Uncertainty Estimation in Photometric Determination of Phosphorus in Feed

Analysis Procedure

Preparation of the Phosphorus Stock Solution

KH2PO4 (M = 136.09 g/mol, purity more than 99.8%) was dried at 103 °C for 1 hour. 4447.2 mg of the obtained salt was weighed and transferred to a 1000.0 ± 0.6 ml volumetric flask and filled to the mark with distilled water. This is the phosphorus stock solution.

Preparation of the Calibration Line

From the stock solution standard solutions were made to 100.0 ± 0.3 ml volumetric flasks. To these flasks 0.500, 1.000, 2.000, 3.000 and 4.000 ml of the stock solution was pipetted and the flasks were filled to the mark. The pipetting operations were carried out using graduated pipettes. From the data in the manufacturer's catalogue it appears that for ± 0.5% of the pipetted volume can be used as the estimate of the calibration uncertainty. For obtaining the calibration line one measurement was made with each of these solutions. For the measurement 10.00 ml of the solution was pipetted (calibration uncertainty of the pipette ± 0.03 ml) into a small stoppered reaction flask. The same pipette was used for pipetting all the standard solutions and the sample solution. To eliminate the carryover effect the pipette was rinsed two times with the respective solution before pipetting. 10.00 ml of molybdatovanadate reagent was added (calibration uncertainty of the pipette ± 0.03 ml). The same pipette was used for adding the reagent both for the calibration solutions and the sample solution. The solution was mixed and let stand for 10 minutes. The solution was then transferred to spectrophotometric cell (the cell was twice rinsed with the solution before the measurement) and the absorbance was measured against blank. The absorbance values obtained were: 0.086, 0.173, 0.341, 0.518 and 0.686 AU, respectively for the five solutions.

Preparation of the Sample

The amount of sample (that had been thoroughly mixed and sieved) taken for the analysis was 2542.1 g. The sample was carefully mixed with 1 g of calcium carbonate and ashed in a muffle furnace at 550 °C. The ash was transferred to a 250 ml beaker with 50 ml of water. 6M HCl solution was added in small batches until the bubbling stopped. Then additional 10 ml of 6M HCl was added and the contents of the beaker were evaporated to dryness. 10 ml of 1M HNO3 was added to the residue and boiled on sand-bath. The resulting liquid was quantitatively transferred to 500.0 ± 0.4 ml volumetric flask and filled to the mark with water.

Measurement of the Sample Solution

The same method was used for measurement as in the case of the calibration standard solutions with the only difference was that before measurement a small part of the solution was filtrated and 10 ml taken from the filtrate. The reading obtained was 0.474 AU. The same photometer was used for all measurements. It has digital display with 3 digits after the comma. From the documentation of the photometer the following data were found: "photometric reproducibility ± 0.002 AU; stability ± 0.0003 AU/h; baseline stability ± 0.001 AU/h". These data correspond to a new instrument, but the used photometer was 8 years old. In addition, with the current method there is the additional source of uncertainty, which is far bigger than the purely instrumental repeatability - the chemical reaction. Therefore the data on drift and reproducibility were determined experimentally in the laboratory (see below).

Parameters Determined Earlier at the Same Laboratory or Obtained from Other Sources

1. Repeatability of weighing. By repeated weighing (10 times) of a sample that had similar mass to the sample of this work it was found that the repeatability standard uncertainty of weighing was u(m, rep) = 0.00017 g (found as standard deviation of the masses). The weighing was done as tared weighing, so the uncertainty originating from taring operation is included in the uncertainty estimate. The repeatability is essentially independent of the mass.

2. Drift of weighing. Drift is more difficult to determine than repeatability. The drift is not necessarily the same on different days and if the laboratory is not air-conditioned (as is the case in this example) then it depends on the season. Based on long-time observations it was found that during 4-5 hours the balance drift is no more than ± 0.0002 g.

3. Repeatability of pipetting. For those cases when the repeatability is not determined directly at the laboratory, it is safe to assume that the repeatability standard uncertainty of pipetting is 0.4% of the pipetted volume.

4. Repeatability of filling volumetric flasks. With all volumetric flasks it is assumed that the flask is filled dropwise and the uncertainty is ± 1drop, that is ± 0.03 ml.

5. Sample preparation recovery R. Extraction recovery was determined using a CRM with similar composition and phosphorus content. (6.8 g/kg). It was found that R = 0.95, u(R) = 0.04. The recovery determined this way takes also to some extent into account the uncertainty due to the inhomogeneity of the sample (be careful, however, because CRM-s tend to be more homogenous than the usual samples).

6. Repeatability of the standard solution measurement. The repeatability was determined at two different concentration levels: one near 0.0 AU and the other near 1.0 AU. Every time new amount of the sample solution was used and the photometric reaction was carried out. This way the determined repeatability includes not only the effects coming from the photometer but also the possible variations of the chemical reaction (that are far bigger, in fact). It was found that the standard uncertainty of repeatability was 0.0012 AU and 0.0021 AU at absorbances 0.0 and 1.0 AU, respectively.

7. Repeatability of the sample measurement. The repeatability uncertainty of the sample measurement is expected to be somewhat higher than the repeatability of the standard solution measurement, because various extraneous ions are present in the solution. It was found that at 0.5 AU level the repeatability uncertainty was 0.0030 AU.

8. Drift of the photometer reading. Drift is more difficult to determine than repeatability. The drift is not necessarily the same on different days and if the laboratory is not air-conditioned (as is the case in this example) then it depends on the season. Based on long-time observations it was concluded that the drift of the photometer during 4-5 hours is not ore than 0.002 and 0.003 AU at absorbance values 0.0 and 1.0 AU, respectively.

9. Linearity of the calibration graph. It was found that in the concentration range 5 .. 40 mg/ml the calibration graph is linear.

10. Temperature in the laboratory. It was found that the temperature in the laboratory during the measurement differed from 20 °C not more than ± 3 °C, also all solutions and volumetric ware were at that temperature during the work. The temperature was constant throughout the work.

Model Equation:

{ Finding the phosphorus content of the sample using the sample solution concentration}

$Q_{sample} = C_{500} * V_{500} / (m_{sample} * R);$

{ Volume of the 500 ml volumetric flask used for sample solution preparation.

For all volumetric equipment the uncertainty consists of 3 components (on the example of V_{500}):

- calibration uncertainty i.e. the uncertainty of the stated volume of the volumetric vessel (V_{500_cal});
- repeatability of using the volumetric vessel (V_{500_rep});
- uncertainty due to the temperature effect (V_{500_temp})

}

$V_{500} = V_{500\_cal} + V_{500\_rep} + V_{500\_temp};$

$V_{500\_temp} = V_{500\_cal} * \Delta t * \gamma;$

{ Uncertainty of sample mass $m_{sample.}$

The uncertainty of mass measurement has 3 uncertainty components (on the example of m_{sample}):

- repeatability of weighing (included in m_{sample_0});
- drift of the balance (m_{sample_drift});
- uncertainty due to rounding of the reading (m_{sample_round})

}

$m_{sample} = m_{sample\_0} + m_{sample\_drift} + m_{sample\_round};$

{ Finding the concentration of the sample solution C_{500} from the absorbance data. }

$C_{500} = (A_{sample} - b_0) / b_1 * (V_{sample\_10} + V_{sample\_reagent}) / V_{sample\_10};$

{ It is assumed that all absorbance measurement results have 3 uncertainty components (on the example of A_{sample}):

- repeatability uncertainty (included in A_{sample_rep});
- uncertainty due to drift (A_{sample_drift})
- uncertainty due to rounding of the reading (A_{sample_round})

}

$A_{sample}=A_{sample\_rep}+A_{sample\_drift}+A_{sample\_round}+A_{sample\_chemical}drift;$

{ Pipetting the reagent solution: The same pipette was used for pipetting the reagent throughout the work, both for the sample and the standard solutions.

Therefore only the quantity representing the repeatability uncertainty contribution changes from one pipettng to another.

The $V_{reagent\_cal}$ and $V_{reagent\_temp}$ are the same for all reagent pipetting operations.

The same holds for pipetting the sample solution.

}

$V_{sample\_reagent} = V_{reagent\_cal} + V_{sample\_reagent\_rep} + V_{reagent\_temp}$;

$V_{reagent\_temp} = V_{reagent\_cal} * \Delta t * \gamma$;

$V_{sample\_10} = V_{10\_cal} + V_{sample\_10\_rep} + V_{10\_temp}$;

$V_{10\_temp} = V_{10\_cal} * \Delta t * \gamma$;

{ Linear regression equations}

b_1=(ΣCA - n * AvgC * AvgA) / (ΣCC - n * AvgC * AvgC);

b_0=AvgA-b_1*AvgC;

ΣCA=$C_1*A_1+C_2*A_2+C_3*A_3+C_4*A_4+C_5*A_5$;

AvgC=$(C_1+C_2+C_3+C_4+C_5)/n$;

AvgA=$(A_1+A_2+A_3+A_4+A_5)/n$;

ΣCC=$C_1*C_1+C_2*C_2+C_3*C_3+C_4*C_4+C_5*C_5$;

{ Absorbances of the calibration standard solutions }

$A_1 = A_{1rep} + A_{1drift} + A_{1round}$;

$A_2 = A_{2rep} + A_{2drift} + A_{2round}$;

$A_3 = A_{3rep} + A_{3drift} + A_{3round}$;

$A_4 = A_{4rep} + A_{4drift} + A_{4round}$;

$A_5 = A_{5rep} + A_{5drift} + A_{5round}$;

{ Concentrations of the standard solutions that were actually measured (after the reaction)}

$C_1 = C_{stock} * (V_{1\_stock} / V_{1\_100}) * V_{1\_10} / (V_{1\_10} + V_{1\_reagent})$;

$C_2 = C_{stock} * (V_{2\_stock} / V_{2\_100}) * V_{2\_10} / (V_{2\_10} + V_{2\_reagent});$

$C_3 = C_{stock} * (V_{3\_stock} / V_{3\_100}) * V_{3\_10} / (V_{3\_10} + V_{3\_reagent});$

$C_4 = C_{stock} * (V_{4\_stock} / V_{4\_100}) * V_{4\_10} / (V_{4\_10} + V_{4\_reagent});$

$C_5 = C_{stock} * (V_{5\_stock} / V_{5\_100}) * V_{5\_10} / (V_{5\_10} + V_{5\_reagent});$

{ Volumes of the stock solution pipetted for preparing the standard solutions }

$V_{1\_stock} = V_{1\_stock\_cal} + V_{1\_stock\_rep} + V_{1\_stock\_temp};$

$V_{1\_stock\_temp} = V_{1\_stock\_cal} * \Delta t * \gamma;$

$V_{2\_stock} = V_{2\_stock\_cal} + V_{2\_stock\_rep} + V_{2\_stock\_temp};$

$V_{2\_stock\_temp} = V_{2\_stock\_cal} * \Delta t * \gamma;$

$V_{3\_stock} = V_{3\_stock\_cal} + V_{3\_stock\_rep} + V_{3\_stock\_temp};$

$V_{3\_stock\_temp} = V_{3\_stock\_cal} * \Delta t * \gamma;$

$V_{4\_stock} = V_{4\_stock\_cal} + V_{4\_stock\_rep} + V_{4\_stock\_temp};$

$V_{4\_stock\_temp} = V_{4\_stock\_cal} * \Delta t * \gamma;$

$V_{5\_stock} = V_{5\_stock\_cal} + V_{5\_stock\_rep} + V_{5\_stock\_temp};$

$V_{5\_stock\_temp} = V_{5\_stock\_cal} * \Delta t * \gamma;$

{ Volumes of the 100 ml volumetric flasks }

$V_{1\_100} = V_{1\_100\_cal} + V_{1\_100\_rep} + V_{1\_100\_temp};$

$V_{1\_100\_temp} = V_{1\_100\_cal} * \Delta t * \gamma;$

$V_{2\_100} = V_{2\_100\_cal} + V_{2\_100\_rep} + V_{2\_100\_temp};$

$V_{2\_100\_temp} = V_{2\_100\_cal} * \Delta t * \gamma;$

$V_{3\_100} = V_{3\_100\_cal} + V_{3\_100\_rep} + V_{3\_100\_temp};$

$V_{3\_100\_temp} = V_{3\_100\_cal} * \Delta t * \gamma;$

$V_{4\_100} = V_{4\_100\_cal} + V_{4\_100\_rep} + V_{4\_100\_temp};$

$V_{4\_100\_temp} = V_{4\_100\_cal} * \Delta t * \gamma;$

$V_{5\_100} = V_{5\_100\_cal} + V_{5\_100\_rep} + V_{5\_100\_temp};$

$V_{5\_100\_temp} = V_{5\_100\_cal} * \Delta t * \gamma;$

{ Volumes of the solutions pipetted into the reaction flasks }

$V_{1\_10} = V_{10\_cal} + V_{1\_10\_rep} + V_{10\_temp};$

$V_{2\_10} = V_{10\_cal} + V_{2\_10\_rep} + V_{10\_temp};$

$V_{3\_10} = V_{10\_cal} + V_{3\_10\_rep} + V_{10\_temp};$

$V_{4\_10} = V_{10\_cal} + V_{4\_10\_rep} + V_{10\_temp}$;

$V_{5\_10} = V_{10\_cal} + V_{5\_10\_rep} + V_{10\_temp}$;

{ Reagent volumes pipetted into the reaction flasks }

$V_{1\_reagent} = V_{reagent\_cal} + V_{1\_reagent\_rep} + V_{reagent\_temp}$;

$V_{2\_reagent} = V_{reagent\_cal} + V_{2\_reagent\_rep} + V_{reagent\_temp}$;

$V_{3\_reagent} = V_{reagent\_cal} + V_{3\_reagent\_rep} + V_{reagent\_temp}$;

$V_{4\_reagent} = V_{reagent\_cal} + V_{4\_reagent\_rep} + V_{reagent\_temp}$;

$V_{5\_reagent} = V_{reagent\_cal} + V_{5\_reagent\_rep} + V_{reagent\_temp}$;

{ Preparation of the stock solution.}

$C_{stock} = M_P / M_{KH2PO4} * P * m_{std} / V_{1000}$;

$m_{std} = m_{std\_0} + m_{std\_drift} + m_{std\_round}$;

$V_{1000} = V_{1000\_cal} + V_{1000\_rep} + V_{1000\_temp}$;

$V_{1000\_temp} = V_{1000\_cal} * \Delta t * \gamma$;

List of Quantities:

Quantity	Unit	Definition
Q_{sample}	mg/g	Phosphorus content of the feed sample
C_{500}	µg/ml	Phosphorus concentration in the 500 ml flask
V_{500}	ml	Volume of the 500 ml flask used for sample preparation
V_{500_cal}	ml	Volume together with the calibration uncertainty of the 500 ml flask used for sample preparation
V_{500_rep}	ml	Repeatability uncertainty of the volume of the 500 ml flask used for sample preparation
V_{500_temp}	ml	Temperature uncertainty of the volume of the 500 ml flask used for sample preparation
m_{sample}	mg	Mass of the sample taken for analysis
R	unitless	Recovery factor
m_{sample_0}	mg	Value of the mass of the sample taken for analysis together with repeatability uncertainty of weighing
m_{sample_drift}	mg	Drift component of the uncertainty of the mass of the sample taken for analysis
m_{sample_round}	mg	Rounding component of the uncertainty of the mass of the sample taken for analysis
Δt	°C	Difference of the laboratory temperature from 20 °C

Quantity	Unit	Definition
γ	1/°C	Thermal expansion coefficient of water
A_{sample}	AU	Absorbance of the sample solution
A_{sample_rep}	AU	Absorbance value of the sample solution together with its repeatability uncertainty component
A_{sample_drift}	AU	Uncertainty of the sample solution absorbance due to photometer drift
A_{sample_round}	AU	Uncertainty component of the sample solution absorbance due to rounding
V_{sample_10}	ml	Volume of the 10 pipette used for pipetting the sample solution into the reaction flask
V_{10_cal}	ml	Value and the calibration uncertainty of the volume of the 10 ml pipette used for pipetting the sample solution into the reaction flask
$V_{sample\_10\_rep}$	ml	Repeatability uncertainty of the 10 ml pipette used for pipetting the sample solution into the reaction flask
V_{10_temp}	ml	Temperature uncertainty of the 10 ml pipette used for pipetting the sample solution into the reaction flask
$V_{sample\_reagent}$	ml	Volume of the 10 pipette used for pipetting the reagent solution into the reaction flask for the measurement of the sample
$V_{reagent\_cal}$	ml	Value and the calibration uncertainty of the 10 ml pipette used for pipetting the reagent solution into the reaction flask
$V_{sample\_reagent\_rep}$	ml	Repeatability uncertainty of the 10 ml pipette used for pipetting the reagent solution into the reaction flask
$V_{reagent\_temp}$	ml	Temperature uncertainty of the 10 ml pipette used for pipetting the reagent solution into the reaction flask
b_0	AU	Intercept of the calibration line
b_1	AU·ml/µg	Slope of the calibration line
n	unitless	Number of points on the calibration line
AvgC	µg/ml	Interim quantity for regression analysis
AvgA	AU	Interim quantity for regression analysis
ΣCC	(µg/ml)²	Interim quantity for regression analysis
ΣCA	AU·µg/ml	Interim quantity for regression analysis
A_1	AU	Absorbance of the 1. calibration standard solution
A_2	AU	Absorbance of the 2. calibration standard solution
A_3	AU	Absorbance of the 3. calibration standard solution
A_4	AU	Absorbance of the 4. calibration standard solution
A_5	AU	Absorbance of the 5. calibration standard solution

Quantity	Unit	Definition
A_{1rep}	AU	Absorbance value and the repeatability uncertainty of the 1. calibration standard solution
A_{2rep}	AU	Absorbance value and the repeatability uncertainty of the 2. calibration standard solution
A_{3rep}	AU	Absorbance value and the repeatability uncertainty of the 3. calibration standard solution
A_{4rep}	AU	Absorbance value and the repeatability uncertainty of the 4. calibration standard solution
A_{5rep}	AU	Absorbance value and the repeatability uncertainty of the 5. calibration standard solution
A_{1drift}	AU	Drift uncertainty component of the absorbance value of the 1. calibration standard solution
A_{2drift}	AU	Drift uncertainty component of the absorbance value of the 2. calibration standard solution
A_{3drift}	AU	Drift uncertainty component of the absorbance value of the 3. calibration standard solution
A_{4drift}	AU	Drift uncertainty component of the absorbance value of the 4. calibration standard solution
A_{5drift}	AU	Drift uncertainty component of the absorbance value of the 5. calibration standard solution
A_{1round}	AU	Rounding uncertainty component of the absorbance value of the 1. calibration standard solution
A_{2round}	AU	Rounding uncertainty component of the absorbance value of the 2. calibration standard solution
A_{3round}	AU	Rounding uncertainty component of the absorbance value of the 3. calibration standard solution
A_{4round}	AU	Rounding uncertainty component of the absorbance value of the 4. calibration standard solution
A_{5round}	AU	Rounding uncertainty component of the absorbance value of the 5. calibration standard solution
C_1	µg/ml	Concentration of the 1. calibration standard solution
C_2	µg/ml	Concentration of the 2. calibration standard solution
C_3	µg/ml	Concentration of the 3. calibration standard solution
C_4	µg/ml	Concentration of the 4. calibration standard solution
C_5	µg/ml	Concentration of the 5. calibration standard solution
V_{1_stock}	ml	Volume of the stock solution pipetted for preparing the standard solution No 1.
V_{1_100}	ml	Volume of the 100 ml volumetric flask used for preparing the standard solution No 1.

Quantity	Unit	Definition
V_{1_10}	ml	Volume of the standard solution No 1. pipetted into the reaction flask
$V_{1\_reagent}$	ml	Volume of the reagent solution pipetted into the reaction flask for measurement of the standard solution No 1.
V_{2_stock}	ml	Volume of the stock solution pipetted for preparing the standard solution No 2.
V_{2_100}	ml	Volume of the 100 ml volumetric flask used for preparing the standard solution No 2.
V_{2_10}	ml	Volume of the standard solution No 2. pipetted into the reaction flask
$V_{2\_reagent}$	ml	Volume of the reagent solution pipetted into the reaction flask for measurement of the standard solution No 2.
V_{3_stock}	ml	Volume of the stock solution pipetted for preparing the standard solution No 3.
V_{3_100}	ml	Volume of the 100 ml volumetric flask used for preparing the standard solution No 3.
V_{3_10}	ml	Volume of the standard solution No 3. pipetted into the reaction flask
$V_{3\_reagent}$	ml	Volume of the reagent solution pipetted into the reaction flask for measurement of the standard solution No 3.
V_{4_stock}	ml	Volume of the stock solution pipetted for preparing the standard solution No 4.
V_{4_100}	ml	Volume of the 100 ml volumetric flask used for preparing the standard solution No 4.
V_{4_10}	ml	Volume of the standard solution No 4. pipetted into the reaction flask
$V_{4\_reagent}$	ml	Volume of the reagent solution pipetted into the reaction flask for measurement of the standard solution No 4.
V_{5_stock}	ml	Volume of the stock solution pipetted for preparing the standard solution No 5.
V_{5_100}	ml	Volume of the 100 ml volumetric flask used for preparing the standard solution No 5.
V_{5_10}	ml	Volume of the standard solution No 5. pipetted into the reaction flask
$V_{5\_reagent}$	ml	Volume of the reagent solution pipetted into the reaction flask for measurement of the standard solution No 5.
$V_{1\_stock\_cal}$	ml	Value and the calibration component of uncertainty of the volume of the stock solution pipetted into the 100 ml flask for preparing the standard solution No 1.

Quantity	Unit	Definition
$V_{1\_stock\_rep}$	ml	Repeatability component of uncertainty of the volume of the stock solution pipetted into the 100 ml flask for preparing the standard solution No 1.
$V_{1\_stock\_temp}$	ml	Temperature component of uncertainty of the volume of the stock solution pipetted into the 100 ml flask for preparing the standard solution No 1.
$V_{2\_stock\_cal}$	ml	Value and the calibration component of uncertainty of the volume of the stock solution pipetted into the 100 ml flask for preparing the standard solution No 2.
$V_{2\_stock\_rep}$	ml	Repeatability component of uncertainty of the volume of the stock solution pipetted into the 100 ml flask for preparing the standard solution No 2.
$V_{2\_stock\_temp}$	ml	Temperature component of uncertainty of the volume of the stock solution pipetted into the 100 ml flask for preparing the standard solution No 2.
$V_{3\_stock\_cal}$	ml	Value and the calibration component of uncertainty of the volume of the stock solution pipetted into the 100 ml flask for preparing the standard solution No 3.
$V_{3\_stock\_rep}$	ml	Repeatability component of uncertainty of the volume of the stock solution pipetted into the 100 ml flask for preparing the standard solution No 3.
$V_{3\_stock\_temp}$	ml	Temperature component of uncertainty of the volume of the stock solution pipetted into the 100 ml flask for preparing the standard solution No 3.
$V_{4\_stock\_cal}$	ml	Value and the calibration component of uncertainty of the volume of the stock solution pipetted into the 100 ml flask for preparing the standard solution No 4.
$V_{4\_stock\_rep}$	ml	Repeatability component of uncertainty of the volume of the stock solution pipetted into the 100 ml flask for preparing the standard solution No 4.
$V_{4\_stock\_temp}$	ml	Temperature component of uncertainty of the volume of the stock solution pipetted into the 100 ml flask for preparing the standard solution No 4.
$V_{5\_stock\_cal}$	ml	Value and the calibration component of uncertainty of the volume of the stock solution pipetted into the 100 ml flask for preparing the standard solution No 5.
$V_{5\_stock\_rep}$	ml	Repeatability component of uncertainty of the volume of the stock solution pipetted into the 100 ml flask for preparing the standard solution No 5.
$V_{5\_stock\_temp}$	ml	Temperature component of uncertainty of the volume of the stock solution pipetted into the 100 ml flask for preparing the standard solution No 5.

Quantity	Unit	Definition
$V_{1\_100\_cal}$	ml	Value and the calibration component of uncertainty of the volume of the 100 ml flask for preparing the standard solution No 1.
$V_{1\_100\_rep}$	ml	Repeatability component of uncertainty of the volume of the 100 ml flask for preparing the standard solution No 1.
$V_{1\_100\_temp}$	ml	Temperature component of uncertainty of the volume of the 100 ml flask for preparing the standard solution No 1.
$V_{2\_100\_cal}$	ml	Value and the calibration component of uncertainty of the volume of the 100 ml flask for preparing the standard solution No 2.
$V_{2\_100\_rep}$	ml	Repeatability component of uncertainty of the volume of the 100 ml flask for preparing the standard solution No 2.
$V_{2\_100\_temp}$	ml	Temperature component of uncertainty of the volume of the 100 ml flask for preparing the standard solution No 2.
$V_{3\_100\_cal}$	ml	Value and the calibration component of uncertainty of the volume of the 100 ml flask for preparing the standard solution No 3.
$V_{3\_100\_rep}$	ml	Repeatability component of uncertainty of the volume of the 100 ml flask for preparing the standard solution No 3.
$V_{3\_100\_temp}$	ml	Temperature component of uncertainty of the volume of the 100 ml flask for preparing the standard solution No 3.
$V_{4\_100\_cal}$	ml	Value and the calibration component of uncertainty of the volume of the 100 ml flask for preparing the standard solution No 4.
$V_{4\_100\_rep}$	ml	Repeatability component of uncertainty of the volume of the 100 ml flask for preparing the standard solution No 4.
$V_{4\_100\_temp}$	ml	Temperature component of uncertainty of the volume of the 100 ml flask for preparing the standard solution No 4.
$V_{5\_100\_cal}$	ml	Value and the calibration component of uncertainty of the volume of the 100 ml flask for preparing the standard solution No 5.
$V_{5\_100\_rep}$	ml	Repeatability component of uncertainty of the volume of the 100 ml flask for preparing the standard solution No 5.
$V_{5\_100\_temp}$	ml	Temperature component of uncertainty of the volume of the 100 ml flask for preparing the standard solution No 5.
$V_{1\_10\_rep}$	ml	Repeatability component of uncertainty of the volume of the standard solution No 1. pipetted into the reaction flask
$V_{2\_10\_rep}$	ml	Repeatability component of uncertainty of the volume of the standard solution No 2. pipetted into the reaction flask
$V_{3\_10\_rep}$	ml	Repeatability component of uncertainty of the volume of the standard solution No 3. pipetted into the reaction flask

Quantity	Unit	Definition
$V_{4\_10\_rep}$	ml	Repeatability component of uncertainty of the volume of the standard solution No 4. pipetted into the reaction flask
$V_{5\_10\_rep}$	ml	Repeatability component of uncertainty of the volume of the standard solution No 5. pipetted into the reaction flask
$V_{1\_reagent\_rep}$	ml	Repeatability component of uncertainty of the volume of the reagent solution pipetted into the reaction flask for measuring the standard solution No 1.
$V_{2\_reagent\_rep}$	ml	Repeatability component of uncertainty of the volume of the reagent solution pipetted into the reaction flask for measuring the standard solution No 2.
$V_{3\_reagent\_rep}$	ml	Repeatability component of uncertainty of the volume of the reagent solution pipetted into the reaction flask for measuring the standard solution No 3.
$V_{4\_reagent\_rep}$	ml	Repeatability component of uncertainty of the volume of the reagent solution pipetted into the reaction flask for measuring the standard solution No 4.
$V_{5\_reagent\_rep}$	ml	Repeatability component of uncertainty of the volume of the reagent solution pipetted into the reaction flask for measuring the standard solution No 5.
C_{stock}	mg/l	Concentration of the phosphorus stock solution
M_P	g/mol	Atomic mass of Phosphorus
M_{KH2PO4}	g/mol	Molar mass of the standard substance KH2PO4
P	unitless	Purity of the standard substance KH2PO4
m_{std}	mg	Mass of the standard substance taken for preparation of the stock solution
V_{1000}	l	Volume of the 1 litre volumetric flask used for preparation of the stock solution
m_{std_0}	mg	Value of the mass of the standard substance together with repeatability uncertainty of weighing
m_{std_drift}	mg	Drift component of the uncertainty of the mass of the standard substance
m_{std_round}	mg	Rounding component of the uncertainty of the mass of the standard substance
V_{1000_cal}	l	Volume together with the calibration uncertainty of the 1000 ml flask used for preparation of the stock solution
V_{1000_rep}	l	Repeatability uncertainty of the volume of the 1000 ml flask used for preparation of the stock solution
V_{1000_temp}	l	Temperature uncertainty of the volume of the 1000 ml flask used for preparation of the stock solution
$A_{sample_chemical}$drift	AU	Uncertainty component of the sample solution absorbance due to chemical drift

V_{500_cal}: Type B rectangular distribution
Value: 500 ml
Halfwidth of Limits: .4 ml

V_{500_rep}: Type B rectangular distribution
Value: 0 ml
Halfwidth of Limits: .09 ml

If the flask is filled dropwise, then it is not likely, that the uncertainty is larger than ± 3 drops. Uncertainty ± 0.03 ml roughly corresponds ± 1 drop.

R: Type B normal distribution
Value: .95 unitless
Expanded Uncertainty: .04 unitless
Coverage Factor: 1

m_{sample_0}: Type B rectangular distribution
Value: 2542.1 mg
Halfwidth of Limits: .17 mg

m_{sample_drift}: Type B rectangular distribution
Value: 0 mg
Halfwidth of Limits: .2 mg

m_{sample_round}: Type B rectangular distribution
Value: 0 mg
Halfwidth of Limits: .05 mg

Δt: Type B rectangular distribution
Value: 0 °C
Halfwidth of Limits: 3 °C

γ: Constant
Value: 0.00021 1/°C

A_{sample_rep}: Type B normal distribution
Value: .474 AU
Expanded Uncertainty: .003 AU
Coverage Factor: 1

A_{sample_drift}: Type B rectangular distribution
Value: 0 AU
Halfwidth of Limits: .0025 AU

The uncertainty due to drift has been estimated by linear interpolation taking into account that at A=0.0 the drift is ±0.002 and at A=1.0 the drift is ±0.003

A_{sample_round}: Type B rectangular distribution
Value: 0 AU
Halfwidth of Limits: 0.0005 AU

V_{10_cal}: Type B rectangular distribution
Value: 10 ml
Halfwidth of Limits: 0.03 ml

$V_{sample\_10\_rep}$: Type B normal distribution
Value: 0 ml
Expanded Uncertainty: .04 ml
Coverage Factor: 1

Repeatability standard uncertainty of pipetting is assumed 0.4% of the pipette volume throughout.

$V_{reagent\_cal}$: Type B rectangular distribution
Value: 10 ml
Halfwidth of Limits: .03 ml

$V_{sample\_reagent\_rep}$: Type B normal distribution
Value: 0 ml
Expanded Uncertainty: .04 ml
Coverage Factor: 1

Repeatability standard uncertainty of pipetting is assumed 0.4% of the pipette volume throughout.

n: Constant
Value: 5 unitless

A_{1rep}: Type B normal distribution
Value: .086 AU
Expanded Uncertainty: .0013 AU
Coverage Factor: 1

The uncertainty due to repeatability has been estimated by linear interpolation taking into account that at A=0.0 the standard uncertainty due to repeatability is 0.0005 AU and at A=1.0 it is 0.0011

A_{2rep}: Type B normal distribution
Value: .173 AU
Expanded Uncertainty: .0014 AU
Coverage Factor: 1

The uncertainty due to repeatability has been estimated by linear interpolation taking into account that at A=0.0 the standard uncertainty due to repeatability is 0.0005 AU and at A=1.0 it is 0.0011

A_{3rep}: Type B normal distribution
Value: .341 AU
Expanded Uncertainty: .0015 AU
Coverage Factor: 1

The uncertainty due to repeatability has been estimated by linear interpolation taking into account that at A=0.0 the standard uncertainty due to repeatability is 0.0005 AU and at A=1.0 it is 0.0011

A_{4rep}: Type B normal distribution
Value: .518 AU
Expanded Uncertainty: .0017 AU
Coverage Factor: 1

The uncertainty due to repeatability has been estimated by linear interpolation taking into account that at A=0.0 the standard uncertainty due to repeatability is 0.0005 AU and at A=1.0 it is 0.0011

A_{5rep}: Type B normal distribution
Value: .686 AU
Expanded Uncertainty: .0018 AU
Coverage Factor: 1

The uncertainty due to repeatability has been estimated by linear interpolation taking into account that at A=0.0 the standard uncertainty due to repeatability is 0.0005 AU and at A=1.0 it is 0.0011

A_{1drift}: Type B rectangular distribution
Value: 0 AU
Halfwidth of Limits: .0020 AU

The uncertainty due to drift has been estimated by linear interpolation taking into account that at A=0.0 the drift is ±0.002 and at A=1.0 the drift is ±0.003

A_{2drift}: Type B rectangular distribution
Value: 0 AU
Halfwidth of Limits: .0022 AU

The uncertainty due to drift has been estimated by linear interpolation taking into account that at A=0.0 the drift is ±0.002 and at A=1.0 the drift is ±0.003

A_{3drift}: Type B rectangular distribution
Value: 0 AU
Halfwidth of Limits: .0023 AU

The uncertainty due to drift has been estimated by linear interpolation taking into account that at A=0.0 the drift is ±0.002 and at A=1.0 the drift is ±0.003

A_{4drift}: Type B rectangular distribution
Value: 0 AU
Halfwidth of Limits: .0025 AU

The uncertainty due to drift has been estimated by linear interpolation taking into account that at A=0.0 the drift is ±0.002 and at A=1.0 the drift is ±0.003

A_{5drift}: Type B rectangular distribution
Value: 0 AU
Halfwidth of Limits: .0027 AU

The uncertainty due to drift has been estimated by linear interpolation taking into account that at A=0.0 the drift is ±0.002 and at A=1.0 the drift is ±0.003

A_{1round}: Type B rectangular distribution
Value: 0 AU
Halfwidth of Limits: .0005 AU

A_{2round}: Type B rectangular distribution
Value: 0 AU
Halfwidth of Limits: .0005 AU

A_{3round}: Type B rectangular distribution
Value: 0 AU
Halfwidth of Limits: .0005 AU

A_{4round}: Type B rectangular distribution
Value: 0 AU
Halfwidth of Limits: .0005 AU

A_{5round}: Type B rectangular distribution
Value: 0 AU
Halfwidth of Limits: .0005 AU

$V_{1\_stock\_cal}$: Type B rectangular distribution
Value: .5 ml
Halfwidth of Limits: .007 ml

$V_{1\_stock\_rep}$: Type B normal distribution
Value: 0 ml
Expanded Uncertainty: .002 ml
Coverage Factor: 1

Repeatability standard uncertainty of pipetting is assumed 0.4% of the pipette volume throughout.

$V_{2\_stock\_cal}$: Type B rectangular distribution
Value: 1 ml
Halfwidth of Limits: .010 ml

$V_{2\_stock\_rep}$: Type B normal distribution
Value: 0 ml
Expanded Uncertainty: .004 ml
Coverage Factor: 1

Repeatability standard uncertainty of pipetting is assumed 0.4% of the pipette volume throughout.

$V_{3\_stock\_cal}$: Type B rectangular distribution
Value: 2 ml
Halfwidth of Limits: .015 ml

$V_{3\_stock\_rep}$: Type B normal distribution
Value: 0 ml
Expanded Uncertainty: .008 ml
Coverage Factor: 1

Repeatability standard uncertainty of pipetting is assumed 0.4% of the pipette volume throughout.

$V_{4\_stock\_cal}$: Type B rectangular distribution
Value: 3 ml
Halfwidth of Limits: .015 ml

$V_{4\_stock\_rep}$: Type B normal distribution
Value: 0 ml
Expanded Uncertainty: .012 ml
Coverage Factor: 1

Repeatability standard uncertainty of pipetting is assumed 0.4% of the pipette volume throughout.

$V_{5\_stock\_cal}$: Type B rectangular distribution
Value: 4 ml
Halfwidth of Limits: .02 ml

$V_{5\_stock\_rep}$: Type B normal distribution
Value: 0 ml
Expanded Uncertainty: .016 ml
Coverage Factor: 1

Repeatability standard uncertainty of pipetting is assumed 0.4% of the pipette volume throughout.

$V_{1\_100\_cal}$: Type B rectangular distribution
Value: 100 ml
Halfwidth of Limits: .3 ml

$V_{1\_100\_rep}$: Type B rectangular distribution
Value: 0 ml
Halfwidth of Limits: .09 ml

If the flask is filled dropwise, then it is not likely, that the uncertainty is larger than ± 3 drops. Uncertainty ± 0.09 ml roughly corresponds ± 3 drop.

$V_{2\_100\_cal}$: Type B rectangular distribution
Value: 100 ml
Halfwidth of Limits: .3 ml

$V_{2\_100\_rep}$: Type B rectangular distribution
Value: 0 ml
Halfwidth of Limits: .09 ml

If the flask is filled dropwise, then it is not likely, that the uncertainty is larger than ± 3 drops. Uncertainty ± 0.09 ml roughly corresponds ± 3 drops.

$V_{3\_100\_cal}$: Type B rectangular distribution
Value: 100 ml
Halfwidth of Limits: .3 ml

$V_{3\_100\_rep}$: Type B rectangular distribution
Value: 0 ml
Halfwidth of Limits: .09 ml

If the flask is filled dropwise, then it is not likely, that the uncertainty is larger than ± 3 drops. Uncertainty ± 0.09 ml roughly corresponds ± 3 drops.

$V_{4\_100\_cal}$: Type B rectangular distribution
Value: 100 ml
Halfwidth of Limits: .3 ml

$V_{4\_100\_rep}$: Type B rectangular distribution
Value: 0 ml
Halfwidth of Limits: .09 ml

If the flask is filled dropwise, then it is not likely, that the uncertainty is larger than ± 3 drop. Uncertainty ± 0.09 ml roughly corresponds ± 3 drops.

$V_{5\_100\_cal}$: Type B rectangular distribution
Value: 100 ml
Halfwidth of Limits: .3 ml

$V_{5\_100\_rep}$: Type B rectangular distribution
Value: 0 ml
Halfwidth of Limits: .09 ml

If the flask is filled dropwise, then it is not likely, that the uncertainty is larger than ± 3 drops. Uncertainty ± 0.09 ml roughly corresponds ± 3 drops.

$V_{1\_10\_rep}$: Type B normal distribution
Value: 0 ml
Expanded Uncertainty: .04 ml
Coverage Factor: 1

Repeatability standard uncertainty of pipetting is assumed 0.4% of the pipette volume throughout.

$V_{2\_10\_rep}$: Type B normal distribution
Value: 0 ml
Expanded Uncertainty: .04 ml
Coverage Factor: 1

Repeatability standard uncertainty of pipetting is assumed 0.4% of the pipette volume throughout.

$V_{3\_10\_rep}$: Type B normal distribution
Value: 0 ml
Expanded Uncertainty: .04 ml
Coverage Factor: 1

Repeatability standard uncertainty of pipetting is assumed 0.4% of the pipette volume throughout.

$V_{4\_10\_rep}$: Type B normal distribution
Value: 0 ml
Expanded Uncertainty: .04 ml
Coverage Factor: 1

Repeatability standard uncertainty of pipetting is assumed 0.4% of the pipette volume throughout.

$V_{5\_10\_rep}$: Type B normal distribution
Value: 0 ml
Expanded Uncertainty: .04 ml
Coverage Factor: 1

Repeatability standard uncertainty of pipetting is assumed 0.4% of the pipette volume throughout.

$V_{1\_reagent\_rep}$: Type B normal distribution
Value: 0 ml
Expanded Uncertainty: .04 ml
Coverage Factor: 1

Repeatability standard uncertainty of pipetting is assumed 0.4% of the pipette volume throughout.

$V_{2\_reagent\_rep}$: Type B normal distribution
Value: 0 ml
Expanded Uncertainty: .04 ml
Coverage Factor: 1

Repeatability standard uncertainty of pipetting is assumed 0.4% of the pipette volume throughout.

$V_{3\_reagent\_rep}$: Type B normal distribution
Value: 0 ml
Expanded Uncertainty: .04 ml
Coverage Factor: 1

Repeatability standard uncertainty of pipetting is assumed 0.4% of the pipette volume throughout.

$V_{4\_reagent\_rep}$: Type B normal distribution
Value: 0 ml
Expanded Uncertainty: .04 ml
Coverage Factor: 1

Repeatability standard uncertainty of pipetting is assumed 0.4% of the pipette volume throughout.

$V_{5\_reagent\_rep}$: Type B normal distribution
Value: 0 ml
Expanded Uncertainty: .04 ml
Coverage Factor: 1

Repeatability standard uncertainty of pipetting is assumed 0.4% of the pipette volume throughout.

M_P: Constant
Value: 30.97 g/mol

M_{KH2PO4}: Constant
Value: 136.09 g/mol

P: Type B rectangular distribution
Value: .999 unitless
Halfwidth of Limits: .001 unitless

m_{std_0}: Type B normal distribution
Value: 4447.2 mg
Expanded Uncertainty: .17 mg
Coverage Factor: 1

m_{std_drift}: Type B rectangular distribution
Value: 0 mg
Halfwidth of Limits: .2 mg

m_{std_round}: Type B rectangular distribution
Value: 0 mg
Halfwidth of Limits: .05 mg

V_{1000_cal}: Type B rectangular distribution
Value: 1 l
Halfwidth of Limits: .0006 l

V_{1000_rep}: Type B rectangular distribution
Value: 0 l
Halfwidth of Limits: .00009 l

If the flask is filled dropwise, then it is not likely, that the uncertainty is larger than ± 3 drops. Uncertainty ± 0.09 ml roughly corresponds ± 3 drops.

$A_{sample_chemical}$drift: Type B rectangular distribution
Value: 0 AU
Halfwidth of Limits: 0.01732 AU

Interim Results:

Quantity	Value	Standard Uncertainty
C_{500}	27.899 µg/ml	0.638 µg/ml
V_{500}	500.000 ml	0.299 ml
V_{500_temp}	0.0 ml	0.182 ml
m_{sample}	2542.100 mg	0.154 mg
A_{sample}	0.4740 AU	0.0105 AU
V_{sample_10}	10.0000 ml	0.0437 ml
V_{10_temp}	0.0 ml	$3.64 \cdot 10^{-3}$ ml
$V_{sample\_reagent}$	10.0000 ml	0.0437 ml
$V_{reagent\_temp}$	0.0 ml	$3.64 \cdot 10^{-3}$ ml
b_0	$320 \cdot 10^{-6}$ AU	$2.24 \cdot 10^{-3}$ AU
b_1	0.033957 AU·ml/µg	$257 \cdot 10^{-6}$ AU·ml/µg
AvgC	10.6159 µg/ml	0.0377 µg/ml
AvgA	0.360800 AU	$931 \cdot 10^{-6}$ AU
ΣCC	773.04 (µg/ml)²	6.20 (µg/ml)²
ΣCA	26.267 AU·µg/ml	0.123 AU·µg/ml
A_1	0.08600 AU	$1.76 \cdot 10^{-3}$ AU
A_2	0.17300 AU	$1.91 \cdot 10^{-3}$ AU
A_3	0.34100 AU	$2.02 \cdot 10^{-3}$ AU
A_4	0.51800 AU	$2.25 \cdot 10^{-3}$ AU
A_5	0.68600 AU	$2.40 \cdot 10^{-3}$ AU
C_1	2.5276 µg/ml	0.0246 µg/ml
C_2	5.0552 µg/ml	0.0400 µg/ml
C_3	10.1104 µg/ml	0.0701 µg/ml
C_4	15.1656 µg/ml	0.0931 µg/ml
C_5	20.221 µg/ml	0.124 µg/ml
V_{1_stock}	0.50000 ml	$4.51 \cdot 10^{-3}$ ml
V_{1_100}	100.000 ml	0.184 ml
V_{1_10}	10.0000 ml	0.0437 ml
$V_{1\_reagent}$	10.0000 ml	0.0437 ml
V_{2_stock}	1.00000 ml	$7.03 \cdot 10^{-3}$ ml
V_{2_100}	100.000 ml	0.184 ml
V_{2_10}	10.0000 ml	0.0437 ml
$V_{2\_reagent}$	10.0000 ml	0.0437 ml
V_{3_stock}	2.0000 ml	0.0118 ml

Quantity	Value	Standard Uncertainty
V_{3_100}	100.000 ml	0.184 ml
V_{3_10}	10.0000 ml	0.0437 ml
$V_{3\_reagent}$	10.0000 ml	0.0437 ml
V_{4_stock}	3.0000 ml	0.0148 ml
V_{4_100}	100.000 ml	0.184 ml
V_{4_10}	10.0000 ml	0.0437 ml
$V_{4\_reagent}$	10.0000 ml	0.0437 ml
V_{5_stock}	4.0000 ml	0.0198 ml
V_{5_100}	100.000 ml	0.184 ml
V_{5_10}	10.0000 ml	0.0437 ml
$V_{5\_reagent}$	10.0000 ml	0.0437 ml
$V_{1\_stock\_temp}$	0.0 ml	$182 \cdot 10^{-6}$ ml
$V_{2\_stock\_temp}$	0.0 ml	$364 \cdot 10^{-6}$ ml
$V_{3\_stock\_temp}$	0.0 ml	$727 \cdot 10^{-6}$ ml
$V_{4\_stock\_temp}$	0.0 ml	$1.09 \cdot 10^{-3}$ ml
$V_{5\_stock\_temp}$	0.0 ml	$1.45 \cdot 10^{-3}$ ml
$V_{1\_100\_temp}$	0.0 ml	0.0364 ml
$V_{2\_100\_temp}$	0.0 ml	0.0364 ml
$V_{3\_100\_temp}$	0.0 ml	0.0364 ml
$V_{4\_100\_temp}$	0.0 ml	0.0364 ml
$V_{5\_100\_temp}$	0.0 ml	0.0364 ml
C_{stock}	1011.037 mg/l	0.777 mg/l
m_{std}	4447.200 mg	0.208 mg
V_{1000}	1.000000 l	$505 \cdot 10^{-6}$ l
V_{1000_temp}	0.0 l	$364 \cdot 10^{-6}$ l

Uncertainty Budgets:

Q_{sample}: **Phosphorus content of the feed sample**

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
C_{500}	27.899 µg/ml	0.638 µg/ml				
V_{500}	500.000 ml	0.299 ml				
V_{500_cal}	500.000 ml	0.231 ml	rectangular	0.012	$2.7 \cdot 10^{-3}$ mg/g	0.0 %
V_{500_rep}	0.0 ml	0.0520 ml	rectangular	0.012	$600 \cdot 10^{-6}$ mg/g	0.0 %
V_{500_temp}	0.0 ml	0.182 ml				
m_{sample}	2542.100 mg	0.154 mg				
R	0.9500 unitless	0.0400 unitless	normal	-6.1	-0.24 mg/g	77.3 %
m_{sample_0}	2542.1000 mg	0.0981 mg	rectangular	$-2.3 \cdot 10^{-3}$	$-220 \cdot 10^{-6}$ mg/g	0.0 %
m_{sample_drift}	0.0 mg	0.115 mg	rectangular	$-2.3 \cdot 10^{-3}$	$-260 \cdot 10^{-6}$ mg/g	0.0 %
m_{sample_round}	0.0 mg	0.0289 mg	rectangular	$-2.3 \cdot 10^{-3}$	$-66 \cdot 10^{-6}$ mg/g	0.0 %
Δt	0.0 °C	1.73 °C	rectangular	not valid!	0.0 mg/g	0.0 %
γ	$210.0 \cdot 10^{-6}$ 1/°C					
A_{sample}	0.4740 AU	0.0105 AU				
A_{sample_rep}	0.47400 AU	$3.00 \cdot 10^{-3}$ AU	normal	12	0.037 mg/g	1.7 %
A_{sample_drift}	0.0 AU	$1.44 \cdot 10^{-3}$ AU	rectangular	12	0.018 mg/g	0.4 %
A_{sample_round}	0.0 AU	$289 \cdot 10^{-6}$ AU	rectangular	12	$3.5 \cdot 10^{-3}$ mg/g	0.0 %
V_{sample_10}	10.0000 ml	0.0437 ml				
V_{10_cal}	10.0000 ml	0.0173 ml	rectangular	not valid!	$-430 \cdot 10^{-21}$ mg/g	0.0 %
$V_{sample\_10\_rep}$	0.0 ml	0.0400 ml	normal	-0.29	-0.012 mg/g	0.2 %
V_{10_temp}	0.0 ml	$3.64 \cdot 10^{-3}$ ml				
$V_{sample\_reagent}$	10.0000 ml	0.0437 ml				
$V_{reagent\_cal}$	10.0000 ml	0.0173 ml	rectangular	not valid!	$-430 \cdot 10^{-21}$ mg/g	0.0 %

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$V_{sample\_reagent\_rep}$	0.0 ml	0.0400 ml	normal	0.29	0.012 mg/g	0.2 %
$V_{reagent\_temp}$	0.0 ml	$3.64 \cdot 10^{-3}$ ml				
b_0	$320 \cdot 10^{-6}$ AU	$2.24 \cdot 10^{-3}$ AU				
b_1	0.033957 AU·ml/µg	$257 \cdot 10^{-6}$ AU·ml/µg				
n	5.0 unitless					
AvgC	10.6159 µg/ml	0.0377 µg/ml				
AvgA	0.360800 AU	$931 \cdot 10^{-6}$ AU				
ΣCC	773.04 (µg/ml)²	6.20 (µg/ml)²				
ΣCA	26.267 AU·µg/ml	0.123 AU·µg/ml				
A_1	0.08600 AU	$1.76 \cdot 10^{-3}$ AU				
A_2	0.17300 AU	$1.91 \cdot 10^{-3}$ AU				
A_3	0.34100 AU	$2.02 \cdot 10^{-3}$ AU				
A_4	0.51800 AU	$2.25 \cdot 10^{-3}$ AU				
A_5	0.68600 AU	$2.40 \cdot 10^{-3}$ AU				
A_{1rep}	0.08600 AU	$1.30 \cdot 10^{-3}$ AU	normal	-0.87	$-1.1 \cdot 10^{-3}$ mg/g	0.0 %
A_{2rep}	0.17300 AU	$1.40 \cdot 10^{-3}$ AU	normal	-1.4	$-1.9 \cdot 10^{-3}$ mg/g	0.0 %
A_{3rep}	0.34100 AU	$1.50 \cdot 10^{-3}$ AU	normal	-2.3	$-3.5 \cdot 10^{-3}$ mg/g	0.0 %
A_{4rep}	0.51800 AU	$1.70 \cdot 10^{-3}$ AU	normal	-3.3	$-5.6 \cdot 10^{-3}$ mg/g	0.0 %
A_{5rep}	0.68600 AU	$1.80 \cdot 10^{-3}$ AU	normal	-4.3	$-7.7 \cdot 10^{-3}$ mg/g	0.0 %
A_{1drift}	0.0 AU	$1.15 \cdot 10^{-3}$ AU	rectangular	-0.87	$-1.0 \cdot 10^{-3}$ mg/g	0.0 %

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
A_{2drift}	0.0 AU	$1.27 \cdot 10^{-3}$ AU	rectangular	-1.4	$-1.7 \cdot 10^{-3}$ mg/g	0.0 %
A_{3drift}	0.0 AU	$1.33 \cdot 10^{-3}$ AU	rectangular	-2.3	$-3.1 \cdot 10^{-3}$ mg/g	0.0 %
A_{4drift}	0.0 AU	$1.44 \cdot 10^{-3}$ AU	rectangular	-3.3	$-4.8 \cdot 10^{-3}$ mg/g	0.0 %
A_{5drift}	0.0 AU	$1.56 \cdot 10^{-3}$ AU	rectangular	-4.3	$-6.7 \cdot 10^{-3}$ mg/g	0.0 %
A_{1round}	0.0 AU	$289 \cdot 10^{-6}$ AU	rectangular	-0.87	$-250 \cdot 10^{-6}$ mg/g	0.0 %
A_{2round}	0.0 AU	$289 \cdot 10^{-6}$ AU	rectangular	-1.4	$-390 \cdot 10^{-6}$ mg/g	0.0 %
A_{3round}	0.0 AU	$289 \cdot 10^{-6}$ AU	rectangular	-2.3	$-680 \cdot 10^{-6}$ mg/g	0.0 %
A_{4round}	0.0 AU	$289 \cdot 10^{-6}$ AU	rectangular	-3.3	$-960 \cdot 10^{-6}$ mg/g	0.0 %
A_{5round}	0.0 AU	$289 \cdot 10^{-6}$ AU	rectangular	-4.3	$-1.2 \cdot 10^{-3}$ mg/g	0.0 %
C_1	2.5276 µg/ml	0.0246 µg/ml				
C_2	5.0552 µg/ml	0.0400 µg/ml				
C_3	10.1104 µg/ml	0.0701 µg/ml				
C_4	15.1656 µg/ml	0.0931 µg/ml				
C_5	20.221 µg/ml	0.124 µg/ml				
V_{1_stock}	0.50000 ml	$4.51 \cdot 10^{-3}$ ml				
V_{1_100}	100.000 ml	0.184 ml				
V_{1_10}	10.0000 ml	0.0437 ml				
$V_{1\_reagent}$	10.0000 ml	0.0437 ml				
V_{2_stock}	1.00000 ml	$7.03 \cdot 10^{-3}$ ml				
V_{2_100}	100.000 ml	0.184 ml				
V_{2_10}	10.0000 ml	0.0437 ml				
$V_{2\_reagent}$	10.0000 ml	0.0437 ml				
V_{3_stock}	2.0000 ml	0.0118 ml				

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
V_{3_100}	100.000 ml	0.184 ml				
V_{3_10}	10.0000 ml	0.0437 ml				
$V_{3\_reagent}$	10.0000 ml	0.0437 ml				
V_{4_stock}	3.0000 ml	0.0148 ml				
V_{4_100}	100.000 ml	0.184 ml				
V_{4_10}	10.0000 ml	0.0437 ml				
$V_{4\_reagent}$	10.0000 ml	0.0437 ml				
V_{5_stock}	4.0000 ml	0.0198 ml				
V_{5_100}	100.000 ml	0.184 ml				
V_{5_10}	10.0000 ml	0.0437 ml				
$V_{5\_reagent}$	10.0000 ml	0.0437 ml				
$V_{1\_stock\_cal}$	0.50000 ml	$4.04 \cdot 10^{-3}$ ml	rectangular	0.15	$600 \cdot 10^{-6}$ mg/g	0.0 %
$V_{1\_stock\_rep}$	0.0 ml	$2.00 \cdot 10^{-3}$ ml	normal	0.15	$300 \cdot 10^{-6}$ mg/g	0.0 %
$V_{1\_stock\_temp}$	0.0 ml	$182 \cdot 10^{-6}$ ml				
$V_{2\_stock\_cal}$	1.00000 ml	$5.77 \cdot 10^{-3}$ ml	rectangular	0.23	$1.3 \cdot 10^{-3}$ mg/g	0.0 %
$V_{2\_stock\_rep}$	0.0 ml	$4.00 \cdot 10^{-3}$ ml	normal	0.23	$930 \cdot 10^{-6}$ mg/g	0.0 %
$V_{2\_stock\_temp}$	0.0 ml	$364 \cdot 10^{-6}$ ml				
$V_{3\_stock\_cal}$	2.00000 ml	$8.66 \cdot 10^{-3}$ ml	rectangular	0.40	$3.5 \cdot 10^{-3}$ mg/g	0.0 %
$V_{3\_stock\_rep}$	0.0 ml	$8.00 \cdot 10^{-3}$ ml	normal	0.40	$3.2 \cdot 10^{-3}$ mg/g	0.0 %
$V_{3\_stock\_temp}$	0.0 ml	$727 \cdot 10^{-6}$ ml				
$V_{4\_stock\_cal}$	3.00000 ml	$8.66 \cdot 10^{-3}$ ml	rectangular	0.57	$4.9 \cdot 10^{-3}$ mg/g	0.0 %
$V_{4\_stock\_rep}$	0.0 ml	0.0120 ml	normal	0.57	$6.8 \cdot 10^{-3}$ mg/g	0.0 %
$V_{4\_stock\_temp}$	0.0 ml	$1.09 \cdot 10^{-3}$ ml				
$V_{5\_stock\_cal}$	4.0000 ml	0.0115 ml	rectangular	0.74	$8.5 \cdot 10^{-3}$ mg/g	0.0 %
$V_{5\_stock\_rep}$	0.0 ml	0.0160 ml	normal	0.74	0.012 mg/g	0.2 %
$V_{5\_stock\_temp}$	0.0 ml	$1.45 \cdot 10^{-3}$ ml				

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$V_{1\_100\_cal}$	100.000 ml	0.173 ml	rectangular	$-750 \cdot 10^{-6}$	$-130 \cdot 10^{-6}$ mg/g	0.0 %
$V_{1\_100\_rep}$	0.0 ml	0.0520 ml	rectangular	$-750 \cdot 10^{-6}$	$-39 \cdot 10^{-6}$ mg/g	0.0 %
$V_{1\_100\_temp}$	0.0 ml	0.0364 ml				
$V_{2\_100\_cal}$	100.000 ml	0.173 ml	rectangular	$-2.3 \cdot 10^{-3}$	$-400 \cdot 10^{-6}$ mg/g	0.0 %
$V_{2\_100\_rep}$	0.0 ml	0.0520 ml	rectangular	$-2.3 \cdot 10^{-3}$	$-120 \cdot 10^{-6}$ mg/g	0.0 %
$V_{2\_100\_temp}$	0.0 ml	0.0364 ml				
$V_{3\_100\_cal}$	100.000 ml	0.173 ml	rectangular	$-8.1 \cdot 10^{-3}$	$-1.4 \cdot 10^{-3}$ mg/g	0.0 %
$V_{3\_100\_rep}$	0.0 ml	0.0520 ml	rectangular	$-8.1 \cdot 10^{-3}$	$-420 \cdot 10^{-6}$ mg/g	0.0 %
$V_{3\_100\_temp}$	0.0 ml	0.0364 ml				
$V_{4\_100\_cal}$	100.000 ml	0.173 ml	rectangular	-0.017	$-2.9 \cdot 10^{-3}$ mg/g	0.0 %
$V_{4\_100\_rep}$	0.0 ml	0.0520 ml	rectangular	-0.017	$-880 \cdot 10^{-6}$ mg/g	0.0 %
$V_{4\_100\_temp}$	0.0 ml	0.0364 ml				
$V_{5\_100\_cal}$	100.000 ml	0.173 ml	rectangular	-0.030	$-5.1 \cdot 10^{-3}$ mg/g	0.0 %
$V_{5\_100\_rep}$	0.0 ml	0.0520 ml	rectangular	-0.030	$-1.5 \cdot 10^{-3}$ mg/g	0.0 %
$V_{5\_100\_temp}$	0.0 ml	0.0364 ml				
$V_{1\_10\_rep}$	0.0 ml	0.0400 ml	normal	$3.7 \cdot 10^{-3}$	$150 \cdot 10^{-6}$ mg/g	0.0 %
$V_{2\_10\_rep}$	0.0 ml	0.0400 ml	normal	0.012	$460 \cdot 10^{-6}$ mg/g	0.0 %
$V_{3\_10\_rep}$	0.0 ml	0.0400 ml	normal	0.040	$1.6 \cdot 10^{-3}$ mg/g	0.0 %
$V_{4\_10\_rep}$	0.0 ml	0.0400 ml	normal	0.085	$3.4 \cdot 10^{-3}$ mg/g	0.0 %
$V_{5\_10\_rep}$	0.0 ml	0.0400 ml	normal	0.15	$5.9 \cdot 10^{-3}$ mg/g	0.0 %
$V_{1\_reagent\_rep}$	0.0 ml	0.0400 ml	normal	$-3.7 \cdot 10^{-3}$	$-150 \cdot 10^{-6}$ mg/g	0.0 %
$V_{2\_reagent\_rep}$	0.0 ml	0.0400 ml	normal	-0.012	$-460 \cdot 10^{-6}$ mg/g	0.0 %

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$V_{3\_reagent\_rep}$	0.0 ml	0.0400 ml	normal	-0.040	$-1.6 \cdot 10^{-3}$ mg/g	0.0 %
$V_{4\_reagent\_rep}$	0.0 ml	0.0400 ml	normal	-0.085	$-3.4 \cdot 10^{-3}$ mg/g	0.0 %
$V_{5\_reagent\_rep}$	0.0 ml	0.0400 ml	normal	-0.15	$-5.9 \cdot 10^{-3}$ mg/g	0.0 %
C_{stock}	1011.037 mg/l	0.777 mg/l				
M_P	30.97 g/mol					
M_{KH2PO4}	136.09 g/mol					
P	0.999000 unitless	$577 \cdot 10^{-6}$ unitless	rectangular	5.8	$3.3 \cdot 10^{-3}$ mg/g	0.0 %
m_{std}	4447.200 mg	0.208 mg				
V_{1000}	1.000000 l	$505 \cdot 10^{-6}$ l				
m_{std_0}	4447.200 mg	0.170 mg	normal	$1.3 \cdot 10^{-3}$	$220 \cdot 10^{-6}$ mg/g	0.0 %
m_{std_drift}	0.0 mg	0.115 mg	rectangular	$1.3 \cdot 10^{-3}$	$150 \cdot 10^{-6}$ mg/g	0.0 %
m_{std_round}	0.0 mg	0.0289 mg	rectangular	$1.3 \cdot 10^{-3}$	$37 \cdot 10^{-6}$ mg/g	0.0 %
V_{1000_cal}	1.000000 l	$346 \cdot 10^{-6}$ l	rectangular	-5.8	$-2.0 \cdot 10^{-3}$ mg/g	0.0 %
V_{1000_rep}	0.0 l	$52.0 \cdot 10^{-6}$ l	rectangular	-5.8	$-300 \cdot 10^{-6}$ mg/g	0.0 %
V_{1000_temp}	0.0 l	$364 \cdot 10^{-6}$ l				
$A_{sample_chemical}$drift	0.0 AU	0.0100 AU	rectangular	12	0.12 mg/g	19.4 %
Q_{sample}	5.776 mg/g	0.277 mg/g				

Results:

Quantity	Value	Expanded Uncertainty	Coverage factor	Coverage
Q_{sample}	5.78 mg/g	0.55 mg/g	2.00	manual