Review Article

Instant Tips for Precise and Current Approach to solve Gas Chromatography Troubleshooting

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ABSTRACT

Gas chromatography is the premier technique for the trace analysis of organic and inorganic compounds. All the work which has been done on air pollution, water pollution, and food safety where we have to analyze for pesticides and toxic chemicals found in food and food products all of these things are done routinely and daily rapidly by gas chromatography. An essential role of chromatography is the quality control of the quality of food but drugs controlling the raw materials control the finished products ensuring the safety of people. This review article focuses on how to develop general troubleshooting strategies and different troubleshooting problems and solutions to those problems of GC are discussed. For easy understanding and reference the troubleshooting problems encountered with the GC system are organized into baseline problems and peak shape problems they are presented in the form of tables apart from textual matter for easy reference.

Keywords: GC, baseline problems, peak shape problems, suggested remedy, troubleshooting.

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INTRODUCTION

Gas chromatography is an instrumental technique that was first introduced in the 1950s and has evolved into a primary tool used in many laboratories. The introduction of Gas-Liquid Partition Chromatography by James & Martin. PerkinElmer set out to make GC more accessible to researchers by introducing their first gas chromatography in 1955. Gas chromatography is a technique that is employed in many analytical laboratories and is often seen as an established technique with the operation of these devices geared towards continuous operation, and when there is a problem, this becomes the domain of the engineer. Some common troubleshooting approaches[1-3], and troubleshooting strategies are mentioned below fig 1.

Common troubleshooting approaches

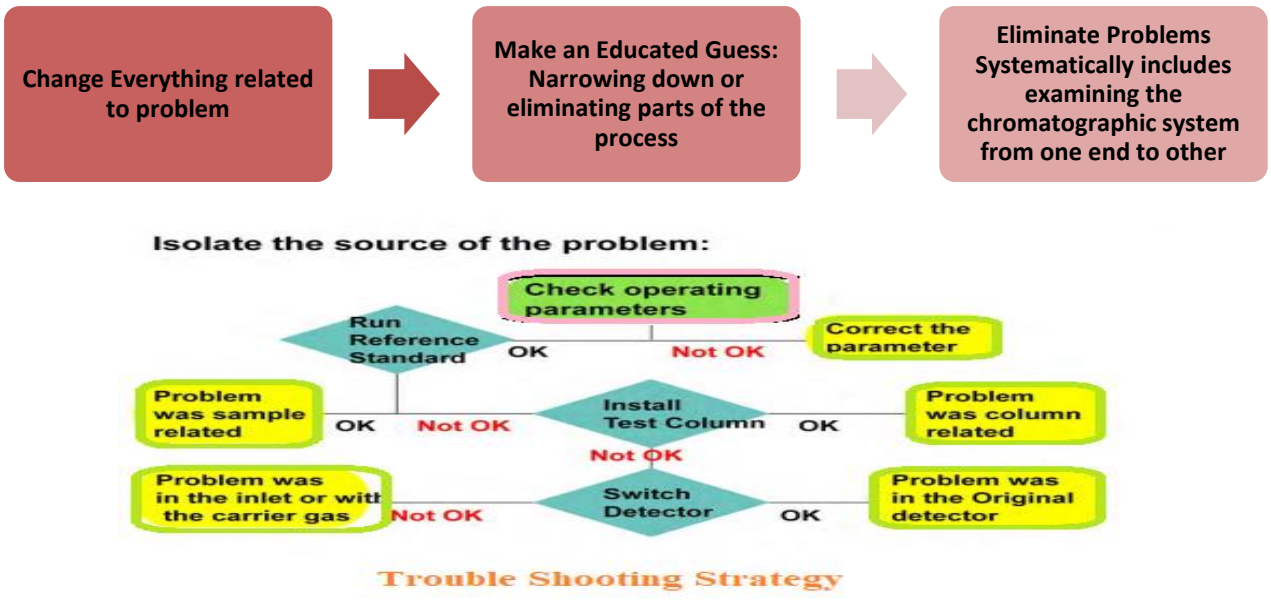


Figure 1: Common trouble shooting approaches and strategies

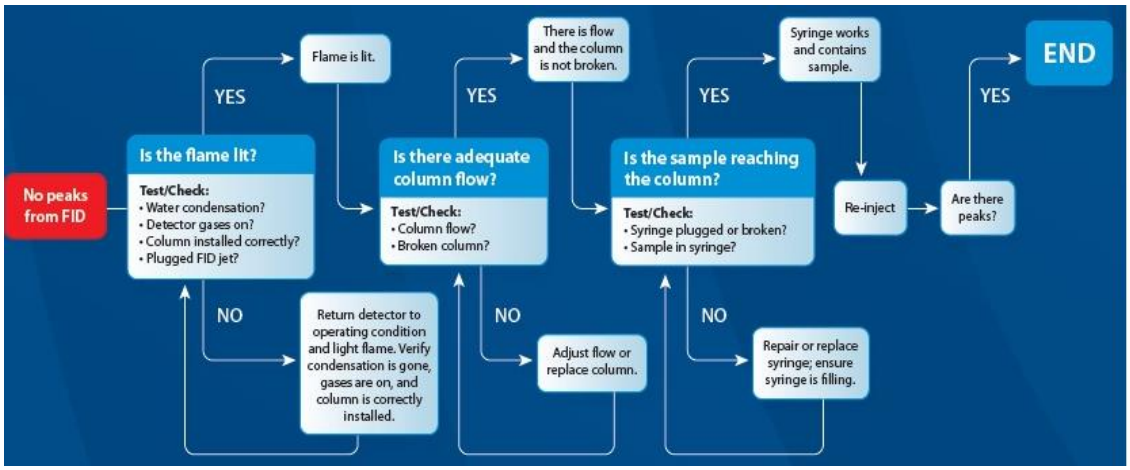


Figure 2: Logical progression of steps that can be used to identify the cause and correct the problem

Symptoms and Solutions

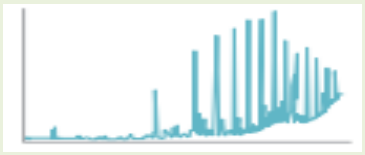
Analytical method development and validation[4-9] are the nonstop and inter-dependent tasks associated with the research and development, quality control, and quality assurance departments exquisite chromatography is crucial to obtaining accurate, reproducible results. Solutions, asymmetric peaks, baseline noise, and other issues are common challenges in the GC laboratory. These analytical problems can be overcome by troubleshooting[10-12] the separations using the tips below

Baseline Problems

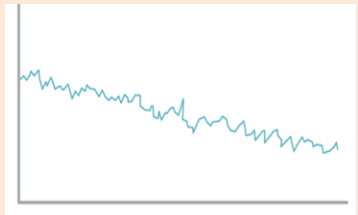
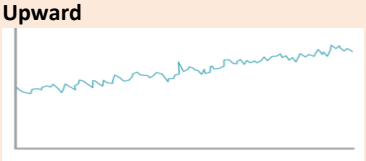
Baseline problems can be divided into 7 categories: Bleed, Drift, noise, offset, spiking and wander, and Waves.

Table 1: Baseline problems of GC[13-16]

a. Bleed

Symptom	Possible Cause	Suggested Remedy
Column Bleed: 	Improper column conditioning	Properly condition the column.
	Contaminated column	There are several options: – Trim the column – Bake out the column – Solvent rinse the column – Replace the column
	Contaminated injector.	Perform inlet maintenance – clean the injector, replace the inlet liner, replace glass wool
Septum Bleed: 	The septum is not conditioned.	Condition septum before analysis or use pre-conditioned septum. Check septa temperature rating – should be sufficient to run at method temperatures.
	Septum core is present in the flow path.	Remove septum core from the inlet. Check the septum nut and make sure it is not over-tightened. Inspect injector syringe for bent or blunt tip and replace as necessary.

b. DRIFT: Slow movement of the baseline in one direction (either up or down)

Symptom	Possible cause	Suggested Remedy
Downward 	Downward drift for a few minutes is normal after installing a new column.	Increase the oven temperature to the maximum continuous operating temperature for the column. Maintain that temperature until a flat baseline is observed. If the detector signal continues to raise or does not drop in 10 minutes, immediately cool the column and check for leaks.
	Downward drift is frequently due to the "bakeout" of contaminants from the detector or other parts of the GC.	Clean out contamination.
Upward 	Excessive damage to the stationary phase of the GC column.	Determine the cause of the damage. It may be due to impurities in the carrier gas or excessive temperatures. Replace column.
	Drift in gas flow rates	Clean or replace flow or pressure regulator(s). Adjust pressure.

c. Noise: Rapid, random movement of the signal amplitude

Symptom	Possible cause	Suggested Remedy
Noise 	The column may be inserted too far into the flame of an FID, NPD, or FPD detector.	Reinstall the column. Be sure to insert the column into the detector at exactly the correct distance specified in the instrument manual.
	Contaminated injector.	Clean injector. Replace the inlet liner. Replace glass wool
	Contaminated column	Bake out the column. Cut off the first 4 inches of the column. Solvent rinses or replace columns.

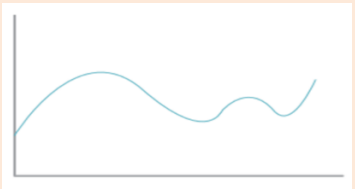
d. Offset: Sudden unexplained changes in baseline position

Symptom	Possible cause	Suggested Remedy
Offset 	Line voltage changes	Monitor line voltage for correlation with offset. If a correlation is found, install a voltage regulator.
	Poor electrical connections.	Check electrical connections. Tighten any loose connections. Clean any dirty or corroded connections.
	Contaminated injector	Clean injector. Replace the inlet liner. Replace glass wool.
	Contaminated column.	Bake out the column. Cut off the first 4 inches of the column. Solvent rinses or replace the column
	Column inserted too far into the flame of FID, NPD, or FPD detectors.	Reinstall the column. Be sure to insert the column into the detector at exactly the correct distance specified in the instrument manual.
	Contaminated detector	Clean the detector.

e. Spiking: Peaks with no width, either positive or negative

Symptom	Possible cause	Suggested Remedy
SPIKING: 	Electrical disturbances enter the chromatogram through power cables, even shielded cables.	Try to correlate spikes with events in equipment near the chromatogram. Periodicity is often a clue. Turn off equipment or move it. If necessary, install a voltage regulator.
	Particulate matter passes through the detector.	Clean the detector and eliminate the source of particles. A clean hydrogen flame is invisible. Most organic matter generates a yellow flame.
	Loose, dirty, or corroded electrical connections in the detector.	Check electrical connections. Tighten any loose connections. Clean any dirty or corroded connections. Replace badly corroded FID parts.

f. Wander: Low-frequency noise

Symptom	Possible cause	Suggested Remedy
	Baseline wandering may be caused by changes in environmental conditions such as temperature or line voltage.	Try to correlate the wandering with environmental parameters.
	Inadequate temperature control. Check if variations can be correlated with changes in the baseline position.	Measure detector temperature. Check detector, if TCD is used.
	Contaminated injector.	Clean injector. Replace the inlet liner. Replace glass wool.
	Contaminated column.	Bake out the column. Cut off the first 4 inches of a column. Solvent rinses or replace columns.

g. Waves: Baseline oscillations are different from typical noise

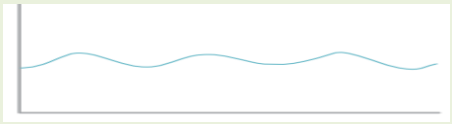
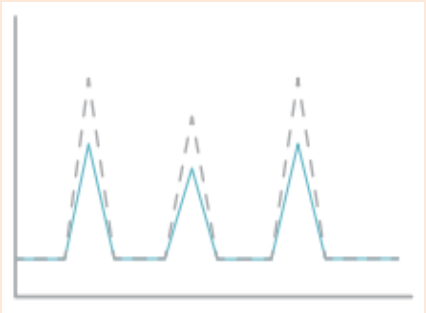
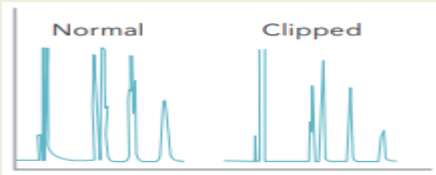
Symptom	Possible cause	Suggested Remedy
Fast 	Detector-related problem.	Baking the detector at the maximum temperature (450 °C for FID) for 30 min to 1 hour may provide temporary relief. For a lasting solution, physically clean the detector
Slow 	Gas pressure fluctuations.	Storage tank pressure varies, causing dips in flow. Adding a dual-stage regulator can minimize pressure fluctuations and help to alleviate the problem.
Square 	Unbalanced column-switching or gas-sampling valves (for TCD detectors	Measure, check, and set flows accurately
S-Shaped 	Excessive column bleed.	Check max column temperature and re-condition column. If the column is damaged beyond repair, replace the column.
Wander 	Contamination during isothermal parts of a run.	The column is separating the contaminants (commonly siloxanes or hydrocarbons) as peaks. Changing samples, wash solvents, liner, gold seal, and sometimes the syringe may be required to eliminate the contamination

Table 2: Peak Shape Problems[17-20]

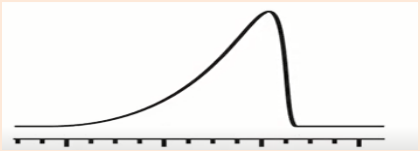
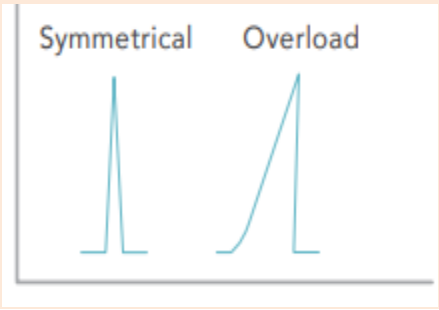
a. Reduced Size: Some or all peaks are reduced in size

Symptom	Possible cause	Suggestion Remedy
All peaks Reduced 	Defective or plugged syringe.	Try a new or proven syringe.
	"Blown" septum or other massive leaks at the inlet or with carrier gas flow. Poor peak shapes usually result from bad leaks.	Find and fix leaks and adjust gas flow.
	Purge flow or split ratio too high.	Adjust gas flow rates.
	Injector and/or column temperature too low for high molecular weight or low volatility samples.	Increase injector and/or column temperature
	For split less injection, if the split vent is closed for too short a period or if the initial column temperature is too high, this may hinder refocusing of the sample.	Increase the time the split vent is closed. Decrease the initial column temperature or use a less volatile solvent so that the initial temperature is below the boiling point of the solvent.
	Inadequate signal amplification.	Check output signal levels.
Some Peaks Reduced 	Activity in the inlet liner or column if the reduced peak is an active compound.	Clean or replace the inlet liner. Ensure an inert column is used. If necessary, replace the column.
	Leak in the injector if the reduced peak is a more volatile compound.	Find or repair the leaks and adjust gas flow.
	Initial temperature too high for split less or on-column injections	Lower the initial column temperature. Use a higher boiling solvent.

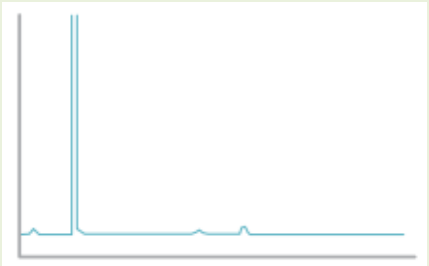
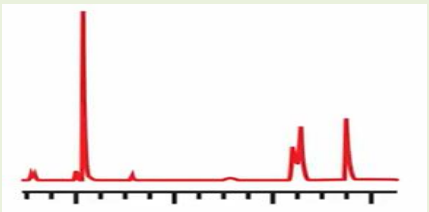
b. Clipped/Flat Peaks: Peaks are clipped and flat at either the top or the bottom

Symptom	Possible cause	Suggestion Remedy
Flat Top peaks 	Detector overload. The broad peaks may have a rounded top or even valleys at the top.	Reduce sample volume, dilute with solvent, or increase or add a split flow.
	Overload of the signal processing electronics. The peaks are clipped with flat tops.	Attenuate detector output to reduce sample volume, or add a split flow
Flat Bottom Peaks 	Detector, recorder, or integrator set too low; detector drifted below zero.	Correctly set zero. Reconnect leads from the recorder and set zero of recorder baseline to ~5 % of full scale. Check the integrator threshold and adjust accordingly. Use an auto-zero function.

c. Fronting: Moderate to severe asymmetry towards the front or left side of the peak

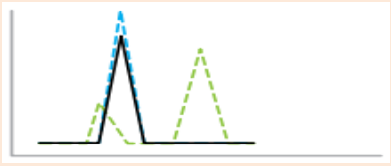
Symptom	Possible cause	Suggestion Remedy
Slight Fronting 	Improper column installation	Reinstall the column.
	A sample is condensing in the injector or column.	Check injector and oven temperature with an accurate thermometer. If accurate, increase the temperature as necessary but do not exceed the maximum temperature limit of the column.
Overloaded or "Shark Fin" 	The column is overloaded as a result of injection volume and split ratio.	Reduce the injection volume; add or increase split flow. Use a column with greater capacity. Columns with larger diameters or thicker stationary phase coatings generally have larger sample capacities; however, resolution may be reduced.
	Polarity mismatch	Polar compounds will have lower concentration capacity in a non-polar phase and vice-versa. Choose a phase with the appropriate polarity and selectivity for your sample.

d. Ghost Peaks: Peaks are observed when no sample has been introduced into the system.

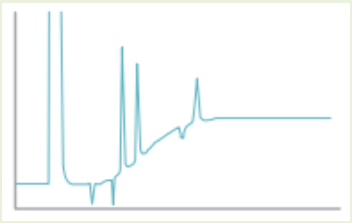
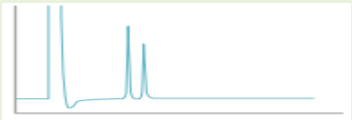
Symptom	Problem Cause	Suggestion Remedy
Normal 	Remnants of previous samples in the inlet or column are most likely to occur when increasing inlet or column temperature(s).	Increase the final temperature and lengthen the run time to allow for the complete elution of previous samples. If ghost peaks continue to occur, clean the inlet**.** Condition the column at a higher temperature that is still lower than the maximum isothermal limit for the column. Cut 4 inches off the inlet end of the column and/or reverse it (end-for-end) before reconditioning. Solvent rinses or replace the column.
Ghost Peaks 	The sample expanded to exceed the volume of the injector liner. These vapors may come in contact with colder spots, such as the septum and gas inlets to the injector. Less volatile components may condense. These condensates may vaporize later and interfere with subsequent analyses, sometimes producing "ghost peaks".	Minimize back flush by using: a septum purge • small injection volumes • large inlet liners • optimal injector temperatures • pulsed pressure programming • increased split flow

	Bleed from the septum or fragments of the septum lodged in the inlet or liner	Clean the inlet. Replace the inlet liner or glass wool, and septum.

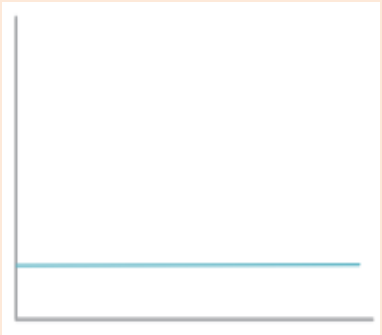
e. Irreproducibility: Peak heights, areas, or retention times are inconsistent from injection to injection

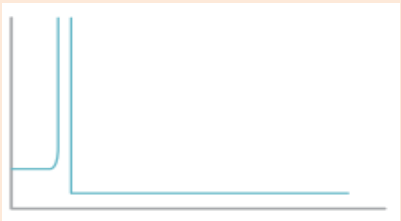
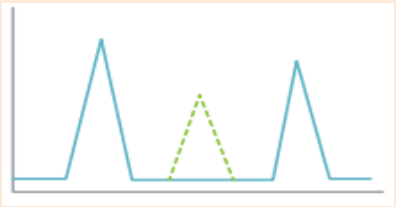
Symptom	Problem Cause	Suggestion Remedy
Irreproducibility 	Inconsistent injection	Develop a reproducible injection technique. Use auto sampler or replace injection needle.
	Distorted peak shapes can adversely affect quantitative determinations.	Correct any problems that result in the distortion of peak shape.
	Baseline disturbances.	Disturbances in the baseline are affecting peaks.

f. Negative Peaks: Some or all peaks dip below the baseline.

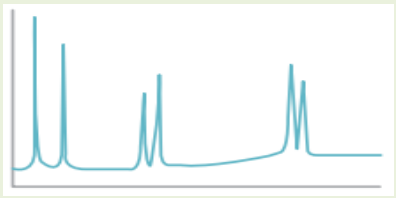
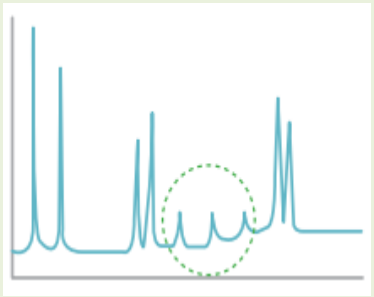
Symptom	Problem Cause	Suggestion Remedy
Some Peaks 	Detector overload in element-specific detectors such as ECD, NPD, FPD, etc. can produce both positive and negative peaks.	Have the compounds of interest arrive at the detector at a different time from the solvent or other compounds in high concentration. H2 produces negative peaks with a TCD and helium carrier gas
	Sample contaminants (hydrocarbons or other non-responders) are present when using ECD, PID, or NPD (thermionic specific) detectors.	Improve sample preparation and cleanup methods before injection.
All Peaks 	The incorrect polarity of the recorder connections results in nearly all peaks being negative	Reverse polarity of recorder connections.
	Recorder-integrator wires reversed	Correct connections.
	Sample injected onto the wrong column for dual-column setups.	Reinjection the sample onto the correct column.
Dip After Solvent Peak 	Detector contamination.	Clean or bake out the detector.
	Sample contamination.	For PID detectors, check that the sample has not been contaminated with methanol or water. If necessary, prepare a fresh sample.

g. No Peaks: Some or all peaks are missing from the run

Symptom	Problem Cause	Suggestion Remedy
All peaks missing 	Defective or clogged syringe.	Try a new or proven syringe
	"Blown" septum or massive leaks at the inlet.	Find and fix leaks.
	Problems with carrier gas flow	Adjust gas flow
	The column may be broken or installed in the wrong detector or inlet.	If breakage is close to the beginning or end, cut off the short piece. The breakage in the middle can be repaired with a press-fit connector. For multiple breakages, replace or reinstall the column.
	The detector is not functioning or is not connected to the recorder or integrator.	Ensure the detector is working properly. (e.g. is the flame in an FID lit?) Check connection to the output device.
	Incorrect injector temperature: • Injector too cold: sample is not vaporized. • Injector too hot: thermally labile sample is decomposing.	Cold injector: check injector and oven temperature with an accurate thermometer. If accurate, increase the temperature as necessary but do not exceed the maximum temperature limit of the column. Inject the sample directly onto the column.

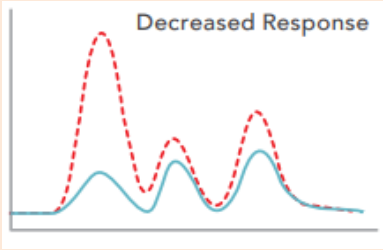
		Hot injector: check injector and oven temperature with an accurate thermometer. If accurate, reduce the temperature as necessary, ensuring compatibility with sample and column minimum limit.
No Peaks After Solvent Peak 	The sample volume is too high.	Inject less sample or use a higher split ratio.
	Incorrect column temperature: column is too hot and the sample is eluting in solvent peak.	Check oven temperature with an accurate thermometer. If accurate, reduce the temperature as necessary, ensuring compatibility with sample and column minimum limit.
	The column cannot separate components from solvent.	Change solvent or column.
Some Peaks missing 	Activity in the inlet liner or column if the missing peak is an active compound.	Clean or replace the inlet liner. Ensure an inert column is used. If necessary, replace the column.

h. Peaks Added: There are more peaks than normal in the run

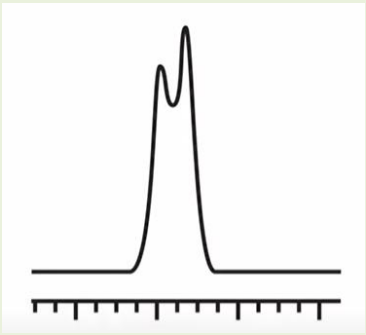
Symptom	Problem Cause	Suggestion Remedy
Normal 	Septum bleed (especially for runs with oven ramp).	Turn off the injector heater. If extra peaks disappear, choose a higher temperature-rated septum or use a lower injection temperature.
	Carryover of samples or contaminants from previous runs.	Increase the analysis time before the next run or bake out the column between runs.
Extra Peaks 	Contaminants in the current sample or solvent.	Inject solvent by itself using a clean syringe. Switch to a higher quality solvent if extra peaks appear. If only solvent appears, run the solvent through any sample preparation methods, analyzing the solvent at each step of the process to identify the source of extra peaks. If only the solvent peak appears, the extra peaks are part of the sample.
	Impurities in carrier gas are eluting.	Install or check gas purifiers. Replace if necessary. Ensure only high-quality gases are used.
	Analytes are decomposing or breaking down for active or thermally labile compounds.	If compounds are thermally labile, lower the temperature and use on-column injection, a column with a thinner stationary phase, a shorter column length, or a higher carrier gas flow rate.

i. Sensitivity Loss: Some or all peaks are displaying decreased response

Symptom	Problem Cause	Suggestion Remedy
	Contamination of column and/or liner can lead to loss of sensitivity for active compounds.	Clean liner. See injector maintenance. Bake out the column. Solvent rinses or replace the column.
	Injector leaks reduce the peak height of the most volatile components of a sample.	Find and fix any leaks.

	The initial column temperature is too high for split less injection preventing refocusing of the sample. This affects the more volatile components most.	Lower temperature below the boiling point of the solvent. Decrease the initial column temperature or use a less volatile solvent.
	Inlet discrimination: injector temperature is too low. Later eluting and less volatile compounds have a low response.	Increase the injection temperature or use on-column injection with a directly connect liner.

j. Split Peaks: Peaks are duplicated or separated.

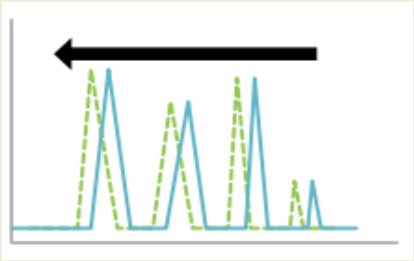
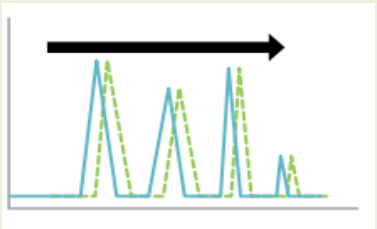
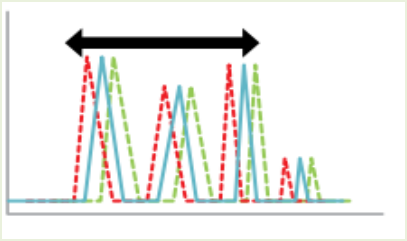
Symptom	Problem Cause	Suggestion Remedy
Split Peaks 	Poor (jerky or erratic) injection for manual injection.	Use smooth, steady plunger depression. Use auto sampler.
	Bad column installation	Reinstall column.
	Solvent mismatch: polarity of the stationary phase does not match the polarity of the solvent.	Change solvents, use a very large split ratio, install a retention gap, or change the stationary phase.
	The wrong inlet liner is not vaporizing samples in one location.	Use a liner with glass wool in the middle of the liner if possible.
	Fluctuations in column temperature.	Repair temperature control system.
	Mixed sample solvent for split less or on-column injections.	Use a single solvent.
	Improper use of "solvent effect" refocusing techniques results in broad, distorted peaks because solutes are not refocused into a narrow band near the beginning of the column. The solvent must form a compact, continuously flooded zone in the column. If the solvent does not wet the stationary phase sufficiently (as might be the case for methanol used with a nonpolar phase), the flood zone may be several meters long and not of uniform thickness	Install a retention gap (5 meters of uncoated but deactivated column) ahead of the column to reduce or eliminate the problem. Change solvent or GC column phase. Use a very high split ratio.

k. Tailing: Moderate to severe asymmetry towards the back or right side of the peak

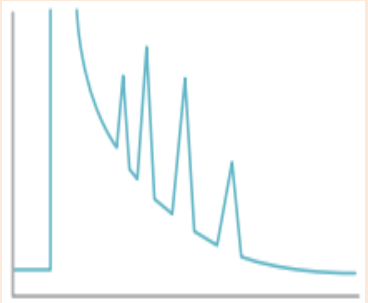
Symptom	Problem Cause	Suggestion Remedy
Tailing 	Contaminated inlet liner or column.	Clean or replace the inlet liner. Bake out or replace the column.
	Activity in the inlet liner or column if the missing peak is an active compound.	Clean or replace the inlet liner. Ensure an inert column is used. If necessary, replace the column.
	Dead volume due to poorly installed liner or column.	Confirm by injecting inert peak methane; if it tails, the column is not properly installed. Reinstall liner and column as necessary
	Ragged column end	Score the tubing lightly with a ceramic scoring wafer before breaking it. Examine the end (a 20-power magnifying glass is recommended). If the break is not clean and the end square, cut the column again. Point the end down while breaking it, and while installing a nut and ferrule, to prevent fragments from entering the column.
	Solvent-phase mismatch.	Change the stationary phase. Usually, polar analytes tail on non-polar columns or dirty columns.
	Flow path disruption	Remove any cold zones in the flow path or check the MS transfer line trap

	Column or inlet liner temperature is too low for tailing hydrocarbons.	Check injector and oven temperature with an accurate thermometer. If accurate, increase the temperature as necessary but do not exceed the maximum temperature limit of the column
	Overloading the inlet	Decrease the sample volume or dilute the sample.
	Some types of compounds such as alcoholic amines, primary and secondary amines, and carboxylic acids tend to tail.	Try a more polar column. Derivatize the sample.

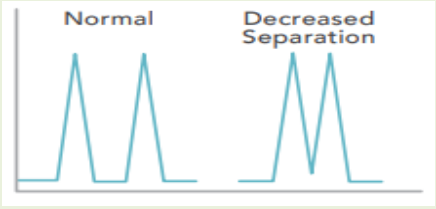
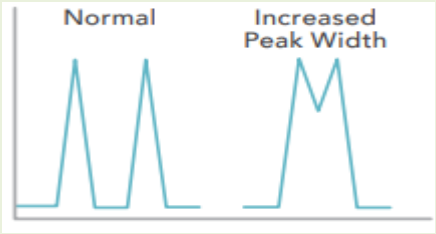
l. Retention Time: Shifts Peak retention times drift or move

Symptom	Problem Cause	Suggestion Remedy
Decreasing retention 	Increase in column temperature.	Check GC oven temperature and adjust as necessary. Ensure run conditions do not exceed the minimum temperature limits of the column.
	Increase in gas flow rate (linear velocity).	Inject a detectable unretained sample such as methane to determine the linear gas velocity. Adjust gas pressure to obtain proper values for your analytical method.
	Change of solvent.	Use the same solvent for standards and samples.
Increasing Retention 	Leak in the injector.	Find the leak and fix it. Check the septum first. Change if necessary.
	Decrease in column temperature.	Check GC oven temperature and adjust as necessary. Ensure run conditions do not exceed the maximum temperature limits of the column.
	Decrease in gas flow rate (linear velocity).	Inject a detectable unretained sample such as methane to determine the linear gas velocity. Adjust gas pressure to obtain proper values for your analytical method.
Irreproducible results 	Poor (jerky or erratic) injection for manual injection.	Use smooth, steady plunger depression. Use auto sampler
	Contaminated column.	Bake out the column. Cut 4 inches off the end of the column. Solvent rinses or replace the column.
	Leak in the injector	Find the leak and fix it. Check the septum first. Change if necessary.

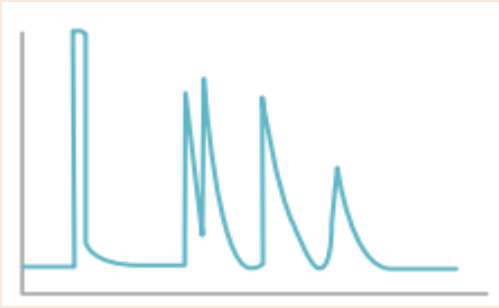
m. Solvent Peak Broad: The solvent peak is wide and coeluting with analyte peaks

Symptom	Problem Cause	Suggestion Remedy
Solvent Peak Coelution 	Bad column installation.	Reinstall column.
	Injector leak.	Find and fix the leak.
	Injection volume too large	Decrease sample injection volume or dilute to 1:10.
	The injection temperature was too low.	Increase injection temperature so the entire sample is vaporized “instantly.” An injection temperature higher than the temperature limit of the column will not damage the column.
	The split ratio is too low.	Increase split ratio
	Column temperature too low	Increase column temperature. Use a lower boiling solvent.

n. Resolution Loss: Peaks begin to coelute or overlap

Symptom	Problem Cause	Suggestion Remedy
	Change in column dimensions or stationary phase; excessive column trimming.	Differences in retention time or peak shape of other compounds will be apparent. Check the column phase and dimensions and switch the column if necessary.
	Damage to column stationary phase.	This is usually indicated by excessive column bleed. Replace the column.
	Damage to column stationary phase.	This is usually indicated by excessive column bleed. Replace the column
	Injector problems.	Check for: • leaks • inappropriate temperature • split ratio • purge time • dirty liner • glass wool in the liner

o. Performance Loss (Column): The column deteriorates too quickly after installation

Symptom	Problem Cause	Suggestion Remedy
	Column too hot for too long.	Stay below the limits specified for the column. Replace column.
	Exposure to oxygen, particularly at elevated temperatures.	Find and fix any leaks. Be sure carrier gas is sufficiently pure
	Chemical damage due to inorganic acids or bases.	Keep inorganic acids or bases out of the column. Neutralize samples.
	Contamination of the column with nonvolatile materials.	Find and fix any leaks. Be sure carrier gas is sufficiently pure.
		Keep inorganic acids or bases out of the column. Neutralize samples.

CONCLUSION

A combination of essential acquaintance and suitable application of helpful techniques is the recipe for fruitfully troubleshooting gas chromatography. Gas chromatography plays a major role in the research, and development of techniques for the analysis of flavones in soy foods and nutraceuticals, cereal-based products. It has robust separation power & even complex mixture can be resolved into constituents. One thing that makes gas chromatography very different than LC is the limited number of mobile phases. One of the challenges of troubleshooting is that you can look in so many areas for the causes of your problem. Divide & conquer is a tool that is used to crack to quickly limit the possible sources of your problem, so you can quickly narrow your focus and then find and fix the problem. So, in conclusion, when a problem occurs with your GC analysis, consider using a systematic approach first. That is, rather than the "shot-gun" approach of changing multiple things at one time, try to isolate the problem by changing one thing at a time. That way, the experience will provide learning on the specific cause of a problem. Finally, keep a maintenance log for future reference, for the benefit of yourself and your colleagues.

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