C-6
67.3	C-2
75.3	C-1
76.5-77.5	solvent





**IR spectrum of the crude product (film)****IR-spectrum of the pure product (film)**

(cm <sup>-1</sup> )	Assignment
3400	O-H-valence
2941, 2862	C-H-valence, alkane