

Head in the Right Direction with Headspace Analysis

Method Development, Method Optimization, and Troubleshooting

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What Is Headspace?

The diagram illustrates a vial containing a liquid phase labeled "Junk" with volume V_S and a gas phase (headspace) above it. Two syringes are inserted into the vial: one labeled "Bad" (red) and one labeled "Good" (green). The "Bad" syringe is positioned higher, drawing more gas from the headspace, while the "Good" syringe is positioned lower, drawing more liquid from the "Junk" phase. The word "HEAT" is written in red below the vial, indicating that the liquid is being heated to volatilize the "Junk".

Chemical formulas surrounding the diagram include:

- $\beta = \frac{V_G}{V_S}$ (top left)
- $C_G = \frac{W_G}{V_G}$ (middle left)
- $C_0 \times V_S = (C_G \times V_G) + (C_S \times V_S) = (C_G \times V_G) + (K \times C_G \times V_S) = C_G \times [K \times V_S + V_G]$ (left side)
- $C_G = \frac{C_0}{K + \beta}$ (bottom left)
- $K = \frac{C_S}{C_G}$ (middle right)
- $C_S = \frac{W_S}{V_S}$ (top right)
- $W_S + W_G = W_0$ (right side)
- $C_0 = C_G \left[\frac{K \times V_S}{V_S} + \frac{V_G}{V_S} \right] = C_G (K + \beta)$ (bottom right)
- $A \propto C_G = \frac{C_0}{K + \beta}$ (bottom right)

Why Headspace?

Offers clean injections into GC systems

- Less maintenance – only the volatile vapors are injected into the system

Less sample preparation

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

*Not suitable for some applications

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 point in the process, the trap is heated to desorb the analytes of interest onto the column to be chromatographed.

- Typically purge and trap
- Headspace trap

Static – The 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. A small amount of sample can be lost as the syringe moves from the vial to the inlet.

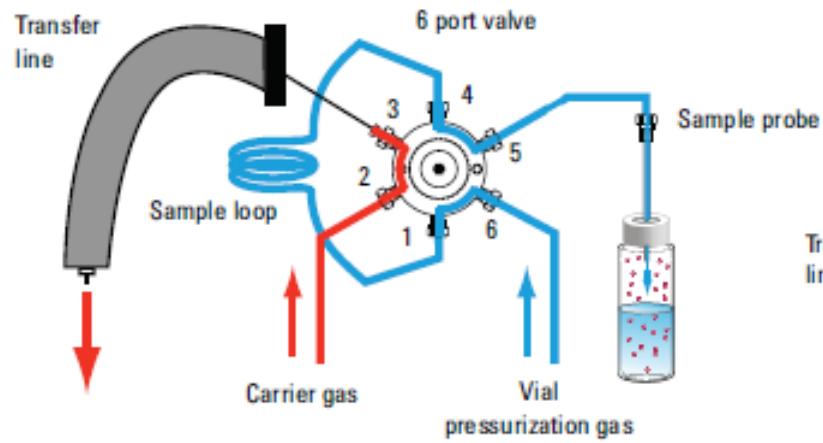
Balanced pressure

- The sample volume injection is regulated by time. Vial pressure is depressurized onto the column. The amount of sample injected is controlled by injection duration.

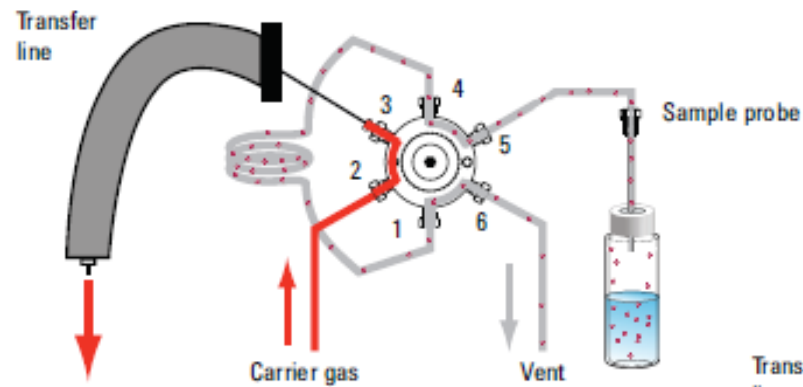
Pressure/loop systems

- Fixed loop size determines injected volume. The metal surface area is greater in the loop system.

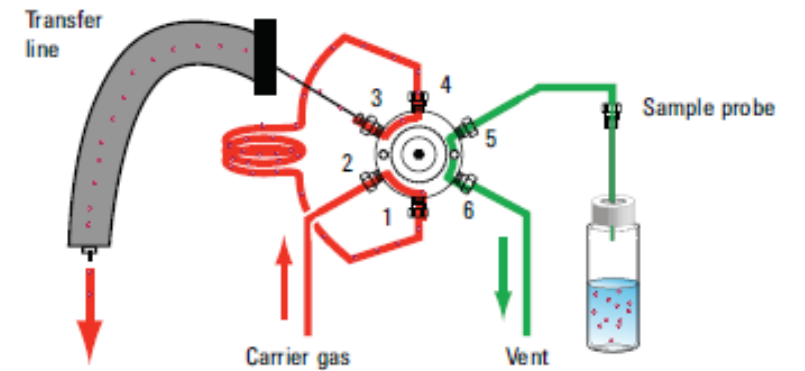
Agilent 7697A Loop System



Vial pressurization

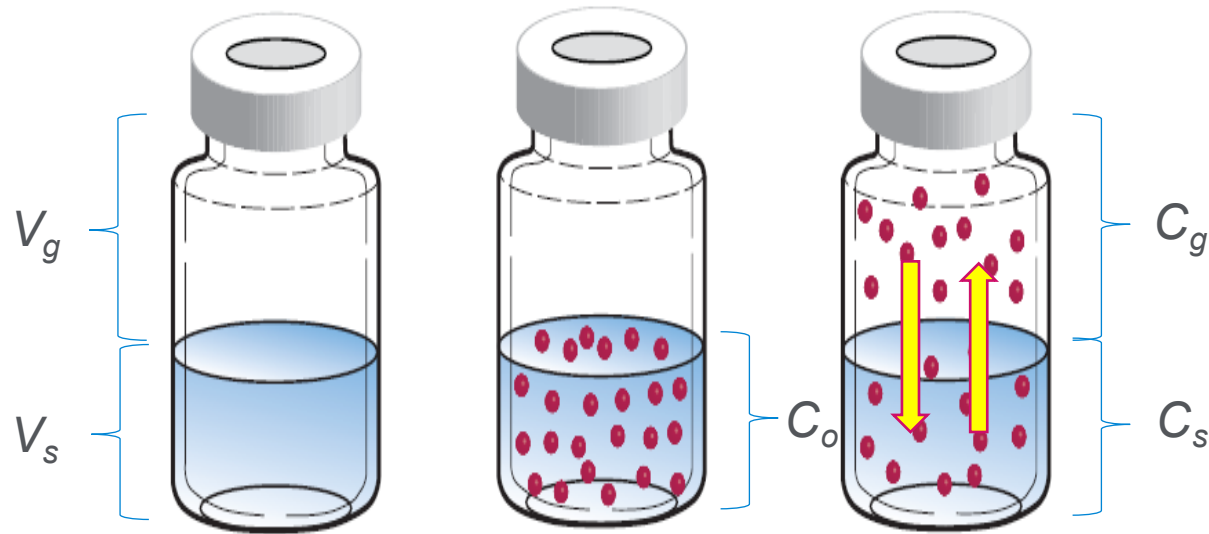


Loop fill



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

- You will need to have at least 5 mL of headspace in the vial.
- Keep the incubation temperature 10 to 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; this results in sharper peaks.
 - Lower splits are 'OK' with larger id columns. Higher volumetric flow transfers sample faster.
- Try to keep the sample from touching the vial septum.
 - Sample can get into the sample probe and contaminate the loop
- Think about the temperature limitation of vial septa
 - Be considerate of sample/analyte degradation

Headspace Parameters

Temperatures

- Oven
- Sample loop
- Transfer line
- Transfer line interface

Times

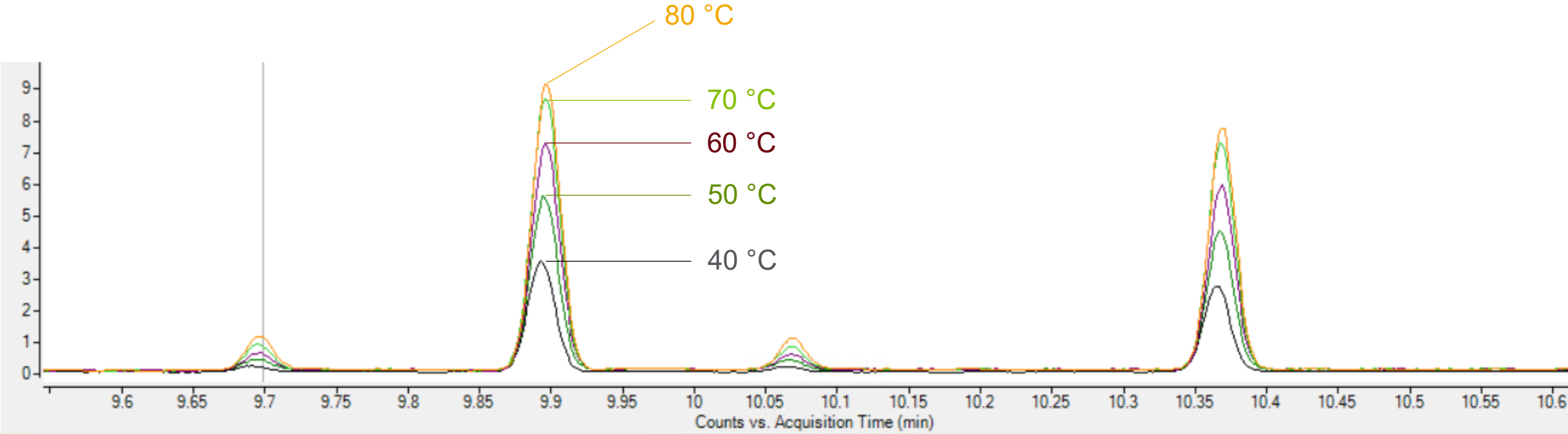
- Vial equilibration
- Injection duration
- GC cycle time

Vial and loop

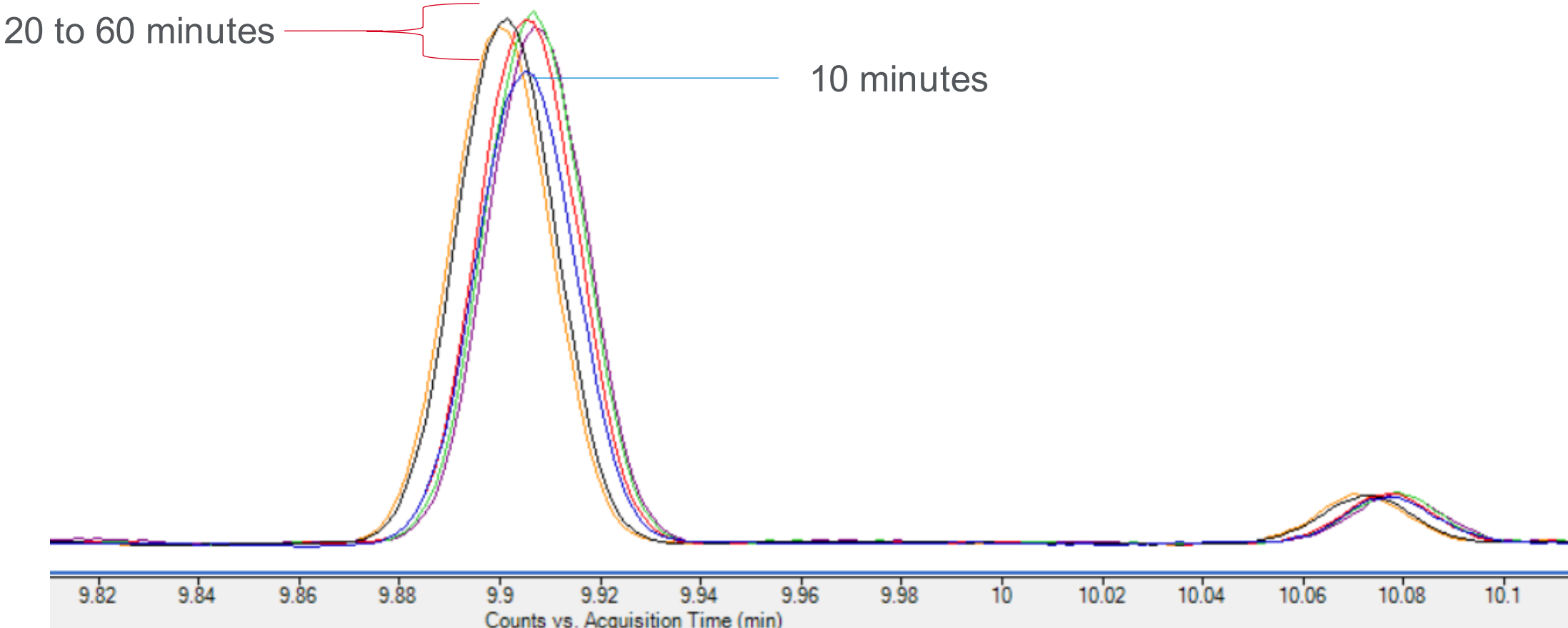
- Vial size
- Shake vials while in oven
- Vial fill mode
- Loop fill mode

Incubation Temperature Increase

20 minutes
K decreases with T
Not equal for all analytes



Incubation Time

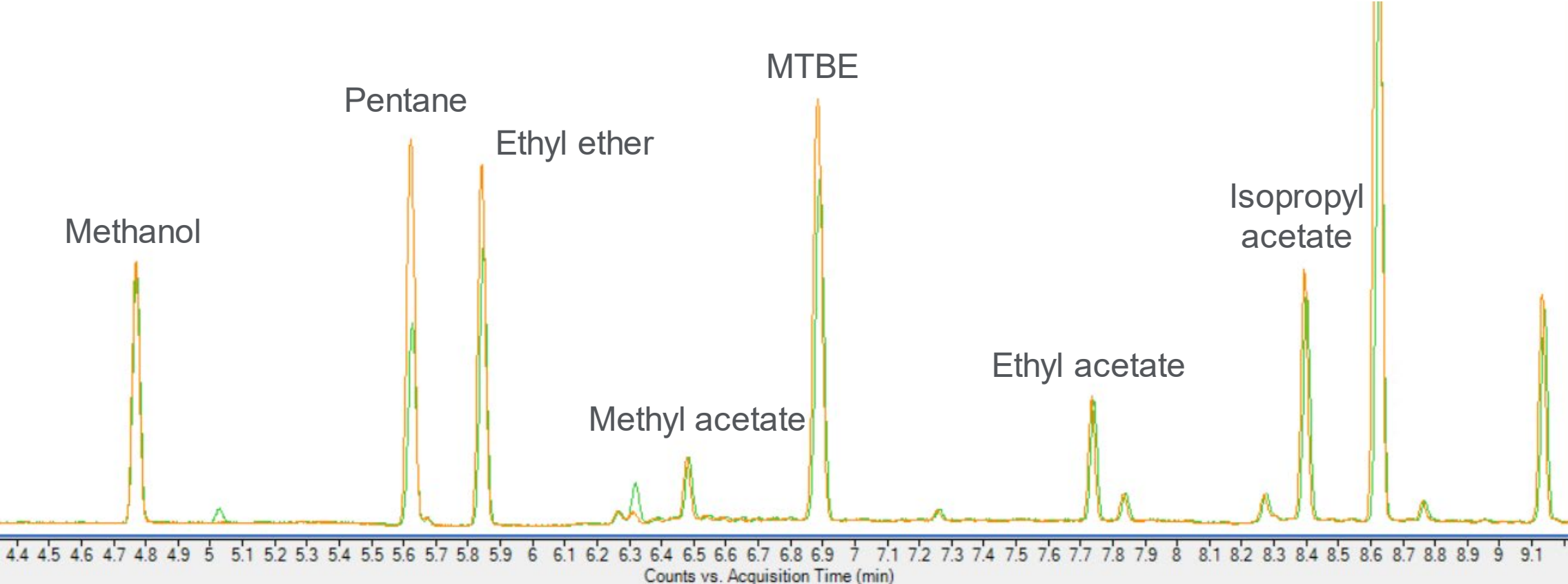


Change in Vial Size

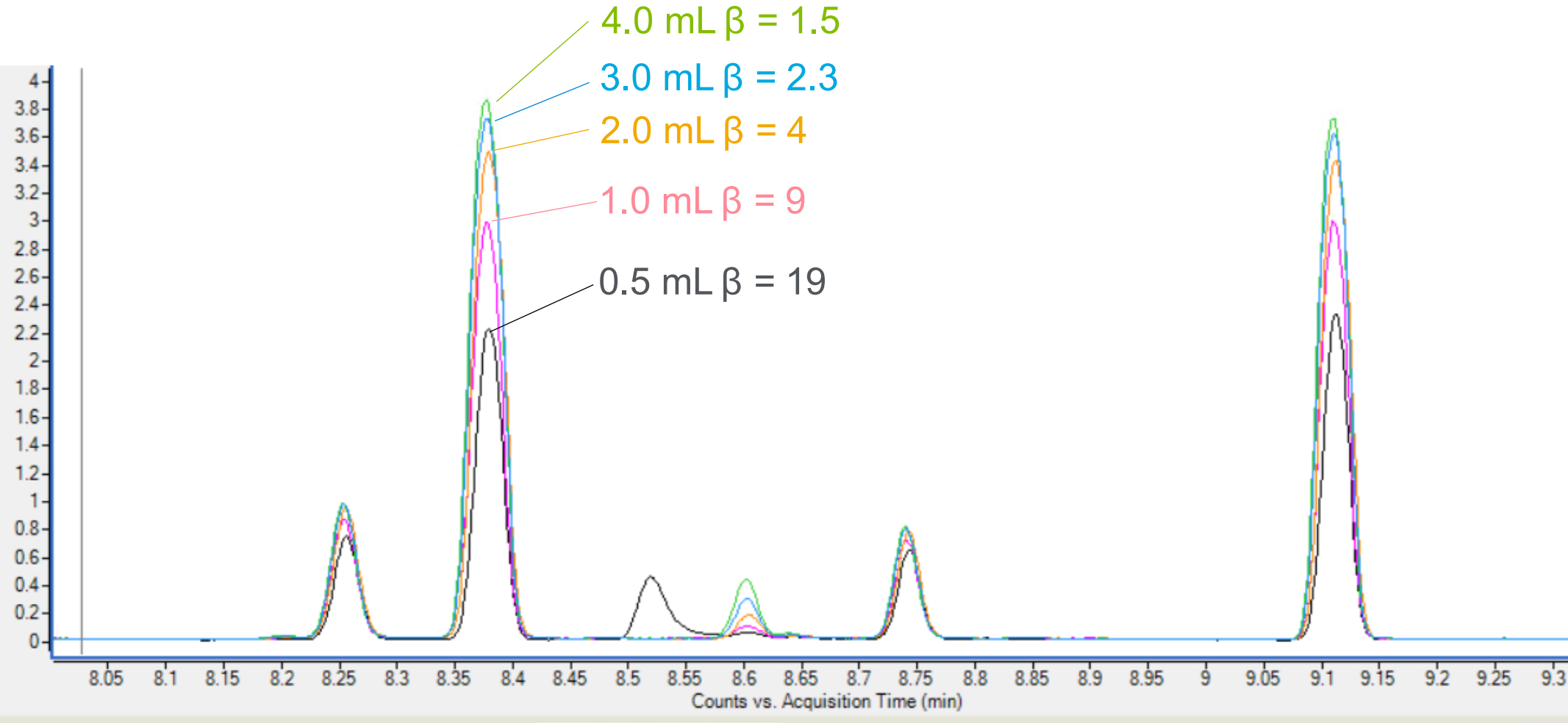
4 mL sample, changing β

10 mL vial $\beta = 1.5$

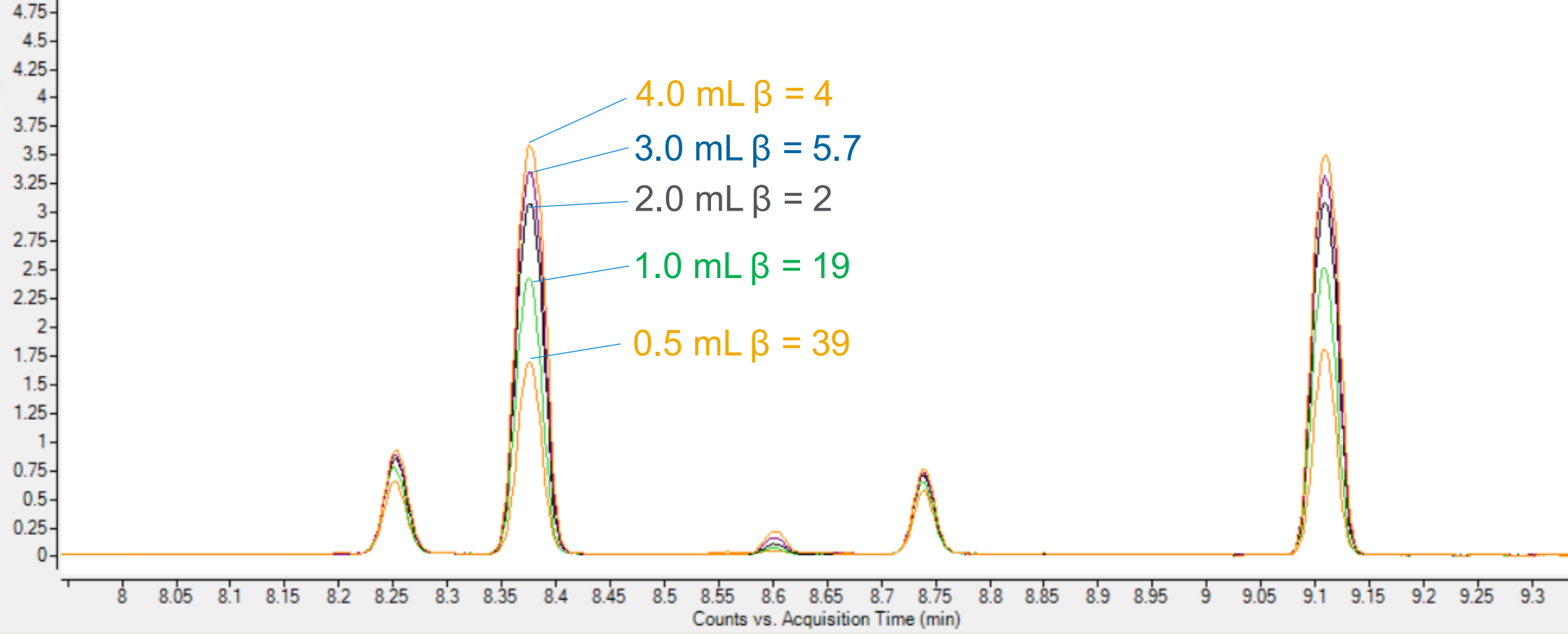
20 mL vial $\beta = 4$



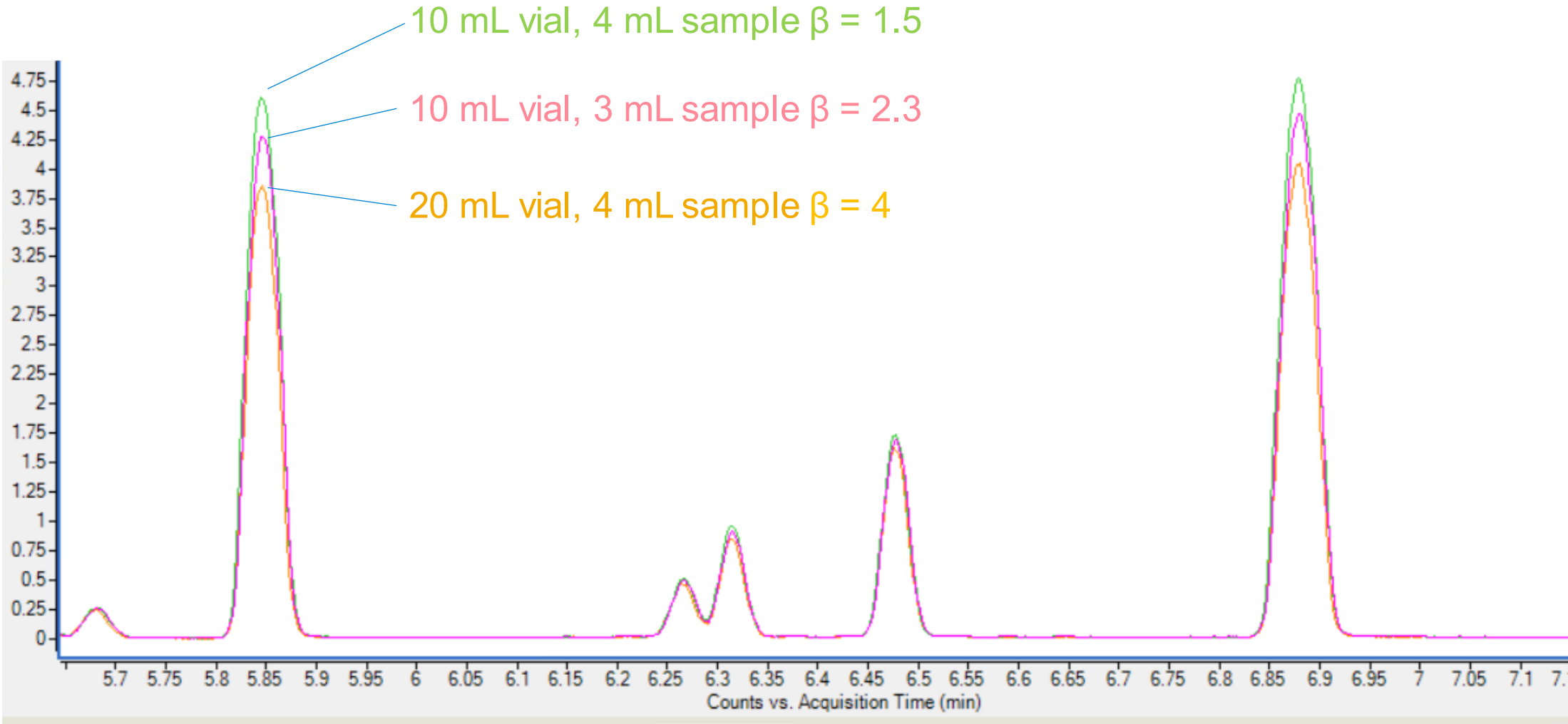
Change in Sample Volume in a 10 mL Vial



Change in Sample Volume in a 20 mL Vial



Change in Sample Volume and Vial Size



What Else Can Effect Signal?

Loop size

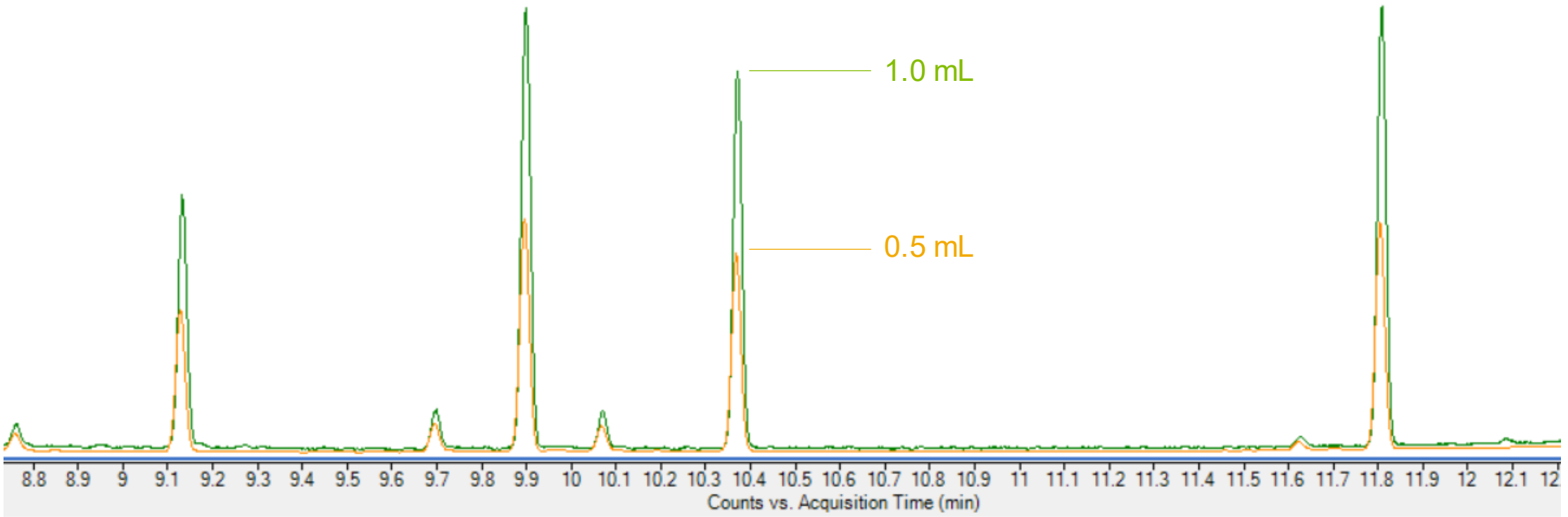
Loop pressure

Split ratio

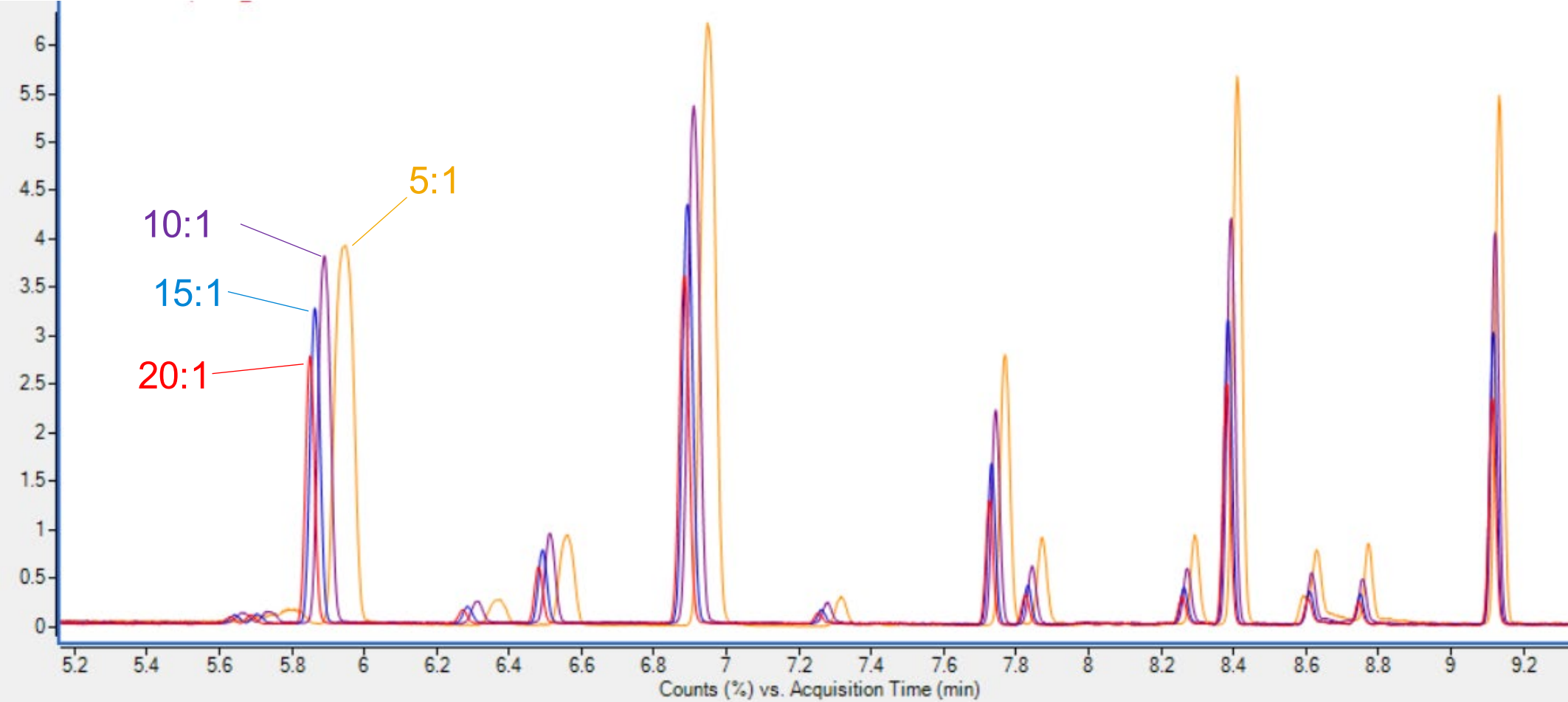
Liner type

Change in Loop Size

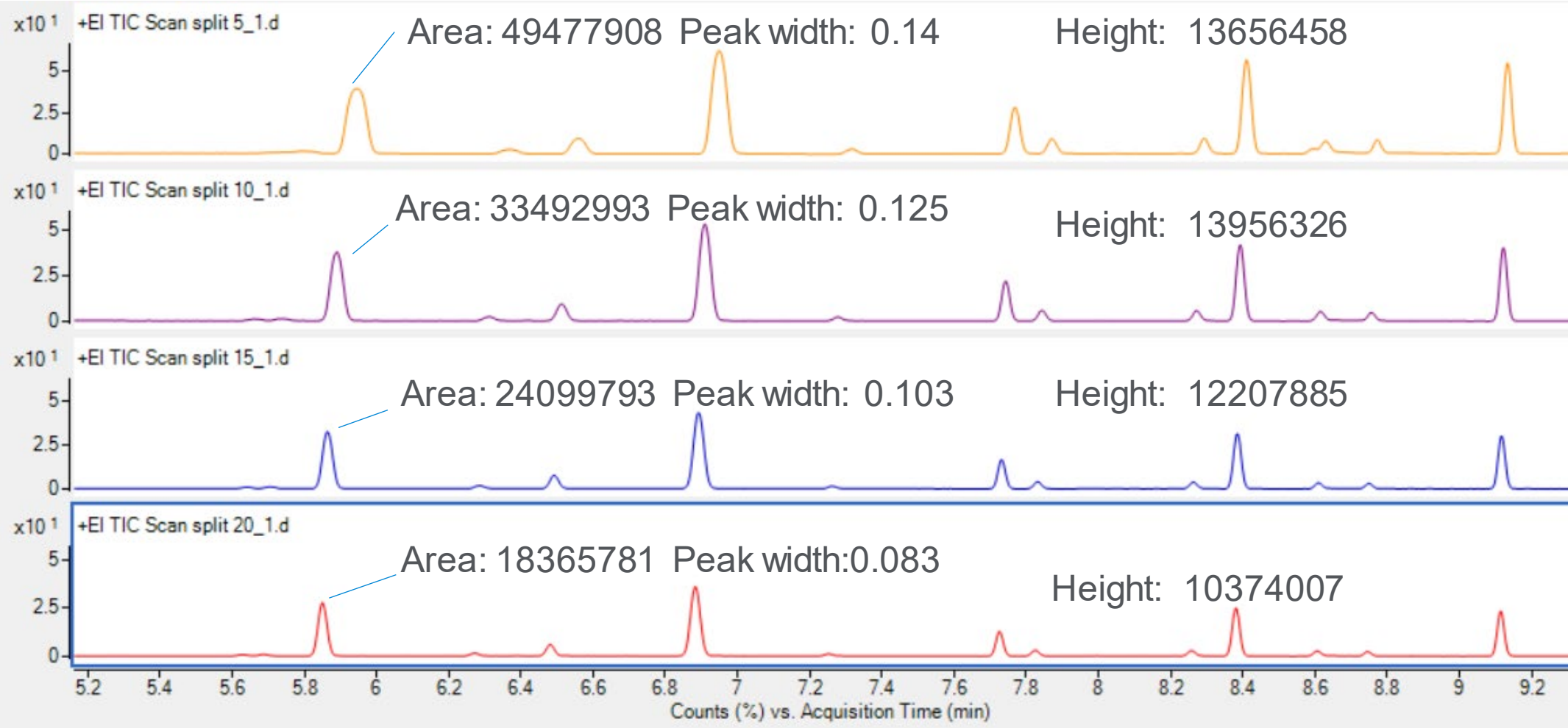
40:1 split (64 mL/min)



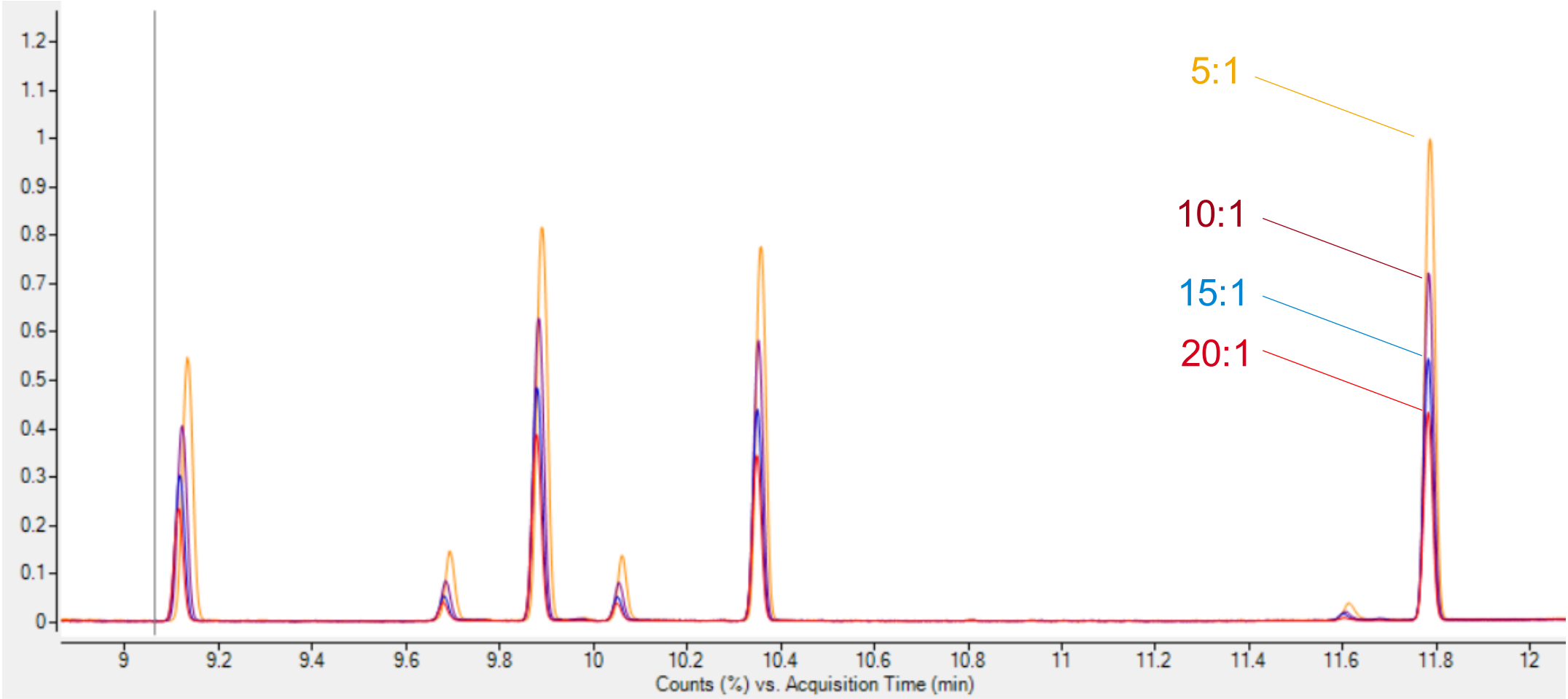
Change in Split Ratio



Change in Split Ratio



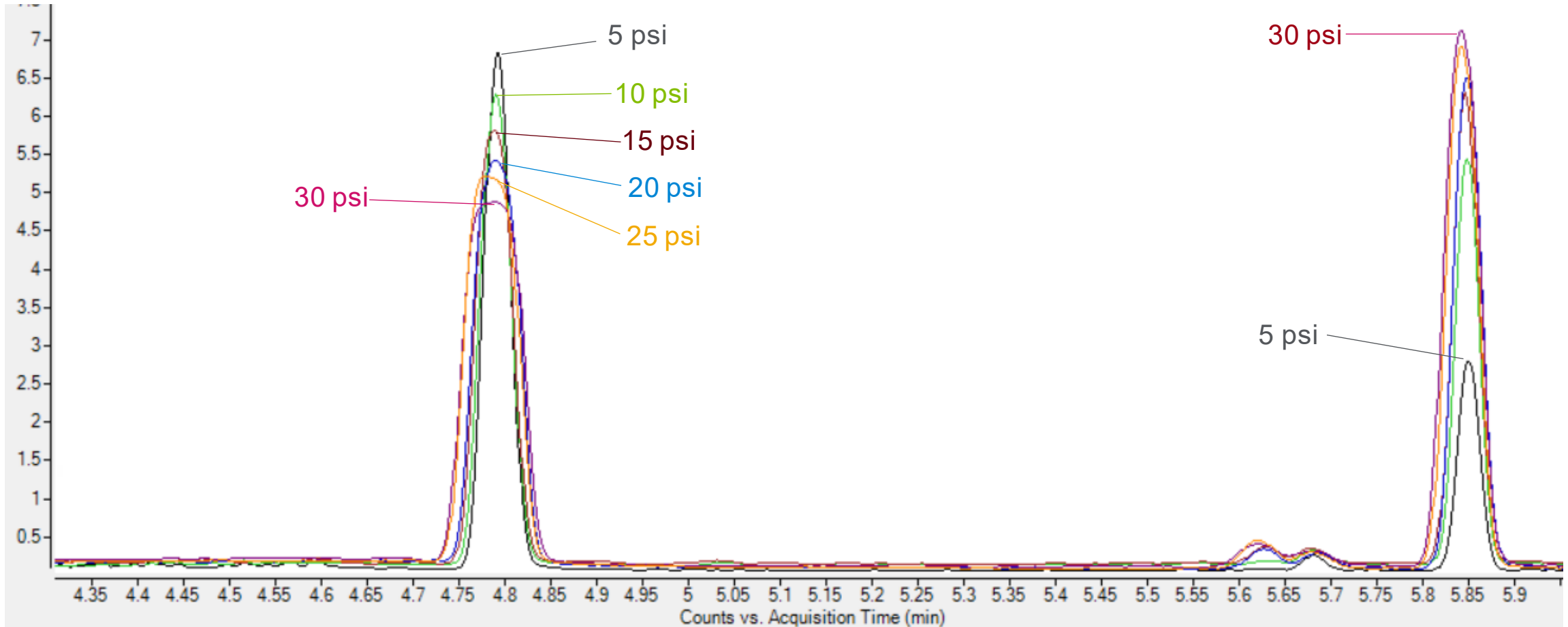
Change in Split Ratio



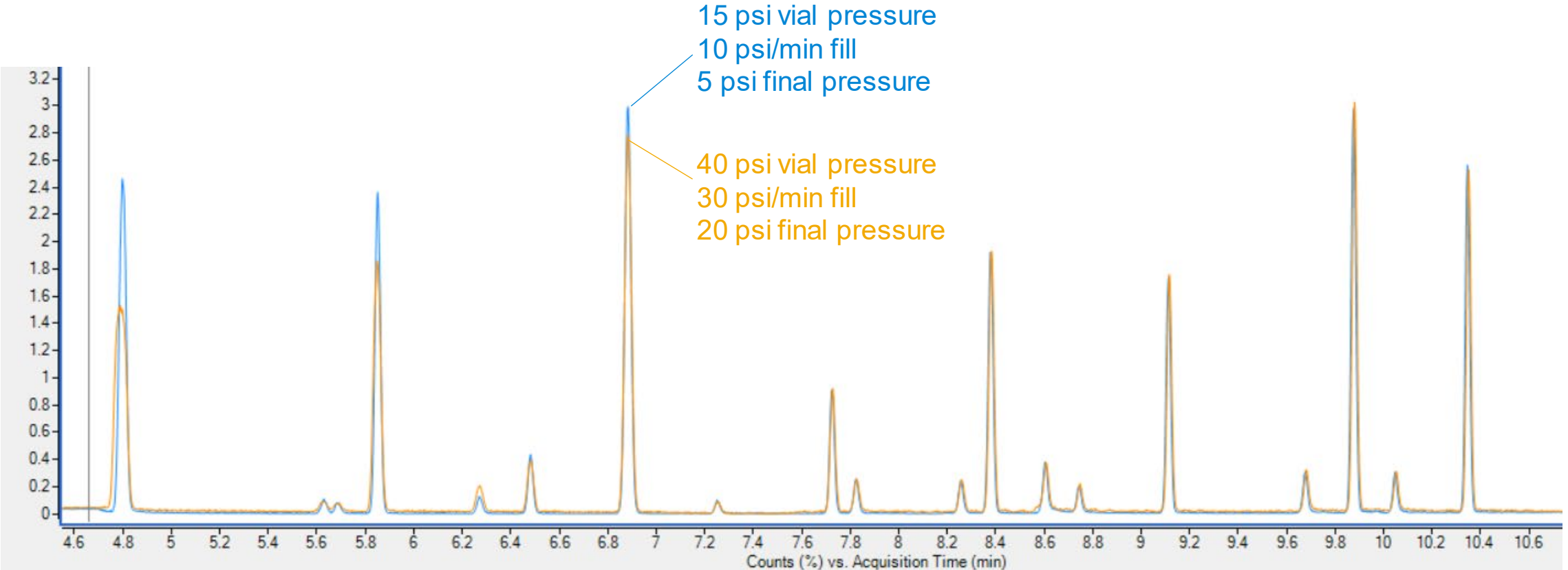
Change in Loop Pressure

First two eluting peaks

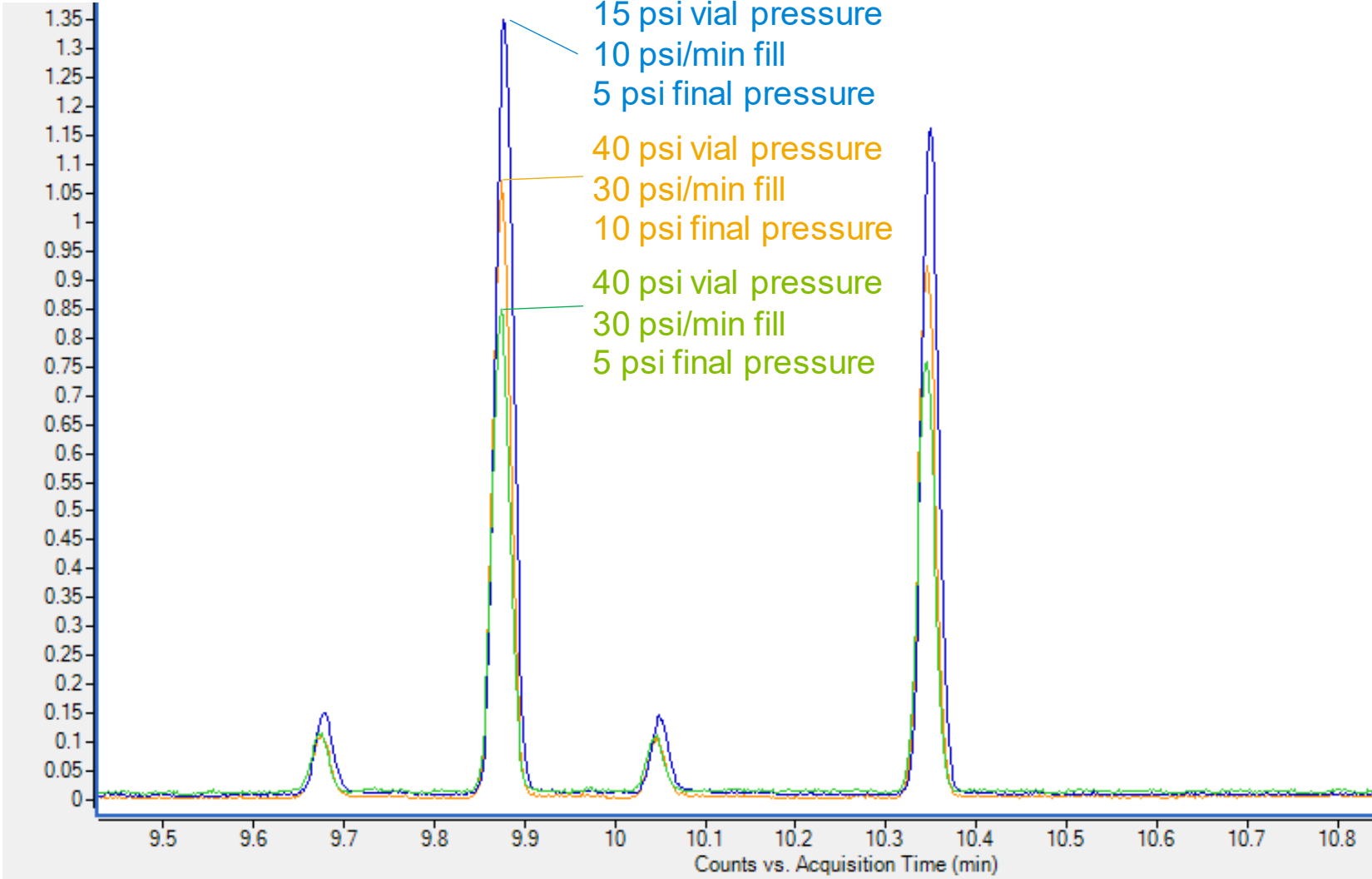
Vial fill pressure: 40 psi
Loop fill rate: 30 psi/min
Inlet pressure: 28.3 psi



Is That a Good Way to Increase Signal?

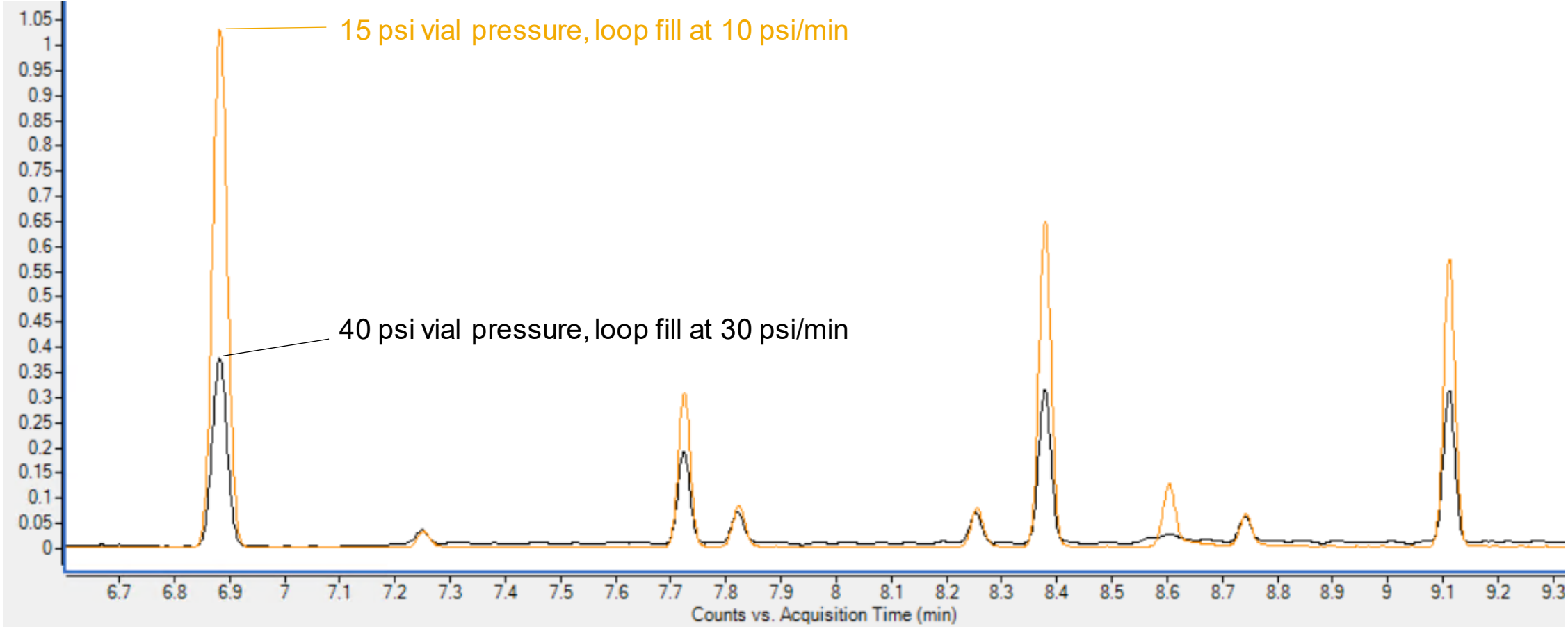


The Effect of Vial Pressure, Loop Pressure, and Fill Rate

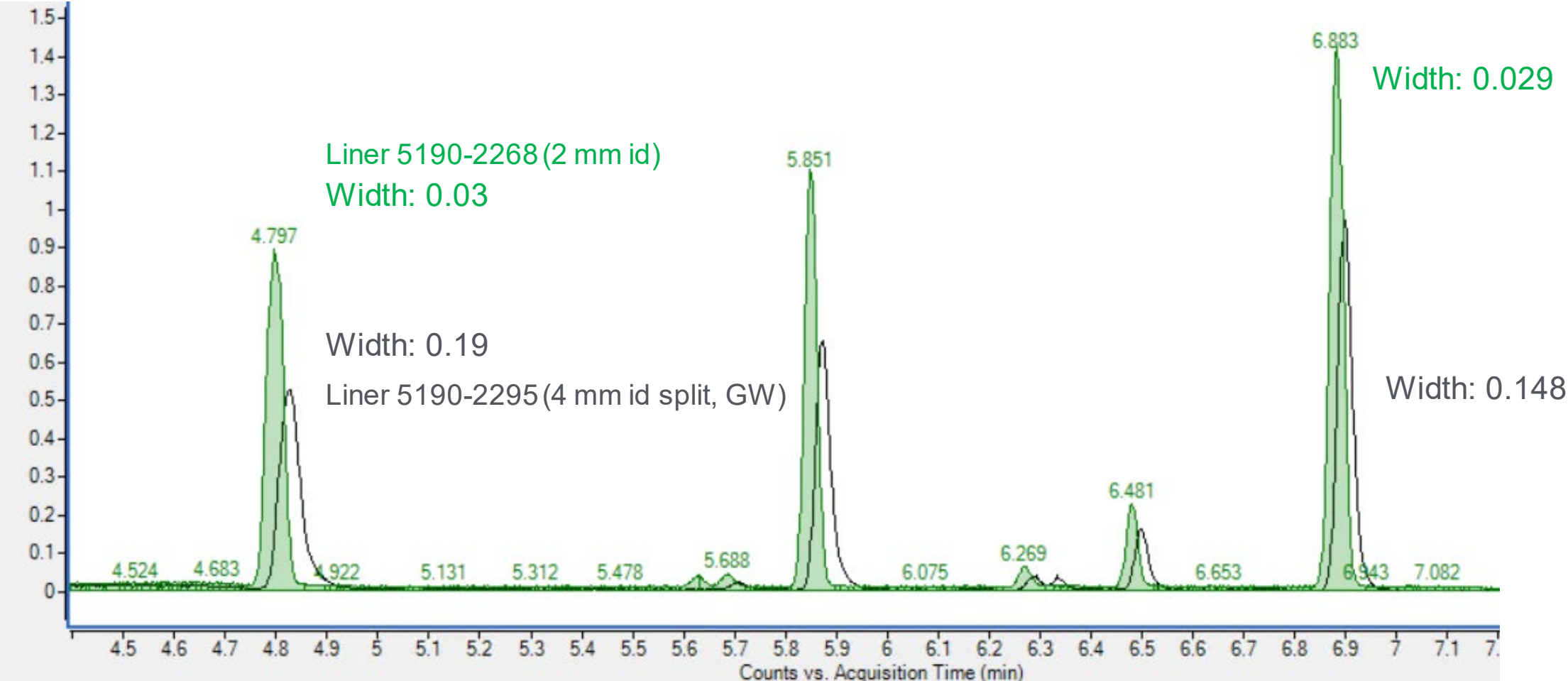


Changing Vial Pressure

5 psi final loop pressure



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 ($NaCl$)

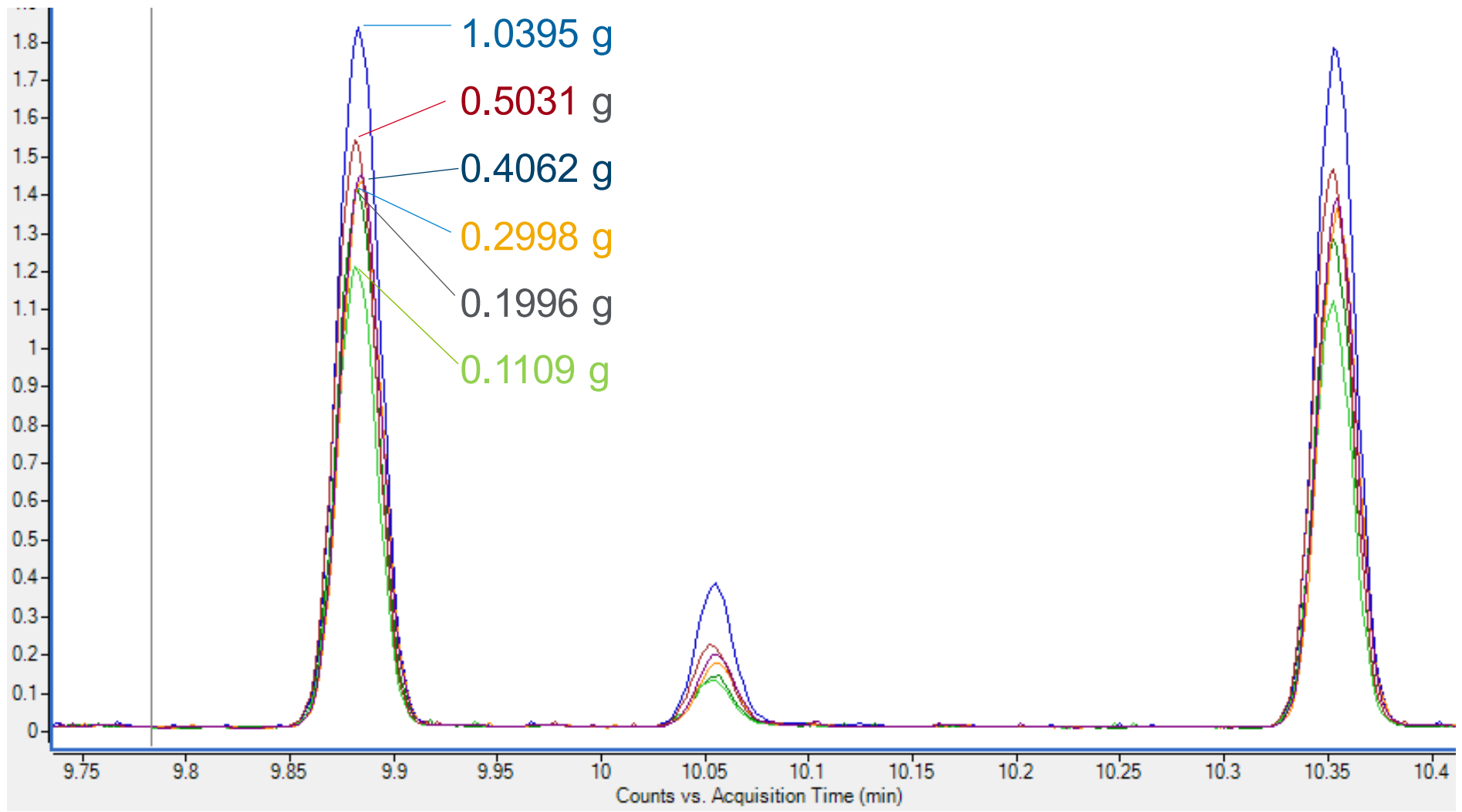
Sodium citrate ($Na_3C_6H_5O_7$)

Sodium sulfate (Na_2SO_4)

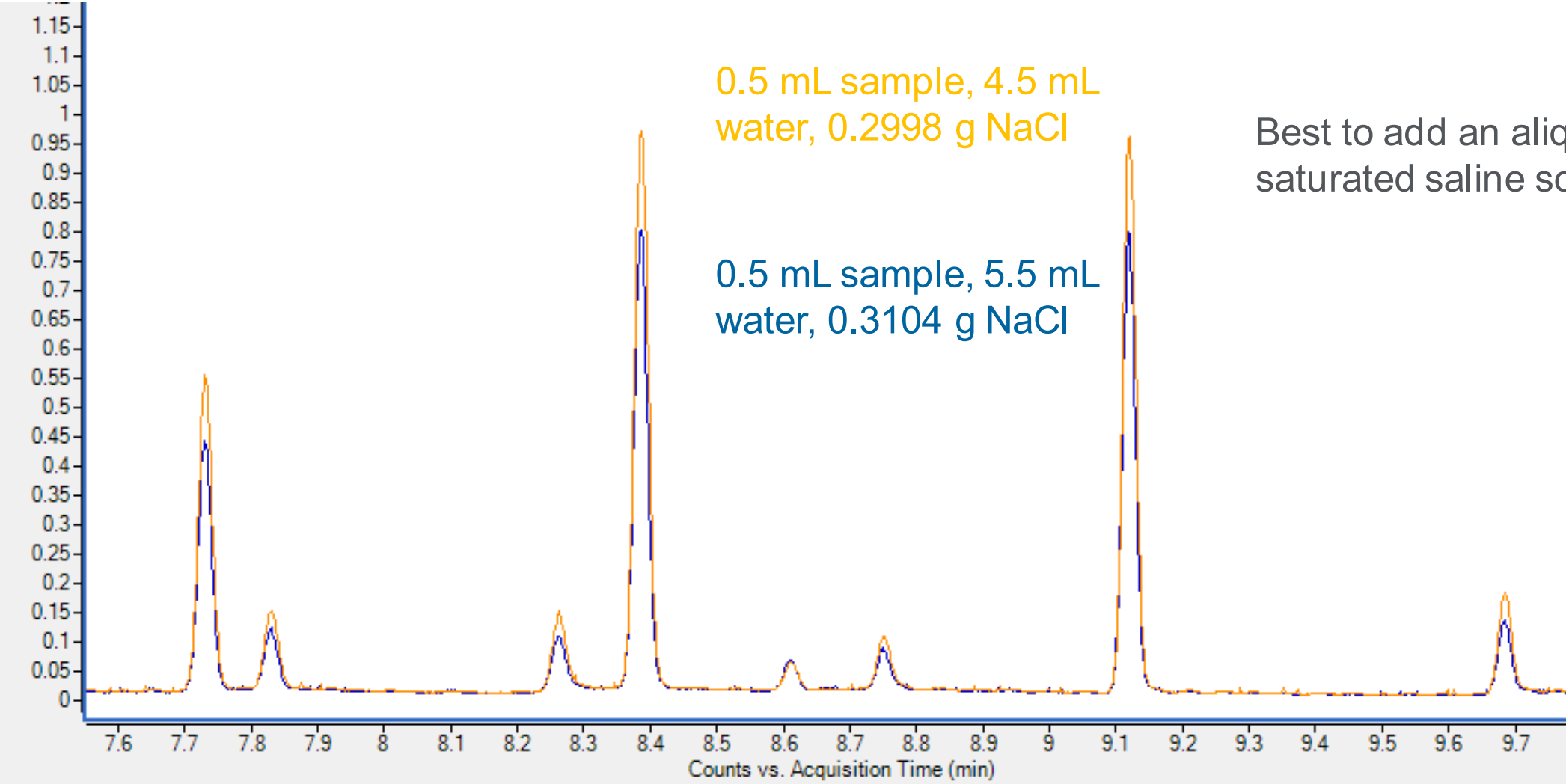
Use high quality, low impurity salts

How Much Salt Do I Add?

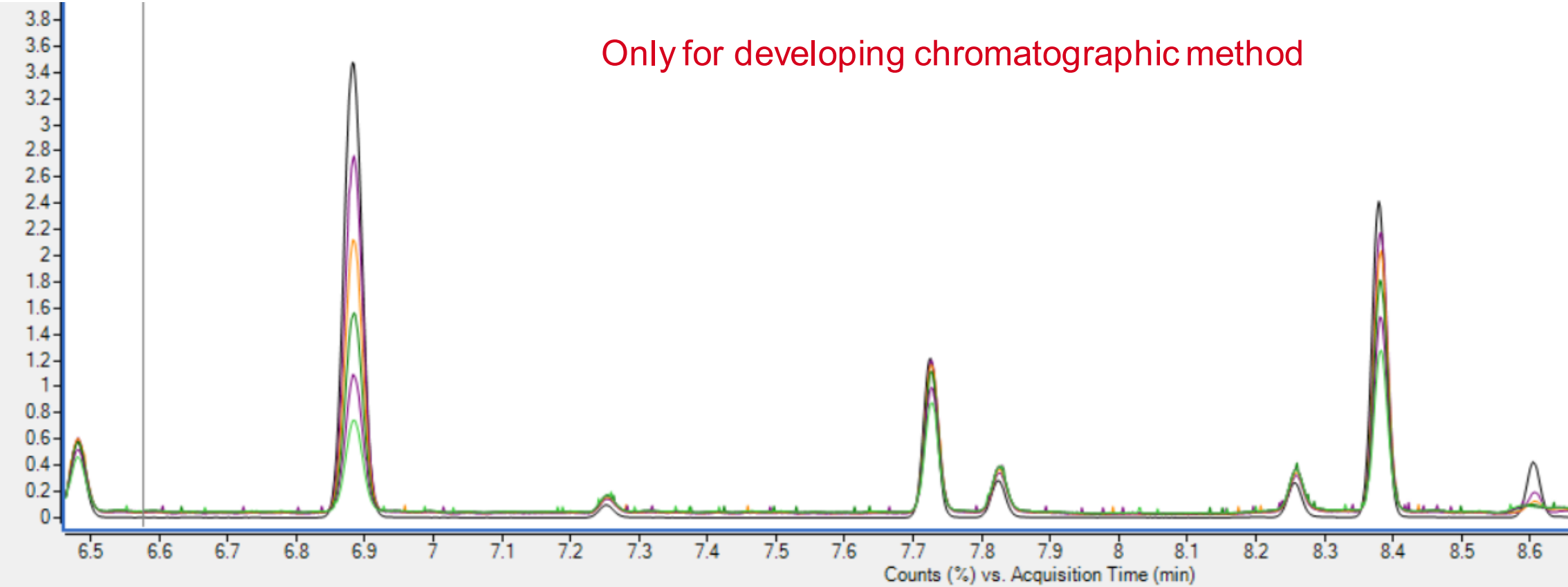
20 mL vial
80 °C oven temperature
20-minute incubation



Change in Matrix Volume with Salt



Can I Inject Multiple Times?



Headspace of Solid Matrices

Samples are ground to increase surface area

They are 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 Tools navigation bar:

- 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

- 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

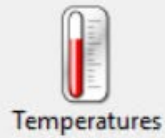
Assisted

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

Export Print Exit

Method Development Tool

Edit Method Parameters



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?

Temperature
 None
 Temperature
 Vial Equilibration
 Shaking

Temperature increment:

Maximum oven temperature:

Choose your setpoints

Choose what you want to increment

Assisted



Create method based on a specific application



Convert an existing valve and loop Headspace method

Method Development Tool

The screenshot shows the 'Edit Method Parameters' dialog box with the 'Method Development' tab selected. The dialog has a title bar with standard window controls and a toolbar with icons for Temperatures, Times, Vial and Loop, Carrier, Advanced Functions, Sequence Actions, and Method Development. The 'Method Development' section contains a 'Manual' section with a question and a dropdown menu, and an 'Assisted' section with three options: 'Create method based on a specific application', 'Convert an existing valve and loop Headspace method', and 'Convert an existing pressure transfer Headspace method'. At the bottom are buttons for 'Apply', 'OK', 'Cancel', and 'Help'.

Edit Method Parameters

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?

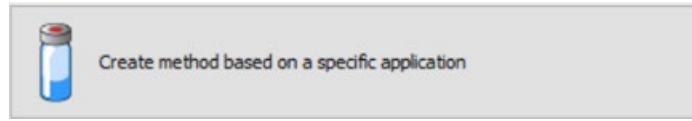
None

Assisted

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

Apply OK Cancel Help

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 the initial method.

Green parameters are the new settings.





Confirm method changes

Original Method		Modified Method	
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:			
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 Size:	20	Vial Size:	20
Vial Shaking:	Level 3, 36 shakes/min	Vial Shaking:	Level 1, 18 shakes/min
with acceleration of 125 cm/s ²		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 Control Mode:	GC controls Carrier	Carrier Control Mode:	GC controls Carrier
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:			
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	Setpoint		Timing	Setpoint
<input checked="" type="checkbox"/>	Oven Thermostatting	80 °C	<input type="checkbox"/>	GC Cycle	25 min
<input checked="" type="checkbox"/>	Needle	80 °C	<input type="checkbox"/>	Thermostatting	15 min
<input checked="" type="checkbox"/>	Transfer Line	120 °C	<input type="checkbox"/>	Pressurization	0.2 min
	Pressure	Expected Value		Other Settings	
	Carrier	28 psi	<input type="checkbox"/>	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



5182-0838



5182-0837



5188-2753



5067-0226

Consumables



Good for SPME



Safety cap
Tears at 45 psi



Max temp 125 °C
Butyl/PTFE

Max temp 180 °C
silicone/PTFE

High Performance Septa

Max temperature 300 °C

Reduce siloxane interferences at high temperature



High power crimpers are recommended for steel caps.

Publication number: 5990-9385EN

High Power Crimper



5190-4067 (crimper with 20 mm jaw set)

Standard Crimpers



5190-3189



5040-4669

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 **Contaminates the probe and loop**

Septum or caps blowing off

- Oven temperature is too high
- Creating too much pressure in the vial

High %RSD

- Vial leaks. Check vial crimping. Sequence actions and logbook.
- 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 logbook.

Change the Loop Purge Time and Flow

Carryover issues

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

Advanced Functions

Extraction Mode

Single extraction Multiple extractions Concentrated extractions

Venting and Purging

Vent vial pressure after extraction

Post-injection purge: Purge flow: 100 mL/min Purge time: 1 min

Dynamic Leak Checking

Acceptable leak rate: Leak flow: 0.2 mL/min

Barcoding of Vials

Barcode symbology:

Vial barcodes include checksum

Vial Leaks

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

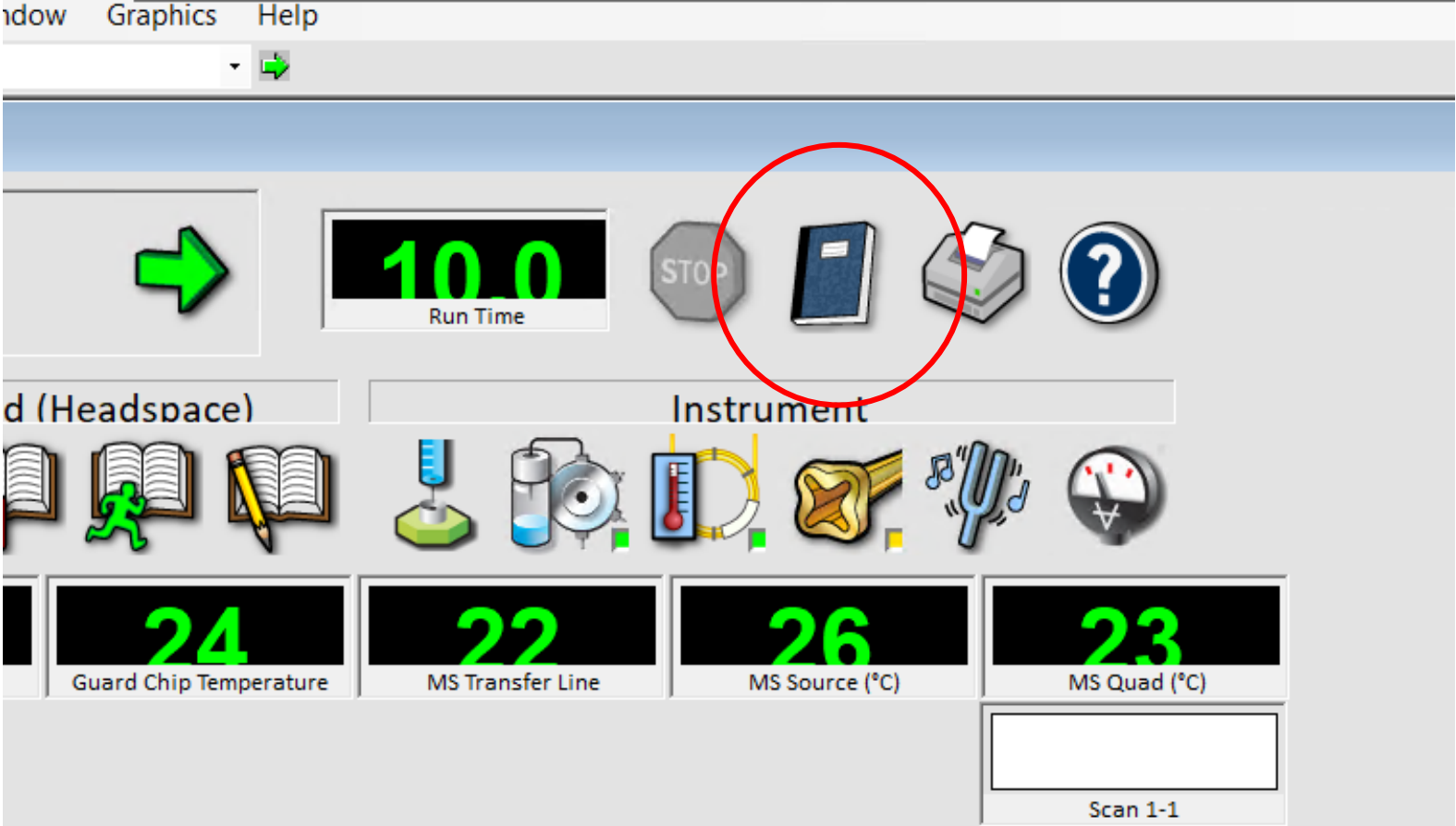
Sequence Actions

What should the sequence do if it encounters the following:

Vial Missing	Wrong Vial Size	Leak Detected	System Not Ready	Wrong Cooling Plate Temp
Skip	Continue	Continue	Abort	Continue

The system always logs detected issues and the action taken.

Logbook 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 **0.5 minutes**
- GC cycle time **Run time + cool down to ready**

Vial and 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 to 20 °C below the boiling point of the solvent/matrix
- Keep a minimum of 5 mL of headspace in the vial
- Use the Method Development tools
 - Don't forget to turn off the function
- Try to maximize parameters based on compounds 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 that every user is successful.
- When troubleshooting, think about what may or may not be causing 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

[Search for 7697A Headspace Sampler on Agilent.com](#)

Contact Agilent Chemistries and Supplies Technical Support



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

Option 1 for GC and GC/MS columns and supplies

Option 2 for LC and LC/MS columns and supplies

Option 3 for sample preparation products, filtration and QuEChERS

Option 4 for spectroscopy supplies

Available in the USA, 8-5 all time zones



gc-column-support@agilent.com



GC columns and supplies

lc-column-support@agilent.com

spp-support@agilent.com

spectro-supplies-support@agilent.com