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A STUDY OF FACTORS AFFECTING CALIBRATIONS AND
CALCULATIONS FOR THE MONOCHROMATIC
X-RAY ABSORPTION-EDGE
ANALYTICAL METHOD

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**A STUDY OF FACTORS AFFECTING CALIBRATIONS AND
CALCULATIONS FOR THE MONOCHROMATIC X-RAY
ABSORPTION-EDGE ANALYTICAL METHOD**

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ABSTRACT

A modified calculation equation gave results more closely following the known values of standard samples. Recommendations are given for improving the choice of standards and calibration procedure for the monochromatic X-ray absorption method.

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SUMMARY

Investigation of the causes of variable results in the X-ray absorption-edge method of analysis led to a study of the equipment calibration and calculation techniques. The mathematical form of the equation was found to be that of a plane in space rather than a line, as previously supposed. No provision was made for concentration intercept with solutions containing none of the element being sought.⁽¹⁾ Addition of a zero concentration intercept gave a calculation equation of the form:

$$\text{Concentration of Element} = K_0 + K_1 R_1 + K_2 R_2 \quad ,$$

where K_0 , K_1 , and K_2 represent experimentally derived constants. R_1 and R_2 are logarithms of the ratio of the X-ray counts taken through water (reference) to the X-ray counts taken through the sample at Angles 1 and 2 on either side of the element absorption edge.

The calculation equation was derived from measurements on standard solutions. Multiple linear regression techniques were employed to compute the equation giving the best least-squares fit to the experimental data. The resulting equation fit the experimental results more closely over the entire range of interest than did the equation without the K_0 constant.

Based on these findings, recommendations are made for improving the method by using the more exact equation form computed by multiple linear regression from composite data of several measurements on standards. The choice of standards for calibration could be altered to more adequately cover the concentration range of interest.

It was demonstrated that an equation calculated from composite data could be used for ten weeks or more without recomputation, thereby reducing the time spent in frequent instrument calibration and equation computations.

INTRODUCTION

X-ray absorption-edge analysis is used extensively by the Plant Laboratory at the Oak Ridge Y-12 Plant^(a) for measurement of uranium in solutions.^(2, 3) Inconsistencies observed in the results obtained from quality control samples led to the present study. The method requires dilution of the sample solution so as to place the uranium content within certain concentration limits. A radiation-type prescreening concentration meter is used to provide an approximate uranium concentration as a basis for the required dilution prior to the absorption-edge measurements.

Degradation of the quality control sample results coincided with a change in the prescreening concentration meter equipment. Examination of the data from repeated analyses of the same control sample *revealed less consistent prescreening concentration estimates* which made for wider variations in the amount of dilution indicated. Even though within the allowable concentration range, X-ray absorption-edge analysis results varied with the uranium concentration of the diluted solution, showing an undesirable nonlinearity in the procedure.

The ensuing investigation included studies of equipment adjustments, standards choice, method of instrument standardization, and methods of calculation.

A brief summary of the X-ray absorption-edge method is given in Appendix A.

(a) Operated by the Union Carbide Corporation's Nuclear Division for the US Atomic Energy Commission.

FACTORS AFFECTING X-RAY ABSORPTION-EDGE METHOD

EQUIPMENT CHECK

One possible source of the variability in the analytical results was an inconsistency in equipment alignment and settings. However, a check showed that the X-ray counting equipment was operating properly. The X-ray tube voltage was set at 31 kilovolts, well below the 34 kilovolts needed to generate radiation with energy equivalent to the second order of the L_{III} absorption edge of uranium (17.16 kV). The second-order radiation would pass through to the counting system at the same crystal angle setting as the first-order radiation.

A recheck of the goniometer alignment of the General Electric XRD-5 X-ray unit showed a drift from zero of less than 0.02 degree over a period of a year. This small amount of drift is insufficient to cause any noticeable change in the results. Corrections were made to bring the goniometer back to its optimum alignment. A new sodium chloride crystal was installed to replace the old one, now etched. No reason for variability of results was found in the equipment.

CALCULATION EQUATIONS

Traditional Equation

A possible source of variation lay in the nonlinearity of the calculation equation. The equation, as derived^(1, 2) and used, was:

$$\text{Uranium Concentration} = K_1 \log \frac{Cw_1}{Cs_1} - K_2 \log \frac{Cw_2}{Cs_2} , \quad (1)$$

where the concentration is in terms of grams of uranium per milliliter of solution analyzed, K_1 and K_2 are the experimentally determined constants characteristic of the sample type and the sample cell, Cw_1 and Cw_2 are the mean X-ray counts taken through water (reference) at Angles 1 and 2 on either side of the uranium absorption edge and accumulated for a preset time, and Cs_1 and Cs_2 are the mean X-ray counts taken through the sample at Angles 1 and 2 and accumulated for a preset time. Equation 1 can be simplified to:

$$C = K_1 R_1 + K_2 R_2 , \quad (2)$$

where R_1 and R_2 are logarithms of the ratio of the X-ray counts through water to the X-ray counts through the sample at Angles 1 and 2, respectively. Equation 2 is the equation for a plane in space and assumes that the plane will pass through the 0-0-0 axes point.

A Generalized Equation

A more general form of the equation for a plane includes a constant, K_0 , for the concentration intercept at zero R_1 and R_2 values:

$$C = K_0 + K_1 R_1 + K_2 R_2 \quad (3)$$

A common situation with instrumental straightline calibrations is linearity over a limited range of concentrations. Extrapolation to zero reading often gives a definite concentration intercept plus or minus. Evidence that a similar situation existed with the planar equation of X-ray absorption was shown by certain uranium standards which generally gave high or low results when calculated back by an experimentally derived equation based on the standard X-ray readings.

Experimental Tests of Equations 2 and 3

To test the fit of Equations 2 and 3, data were collected on five standard uranium solutions routinely analyzed. Data from 23 days over a two-month period were used to solve for K_0 , K_1 , and K_2 in Equation 3 by multiple linear regression techniques giving a least-squares fit of a plane to the data points. These same data plus X-ray measurements on these standards for additional days covering a three-month period (39 days total) were used to calculate the K_1 and K_2 values in Equation 2. Data values for the standards were inserted in Equation 1, providing equations in two unknowns. The equations for each of two pure standard solutions were paired with the equation for each of three impure standard solutions. A solution of the six pairs of simultaneous equations provided K_1 and K_2 values which were averaged to give the calculation equation.⁽³⁾

The standards concentrations, based on the derived equations, were calculated by inserting the X-ray readings of the standards into the derived equations for the day. The results are reported in Tables B-1 and B-2, Appendix B.

The standard solutions were uranyl nitrate, some of which had added impurities such as ferric nitrate. Four of the five standards calculated back from the two-constant equation (Equation 2) showed a significant bias. All five standards calculated back from the least squares fit solution of Equation 3 gave concentrations very close to the accepted values. (Note: A least-squares solution using the standards in Equation 2 with $K_0 = 0$ gave results almost identical to those obtained by averaging results of six pairs of simultaneous equations. This solution shows the means of K_1 and K_2 values to be quite good.)

The much-improved agreement of the calculated to the accepted standards values shows that the addition of the K_0 intercept value in Equation 3 is desirable.

CHOICE OF STANDARDS

Laboratory Practice

The usual choice of standards in the Y-12 Plant Laboratory for the concentration range studied was 7500 to 10,000 micrograms of uranium per milliliter for impure solutions and 10,000 to 15,000 micrograms of uranium per milliliter for pure solutions. This selection does not adequately cover the entire planar area of interest for both pure and impure samples.

Standards of Maximum and Minimum Concentrations

Experiments were conducted with three standards each of the 7500 and 15,000 micrograms per milliliter concentrations. Each concentration included pure, intermediate-impurity, and

high-impurity standards. The iron-containing standards contained the greatest amount of impurities, while tin or aluminum were inserted in the X-ray beam with the pure uranium standards to provide conditions for intermediate impurity levels. X-ray measurements were made on these six standards on seven days. Least-squares fit solutions for Equation 3 were computed each day and data calculated back from the derived equations as before. The data are given in Table B-3, Appendix B.

No significant differences between the mean calculated values and accepted values were observed. The least-squares fit plane of Equation 3, therefore, adequately covered the data points.

Standards Covering Center and Extremes of Concentrations

A more representative choice of standards included 7500 and 15,000 micrograms of uranium per milliliter in both the pure and maximum impurity forms, plus two standards of intermediate purity at 10,000 and 12,000 micrograms of uranium per milliliter. These six standards were measured on each of nine days. Least-squares fit solutions to Equation 3 were computed each day and the data entered into the derived equations to calculate back the concentration of the standards as before. The mean calculated concentrations showed no significant deviation from the accepted values. The data are summarized in Table B-4, Appendix B.

The results of this and the previous experiment showed no significant curvature of the experimental concentration plane with varying uranium or impurity concentrations.

COMPUTATION OF EQUATION CONSTANTS

Daily Computation

Recent practice in the Y-12 Plant Laboratory has been to compute a new calculation equation daily. This practice has been made possible by the availability of desk-top and time-sharing computers to perform the calculations.

Due to the random nature of X-ray generation and counting, the measured values of R_1 and R_2 in Equation 3 vary by as much as 0.7% from day to day or even on the same day for any given standard solution. Computed K values in Equation 3 are therefore not truly representative when based on only one set of X-ray measurements. Several measurements are necessary to obtain a reliable average value.

Computation from Composite Data

X-ray measurements taken on each of nine days of the six standards, covering center and extremes of uranium concentration range, were pooled to compute the K values for Equation 3 by multiple linear regression techniques. Representative K values obtained were $K_0 = 0.000141$, $K_1 = 0.032471$, and $K_2 = 0.029378$. The computed equation was then used to calculate results from 230 measurements of standards taken over a 2 1/2-month period. The 54 measurements used in the composite equation calculation were included. Earlier measurements were not included because these were taken with an old sample cell which

became unusable. Computed equations are valid only for the cell in which measurements were taken. Results are tabulated in Table B-5, Appendix B.

Statistical analysis showed no significant differences in the standard deviations with varying concentration levels of the standards. All 230 results were pooled to calculate an overall standard deviation of ± 38.6 micrograms of uranium per milliliter of solution over the tested range of 7500 to 15,000 micrograms per milliliter. The greatest deviation of a mean from the accepted value of a standard was 22 micrograms of uranium per milliliter.

A time-sharing computer program for calculating K values has been written. K values are easily computed by entering the X-ray count readings of standards in the order requested by the program. New composite equations are calculated as new readings are obtained until the desired number of sets of readings are accumulated. A printout from this program is presented in Appendix C.

CHOICE OF ANALYSIS ANGLES

The 2θ sodium chloride crystal angles chosen for the goniometer settings were determined from a curve of X-ray counts taken through a uranium solution at various angle settings around the absorption edge of uranium. Figure 1 is a graph for both a narrow, 0.1-degree detector slit, as used with a small cell [1/2 inch (1.3 cm) path length], and a 0.3-degree detector slit, as used with a large cell [1 inch (2.5 cm) path length].

The optimum angle setting for best sensitivity would be at the maximum and minimum X-ray counts on either side of the uranium absorption edge. A small margin of error in angle beyond the absorption edge should be allowed to include any possible drift in goniometer adjustment over a period of time. The observed drift has been 0.02 to 0.03 degree 2θ over periods of up to one year. A setting of 0.05 degree on either side of the experimentally located absorption edge would allow for normal drift before realignment of the goniometer is needed.

In one experiment with the small cell and a 0.1-degree detector slit for uranium analysis, a 2θ angle setting at 0.05 degree from the absorption edge breaks gave an increase in count differential between Angles 1 and 2 of 22.5% over the settings of 14.45 and 15.00 degrees routinely used in the Plant Laboratory. The latter settings are approximately 0.2 degree away from the absorption edge for the small sample cell used in these experiments.

Figure 1. EXPERIMENTAL URANIUM L_{III} ABSORPTION EDGE. (Curve A with a 0.1-Degree Detector Slit; Curve B with a 0.3-Degree Detector Slit)

CONCLUSIONS

The variation in results from the laboratory uranium control samples was due to poor fit of the calculation equation based on Equation 2. The plane represented by this equation was forcibly tilted to pass through the 0-0-0 axes point. Variability in the prescreening concentration estimates resulted in variable dilutions of the control samples before analysis. Any sample, diluted so as to lie away from the central concentration area, fell in a tilted portion of the calculated plane. Insertion of a concentration intercept, K_0 , as in Equation 3, provided a plane which more nearly followed laboratory measurements.

Choosing the standards to cover the extremes and center of the concentration range provided more complete coverage of the range. The traditional standards did not cover the entire planar range for both the pure and impure samples.

A more representative equation was calculated from X-ray readings of several sets of standards taken over a period of several days. Such a composite equation holds over an extended time, requiring new computations only when some obvious change has occurred.

The criteria found for the automated XRD-5 instrument on which these experiments were conducted are applicable to other elements, concentrations, and instruments.

RECOMMENDATIONS FOR IMPROVEMENT OF X-RAY ABSORPTION ANALYSIS

Improvements in X-ray absorption analysis can be realized through the following suggestions:

1. Use an equation which accounts for a concentration intercept:

$$\text{Element Concentration} = K_0 + K_1 R_1 + K_2 R_2 \quad (3)$$

2. Choose standards to cover the four extreme concentrations of interest plus two standards near average in concentration both as to element being analyzed and impurity level.
3. Calculate the K factors in Equation 3 by a least-squares fit, multiple-linear-regression technique from composite readings of standards measured over a period of several days (≥ 5). Separate K factors are needed for each element, cell, instrument, and slit width as at present.
4. Use the same K values until the need for change is demonstrated by the daily analysis of two control samples. Control sample element concentrations should lie within the range of interest rather than at the extremes, preferably in the area of the greatest number of samples analyzed.
 - a. New K values are needed when the control sample results lie outside the long-term statistical limits (± 3 standards deviations from the accepted value) as established by experience. For small-cell uranium analysis on the automated XRD-5, the limits were

found to be ± 114 (3×38) for all concentrations from 7500 to 15,000 micrograms of uranium per milliliter.

- b. New K values are needed in the case of a definite drift of control results. The control sample results should be plotted daily on a chart to detect any drifting trends.
5. Bring the angle settings used closer to the X-ray absorption edge of the element analyzed. A margin of 0.05 degree would compensate for normal drift.

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APPENDIX A

SUMMARY OF THE X-RAY ABSORPTION-EDGE METHOD

Samples must be in solution form for final X-ray measurements. Solids must be dissolved or leached to recover the uranium. The incoming sample is prescreened for approximate uranium concentration by placing the sample bottle in a radiation counting chamber. Based on the prescreening results, the sample solution is diluted to lie within an appropriate uranium concentration range for final X-ray absorption-edge readings. For example, a solution of 22,000 micrograms of uranium per milliliter would be diluted to twice its volume to produce a final concentration of 11,000 micrograms of uranium per milliliter. This value lies near the center of one of the analysis ranges of 7500 to 15,000 micrograms of uranium per milliliter.

A portion of the diluted sample is placed in a sample cell in the beam of an X-ray spectrometer (Figure A-1). A set of three measurements of the X rays passing through the sample is taken at wavelengths on either side of the X-ray absorption edge of uranium. Substitution of the readings in Equation 1 (Page 8) gives the uranium concentration of the diluted solution. Application of appropriate dilution factors and sample weights gives the grams of uranium per gram of incoming sample.

Figure A-1. PRINCIPAL COMPONENTS OF THE X-RAY ABSORPTION SYSTEM.

APPENDIX B

DETAILED CALCULATED DATA

Table B-1

CALCULATED VALUES OF STANDARDS FROM EQUATIONS
 DERIVED DAILY BY SOLUTION OF SIMULTANEOUS EQUATIONS
 (No Zero Reading Intercept - See Equation 2)

Date		Accepted Concentration of Solution ($\mu\text{g U/ml}$)				
		7500 Fe	10000 Fe	10000 Pure	12000 Pure	15000 Pure
May	31	7453	10047	10008	12009	14976
June	1	7513	9987	9968	11995	15055
	5	7493	10008	9983	11982	15050
	6	7520	9980	10009	12009	14976
	7	7466	10041	9969	11946	15118
	8	7534	9958	9987	12013	15004
	11	7479	10025	9965	11998	15057
	15	7441	10065	9959	11978	15093
	20	7502	9997	9942	12028	15055
	28	7497	10004	9965	12025	15023
	29	7487	10014	9981	12021	15003
July	1	7480	10021	9941	12022	15064
	3	7519	9978	9999	12004	14996
	5	7458	10046	9989	11985	15036
	6	7518	9980	9961	11997	15065
	9	7514	9984	9959	11994	15071
	10	7479	10023	9956	12023	15040
	11	7530	9967	9945	12003	15083
	18	7491	10009	10004	12025	14963
	19	7496	10004	9954	12036	15026
	20	7427	10071	9973	11960	15093
	23	7478	10021	9985	11993	15032
	24	7475	10025	9931	11982	15131
	25	7467	10033	10013	11986	14999
	26	7475	10026	9966	11998	15055
	30	7469	10032	9953	12011	15060
	31	7493	10007	10002	12012	14982
August	3	7495	10005	9953	12036	15027
	6	7496	10004	9978	12030	14996
	7	7474	10027	9961	11998	15063
	8	7465	10036	10014	12010	14966
	9	7502	9998	9977	11994	15043
	14	7502	9998	9997	11984	15025
	20	7465	10035	9978	11968	15075
	24	7492	10008	9969	11966	15092
	28	7464	10036	10019	11996	14976
	31	7480	10021	10002	11994	15005
September	5	7483	10018	9985	11991	15034
	6	7511	9988	9978	11981	15059
Number of Measurements		39	39	39	39	39
Mean		7487	10014	9976	12000	15038

Table B-2
CALCULATED VALUES OF STANDARDS FROM EQUATIONS DERIVED DAILY
BY REGRESSION USING THREE VARIABLES
(Equation Contains K₀ Intercept - See Equation 3)

Date		Accepted Concentration of Solution (µg U/ml)				
		7500 Fe	10000 Fe	10000 Pure	12000 Pure	15000 Pure
May	31	7450	10044	10010	12012	14972
June	1	7529	9972	9989	11993	15017
	5	7509	9992	10007	11982	15011
	6	7509	9991	9990	12008	15001
	7	7511	9992	10026	11946	15026
	8	7533	9973	9973	12008	15013
	11	7505	9990	9999	11990	15004
	14	7493	10023	10003	11975	15006
	15	7483	10015	10023	11979	15000
	20	7526	9977	9970	12023	15003
	29	7494	10006	9991	12022	14988
	6	7539	9966	9981	11992	15022
	9	7537	9967	9983	11990	15022
	10	7501	10000	9986	12022	14991
	18	7484	10017	9993	12026	14981
	19	7510	9991	9975	12034	14991
	20	7489	10032	10038	11982	14999
July	23	7493	10007	10008	11993	14999
	24	7421	9979	10002	11980	15018
	25	7471	10029	10022	11988	14990
	30	7497	10002	9995	12010	14995
	31	7490	10010	9998	12013	14990
August	3	7510	9991	9974	12034	14991
Number of Measurements		23	23	23	23	23
Mean		7499	9999	9997	11999	15001

Table B-3
CALCULATED VALUES OF STANDARDS FROM EQUATIONS DERIVED DAILY
BY REGRESSION - 3 VARIABLES - 6 STANDARDS (SEE EQUATION 3)

Date		Accepted Concentration of Solution (µg U/ml)				
		7500 Pure	7500 Al	7500 Fe	15000 Pure	15000 Al
June	14	7520	7468	7512	14983	15034
	15	7469	7481	7551	15061	14974
	20	7510	7492	7499	15004	14973
	29	7513	7527	7480	14961	15007
July	6	7485	7460	7557	15065	14948
	9	7500	7484	7517	15031	14952
	10	7522	7506	7472	14973	14985
Number of Measurements		7	7	7	7	7
Mean		7503	7488	7510	15011	14982

Table B-4
CALCULATED VALUES OF STANDARDS FROM EQUATIONS OF THREE VARIABLES
DERIVED DAILY BY REGRESSION (SEE EQUATION 3)
(Four Standards of Extremes of Uranium and Impurity Concentrations
and Two Standards of Intermediate Concentrations)

Date		Accepted Concentration of Solution (µg U/ml)				
		7500 Pure	7500 Fe	10000 Al	12000 Al	15000 Pure
July	18	7524	7470	10011	12000	14957
	19	7507	7488	10009	11999	14984
	20	7512	7511	9997	11948	15014
	23	7510	7519	9951	12009	15014
	24	7490	7541	9950	11980	15045
	25	7500	7474	10009	12052	14962
	30	7503	7509	9976	12009	15006
	31	7510	7502	9984	11981	14998
August	3	7512	7504	9990	11976	15003
Number of Measurements		9	9	9	9	9
Mean		7509	7502	9987	11996	14998

Table 8-5

CALCULATED VALUES OF STANDARDS FROM THREE-VARIABLE EQUATION DERIVED FROM COMPOSITE OF MEASUREMENTS ON SIX STANDARDS TAKEN OVER A NINE-DAY PERIOD

		Accepted Concentration of Solution (µg U/ml)										
		7500	7500	7500	10000	10000	10000	12000	12000	15000	15000	15000
Date		Pure	Al	Fe	Pure	Al	Fe	Pure	Al	Pure	Al	Sn
June	20	7523	7523	7551	9971		10017	12034		15027	15015	15077
	28			7544	10053		10031	12104		15086		
	29	7512	7536	7483	10012		9975	12031		14981	15038	15070
July	1	7489		7486	9960		9992	12017		15024		
	3			7542	10067		9976	12059		15030		
	5	7579	7474	7519	10070	10006	10087	12055		15088		
	6	7507	7495	7607	10018		10050	12037		15079	14976	15022
	9	7529	7507	7533	10009		9974	12026		15076	14991	15053
	10	7510	7485	7442	9960		9944	12002		14978	14983	15034
	11			7575	9952		9980	11983		15022		
	18	7538		7528	10059	10037	10015	12055	12022	14956		15066
	19	7525		7482	9991	10021	9964	12052	12013	15012		15026
	20	7479		7425	9974	9955	10033	11933	11917	15023		14992
	23	7481		7472	10018	9924	9988	12005	11988	15013		14982
	24	7477		7520	9950	9956	10039	11976	12002	15087		15016
	25	7538		7517	10035	10037	10053	11984	12069	14962		15005
	26			7473	10007		9997	12020		15049		
	30	7474		7454	9937	9932	9976	11963	11962	14965		14937
31	7548		7569	10029	10005	10055	12016	11981	14953		14996	
August	1		7505	7535	9998	10053	10047	11973	12068		15014	14990
	3	7516		7560	9987	10016	10043	12047	12001	15005		15052
	6			7535	10026		10019	12060		14998		
	7			7502	9974	9946	10023	11986	12048	15011		15020
	8			7532	10021		10070	11990		14906		
	9	7554		7571	10026		10045	12025	12027	15046		15036
	14			7562	10039		10034	12007		15018		
	20			7488	10012		10031	11981		15055		
	24			7554	10006		10045	11982		15075		
	28			7515	10051		10060	12007		14954		
	31			7525	10016		10034	11982		14955		
	September	5			7532	9998		10034	11978		14982	
	6			7532	9977		9974	11952		14986		
Number of Measurements		17	7	32	32	12	32	32	12	31	6	17
Mean		7516	7504	7521	10006	9991	10019	12010	12008	15013	15003	15022
Standard Deviation		30.0	21.6	41.2	35.3	45.3	35.3	37.4	43.8	47.6	23.5	36.4

APPENDIX C

PRINTOUT FROM COMPUTER PROGRAM FOR CALCULATING K VALUES

TYPE DATA IN ORDER GIVEN. PUT 'SPACE' BETWEEN EACH NUMBER.

NEW STDS? Y

NUMBER OF STDS TO BE LISTED? 6

DATE STDS RUN? 19 JUL

H2O CTS- ANG 1(3), ANG 2(3)?

394278 394166 393553 326617 325924 326536

CONC(G/ML) ANG 1 CNTS(3) ANG 2 CNTS(3)

STD	1	.0075	152077	153716	153168	204372	204742	204753
STD 2	.0075	93008	93146	92767	118101	117520	117174	
STD 3	.010	91317	91751	91316	140961	140777	141003	
STD 4	.012	71616	71728	71411	125319	125677	125946	
STD 5	.015	60536	60020	60223	131649	131340	131187	
STD 6	.015	43099	43298	43286	90766	91282	91298	

CONC	AVE CNT1	AVE CNT2
H2O	393999	326359
0.0075	152987	204624
0.0075	92974	117598
0.0100	91461	140914
0.0120	71585	125647
0.0150	60260	131392
0.0150	43228	91115

IS DATA OK? Y

INCLUDE STORED DATA? Y

OPENING FILE 4, SYMBOLIC INPUT, NAME: /REBDXRF/

	AVE CNT1	CONC	% DEV	STD VAL
19 JUL	152987	0.007509	0.1	0.0075
19 JUL	92974	0.007456	-0.6	0.0075
19 JUL	91461	0.010001	0.0	0.0100
19 JUL	71585	0.011995	-0.0	0.0120
19 JUL	60260	0.014999	-0.0	0.0150
19 JUL	43228	0.015007	0.0	0.0150
18 JUL 73	153092	0.007522	0.3	0.0075
18 JUL 73	93279	0.007503	0.0	0.0075
18 JUL 73	91796	0.010018	0.2	0.0100
18 JUL 73	71707	0.012004	0.0	0.0120
18 JUL 73	60566	0.014942	-0.4	0.0150
18 JUL 73	42871	0.015046	0.3	0.0150

DELETE A STD? N

STORE DATA? N

K0= 0.000122

K1= 0.032516

K2= -0.029456

MEAN SQUARE RESIDUAL= 9.32902E-10

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