TotalQuant Analysis in NexION ICP Mass Spectrometers

Introduction

Syngistix™ software for NexION® ICP-MS instruments provides several different ways of data acquisition, depending on analysis needs and desirable results. The following analysis modes are available: quantitative, TotalQuant, isotope dilution, isotope ratio and data only.

TotalQuant, a feature in Syngistix for ICP-MS software unique to PerkinElmer’s NexION ICP-MS systems, offers the capability to quantify multiple elements in a sample via the interpretation of the complete mass spectrum. This technical note describes TotalQuant (TQ) principles, features, and applications to provide a better understanding of this specific type of analysis. These applications include semi-quantitative analysis, quantitative analysis, fingerprinting and quick survey scan.
TotalQuant Principle

During the analysis, TQ measures the complete mass spectrum (all isotopes in selected ranges). Using heuristic, knowledge-driven routines in combination with numerical calculations, Syngistix software performs an automated interpretation of the total mass spectrum. Intensities are assigned to each isotope after heuristic or “rule of thumb” corrections are done for interferences, including common polyatomic and doubly-charged species. In Figure 1, a partial TQ spectrum is shown with erbium (Er) natural abundances overlayed in red on top of the unknown sample spectrum in black. Not all counts in the mass range 162-170 are assigned to Er. When the natural abundance of ytterbium (Yb) is shown on the same spectrum (Figure 2), it is obvious that the extra counts on mass 170 not assigned to Er belong to Yb.

![Figure 1: Partial TQ spectrum with Er abundance sensitivity shown in red.](image1)

![Figure 2: Partial TQ spectrum with Yb abundance sensitivity shown in red.](image2)

After a total spectrum evaluation for each element, the resulting final isotope intensity counts are summed for each element and are then compared with a stored response table in Syngistix software which converts them into concentrations. Figure 3 shows the response table for a Standard mode analysis, as visualized in Syngistix for ICP-MS software.

![Figure 3: Default TotalQuant response table for Standard (no gas) mode.](image3)

Sensitivity and mass response can slightly differ from instrument to instrument requiring the response table to be updated using a blank and a single calibration standard containing few elements distributed across the mass range. The user can choose how many elements to use to update the response table, from as few as 3 to more than 20. Using more elements to update the TotalQuant response table can improve the accuracy of the results.

TotalQuant analysis is not limited to Standard mode and can be performed in Collision mode with kinetic energy discrimination (KED), alleviating or removing many polyatomic spectral interferences. A typical Collision mode response table is shown in Figure 4.

![Figure 4: Typical Collision mode response table.](image4)
Additionally, the use of TotalQuant in the NexION 5000 Multi-Quadrupole ICP-MS also enhances analytical accuracy by separating matrix elements from analyte elements using triple-quad and/or multi-quad technology. Figure 5 shows a typical Collision mode TotalQuant method for the NexION 5000. Masses 40 and 41 are omitted due to extremely high Ar and ArH signals, and the range of 210-230 amu is omitted as no stable isotopes exist in this region of the mass spectrum. In the TotalQuant method, peak-hopping with one-point per amu and short dwell times were used.

![Figure 5: Typical TotalQuant method for NexION 5000 in Collision (KED) mode.](image)

<table>
<thead>
<tr>
<th>Method Parameters</th>
<th>Method Timing</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sweeps/Reading</strong></td>
<td><strong>For each reading</strong> 107.93s</td>
<td>Total estimated sample time: 0hrs 1min 57sec</td>
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<td><strong>MassCal File</strong></td>
<td><strong>For each replicate</strong> 107.98s</td>
<td></td>
</tr>
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<td><strong>Pressurization delays</strong> +10s</td>
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<td><strong>Readings/Replicate</strong></td>
<td><strong>Exhaust delays</strong> +0s</td>
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<td><strong>Channel delays</strong> +0s</td>
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<tr>
<td>default.dac</td>
<td><strong>Flow switching</strong> +0s</td>
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</tr>
<tr>
<td><strong>Replicates</strong></td>
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<table>
<thead>
<tr>
<th>Analytes</th>
<th>Scan Mode</th>
<th>Q1 Begin Mass</th>
<th>Q1 End Mass</th>
<th>Q3 Begin Mass</th>
<th>Q3 End Mass</th>
<th>MCA Channels</th>
<th>ISM</th>
<th>Dwell Time Per AMU</th>
<th>Integration Time</th>
<th>Profile</th>
<th>Helium KED</th>
<th>R²q</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MS/MS</td>
<td>6</td>
<td>39</td>
<td>6</td>
<td>39</td>
<td>1</td>
<td>Extraction</td>
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<td>17000</td>
<td>Helium KED</td>
<td>4.5</td>
<td>0.25</td>
</tr>
<tr>
<td>2</td>
<td>MS/MS</td>
<td>230</td>
<td>240</td>
<td>230</td>
<td>240</td>
<td>1</td>
<td>Extraction</td>
<td>50</td>
<td>5500</td>
<td>Helium KED</td>
<td>4.5</td>
<td>0.25</td>
</tr>
<tr>
<td>3</td>
<td>MS/MS</td>
<td>41</td>
<td>210</td>
<td>41</td>
<td>210</td>
<td>1</td>
<td>Extraction</td>
<td>50</td>
<td>185000</td>
<td>Helium KED</td>
<td>4.5</td>
<td>0.25</td>
</tr>
</tbody>
</table>

![Figure 4: Example TotalQuant response table for He Collision (KED) mode.](image)
TotalQuant Analysis Applications

TotalQuant is often termed a semi-quantitative method, giving approximate concentrations for 70-80 elements in a sample in one short 1-2 minute run. TotalQuant can be used as a screening tool by providing an easy way to determine which elements are present in a sample and at approximately what concentrations. This can indicate if further dilutions are needed and what elements may be used as internal standards. As a result, TQ is very useful in the method development process. Figure 6 shows results from a TotalQuant analysis of NIST SRM 1643f for drinking water. There was good agreement between the TotalQuant results and the certified values.

The TQ accuracy can be improved to provide quantitative results, based on the number of elements used to update the stored response table. When 20 or more elements are used to update the response table, accuracies within ± 20% or better have been achieved for the elements present in the standard with semi-quantitative results obtained for elements not present in the standard. In Figure 7, TQ results for a Canadian CRM (REE-1, NRC, Ottawa, Canada) are shown. After lithium metaborate fusion and digestion, the CRM was diluted and measured against the response table and updated with one standard including REE and 20 other elements. The agreement of the results with the certified values, especially for REE, was excellent.

Using internal standards in a TQ method can further improve the precision of the results. Geological labs quite often use such methods for quick turnaround of exploration samples. For example, unexpected high concentrations of precious metals or REE could be quite valuable to a geochemical survey lab.

TotalQuant is also a useful tool for fingerprinting and the comparison of similar matrices. Instead of running a long quantitative analysis with an extensive calibration of 80 elements, TQ analysis can quickly carry out a scan from Li to U and provide a comparison between samples. In Figure 8, TotalQuant results were plotted as % difference in concentration between the same type of wines from Napa Valley in California and Southeast region of Australia.
TotalQuant can also be used with solid sampling techniques such as laser ablation to quickly identify differences between different samples. In Figure 9, laser ablation ICP-MS was used to examine solid pigment beads for variances between good beads and ones that caused product failures in an industrial forensics example.

This can be an extremely valuable tool to provide confirmation of results that could be affected by interferences. For example, in the case of a potential $^{150}\text{Sm}^{2+}$ or $^{150}\text{Nd}^{2+}$ interference on $^{75}\text{As}^{+}$ or a potential $^{164}\text{Er}^{2+}$ or $^{164}\text{Dy}^{2+}$ interference on $^{82}\text{Se}^{+}$, the survey scan data can be used to indicate whether Nd or Sm are actually present in an unknown sample at a level where doubly-charged interferences would impact the accurate quantitation of As or Se.

To illustrate this point, a standard containing similar concentrations of As and Se was spiked with significant concentrations of Er and Dy and analyzed in Standard mode. The resulting quantitative analysis and survey scan data indicate that As probably does not have any significant interferences on it since it was quantified at the expected concentration; however, elevated Se results suggest a potential interference on this isotope. While Er and Dy were not determined in the quantitative analysis, their presence was confirmed at approximately 40 ppb by the survey scan (Figure 10) – this provides useful data to the analyst to be aware of a potential interference for Se.

Another important application of TotalQuant is the ability to run it as a survey scan during the same data acquisition cycle as the quantitative analysis. While the quantitative analysis gives accurate results for selected elements after a multi-point calibration, the survey scan shows semi-quantitative concentration values for all analytically valid elements from Li to U without direct calibration by using the current response table available in Syngistix software.

Methods used for the survey scan are very similar to regular TotalQuant methods; however, the isotope measuring time is very short, only 15-20 s per analysis. In Figure 10, a selected portion of the quantitative and survey scan results are shown from the software’s Reporter view which can be exported to Excel.
Summary

TotalQuant, a unique feature only available in PerkinElmer’s Syngistix software for the NexION ICP-MS portfolio, intelligently interprets the complete mass spectrum, providing semi-quantitative to quantitative results for all elements. TQ and survey scan can provide supplementary and confirmatory information about unknown samples that can aid in method development, sample characterization and fingerprinting. The acquisition time is very fast, from 1-2 minutes for a TotalQuant analysis to as little as 15-20 seconds for a survey scan analysis.

Table 1 summarizes three different ways of analyzing samples.

<table>
<thead>
<tr>
<th>Classical Quantitative Analysis</th>
<th>TotalQuant Analysis</th>
<th>Survey Scan Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knows only what you tell it</td>
<td>Determines 80 elements in 1-2 minutes/sample</td>
<td>Determines 80 elements in 15-20 seconds/sample</td>
</tr>
<tr>
<td>Quantitates only the elements you specify</td>
<td>Looks at the complete mass spectrum</td>
<td>Looks at the complete mass spectrum</td>
</tr>
<tr>
<td>Looks at only the isotopes you specify</td>
<td>Calibrates for all elements using information for only a few</td>
<td>Quantifies all the elements all the time</td>
</tr>
<tr>
<td>Uses the same element isotope for every sample</td>
<td>Quantifies all the elements all the time</td>
<td>Calibrates for all elements using stored response table</td>
</tr>
<tr>
<td>Only corrects for molecular overlap interferences using the elemental equations you tell it</td>
<td>Uses heuristics to fit isotopic fingerprint to unknown spectrum</td>
<td>Provides confirmation of presence/absence of potential interfering elements</td>
</tr>
<tr>
<td>Must have a specific calibration for each element to be determined</td>
<td>Able to avoid interferences or correct for them when needed</td>
<td>Uses heuristics to fit isotopic fingerprint to unknown spectrum</td>
</tr>
</tbody>
</table>