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

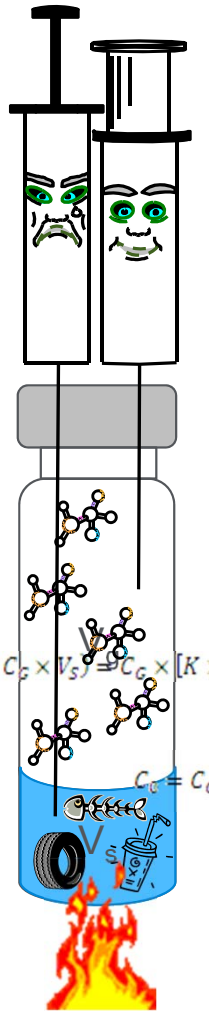
Method Development,
Method Optimization,
And Troubleshooting

Simon Jones
GC Application Scientist
April 29, 2020

Agilent
Trusted Answers

DE.5440509259

What Is Headspace?



$$\beta = \frac{V_G}{V_S}$$

$$K = \frac{C_S}{C_G}$$

$$C_S = \frac{W_S}{V_S}$$

$$C_G = \frac{W_G}{V_G}$$

$$W_S + W_G = W_0$$

$$C_0 \times V_S = (C_G \times V_G) + (C_S \times V_S) = (C_G \times V_G) + (K \times C_G \times V_S) = C_G \times [K \times V_S + V_G]$$

$$C_0 = C_G\left[\frac{K \times V_S}{V_S} + \frac{V_G}{V_S}\right] = C_G(K + \beta)$$

$$C_G = \frac{C_0}{K + \beta}$$

$$A\ \alpha\ C_G = \frac{C_0}{K + \beta}$$

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.

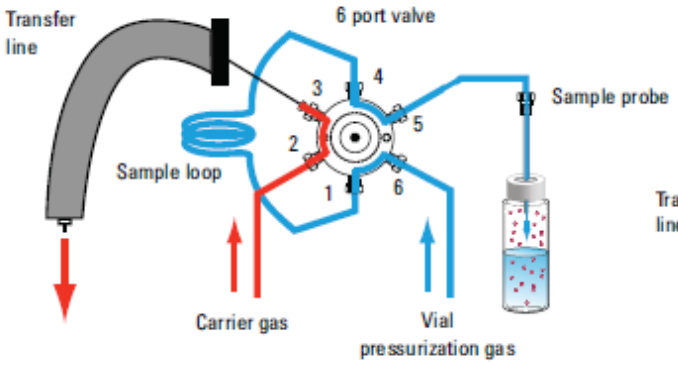
Balanced Pressure

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

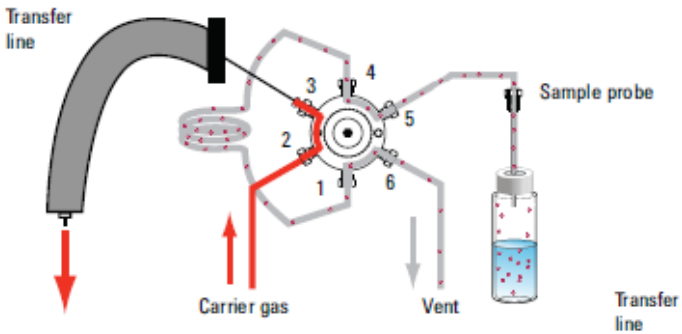
Pressure/Loop Systems

Fixed loop size determines injected volume. More metal surfaces!

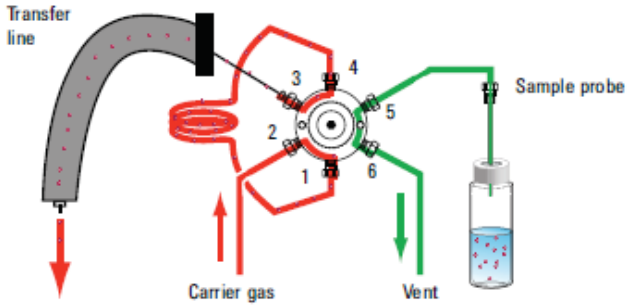
Agilent 7697A Loop System



Vial Pressurization

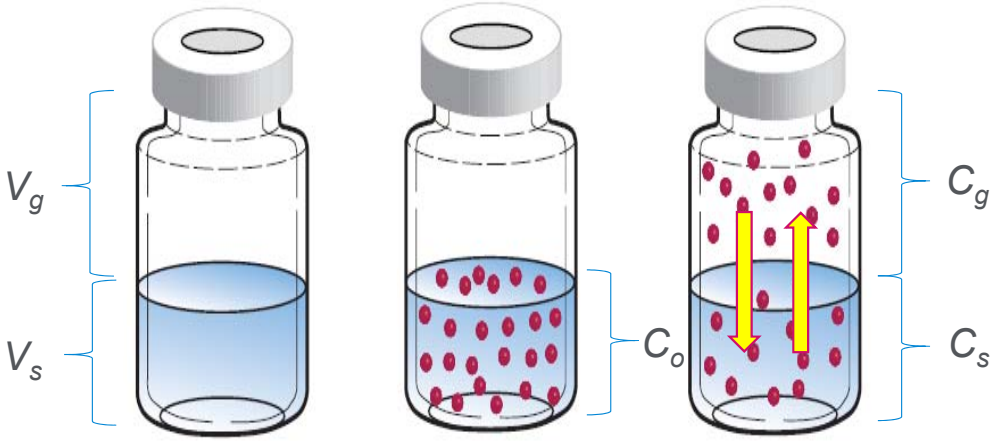


Loop Fill



Injection

Some Math to Make it Fun….



$$CoVs = CgVg + CsVs$$

Partition Coefficient: $K = \frac{Cs}{Cg}$

Phase Ratio: $\beta = \frac{Vg}{Vs}$

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

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: $K = \frac{Cs}{Cg}$

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^{o}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

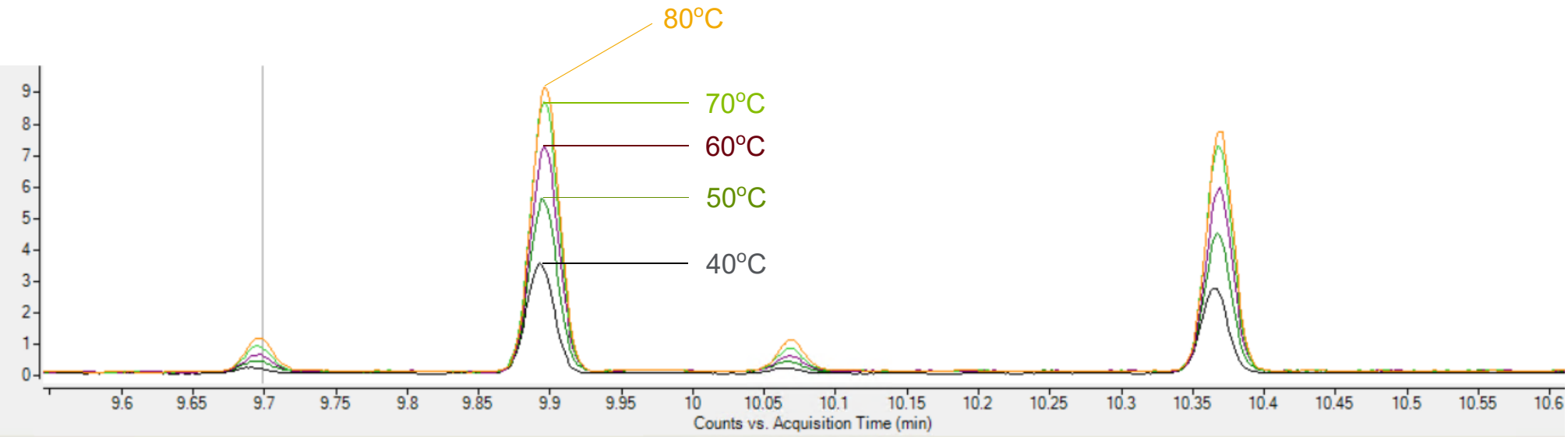
- Vial Size
- Shake vials while in oven
- Vial Fill Mode
- Loop Fill mode

Incubation Temperature Increase

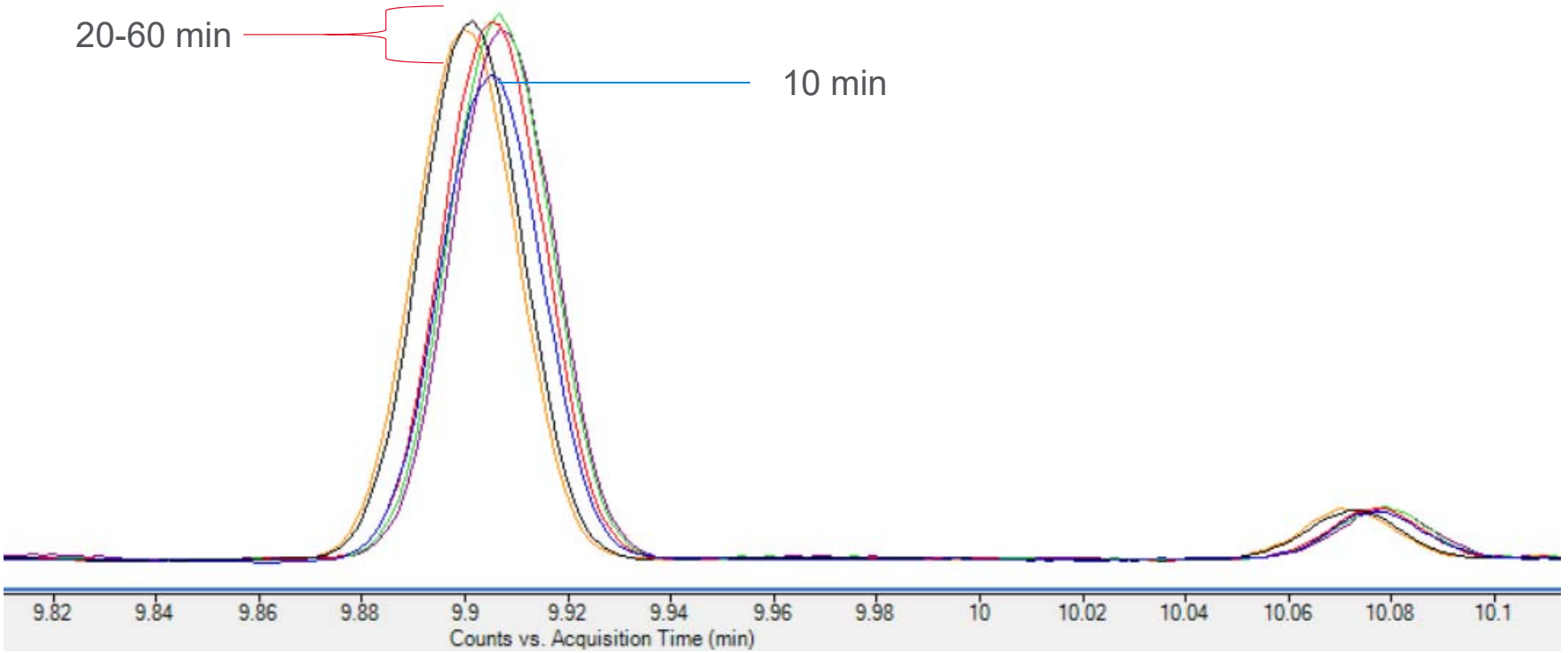
**20 Minutes

K decreases with *T*

Not equal for all analytes



Incubation Time

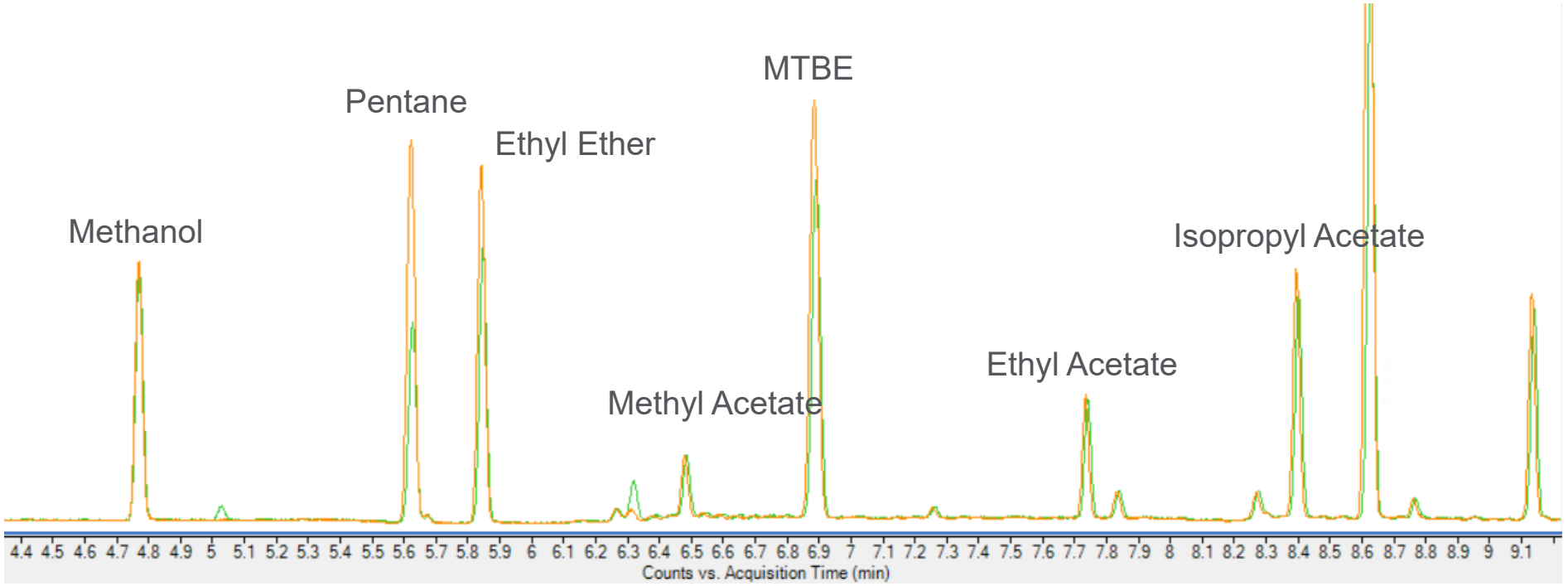


Change in Vial Size

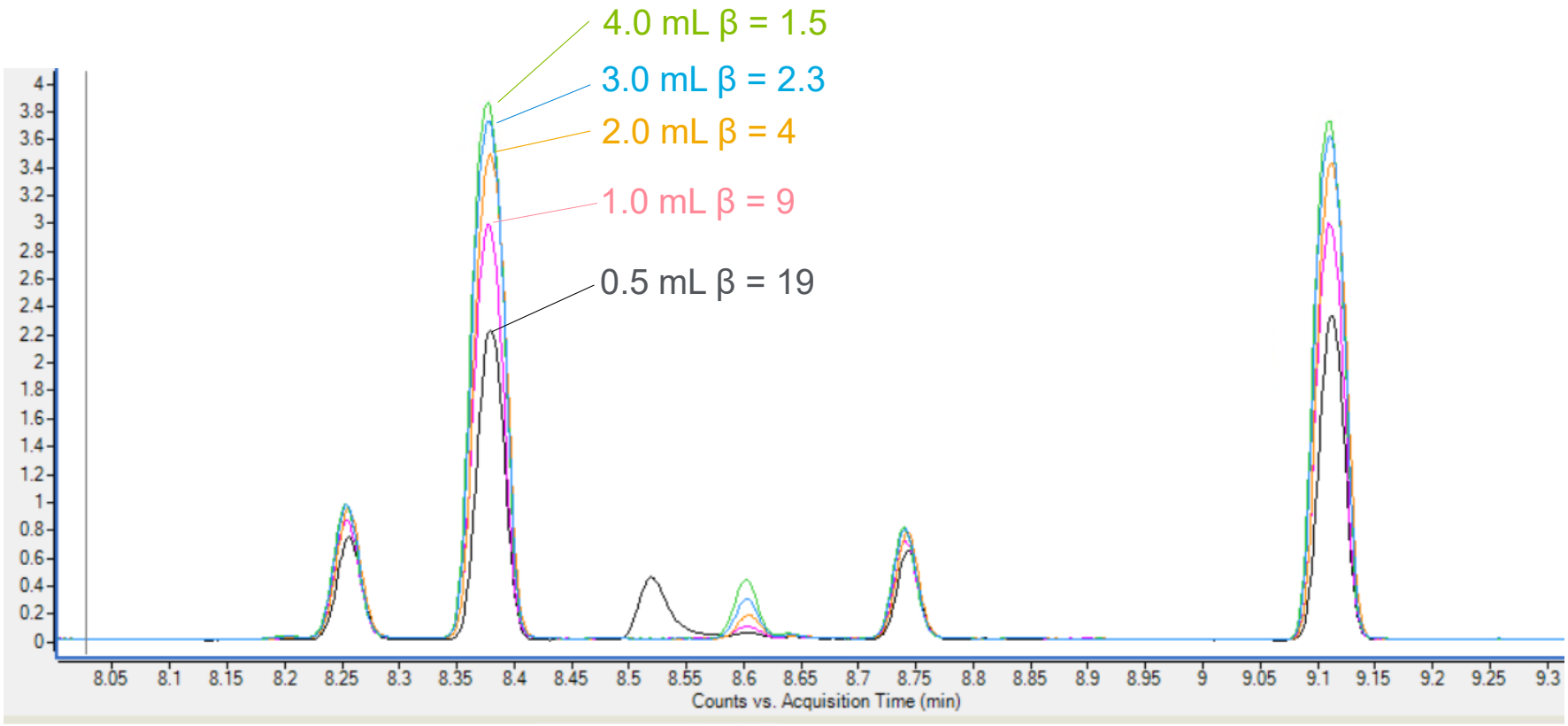
4 mL sample Changing β

10 mL vial β = 1.5

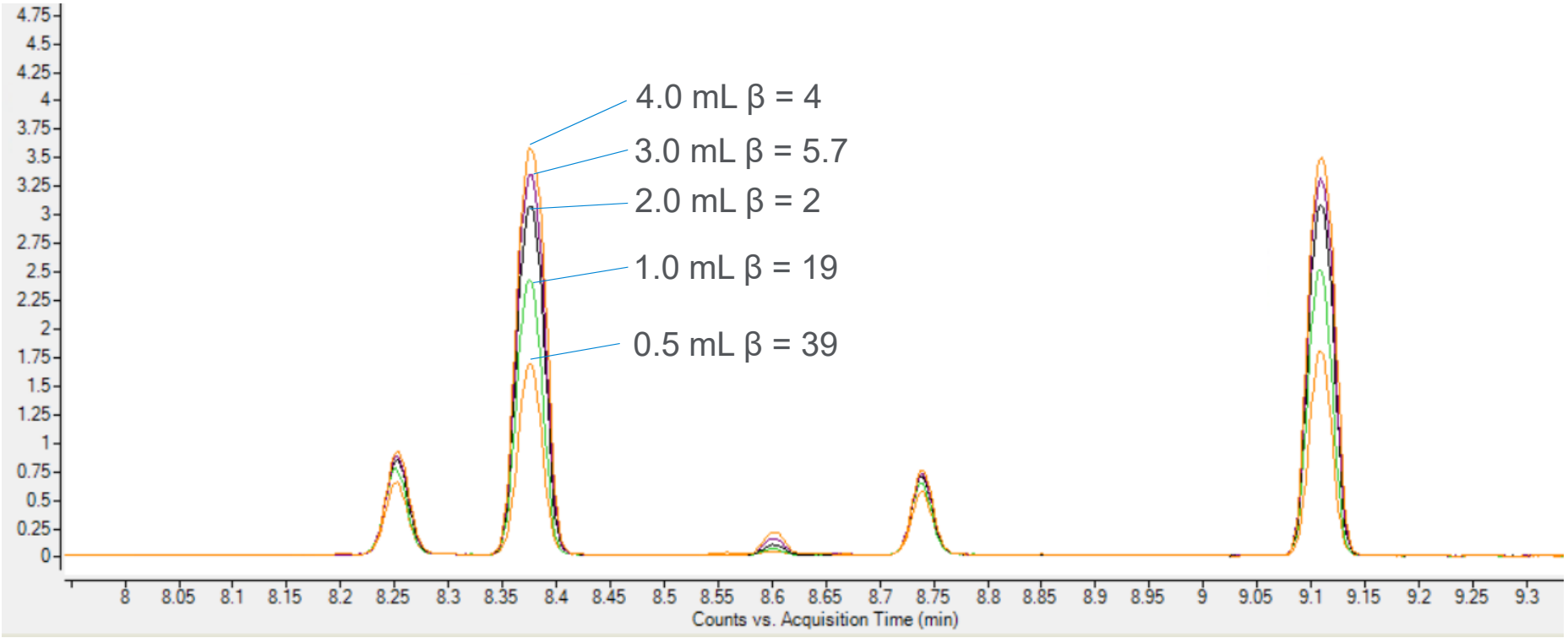
20 mL vial β = 4



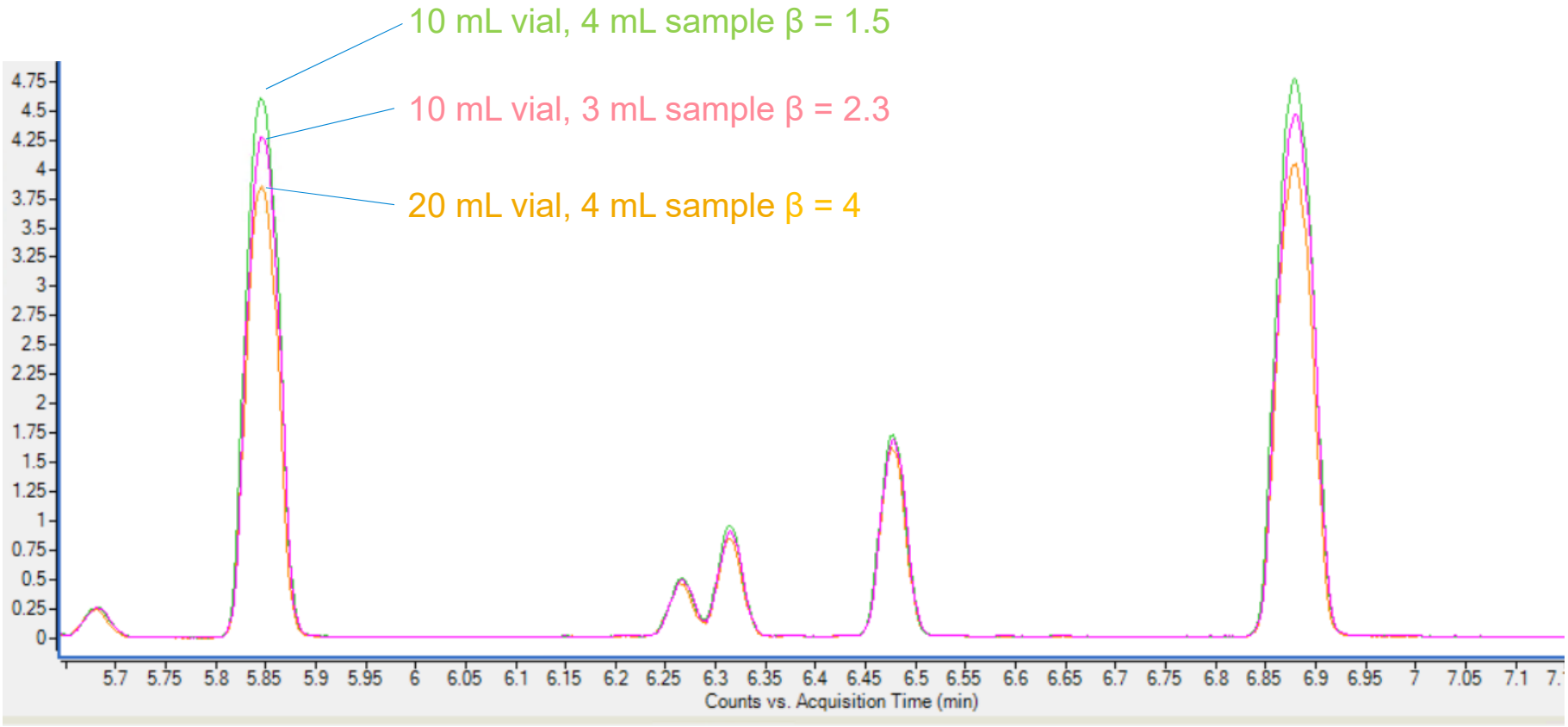
Change in sample volume 10 mL vial



Change in sample volume 20 mL vial

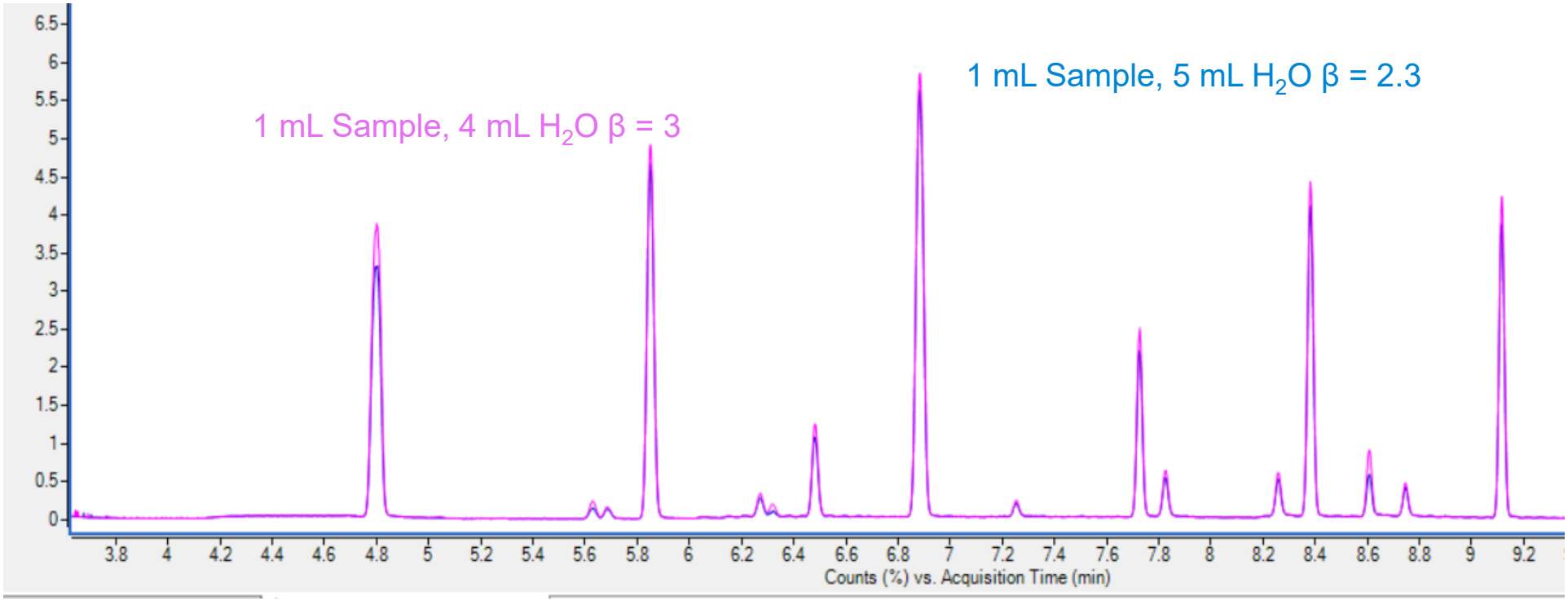


Change in sample volume and vial size



Does β Really Matter?

Same volume of sample
Different volume of diluent



What Else Can Effect Signal??

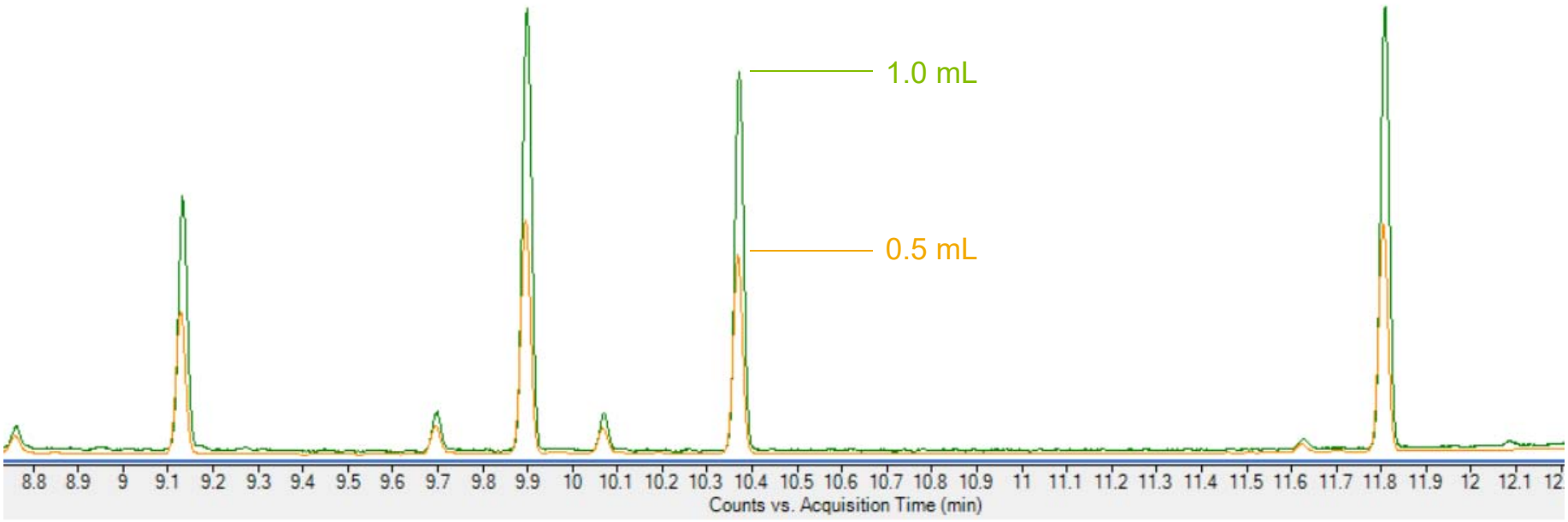
Loop Size

Loop Pressure

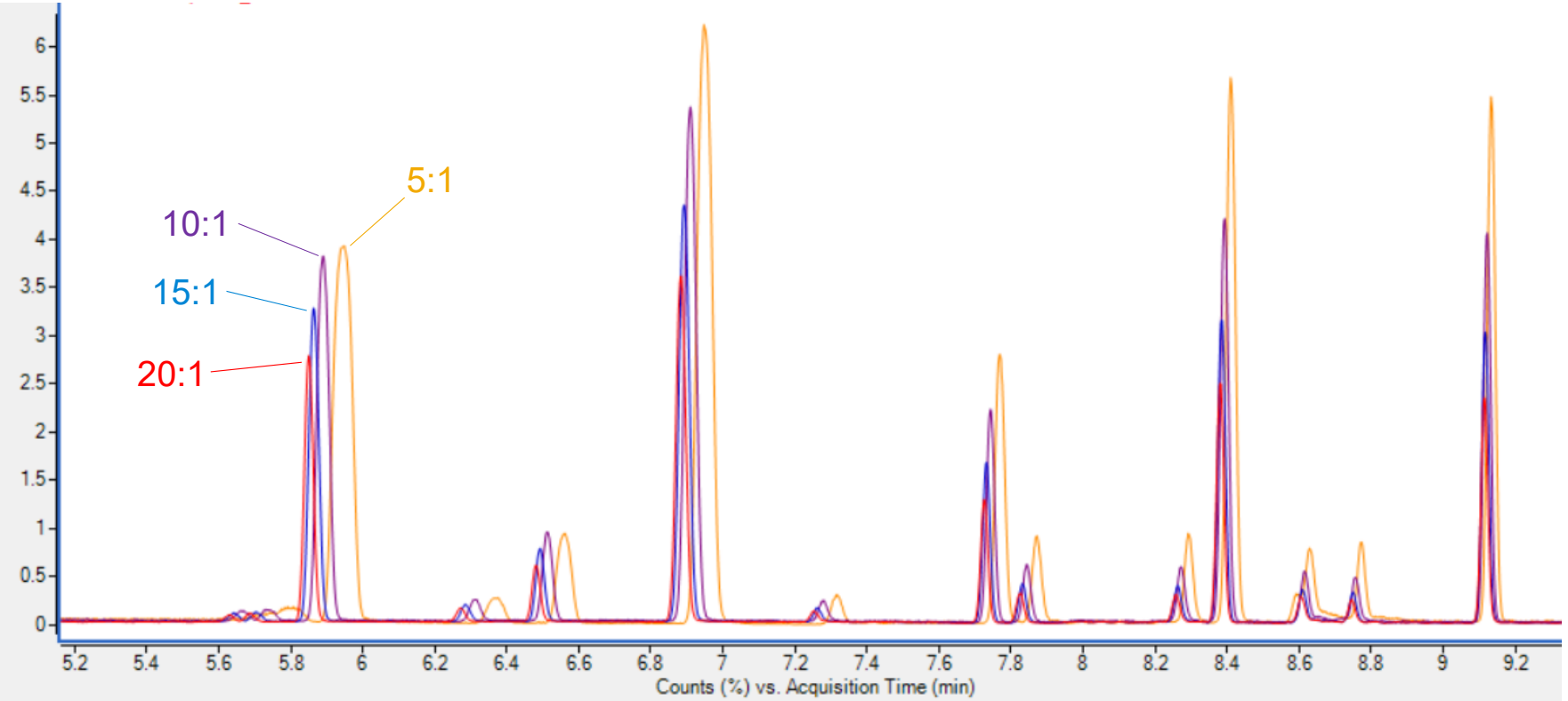
Split Ratio

Liner Type??

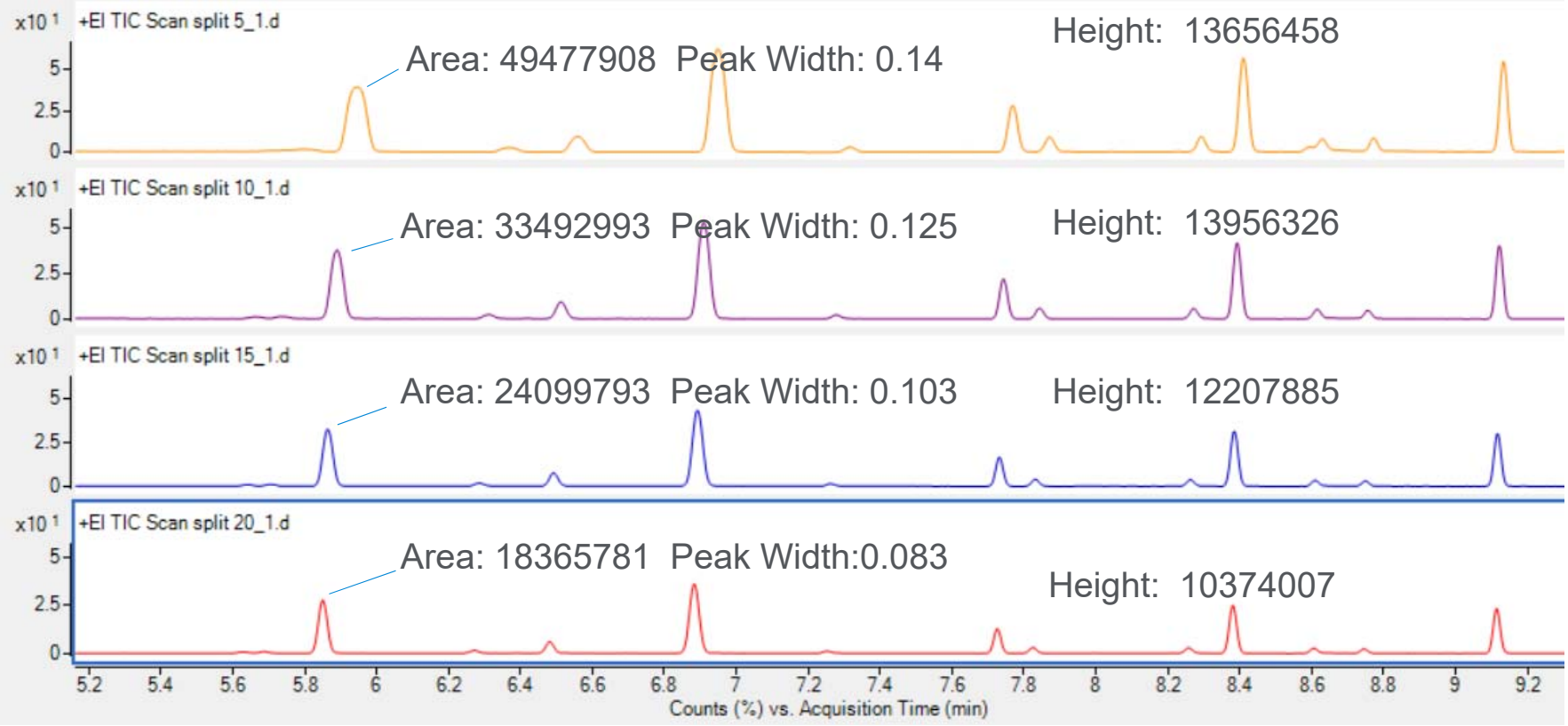
Change in Loop Size
40:1 split (64 mL/min)



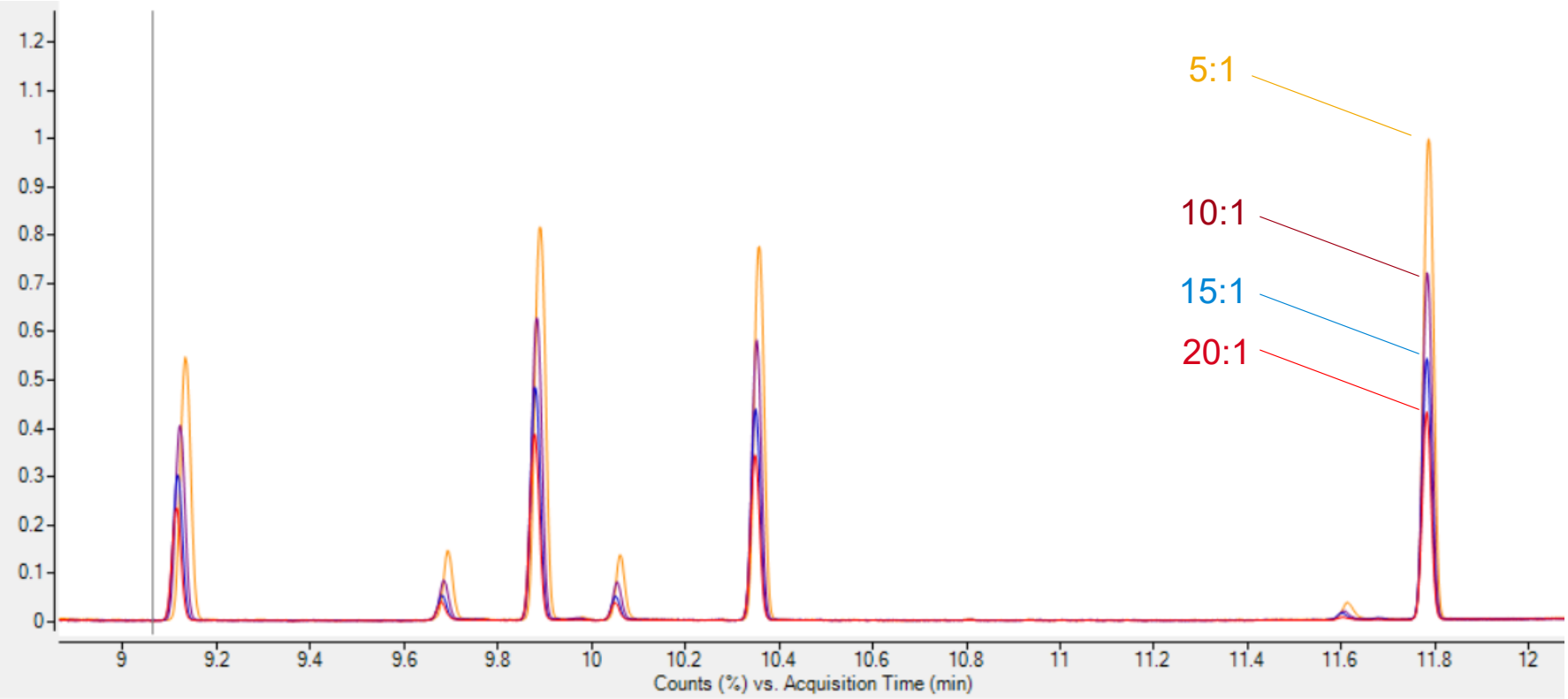
Change in Split Ratio



Change in Split Ratio



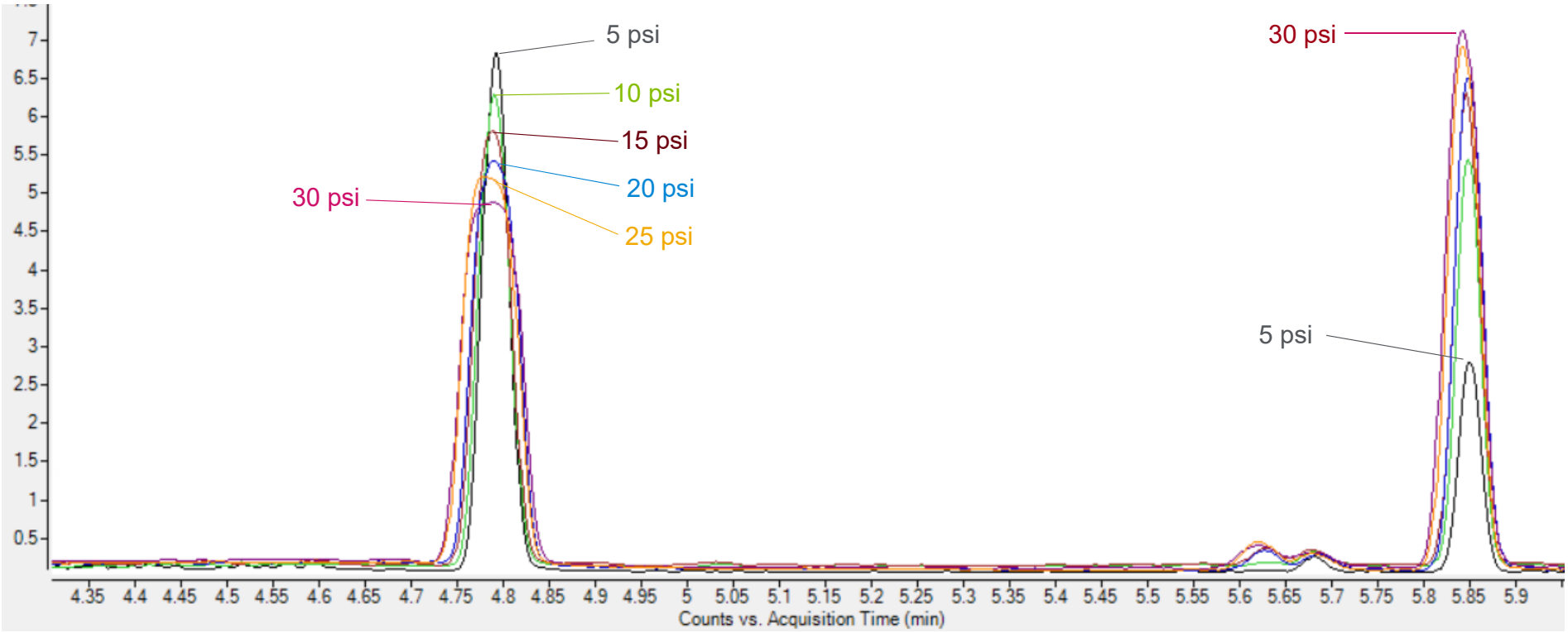
Change in Split Ratio



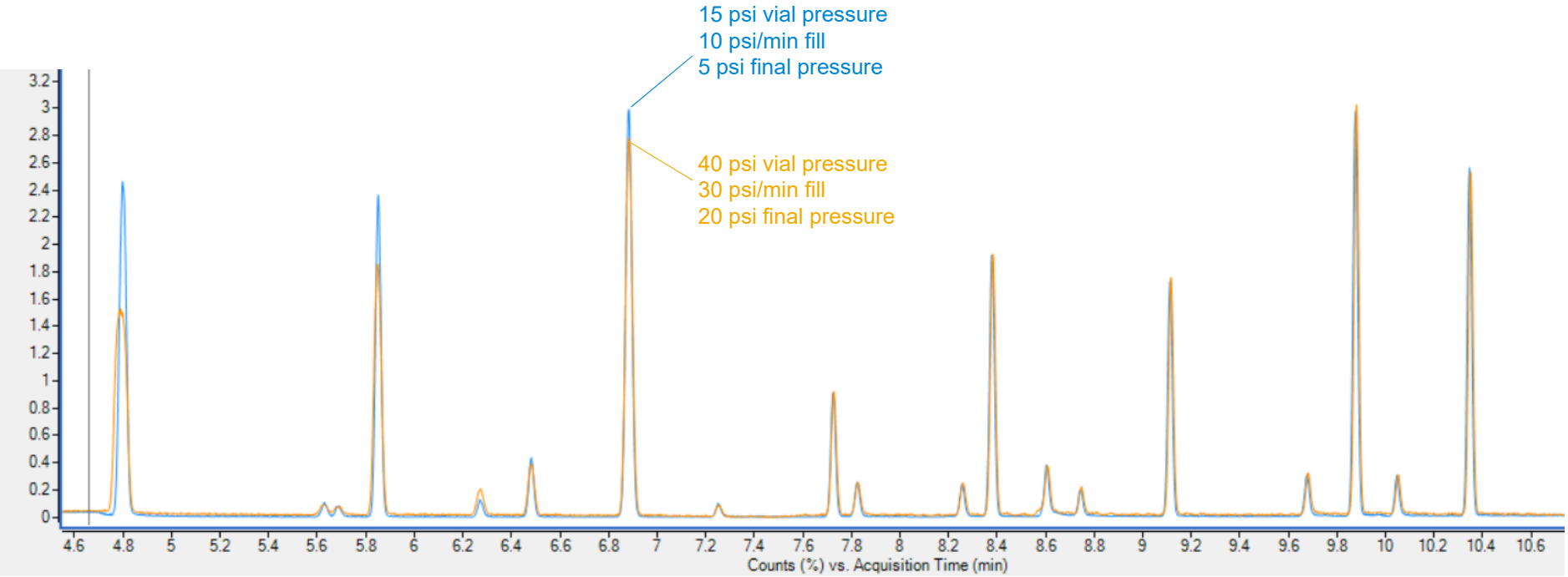
Change in Loop Pressure

First 2 eluting peaks

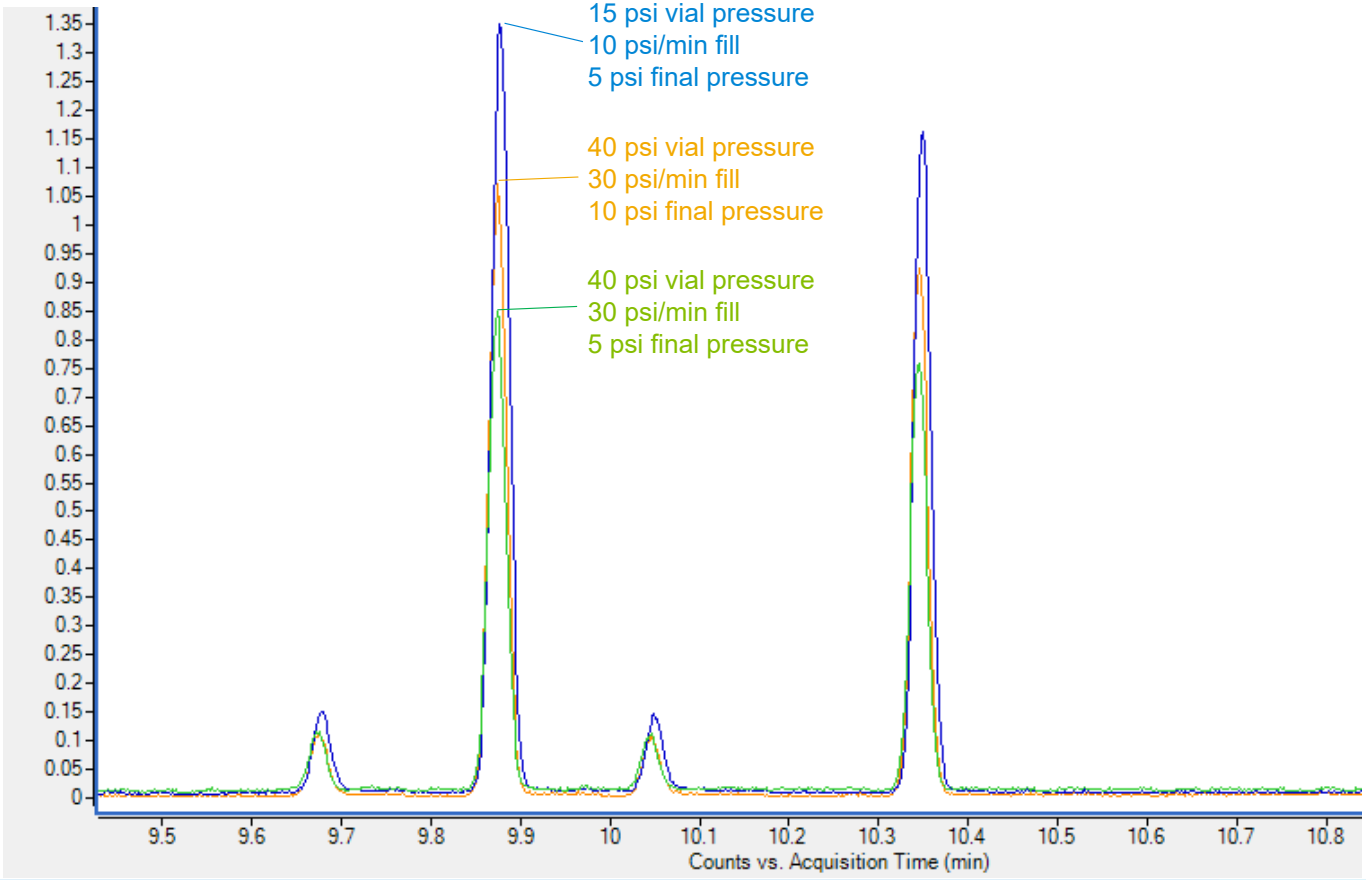
Vial Fill Pressure: 40 psi
Loop Fill Rate: 30 psi/min
Inlet Pressure: 28.3 psi



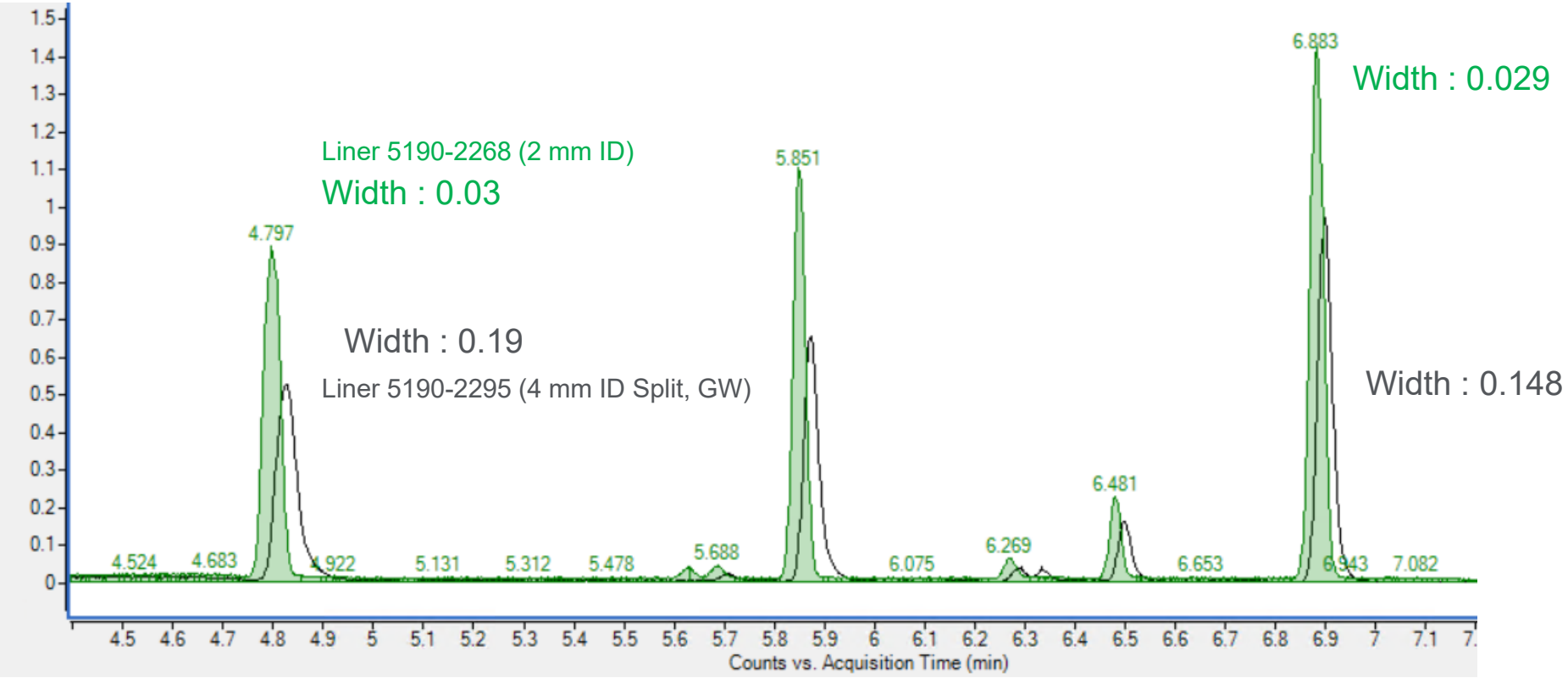
Is that a good way to increase signal?



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

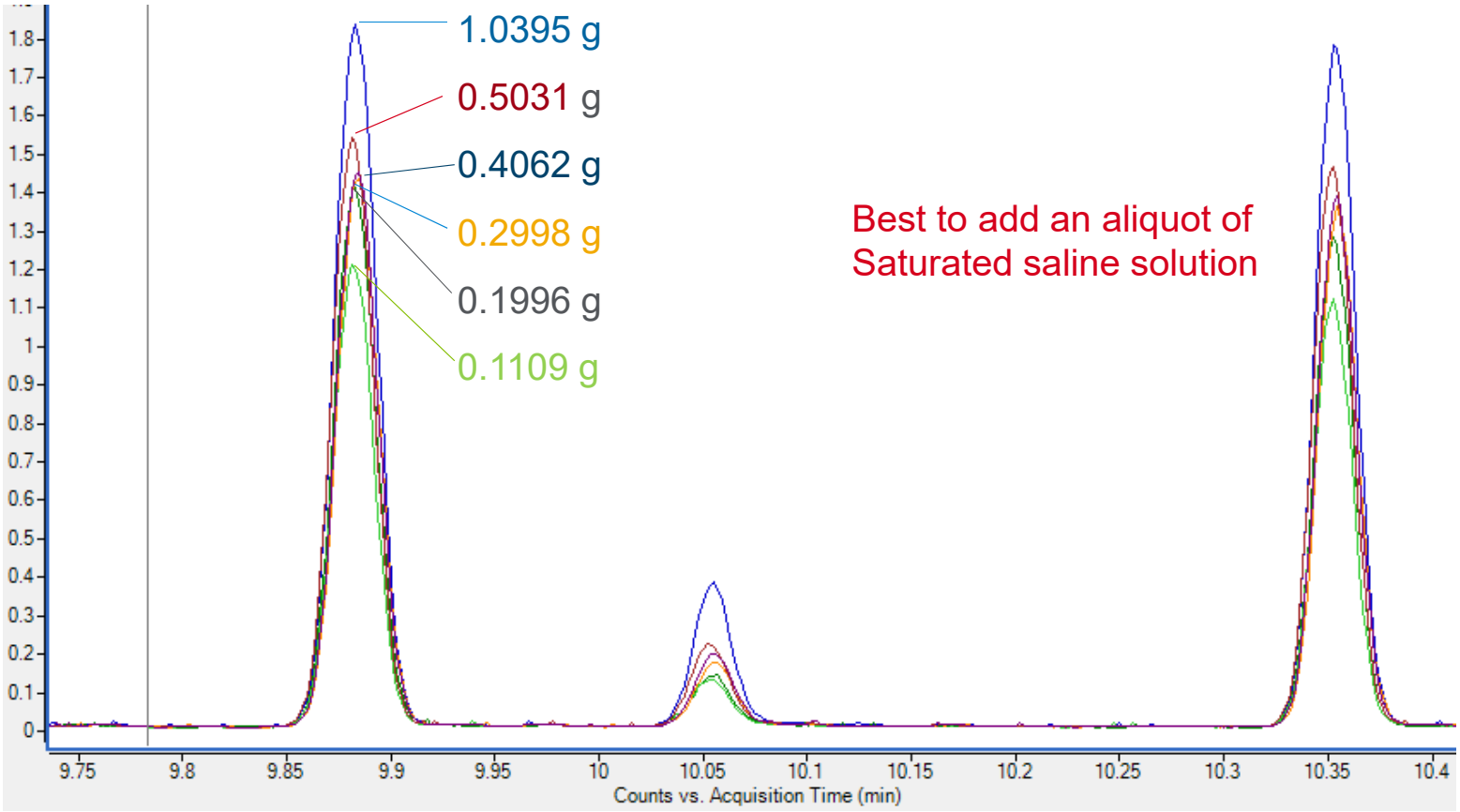
Potassium Carbonate (K_2CO_3)
Ammonium chloride (NH_4Cl)
Ammonium sulfate ($(NH4)_2SO_4$)

Sodium Chloride (NaCl)
Sodium Citrate ($Na_3C_6H_5O_7$)
Sodium Sulfate (Na_2SO_4)

Use high quality, low impurity salts!!!

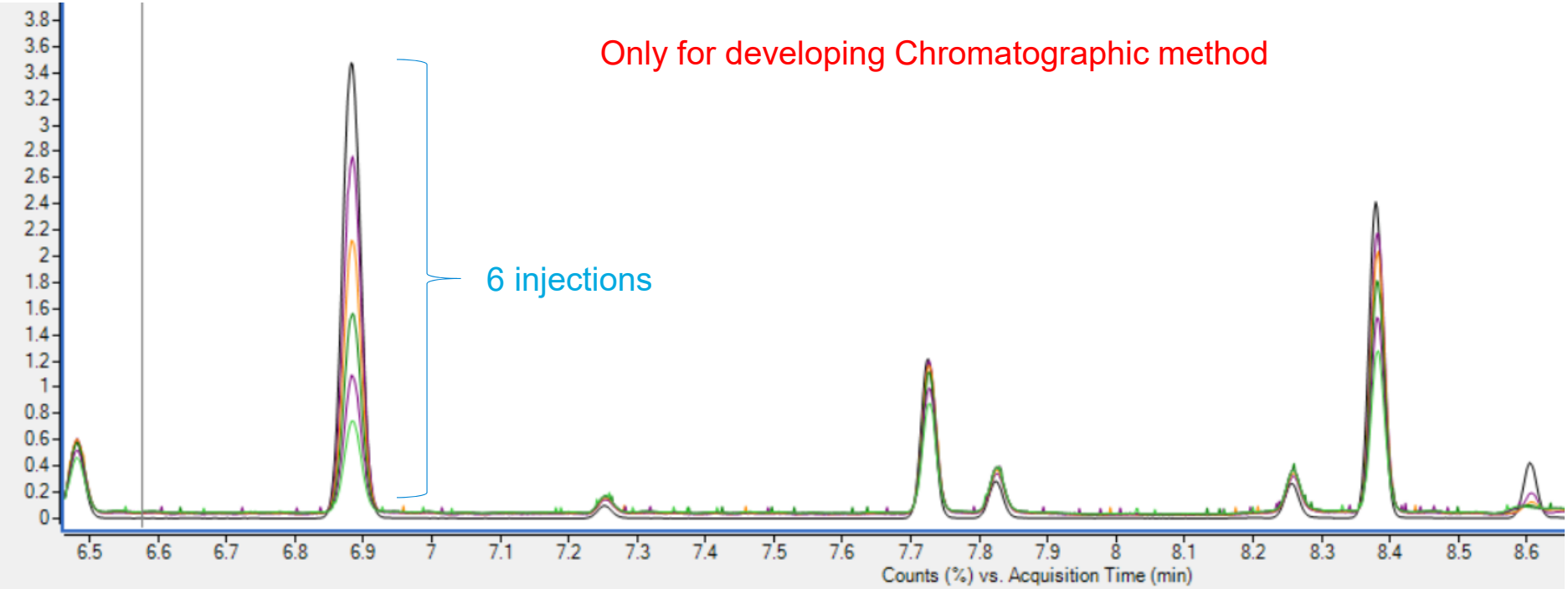
How Much Salt Do I Add?

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

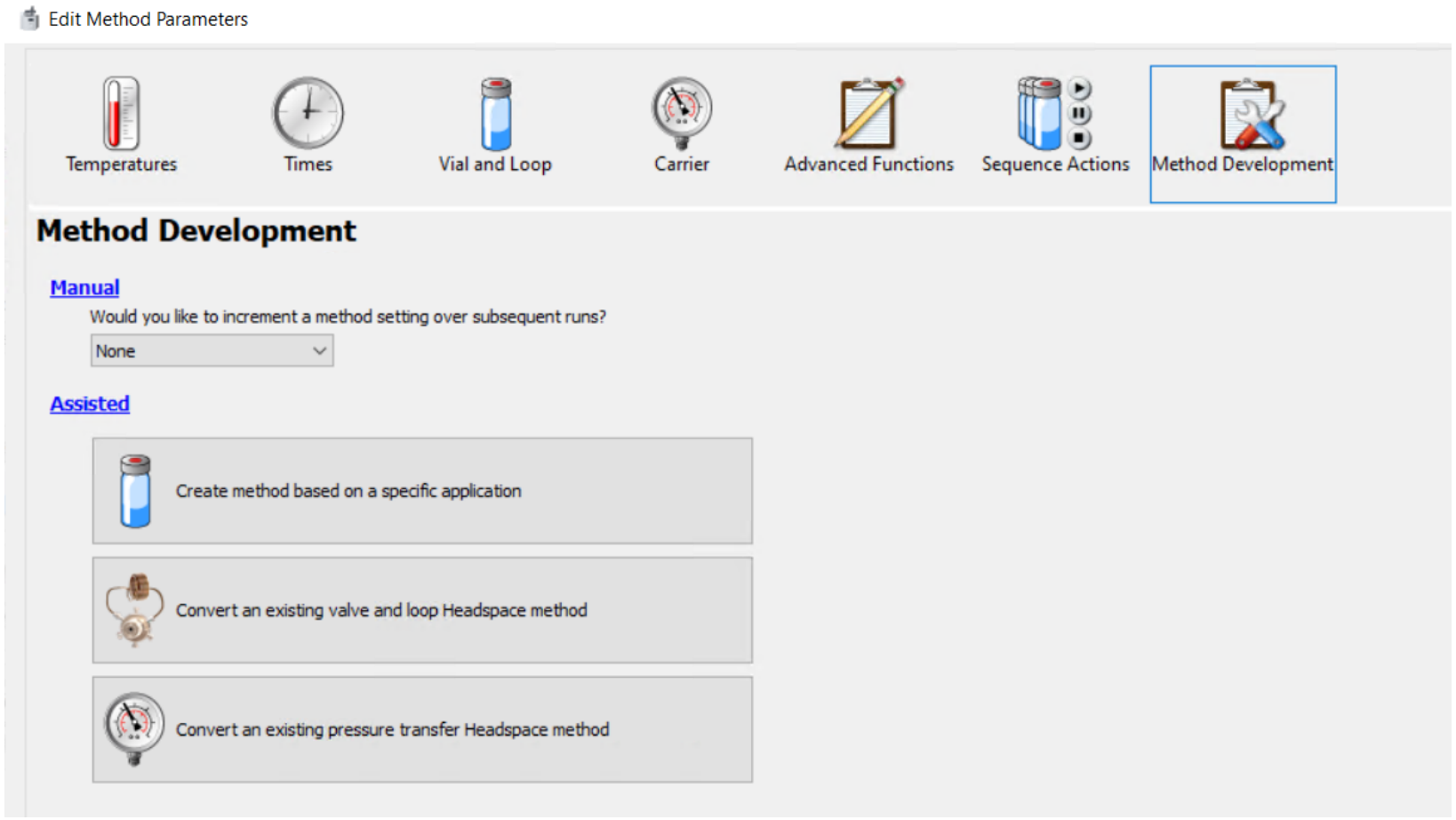
Samples are ground to increase surface area

Used for solvents in plastics or polymers

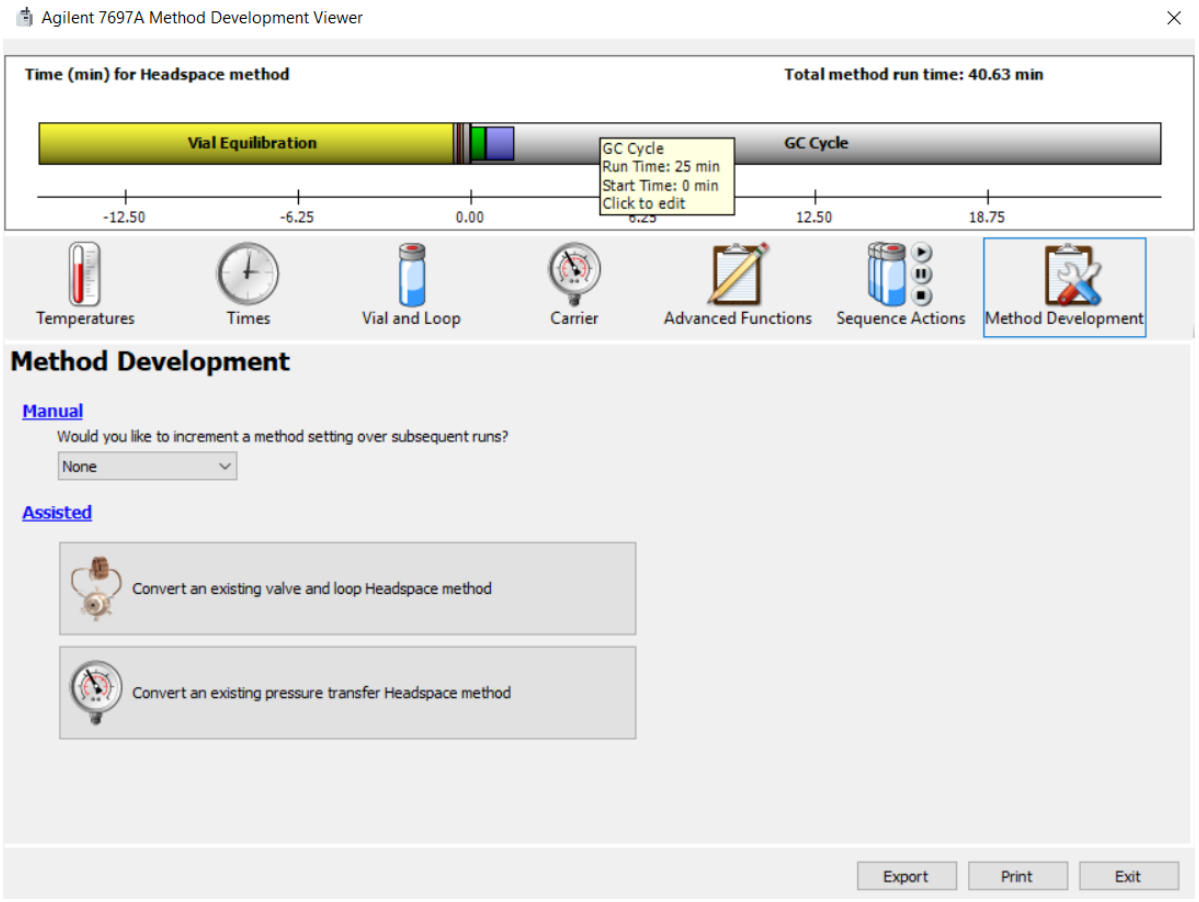
When a matrix match is not available, MHE – “Multiple Headspace Extraction” is used

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

Method Development Tools

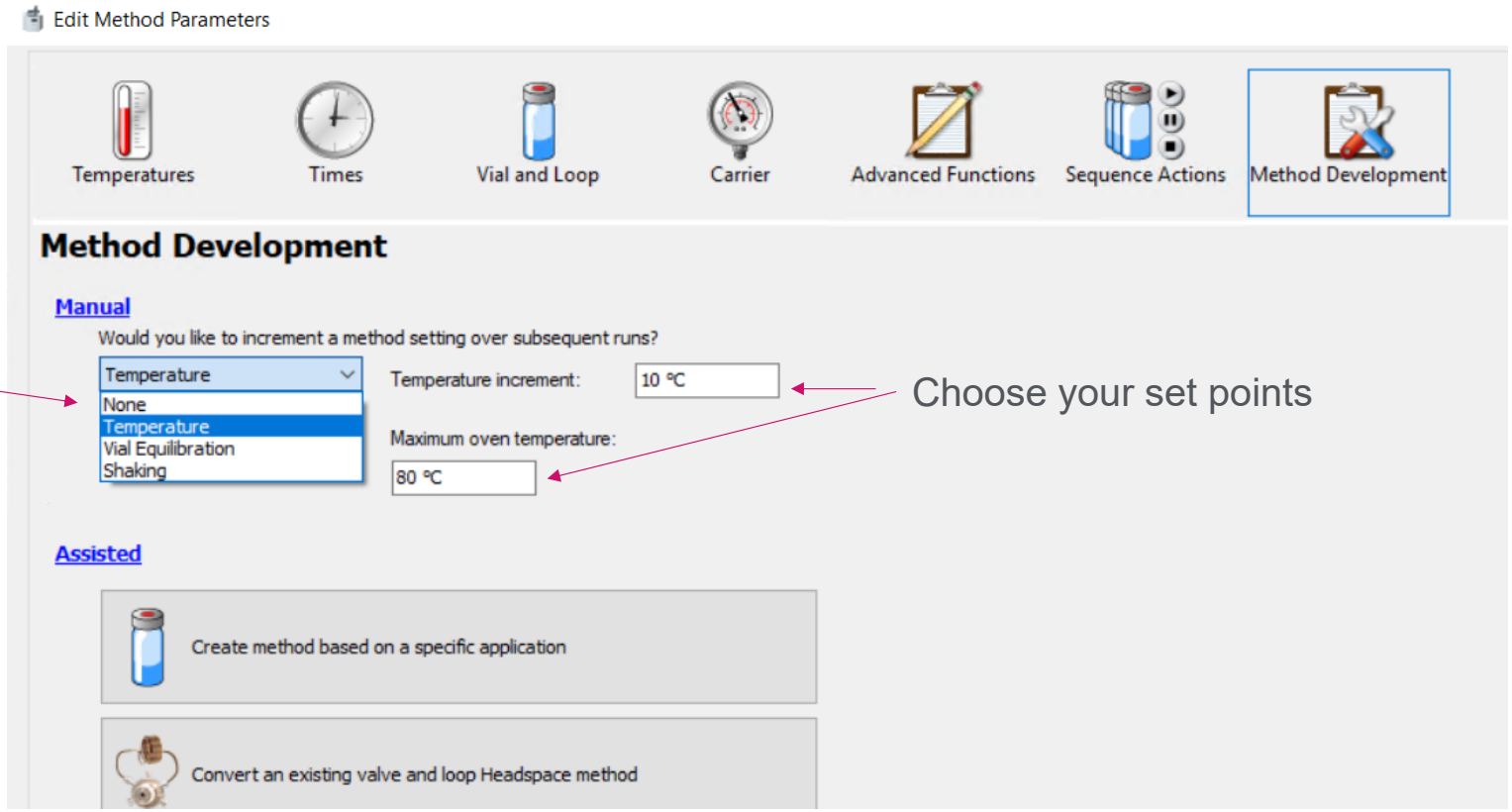


Stand Alone HS Method Development Viewer



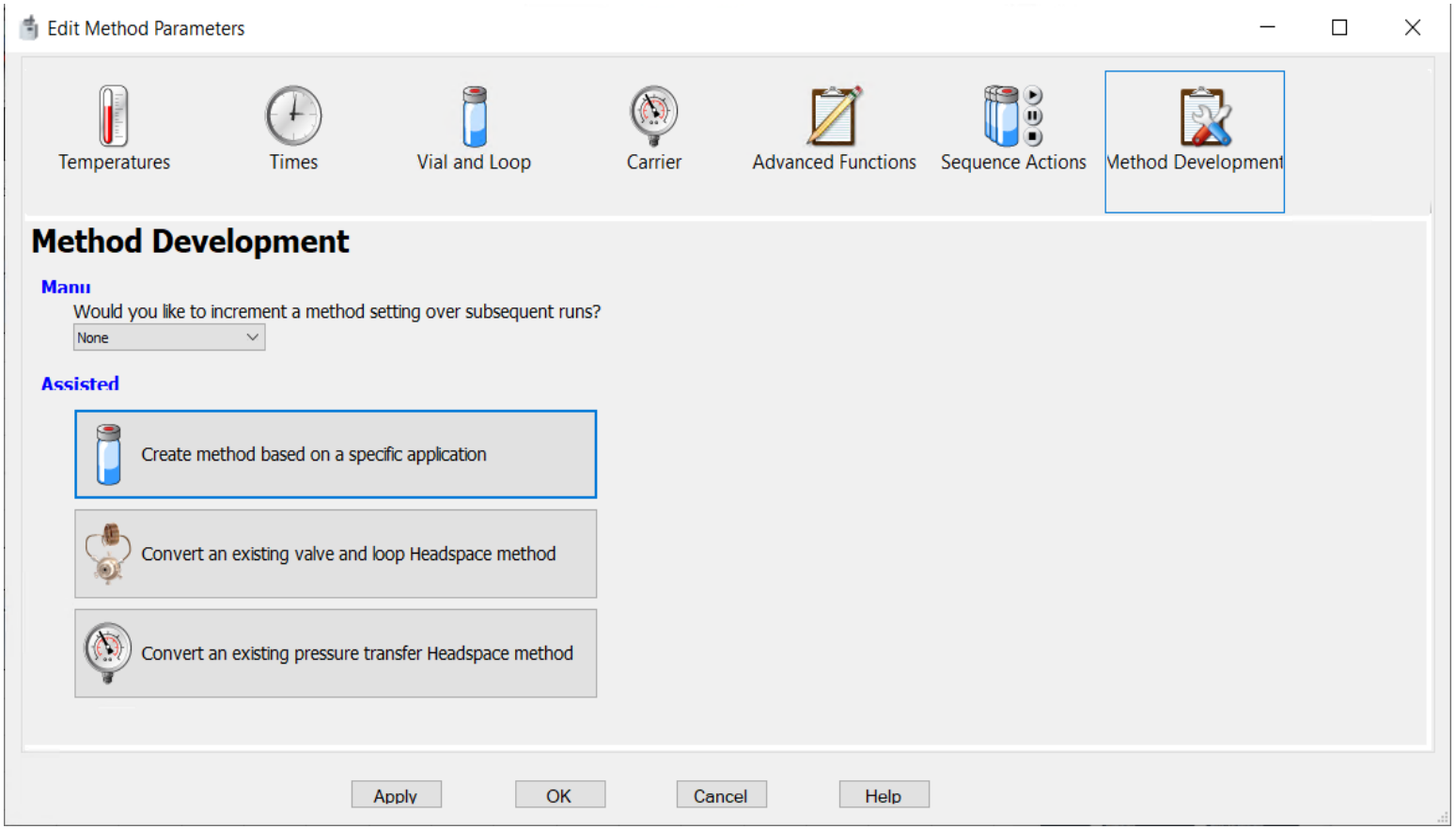
Method Development Tool:

Choose what you want to increment

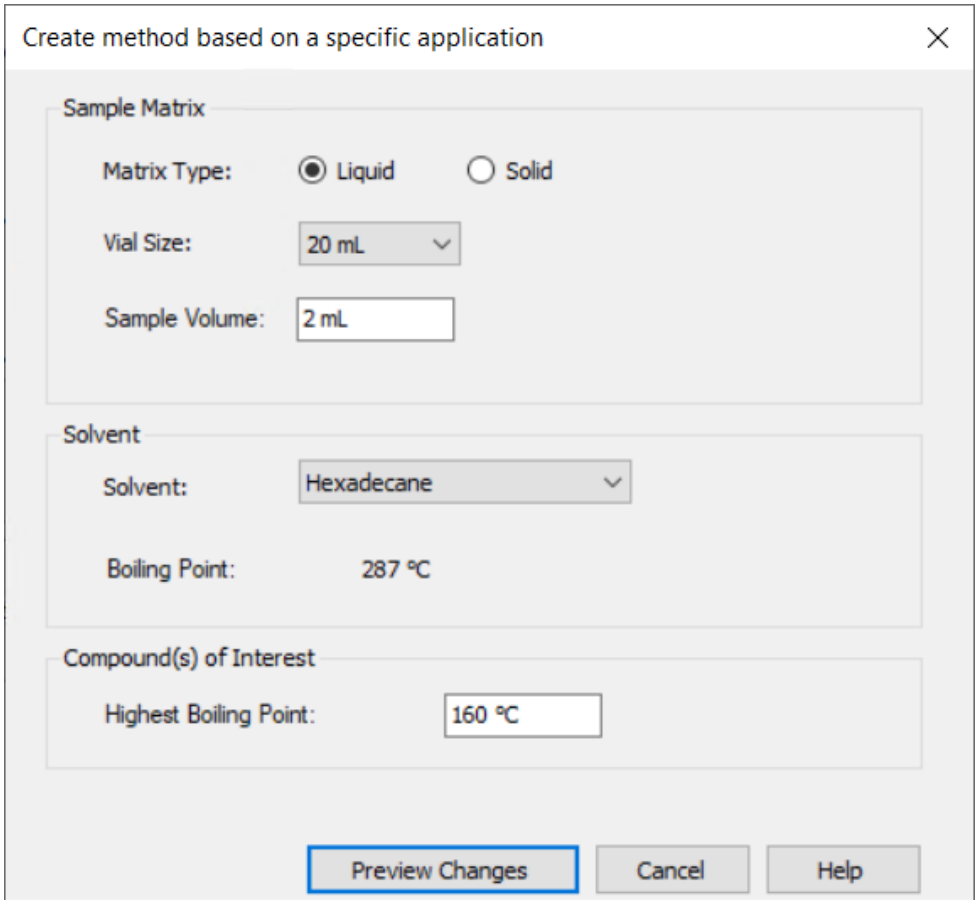


Choose your set points

Method Development Tool:



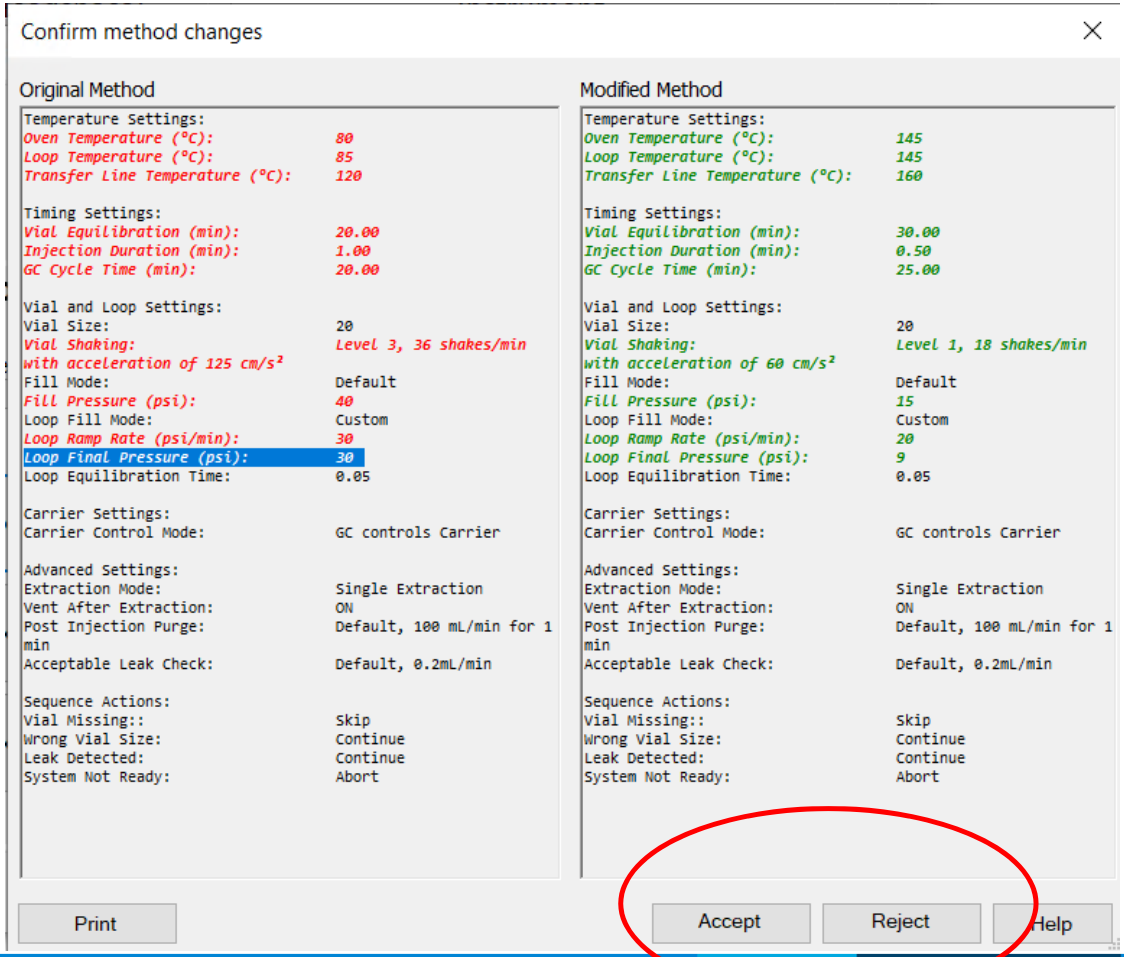
Method Development Tools



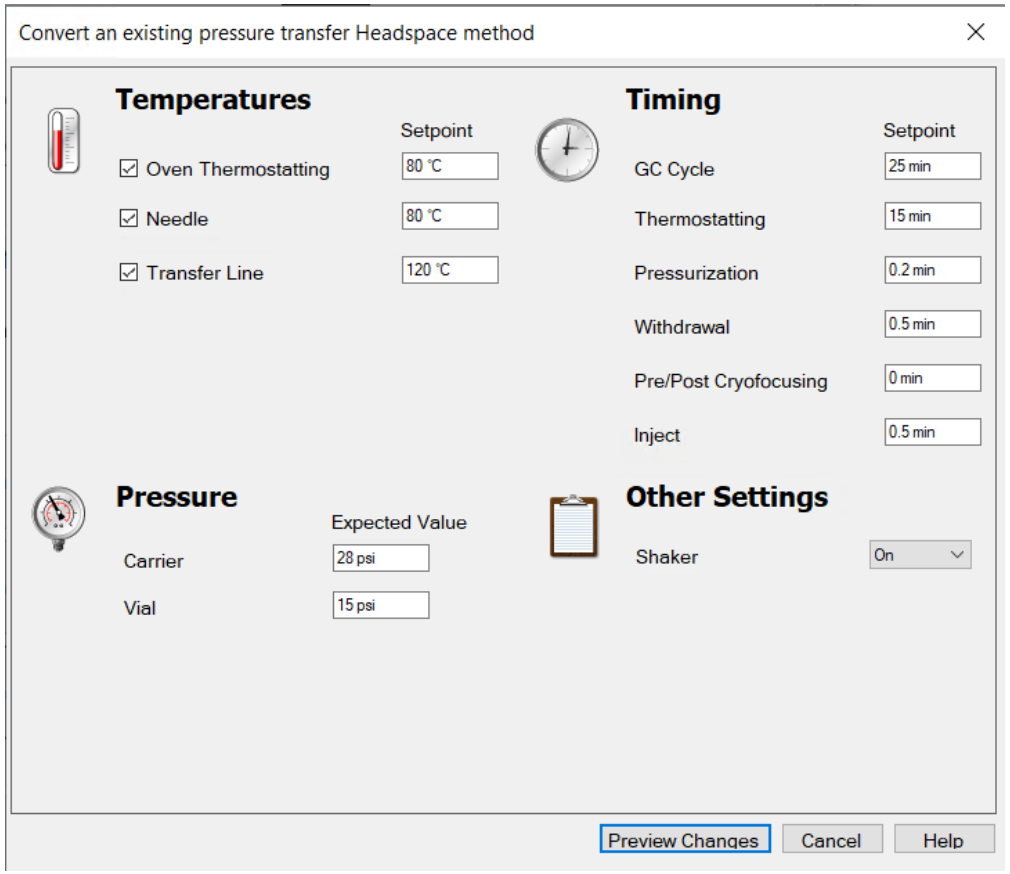
Create Method Based on Specific Application

Red parameters are what will be change from initial method.

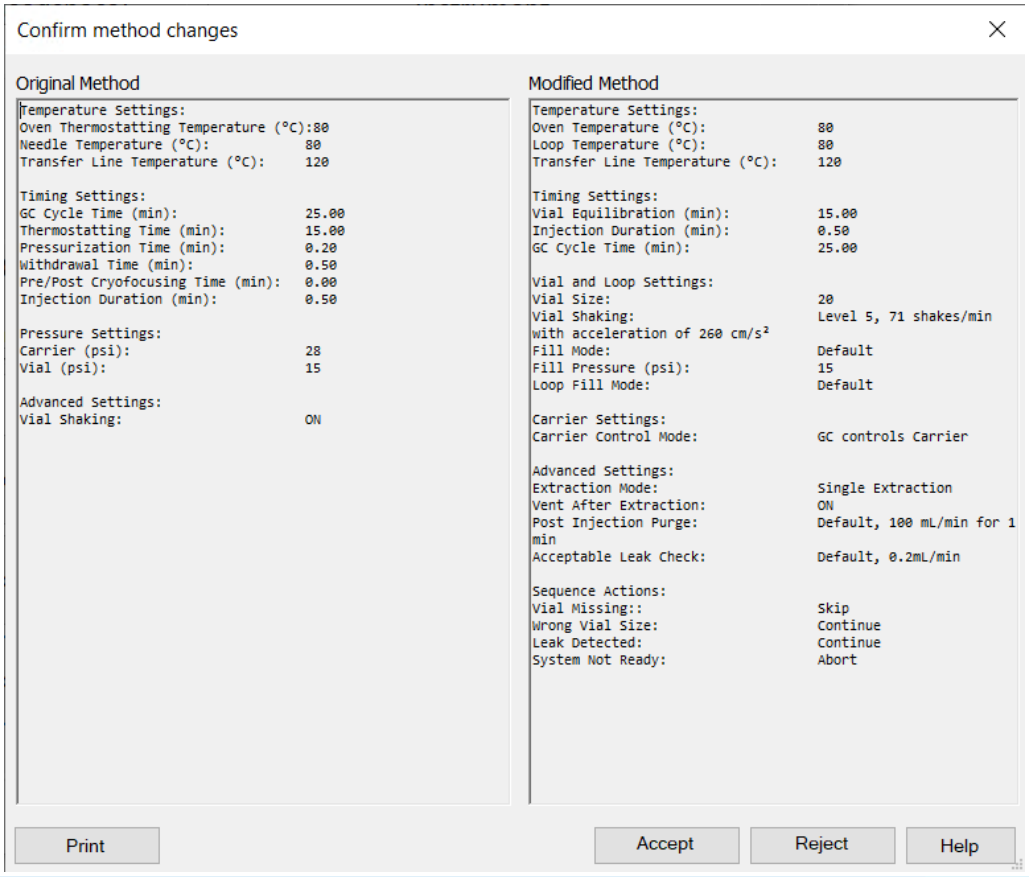
Green parameters are the new settings.



Convert an Existing Pressure Transfer Method



Convert an Existing Pressure Transfer Method



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

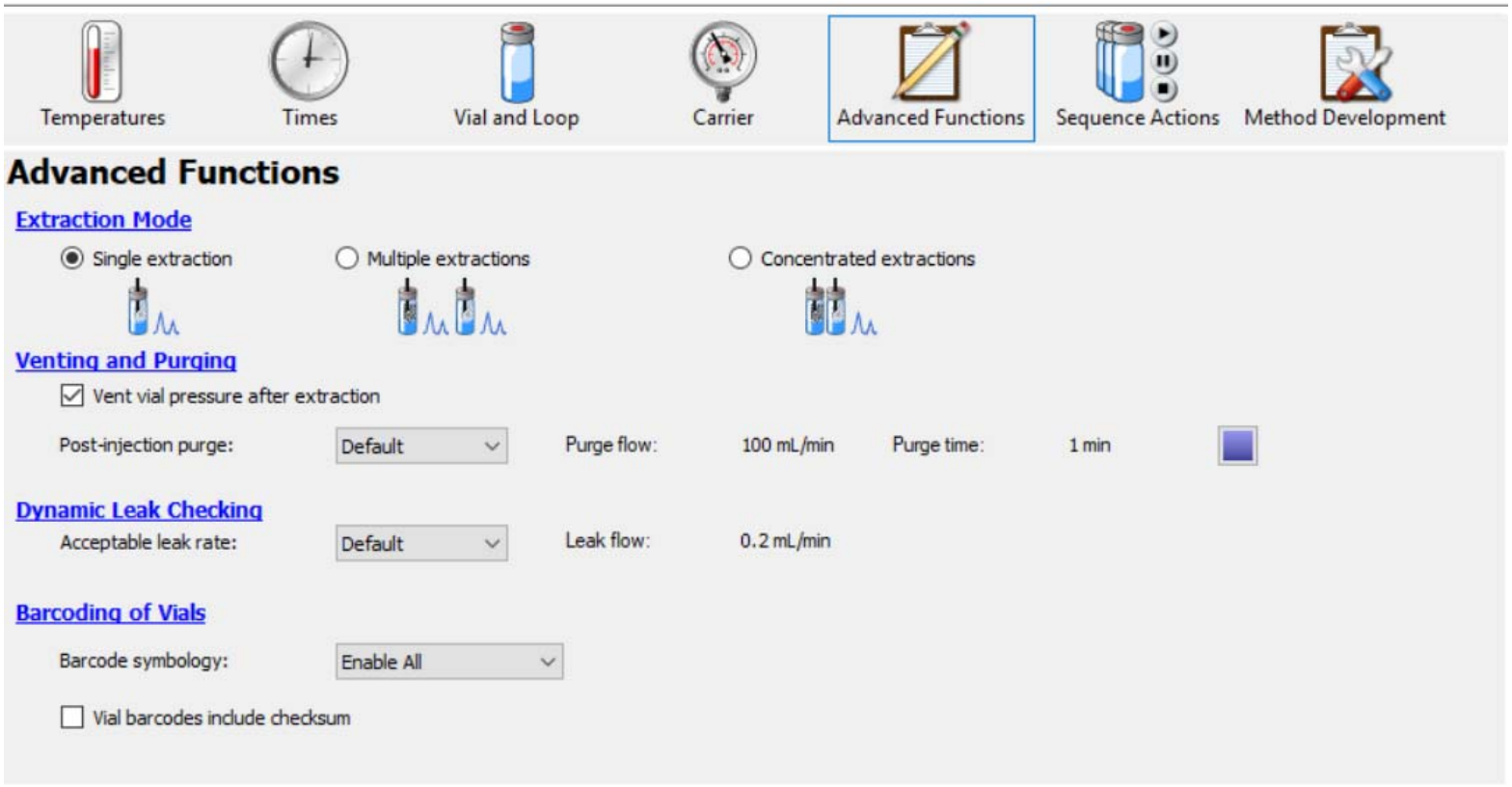
Too tight

Too loose

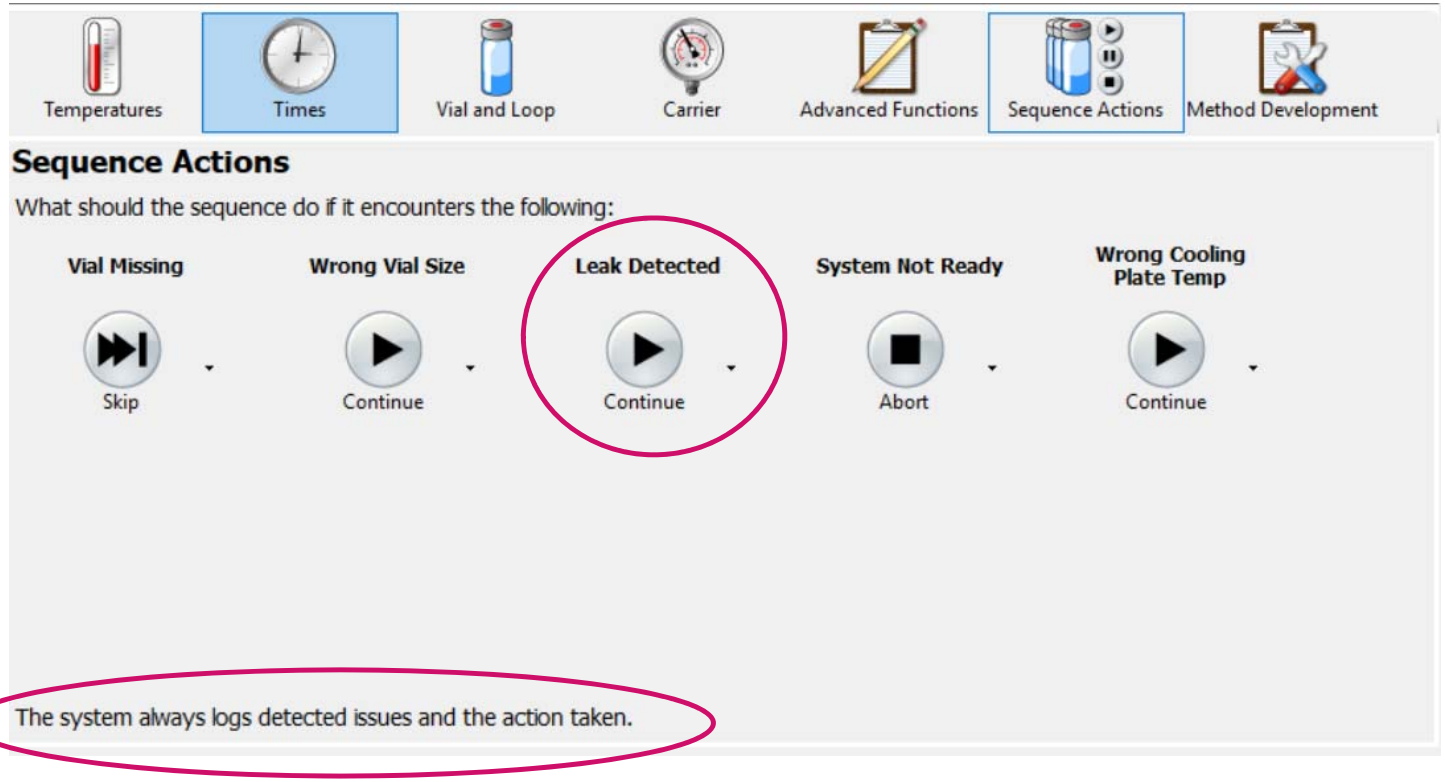
Common Issues

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.	

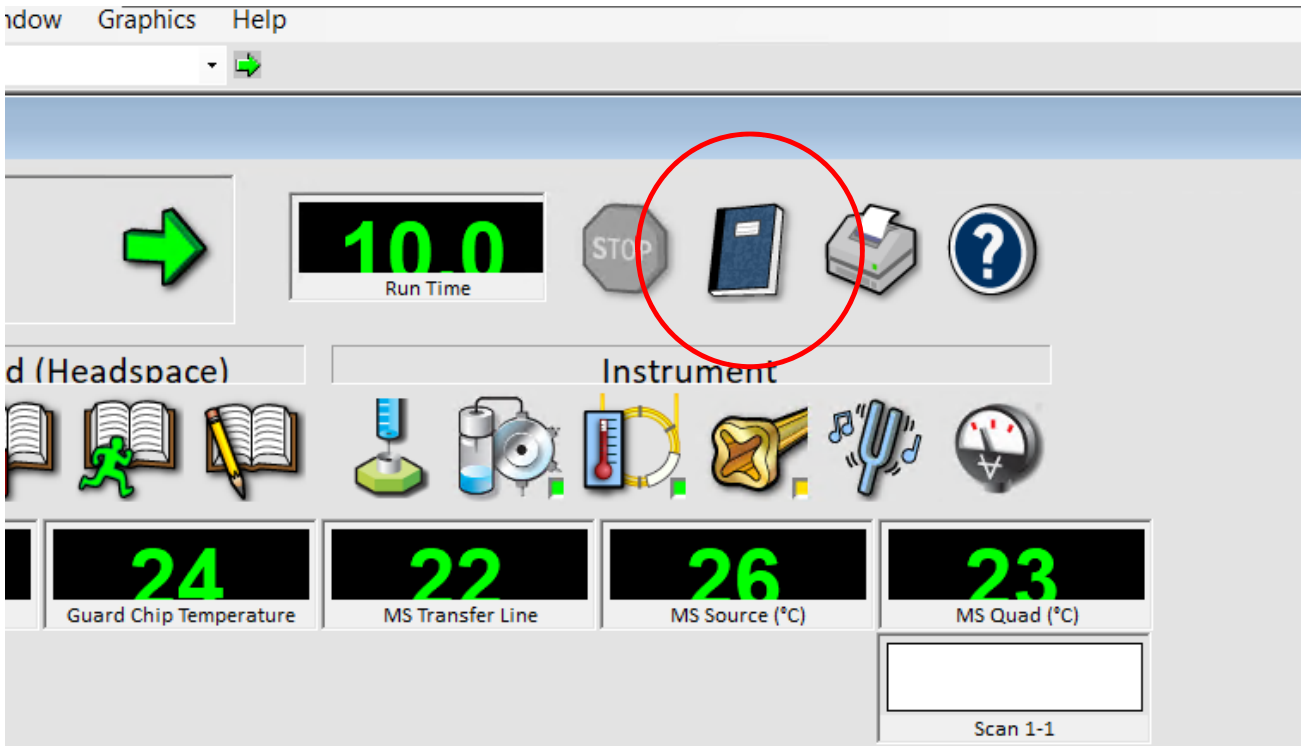
Change the Loop Purge Time and Flow
--Carryover Issues



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
Skip
Wrong Vial Size
Continue
Leak Detected
Continue
System Not Ready
Abort
Wrong Cooling Plate Temp
Continue
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 ← GC columns and supplies

lc-column-support@agilent.com

spp-support@agilent.com

spectro-supplies-support@agilent.com