Troubleshooting Methods in GC

Tony Edge
Site Director
Anthony.edge@avantorsciences.com

avantor™

In Partnership with MAC-MOD, our authorized channel partner. MAC-MOD have been a trusted partner for over 20 years with expertise in HPLC & UHPLC

Introduction

01

– Understanding the GC components

02

– Column Installation

03

– Troubleshooting

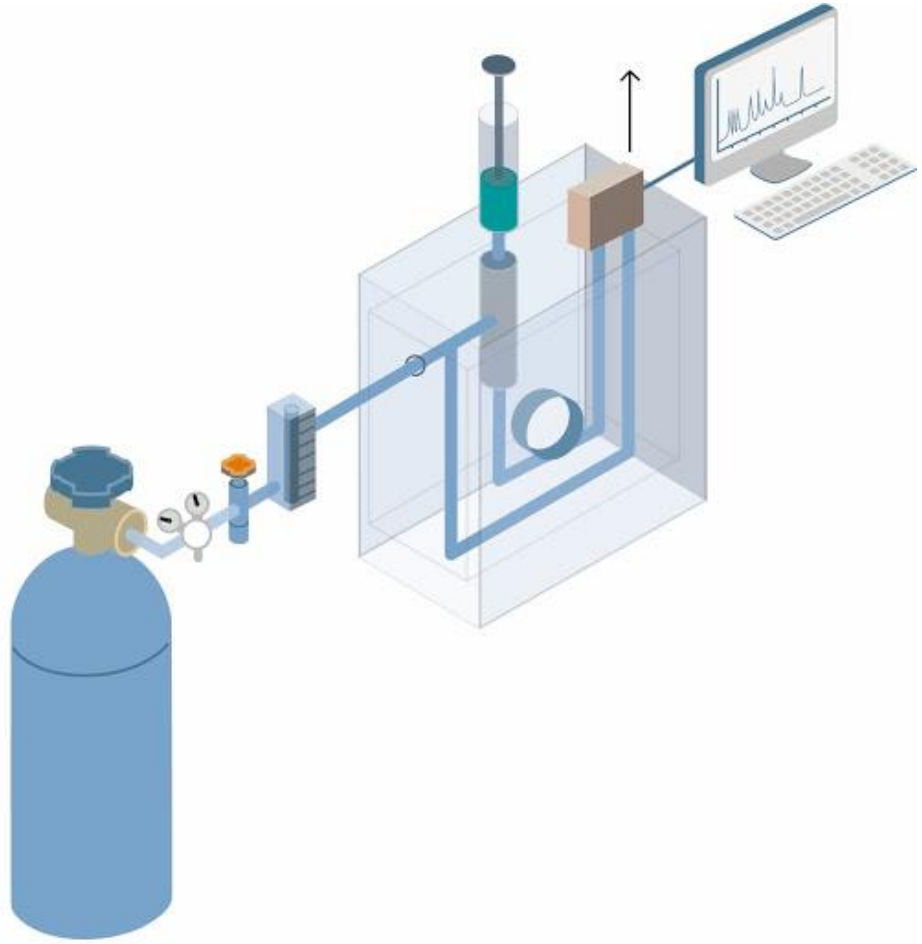
04

– Conclusions

05

06

GC Components and Murphy's Law



Components for a GC
- Gas supply
- Gas filters
- Injector
- Column
- Oven
- Detector

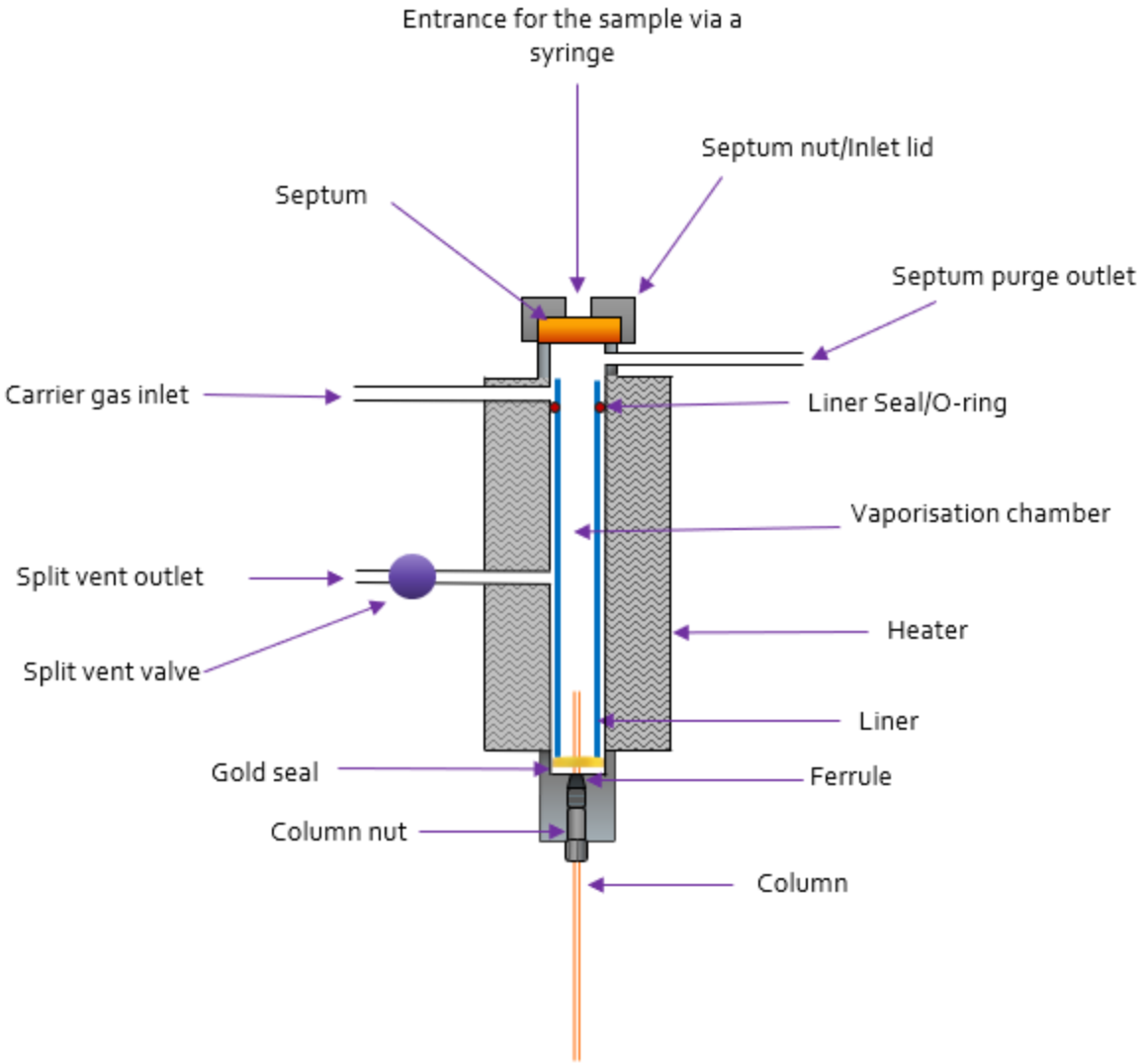
- Sample

Needle Types

Needle Tip Style	Needle design	Features / Applications
Cone (Tapered tip)		Most versatile needle.
Bevel (Sharp tip)		Typically used for manual injections.
Side Hole		Usually used for headspace or large volume injections.
Blunt End		Used with injectors that do not use a septa.
Dual Gauge		Narrow part suitable for mega bore on column injections, larger bore suitable for autosampler use.

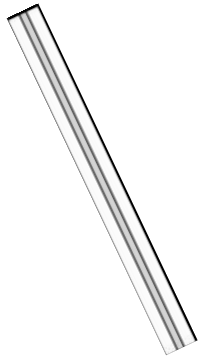
Gauge number is a measure of thickness, with higher numbers being a thinner gauge.

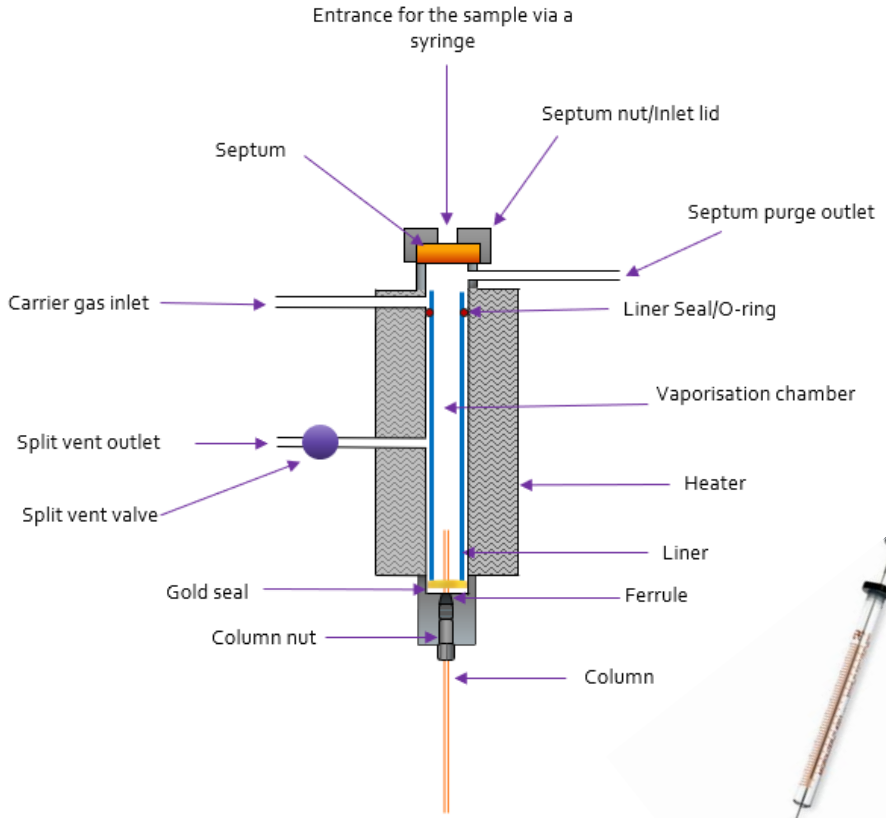
Generic Design of GC Autosampler



- Sample introduced and then volatilised
- Avoid discrimination between different boiling points
- Avoid adsorption
- Ensure sample is contained

Generic Design of GC Autosampler





What can go wrong?

- Sample not introduced correctly
- Sample not heated effectively
- Septum does not seal
- Liner chosen incorrectly
- Column not connected properly
- Sample evenly distributed between waste and column

Considerations Choosing the Injector Type

- Consider assay requirements and the sample type
  - High temperature application
  - Trace level
  - Dirty/clean sample

    Is sample preparation required to remove matrix
  - Residual solvent
  - Solid
  - Determine volatility of sample

WRONG INJECTOR SELECTION WILL CAUSE ISSUES WITH;

- PEAK SHAPE
- SENSITIVITY

Images reproduced with thanks to;
Andre' Kuenzelmann
Markhamilton at English Wikipedia.

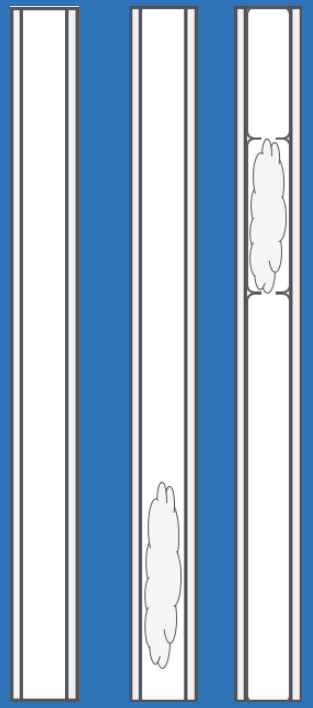
GC Capillary Inlet Types & Injection Modes

MMI

Inlet	Mode	Sample Concentration	Amount of Sample transferred to column	Suitable columns	Further information
SS = Split / Splitless Hot injections, standard for GC with wide range of injection modes.	▪ Split ▪ Purged split ▪ Splitless ▪ Purged splitless	▪ High - 50 ppm - %-level ▪ High ▪ Low - 0.5 ppm – 50 ppm ▪ Low	▪ Very little ▪ Very little ▪ All ▪ All	▪ Split – All capillary ▪ Purged split - ▪ Splitless – 0.53 ID ▪ Purged splitless - 0.53 ID	Flexible inlet type, popular due to method flexibility. Not suitable for cold injections. Thermal degradation can be a common issue.
COC = Cool on-column Wide boiling point range, chemically and thermally labile samples.	N/A – No liner	Low or labile - 0.25 ppm – 50 ppm	All	0.53 ID column recommended	No split line, similar to PTV but injection is direct into the column. Cold Splitless injections.
PTV = Programmable Temperature Vaporisation "Cold" injections, then rapid heating. Wide boiling point range and thermally labile samples.	▪ Split ▪ Pulsed split ▪ Splitless ▪ Pulsed splitless ▪ Solvent vent	▪ High ▪ High ▪ Low ▪ Low ▪ Low	▪ Very little All ▪ All ▪ Most	▪ Split – All capillary ▪ Purged split ▪ Splitless – 0.53 ID ▪ Purged splitless - 0.53 ID	Not great for HOT injections, smaller liner volume. Can concentrate analytes and vent solvent. Low oven temp, retention gaps focus and for cold splitless injection.
VI = Volatiles interface	▪ Direct ▪ Split ▪ Splitless	▪ Low ▪ High ▪ Low	▪ All ▪ Very little ▪ All	▪ Direct – 0.53 ID ▪ Split ▪ Splitless	Purge and Trap and Headspace.

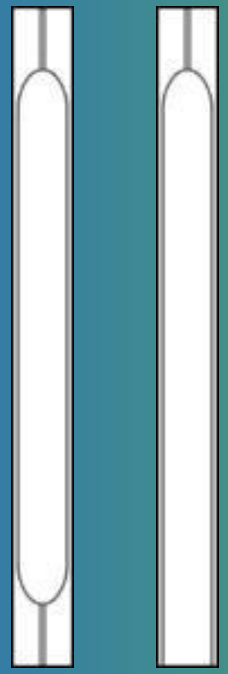
Split/Splitless GC liners – Summary/Geometry

Split liners tend to have both ends open to allow movement of the increased flow of gas related to the split flow.



Split/Splitless liners can have tapered top and bottom ends tapered.

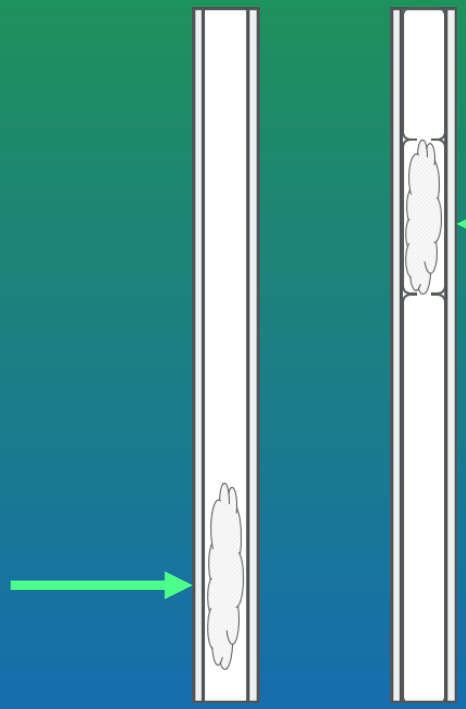
Tapered top helps to reduce discrimination of sample, and tapered bottom helps to focus and direct sample onto the column.



Splitless liners commonly have tapered bottom to help focus, direct sample onto the column and to reduce contact of sample with metal surfaces in the inlet.

GC liners – Quartz wool

Quartz wool helps with inertness of liner, mixing sample and enhancing vaporisation. But functions differently in different positions.



Wipe needle tip of syringe to reduce contamination and helps the sample mix in the liner chamber.

Traps non-volatiles and functions as a area for sample to vaporise.

Impact of Split Ratio

1 : 5 ratio Poor peak shape of early eluting peak and solvent peak. Split ratio too low

Too Low split ratio = poor peak shapes, peak broadening

Too high split ratio = wasteful of gases and poor sensitivity

Split ratio adjusted to 1 : 50 ratio improves peak shape and solvent peak

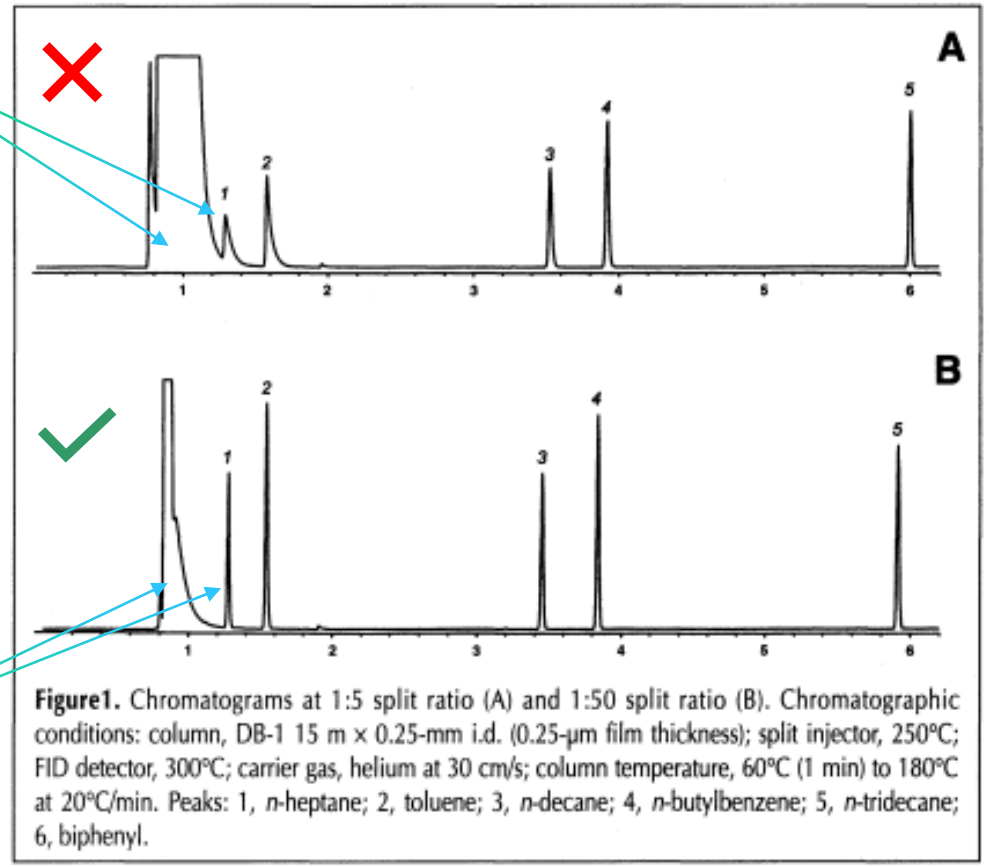


Figure1. Chromatograms at 1:5 split ratio (A) and 1:50 split ratio (B). Chromatographic conditions: column, DB-1 15 m x 0.25-mm i.d. (0.25-µm film thickness); split injector, 250°C; FID detector, 300°C; carrier gas, helium at 30 cm/s; column temperature, 60°C (1 min) to 180°C at 20°C/min. Peaks: 1, *n*-heptane; 2, toluene; 3, *n*-decane; 4, *n*-butylbenzene; 5, *n*-tridecane; 6, biphenyl.

Journal of Chromatographic Science, Vol. 36, September 1998, Page 476

COC Troubleshooting

- Bent needles
  - Associated with wrong size needle or insert
  - Insert has burrs
- Plugged needles due to septum coring
- Loss of peak shape
  - Check column for any obvious flaws due to discolouration or particles
- Injection volume too large
  - Typical injection volumes < 0.2 µL
  - Thermal expansion now occurs in column

- Inlet temperature must be below boiling point of solvent being used
- Use retention gap to protect analytical column and to focus samples

Selecting Dimensions – Column Diameter/ID

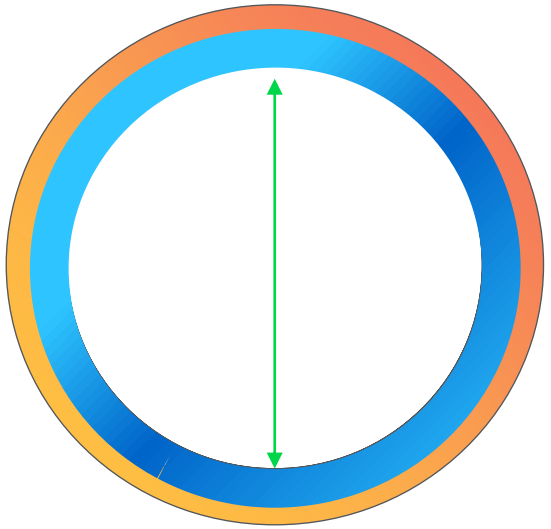
Larger ID
0.32-0.53mm

Smaller ID
< 0.32mm

Advantages
- Higher load capacity
- Higher concentration
- Lower pressure
- Higher flow methods, HS

Disadvantages
- Higher flow rates
- Lower Resolution
- Longer analysis time

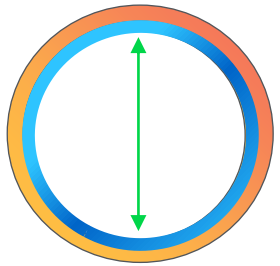
Split, splitless methods, Gas analysis, headspace



Advantages
- Higher resolution
- Lower flow rates
- High matrix
- GCMS, Fast GC

Disadvantages
- Lower loading capacity
- Pressure increases

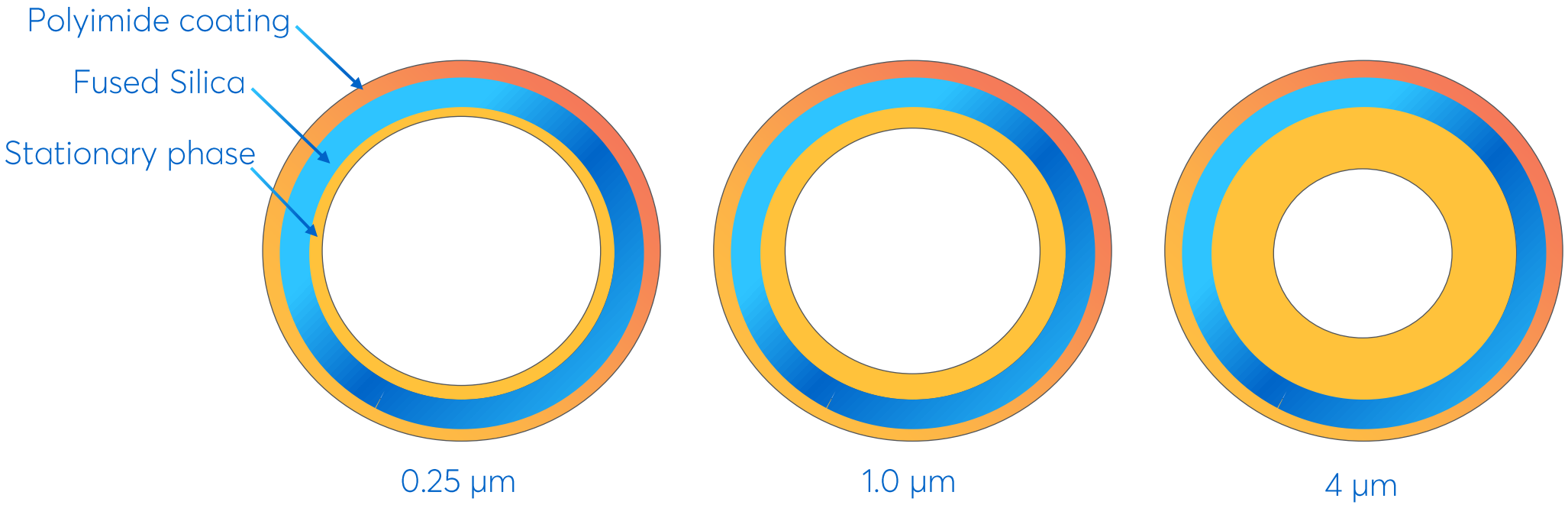
Split methods important to avoid overloading the column



Selecting Dimensions - Film Thickness

Impacts retention, column bleed, loading capacity and inertness

- Stationary phase FT ranges from 0.10-10µm.
- The thinner the FT, the less time the analyte spends in the stationary phase
  - Shorter analysis time
- The thicker the FT, the longer the analyte spends time in the stationary phase
  - Longer analysis
- Thick FT = More retention
- Thin FT = Less retention

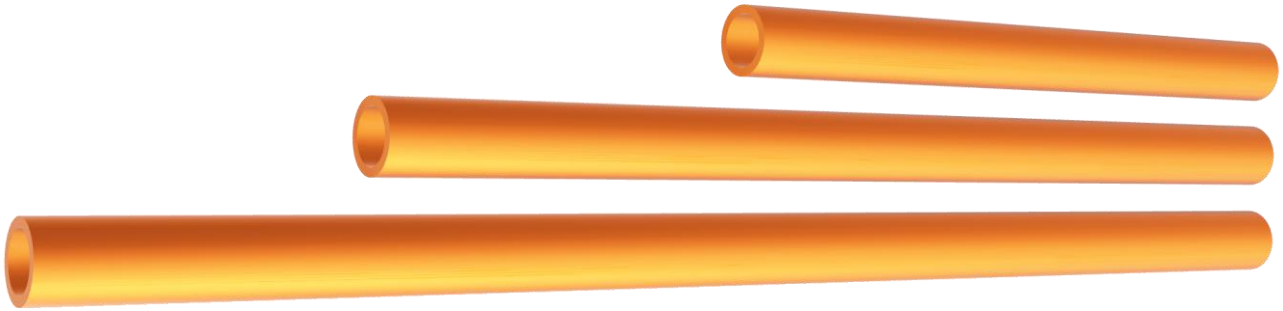


Selecting Dimensions - Length

Impacts Resolution, Pressure and Retention

- Shorter columns decrease analysis time.
- Shorter columns may be suitable where great resolution is not a priority.
- Combining with a small ID can maintain or even increase resolution.

- Longer columns increase resolution.
- Increased length required when ID cannot be reduced and when increasing carrier gas velocity decreases the efficiency.

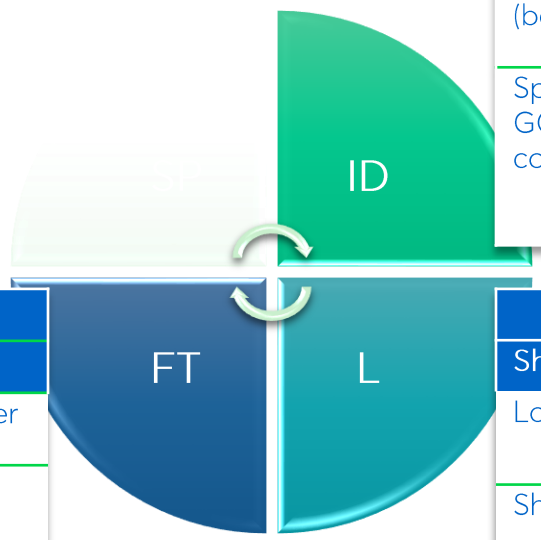


COLUMNS SHOULD NOT BE CUT IN HALF
The column is tested after production at the designated length. Performance of a column cut in half is not guaranteed.

- >15 m = Short run times, Fast GC, screening methods.
- 30 m = General use GC, best balance.
- 60-100 m = Long RT, expensive, application specific.
- Longer columns are a last resort to increase resolution.
- Doubling length increases resolution by approx. 40% and analysis will be twice as long.

Column Selection Considerations

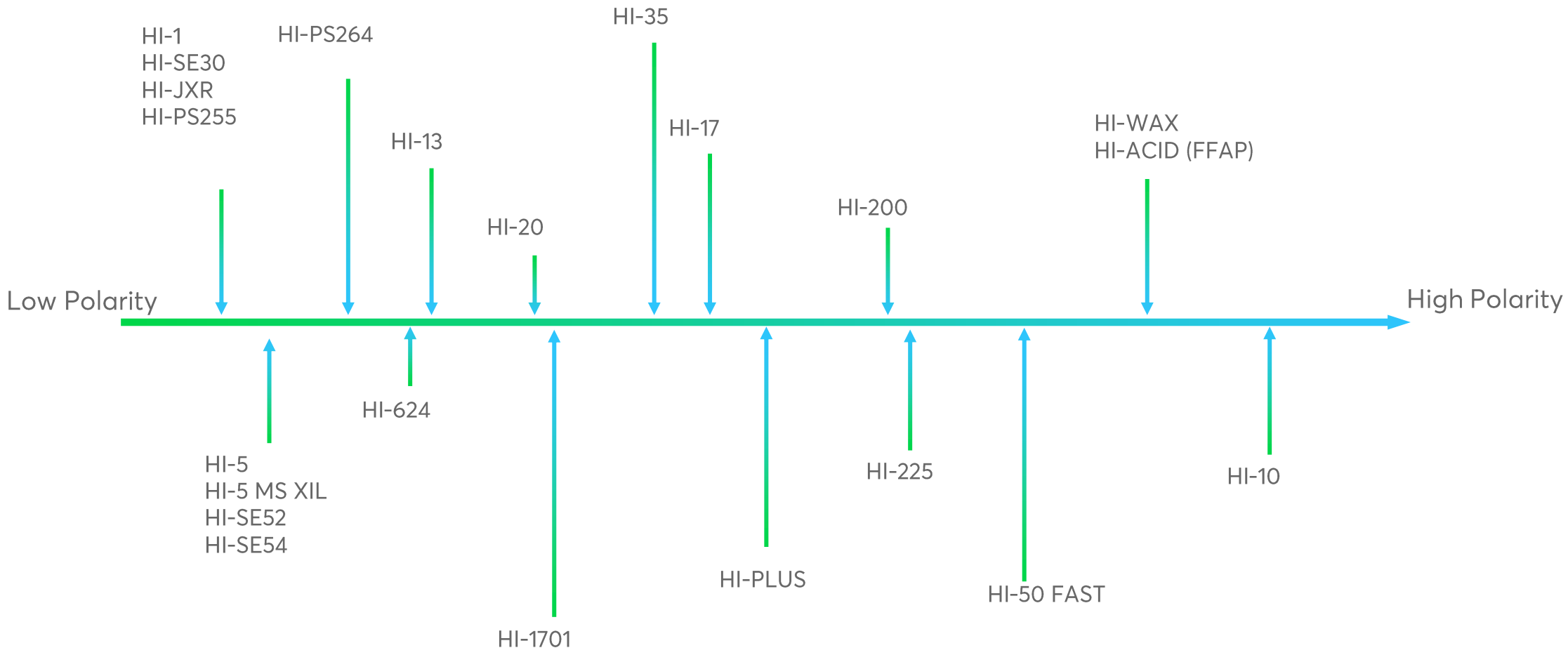
Column ID		
0.10-0.18 mm	0.25-0.32 mm	0.40-0.53 mm ID
Short RT	Moderate RT	Long RT
Low flow	Moderate flow	High flow
Lower sample capacity, <50 ng (based on 0.25 µm FT)	Medium sample capacity, <200 ng (based on 0.25 µm FT)	Higher sample capacity, < 2000 ng (based on 0.25 µm FT)
Split mode, Fast GC, GCMS, highly complex samples	Complex samples, split, splitless, DI, HS and on-column modes, broad conc. range.	Split, splitless, DI, HS and on-column modes.



Film Thickness	
Thin FT 0.10–0.50 µm	Thick FT 1–10 µm
Decreased retention and short RT	Increased Retention and longer RT
Lower sample capacity	Higher sample capacity
Higher temperatures	Lower Temperatures
Low column bleed	High column bleed
Medium to high molecular weight compounds	Volatiles and low molecular weight compounds

Column Length		
Short <15 m	Medium 20-30 m	60-100 m
Lower resolution	Medium resolution, suits broad range	Increased Resolution
Short RT	Moderate RT	Long RT
Lower cost	Medium cost, more popular, general use length at 30 m	Higher cost, consider other options before increasing length
A few compounds in sample, high boilers, Fast GC, GCMS	Medium complexity of samples, GCMS	Very complex samples, low boilers

Stationary Phases



"Classic" Stationary Phases

HI-1

APOLAR PHASE
100% Polysiloxane

Formats available
- HI-1
- HI-1 HT
- HI-1 MS
- HI-1 PLUS

HI-5

Most commonly used phase

WIDELY USED
5% Phenyl

Formats available
- HI-5
- HI-5 HT
- HI-5 MS
- HI-5 MS PLUS
- HI-5 MS XIL

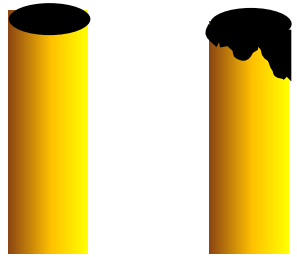
HI-WAX

HIGHLY POLAR PHASE
Polyethyleneglycol (PEG)

Formats available
- HI-WAX
- HI-WAX HT
- HI-WAX MS
- HI-WAX PLUS

Column Installation (1)

- Ensure that the system is cool before installing a column
- Ensure that gas filters and cylinders are good to go
  - Avoids contaminating the column
- Clean the injector
  - Avoids contaminating the column
- Clean the detector
- Ensure that the end of column has a clean cut
  - Ensures that there are no leaks
- If in doubt cut 10 cm off using a sapphire or ceramic knife
  - Score the column and then break, do not cut through column as this will leave a very jagged edge



Column Installation (2)

- Place nut then ferrule over column, ensuring not to damage end of column
  - Ferrule should be of an appropriate size, and ideally a new ferrule should be used on each installation
  - Ensure that correct position. So for detector and injector follow manufacturers guidelines

- Turn on gases
  - This will sweep any debris away
  - Connect column to detector
  - Perform a leak test, ideally not using a detergent based solution

Ferrule Types

- 100% graphite
  - Reusable, porous to oxygen so cannot be used with MS detectors. Provide a soft seal, so can be reused, ferrules do not shrink on heating, so retightening not required. They do have a tendency to flake which can contaminate columns/injector/detector

- 15% graphite 85% vespel
  - Non-porous to oxygen, reusable, shrink on heating so will require a degree of retightening, however once retightened they are good for the life of the column

- SilTite™ – metal equivalent to vespel frits designed to be installed with finger tight application

Detectors

- FID (Flame ionisation detector)
- NPD (Nitrogen phosphorous detector)
- ECD (Electron capture detector)
- TCD (Thermal conductivity detector)
- FPD (Flame photometric detector)
- PID (Photoionisation detector)
- MS (Mass Spectrometry) ……..

Detector needs the right operating conditions (suitable gas supplies, temperatures etc.)

Prevention!

Many GC problems can be prevented by performing routine maintenance:

- Replace liner (when performance drops below a preset level) and septum (daily) regularly
- Keep the injector and detector clean and well-maintained
- Check for leaks from the primary gas supply to the GC
- Instrumentation should ideally undergo a PM every year

Approach to Troubleshooting

- Always be systematic
- Record all data
- Try not to assume anything
- Start with the least time-consuming ideas
- Give yourself a time limit and then have a plan B, typically get an engineer in
- Remember that I can save myself a 5 minute conversation by doing 6 months work in the lab

The Tool Kit

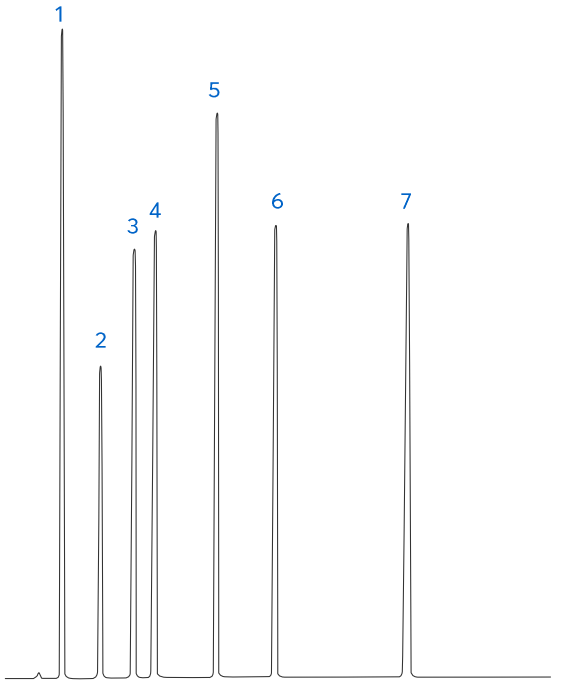
- Flow meter with a range of 10 to 500 mL/minute
- New syringes
- Non-retained, detectable compound such as methane or propane
- Septa, ferrules, inlet liners, and other consumables
- Electronic leak detector
- Reference sample
- Reference column with known performance
- Appropriately sized spanners and other tools

Common Problems

Baseline related problems

Peak related problems

Results related problems



1. Diazinon
2. Chlorpyrifos-methyl
3. Parathion-methyl
4. Malathion
5. Methidathion
6. Ethion
7. Azinphos-methyl

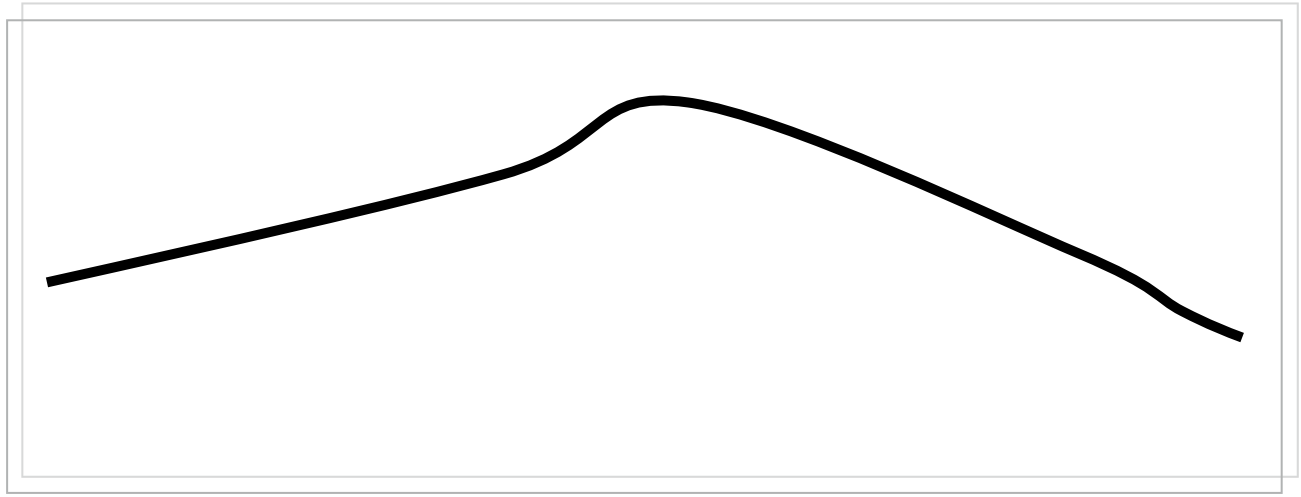
Figure 1: Separation of organophosphate pesticides using the HI-1701 phase.

Baseline Related Problems

Baseline Drifting

Possible Causes:

- Accumulation of impurities in the column
- Accumulation of stationary phase
  - This can also result in extra and distorted peaks
- Carrier gas cylinder pressure too low to allow control
- Drifting carrier gas or combustion gas flows



Baseline Drifting

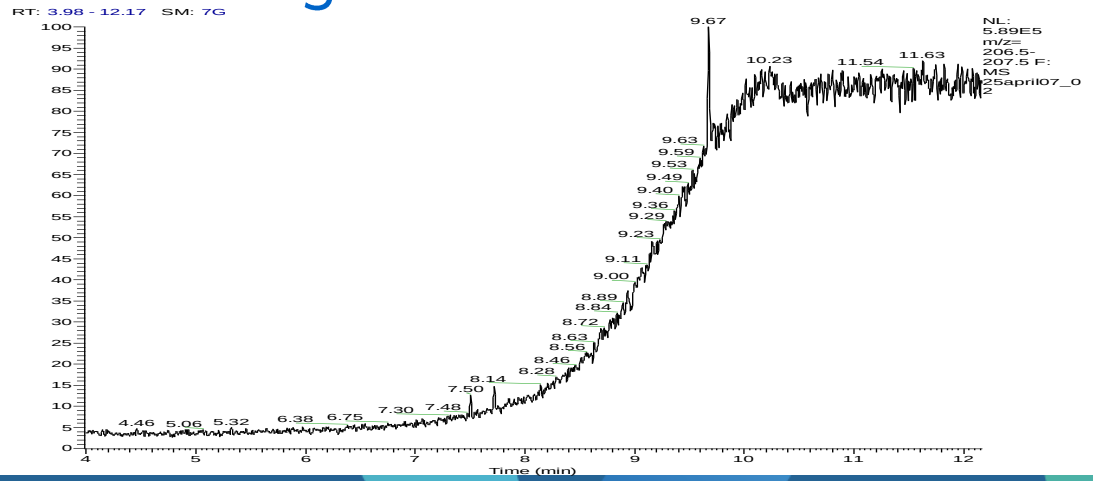
Remedy:

- Check purity of carrier gas
- Replace or install appropriate gas filters
- Remove the end section of the column
- Replace the carrier gas cylinder
- Increase the pressure of cylinder
- Check the gas controllers
- Replace column with a new or low bleed version

Baseline Rising

Possible Causes:

- A poorly conditioned column or one that has been exposed to O_2 may experience some phase decomposition
- This will increase with oven temperature to give a baseline lift mimicking the temp gradient
- Key m/z's to beware of are 207, 281 & 149 (stationary phases / phthalates)
- Impurities in the carrier gas line



Baseline Falling

Possible Causes:

- Carrier gas leak in the system
- Column is baking out
- Unequilibrated detector

Remedy:

- Perform a leak test. Check the tightness of the connections on the carrier gas line
- Allow enough time for the column/detector to stabilise

Baseline Falling Away Slowly After a High Initial Value

Possible Causes:

- Purge value left closed during acquisition
- Inadequate purge flow rate
- Solvent tail peak
- Pre-filters are dirty (when using a quadrupole MS detector)

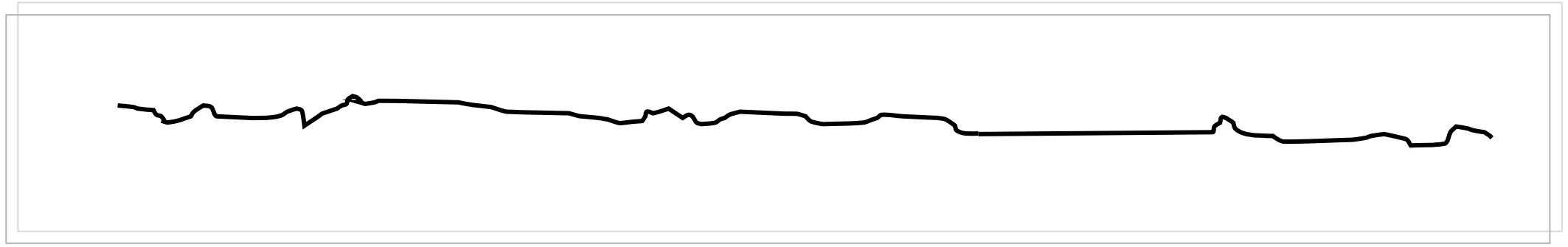
Remedy:

- Alter the GC program
- Increase the purge flow rate
- Increase the solvent delay. Shorten the purge time
- Clean up the prefilter

Noise

Possible Causes:

- Contaminated injector or/and column
- Defective detector
- The column may be inserted too far into the flame of an FID, NPD, or FPD detector
- Detector temperature higher than column maximum temperature
- Loose column fittings



Noise

Remedy:

- Clean injector. Replace septa and liners
- Bake out the column. Cut the first 10 cm of the column. If it does not help, replace the column
- Be sure to insert the column into the detector exactly the correct distance specified in the manual
- Reduce the detector temperature to the column temperature upper limit
- Tighten fittings accordingly

No Noise

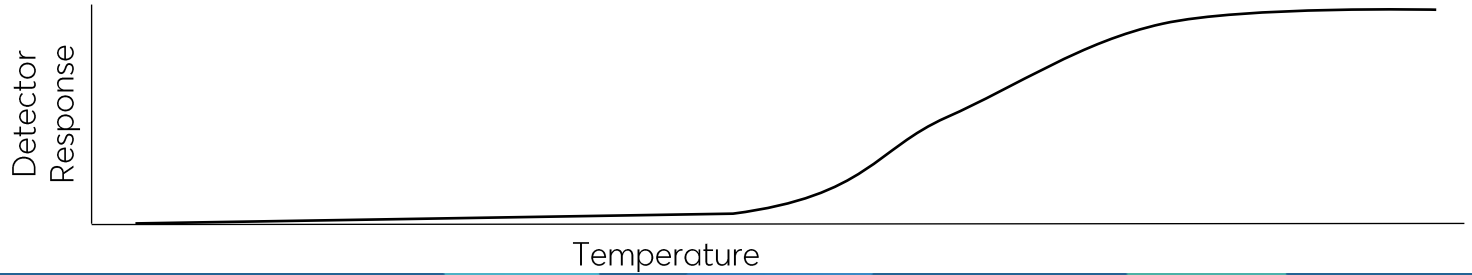
Baseline : S-shaped

Possible Causes:

- Excessive column bleed during column temperature programming
- Oxygen contamination is decomposing the stationary phase

Remedy:

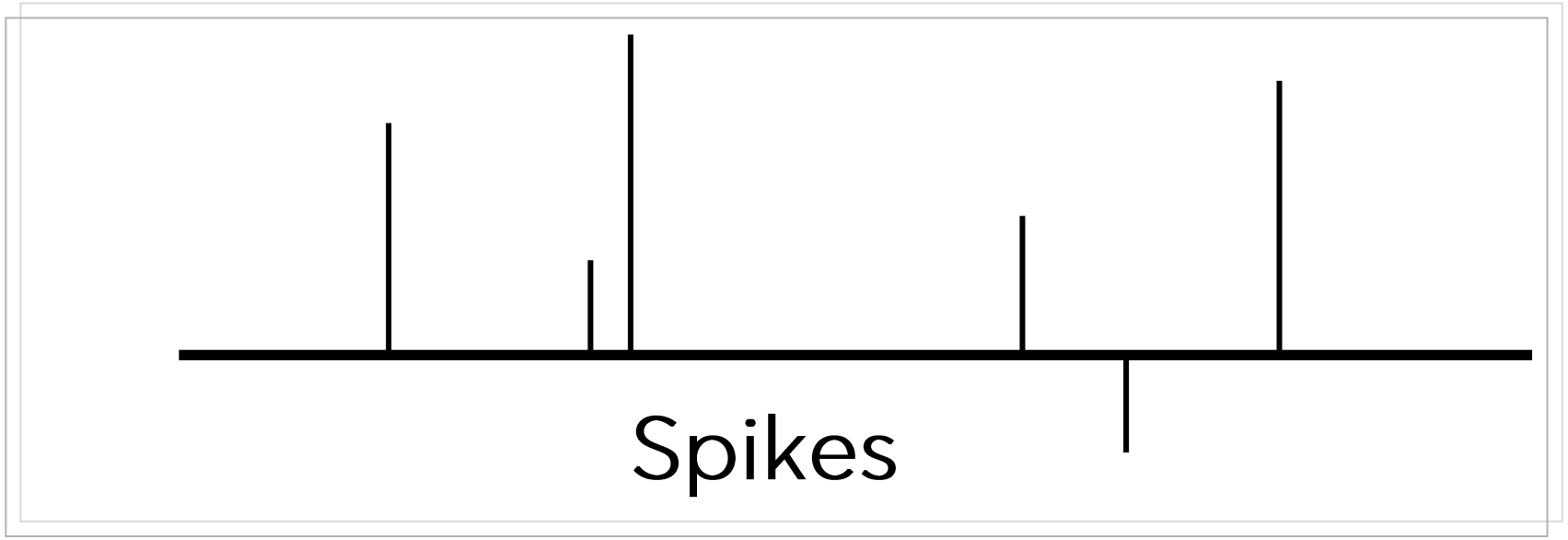
- Reduce the upper column temperature. Bake out the column. Install a high temperature column
- Install oxygen filters in the carrier gas line. Check the pneumatic and inlet systems for leaks. Use correct gas purity with low oxygen content.



Baseline Spiking

Possible Causes:

- Electrical disturbances
- Column too close to flame (When using an FID)
- Dirty jet or detector
- FID temperature too low (When using a FID)



Baseline Spiking

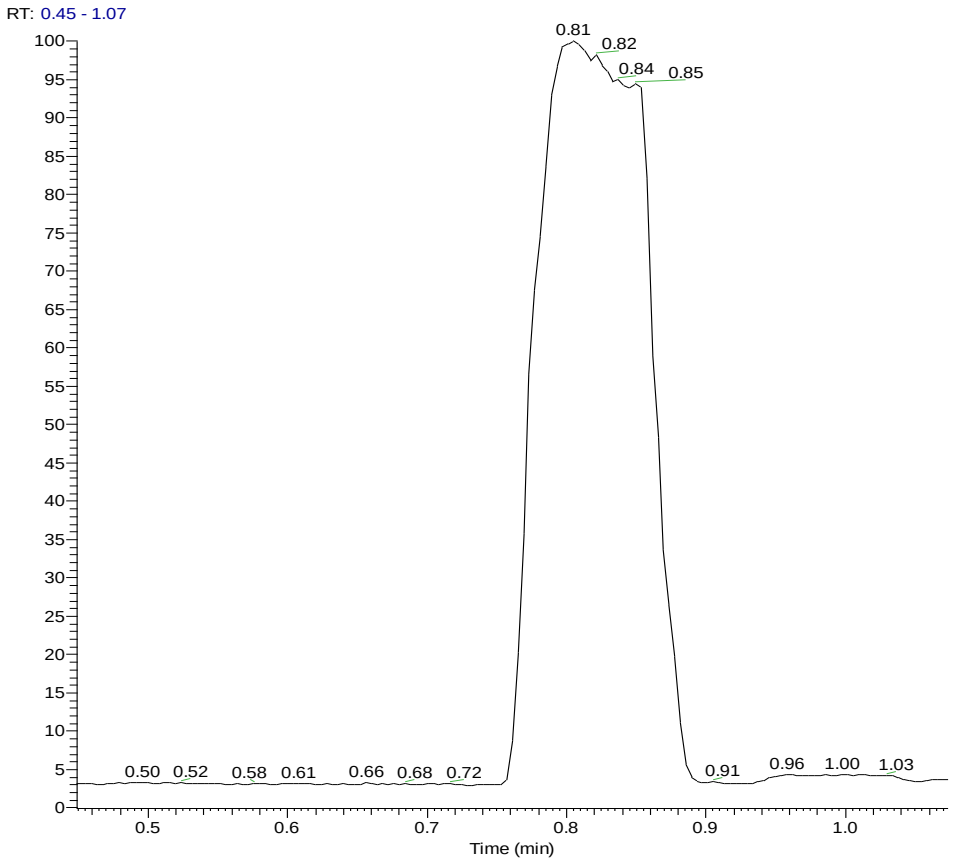
Remedy:

- Lower the column to the correct position (2-3 mm below the tip of the jet)
- Isolate the detector from the electronics. If the spiking disappears, clean the jet and the collectors
- Increase the FID temperature to at least 150 °C

No Spikes

Peak Related Problems

Overloading



Overloading the head of the column can lead to a fronting or wide flat topped peak.

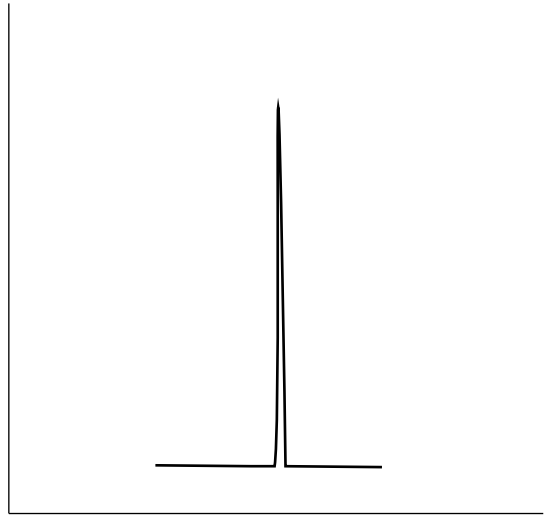
Remedy this by:

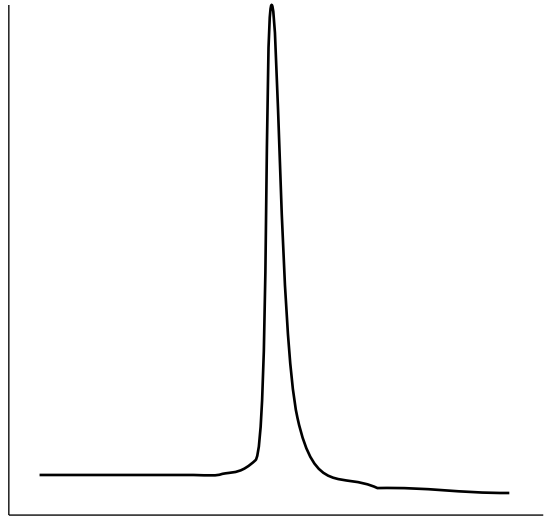
- Injecting less
- Use a split the injection
- Change the column to a wider bore

Peak tailing

Sample Peak Tailing can be caused by:

- Only some of the peaks are tailing
- Chemical problem causing secondary interactions
- Inlet temperature too low
- The column degradation causing activity
- The column contaminated at inlet
- The transfer Line
- Contaminated liner

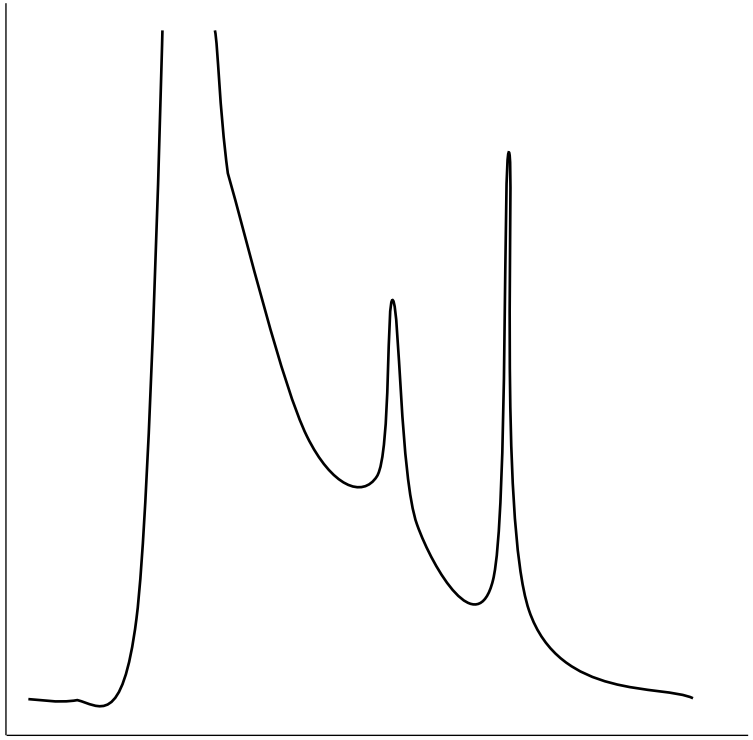




Remedy:

- Increase the inlet temperature
- Inject a test mixture and evaluate the column
- Remove first metre of column
- Increase the temperature of transfer line

Peak Tailing



Solvent Peak Tailing can be caused by:

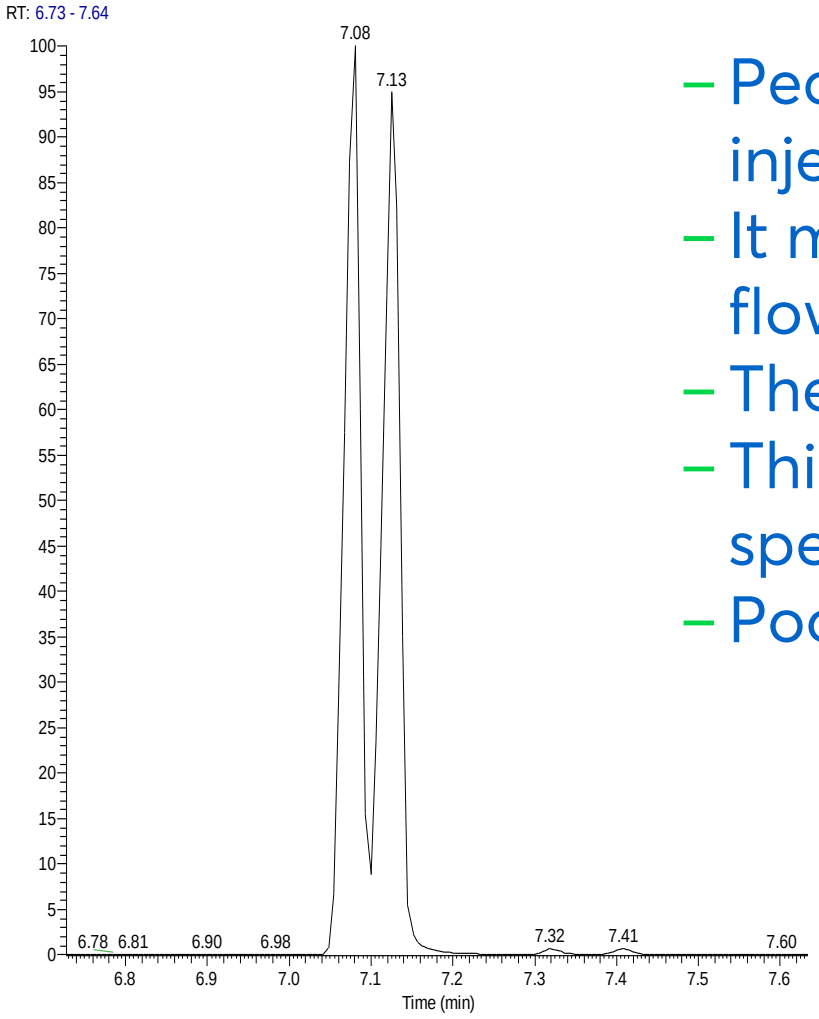
- It may be evident in splitless injections when high gas flows are used

- The cause is a disruption in the transfer to the column
- Incorrect column position in inlet
- Initial oven temperature too high
- Septum purge flow too low and/or SSL vent flow too low

Remedy:

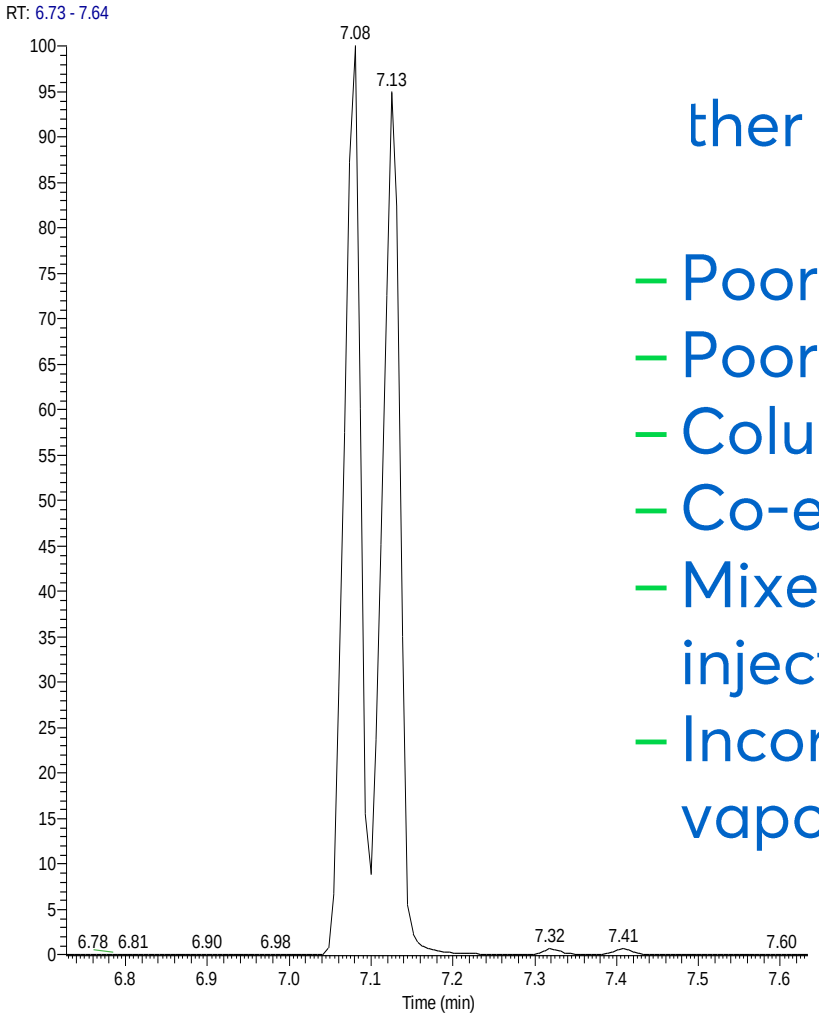
- Reinstall the column
- Reduce the initial oven temperature
- Check and adjust the septum purge and vent flows

Peak Splitting



- Peak splitting is normally found in Split mode injections
- It may be evident in splitless injections when high gas flows are used
- The cause is a disruption in the transfer to the column
- This can be remedied by increasing the injection speed.
- Poor column installation

Peak Splitting

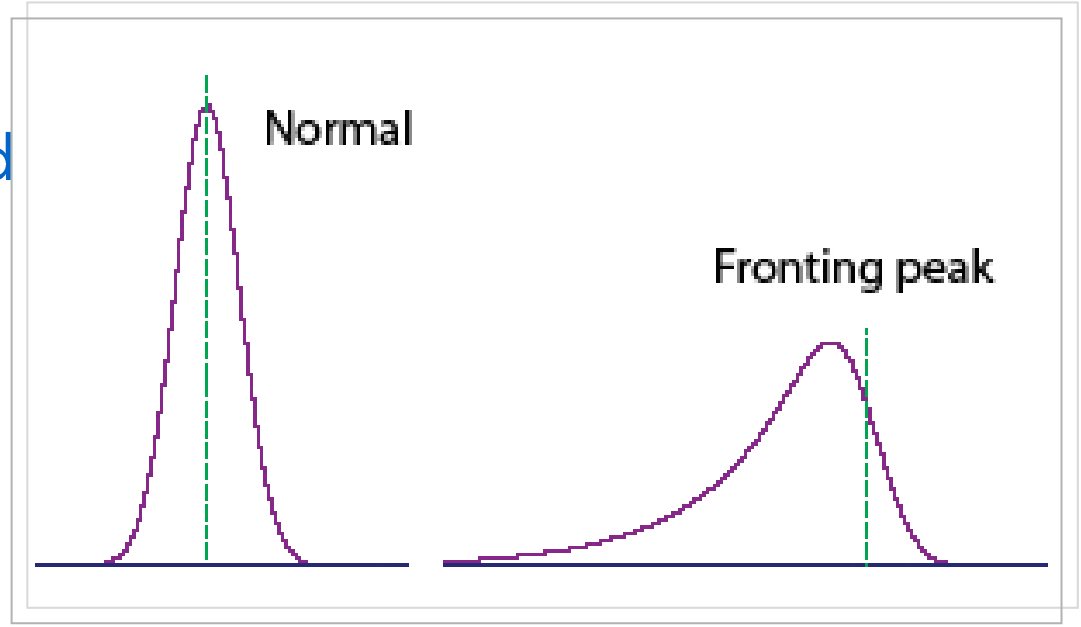


ther possible causes:

- Poor injection technique
- Poorly installed column in the injector
- Column temperature fluctuations
- Co-elution of two or more compounds
- Mixed sample solvent for splitless or on-column injections
- Incorrect choice of inlet, resulting in sample not vaporizing in one location

Peak Fronting

Possible causes



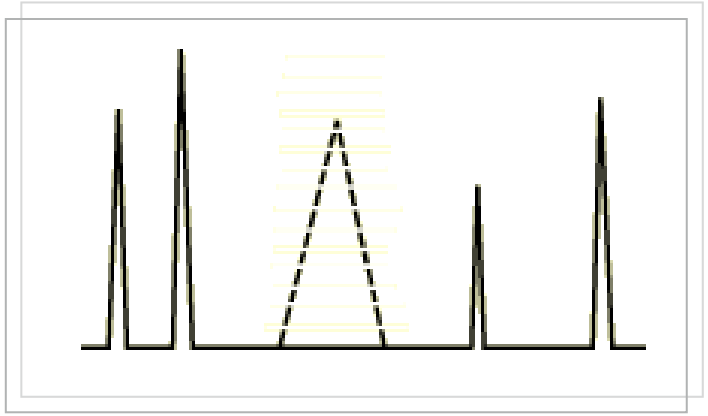
Remedy:
- Decrease in column or detector overloaded
- Column temperature too low
- Stationary phase too thin
- Poor injection technique

Remedy:
- Decrease the injection amount
- Decrease the analyte concentration or increase the split ratio
- Increase the temperature
- Use a thicker film column
- Repeat with a better injection technique

Ghost Peaks

Possible Causes:

- Contaminated carrier gas
- Contamination from laboratory glassware
- Decomposition of injected sample
- Dirty injection solution
- Activity on liner



Remedy:

- Replace the cylinder and/or the filter
- Ensure the glassware is contamination-free and clean
- Decrease the injection port temperature or use the on-column injection technique
- Carry out adequate clean-up of sample prior to injection
- Replace liner

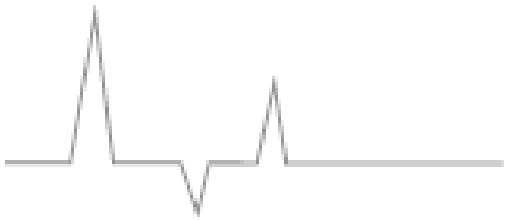
Positive & Negative Peaks….Strange things can happen!

Negative peaks can be caused by:

- Incorrect polarity of the detector
- Sample compound has greater thermal conductivity than the carrier gas and you are using a TCD or u-TCD detector

Positive and negative peaks can be due to:

- Detector overload in element-specific detectors such as ECD, NPD, FPD, etc
- Dirty ECD detector can give negative peak after a positive one



Positive & negative peaks

No Peaks

- Defective syringe
- "Blown" septum or massive leaks at the end
- Broken column or column installed incorrectly
- FID flame is not lit
- Incorrect column position in S/SL injector (too high)
- No carrier gas

Results Related Problems

Low Reproducibility of Peak Area

Possible Causes:

- Concentration not compatible with the dynamic range of the detection system
- Incorrect column installation
- Inappropriate injection technique
- Leaking syringe or septum
- Poor split flow or ratio control

Remedy:

- Ensure that the sample concentration is suitable for the detection system
- Try a different injection technique
- Check and replace the syringe/septum at regular intervals
- Monitor the flow. Replace the in-line filter
- Re-install column

Poor Sensitivity

Possible Causes:

…With Increased Retention Time
- Carrier gas flow rate too low

… With Normal Retention Time
- Oven or injector parameters are not optimised
- Leaks in the GC carrier gas line
- Syringe leaks during injection
- Split injection temperature too low
- Column is in poor condition, or wrong column type used

Retention Time Shifts

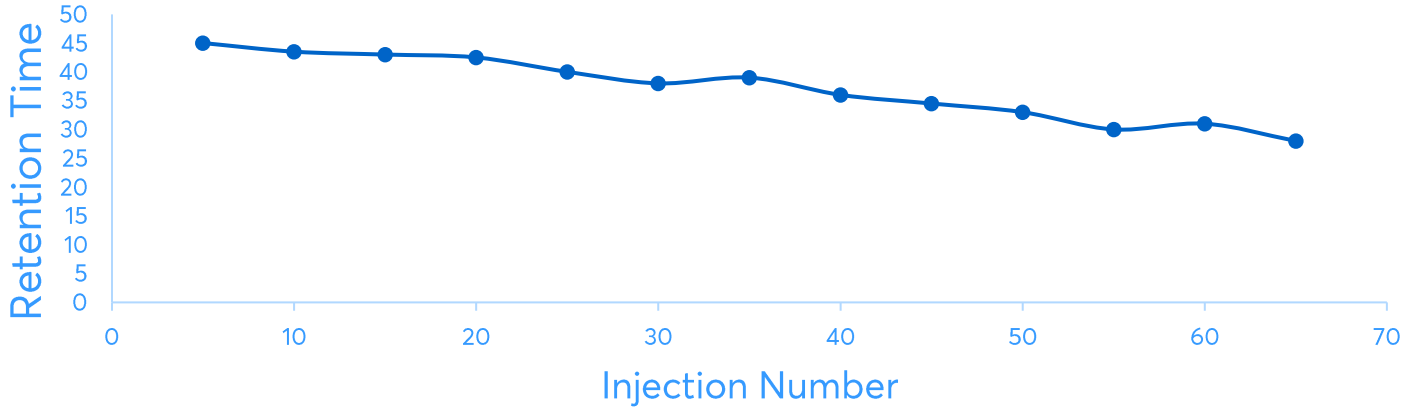
IF RETENTION TIME DECREASES:

Possible Causes:

- Stationary phase deteriorated by oxygen and/or water
- Stationary phase loss due to column bleeding
- Leak
- Column length reduced dramatically

Remedy:

- Use a carrier gas free of oxygen and water
- Reduce the column temperature
- Reinstall column
- Change column

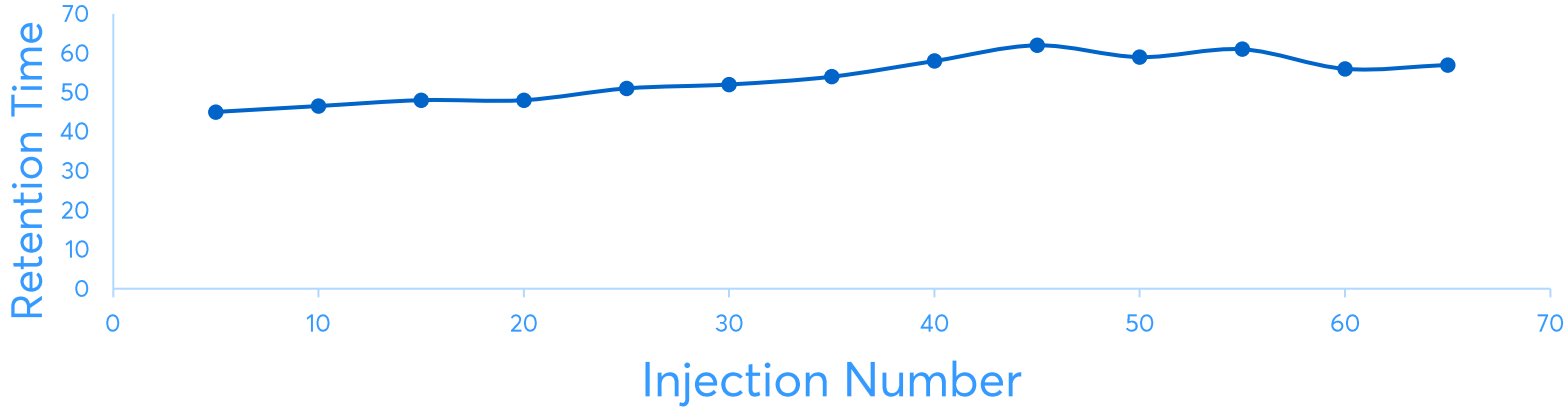


Retention Time Shifts

IF RETENTION TIME INCREASES:

Possible Causes:
- Increment of carrier gas leakage
- Carrier gas supply running out
- Temperature issues

Remedy:
- Check the septum and column connections
- Replace the gas cylinder



Low Reproducibility of Retention Time

Causes:

- Poor injection technique
- Sample size is too large
- Unstable column temperature
- GC column is in poor condition
- Oven temperature programmed to rise too quickly
- Air is leaking into the system at the injector seal or the carrier gas manifold

Remedy:

- Repeat with better injection technique
- Reduce the injected amount and/or volume
- Check the main oven door. Monitor the column temperature
- Condition the column. Change the column
- Reduce oven temperature ramp rate
- Trace and repair the leak

Other Issues

List is by no means exhaustive;

- Septa bleed issues not discussed
- Losing resolution
- Baseline oscillations
- Square wave peaks
- Contamination

Conclusions

01
– Understanding the GC components

02
– Column Installation

03
– Troubleshooting

04
– Conclusions

05

06