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**Infant formula and adult  
nutritionals — Determination of  
vitamin D by liquid chromatography-  
mass spectrometry**

*Formules infantiles et produits nutritionnels pour adultes —  
Détermination de la teneur en vitamine D par chromatographie  
liquide couplée à la spectrométrie de masse*

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# Contents

Page

|                                                                        |           |
|------------------------------------------------------------------------|-----------|
| <b>Foreword</b>                                                        | <b>iv</b> |
| <b>1 Scope</b>                                                         | <b>1</b>  |
| <b>2 Normative references</b>                                          | <b>1</b>  |
| <b>3 Terms and definitions</b>                                         | <b>1</b>  |
| <b>4 Principle</b>                                                     | <b>1</b>  |
| <b>5 Reagents and materials</b>                                        | <b>2</b>  |
| 5.1 General                                                            | 2         |
| 5.2 Reagent preparation                                                | 2         |
| 5.3 Standard preparation                                               | 3         |
| 5.4 Calibration standard solutions                                     | 4         |
| <b>6 Apparatus</b>                                                     | <b>4</b>  |
| <b>7 Sample preparation</b>                                            | <b>5</b>  |
| 7.1 Powder sample preparation                                          | 5         |
| 7.2 Slurry sample preparation                                          | 5         |
| 7.3 Liquid sample preparation                                          | 5         |
| <b>8 Procedure</b>                                                     | <b>6</b>  |
| 8.1 Extraction and derivatisation                                      | 6         |
| 8.2 Chromatography                                                     | 6         |
| 8.3 Mass spectrometry                                                  | 7         |
| <b>9 Calculations</b>                                                  | <b>8</b>  |
| <b>10 Results</b>                                                      | <b>12</b> |
| <b>11 Precision</b>                                                    | <b>12</b> |
| 11.1 General                                                           | 12        |
| 11.2 Repeatability                                                     | 12        |
| 11.3 Reproducibility                                                   | 13        |
| <b>Annex A (informative) Examples of spectra and chromatograms</b>     | <b>15</b> |
| <b>Annex B (informative) Precision data</b>                            | <b>18</b> |
| <b>Annex C (informative) Alternative instrument settings</b>           | <b>20</b> |
| <b>Annex D (informative) Comparison between ISO 20636 and EN 12821</b> | <b>21</b> |
| <b>Bibliography</b>                                                    | <b>23</b> |

## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 34, *Food products*, in collaboration with AOAC INTERNATIONAL. It is being published by ISO and separately by AOAC INTERNATIONAL. The method described in this document is equivalent to the AOAC Official Method 2016.05, *Analysis of Vitamin D<sub>2</sub> and Vitamin D<sub>3</sub> in Fortified Milk Powders, Infant Formulas, and Adult/Pediatric Nutritional Formulas*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

# Infant formula and adult nutritionals — Determination of vitamin D by liquid chromatography-mass spectrometry

**WARNING — The use of this method can involve hazardous materials, operations and equipment. This method does not purport to address all the safety problems associated with its use. It is the responsibility of the user of this method to establish appropriate safety and health practices.**

## 1 Scope

This document specifies a method for the quantitative determination of vitamin D<sub>2</sub> and/or vitamin D<sub>3</sub> in infant formula, and adult nutritionals in solid (i.e. powders) or liquid (i.e. ready-to-feed liquids and liquid concentrates) forms using liquid chromatography-mass spectrometry. The application range runs from 0,15 µg/100 g (limit of quantification) to 59 µg/100 g for vitamin D<sub>2</sub> and from 0,25 µg/100 g to 65 µg/100 g for vitamin D<sub>3</sub>.

## 2 Normative references

There are no normative references in this document.

## 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

### 3.1

#### **adult nutritional**

nutritionally complete, specially formulated food, consumed in liquid form, which may constitute the sole source of nourishment, made from any combination of milk, soy, rice, whey, hydrolysed protein, starch and amino acids with and without intact protein

### 3.2

#### **infant formula**

breast-milk substitute specially manufactured to satisfy, by itself, the nutritional requirements of infants during the first months of life up to the introduction of appropriate complementary feeding

[SOURCE: CODEX STAN 72-1981]

## 4 Principle

Samples are saponified at high temperature then lipid soluble components are extracted into isooctane. A portion of the isooctane layer is transferred, washed, and an aliquot of 4-phenyl-1,2,4-triazoline-3,5-dione (PTAD) is added to derivatise vitamin D to form a high molecular mass, easily ionisable adduct. The vitamin D-adduct is then re extracted into a small volume of acetonitrile and analysed by reversed-phase liquid chromatography. Detection is by mass spectrometry using multiple reaction monitoring (MRM). Stable isotope labelled *d*6-vitamin D<sub>2</sub> and *d*6-vitamin D<sub>3</sub> internal standards are used for quantitation to correct for losses in extraction and any variation in derivatisation and ionisation efficiencies[2].

## 5 Reagents and materials

During the analysis, unless otherwise stated, use only reagents of recognized analytical grade and distilled or demineralized water or water of equivalent purity.

### 5.1 General

- 5.1.1 **Standards**,  $\geq 99\%$  pure.
- 5.1.2 **Vitamin D<sub>2</sub>**, ergocalciferol.
- 5.1.3 **Vitamin D<sub>3</sub>**, cholecalciferol.
- 5.1.4 **d6-Vitamin D<sub>2</sub>**, 26,26,26,27,27,27-d6 ergocalciferol.
- 5.1.5 **d6-Vitamin D<sub>3</sub>**, 26,26,26,27,27,27-d6 cholecalciferol.
- 5.1.6 **PTAD** (4-phenyl-1,2,4-triazoline-3,5-dione).
- 5.1.7 **Formic acid** (HCO<sub>2</sub>H), LC-MS grade.
- 5.1.8 **Potassium hydroxide** (KOH).
- 5.1.9 **Pyrogallol** (C<sub>6</sub>H<sub>3</sub>(OH)<sub>3</sub>).
- 5.1.10 **Ethanol** (C<sub>2</sub>H<sub>5</sub>OH).
- 5.1.11 **Methanol** (CH<sub>3</sub>OH), LC-MS grade.
- 5.1.12 **Isooctane** ((CH<sub>3</sub>)<sub>3</sub>CCH<sub>2</sub>CH(CH<sub>3</sub>)<sub>2</sub>).
- 5.1.13 **Acetone** (CH<sub>3</sub>COCH<sub>3</sub>).
- 5.1.14 **Acetonitrile** (CH<sub>3</sub>CN), LC-MS grade.

### 5.2 Reagent preparation

- 5.2.1 **PTAD solution**,  $c(4\text{-phenyl-1,2,4-triazoline-3,5-dione}) = 10 \text{ mg/ml}$ . Dissolve 50 mg PTAD (5.1.6) in 5,0 ml acetone (5.1.13).
- 5.2.2 **Potassium hydroxide solution**,  $c(\text{KOH}) = 8,9 \text{ mol/l}$ . Dissolve 100 g potassium hydroxide (5.1.8) in 200 ml water.
- 5.2.3 **Ethanollic pyrogallol solution**,  $c(\text{C}_6\text{H}_3(\text{OH})_3) = 0,079 \text{ mol/l}$ . Dissolve 5 g pyrogallol (5.1.9) in 500 ml ethanol (5.1.10).
- 5.2.4 **Mobile phase A**,  $c(\text{HCO}_2\text{H}) = 0,026 \text{ 5 mol/l}$ . To 500 ml of water, add 0,5 ml formic acid (5.1.7).
- 5.2.5 **Mobile phase B**, methanol, 500 ml (5.1.11).

### 5.3 Standard preparation

**5.3.1** Vitamin D is sensitive to light. Perform all steps under low-level incandescent lighting. If exclusively vitamin D<sub>3</sub> is required for analysis, then standards pertaining to vitamin D<sub>2</sub> need not be used and vice versa. Calibration standards should be bracketed at the beginning and at the end of an analytical run.

**5.3.2 Vitamin D<sub>2</sub> stable isotope labelled stock standard solution**,  $\rho \approx 10 \mu\text{g/ml}$ . Dispense the contents of a 1 mg vial of *d6*-vitamin D<sub>2</sub> (5.1.4) into a 100 ml volumetric flask. Dissolve in 90 ml of ethanol (5.1.10). To promote dissolution, sonicate if necessary. Mix thoroughly, make up to volume with ethanol (5.1.10). Measure the absorbance of an aliquot at 265 nm. The spectrophotometer should be zeroed against an ethanol (5.1.10) blank solution. Calculate and record concentration. Immediately dispense aliquots ( $\sim 1,3 \text{ ml}$ ) into cryogenic vials and freeze at  $< -15^\circ\text{C}$  for up to 6 months.

**5.3.3 Vitamin D<sub>3</sub> stable isotope labelled stock standard solution**,  $\rho \approx 10 \mu\text{g/ml}$ . Dispense the contents of a 1 mg vial of *d6*-vitamin D<sub>3</sub> (5.1.5) into a 100 ml volumetric flask. Dissolve in 90 ml of ethanol (5.1.10). To promote dissolution, sonicate if necessary. Mix thoroughly, make up to volume with ethanol (5.1.10). Measure the absorbance of an aliquot at 265 nm. The spectrophotometer should be zeroed against an ethanol (5.1.10) blank solution. Calculate and record concentration. Immediately dispense aliquots ( $\sim 1,3 \text{ ml}$ ) into cryogenic vials and freeze at  $< -15^\circ\text{C}$  for up to 6 months.

**5.3.4 Stable isotope labelled internal standard solution**,  $\rho \approx 1 \mu\text{g/ml}$ . Depending on the number of samples that need to be analysed in a run, more or less stable isotope labelled internal standard solution needs to be made up. For every 15 samples (or part thereof) in an analytical run, remove 1 vial of Vitamin D<sub>2</sub> stable isotope labelled stock standard solution (5.3.2) and/or 1 vial of Vitamin D<sub>3</sub> stable isotope labelled stock standard solution (5.3.3) from the freezer and allow to warm to room temperature. Pipette 1,0 ml of vitamin D<sub>2</sub> stable isotope labelled stock standard solution (5.3.2) and/or 1,0 ml of vitamin D<sub>3</sub> stable isotope labelled stock standard solution (5.3.3) into a 10 ml volumetric flask (use a separate 10 ml volumetric flask for each set of 15 samples). Make each 10 ml volumetric flask to volume with acetonitrile, pool together and mix thoroughly. Make fresh daily.

**5.3.5 Vitamin D<sub>2</sub> non-labelled stock standard solution**,  $\rho \approx 1 \text{ mg/ml}$ . Weigh accurately, approximately 50 mg of vitamin D<sub>2</sub> (5.1.2) into a 50 ml volumetric flask. Dissolve in 40 ml of ethanol (5.1.10). To promote dissolution, sonicate if necessary. Mix thoroughly, make up to volume with ethanol (5.1.10). Store in freezer at  $< -15^\circ\text{C}$  for up to 1 month.

**5.3.6 Vitamin D<sub>3</sub> non-labelled stock standard solution**,  $\rho \approx 1 \text{ mg/ml}$ . Weigh accurately, approximately 50 mg of vitamin D<sub>3</sub> (5.1.3) into a 50 ml volumetric flask. Dissolve in 40 ml of ethanol (5.1.10). To promote dissolution, sonicate if necessary. Mix thoroughly, make up to volume with ethanol (5.1.10). Store in freezer at  $< -15^\circ\text{C}$  for up to 1 month.

**5.3.7 Vitamin D<sub>2</sub> non-labelled purity standard solution**,  $\rho \approx 10 \mu\text{g/ml}$ . Pipette 1,0 ml of vitamin D<sub>2</sub> non-labelled stock standard solution (5.3.5) into a 100 ml volumetric flask. Make to volume with ethanol (5.1.10). Measure the absorbance of an aliquot at 265 nm. The spectrophotometer should be zeroed against an ethanol (5.1.10) blank solution. Record absorbance and calculate concentration. Make fresh daily.

**5.3.8 Vitamin D<sub>3</sub> non-labelled purity standard solution**,  $\rho \approx 10 \mu\text{g/ml}$ . Pipette 1,0 ml of vitamin D<sub>3</sub> non-labelled stock standard solution (5.3.6) into a 100 ml volumetric flask. Make to volume with ethanol (5.1.10). Measure the absorbance of an aliquot at 265 nm. The spectrophotometer should be zeroed against an ethanol (5.1.10) blank solution. Record absorbance and calculate concentration. Make fresh daily.

**5.3.9 Non-labelled working standard solution**,  $\rho \approx 1 \mu\text{g/ml}$ . Pipette 1,0 ml of vitamin D<sub>2</sub> non-labelled purity standard solution (5.3.7) and/or 1,0 ml of vitamin D<sub>3</sub> non-labelled purity standard solution (5.3.8) into a 10 ml volumetric flask. Make to volume with acetonitrile (5.1.14) and mix thoroughly. Make fresh daily.

## 5.4 Calibration standard solutions

**5.4.1** See [Table 1](#) for nominal vitamin D concentrations of the calibration standard solutions. Make fresh daily.

**5.4.2 Calibration standard 1.** Pipette 10 µl non-labelled working standard solution ([5.3.9](#)) and 250 µl stable isotope labelled internal standard solution ([5.3.4](#)) into a 25 ml volumetric flask. Add 5 ml of acetonitrile ([5.1.14](#)) and 75 µl of PTAD solution ([5.2.1](#)), shake to mix and leave in the dark for 5 min. Add 6,25 ml of water then make to volume with acetonitrile ([5.1.14](#)), mix, and transfer to HPLC vial ready for analysis.

**5.4.3 Calibration standard 2.** Pipette 50 µl non-labelled working standard solution ([5.3.9](#)) and 250 µl stable isotope labelled internal standard solution ([5.3.4](#)) into a 25 ml volumetric flask. Add 5 ml of acetonitrile ([5.1.14](#)) and 75 µl of PTAD solution ([5.2.1](#)), shake to mix and leave in the dark for 5 min. Add 6,25 ml of water then make to volume with acetonitrile ([5.1.14](#)), mix, and transfer to HPLC vial ready for analysis.

**5.4.4 Calibration standard 3.** Pipette 250 µl non-labelled working standard solution ([5.3.9](#)) and 250 µl stable isotope labelled internal standard solution ([5.3.4](#)) into a 25 ml volumetric flask. Add 5 ml of acetonitrile ([5.1.14](#)) and 75 µl of PTAD solution ([5.2.1](#)), shake to mix and leave in the dark for 5 min. Add 6,25 ml of water then make to volume with acetonitrile ([5.1.14](#)), mix, and transfer to HPLC vial ready for analysis.

**5.4.5 Calibration standard 4.** Pipette 500 µl non-labelled working standard solution ([5.3.9](#)) and 250 µl stable isotope labelled internal standard solution ([5.3.4](#)) into a 25 ml volumetric flask. Add 5 ml of acetonitrile ([5.1.14](#)) and 75 µl of PTAD solution ([5.2.1](#)), shake to mix and leave in the dark for 5 min. Add 6,25 ml of water then make to volume with acetonitrile ([5.1.14](#)), mix, and transfer to HPLC vial ready for analysis.

**5.4.6 Calibration standard 5.** Pipette 1 250 µl non-labelled working standard solution ([5.3.9](#)) and 250 µl stable isotope labelled internal standard solution ([5.3.4](#)) into a 25 ml volumetric flask. Add 5 ml of acetonitrile ([5.1.14](#)) and 75 µl of PTAD solution ([5.2.1](#)), shake to mix and leave in the dark for 5 min. Add 6,25 ml of water then make to volume with acetonitrile ([5.1.14](#)), mix, and transfer to HPLC vial ready for analysis.

**Table 1 — Nominal concentration of calibration standards**

| Calibration solution | Concentration of vitamin D<br>ng/ml | Concentration of d6-vitamin D<br>ng/ml |
|----------------------|-------------------------------------|----------------------------------------|
| 1                    | 0,4                                 | 10                                     |
| 2                    | 2,0                                 | 10                                     |
| 3                    | 10                                  | 10                                     |
| 4                    | 20                                  | 10                                     |
| 5                    | 50                                  | 10                                     |

## 6 Apparatus

Usual laboratory glassware and equipment and, in particular, the following.

**6.1 Ultra high performance liquid chromatography (UHPLC) system**, consisting of dual pump system, a sample injector unit, a degasser unit, and a column oven.

**6.2 Triple quadrupole mass spectrometer**, with sufficient sensitivity to detect and quantify vitamin D in PTAD adduct at 0,4 ng/ml.



- 6.3 **Solid core silica column**, e.g. Phenomenex Kinetex<sup>1)</sup> C<sub>18</sub> 2,6 µm, 2,1 mm × 50 mm, or equivalent.
- 6.4 **Spectrophotometer**, capable of digital readout to three decimal places.
- 6.5 **Centrifuge tubes**, polypropylene, 15 ml.
- 6.6 **Boiling tubes**, glass, 60 ml.
- 6.7 **Water bath**, 20 °C to 70 °C.
- 6.8 **Disposable syringes**, capacity 1 ml.
- 6.9 **Syringe filters**, PTFE, 0,2 µm, 13 mm.
- 6.10 **Centrifuges**, suitable for 60 ml boiling tubes, and 15 ml centrifuge tubes.
- 6.11 **Pasteur pipettes**, glass, ~140 mm.
- 6.12 **Horizontal shaker**.
- 6.13 **Micro centrifuge tubes**, 2 ml.
- 6.14 **Filter membranes**, 0,45 µm polyamide.
- 6.15 **Cryogenic vials**, 2 ml.
- 6.16 **High performance liquid chromatography (HPLC) vials, septa, and caps**.

## 7 Sample preparation

### 7.1 Powder sample preparation

Accurately weigh 1,8 g to 2,2 g of powder sample into a boiling tube. Record mass.

### 7.2 Slurry sample preparation

Accurately weigh 19,0 g to 21,0 g of powder to a disposable slurry container. Record mass.

Accurately weigh ~80 ml water to container. Record mass.

Shake thoroughly until mixed. Place in the dark at room temperature for 15 min and shake to mix every 5 min.

Accurately weigh 9,5 g to 10,5 g of slurry or reconstituted powder sample into a boiling tube. Record mass.

### 7.3 Liquid sample preparation

Accurately weigh 10,0 ml of liquid milk into a boiling tube. Record mass.

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1) This is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.

## 8 Procedure

### 8.1 Extraction and derivatisation

To powder, slurry, or liquid sample in a boiling tube, add 10 ml of ethanolic pyrogallol solution (5.2.3), and 0,5 ml of stable isotope labelled internal standard solution (5.3.4), cap and vortex mix.

Add 2 ml of potassium hydroxide solution (5.2.2) to boiling tube, cap and vortex mix.

Place boiling tube in water bath at 70 °C for 1 h, vortex mix every 15 min.

Place boiling tube in water bath at room temperature until cool.

Add 10 ml of isooctane (5.1.12) to the boiling tube; cap boiling tube tightly and place on horizontal shaker for 10 min.

Add 20 ml of water to boiling tube and invert tube 10 times; place in centrifuge at  $\geq 250g$  for 15 min.

Transfer a 5 ml aliquot of the upper isooctane layer into a 15 ml centrifuge tube using a Pasteur pipette, taking care not to transfer any of the lower layer (discard boiling tube with lower layer).

Add 5 ml of water to centrifuge tube, cap and vortex mix and place in centrifuge at 2 000g for 5 min.

Transfer 4 ml to 5 ml of upper isooctane layer to a new 15 ml disposable centrifuge tube using a disposable pipette, taking care not to transfer any of the lower layer (discard centrifuge tube with lower layer).

Add 75  $\mu$ l of PTAD solution (5.2.1) to centrifuge tube, cap and immediately vortex mix.

Allow to stand in the dark for 5 min to allow for derivatization reaction to complete.

Add 1 ml acetonitrile to centrifuge tube, cap and vortex mix, place in centrifuge at 2 000g for 5 min.

Using a variable volume pipette, transfer 500  $\mu$ l of the lower layer into a micro centrifuge tube (6.13) taking care not to transfer any of the upper layer.

Add 167  $\mu$ l of water to the micro centrifuge tube (6.13), cap and vortex mix.

Using a syringe filter, transfer an aliquot from the micro centrifuge tube (6.13) to an amber HPLC vial, cap ready for analysis.

### 8.2 Chromatography

Form high pressure gradients by mixing the two mobile phases, A and B, using the procedure given in Table 2. Information on expected retention times and product ion spectra are given in Annex A.

**Table 2 — Gradient procedure for chromatographic separation**

| Time<br>min | Flow rate<br>ml/min | Mobile phase A<br>% | Mobile phase B<br>% |
|-------------|---------------------|---------------------|---------------------|
| 0 START     | 0,6                 | 25                  | 75                  |
| 3,3 PUMP    | 0,6                 | 0                   | 100                 |
| 3,7 PUMP    | 1,0                 | 0                   | 100                 |
| 4,8 PUMP    | 1,0                 | 0                   | 100                 |
| 4,9 PUMP    | 0,6                 | 25                  | 75                  |
| 5,5 STOP    | 0,6                 | 25                  | 75                  |

### 8.3 Mass spectrometry

Set up the mass spectrometer with the instrument setting shown in [Table 3](#). These values are indicative and need to be optimized for each instrument used. Examples of alternative instrument settings are given in [Annex C](#).

**Table 3 — Mass spectrometer instrument settings**

| Instrument parameter | Value            |
|----------------------|------------------|
| ionization mode      | ESI <sup>+</sup> |
| curtain gas          | 207 kPa (30 psi) |
| nebulizer gas        | 277 kPa (40 psi) |
| heater gas           | 277 kPa (40 psi) |
| collision gas        | N <sub>2</sub>   |
| source temperature   | 300 °C           |
| ion spray voltage    | 5 500 V          |

Settings are applicable to Sciex 6500 mass spectrometer. Sciex 6500 mass spectrometer is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.

Compound specific parameters to be used are shown in [Table 4](#) and [Table 5](#).

**Table 4 — Compound parameters (vitamin D<sub>2</sub> instrument method only)**

| Vitamin D <sub>2</sub> ion <sup>a</sup> | Precursor ion<br><i>m/z</i> | Product ion<br><i>m/z</i> | DP<br>V | EP<br>V | CE<br>V | CXP<br>V | Dwell time<br>ms |
|-----------------------------------------|-----------------------------|---------------------------|---------|---------|---------|----------|------------------|
| analyte quantifier                      | 572,2                       | 298,0                     | 81      | 10      | 23      | 22       | 120              |
| analyte qualifier                       | 572,2                       | 280,0                     |         |         | 39      | 16       | 80               |
| internal standard quantifier            | 578,2                       | 298,0                     |         |         | 23      | 22       | 120              |
| internal standard qualifier             | 578,2                       | 280,0                     |         |         | 39      | 16       | 80               |

**Key**

DP: declustering potential

EP: entrance potential

CE: collision energy

CXP: collision cell exit potential

<sup>a</sup> Analyte = vitamin D<sub>2</sub>-PTAD adduct, Internal standard ion = *d*6-vitamin D<sub>2</sub>-PTAD adduct.

Table 5 — Compound parameters (vitamin D<sub>3</sub> instrument method only)

| Vitamin D <sub>3</sub> ion <sup>a</sup>                                                                                                                                                                                                                                     | Precursor ion<br><i>m/z</i> | Product ion<br><i>m/z</i> | DP<br>V | EP<br>V | CE<br>V | CXP<br>V | Dwell time<br>ms |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|---------------------------|---------|---------|---------|----------|------------------|
| analyte quantifier                                                                                                                                                                                                                                                          | 560,2                       | 298,0                     | 151     | 10      | 21      | 18       | 120              |
| analyte qualifier                                                                                                                                                                                                                                                           | 560,2                       | 280,0                     |         |         | 37      | 18       | 80               |
| internal standard quantifier                                                                                                                                                                                                                                                | 566,2                       | 298,0                     |         |         | 21      | 18       | 120              |
| internal standard qualifier                                                                                                                                                                                                                                                 | 566,2                       | 280,0                     |         |         | 37      | 18       | 80               |
| <b>Key</b><br>DP: declustering potential<br>EP: entrance potential<br>CE: collision energy<br>CXP: collision cell exit potential<br><br><sup>a</sup> Analyte = vitamin D <sub>3</sub> -PTAD adduct, Internal standard ion = <i>d</i> 6-vitamin D <sub>3</sub> -PTAD adduct. |                             |                           |         |         |         |          |                  |

## 9 Calculations

**9.1** Calculate the concentration of *d*6-vitamin D<sub>2</sub> in vitamin D<sub>2</sub> stable isotope labelled stock standard solution (5.3.2) using Formula (1):

$$\text{SILD}_2\text{SS}_{\text{D2conc}} = \frac{\text{SILD}_2\text{SS}_{\text{abs}(\lambda_{\text{max}})}}{E_{1\text{cm}}^{1\%}} \times 10\,000 \quad (1)$$

where

$\text{SILD}_2\text{SS}_{\text{D2conc}}$  is the concentration of *d*6-vitamin D<sub>2</sub> in stock standard (µg/ml);

$\text{SILD}_2\text{SS}_{\text{abs}(\lambda_{\text{max}})}$  is the UV absorbance of stock standard at 265 nm (1/cm);

$E_{1\text{cm}}^{1\%}$  is the extinction coefficient for vitamin D<sub>2</sub> in ethanol [461] (dl/g.cm);

10 000 is the concentration conversion factor (g/dl to µg/ml).

**9.2** Calculate the concentration of *d*6-vitamin D<sub>3</sub> in vitamin D<sub>3</sub> stable isotope labelled stock standard solution (5.3.3) using Formula (2):

$$\text{SILD}_3\text{SS}_{\text{D3conc}} = \frac{\text{SILD}_3\text{SS}_{\text{abs}(\lambda_{\text{max}})}}{E_{1\text{cm}}^{1\%}} \times 10\,000 \quad (2)$$

where

$\text{SILD}_3\text{SS}_{\text{D3conc}}$  is the concentration of *d*6-vitamin D<sub>3</sub> in stock standard (µg/ml);

$\text{SILD}_3\text{SS}_{\text{abs}(\lambda_{\text{max}})}$  is the UV absorbance of stock standard at 265 nm (1/cm);

$E_{1\text{cm}}^{1\%}$  is the extinction coefficient for vitamin D<sub>3</sub> in ethanol [485] (dl/g.cm);

10 000 is the concentration conversion factor (g/dl to µg/ml).

**9.3** Calculate the concentration of *d6*-vitamin D<sub>2</sub> in stable isotope labelled internal standard solution (5.3.4) using Formula (3):

$$\text{SILIS}_{\text{D2conc}} = \text{SILD}_2\text{SS}_{\text{D2conc}} \times \frac{1,0}{10} \times 1\,000 \quad (3)$$

where

$\text{SILIS}_{\text{D2conc}}$  is the concentration of *d6*-vitamin D<sub>2</sub> in internal standard (ng/ml);

$\text{SILD}_2\text{SS}_{\text{D2conc}}$  is the concentration of *d6*-vitamin D<sub>2</sub> in stock standard (µg/ml);

1 000 is the concentration conversion factor (µg/ml to ng/ml).

**9.4** Calculate the concentration of *d6*-vitamin D<sub>3</sub> in stable isotope labelled internal standard solution (5.3.4) using Formula (4):

$$\text{SILIS}_{\text{D3conc}} = \text{SILD}_3\text{SS}_{\text{D3conc}} \times \frac{1,0}{10} \times 1\,000 \quad (4)$$

where

$\text{SILIS}_{\text{D3conc}}$  is the concentration of *d6*-vitamin D<sub>3</sub> in internal standard (ng/ml);

$\text{SILD}_3\text{SS}_{\text{D3conc}}$  is the concentration of *d6*-vitamin D<sub>3</sub> in stock standard (µg/ml);

1 000 is the concentration conversion factor (µg/ml to ng/ml).

**9.5** Calculate the concentration of vitamin D<sub>2</sub> in vitamin D<sub>2</sub> non-labelled purity standard solution (5.3.7) using Formula (5):

$$\text{NLD}_2\text{PS}_{\text{D2conc}} = \frac{\text{NLD}_2\text{PS}_{\text{abs}(\lambda_{\text{max}})}}{E_{1\text{cm}}^{1\%}} \times 10\,000 \quad (5)$$

where

$\text{NLD}_2\text{PS}_{\text{D2conc}}$  is the concentration of vitamin D<sub>2</sub> in purity standard (µg/ml);

$\text{NLD}_2\text{PS}_{\text{abs}(\lambda_{\text{max}})}$  is the UV absorbance of purity standard at 265 nm (1/cm);

$E_{1\text{cm}}^{1\%}$  is the extinction coefficient for vitamin D<sub>2</sub> in ethanol [461] (dl/g.cm);

10 000 is the concentration conversion factor (g/dl to µg/ml).

**9.6** Calculate the concentration of vitamin D<sub>3</sub> in vitamin D<sub>3</sub> non-labelled purity standard solution, (5.3.8) using Formula (6):

$$\text{NLD}_3\text{PS}_{\text{D3conc}} = \frac{\text{NLD}_3\text{PS}_{\text{abs}(\lambda_{\text{max}})}}{E_{1\text{cm}}^{1\%}} \times 10\,000 \quad (6)$$

where

- $NLD_3PS_{D3conc}$  is the concentration of *d6*-vitamin D<sub>3</sub> in purity standard (µg/ml);
- $NLD_3PS_{abs(\lambda_{max})}$  is the UV absorbance of purity standard at 265 nm (1/cm);
- $E_{1cm}^{1\%}$  is the extinction coefficient for vitamin D<sub>3</sub> in ethanol [485] (dl/g.cm);
- 10 000 is the concentration conversion factor (g/dl to µg/ml).

**9.7** Calculate the concentration of vitamin D<sub>2</sub> in non-labelled working standard solution (5.3.9) using Formula (7):

$$NLWS_{D2conc} = NLD_2PS_{D2conc} \times \frac{1,0}{10} \times 1\,000 \quad (7)$$

where

- $NLWS_{D2conc}$  is the concentration of vitamin D<sub>2</sub> in working standard (ng/ml);
- $NLD_2PS_{D2conc}$  is the concentration of vitamin D<sub>2</sub> in purity standard (µg/ml);
- 1 000 is the concentration conversion factor (µg/ml to ng/ml).

**9.8** Calculate the concentration of vitamin D<sub>3</sub> in non-labelled working standard solution (5.3.9) using Formula (8):

$$NLWS_{D3conc} = NLD_3PS_{D3conc} \times \frac{1,0}{10} \times 1\,000 \quad (8)$$

where

- $NLWS_{D3conc}$  is the concentration of vitamin D<sub>3</sub> in working standard (ng/ml);
- $NLD_3PS_{D3conc}$  is the concentration of vitamin D<sub>3</sub> in purity standard (µg/ml);
- 1 000 is the concentration conversion factor (µg/ml to ng/ml).

**9.9** Calculate the concentration of vitamin D<sub>2</sub> and/or vitamin D<sub>3</sub> in calibration standard solutions (5.4) using Formulae (9) to (13):

$$CS1_{Dconc} = NLWS_{Dconc} \times \frac{0,01}{25} \quad (9)$$

$$CS2_{Dconc} = NLWS_{Dconc} \times \frac{0,05}{25} \quad (10)$$

$$CS3_{Dconc} = NLWS_{Dconc} \times \frac{0,25}{25} \quad (11)$$

$$CS4_{Dconc} = NLWS_{Dconc} \times \frac{0,5}{25} \quad (12)$$

$$CS5_{Dconc} = NLWS_{Dconc} \times \frac{1,25}{25} \quad (13)$$

where

$CS1-5_{Dconc}$  is the concentration of vitamin D<sub>2</sub> or vitamin D<sub>3</sub> in calibration standards (ng/ml);

$NLWS_{Dconc}$  is the concentration of vitamin D<sub>2</sub> or vitamin D<sub>3</sub> in working standard (ng/ml).

**9.10** Calculate the concentration of *d6*-vitamin D<sub>2</sub> and/or *d6*-vitamin D<sub>3</sub> in calibration standard solutions (5.4) using Formula (14):

$$CS1-5_{Dconc} = SILIS_{Dconc} \times \frac{0,25}{25} \quad (14)$$

where

$CS1-5_{Dconc}$  is the concentration of *d6*-vitamin D<sub>2</sub> or *d6*-vitamin D<sub>3</sub> in calibration standard (ng/ml);

$SILIS_{Dconc}$  is the concentration of *d6*-vitamin D<sub>2</sub> or *d6*-vitamin D<sub>3</sub> in internal standard (ng/ml).

**9.11** Calculate the mass of powder in slurried sample (7.2) using Formula (15):

$$m_s = \frac{m_d}{(m_d + m_w)} \times m_A \quad (15)$$

where

$m_s$  is the mass of sample (g);

$m_d$  is the mass of dry powder added to slurried sample (g);

$m_w$  is the mass of water added to slurried sample (g);

$m_A$  is the mass of aliquot of slurried sample used in analysis (g).

**9.12** Determine the linear regression of the calibration curve  $y = mx + c$  (using the “least squares” method) for the ratio of peaks areas (non-labelled vitamin D/stable isotope labelled *d6*-vitamin D) versus the ratio of concentrations (non-labelled vitamin D/stable isotope labelled *d6*-vitamin D) for five calibration standards with the y-intercept forced through zero.

**9.13** Interpolate the vitamin D<sub>2</sub> or vitamin D<sub>3</sub> contents in unknown samples from the calibration curves.

Calculate the mass fractions of vitamin D<sub>2</sub> or vitamin D<sub>3</sub> in dry powders or ready-to-feed liquids using Formula (16):

$$w_D = \frac{A_{nd}}{A_{is}} \times \frac{1}{l} \times \frac{(\rho_{is} \times V_{is})}{m_s} \times \frac{100}{1\,000} \quad (16)$$

where

$w_D$  is the mass fraction of vitamin D<sub>2</sub> or vitamin D<sub>3</sub> in sample (µg/100 g);

$A_{nd}$  is the peak area of vitamin D<sub>2</sub> or vitamin D<sub>3</sub> in sample;

$A_{is}$  is the peak area of *d6*-vitamin D<sub>2</sub> or *d6*-vitamin D<sub>3</sub> in sample;

$l$  is the slope of the calibration curve;

$\rho_{is}$  is the concentration of *d6*-vitamin D<sub>2</sub> or *d6*-vitamin D<sub>3</sub> in internal standard (ng/ml);

$V_{is}$  is the volume of internal standard spiked to sample (ml);

$m_s$  is the mass of sample (g);

1 000 is the mass conversion factor (ng/g to µg/g);

100 is the mass conversion factor (µg/g to µg/100 g).

Calculate the mass concentrations of vitamin D<sub>2</sub> or vitamin D<sub>3</sub> in ready-to-feed liquids using [Formula \(17\)](#):

$$\rho_D = \frac{A_{nd}}{A_{is}} \times \frac{1}{l} \times \frac{(\rho_{is} \times V_{is})}{V_s} \times \frac{100}{1\,000} \quad (17)$$

where

$\rho_D$  is the mass concentration of vitamin D<sub>2</sub> or vitamin D<sub>3</sub> in sample (µg/100 ml);

$A_{nd}$  is the peak area of vitamin D<sub>2</sub> or vitamin D<sub>3</sub> in sample;

$A_{is}$  is the peak area of *d*6-vitamin D<sub>2</sub> or *d*6-vitamin D<sub>3</sub> in sample;

$l$  is the slope of the calibration curve;

$\rho_{is}$  is the concentration of *d*6-vitamin D<sub>2</sub> or *d*6-vitamin D<sub>3</sub> in internal standard (ng/ml);

$V_{is}$  is the volume of internal standard spiked to sample (ml);

$V_s$  is the volume of sample (ml);

1 000 is the mass conversion factor (ng/ml to µg/ml);

100 is the mass conversion factor (µg/ml to µg/dl).

## 10 Results

Report the result as µg/100 g or µg/100 ml to one decimal place.

## 11 Precision

### 11.1 General

Details of the interlaboratory study for the determination of the precision of the method are summarized in [Annex B](#). The values derived from the interlaboratory test may not be applicable to analyte concentration ranges and/or matrices other than those given in [Annex B](#). In addition, [Annex C](#) provides data for comparison between this document and EN 12821.

### 11.2 Repeatability

The absolute difference between two single test results obtained on identical test material by one operator using the same apparatus within the shortest feasible time interval will exceed the repeatability limit,  $r$ , in not more than 5 % of the cases.

The values for vitamin D<sub>2</sub> are as follows:

|                | $\bar{x}$ , µg/100 g | $r$ , µg/100 g |
|----------------|----------------------|----------------|
| NIST SRM 1869: | 13,8                 | 2,2            |



The values for vitamin D<sub>3</sub> are as follows:

|                                                        | $\bar{x}$ , µg/100 g | $r$ , µg/100 g |
|--------------------------------------------------------|----------------------|----------------|
| NIST SRM 1849a:                                        | 10,2                 | 0,9            |
| Infant formula powder partially hydrolysed soy based:  | 8,6                  | 0,9            |
| Infant elemental powder:                               | 8,2                  | 0,5            |
| Adult nutritional RTF high protein:                    | 1,0                  | 0,1            |
| Infant formula powder soy based:                       | 9,9                  | 1,2            |
| Child elemental powder:                                | 8,3                  | 1,0            |
| Infant formula RTF milk based:                         | 0,7                  | 0,1            |
| Adult nutritional RTF high fat:                        | 1,3                  | 0,1            |
| Child formula powder:                                  | 7,6                  | 0,4            |
| Infant formula powder partially hydrolysed milk based: | 8,8                  | 0,8            |
| Toddler formula powder milk-based:                     | 8,7                  | 0,7            |
| Milk-based infant formula:                             | 10,1                 | 1,5            |
| Infant formula powder FOS/GOS based:                   | 6,9                  | 0,9            |
| Low-fat adult nutritional powder:                      | 3,3                  | 0,4            |

### 11.3 Reproducibility

The absolute difference between two single test results obtained on identical test material reported by two laboratories will exceed the reproducibility limit,  $R$ , in not more than 5 % of the cases.

The values for vitamin D<sub>2</sub> are as follows:

|           | $\bar{x}$ , µg/100 g | $R$ , µg/100 g |
|-----------|----------------------|----------------|
| SRM 1869: | 13,8                 | 4,9            |

The values for vitamin D<sub>3</sub> are as follows:

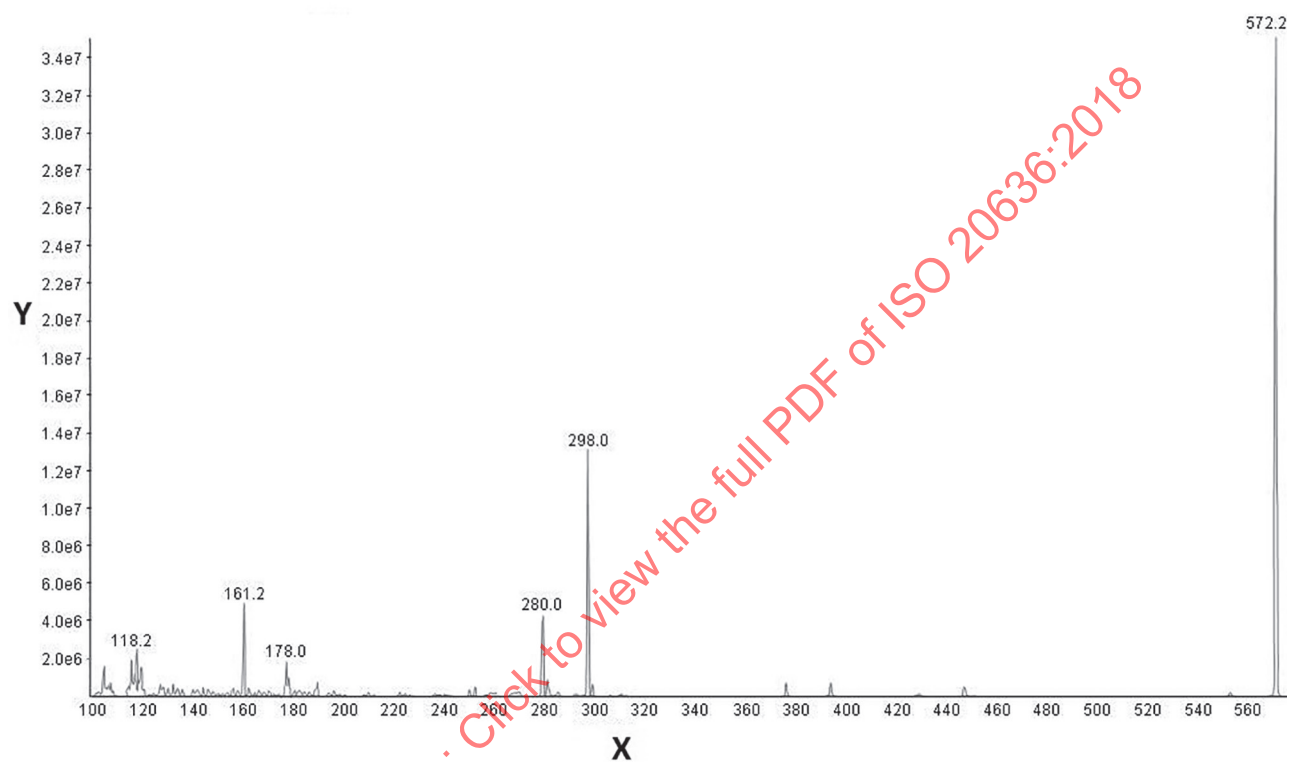
|                                                       | $\bar{x}$ , µg/100 g | $R$ , µg/100 g |
|-------------------------------------------------------|----------------------|----------------|
| SRM 1849a:                                            | 10,2                 | 2,1            |
| Infant formula powder partially hydrolysed soy based: | 8,6                  | 2,1            |
| Infant elemental powder:                              | 8,2                  | 1,9            |
| Adult nutritional RTF high protein:                   | 1,0                  | 0,3            |
| Infant formula powder soy based:                      | 9,9                  | 3,0            |
| Child elemental powder:                               | 8,3                  | 1,8            |
| Infant formula RTF milk based:                        | 0,7                  | 0,2            |

|                                                        |      |     |
|--------------------------------------------------------|------|-----|
| Adult nutritional RTF high fat:                        | 1,3  | 0,2 |
| Child formula powder:                                  | 7,6  | 1,4 |
| Infant formula powder partially hydrolysed milk based: | 8,8  | 1,6 |
| Toddler formula powder milk-based:                     | 8,7  | 2,4 |
| Milk-based infant formula:                             | 10,1 | 2,3 |
| Infant formula powder FOS/GOS based:                   | 6,9  | 1,7 |
| Low-fat adult nutritional powder:                      | 3,3  | 1,1 |

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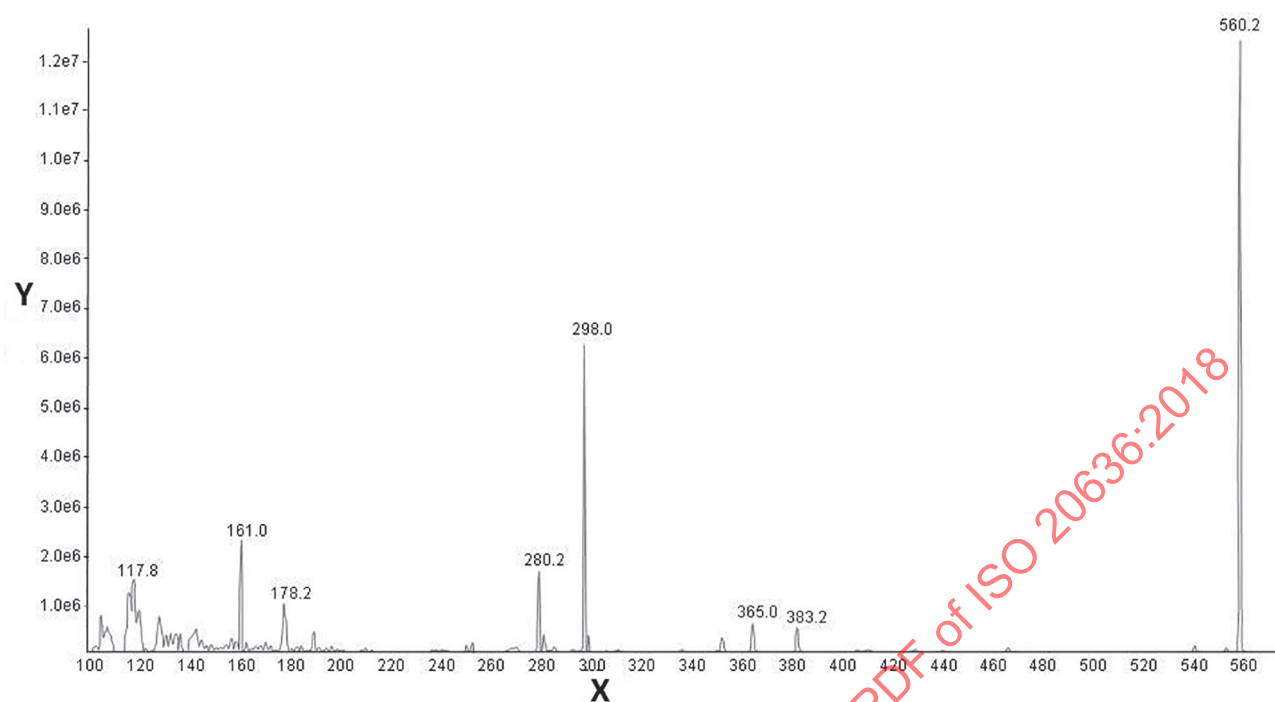
## Annex A (informative)

### Examples of spectra and chromatograms

**Key**X  $m/z$ , in Da

Y intensity, in counts per second

**Figure A.1 — Product ion spectrum for vitamin D<sub>2</sub>**

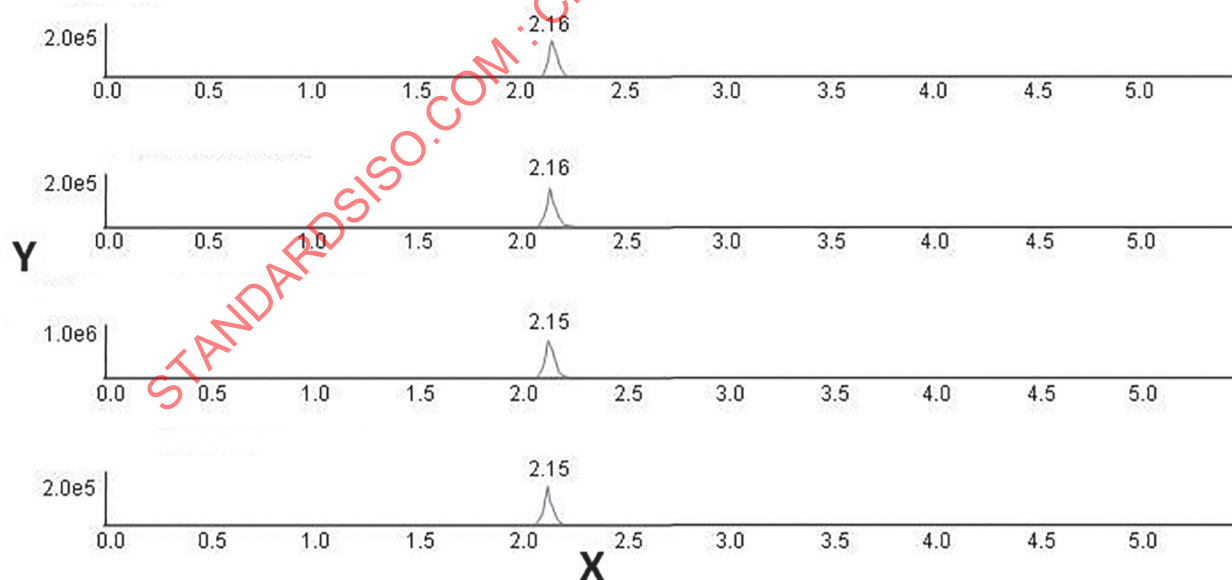


**Key**

X  $m/z$ , in Da

Y intensity, in counts per second

**Figure A.2 — Product ion spectrum for vitamin D<sub>3</sub>**

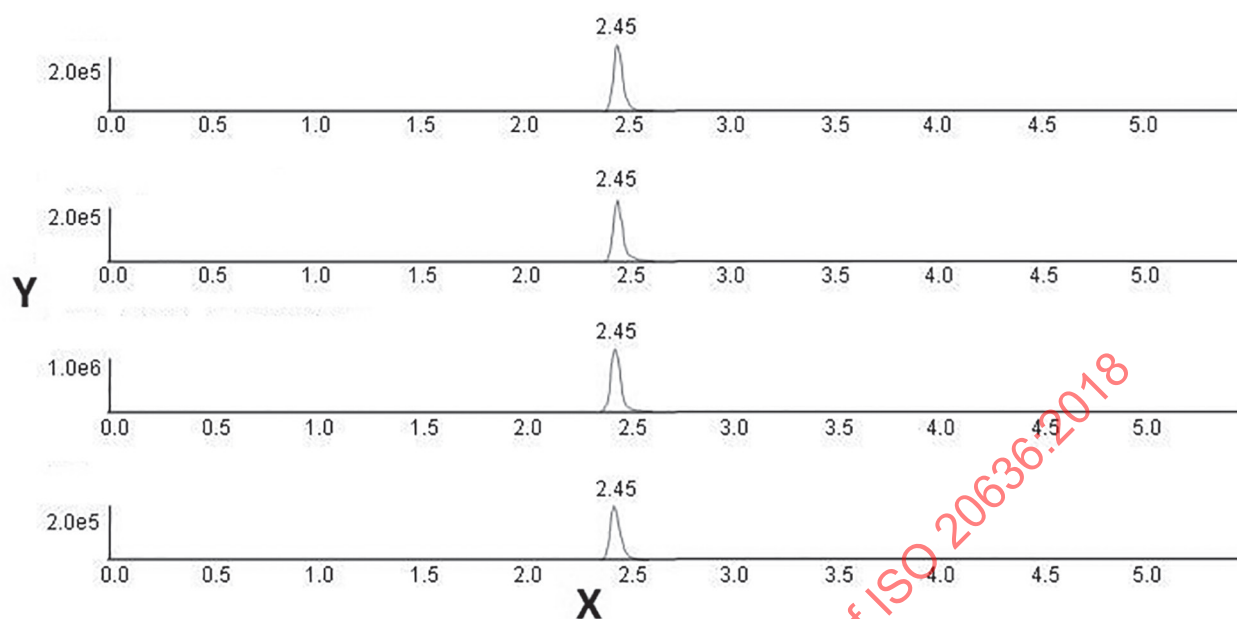


**Key**

X time, in min

Y intensity, in counts per second

**Figure A.3 — Multiple reaction monitoring chromatogram for vitamin D<sub>2</sub>**

**Key**

X time, in min

Y intensity, in counts per second

**Figure A.4 — Multiple reaction monitoring chromatogram for vitamin D<sub>3</sub>**

## Annex B (informative)

### Precision data

The data given in [Table B.1](#) and [Table B.2](#) were obtained from an interlaboratory study<sup>[3][4]</sup>, in accordance with ISO 5725-2<sup>[5]</sup> and the AOAC-IUPAC harmonized protocol for collaborative study procedures, to assess precision characteristics of a method of analysis<sup>[6]</sup>. The study was performed based on requirements given in Reference [\[7\]](#).

**Table B.1 — Precision data for vitamin D<sub>2</sub>**

| Sample                                                        | 1 <sup>a</sup> |
|---------------------------------------------------------------|----------------|
| Year of interlaboratory test                                  | 2016           |
| Number of laboratories                                        | 9              |
| Number of non-compliant laboratories                          | 0              |
| Number of laboratories retained after eliminating outliers    | 9              |
| Number of outliers (laboratories)                             | 2              |
| Number of accepted results                                    | 34             |
| Mean value, $\bar{x}$ , µg/100 g <sup>b</sup>                 | 13,8           |
| Repeatability standard deviation, $s_r$ , µg/100 g            | 0,8            |
| Reproducibility standard deviation, $s_R$ , µg/100 g          | 1,8            |
| Coefficient of variation of repeatability, $C_{V,r}$ , %      | 5,8            |
| Coefficient of variation of reproducibility, $C_{V,R}$ , %    | 12,7           |
| Repeatability limit, $r$ [ $r = 2,8 \times s_r$ ], µg/100 g   | 2,2            |
| Reproducibility limit, $R$ [ $R = 2,8 \times s_R$ ], µg/100 g | 4,9            |
| HorRat value, according to Reference <a href="#">[8]</a>      | 0,6            |
| <sup>a</sup> NIST candidate SRM 1869.                         |                |
| <sup>b</sup> 100 g refers to the powder.                      |                |