Practical ways to reduce analysis time in Gas chromatography using Existing Instrumentation

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Why faster analysis?

• More analysis per GC
• Reduced cost per analysis
Resolution Equation (simplified)

\[ R_s = \frac{1}{4} x \left[ \alpha - 1 \right] x \left[ \frac{k}{k + 1} \right] x \sqrt{N_{th}} \]

The \( \alpha \) has biggest impact on the Resolution

Practical approach for reducing analysis time:

1. Maximize \( \alpha \)
2. Optimize column dimensions
3. Set operational Parameters
How can we reduce analysis time?

If there is **enough** resolution

- Reduce column length
- Increase temperature
- Use higher gas velocity EPC

If there is **JUST enough** resolution

- Use faster Carrier gas type
- Reduce internal diameter
If there is **enough** resolution..

Using shorter columns
Analysis on a 30 meter column: No critical separations

9 minutes
Reducing the column length to 15 meters.

Still a very good separation is obtained using a 15 m column.
Faster analysis

Using higher temperatures or faster temperature programming
Increase Temperature/ Faster Heating

Each 15 °C the retention factor reduces / increases with 50%

- Use a faster temperature program rate
- Start at higher temperature

Can only be done if there is sufficient resolution present between components
Enough resolution: Faster programming

60°C, 2 min + 5 ºC/min
Run time = 24min
Elution temp = 173.2 C

60°C, 2 min + 10 ºC/min
Run time = 15 min
Elution temp = 192.7 C

60°C, 2 min + 15 ºC/min
Run time = 12 min
Elution temp = 211.4 C
Higher (and different) elution temperatures

- Column may show increased bleed signal, which can reduce S/N ratio
- Peaks may start to “shift” relative from each other: some separations improve, some will get worse..
- Components may interact / decompose

Example using Rtx-Cl Pesticides
Pesticides on Rtx-Cl Pesticides

- α-Chlordane
- Endosulfan I
- 4,4'-DDE
- Dieldrin

Programs:
- Program 6 ºC/min
- Program 12 ºC/min
- Program 24 ºC/min
- Program 9 ºC/min

Temperature elution points:
- Program 6: 204 ºC
- Program 12: 223 ºC
- Program 24: 248 ºC
- Program 9: 214 ºC

Chromatography Products
www.restek.com
Direct heating (cooling) modules

Direct heating

Temperature program rate 200-1000 °C/min

Very Fast!
Challenges

• Column maintenance very limited: use of pre columns can be done, but they are OUTSIDE the fast heating zone. (can set oven at high temperature)

• Cost per analysis caused by column will be higher as unit will me more expensive then only changing a column.

• Higher elution temperatures

• Selectivity changes can occur: be careful for method conversions..

• Need to have a detector capable for fast data collection
Faster analysis

Using a higher column Flow rate
Use of EPC, EFC or EGC

EPC = Electronic Pressure Control
EFC = Electronic Flow Control
EGC = Electronic Gas Control

Faster elution by increasing the carrier gas velocity..

At higher velocities the column will be less efficient.. (Less theoretical plates)

For simple samples this not a problem
• When we change flow using the SAME temperature program, the elution temperature of the components will change. This may result in peak shifting in the chromatogram.

• If we want to eliminate peak shifting we need the SAME elution temperature, by changing the temperature program also: This will give us the best possible “match” with the original chromatogram (and the most profit in analysis time)
Impact of using Higher column flow rate (same temp program)
60°C, 2 min → 250 °C @ 10°C/min

30 cm/s; 1.0 mL/min
Elution temp = 185.9 °C

60 cm/s; 2.03 mL/min
Elution temp = 169.4 °C

120 cm/s; 3.7 mL/min
Elution temp = 154.9 °C
Peak positions change due to difference in elution temperature
To get the same elution temperatures we have to “calculate” the oven program rate and the Iso-times. (Iso temperatures must remain the same)

Oven program is linear with the increase in carrier gas velocity, in formula:

\[
\text{New program rate} = \frac{\text{Old program rate} \times \text{New average linear velocity}}{\text{Old average linear velocity}}
\]

For isothermal times are indirect linear with carrier gas increase::

\[
\text{New iso time} = \frac{\text{Old iso time} \times \text{New average linear velocity}}{\text{Old average linear velocity}}
\]
60°C, 2 min → 250 °C @ 10ºC/min
2 x 30/60
60°C, 1 min → 250 °C @ 20ºC/min
1 x 30/60
60°C, 0.5 min → 250 °C @ 40ºC/min
10 x 60/30
20 x 120/60

Old average linear velocity

New iso time = Old iso time x

New program rate = Old program rate x

Old average linear velocity
Temperature programs needed to get the SAME elution temperature

<table>
<thead>
<tr>
<th>Speed</th>
<th>Temperature Program</th>
<th>Elution Temp E₁₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 cm/s</td>
<td>60ºC, 2 min → 250 ºC @ 10ºC/min</td>
<td>Elution temp E₁₂ = 185.9 ºC</td>
</tr>
<tr>
<td>60 cm/s</td>
<td>60ºC, 1 min → 250 ºC @ 20ºC/min</td>
<td>Elution temp E₁₂ = 185.9 ºC</td>
</tr>
<tr>
<td>120 cm/s</td>
<td>60ºC, 0.5 min → 250 ºC @ 40ºC/min</td>
<td>Elution temp E₁₂ = 185.9 ºC</td>
</tr>
</tbody>
</table>

Elution temp E₁₂ = 185.9 ºC
• For “simple” samples no problem at all

• For “complex” samples some loss of separation efficiency will be observed.

Example of complex sample:
Perfume “eternity”, run at 60 and 120 cm/s
Perfume analysis on Rxi-5Sil MS, 30/0.25/0.25 at 60 and 120 cm/s

60 cm/s

60°C, 1 min → 250 °C @ 20°C/min

20 minutes

120 cm/s

60°C, 0.5 min → 250 °C @ 40°C/min

10.5 minutes
Detail of cluster

60 cm/s

60°C, 1 min → 250 °C @ 20°C/min

120 cm/s

60°C, 0.5 min → 250 °C @ 40°C/min

13.4

13.8 [min]

7

7.3 [min]
If there is **JUST** enough resolution..

*We are not allowed to loose any separation efficiency.*
Van Deemter curve for different gases

Van Deemter Plot

- $N_2$
- He
- $H_2$

HETP (mm)

Average Linear Velocity (cm/sec)
Additional advantage besides 2x faster

Peaks are 2x narrower, they are 2x higher

For same sensitivity only 50% has to be injected..

This means:

• 2x less liner contamination
• 2x less column contamination
• reduced costs per analysis
Hydrogen and oven settings

The linear velocity using H2 is approx. 2x faster compared with Helium

For the SAME peak elution order, we need to have similar elution temperatures

For temperature programmed conditions:
DOUBLE the temp program rate..
HALF the isothermal times..

Example

He: 50 °C, 6 min, 8 °C/min → 100°C, 4 min, 15°C/min → 250°C, 10 min

H₂: 50 °C, 3 min, 16 °C/min → 100°C, 2 min, 30°C/min → 250°C, 5 min

Same as we saw with the use of higher Flows
Use a smaller bore capillary.

Reducing Column Internal Diameter...
Influence of column diameter on separation

50 m x 0.53 mm => 100,000 plates
25 m x 0.25 mm => 100,000 plates
15 m x 0.15 mm => 100,000 plates
10 m x 0.10 mm => 100,000 plates

All these columns will generate the same separation
Influence of column diameter on optimal gas velocity and HETP

The optimum gas velocity INCREASES with smaller Internal diameter...
Is there another solution for speeding up analysis time that is easier to implement and is less risky?

0.15-0.18 mm ID
Fused silica columns

A good intermediate diameter capillary that provides many advantages for implementing faster GC which is easily achievable with the standard GC.
Scope of implementation of 0.15-0.18 mm ID columns

Reduction of analysis time by minimal a factor 2

- Same GC
- Same samples
- Same injection system and injection amount
- Same detection system
- Generating the same elution order, only 2 times faster

By:
1  Replacing the existing 0.32 or 0.25 mm capillary for a 0.15mm ID column, (having same phase ratio)
2  Adjust the carrier gas Flow and the Split Flow..
3  Use a faster Oven temperature program..
## Dimensions

FASTER analysis with SAME separation efficiency;

<table>
<thead>
<tr>
<th>Present column</th>
<th>Replaced by</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 m x 0.25 x 0.25um</td>
<td>10 m x 0.15 x 0.15um</td>
</tr>
<tr>
<td>30 m x 0.25</td>
<td>20 m x 0.15</td>
</tr>
<tr>
<td>60 m x 0.25</td>
<td>40 m x 0.15</td>
</tr>
<tr>
<td>15 m x 0.32</td>
<td>10 m x 0.15</td>
</tr>
<tr>
<td>30 m x 0.32</td>
<td>15 m x 0.15</td>
</tr>
<tr>
<td>60 m x 0.32</td>
<td>30 m x 0.15</td>
</tr>
</tbody>
</table>
General formula to calculate temp. program for SAME elution temperatures

Column 1 : Initial column used
Column 2 : new column for faster method

General formula

\[
\text{New Temp Program (2)} = \frac{\text{Old Temp Program (1)}}{\text{Length column 1}} \times \frac{\text{Length column 2}}{\text{Gas velocity 2}} \times \frac{\text{Gas velocity 1}}{\text{Gas velocity 2}}
\]

\[
\text{New Iso Times (2)} = \frac{\text{Old Iso Times (1)}}{\text{Length column 1}} \times \frac{\text{Length column 2}}{\text{Gas velocity 1}} \times \frac{\text{Gas velocity 1}}{\text{Gas velocity 2}}
\]
### OLD METHOD

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column</td>
<td>Rxi-5Sil MS, 30m x 0.25mm, df = 0.25μm</td>
</tr>
<tr>
<td>Carrier</td>
<td>H2, 1.2 mL/min, ( u = 36 \text{ cm/s} ) constant flow</td>
</tr>
<tr>
<td>Spit inject</td>
<td>1:100; 1.0 μl</td>
</tr>
<tr>
<td>Oven</td>
<td>100°C, 2 min, 5°C/min → 250 °C</td>
</tr>
<tr>
<td>GC</td>
<td>Agilent 6890</td>
</tr>
</tbody>
</table>

### NEW METHOD

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column</td>
<td>Rxi-5Sil MS, 20m x 0.15mm, df = 0.15μm</td>
</tr>
<tr>
<td>Carrier</td>
<td>H2, 0.5 mL/min, ( u = 50 \text{ cm/s} ) constant flow</td>
</tr>
<tr>
<td>Spit inject</td>
<td>1:100; 1.0 μl</td>
</tr>
<tr>
<td>Oven</td>
<td>100°C, 0.9 min, 9.75°C/min → 250 °C</td>
</tr>
<tr>
<td>GC</td>
<td>Agilent 6890</td>
</tr>
</tbody>
</table>
Analysis of Perfume “Eternity Moment”

30m x 0.25mm Rxi-5Sil MS, df = 0.25 μm

20m x 0.15mm Rxi-5Sil MS, df = 0.15 μm
Detail of Analysis of Perfume “Eternity Moment”

30m x 0.25mm Rxi-5Sil MS, df = 0.25 um

20m x 0.15mm Rxi-5Sil MS, df = 0.15 um
Practical Note using smaller bore capillaries:

- 50% of normal sample size can be injected as peaks are 2x faster, they are 2x higher
  = More analysis per column

- Also: Contamination of injection port will be 2x Less!!
  = Less liner maintenance..
EPA 8260B   Volatiles

- **Column**: 20m x 0.18mm x df = 1.00 um Rtx-VMS
- **Flow**: ~ 1.0 ml/min Const. Flow
- **Oven**: 50(4)18/100(0)40/230(3)
- **Conc**: 5 ppb in 5ml H2O
- **GC**: HP6890 (1/40 split), 5973 MS, scan 35-260amu
- **P&T**: Tekmar 3100

97 compounds

10 minute run time
Summary fast GC using existing Instrumentation

• If resolution allows, analysis time can be reduced by:
  • Shorter columns
  • Higher gas velocity
  • Faster temperature programming – direct heating-

• If critical separations are present
  • Use hydrogen as carrier gas
  • Use smaller bore columns

When changing column length, type of carrier gas, column flow or column ID, the temperature program must be adjusted, to obtain same elution temperatures.(and have same peak elution order)
Thank you for your attention

For a detailed PDF copy, please sent an email to jaap.dezeeuw@restek.com