

# Benchtop NMR: What can it do for *you* ?



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**Spinsolve™**  
The fastest compact NMR spectrometer

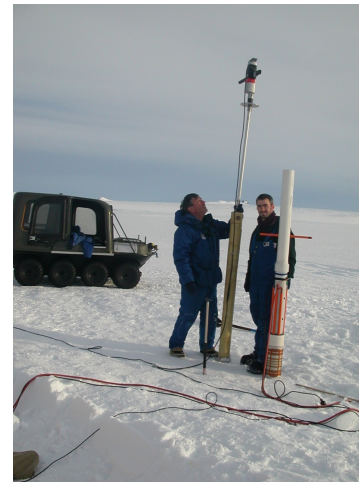
# The history of Magritek

**Magritek** was founded in 2004 to **develop mobile and benchtop NMR and MRI instruments** to enable new applications in Industry, Research and Education.

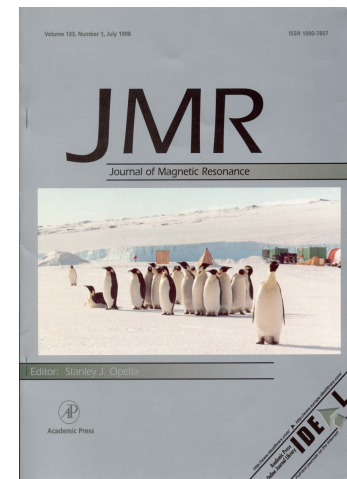
The original IP was developed during two decades of research by teams at RWTH Aachen in Germany and Massey and Victoria Universities in New Zealand



**Prof Bernhard Blümich**, Ampere Prize  
Mobile NMR, Germany

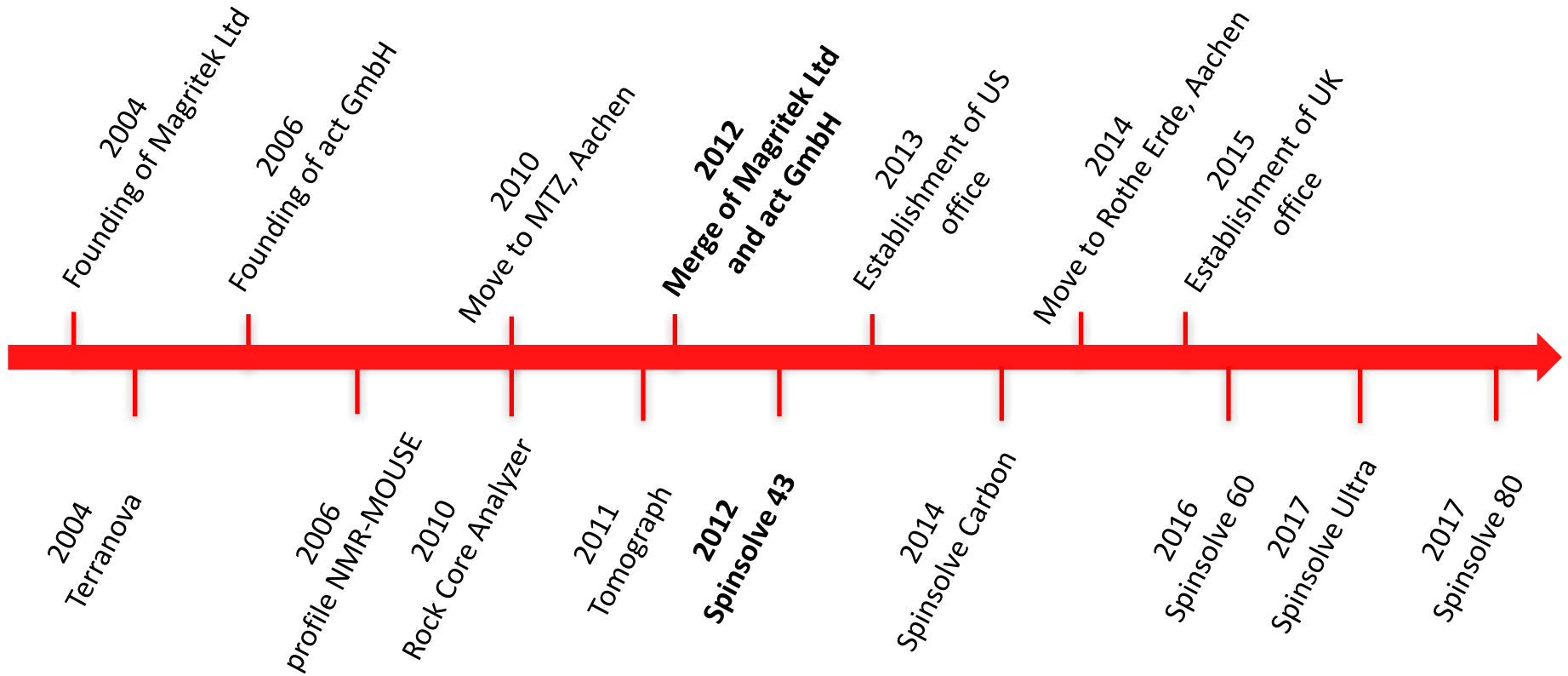


**Prof Paul Callaghan**, Günther Laukien  
Prize, NMR in Antarctica, New Zealand





# The history of Magritek



Spinsolve family

# Magritek today

**Magritek** today has manufacturing and research facilities in Germany and New Zealand, sales and support offices in the USA and UK, and a network of distributors and agents around the world



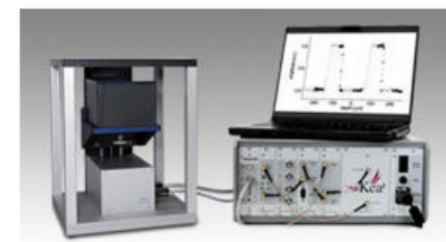
## NMR Spectroscopy



## MRI



## TD-NMR T1, T2, Diffusion



# Magritek's facility in Aachen

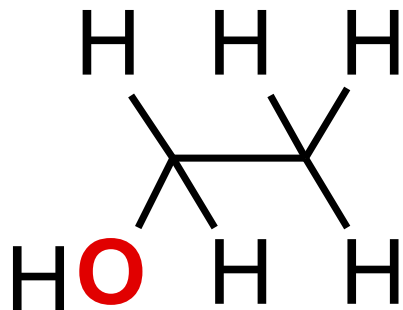


## In the Aachen facility

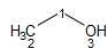
- Production
- R&D
- Application / Application Lab
- **Sample Analysis**
- Customer Demonstrations
- Marketing
- Administration and Controlling



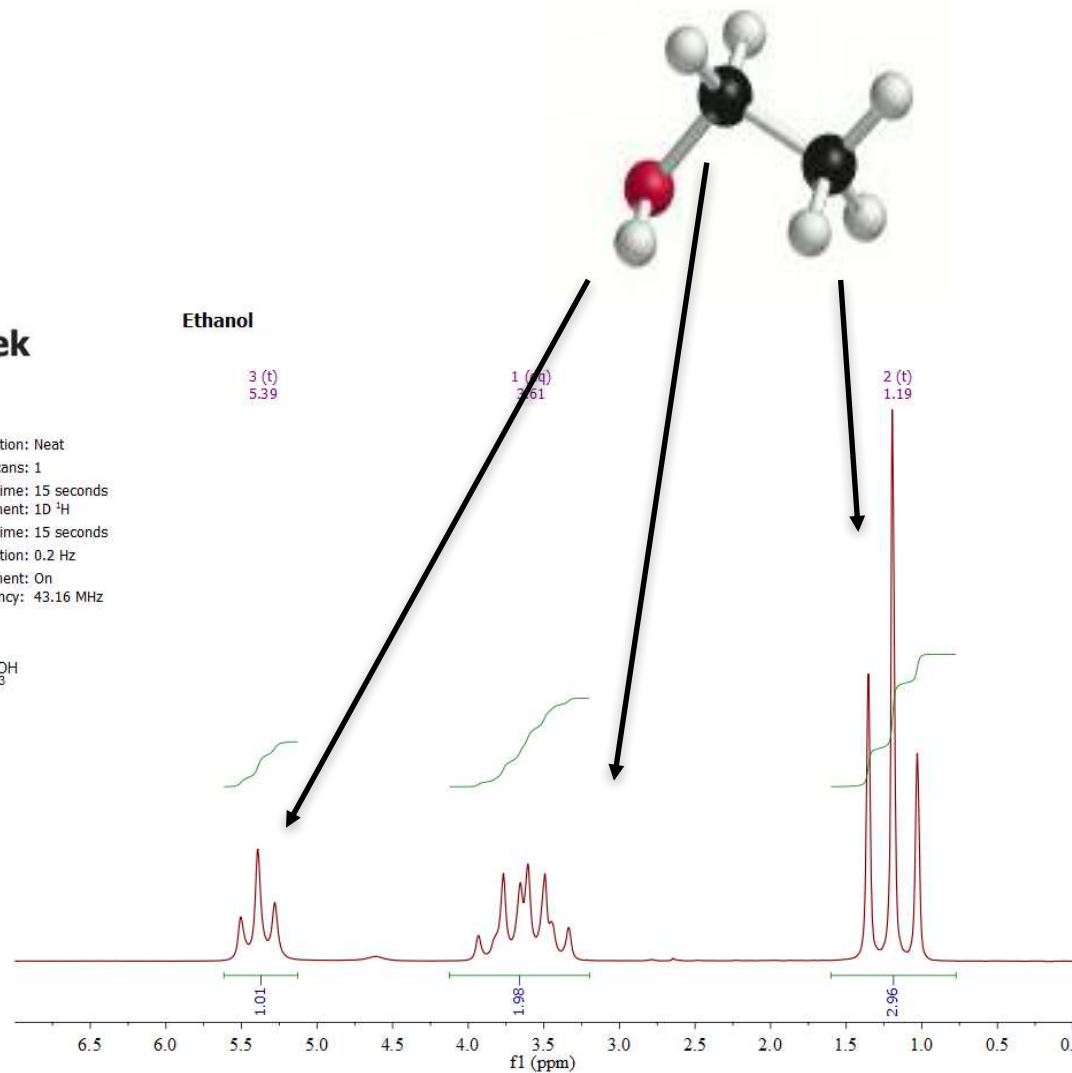
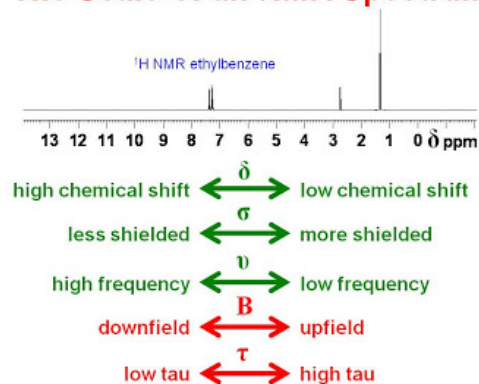
# 1D $^1\text{H}$ NMR spectrum of ethanol



Concentration: Neat  
 Number of scans: 1  
 Repetition time: 15 seconds  
 Experiment: 1D  $^1\text{H}$   
 Total acquisition time: 15 seconds  
 Apodization: 0.2 Hz  
 Resolution enhancement: On  
 Spectrometer frequency: 43.16 MHz



## The Scale of an NMR Spectrum



This ethanol sample has very little water in it, which means the hydroxyl proton couples to the CH<sub>2</sub>. This results in the OH appearing as a triplet and the CH<sub>2</sub> appearing as a doublet of quartets.



# Benefits of NMR

- NMR is a powerful, information rich analytical technique, that can **elucidate molecular structures**
- Essential for organic or synthetic chemists  
“Have I made what I thought I made?”
- Quantifiable  
“How much or how pure is my product?”
- Non-destructive



# Why Benchtop NMR Spectroscopy ?

## High-field NMR systems

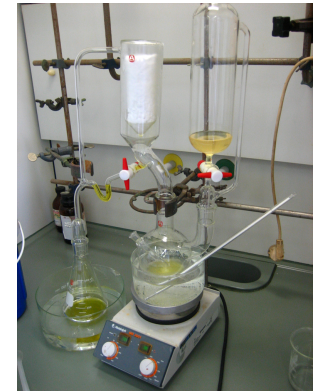
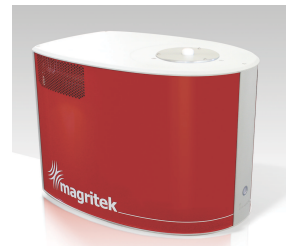
- **Expensive** (capital, cryogen fills, operation, requires special facilities)
- **Complicated** (limited to experts)
- **Fragile** (environment)



Take the sample to the spectrometer

## Benchtop NMR Spectroscopy technology

- **Affordable** (cryogen-free, no special requirements, minimum running costs)
- **Easy to use** (more people can access the technology)
- **Robust** (operates in wide range of environments)



Take the spectrometer to the sample

# Spinsolve Benchtop NMR

Spinsolve™ 43

Spinsolve™ 60

Spinsolve™ 80 **NEW**



**43, 60 and 80 MHz Permanent Magnets**  
with  $^1\text{H}$ ,  $^{19}\text{F}$   
and  
 $^{13}\text{C}$ ,  $^{31}\text{P}$ ,  $^{15}\text{N}$ ,  $^{29}\text{Si}$ ,  $^{11}\text{B}$ ,  $^2\text{H}$  Capabilities  
(one of those / X nuclei)

<sup>1</sup> Each Spinsolve System features patented magnet technology.

The following patents apply: US20100013473A1, US8148988, EP2144076A1, EP2144076B1



# Spinsolve 80 Carbon



80 MHz permanent magnet

No cryogenics

$^1\text{H}$ ,  $^{19}\text{F}$  and  $^{13}\text{C}$

Built in External Lock

No spinning, no air required

Benchtop size and weight

5mm NMR tubes

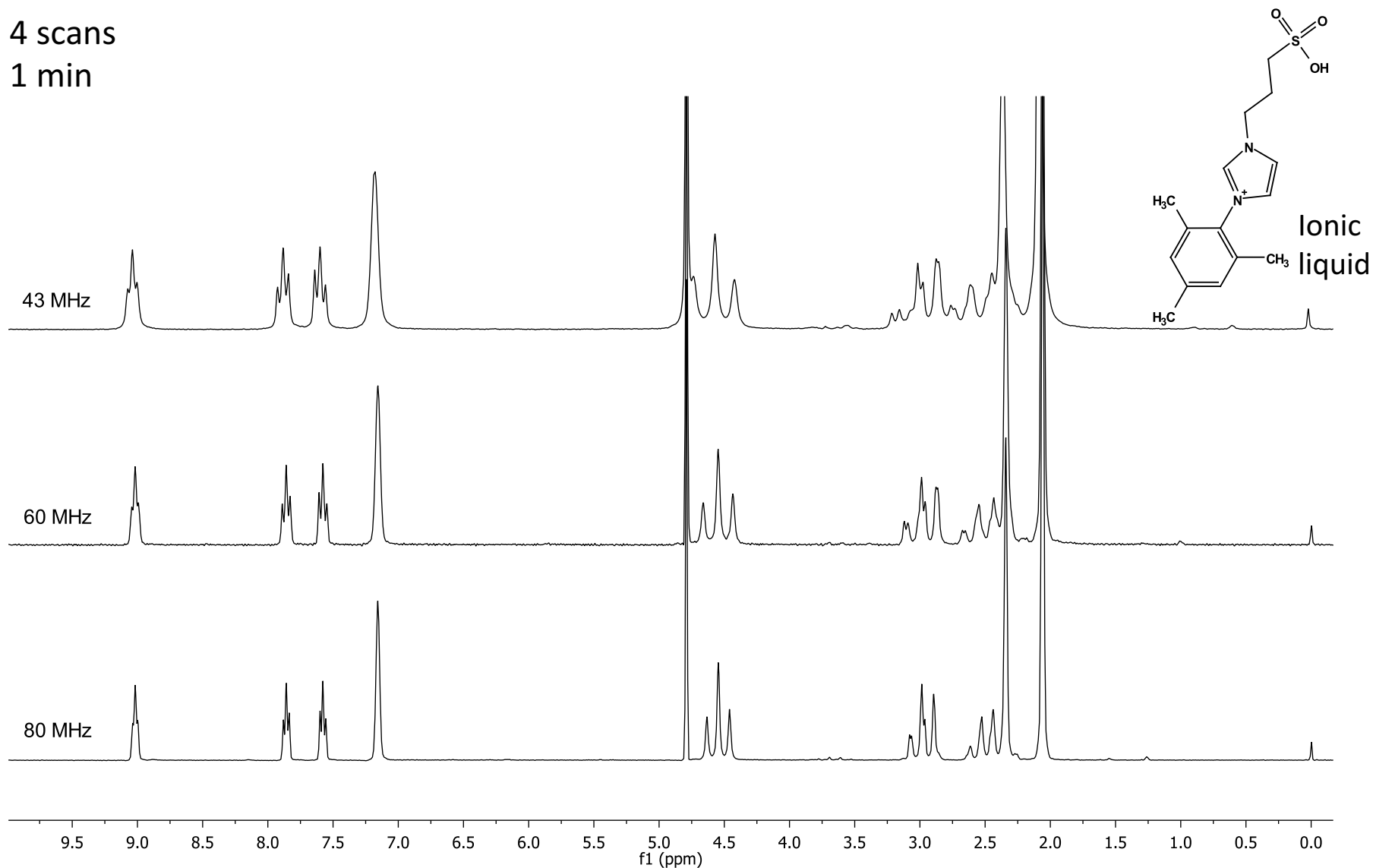
Easy to use software

Robust and Low Maintenance



# Benefit of higher frequency – 1D $^1\text{H}$

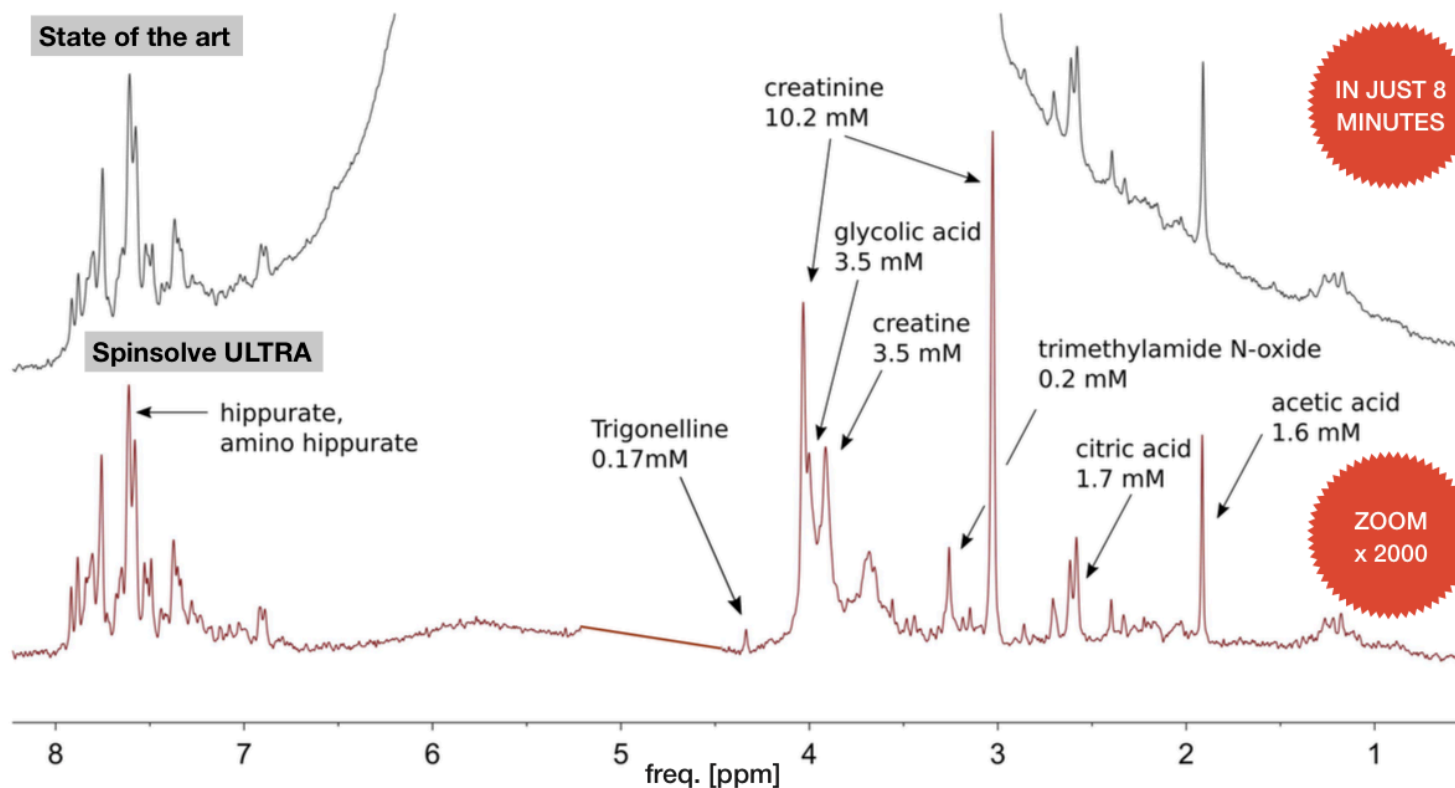
4 scans  
1 min



# Spinsolve ULTRA (43 / 60 MHz)

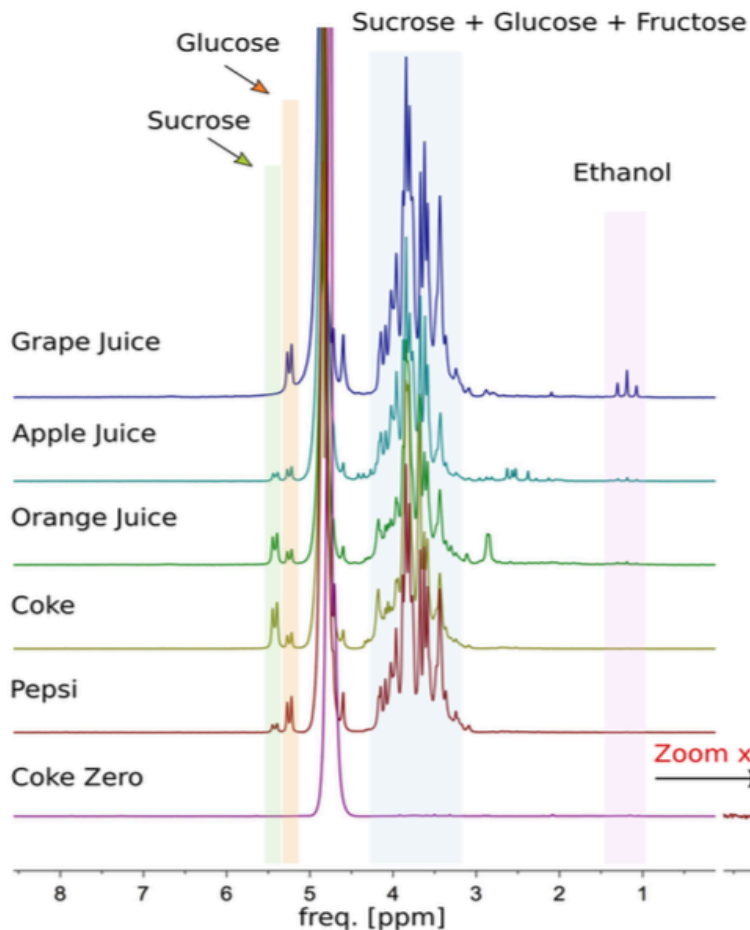
Ultra-high field homogeneity combined with solvent suppression allows you to resolve compounds dissolved at sub-millimolar concentrations in protonated solvents, such as water.

## Resolving metabolites in urine at milli-molar concentrations

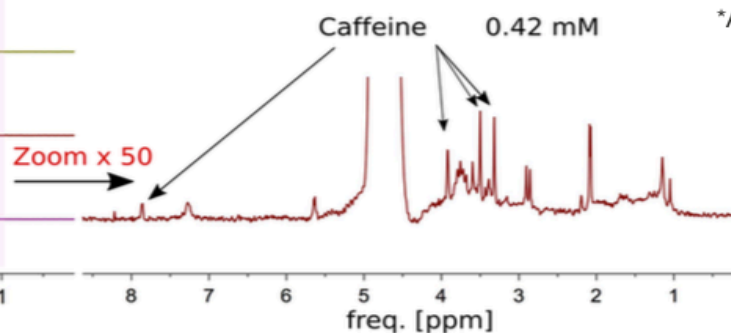


## Measuring sugar content in soft drinks

Spinsolve ULTRA measures not only the sugar content but can also identify the type of sugars present in the sample. The high sensitivity of the system allows you to quantify with high accuracy the ethanol content typically present at very low concentrations in natural fruit juices. The samples here are all neat. All measurements took 8 minutes, except Coke Zero was 1 hour.



	Sucrose	Glucose	Fructose	Total (NMR)	Total (Label)	Ethanol
Grape	0.0	10.0	6.2	16.2	16.0	0.16
Apple	1.1	2.4	6.4	9.8	9.8	0.03
Orange	3.7	2.0	3.8	9.5	9.0	0.02
Coke	6.0	2.8	1.9	10.7	10.7	0
Pepsi	1.1	5.6	4.4	11.2	10.7	0
Zero	0	0	0	0	0	0



\*All units g/100ml. Ethanol is % vol.

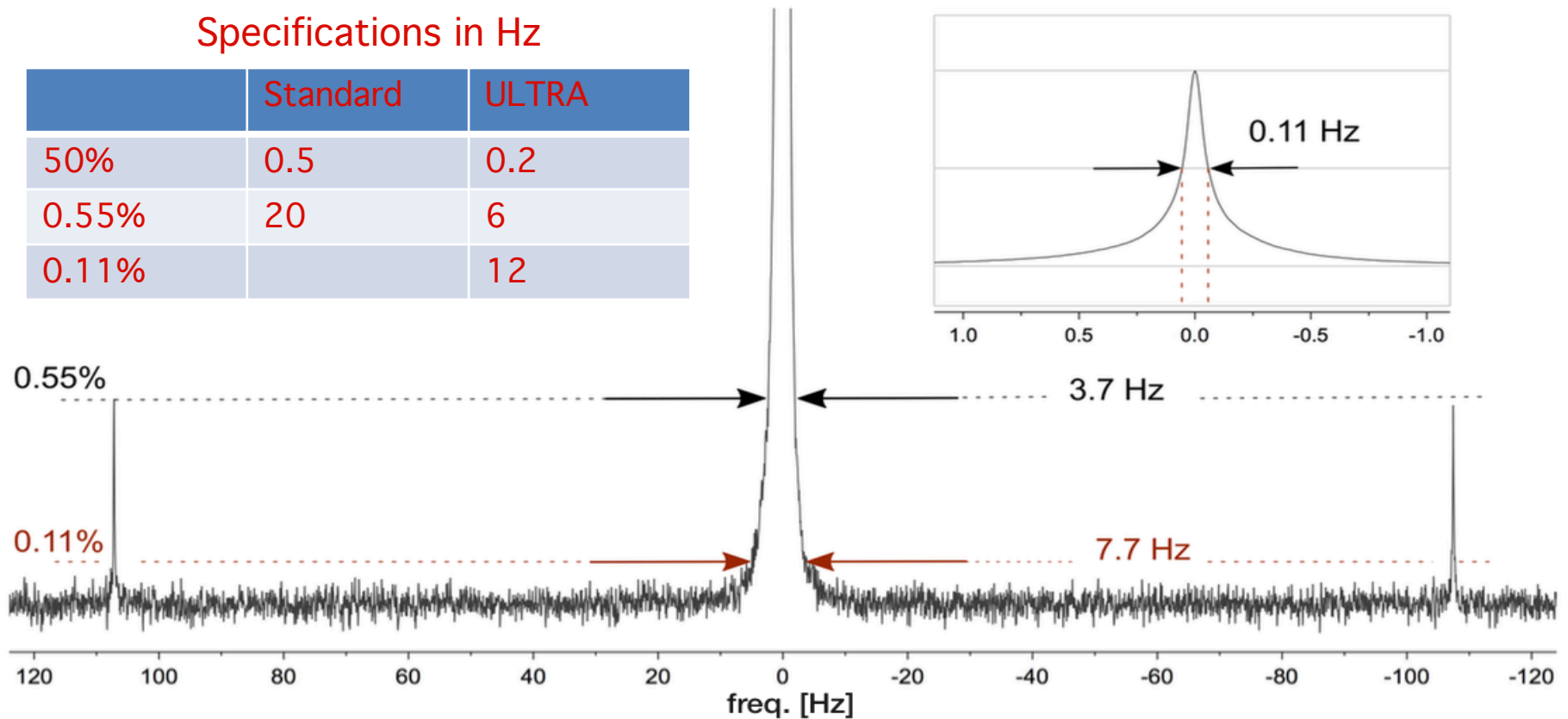
# Resolution (Standard and ULTRA) / Line Shape

## Linewidth measured in a chloroform spectrum

- No sample spinning, no spinning side bands, no requirement for compressed air
- No reference deconvolution, only standard NMR data processing is used

### Specifications in Hz

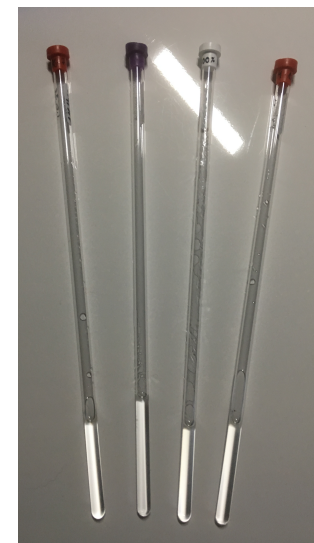
	Standard	ULTRA
50%	0.5	0.2
0.55%	20	6
0.11%		12



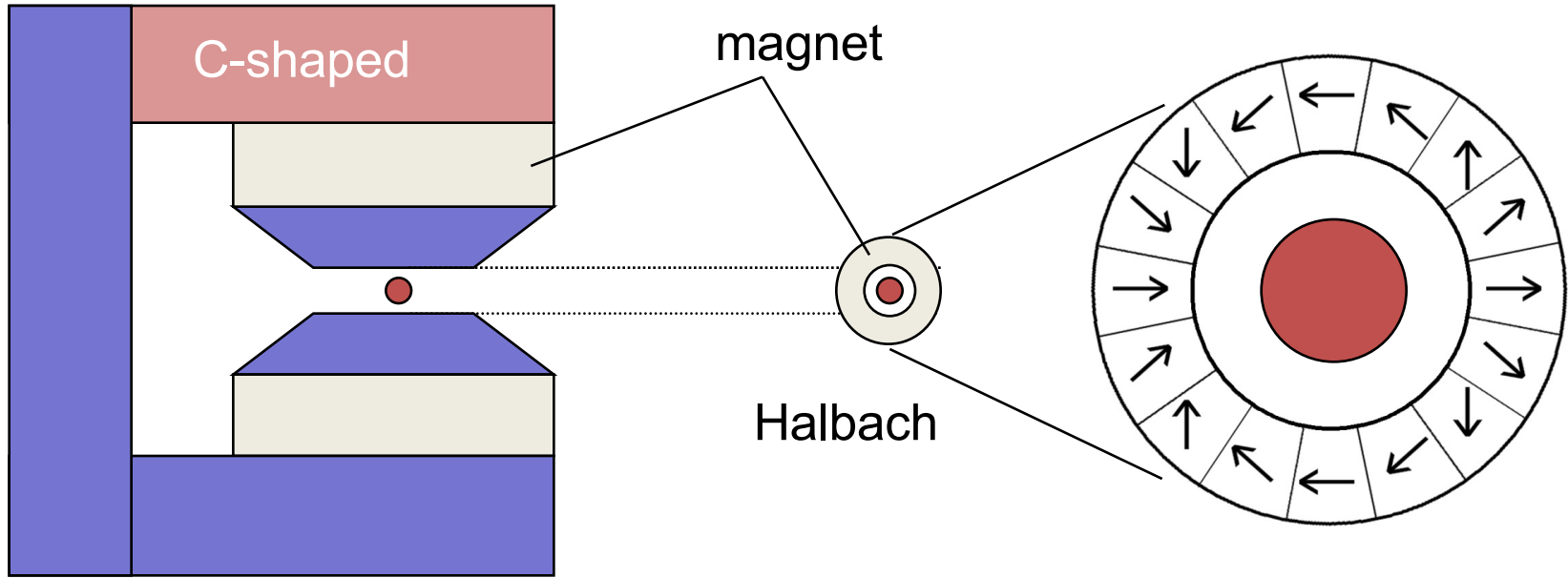


# Benefits of the Spinovle

- Compact, fits on normal lab bench
- No cryogenes needed
- Robust and easy to use software
- Fast results
- Standard size economy style 5 mm NMR tubes can be used
- Alternative: Reaction Monitoring Setup
- No sample spinning/compressed gas
- Deuterated solvents are not necessary
- Superior sensitivity, resolution, and stability compared to other benchtop NMR

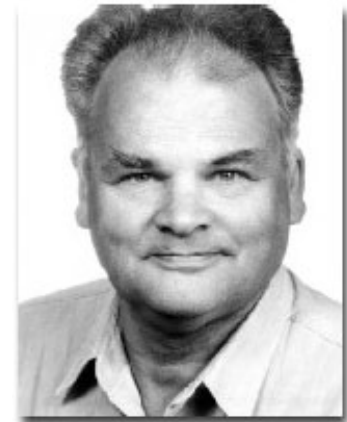


# Halbach Magnet vs. C-Shaped Magnet



$$B_0(\vec{r}) = K \ln(r_{out} / r_{in})$$

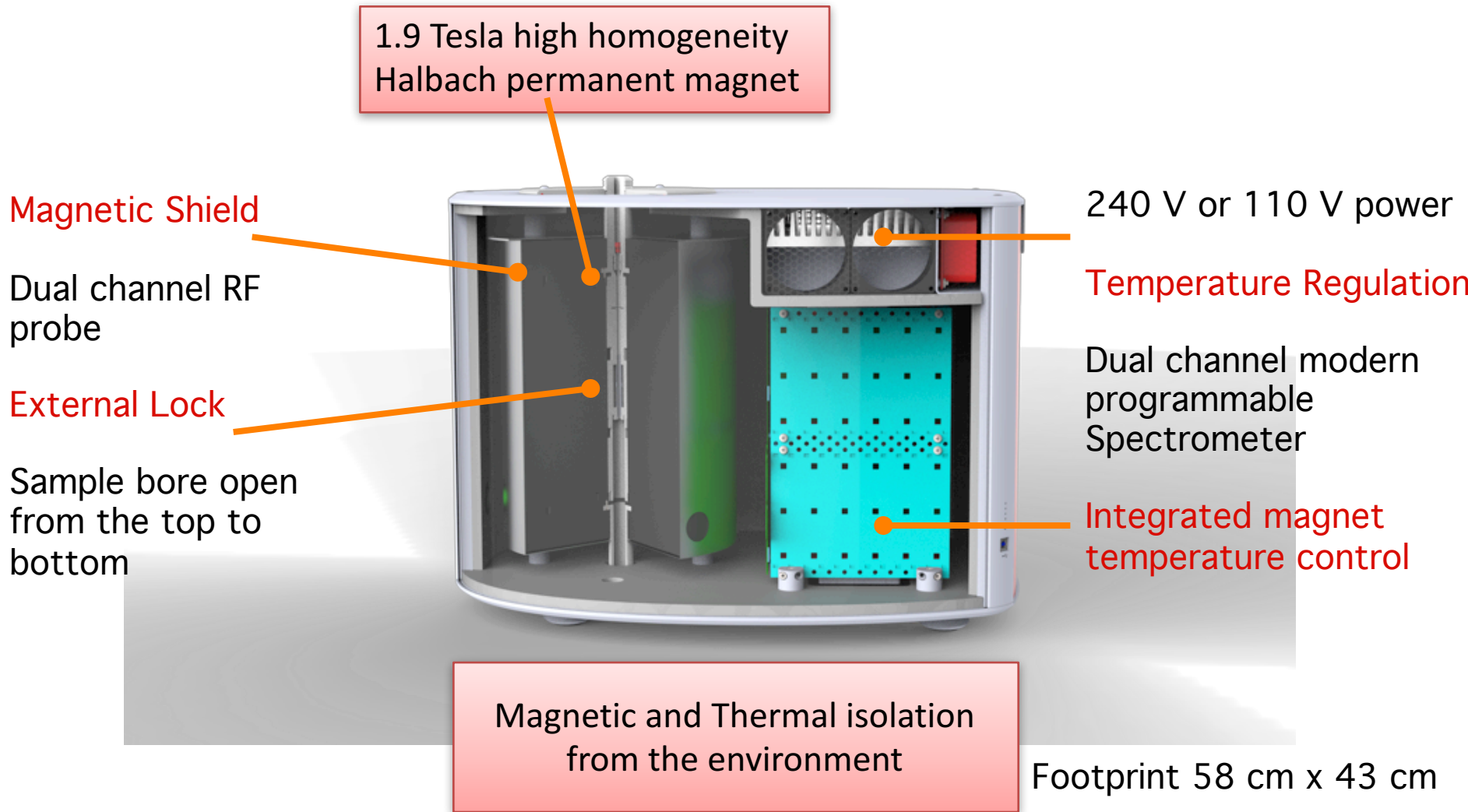
K. Halbach, Nucl. Instr. Meth. 169 (1980)



<sup>1</sup> Each Spinsolve System features patented magnet technology.

The following patents apply: US20100013473A1, US8148988, EP2144076A1, EP2144076B1

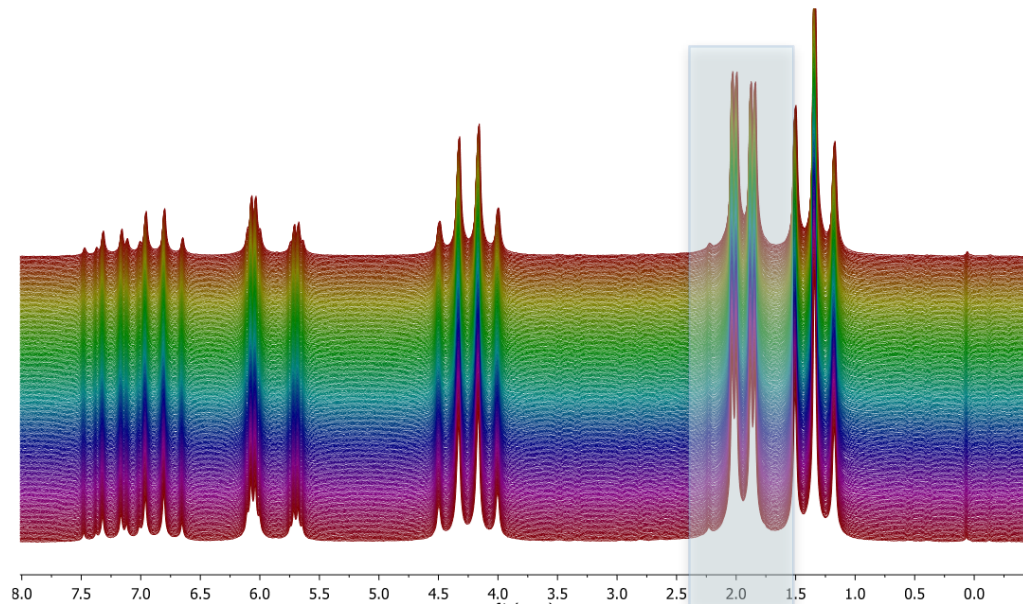
# Spinsolve 80 Carbon Hardware (73 kg)



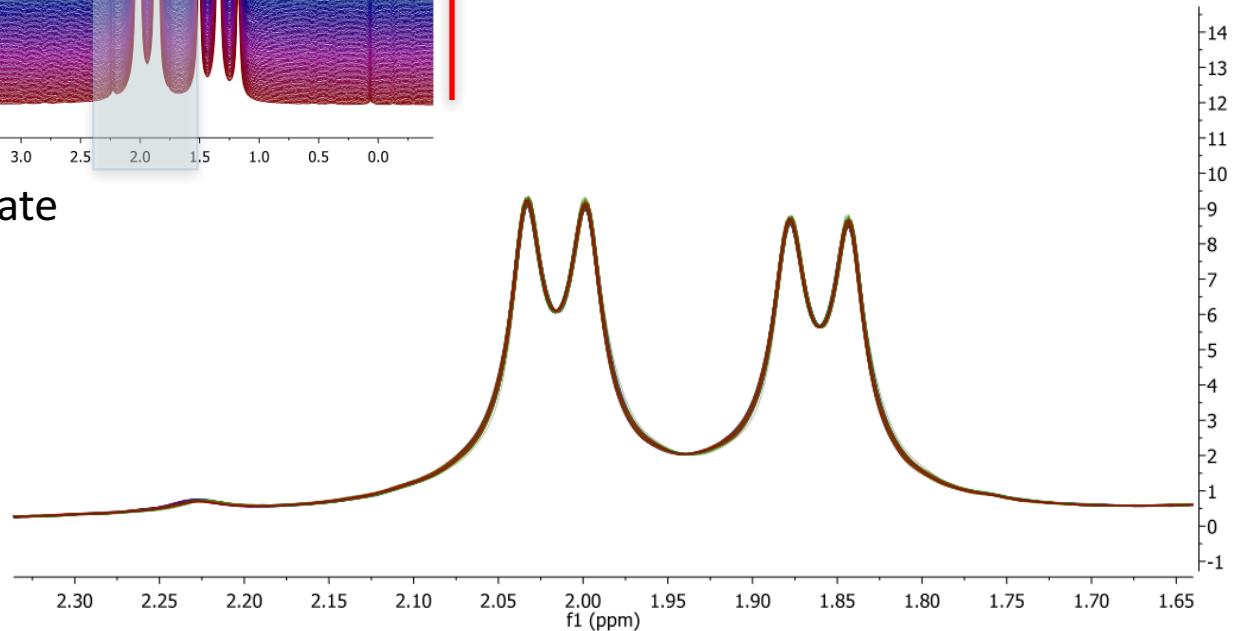
Very similar situation for the 43/60 MHz Spinsolve Systems (55/60 kg)

# Spinsolve Stability

- 1 scan every 30 minutes
- 250 scans
- No shimming between scans
- **5 day experiment !!**

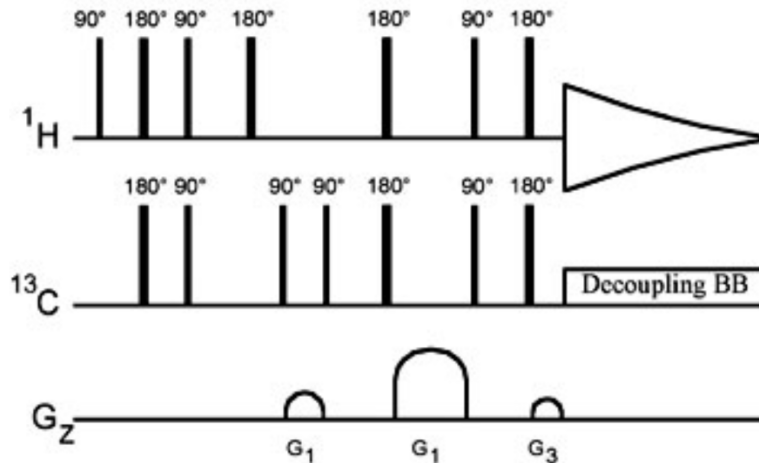


Ethyl Crotonate



**5 days of scans superimposed**





2D HETCOR  
2D HMBC  
2D HMQC  
2D HSQC  
2D HSQC-ME ...

## Modern NMR Pulse sequences

- Multipulse electronics capability
- 2D NMR sequences
- Inverse detection
- Coherence selection
- Decoupling
  
- Artifacts :  $T_1$  noise, phase, ...

Stability

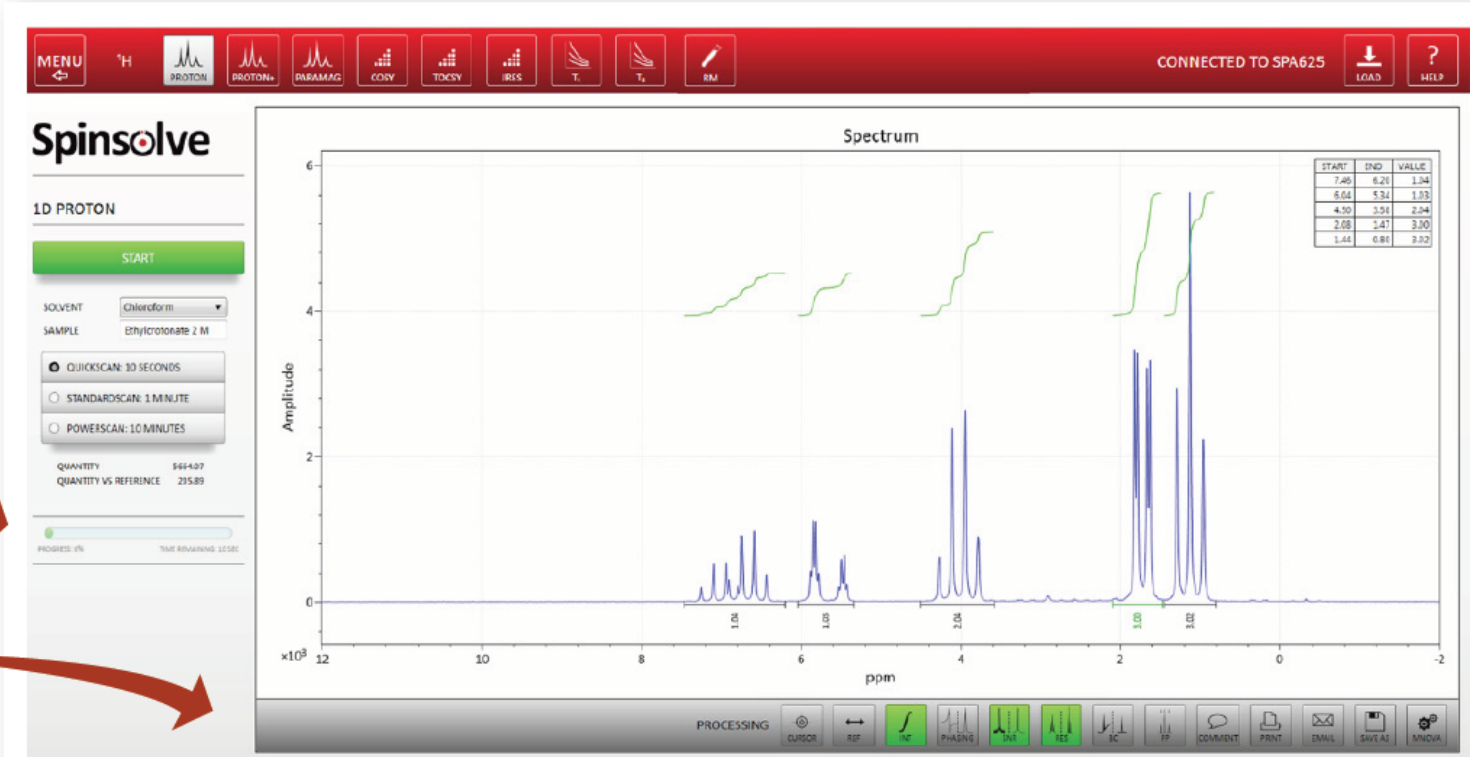
# Easy to Use Standard Software

Easy experiment selection in the upper menu

Single button start

Progress bar

One-click processing buttons



The screenshot displays the Spinsolve software interface. At the top, a red menu bar contains icons for various experiments: MENU,  $^1\text{H}$ , PROTON, PROTON+, PARAMAG, COSY, TOCSY, JRES,  $T_1$ ,  $T_2$ , and RM. On the right of the menu bar, it shows 'CONNECTED TO SPA625' and buttons for 'LOAD' and 'HELP'. The main window is titled 'Spinsolve' and features a '1D PROTON' section with a prominent green 'START' button. Below this, there are settings for 'SOLVENT' (Chloroform) and 'SAMPLE' (Ethylcrotonate 2 M). Three scan options are available: 'CLICKSCAN: 30 SECONDS' (selected), 'STANDARDSCAN: 1 MINUTE', and 'POWERSCAN: 10 MINUTES'. A 'QUANTITY' field shows '966407' and 'QUANTITY VS REFERENCE' shows '29589'. A progress bar at the bottom of this section indicates 'PROGRESS: 6%' and 'TIME REMAINING: 12:58'. The central area displays a 'Spectrum' plot of Amplitude vs. ppm (x10<sup>3</sup>). The x-axis ranges from 12 to -2 ppm. The spectrum shows several peaks, with integration curves overlaid in green. A data table in the top right corner of the plot area provides integration values:

START	END	VALUE
7.46	6.21	1.34
6.04	5.34	1.33
4.30	3.51	2.34
2.68	1.47	3.30
1.44	0.81	3.32

At the bottom of the interface, a 'PROCESSING' bar contains various tool icons: CURSOR, REF, F1, PHASING, INT, JRES, T1, T2, and RM.

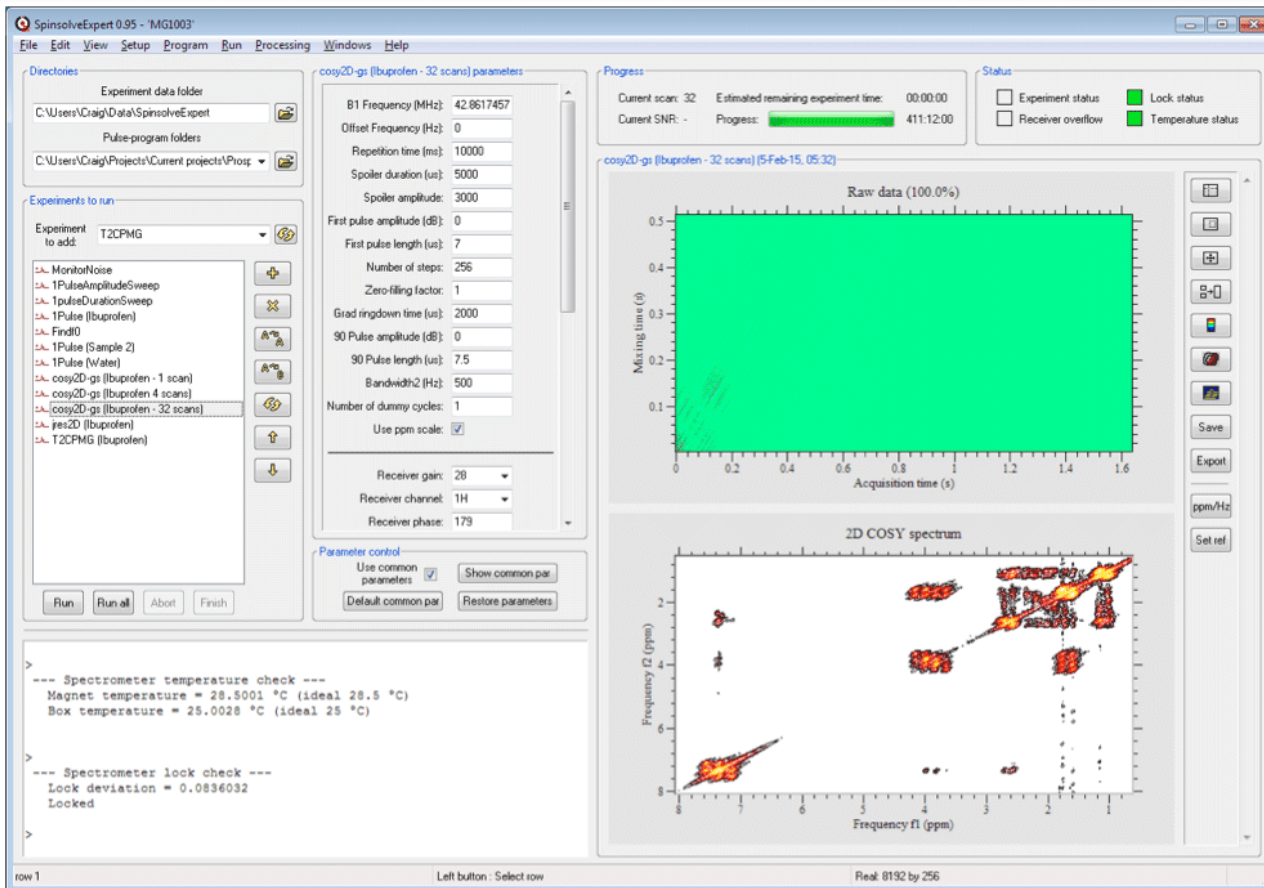


A red menu bar with five icons: MENU,  $^1\text{H}$ ,  $^{19}\text{F}$ , SYSTEM, and SCRIPTS.



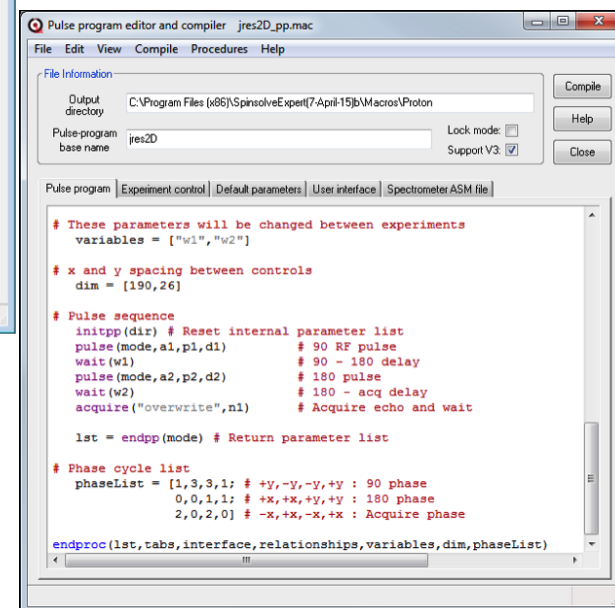
A red menu bar with ten icons: MENU,  $^1\text{H}$ , PROTON, PROTON+, PARAMAG, COSY, TOCSY, JRES,  $T_1$ ,  $T_2$ , and RM.

# Advanced Expert Software



The screenshot shows the SpinsolveExpert 0.95 software interface. The main window is titled "SpinsolveExpert 0.95 - 'MG1003'". It features a menu bar (File, Edit, View, Setup, Program, Run, Processing, Windows, Help) and a toolbar. The interface is divided into several panels:

- Directories:** Shows the experiment data folder and pulse-program folders.
- Experiments to run:** A list of experiments including MonitorNoise, 1PulseAmplitudeSweep, 1PulseDurationSweep, 1Pulse (buprofen), Find0, 1Pulse (Sample 2), 1Pulse (Water), cosy2D-gs (buprofen - 1 scan), cosy2D-gs (buprofen 4 scans), cosy2D-gs (buprofen - 32 scans), jes2D (buprofen), and T2CPMG (buprofen).
- Parameters:** A list of parameters for the "cosy2D-gs (buprofen - 32 scans)" experiment, such as B1 Frequency (42.8617457 MHz), Offset Frequency (0 Hz), Repetition time (10000 ms), Spoiler duration (5000  $\mu$ s), Spoiler amplitude (3000), First pulse amplitude (0 dB), First pulse length (7  $\mu$ s), Number of steps (256), Zero-filling factor (1), Grad ringdown time (2000  $\mu$ s), 90 Pulse amplitude (0 dB), 90 Pulse length (7.5  $\mu$ s), Bandwidth2 (500 Hz), and Number of dummy cycles (1).
- Progress:** Shows the current scan (32), estimated remaining time (00:00:00), current SNR, and progress bar (411:12:00).
- Status:** Includes checkboxes for Experiment status, Lock status, Receiver overflow, and Temperature status.
- Raw data (100.0%):** A 2D plot of Mixing time (s) vs Acquisition time (s) showing a green background with some faint patterns.
- 2D COSY spectrum:** A 2D plot of Frequency f2 (ppm) vs Frequency f1 (ppm) showing several peaks and cross-peaks.
- Parameter control:** Includes checkboxes for "Use common parameters" and "Show common par", and buttons for "Default common par" and "Restore parameters".
- Log/Status:** A text area at the bottom left showing spectrometer temperature and lock check results.



The screenshot shows the Pulse program editor and compiler interface for the file "jes2D\_pp.mac". The window title is "Pulse program editor and compiler jes2D\_pp.mac". It has a menu bar (File, Edit, View, Compile, Procedures, Help) and a toolbar. The interface includes:

- File Information:** Shows the output directory (C:\Program Files (x86)\SpinsolveExpert\7-April-15\bin\Macros\Proton) and the pulse-program base name (jes2D).
- Code Editor:** Contains the pulse program code, which includes comments and instructions for setting variables, pulse sequence, and phase cycle list.

```
# These parameters will be changed between experiments
variables = ["w1", "w2"]

# x and y spacing between controls
dim = [190, 26]

# Pulse sequence
initpp(dir) # Reset internal parameter list
pulse(mode, a1, p1, d1) # 90 RF pulse
wait(w1) # 90 - 180 delay
pulse(mode, a2, p2, d2) # 180 pulse
wait(w2) # 180 - acq delay
acquire("overwrite", n1) # Acquire echo and wait

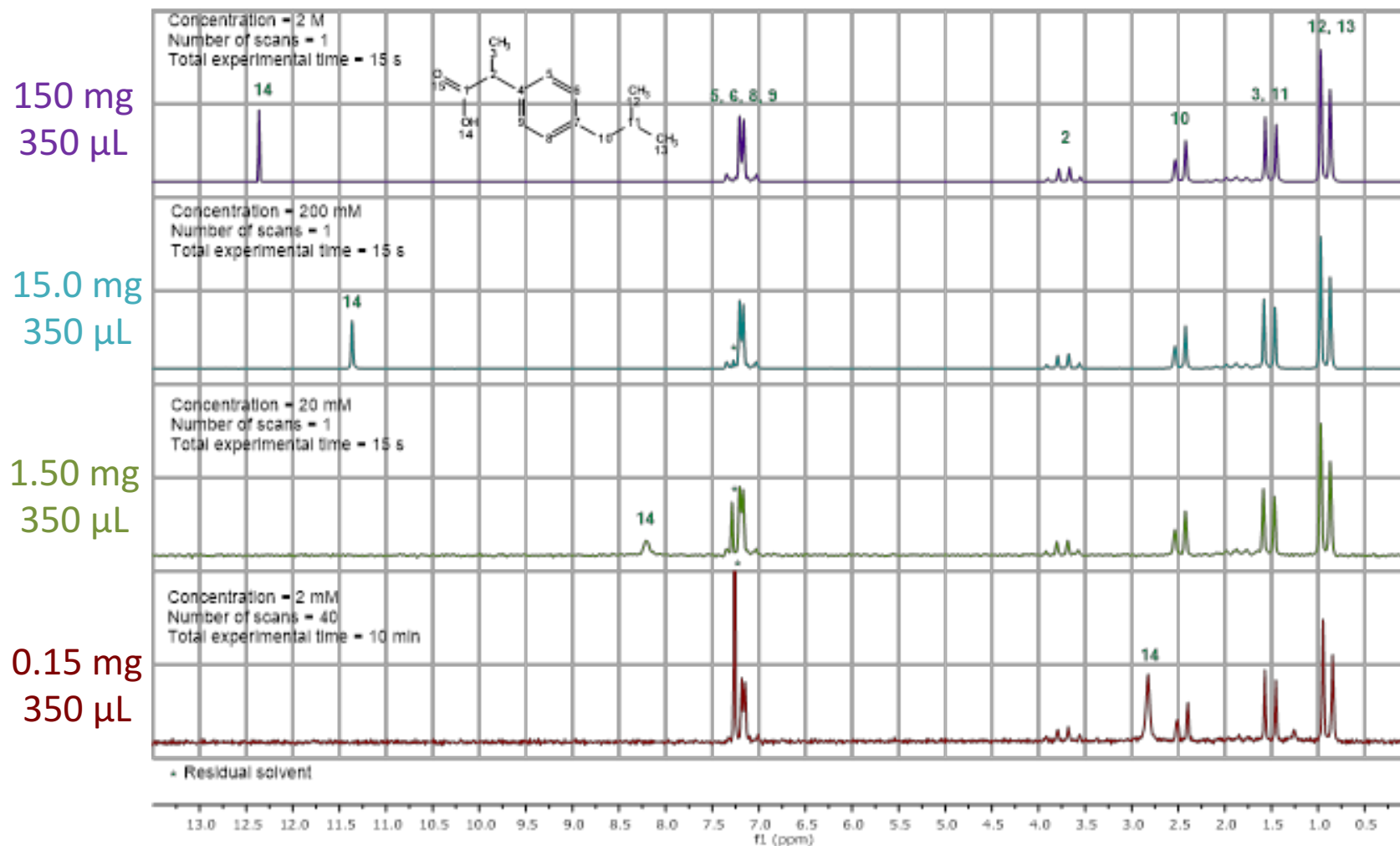
lst = endpp(mode) # Return parameter list

# Phase cycle list
phaseList = [1, 3, 3, 1: # +y, -y, -y, +y : 90 phase
0, 0, 1, 1: # +x, +x, +y, +y : 180 phase
2, 0, 2, 0] # -x, +x, -x, +x : Acquire phase

endproc(lst, tabs, interface, relationships, variables, dim, phaseList)
```

# Proton Sensitivity

NMR Spectra (60 MHz) of Ibuprofen  
2 M, 200 mM, 20 mM and 2 mM in Chloroform



# 1D <sup>1</sup>H Ethyl crotonate

## Ethyl crotonate

Solvent = CDCl<sub>3</sub>

Concentration = 250 mM

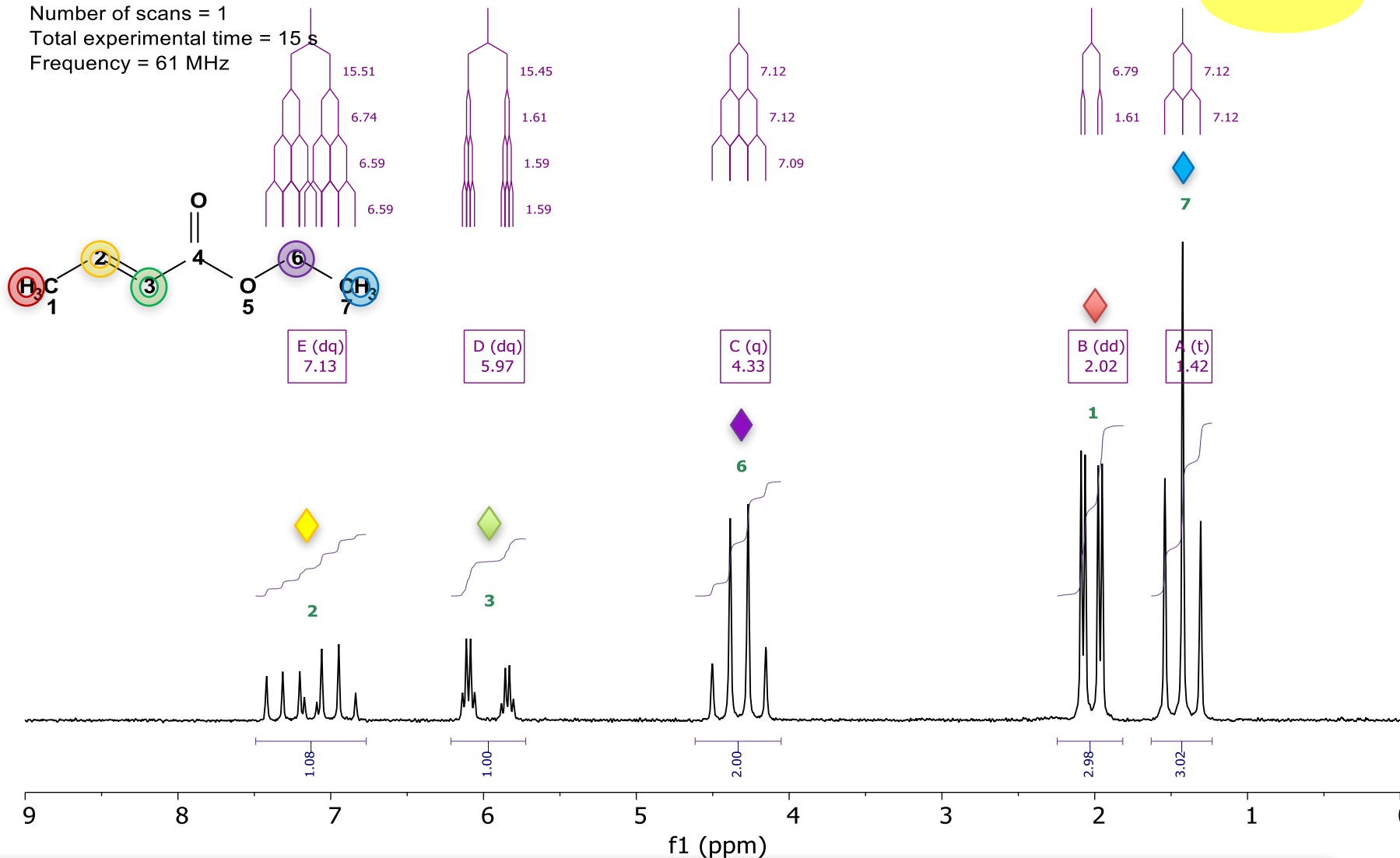
Number of scans = 1

Total experimental time = 15 s

Frequency = 61 MHz



15 seconds



# 2D Homonuclear COSY



10 min

## Ethyl crotonate

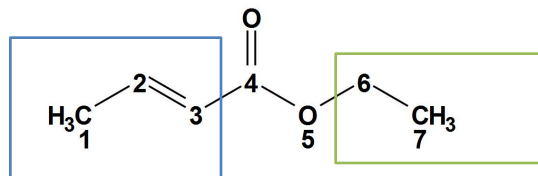
Solvent = CDCl<sub>3</sub>

Concentration = 250 mM

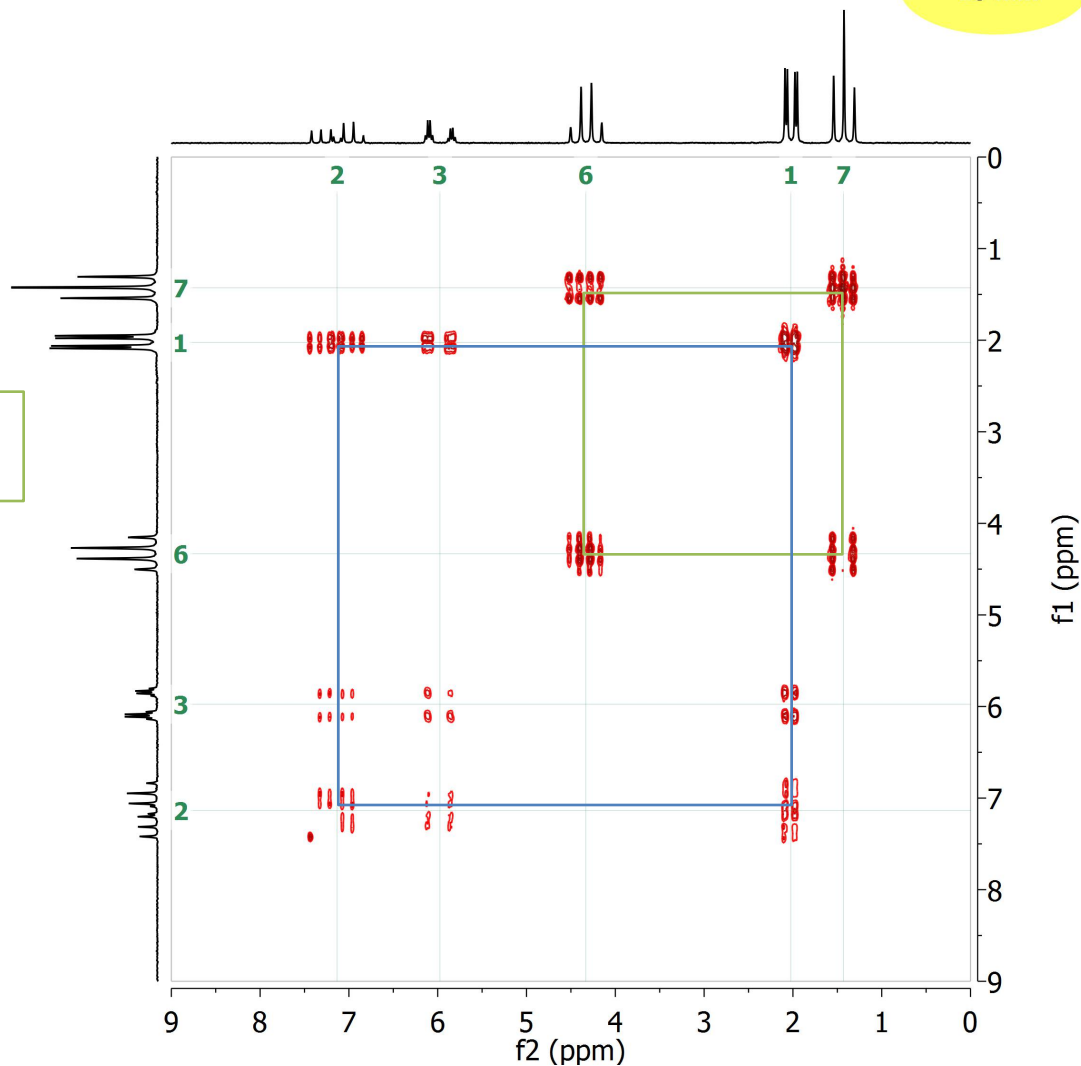
Number of scans = 1

Total experimental time = 10 min

Frequency = 61 MHz



No Symmetrization



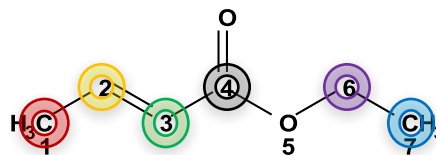


# 1D <sup>13</sup>Carbon DEPT Cycle



## Ethyl crotonate

Solvent = CDCl<sub>3</sub>  
Concentration = 1 M  
Frequency = 15 MHz



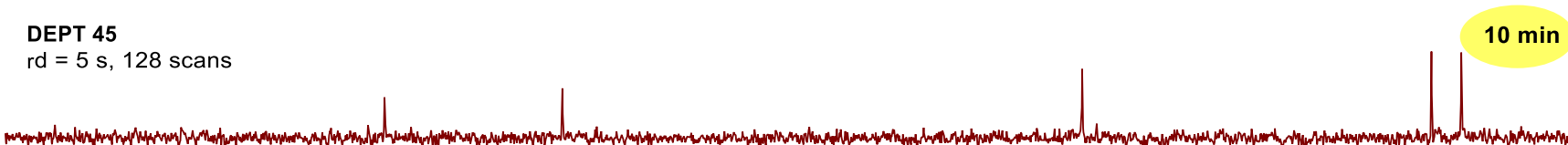
### 1D Carbon

rd = 2 s, 1024 scans  
pulse angle = 45°



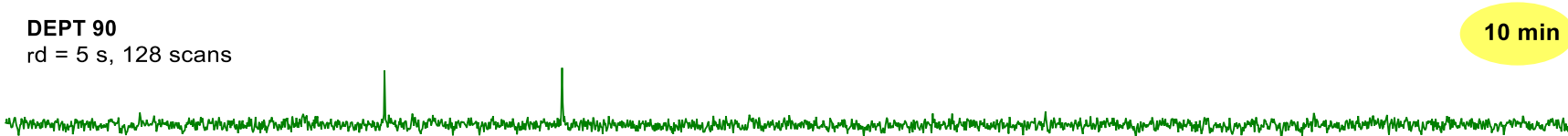
### DEPT 45

rd = 5 s, 128 scans



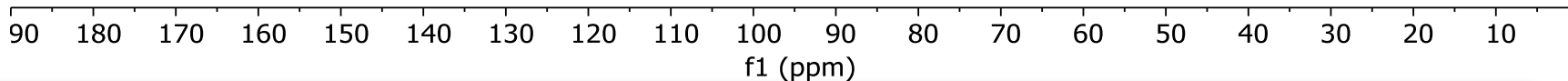
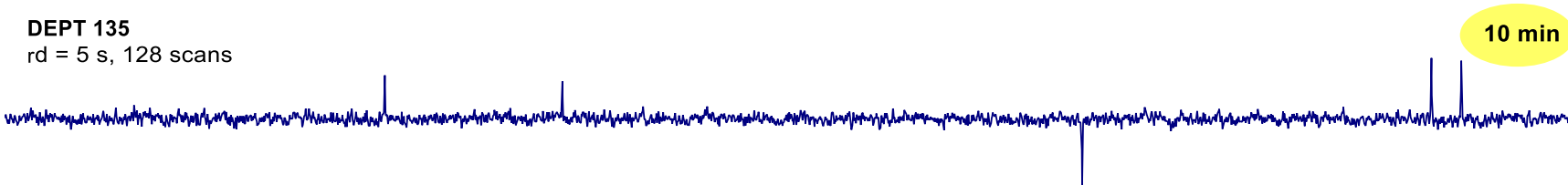
### DEPT 90

rd = 5 s, 128 scans

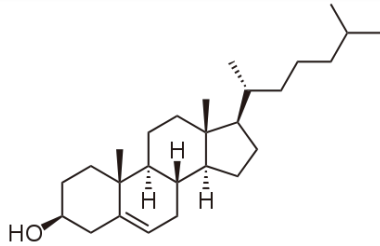


### DEPT 135

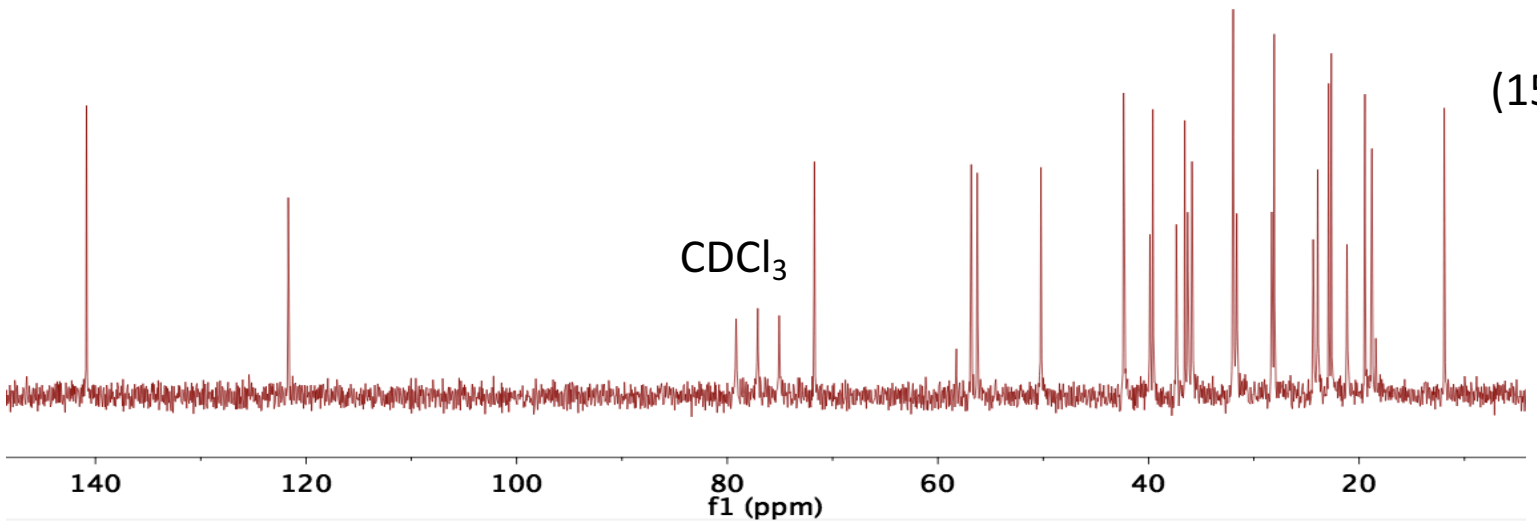
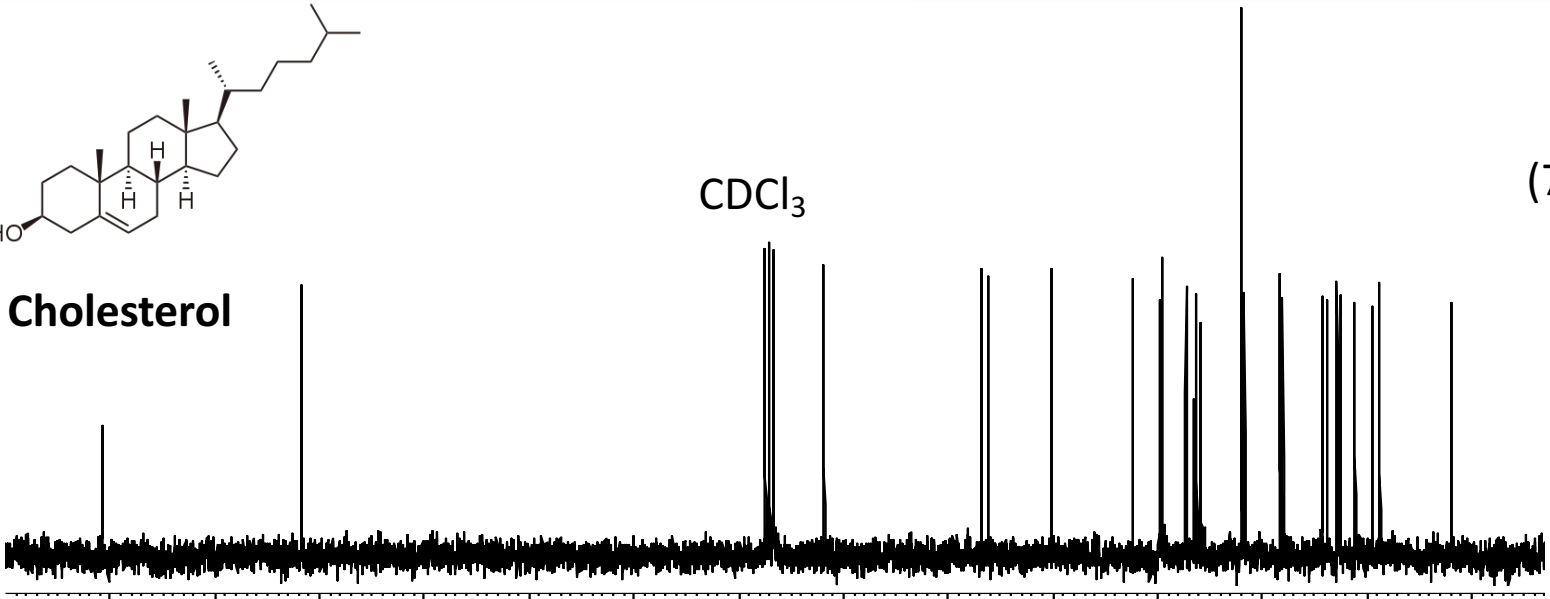
rd = 5 s, 128 scans



# Structure elucidation – $^{13}\text{C}$ Spectra are similar



Cholesterol

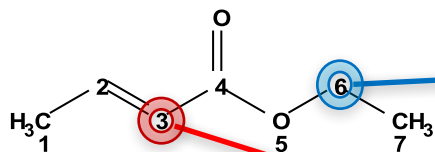


# 2D HSQC – Multiplicity Edited (ME)



## Ethyl crotonate

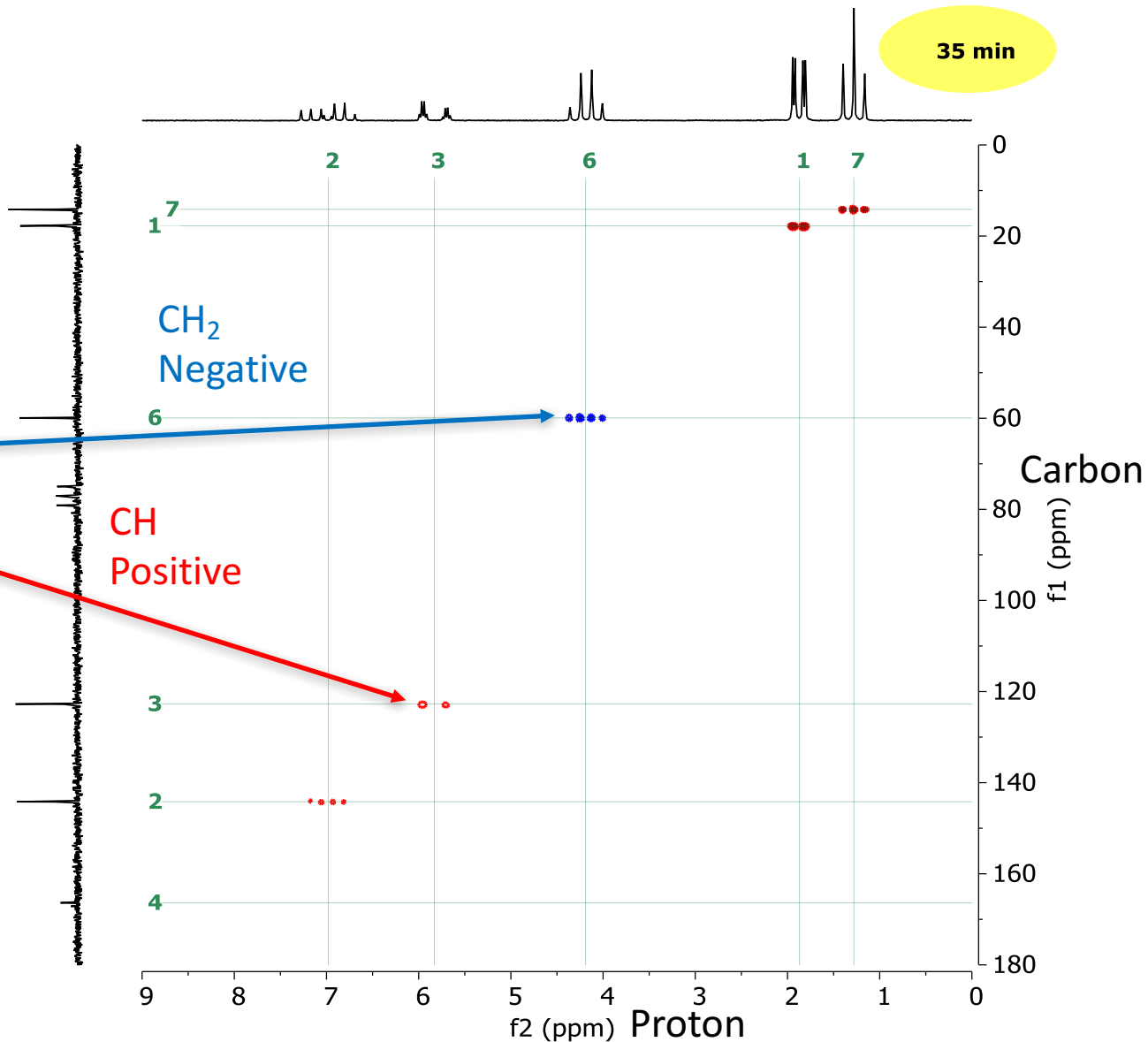
Solvent =  $\text{CDCl}_3$   
Concentration = 1 M  
Number of scans = 4  
Repetition time = 2 s  
Total experimental time = 35 min  
Frequency = 15 MHz



Single bond connectivity  
Inverse detection  
With multiplicity information

Red = CH and  $\text{CH}_3$

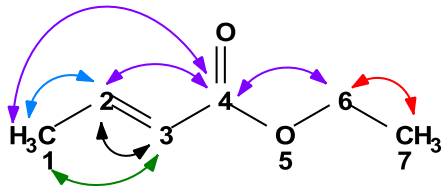
Blue =  $\text{CH}_2$



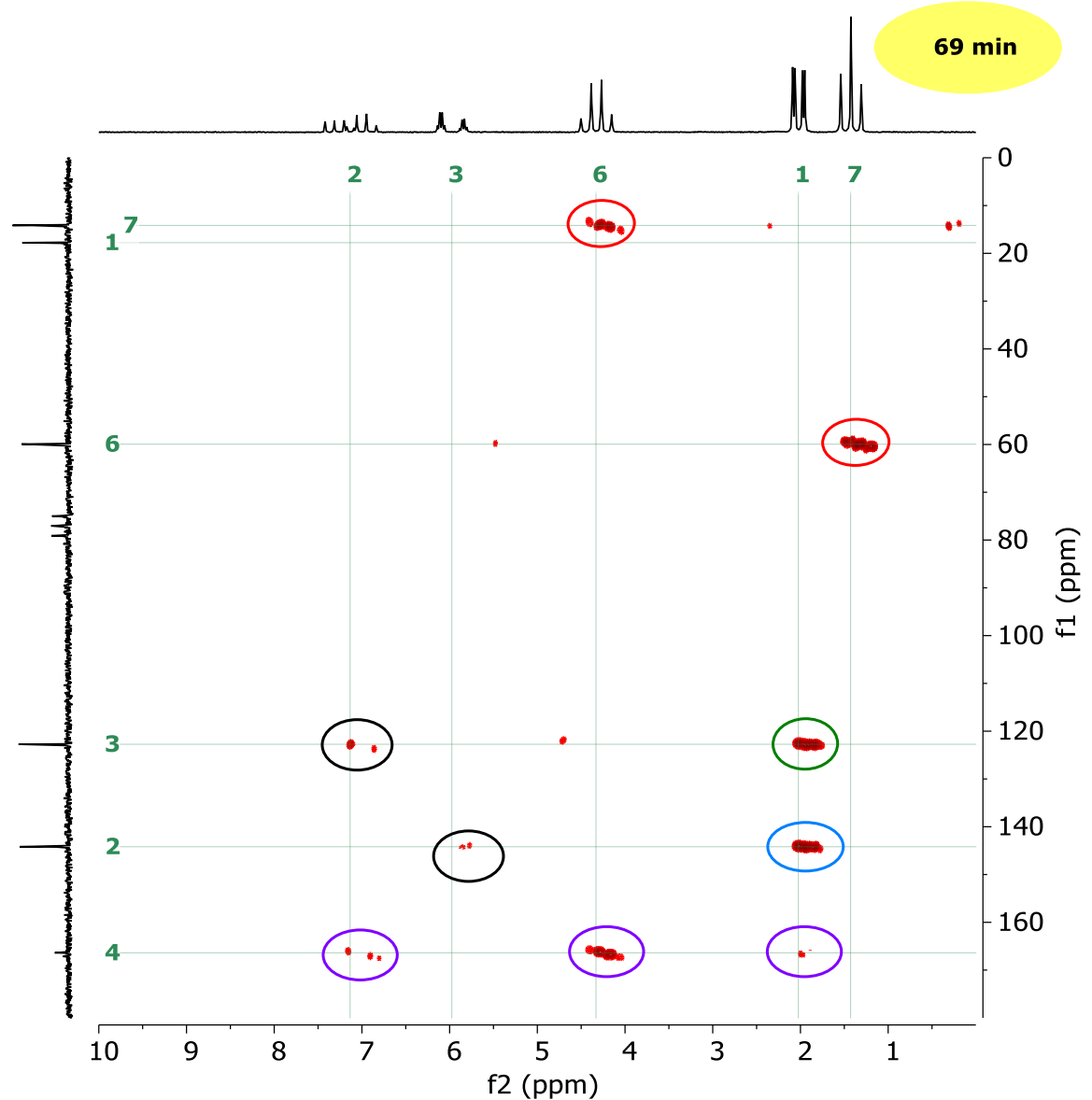
# 2D HMBC Ethyl crotonate

## Ethyl crotonate

Solvent =  $\text{CDCl}_3$   
Concentration = 1 M  
Number of scans = 16  
Repetition time = 2 s  
Total experimental time = 69 min  
Frequency = 15 MHz



Multiple bond connectivity  
Inverse detection



# Spinsolve Pulse Sequences

## 1H Proton

- 1D PROTON
- Paramagnetic Wideband
- 13C-decoupled 1D Proton
- 19F-decoupled 1D proton
- 2D COSY
- 2D TOCSY
- 2D ROESY
- 2D JRES
- T1, T2
- Reaction Monitoring

## 19F Fluorine

- 1D Fluorine
- Paramagnetic Wideband
- 1H-decoupled 1D Fluorine
- 2D F COSY
- 2D F JRES
- 2D FH COSY
- Reaction Monitoring

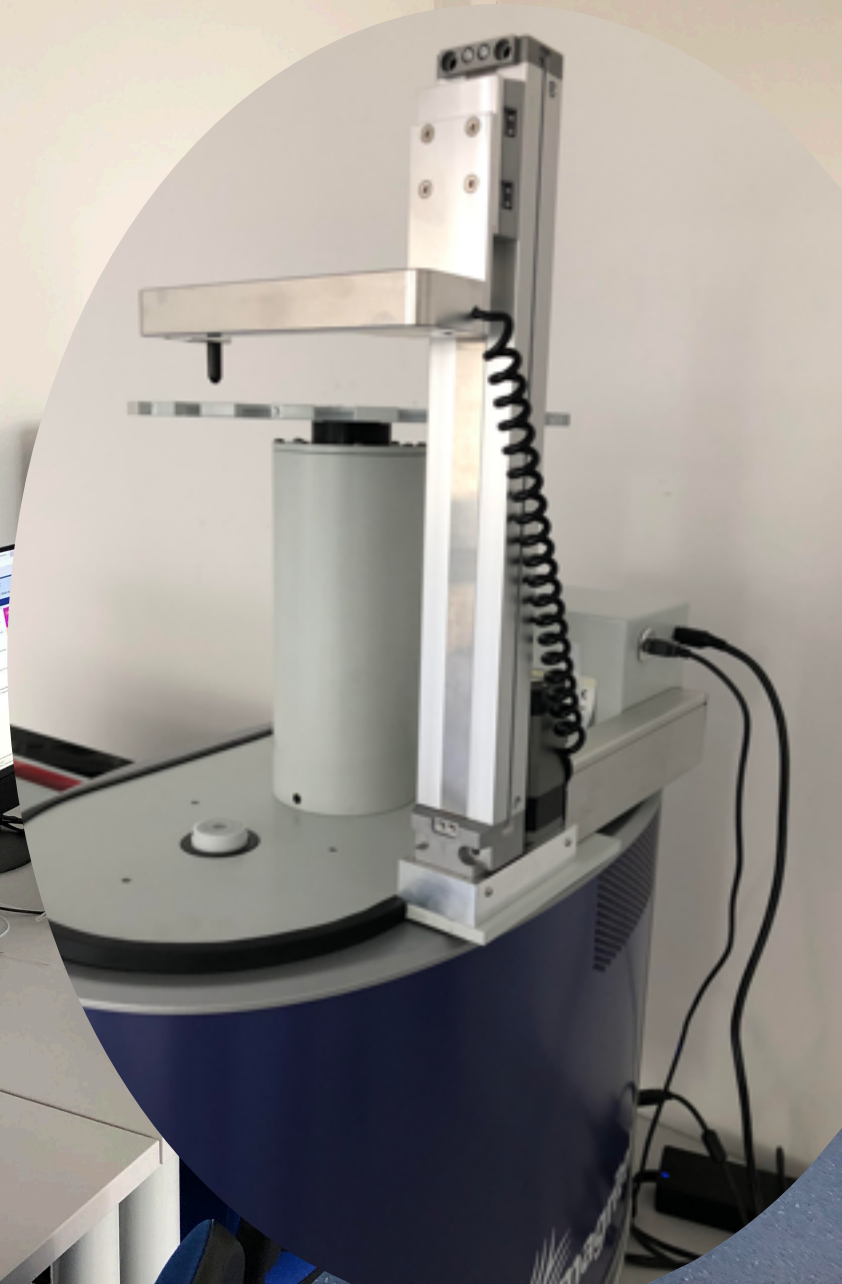
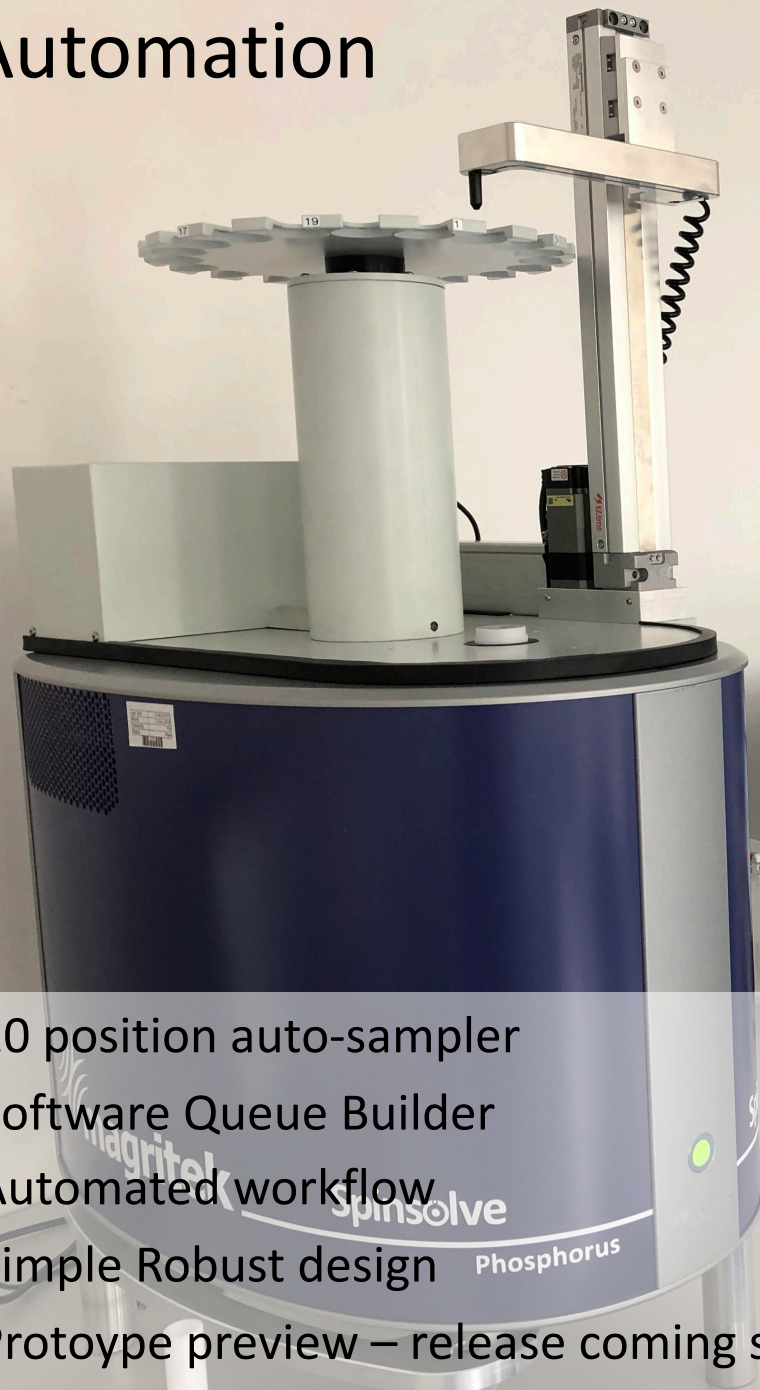
## <sup>13</sup>C Carbon (<sup>31</sup>P, X)

- 1D spectra
- DEPT
- 2D HETCOR
- 2D HMBC
- 2D HMQC
- 2D HSQC
- 2D HSQC-ME
  
- PLUS
  - Scripting
  - Automation
  - qNMR
  - Autoshim

## Expert

- 2D NOESY
- DQF-COSY
- Non Uniform Sampling (NUS)
- PGSE (Diffusion)
- PSYCHE
- Pure Shift HSQC

# Automation



- 20 position auto-sampler
- Software Queue Builder
- Automated workflow
- Simple Robust design
- Prototype preview – release coming soon

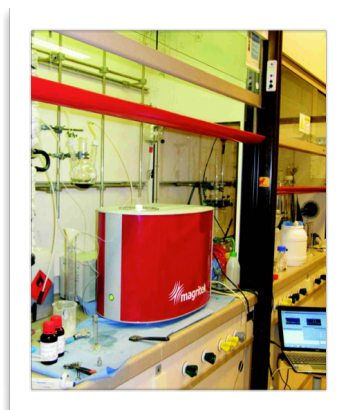


# Applications of Benchtop NMR



## Industrial Applications:

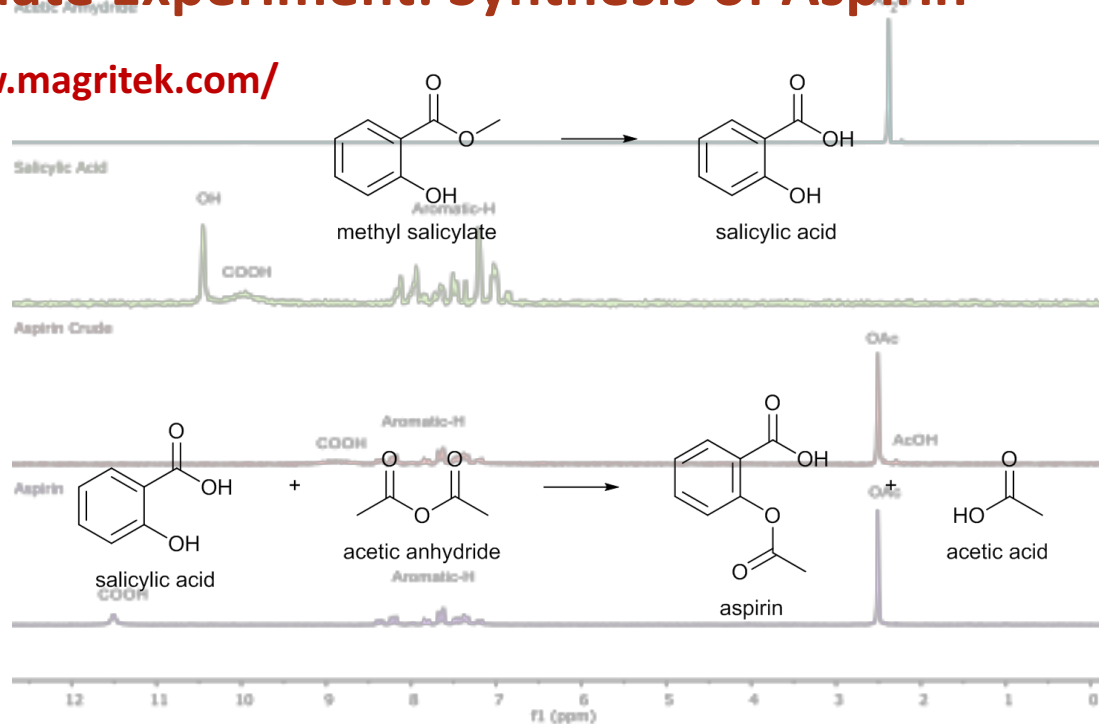
- Education
- Organic Synthesis
- Process Control
- QA/QC
- Chemical Analysis
- Quantification (qNMR)
- Reaction Monitoring
- Fumehood Reactions



## Traditional Undergraduate Experiment: Synthesis of Aspirin

Contents of [lab manuals](http://www.magritek.com/applications/chemistry-education/) (see <http://www.magritek.com/applications/chemistry-education/>)

- Objectives
- Introduction
- Synthesis of salicylic acid from oil of wintergreen
- Procedure
- Risk Assessment
- $^1\text{H-NMR}$  Spectra
- Synthesis of aspirin from salicylic acid
- $^1\text{H-NMR}$  Spectra
- Tasks and Questions



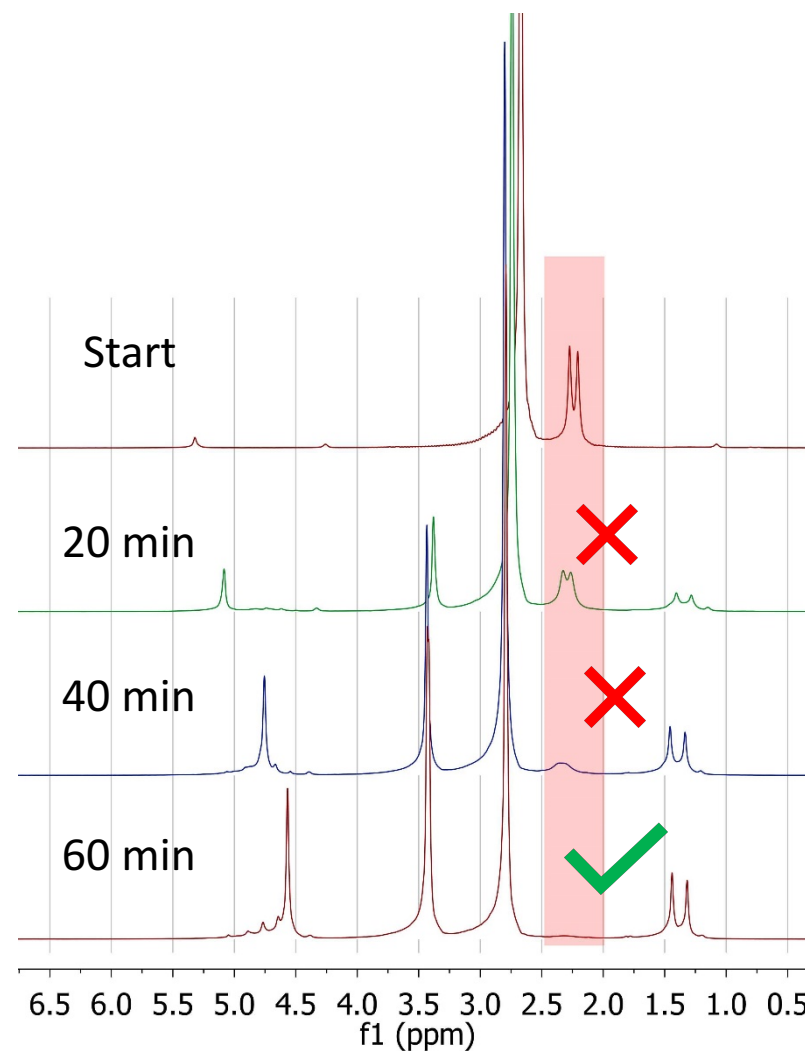
### Tasks and Questions

1. Calculate % yield for each step of the synthesis.
2. Assign the peaks in the  $^1\text{H-NMR}$  spectra of all starting materials and products, and identify functional groups that are unique in each sample.
3. Identify the impurities in the crude products. Did recrystallization remove these impurities?

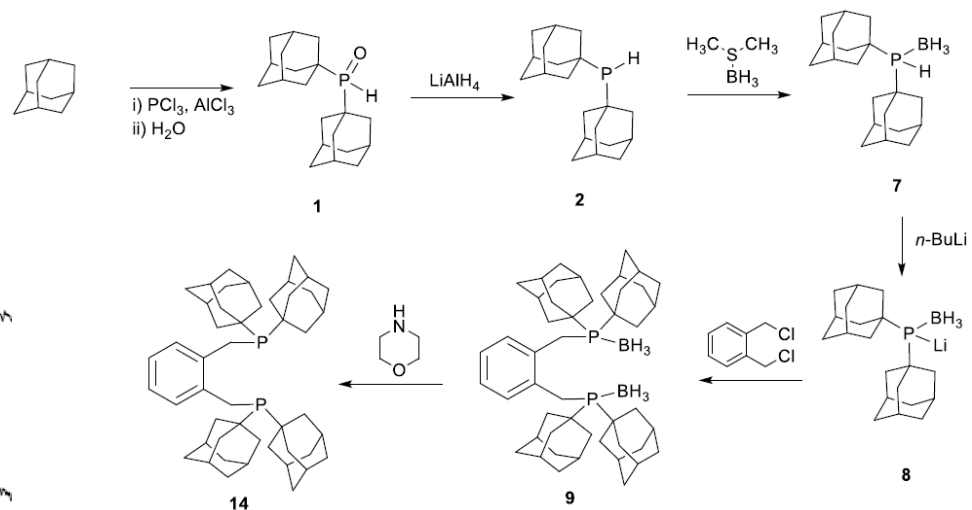
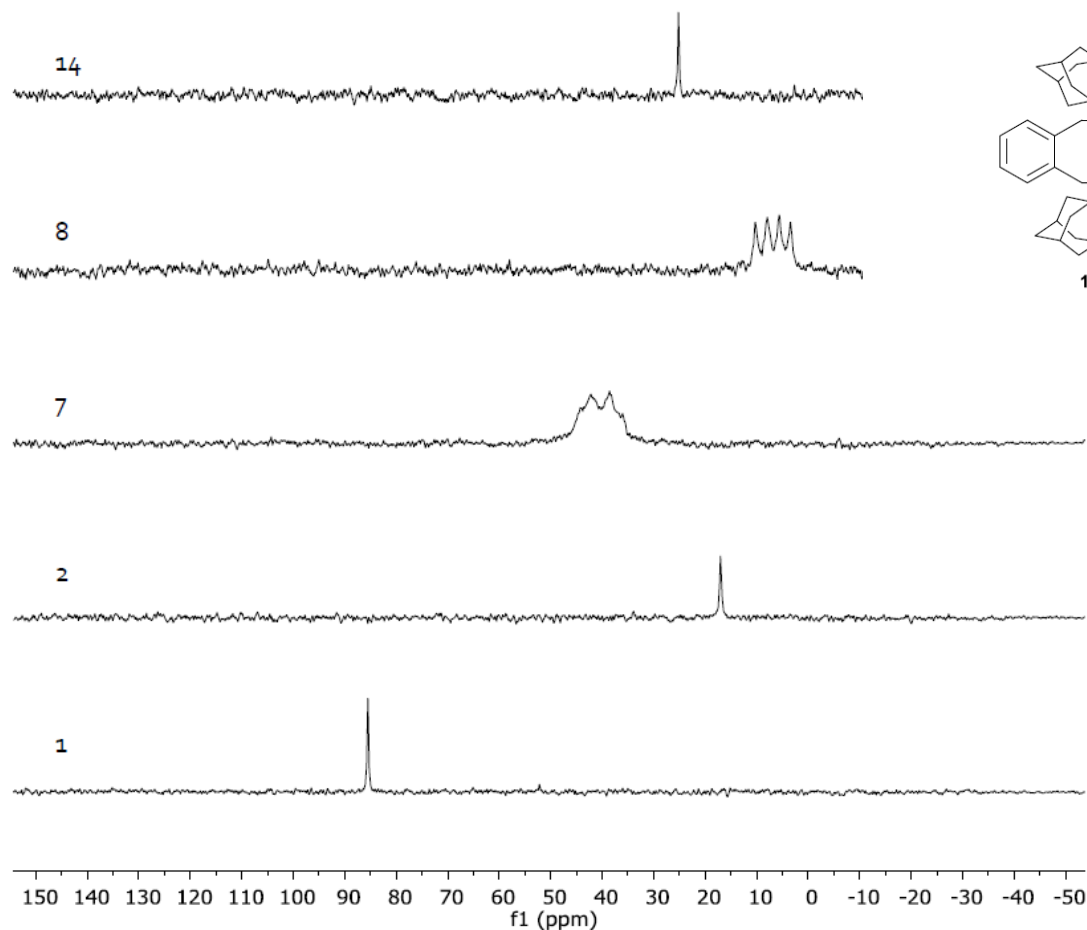


# Reaction completion- $^1\text{H}$

- Reaction complete? Product expected one?
- Check is done by either **high field NMR (expensive/takes longer)** or less specific methods like thin layer chromatography (TLC)
- **Spinsolve** offers the chance to **directly do this in the lab** without delays !
- No waiting at high field machine and way more information than TLC

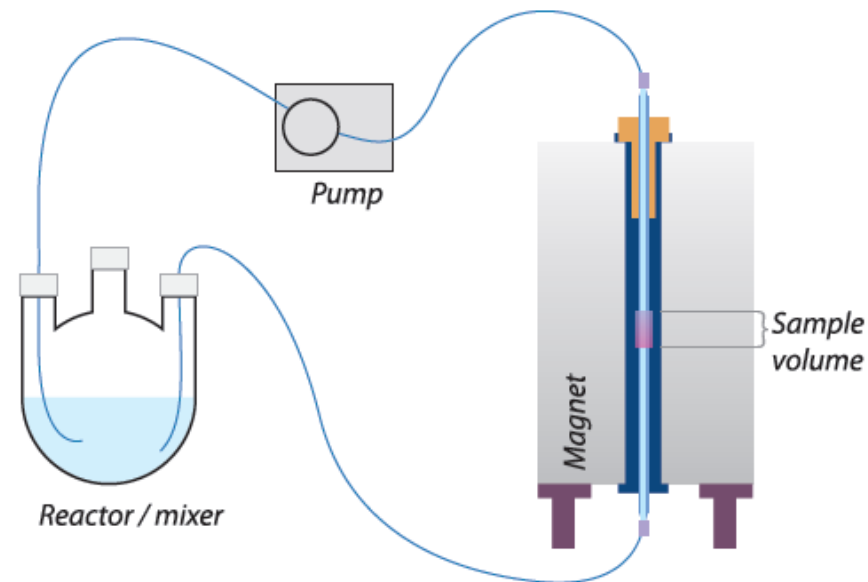


## Preparation of Phosphine ligand Bis(diadamantylphosphinomethyl)benzene



- $^{31}\text{P}$  NMR can be used to follow Phosphorus involving organometallic reactions
- Spinsolve allows the use of Young's tubes

Following the progress of a reaction from starting material to end-point

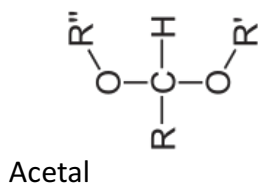
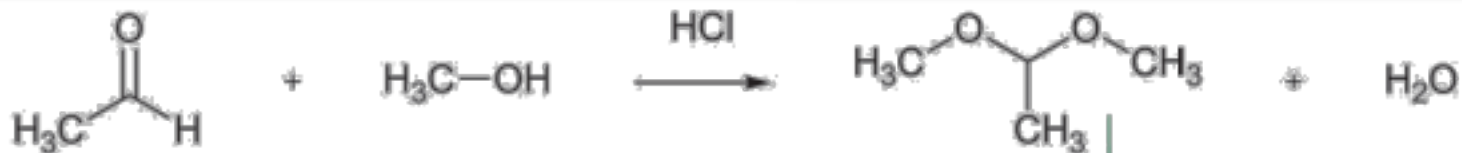


## Flow reaction monitoring setup

- ❖ Every Spinsolve system has an opening all the way from top to bottom
- ❖ So a flow cell can be positioned into the NMR spectrometer
- ❖ Take an NMR spectrum all 30 ... 60 seconds
- ❖ Run the setup either in continuous or stop-flow mode

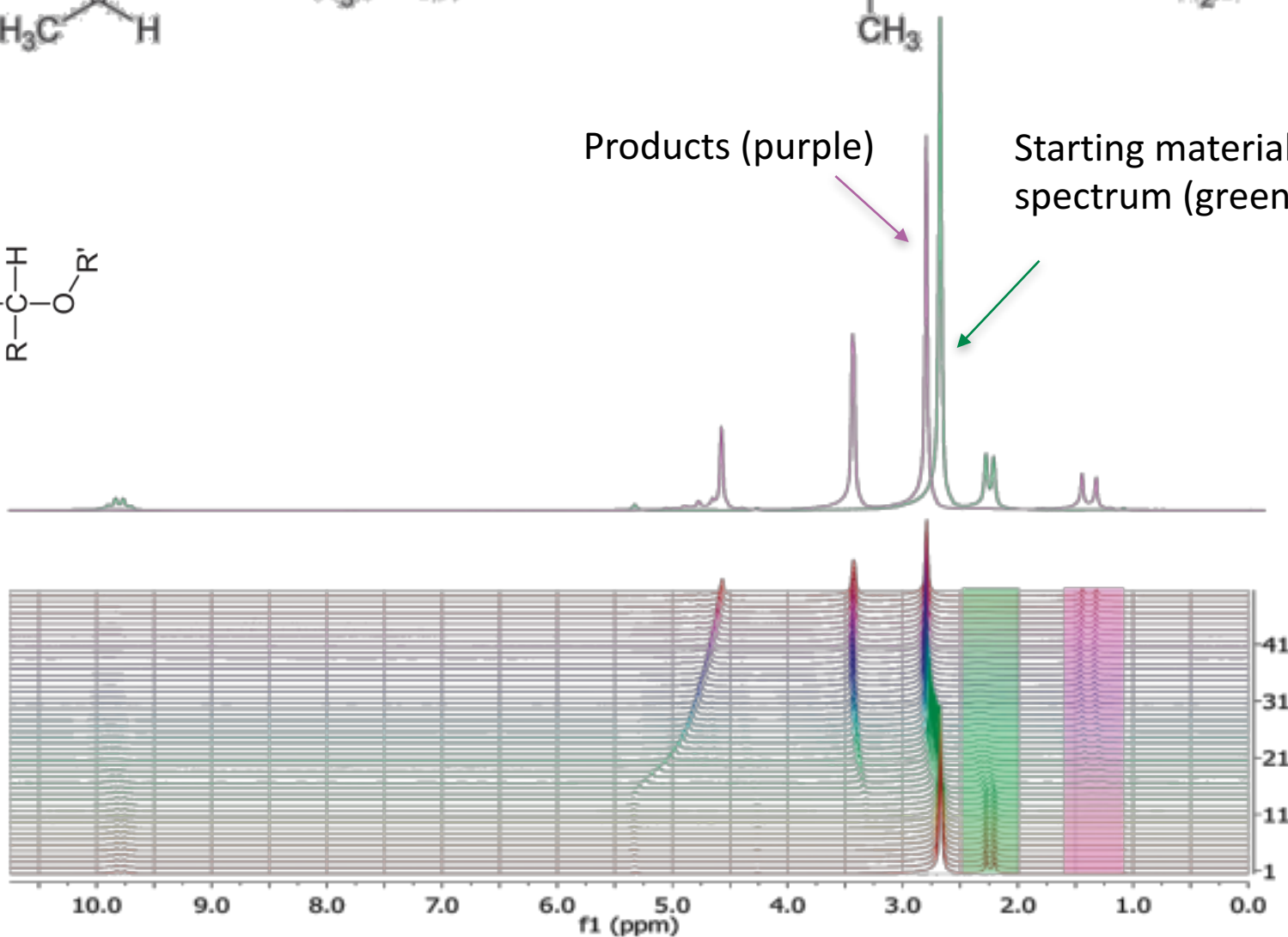


# Acetalization of Acetaldehyde

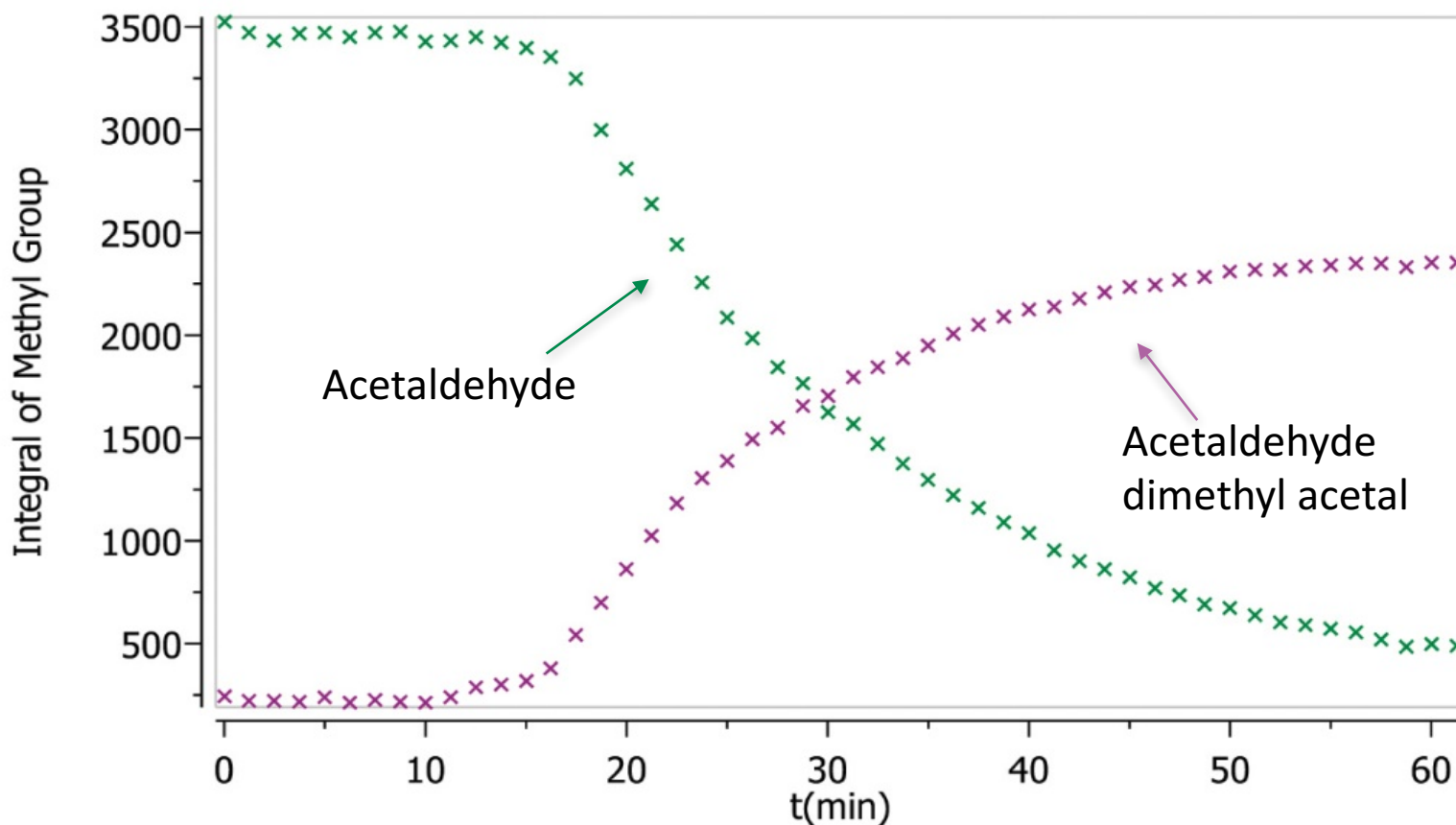


Products (purple)

Starting material spectrum (green)



# Acetalization of Acetaldehyde

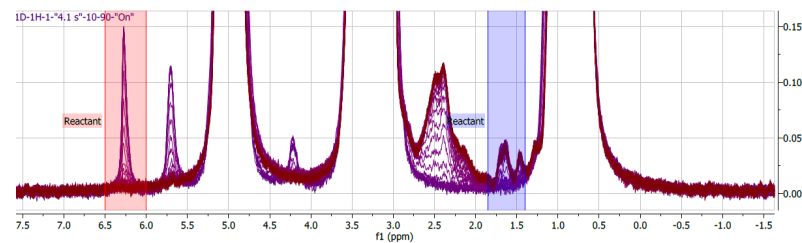
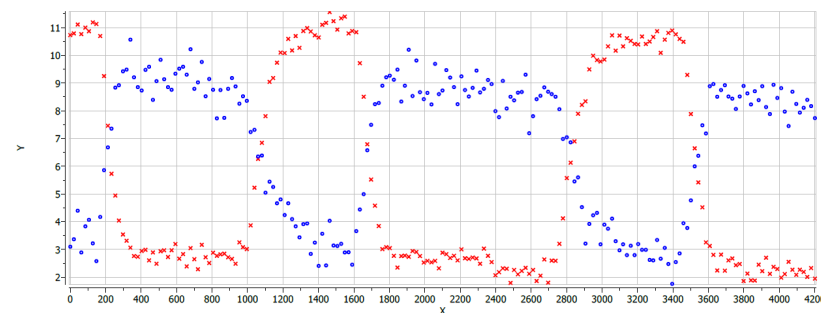
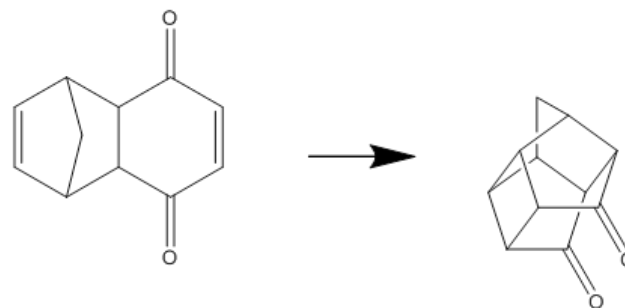


- **Green:** methyl group of the acetaldehyde at 2.25ppm
- **Purple:** methyl group of the product acetaldehyde dimethyl acetal at 1.4ppm
- Can easily and accurately monitor the progress of the reaction as it occurs

# Reaction monitoring of UV-induced 1,4-Cycloaddition in Ethanol



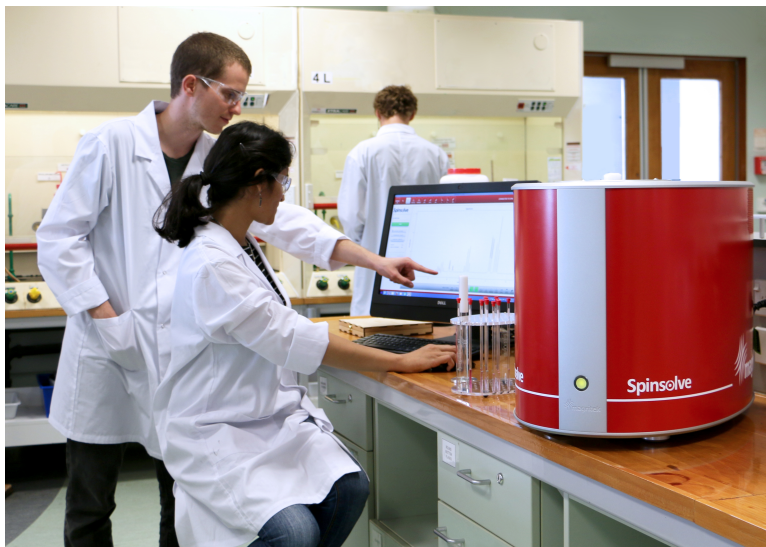
Real-time monitoring of changes within the flow reaction setup



# Closure / Thank you

- For further Information, please contact [sales@magritek.com](mailto:sales@magritek.com)
- Further information is also located on the Web page [www.magritek.com](http://www.magritek.com)
- Typical Spinsolve Example Spectra can be found via <http://www.magritek.com/products/spinsolve/nmr-spectra-examples/>

Standard Laboratory Setup



Reaction Monitoring Setup