

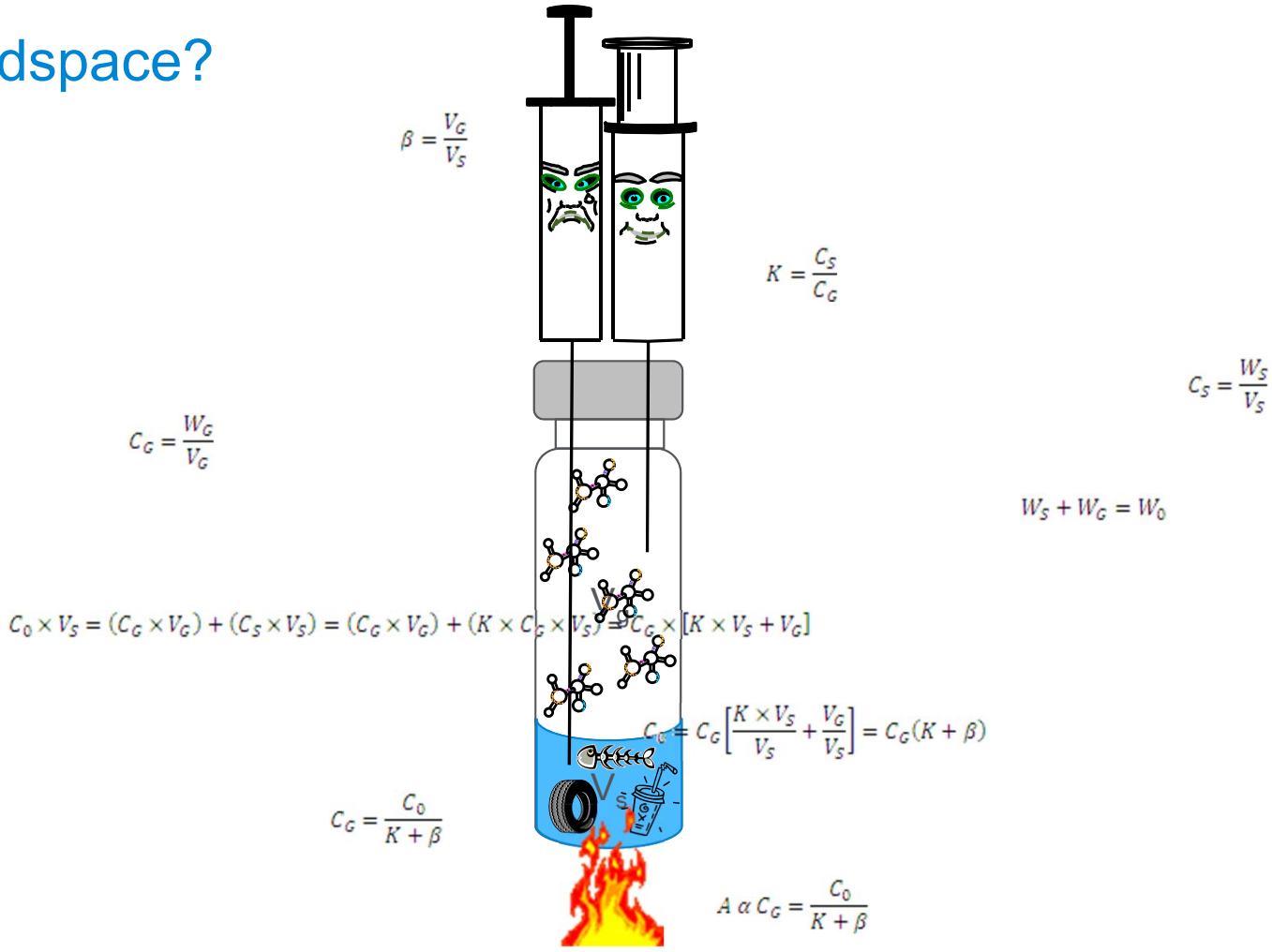
An Introduction to Headspace: Analyzing Volatile Analytes in a Non- volatile Matrix Doesn't Have to Be Messy

Method Development,
Method Optimization,
And Troubleshooting

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GC Application Scientist
April 29, 2020



What Is Headspace?



Why Headspace?

Clean injection into GC

Less Maintenance – only the volatile vapors are injected into the system

Less Sample Prep

For analysis of volatile analytes in matrices that can't be directly injected into the GC

**Not suitable for every application!

Types of Headspace

Static vs. Dynamic

Dynamic -- a continuous gas stream is passed through a sample that then elutes the compounds of interest onto a trap where they are held and concentrated. At some time, the trap is heated to desorb the analytes of interest onto the column to be chromatographed.

Typically Purge & Trap

Headspace-trap

Static – Sample is placed into a closed vial, the vial is heated and shaken and the sample is extracted and injected directly into the GC.

Loop system

Syringe

Pressure balance

Types of Static Headspace Autosamplers

Gas Tight Syringes

Not a 'true' closed system. Can lose a little sample as the syringe moves from the vial to the inlet.

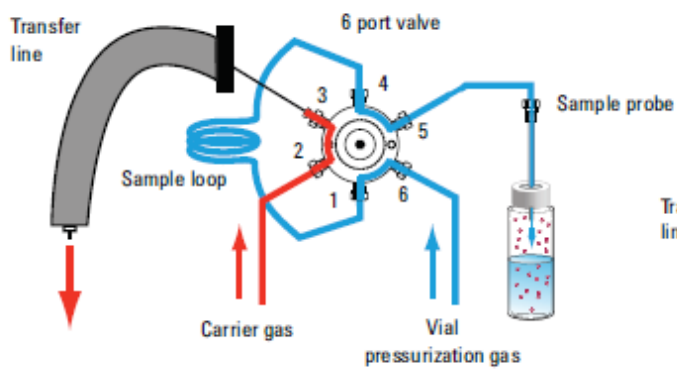
Balanced Pressure

Sample volume injected regulated by time. Vial pressure depressurized onto the column. Amount of sample injected is controlled by injection duration.

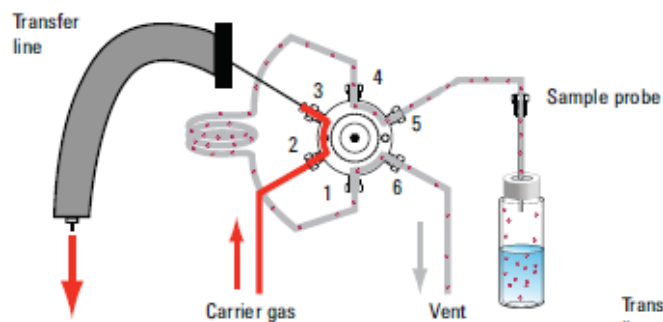
Pressure/Loop Systems

Fixed loop size determines injected volume. More metal surfaces!

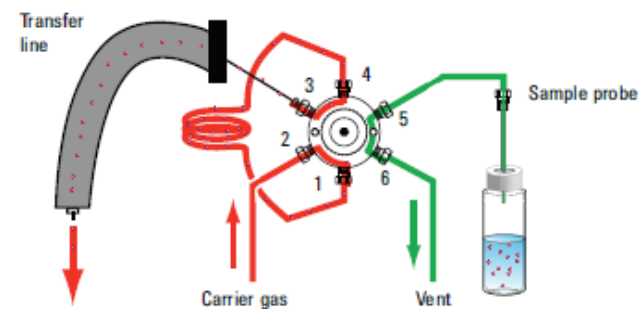
Agilent 7697A Loop System



Vial Pressurization

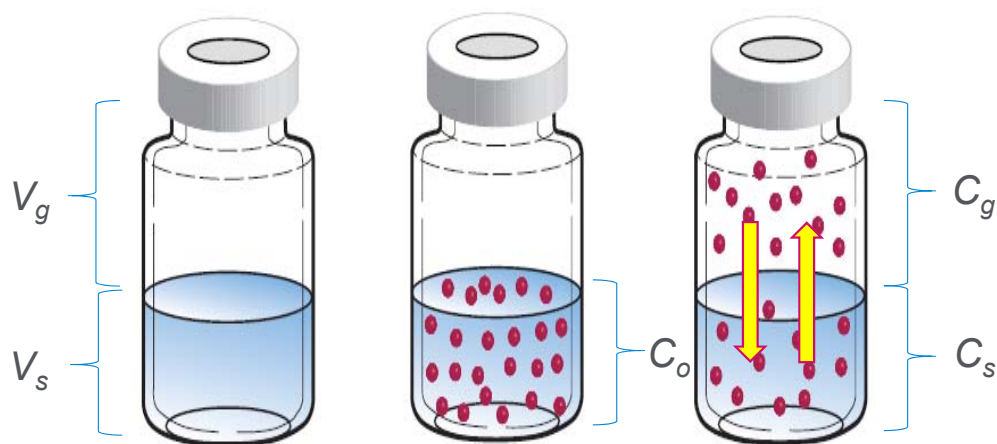


Loop Fill



Injection

Some Math to Make it Fun....



$$C_o V_s = C_g V_g + C_s V_s$$

$$\text{Partition Coefficient: } K = \frac{C_s}{C_g}$$

$$\text{Phase Ratio: } \beta = \frac{V_g}{V_s}$$

$$C_g = \frac{C_o}{(\beta + K)}$$

What Should We Focus On???

$$Cg = \frac{Co}{(\beta + K)}$$

When K is small, β has a bigger effect

When K is large, β has a minimal effect

What Should We Focus On???

Partition Coefficient: $K = \frac{C_s}{C_g}$

The smaller “ K ” the greater the concentration of the analyte in the gas phase

Like dissolves Like. The greater the solubility or affinity that an analyte has for the matrix, the larger the K

What drives K ?

What Drives K ?

Temperature:

higher temperatures drive K down:

Solubility.....

add salt!!!

add another solvent to the matrix

What Parameters Drive Success?

Incubation Temperature

Typically 20°C below the solvent BP

Incubation Time

Shaking

Efficient transfer of the sample from the vial to the column!

Use of Salts

Things to Consider:

Need to have at least 5 mL of headspace in the vial.

Keep Incubation temperature 10-20°C below the BP of the solvent/matrix

Long Incubation times 'generally' only delay the first sample

Higher split ratios help get the sample onto the column more efficiently –sharper peaks!!
lower splits are 'OK' with larger ID columns. Higher volumetric flow.

Try to keep sample from touching the vial septum
sample can get into the sample probe and contaminate the loop etc

Temperature Limitation of vial septa
be considerate of sample/analyte degradation

Headspace Parameters

Temperatures

- Oven
- Sample Loop
- Transfer Line
- Transfer Line Interface

Times

- Vial Equilibration
- Injection Duration
- GC Cycle Time

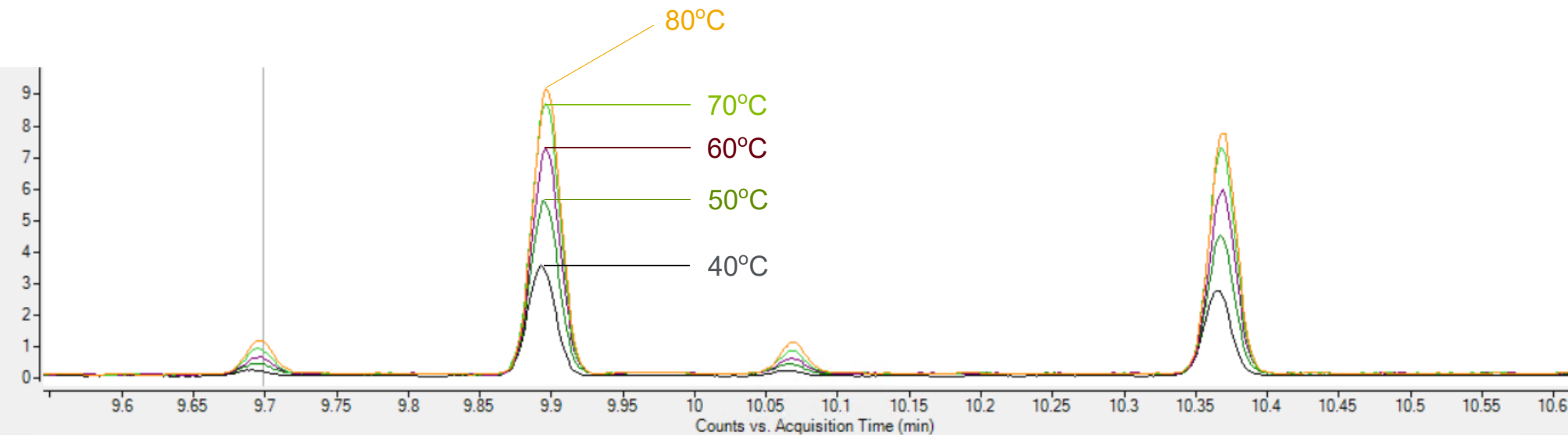
Vial & Loop

- Vial Size
- Shake vials while in oven
- Vial Fill Mode
- Loop Fill mode

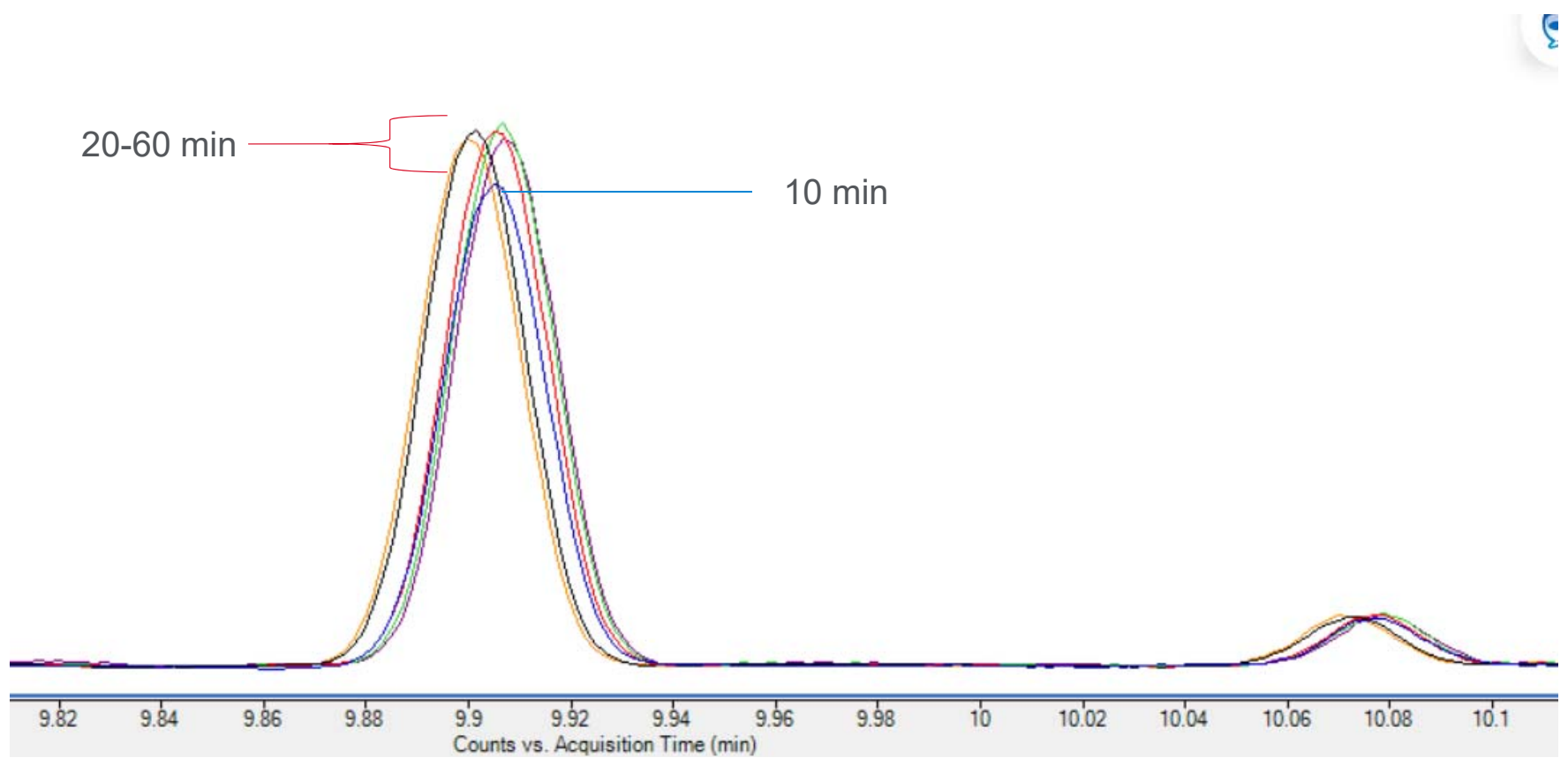
Incubation Temperature Increase

**20 Minutes

K decreases with T
Not equal for all analytes



Incubation Time

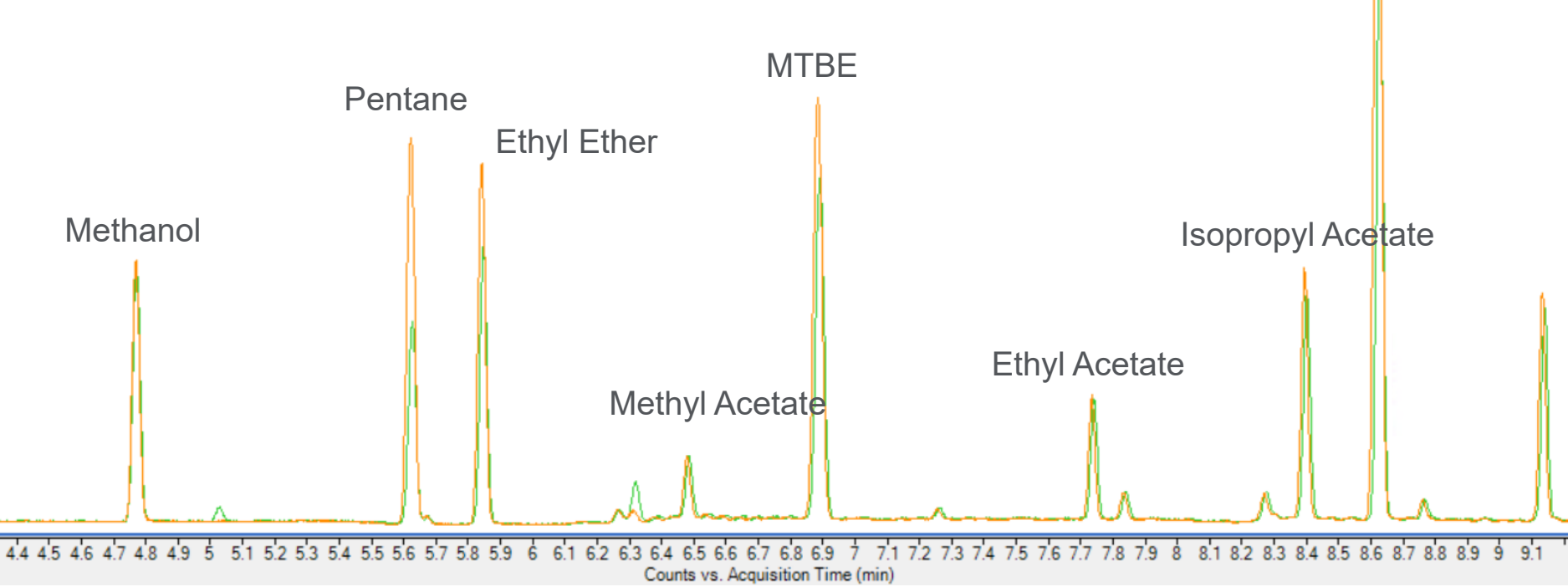


Change in Vial Size

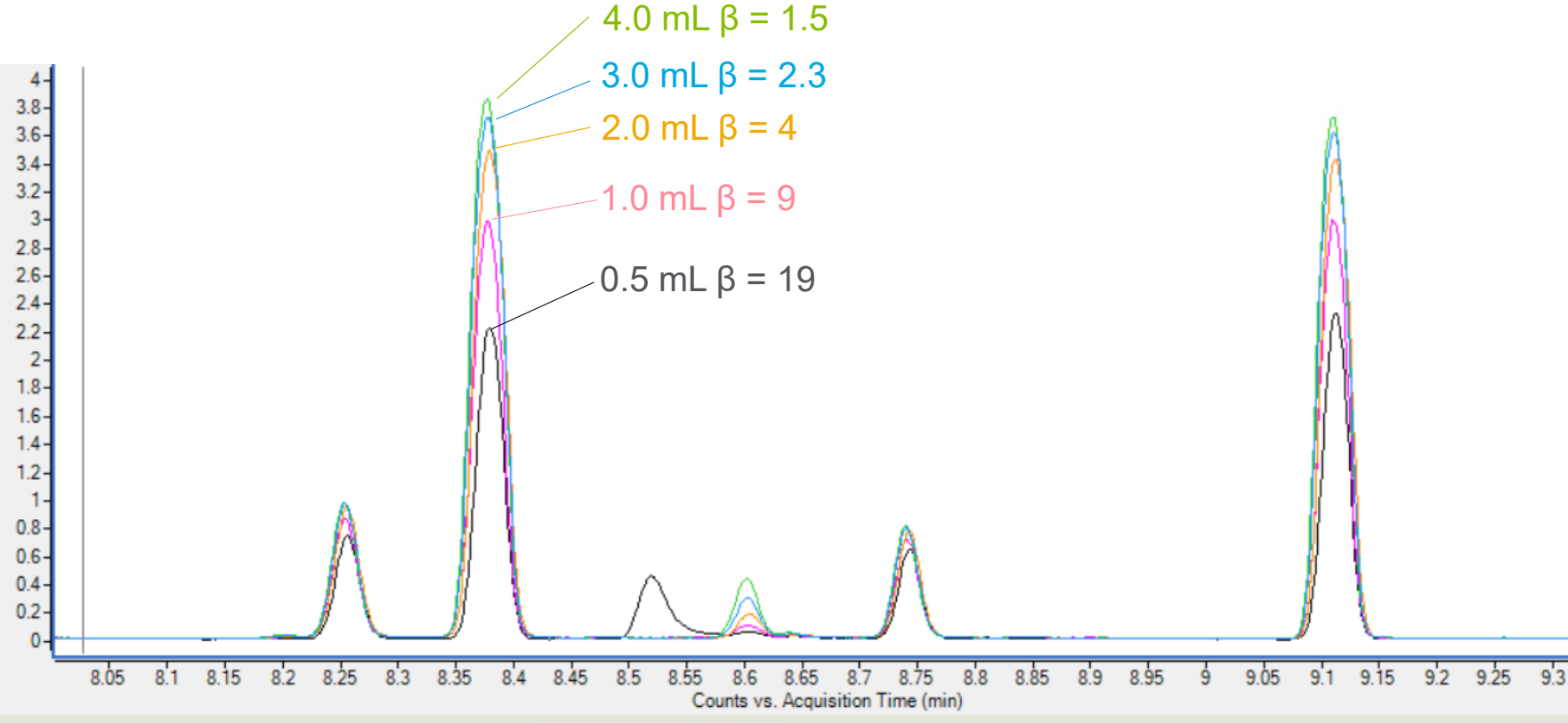
4 mL sample Changing β

10 mL vial $\beta = 1.5$

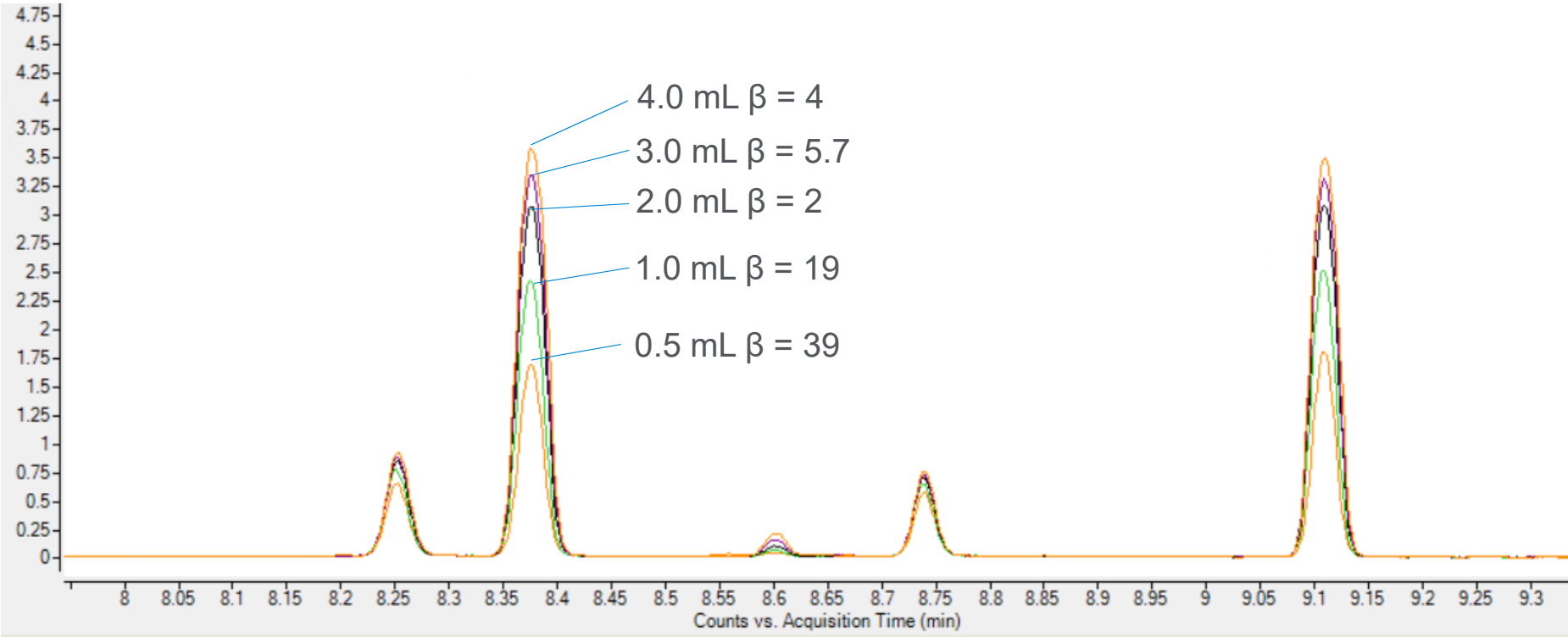
20 mL vial $\beta = 4$



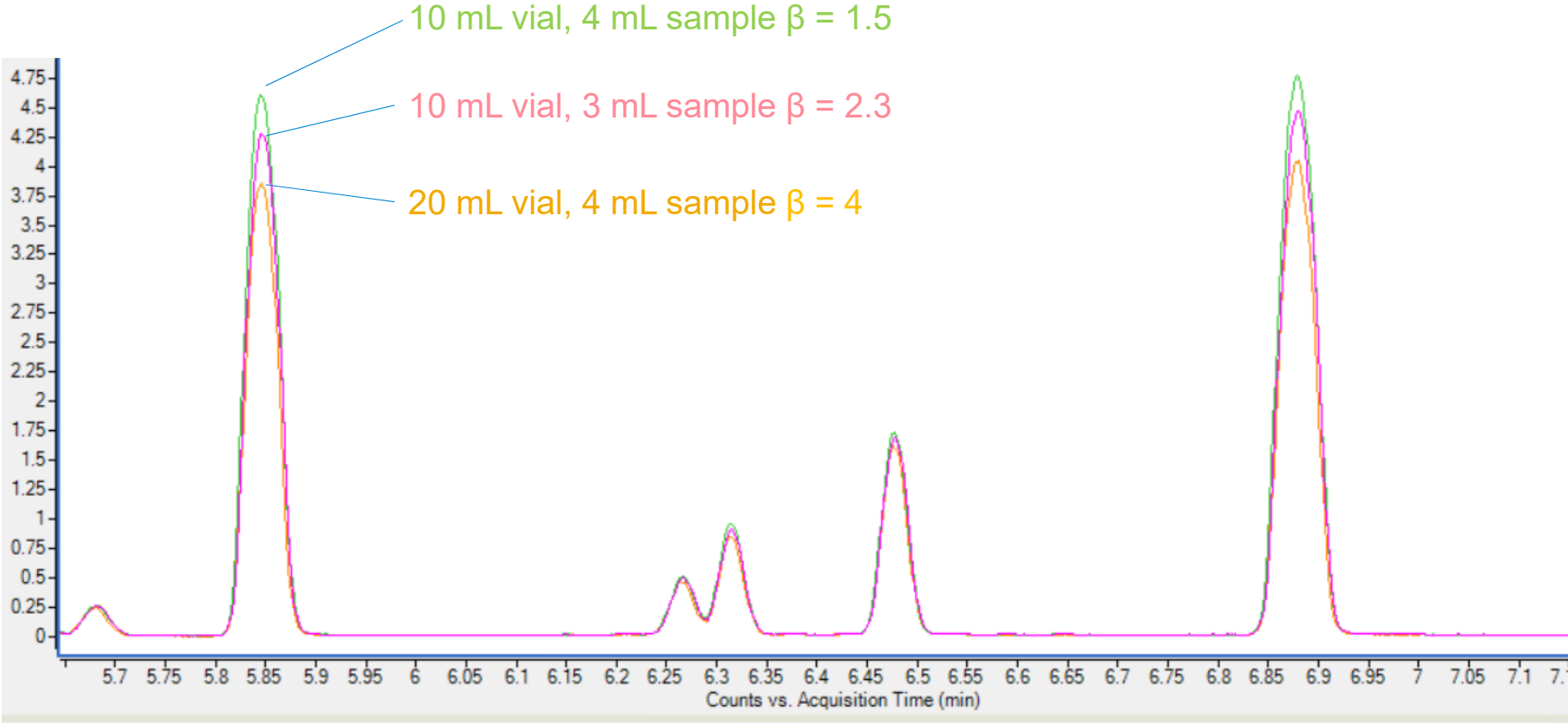
Change in sample volume 10 mL vial



Change in sample volume 20 mL vial

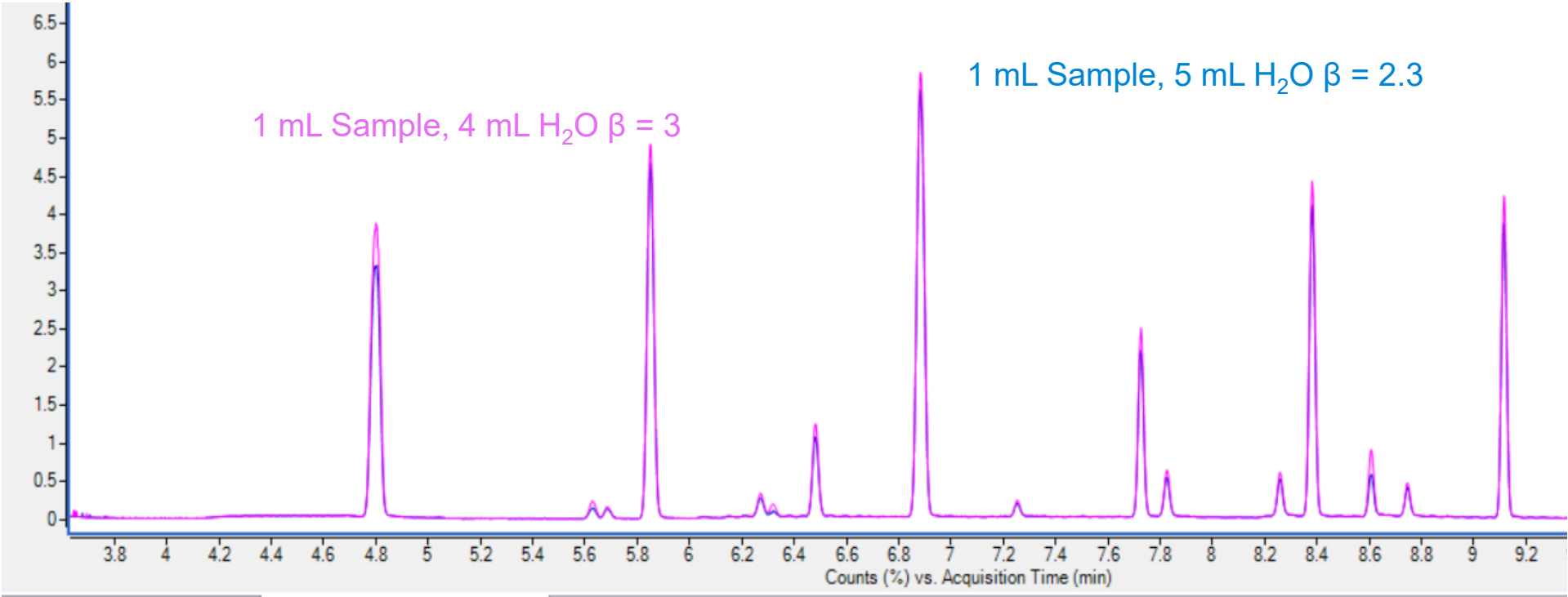


Change in sample volume and vial size



Does β Really Matter?

Same volume of sample
Different volume of diluent



What Else Can Effect Signal??

Loop Size

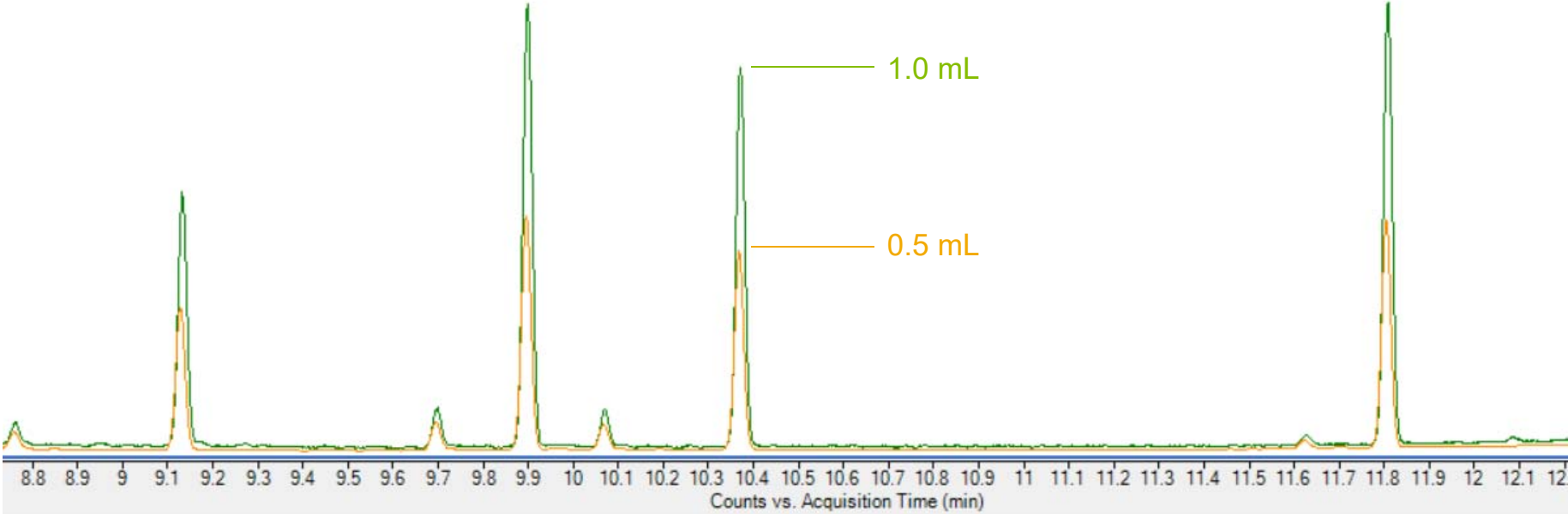
Loop Pressure

Split Ratio

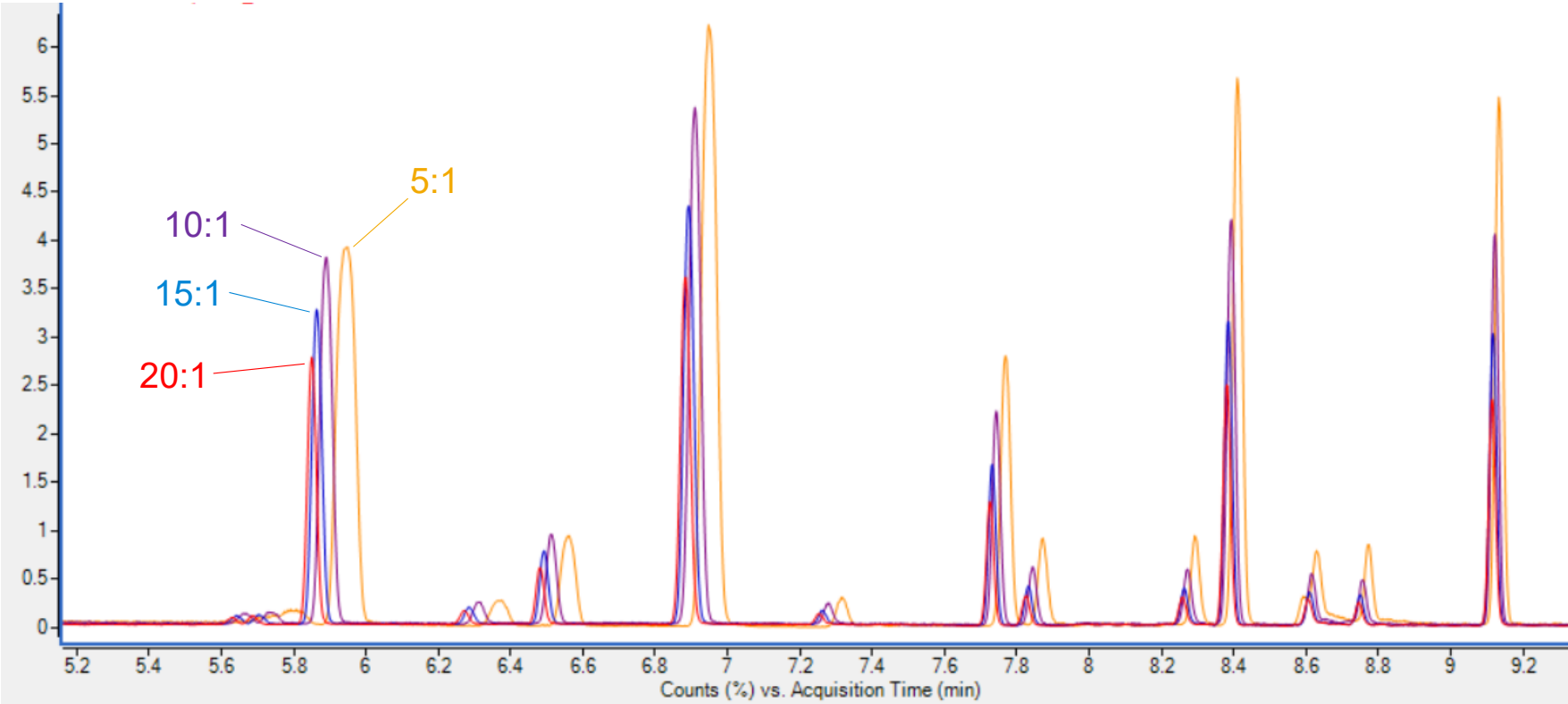
Liner Type??

Change in Loop Size

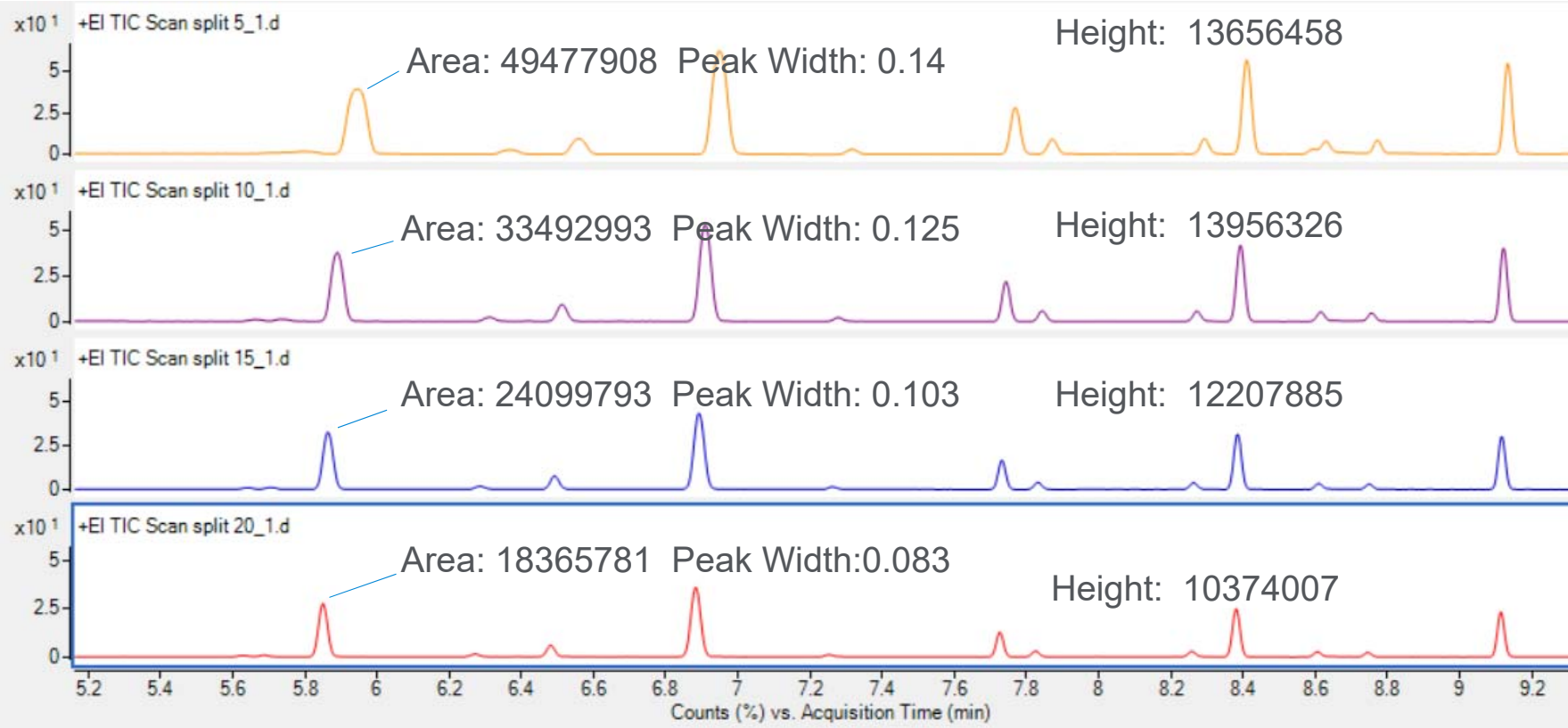
40:1 split (64 mL/min)



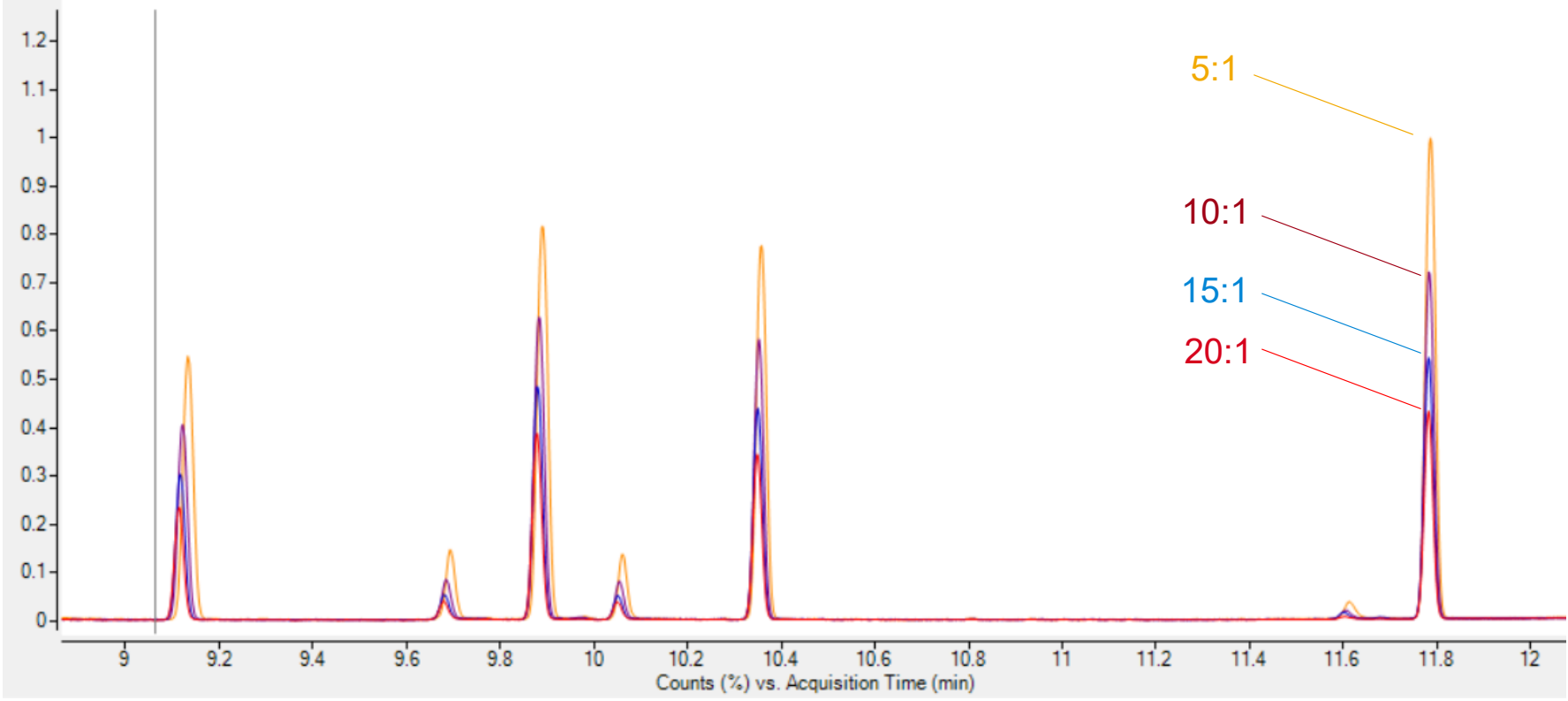
Change in Split Ratio



Change in Split Ratio



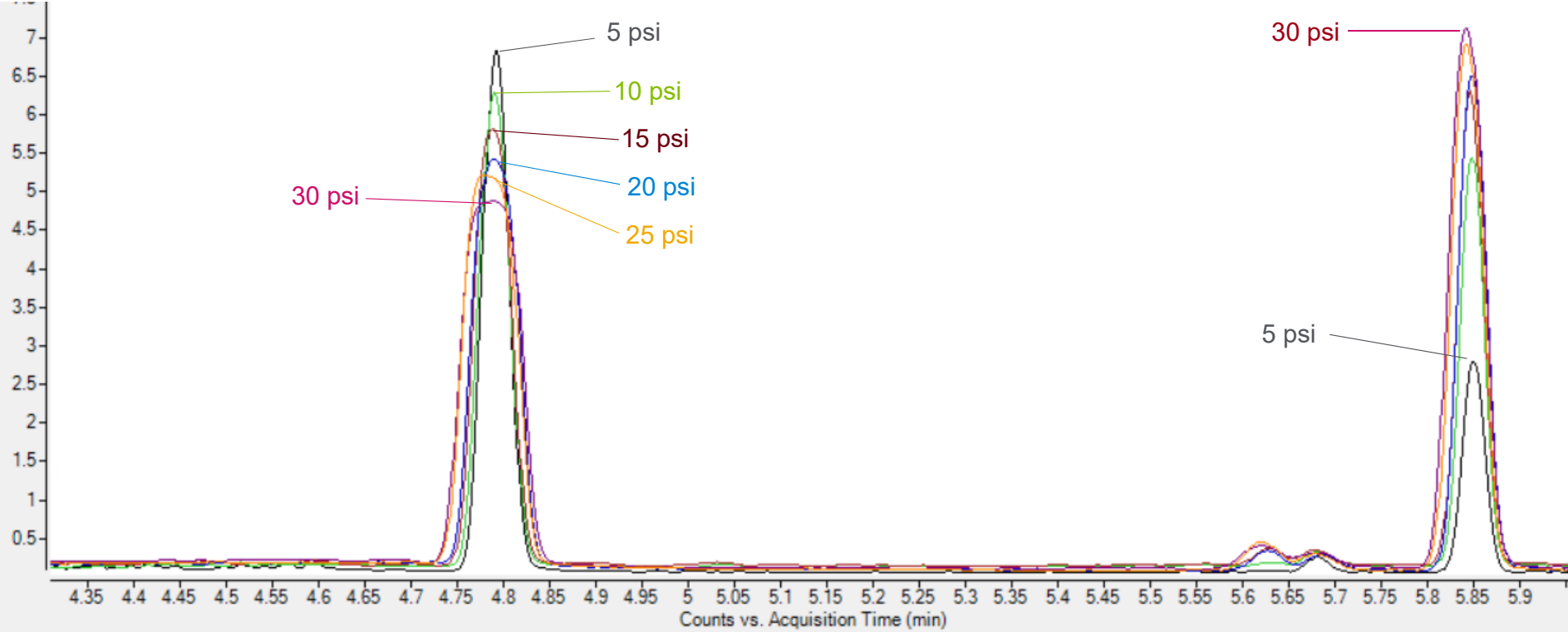
Change in Split Ratio



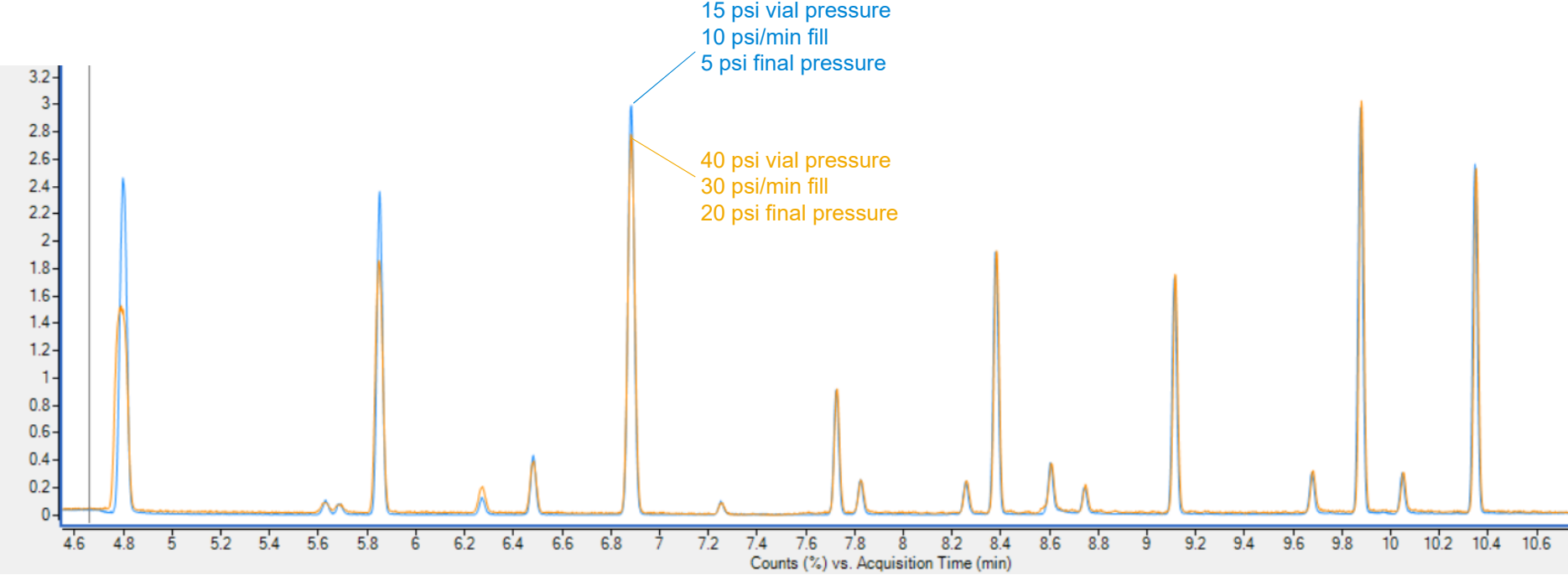
Change in Loop Pressure

First 2 eluting peaks

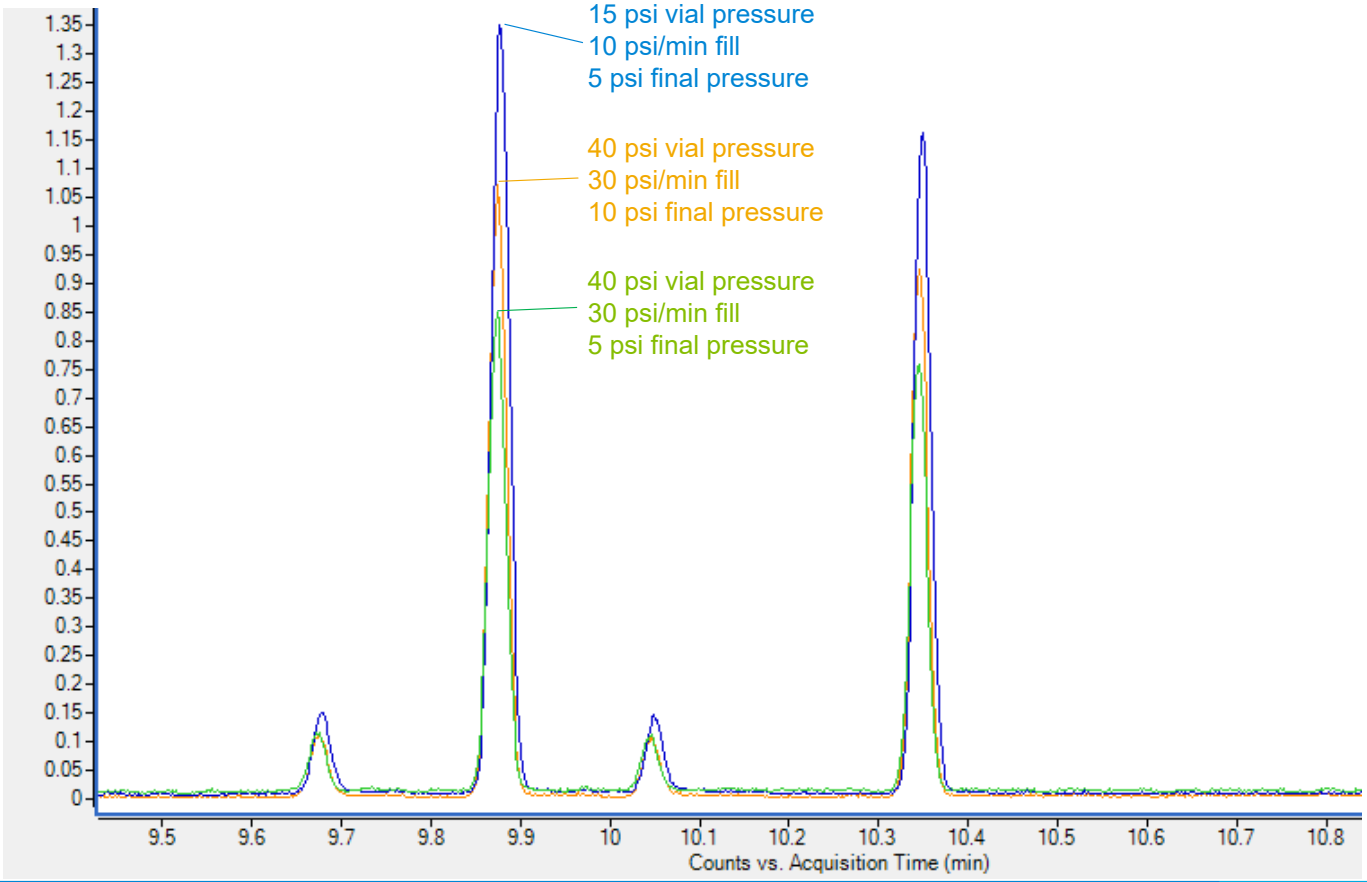
Vial Fill Pressure: 40 psi
Loop Fill Rate: 30 psi/min
Inlet Pressure: 28.3 psi



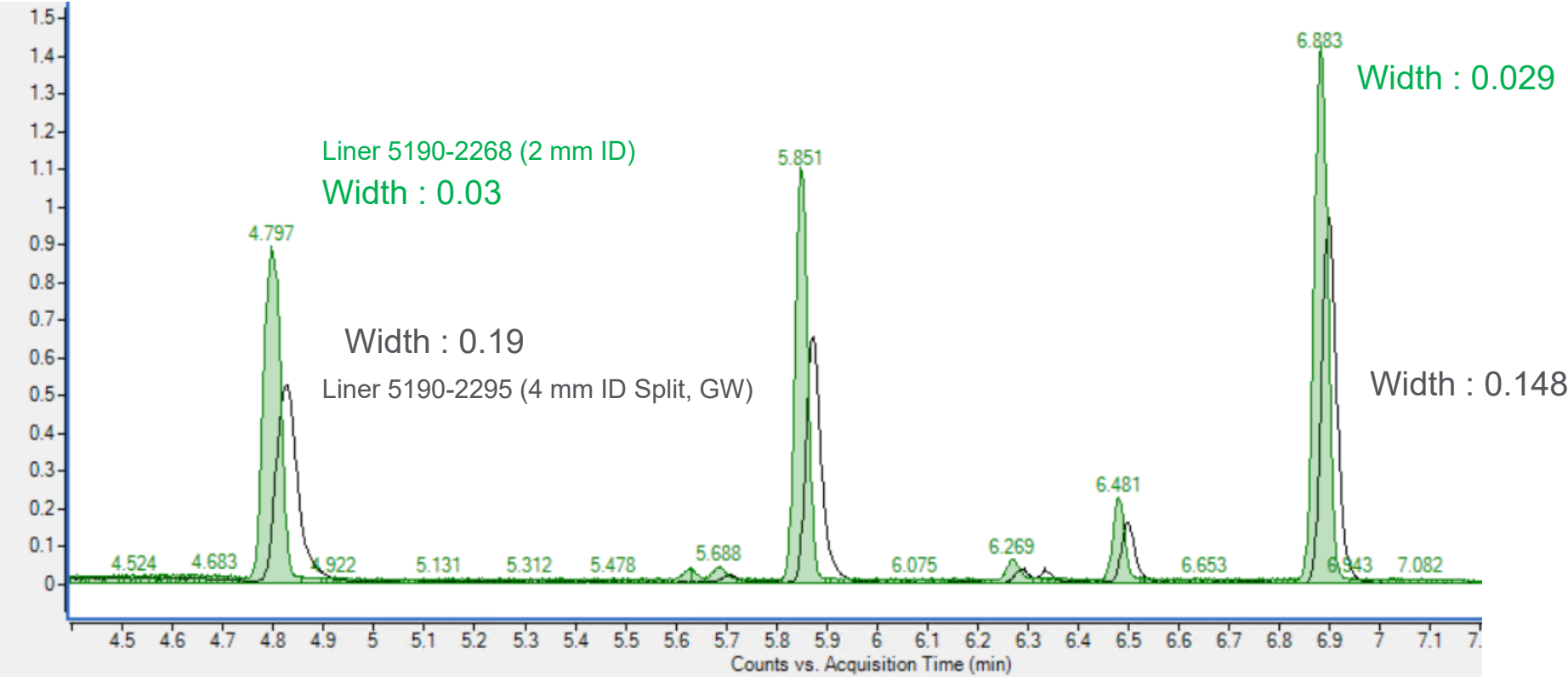
Is that a good way to increase signal?



The Effect of Vial Pressure, Loop Pressure and Fill Rate



Liner Size and Type



Use of Salts

Decreases the solubility of polar analytes in aqueous samples

Decreases K favoring the gas (headspace) phase

Potassium Carbonate (K_2CO_3)

Ammonium chloride (NH_4Cl)

Ammonium sulfate ($(NH_4)_2SO_4$)

Sodium Chloride ($NaCl$)

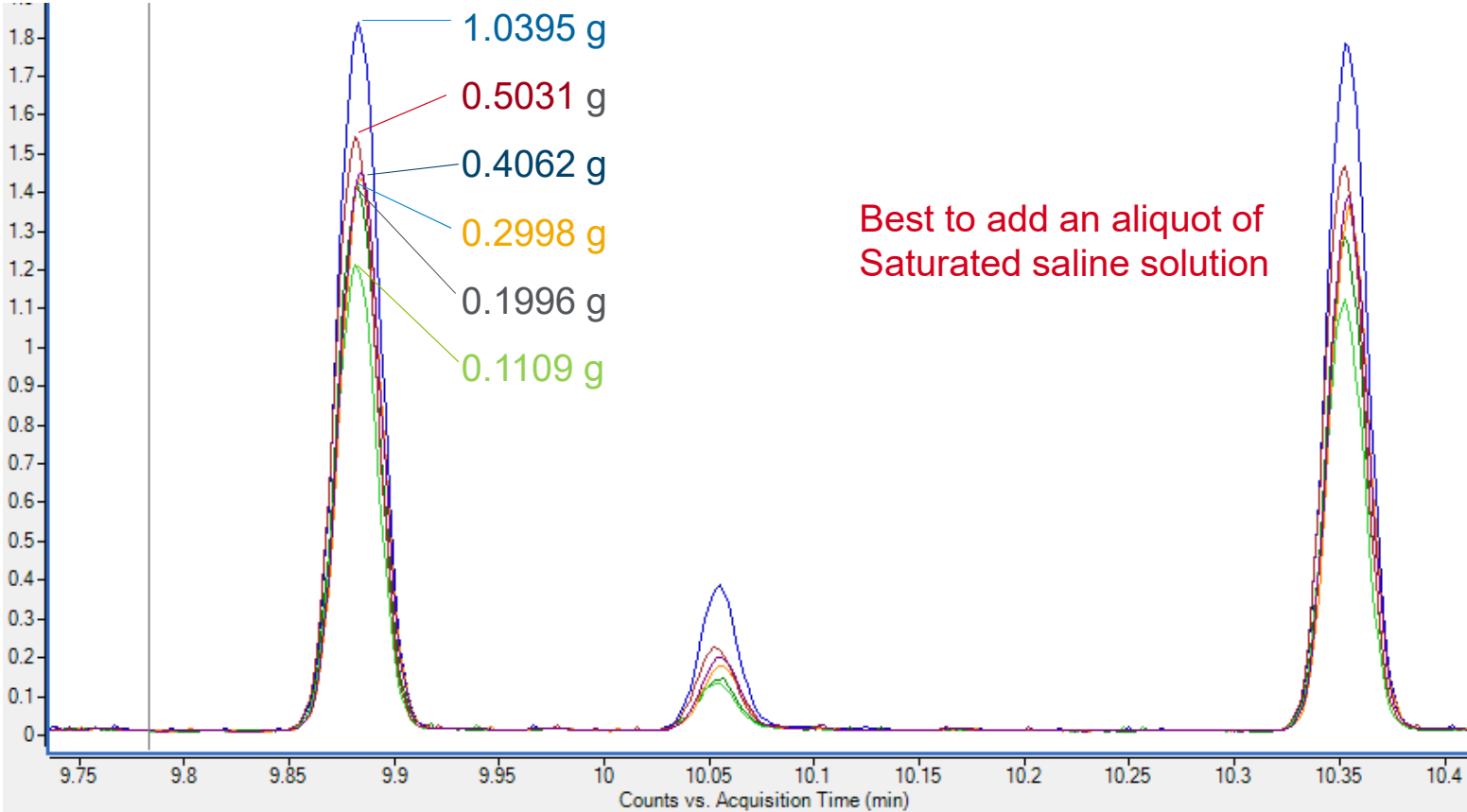
Sodium Citrate ($Na_3C_6H_5O_7$)

Sodium Sulfate (Na_2SO_4)

Use high quality, low impurity salts!!!

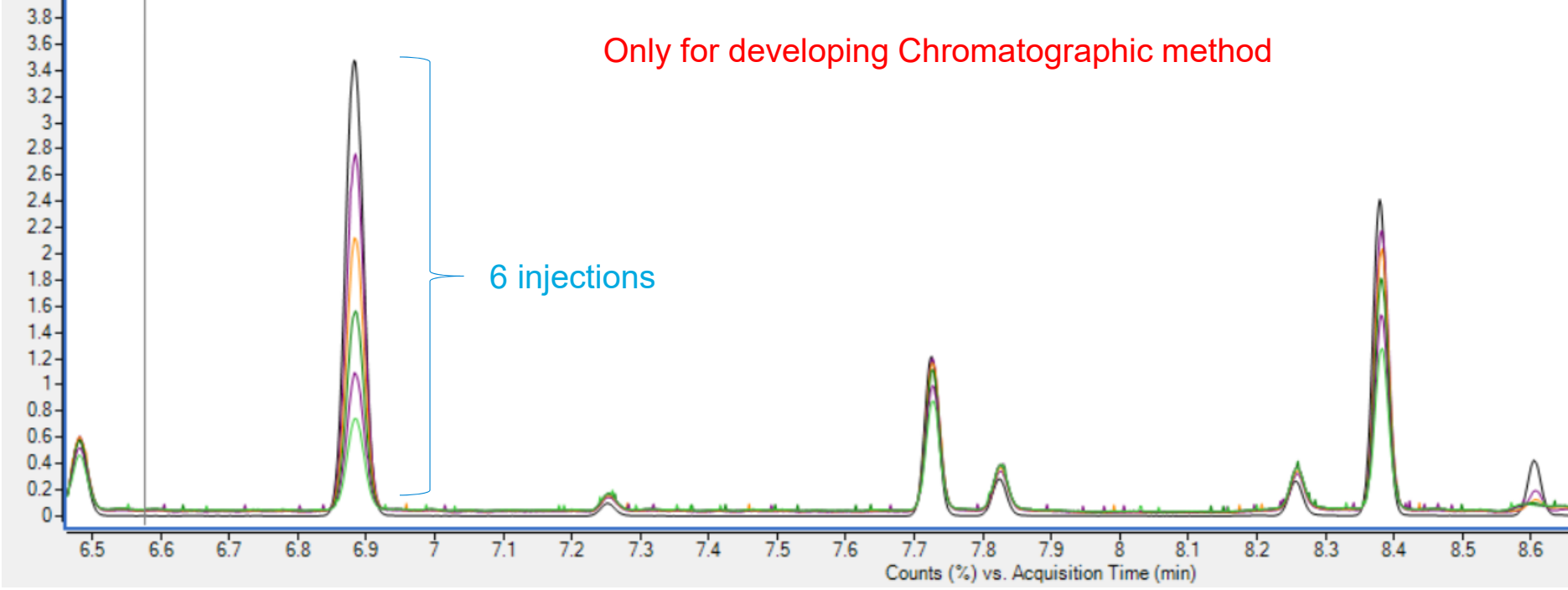
How Much Salt Do I Add?

20 mL vial
80°C oven Temp
20 minute incubation



Best to add an aliquot of Saturated saline solution

Can I Inject Multiple Times??



Headspace of Solid Matrices

Samples are ground to increase surface area

Used for solvents in plastics or polymers

When a matrix match is not available, MHE – “Multiple Headspace Extraction” is used

“Multiple Headspace Extraction for the Quantitative Determination of Residual Monomer and Solvents in Polystyrene” 5991-0974EN

Method Development Tools

Edit Method Parameters

Method Development

Manual

Would you like to increment a method setting over subsequent runs?

None

Assisted

- Create method based on a specific application
- Convert an existing valve and loop Headspace method
- Convert an existing pressure transfer Headspace method

Stand Alone HS Method Development Viewer

Agilent 7697A Method Development Viewer

Time (min) for Headspace method **Total method run time: 40.63 min**

-12.50 -6.25 0.00 6.25 12.50 18.75

Temperatures Times Vial and Loop Carrier Advanced Functions Sequence Actions **Method Development**

Method Development

Manual

Would you like to increment a method setting over subsequent runs?

None

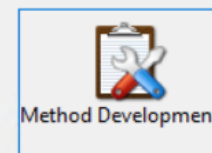
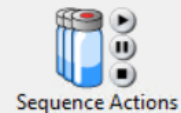
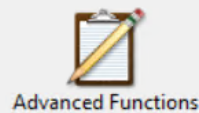
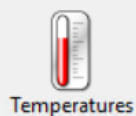
Assisted

- Convert an existing valve and loop Headspace method
- Convert an existing pressure transfer Headspace method

Export Print Exit

Method Development Tool:

Edit Method Parameters



Method Development

Manual

Would you like to increment a method setting over subsequent runs?

Temperature
None
Temperature
Vial Equilibration
Shaking

Temperature increment: 10 °C

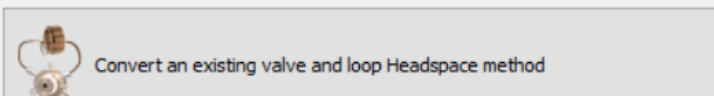
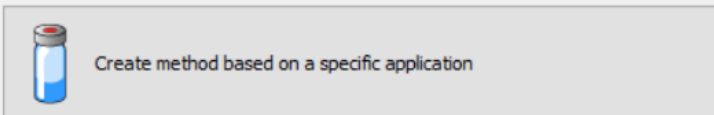
Maximum oven temperature:

80 °C

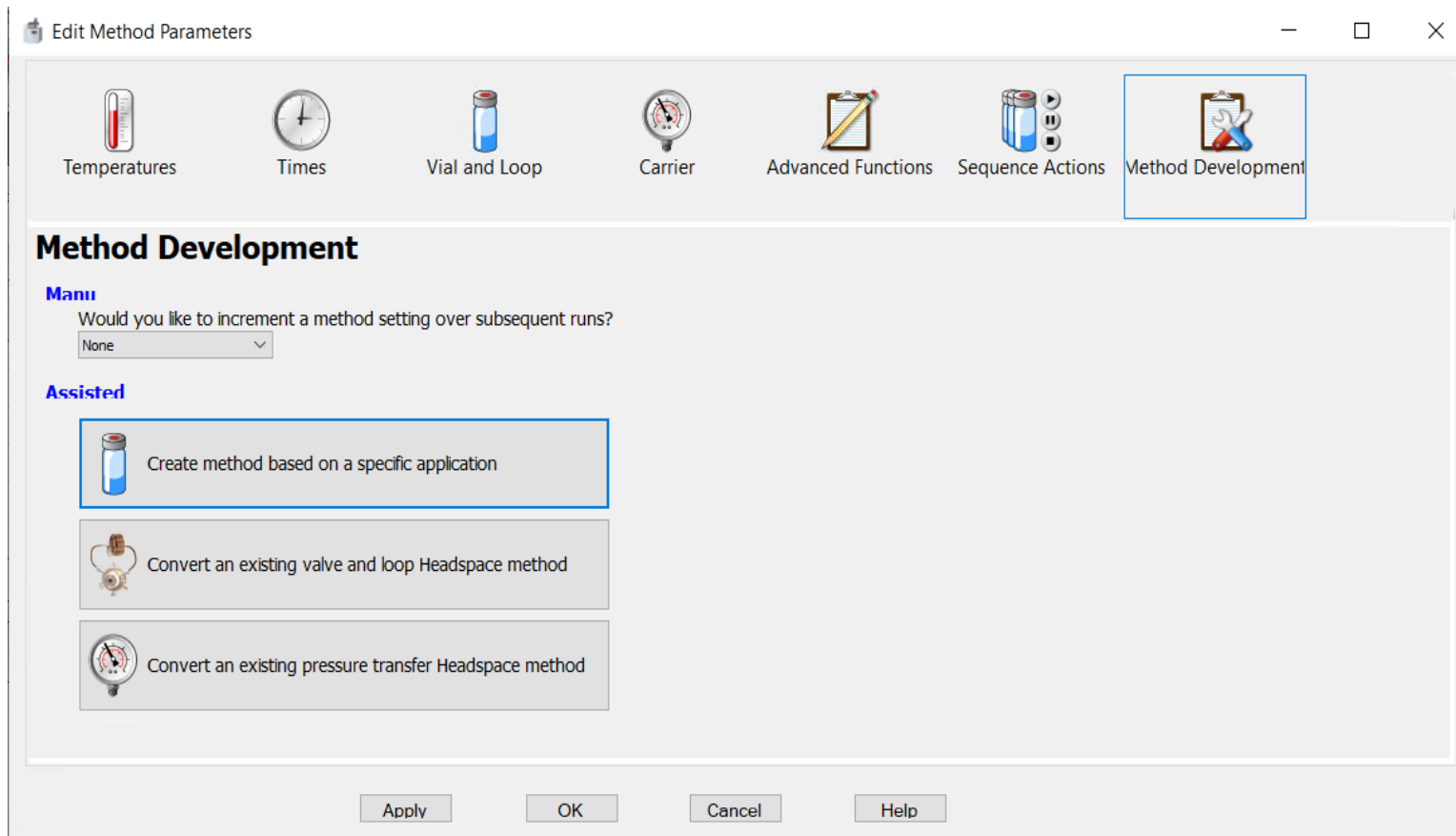
Choose your set points

Choose what you want to increment

Assisted



Method Development Tool:



Method Development Tools



Create method based on a specific application ✕

Sample Matrix

Matrix Type: Liquid Solid

Vial Size: 20 mL ▼

Sample Volume: 2 mL

Solvent

Solvent: Hexadecane ▼

Boiling Point: 287 °C

Compound(s) of Interest

Highest Boiling Point: 160 °C

[Preview Changes](#) [Cancel](#) [Help](#)

Create Method Based on Specific Application

Red parameters are what will be change from initial method.

Green parameters are the new settings.


Confirm method changes



Original Method	Modified Method
Temperature Settings:	Temperature Settings:
Oven Temperature (°C): 80	Oven Temperature (°C): 145
Loop Temperature (°C): 85	Loop Temperature (°C): 145
Transfer Line Temperature (°C): 120	Transfer Line Temperature (°C): 160
Timing Settings:	Timing Settings:
Vial Equilibration (min): 20.00	Vial Equilibration (min): 30.00
Injection Duration (min): 1.00	Injection Duration (min): 0.50
GC Cycle Time (min): 20.00	GC Cycle Time (min): 25.00
Vial and Loop Settings:	Vial and Loop Settings:
Vial Size: 20	Vial Size: 20
Vial Shaking: Level 3, 36 shakes/min with acceleration of 125 cm/s ²	Vial Shaking: Level 1, 18 shakes/min with acceleration of 60 cm/s ²
Fill Mode: Default	Fill Mode: Default
Fill Pressure (psi): 40	Fill Pressure (psi): 15
Loop Fill Mode: Custom	Loop Fill Mode: Custom
Loop Ramp Rate (psi/min): 30	Loop Ramp Rate (psi/min): 20
Loop Final Pressure (psi): 30	Loop Final Pressure (psi): 9
Loop Equilibration Time: 0.05	Loop Equilibration Time: 0.05
Carrier Settings:	Carrier Settings:
Carrier Control Mode: GC controls Carrier	Carrier Control Mode: GC controls Carrier
Advanced Settings:	Advanced Settings:
Extraction Mode: Single Extraction	Extraction Mode: Single Extraction
Vent After Extraction: ON	Vent After Extraction: ON
Post Injection Purge: Default, 100 mL/min for 1 min	Post Injection Purge: Default, 100 mL/min for 1 min
Acceptable Leak Check: Default, 0.2mL/min	Acceptable Leak Check: Default, 0.2mL/min
Sequence Actions:	Sequence Actions:
Vial Missing:: Skip	Vial Missing:: Skip
Wrong Vial Size: Continue	Wrong Vial Size: Continue
Leak Detected: Continue	Leak Detected: Continue
System Not Ready: Abort	System Not Ready: Abort

Print Accept Reject Help

Convert an Existing Pressure Transfer Method

Convert an existing pressure transfer Headspace method ✕

Temperatures		Timing	
<input checked="" type="checkbox"/> Oven Thermostatting	Setpoint: 80 °C	 GC Cycle	Setpoint: 25 min
<input checked="" type="checkbox"/> Needle	80 °C	Thermostatting	15 min
<input checked="" type="checkbox"/> Transfer Line	120 °C	Pressurization	0.2 min
		Withdrawal	0.5 min
		Pre/Post Cryofocusing	0 min
		Inject	0.5 min

Pressure		Other Settings	
 Carrier	Expected Value: 28 psi	 Shaker	On ▾
Vial	15 psi		

[Preview Changes](#) [Cancel](#) [Help](#)

Convert an Existing Pressure Transfer Method

✕

Confirm method changes

Original Method	Modified Method
Temperature Settings: Oven Thermostatting Temperature (°C): 80 Needle Temperature (°C): 80 Transfer Line Temperature (°C): 120	Temperature Settings: Oven Temperature (°C): 80 Loop Temperature (°C): 80 Transfer Line Temperature (°C): 120
Timing Settings: GC Cycle Time (min): 25.00 Thermostatting Time (min): 15.00 Pressurization Time (min): 0.20 Withdrawal Time (min): 0.50 Pre/Post Cryofocusing Time (min): 0.00 Injection Duration (min): 0.50	Timing Settings: Vial Equilibration (min): 15.00 Injection Duration (min): 0.50 GC Cycle Time (min): 25.00
Pressure Settings: Carrier (psi): 28 Vial (psi): 15	Vial and Loop Settings: Vial Size: 20 Vial Shaking: Level 5, 71 shakes/min with acceleration of 260 cm/s ² Fill Mode: Default Fill Pressure (psi): 15 Loop Fill Mode: Default
Advanced Settings: Vial Shaking: ON	Carrier Settings: Carrier Control Mode: GC controls Carrier
	Advanced Settings: Extraction Mode: Single Extraction Vent After Extraction: ON Post Injection Purge: Default, 100 mL/min for 1 min Acceptable Leak Check: Default, 0.2mL/min
	Sequence Actions: Vial Missing:: Skip Wrong Vial Size: Continue Leak Detected: Continue System Not Ready: Abort

Print
Accept
Reject
Help

Types of Vials



Consumables



Good for SPME



Max Temp 125°C
Butyl/PTFE



Safety Cap
Tears at 45 psi



Max Temp 180°C
Silicone/PTFE

High Performance Septa

300°C

Reduce siloxane interferences at high temperature



Steel caps!! Recommend the high power crimper!

Pub# 5990-9385EN

High Power Crimper



Standard Crimpers



How Tight is Right???



Good crimp



Too tight



Too loose

Common Issues

Carryover/Contamination

- Too much Sample in the vial
- Shaking is set too high
- Sample condensing in the loop

Conatminates the Probe, loop,.....

Septum or Caps blowing off

- Oven temperature is too high
- Creating too much pressure in the vial..high performance caps??

High %RSD

- Vial Leaks. Check vial crimping. Sequence Actions and log book.
- Condensation in the flow path.
- Check temperatures.
- Vial equilibration time too short

Can Run Leak Check

Sequence makes it through first sample only

- GC cycle time is too short. Check Sequence Actions and log book.

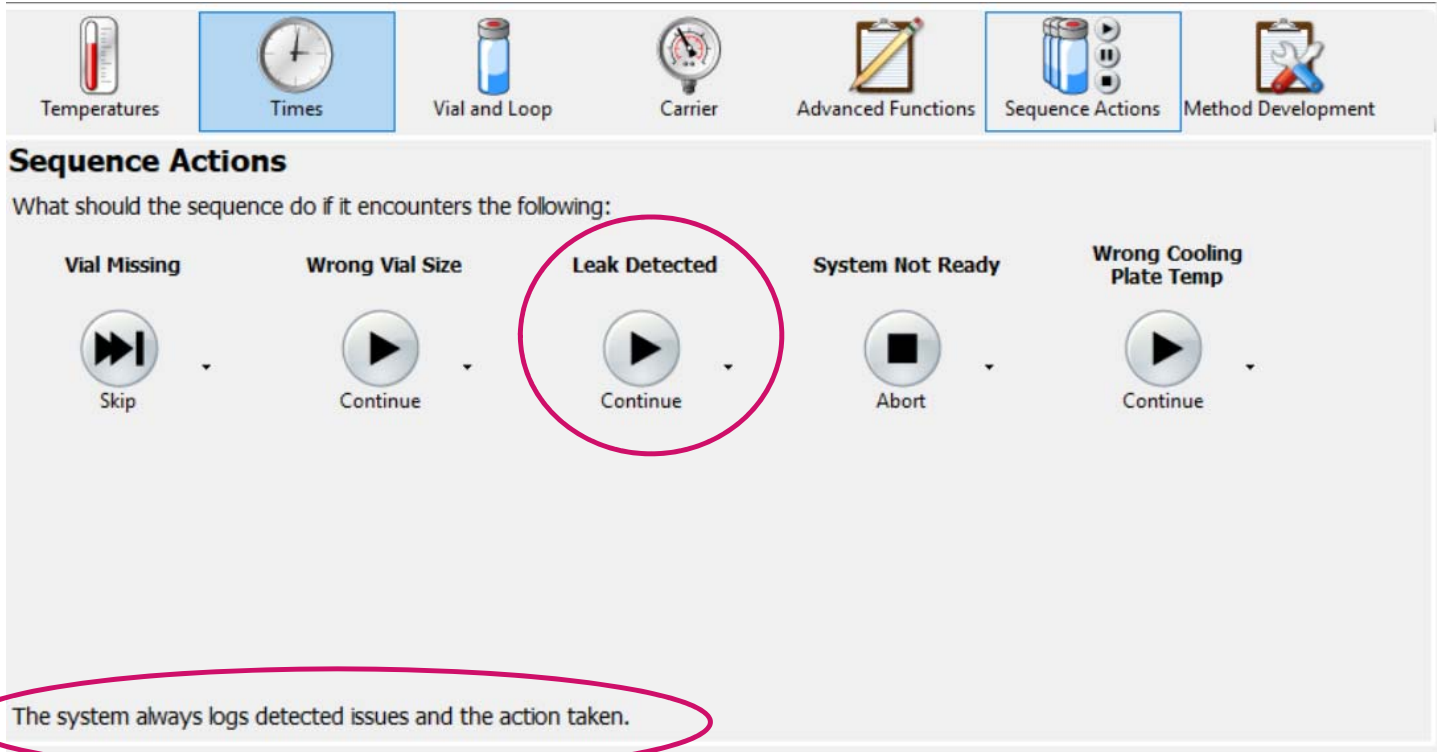
Change the Loop Purge Time and Flow

--Carryover Issues

The screenshot displays the 'Advanced Functions' tab in the software interface. The 'Venting and Purging' section is active, showing the following settings:

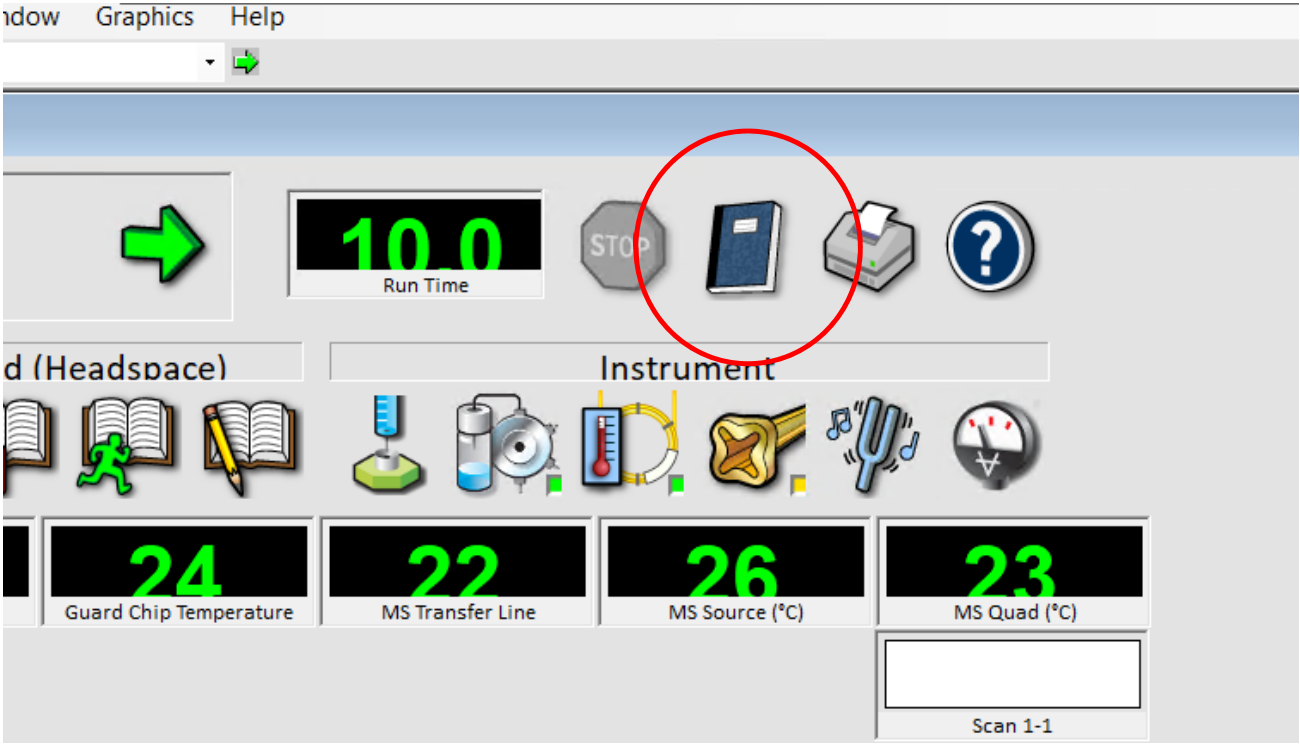
- Extraction Mode:** Single extraction (selected), Multiple extractions, Concentrated extractions.
- Venting and Purging:**
 - Vent vial pressure after extraction
 - Post-injection purge: Default
 - Purge flow: 100 mL/min
 - Purge time: 1 min
- Dynamic Leak Checking:**
 - Acceptable leak rate: Default
 - Leak flow: 0.2 mL/min
- Barcoding of Vials:**
 - Barcode symbology: Enable All
 - Vial barcodes include checksum

Vial Leaks



The screenshot displays the 'Sequence Actions' configuration screen. At the top, a navigation bar includes icons for Temperatures, Times, Vial and Loop, Carrier, Advanced Functions, Sequence Actions, and Method Development. The 'Sequence Actions' section is titled 'Sequence Actions' and asks 'What should the sequence do if it encounters the following:'. Below this, five error conditions are listed with corresponding action buttons: 'Vial Missing' (Skip), 'Wrong Vial Size' (Continue), 'Leak Detected' (Continue), 'System Not Ready' (Abort), and 'Wrong Cooling Plate Temp' (Continue). The 'Leak Detected' option and its 'Continue' button are highlighted with a red circle. A red oval at the bottom of the screen contains the text: 'The system always logs detected issues and the action taken.'

Log Book is in the Instrument Control Screen



Starting Parameters

Temperatures

- Oven **20°C below the BP of the matrix**
- Sample Loop **Same Temp as Oven**
- Transfer Line **Hot enough not to have anything condense**
- Transfer Line Interface **Same as inlet**

Times

- Vial Equilibration **10 minutes, but use Method Development**
- Injection Duration **.5 minutes**
- GC Cycle Time **Run time + Cool down to Ready**

Vial & Loop

- Vial Size **20 mL**
- Shake vials while in oven **3 (Low)**
- Vial Fill Mode **Default 15 psi**
- Loop Fill mode **Default**

Summary

Stay 10-20°C below the boiling point of the solvent/matrix

Keep a minimum of 5 mL of headspace in the vial

Utilize the method development tools
Don't forget to turn off the function!!!

Try to maximize parameters based on compound(s) with highest K
not every compound responds/reacts the same way

Use 10 mL vials if appropriate

Be consistent with crimping vials. Set the crimper properly so everyone is successful!

When troubleshooting think about what can or cannot cause the issues you are experiencing

Contact technical support!!

Additional Resources

[7697A Headspace Sampler Troubleshooting \(PDF\)](#) G4556-90018

[7697A Headspace Sampler Advanced Operation \(PDF\)](#) G4556-90016

Agilent.com Search for 7697A

Contact Agilent Chemistries and Supplies Technical Support



1-800-227-9770 Option 3, Option 3:

Option 1 for GC/GCMS Columns and Supplies

Option 2 for LC/LCMS Columns and Supplies

Option 3 for Sample Prep Products, Filtration and QuEChERS

Option 4 for Spectroscopy Supplies

Available in the USA 8-5 all time zones



gc-column-support@agilent.com

lc-column-support@agilent.com

spp-support@agilent.com

spectro-supplies-support@agilent.com



GC columns and supplies