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DETERMINATION OF HYDROXIDE IN THE PRESENCE OF ALUMINATE
USING A MODIFIED POTENTIOMETRIC TITRATION

Terry J. Hanson

Process Control Laboratories
Engineering Department
Production and Waste Management Division

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ABSTRACT

A procedure for the determination of hydroxide concentration in the presence of aluminate and other interfering ions was developed using the method of standard additions (or more specifically in this case, standard subtractions). The procedure called for titration with a strong acid which was added in equal increments at regular time intervals. The potential was recorded after each addition of acid. The data was plotted on Gran's Plot Paper, which is based on work done originally by Gran¹, or it was entered into a computer to determine the equivalence volume of the titrant. When used on many different samples in different matrices, the method gave results that were approximately $100 \pm 1\%$ of the calculated value. This was shown to be true even in systems containing aluminate $[\text{Al}(\text{OH})_4^-]$, phosphate (PO_4^{3-}) , sulfate (SO_4^{2-}) , nitrate (NO_3^-) , nitrite (NO_2^-) , carbonate (CO_3^{2-}) , and other ions. The effect of these ions was shown to be negligible if the initial OH^- concentration was at least 10^{-3} M and barium chloride (BaCl_2) was added to complex the PO_4^{3-} and CO_3^{2-} ions. These ions were checked at levels of up to 3 M for $\text{Al}(\text{OH})_4^-$ and NO_3^- , 2 M for NO_2^- , and 1 M for SO_4^{2-} , PO_4^{3-} , and CO_3^{2-} . The method is applicable to radioactive as well as nonradioactive samples and any heat involved with a radioactive sample is insufficient to cause an error in the determination. On the basis of the work performed it was shown that the method was general enough to be run on a routine basis.

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INTRODUCTION

For a number of years there has been a problem in analyzing material coming from the processing of nuclear waste material because there has been no simple, accurate procedure for determining the hydroxide concentration in the presence of $\text{Al}(\text{OH})_4^-$. The primary difficulty encountered in determining the OH^- concentration in a system such as this is that as the titration progresses the $\text{Al}(\text{OH})_4^-$ begins to precipitate as $\text{Al}(\text{OH})_3$ in the pH range of 8-10.5 depending upon the initial $\text{Al}(\text{III})$ concentration. This precipitation causes a masking of the endpoint one would normally observe for the titration of a strong base by a strong acid. (See Figure 1) Other anions (notably NO_3^- and NO_2^-) are also present but none of them seem to cause as much trouble as the $\text{Al}(\text{OH})_4^-$. A thermometric method for this analysis has recently been developed by van Dalen² for use in the aluminum industry. Several other procedures also exist^(3,4) for this type of analysis but they are either inaccurate at high $\text{Al}(\text{OH})_4^-$ concentrations or they tend to be time consuming.

Because of the problems involved in developing a truly general technique applicable to all systems, an NaOH solution was used initially and then other species were added one at a time to determine their affect upon the analysis. The first anion to be added was $\text{Al}(\text{OH})_4^-$, then NO_3^- , NO_2^- , and finally PO_4^{3-} , SO_4^{2-} , and CO_3^{2-} . A matrix containing these ions closely approximates the matrix of much of the waste material which is routinely analyzed.

SUMMARY AND CONCLUSIONS

A highly selective and reasonably accurate method for determining hydroxide concentrations in the presence of interfering ions was developed. The procedure is based on the method of standard subtractions which has become a routine analytical tool. It also makes use of Gran's Plot Paper to determine the equivalence volume of the titrant. The procedure is easy to run and makes use of equipment already available in many analytical laboratories. Also, if there is ready access to a computer, the data can be entered into the computer using an appropriate program (see Appendix I) and the equivalence volume is calculated by the computer.

In order to determine the applicability of this method for different types of matrices, several different sample matrices were used. The simplest matrix contained OH^- as the only anion. After verifying the method for the simplest case, $\text{Al}(\text{OH})_4^-$ was added to the matrix. Finally, other anions were added one at a time to the matrix until it contained OH^- , $\text{Al}(\text{OH})_4^-$, NO_3^- , NO_2^- , PO_4^{3-} , CO_3^{2-} , and SO_4^{2-} . The concentration of each species in a solution was known and the value obtained for the OH^- concentration from the procedure could be compared with the known concentrations. The only ions found to have a significant effect upon the determination were CO_3^{2-} and PO_4^{3-} . This interference could be removed by adding 0.1 M BaCl_2 which precipitated the CO_3^{2-} and PO_4^{3-} as their Ba salts.

The primary problem noted with the procedure was that the response varied from electrode to electrode. The response for a given electrode was found to be reasonably constant so that one could correct for it. Baumann⁽⁵⁾ has shown the effect of high salt concentrations upon various types of electrodes. The work showed that for this procedure an electrode with an E-2 glass bulb (one with low sodium error) was advantageous because it has a linear response in the pH region of 11-13. Electrodes which have General Purpose (GP) glass bulbs do not have a linear response

in the presence of sodium ions (Na^+) or in matrices with high salt content, so determinations carried out in this type of solution will need to be run in the same potential region. The value obtained will need to be corrected to take into account the non-linear response. Early work was carried out using electrodes with GP glass bulbs and a "correction factor" was used to compensate for the non-linear response. From computer calculations, a value for the equivalence volume for each titration of a standard NaOH solution was obtained. This value was then compared with the equivalence volume obtained from the titration curve. If the two values were different, the titration curve value was divided by the computer value to give the "correction factor" for use in subsequent determinations (using that electrode).

Another problem encountered with the procedure in early determinations was that at high pH values there is a certain amount of error in the potential readings due to sodium diffusion between the solution and the electrode. With electrodes incorporating GP glass bulbs it became necessary to adjust sample sizes so that the initial potential was ≥ -250 mV. However, electrodes with E-2 glass bulbs could be used in solutions with initial potentials as low as -350 mV. This lower potential made it possible to eliminate several interference problems encountered with the GP bulb.

EXPERIMENTAL

REAGENTS

Standard Nitric Acid (HNO_3)

This solution was standardized against standards from the National Bureau of Standards (NBS). Best results were obtained when the H^+ concentration of the titrant was 1.000 ± 0.005 M. This solution was used as the titrant for this method.

Standard Sodium Hydroxide Solution (NaOH)

This reagent should be standardized against NBS standards using normal standardization techniques. A concentration of $1.000 \pm 0.005 \text{ M}$ is needed for calibrating the electrode and determining the electrode response.

APPARATUS

100 ml. polyethylene beakers

glass covered stir bars

combination pH electrodes -- Beckman and Corning models with GP glass bulbs and a Beckman model with an E-2 glass bulb

A pH meter - digital display capable of operating between -1000 and +1000 mV, read to the nearest 0.1 mV

A 2.5 ml microburet

A magnetic stirrer

GENERAL PROCEDURE

The first step is to determine the slope of the electrode (potential change per decade concentration change). The easiest way to do this is to use pH 7 and pH 10 buffer solutions. The slope is determined by reading the potentials for the pH 7 and pH 10 buffers and dividing the difference by 3. This step was carried out once or twice a day.

Next, the electrode is calibrated to see if the calculated equivalence volume agrees with the equivalence volume obtained from the titration curve for the neutralization of the 1.000 M NaOH solution by the 1.000 M HNO_3 titrant. This is done by pipetting 50 ml of H_2O into a beaker containing a stir bar. As the water is stirring add 1.000 ml of 1.000 M NaOH solution. Record the potential of the solution then place the tip of the manostat in the solution. Add acid in 100 μl increments and record the potential 30 seconds after each addition. As the endpoint is approached, the size of the increments should be decreased to 1 or 2 μl so that an accurate endpoint can be determined. This step is carried out several times to insure its validity.

After the calibration step has been performed the samples can be run. The first step in analyzing samples is to determine the sample size needed. If an electrode with an E-2 glass bulb is used, the sample size chosen should produce a potential of ~ 300 mV after dilution in the water. Next the standardized HNO_3 solution is added in increments that will produce about a 2 mV potential change for the first addition. The amount of titrant in each increment will be dependent upon the total amount of OH^- present. The determination is carried out in the same way as the calibration except that only 5 or 6 additions are needed.

If a GP electrode is used, greater care must be taken in determining sample size and in interpreting the results. The sample size should be adjusted so that the initial potential of the diluted sample is ≥ -250 mV. Preferably, the reading should be between -235 and -250 mV. The determination is carried out in the same way as when the E-2 electrode is used. The -250 mV is arbitrary and if some other value was more convenient it could be used. However, if the value is much higher, the aluminate may interfere and if it is much lower, the sodium diffusion problem adversely affects results.

After the titration has been carried out, the data can be graphed on Gran's Plot Paper that is 10% volume corrected and assumes an electrode slope of $58 \frac{\text{mV}}{\text{decade conc. change}}$. It can also be fed into a computer in a program based upon Gran's Plot. However, if the computer calculation is used it is necessary for one to determine the slope of the electrode at least once a day as described earlier in this section.

RESULTS AND DISCUSSION

Because of the complex nature of the waste tank solution, preliminary work was carried out on systems containing OH^- and systems containing OH^- and $\text{Al}(\text{OH})_4^-$. After examination of the results from these simple systems, it was possible to look at more complex systems.

The easiest system to analyze was an aqueous NaOH solution. For this system a normal strong acid-strong base potentiometric titration can be carried out and the endpoint was determined from both the computer calculation and the titration curve for each titration. The results of these studies are shown in Table I. It is readily apparent that the ratios of the endpoint from a Gran's Plot determination to the endpoint from the titration curves are less than 1.0 for the GP type electrodes in the potential range used for these determinations (-220 mV to -250 mV). However, for the electrodes with E-2 glass bulbs the ratio is seen to be ~ 1 and it is not necessary to use any type of correction factor. (This was true for the electrodes used in these studies, but may not be true for all E-2 electrodes). If a GP electrode is used it is necessary to specify a small potential range in which all samples must be run. Determinations carried out in this range can be multiplied by the appropriate "correction factor" if so desired. The error which arises with the use of GP electrodes is due to non-linear response in the presence of Na^+ ions in the solution. This deviation from linearity varies from electrode to electrode and may change to a small degree from day to day for a given electrode. Even though the ratios for the E-2 electrode are ~ 1 and the slope is linear throughout the pH range of 9-13, it is best if the same approximate potential range is used for each determination.

The data in Table I shows that this is a reasonable method for determining hydroxide concentrations in a simple NaOH solution. With the E-2 electrode used for these determinations the Gran's Plot determination was between 98 and 100% of the titration curve determination. If this method is to be useful in determining OH^- concentration for any sample, then the addition of $\text{Al}(\text{OH})_4^-$ to the system should have very little effect if any. To see if this is true, aluminum was added to NaOH solutions and the results are shown in Table II. It is clear from the data in this table that the addition of $\text{Al}(\text{OH})_4^-$ to the system has no detectable effect upon the OH^- determination. Figure 1 shows the effect upon the normal acid-base titration of adding $\text{Al}(\text{OH})_4^-$ to a

FIGURE 1
THE EFFECT UPON THE TITRATION OF AN NaOH SOLUTION CAUSED BY
THE ADDITION OF NaAlO₂

TABLE 1
THE DETERMINATION OF $[\text{OH}^-]$ IN NaOH SOLUTIONS USING COMBINATION pH ELECTRODES

SAMPLE NO.	ELECTRODE TYPE	SAMPLE SIZE (ml)	$[\text{OH}^-]$ (M)		GRAN'S PLOT $[\text{OH}^-]$ TITRATION CURVE $[\text{OH}]$
			TITRATION CURVE	GRAN'S PLOT	
1	E-2	1.000	0.953	0.951	0.998
2	E-2	1.000	0.950	0.945	0.995
3	E-2	1.000	0.951	0.942	0.991
4	E-2	0.250	0.951	0.924	0.972
5	E-2	0.250	0.949	0.930	0.980
6	E-2	0.250	0.951	0.934	0.982
7	E-2	0.100	0.935	0.915	0.979
8	E-2	0.100	0.933	0.919	0.985
9	E-2	0.100	0.933	0.915	0.981
10	GP	1.000	0.950	0.881	0.927
11	GP	1.000	0.952	0.885	0.930
12	GP	0.250	0.950	0.903	0.950
13	GP	0.250	0.949	0.908	0.957
14	GP	0.100	0.934	0.914	0.979
15	GP	0.100	0.935	0.916	0.980

hydroxide solution. As can be seen from the titration curve, the OH^- endpoint is masked by the addition of the $\text{Al}(\text{OH})_4^-$ because the $\text{Al}(\text{OH})_4^-$ begins to compete effectively for the H^+ ions after the OH^- concentration has been decreased. By using the method of standard subtractions only the part of the titration in which essentially all H^+ reacts with OH^- is used, and a valid OH^- concentration can be obtained.

The next step was to add NaNO_3 and NaNO_2 to the solutions containing OH^- and $\text{Al}(\text{OH})_4^-$ and titrate them in the same manner used for the previous systems. The results for some of these titrations are shown in Table III. The close agreement between the experimental values and the calculated values is clearly seen. Because of these results it was decided that the procedure would be valid for routine use in analytical labs.

INTERFERING IONS

The first possible interfering ions to be checked were NO_3^- and NO_2^- . The results of these studies have already been discussed. These were the first ions checked because they are most commonly found with OH^- and $\text{Al}(\text{OH})_4^-$ in the waste tank matrices that were being examined. None of these ions showed any effect upon the determination of the OH^- concentration. However, the $\text{OH}^-:\text{Al}(\text{OH})_4^-$ ratio may have an effect upon OH^- determination.

Initially the problem of interfering ions such as CO_3^{2-} , PO_4^{3-} , and SO_4^{2-} , which are often found in waste tank material, was not examined. The pK_a values for carbonic acid (H_2CO_3), phosphoric acid (H_3PO_4), and sulfuric acid (H_2SO_4) indicated that there would be probable interference from CO_3^{2-} and PO_4^{3-} but not SO_4^{2-} . Since this was found to be true, steps had to be taken to eliminate the interference problems. The simplest way to do this is to add BaCl_2 to the sample which will cause precipitation of the CO_3^{2-} and PO_4^{3-} as their Ba salts. Table IV shows the results obtained from samples containing SO_4^{2-} , PO_4^{3-} , CO_3^{2-} , and the anions already studied. If SO_4^{2-} and CO_3^{2-} are present, PO_4^{3-} is absent, and the pH is greater than 11.5 in the diluted sample, it is not

TABLE II
THE DETERMINATION OF $[\text{OH}^-]$ OF SOLUTIONS CONTAINING NaOH AND $\text{NaAl}(\text{OH})_4$
BY GRAN'S PLOT

SAMPLE NO.	SAMPLE SIZE (ml)	$[\text{Al}(\text{OH})_4^-]$ (M)	$[\text{OH}^-]$ (M)		% ERROR
			GRAN'S PLOT	CALCULATED	
1	1.000	0.210	0.963	0.957	0.627
2	1.000	0.210	0.952	0.957	0.522
3	0.250	0.210	0.951	0.957	0.627
4	0.100	0.210	0.925	0.957	3.34
5	0.250	0.233	1.004	1.006	0.199
6	0.250	0.233	0.997	1.006	0.895
7	0.500	0.233	1.007	1.006	0.099
8	0.500	0.255	0.999	1.006	0.696
9	0.500	0.185	1.003	1.006	0.298

TABLE III
DETERMINATION OF $[\text{OH}^-]$ IN SOLUTIONS CONTAINING OH^- , $\text{Al}(\text{OH})_4^-$, NO_2^- ,
AND NO_3^- BY GRAN'S PLOT

SAMPLE NO.	SAMPLE SIZE (ml)	$[\text{NO}_2^-]$ (M)	$[\text{NO}_3^-]$ (M)	$[\text{Al}(\text{OH})_4^-]$ (M)	$[\text{OH}^-]$ (M)		% ERROR
					GRAN'S PLOT	CALCULATED	
1	0.250	0.500	0.500	0.205	1.009	1.011	0.198
2	0.500	0.500	0.500	0.205	1.012	1.011	0.099
3	0.500	0.500	0.500	0.205	1.008	1.011	0.297
4	1.000	0.500	0.500	0.205	1.010	1.011	0.099
5	1.000	0.350	0.250	0.260	0.911	0.906	0.552
6	0.250	0.350	0.250	0.260	0.901	0.906	0.552
7	0.250	0.350	0.250	0.260	0.893	0.906	1.43

necessary to add the BaCl_2 solution. If the initial potential after dilution is ≤ -280 mV, the CO_3^{2-} will not interfere appreciably with the results. For the sake of generality it is easiest to add BaCl_2 each time the procedure is used. With GP electrodes both CO_3^{2-} and PO_4^{3-} interfered and it was necessary to use the BaCl_2 any time either of these anions was present.

No metal ions other than Na^+ and $\text{Al}(\text{OH})_4^-$ were checked for interference for three reasons. First, the other metal ions have relatively low concentration. Secondly, some metals precipitate out at high pH values. Thirdly, most hydrolyzable metal ion complexes are soluble in the pH range normally used for these determinations and will have a negligible effect upon the determination. Hydrolyzable metal ions will not affect this type of determination unless there is a move, during the titration, into a pH region where the metal ion complexes are insoluble.

PRECISION AND ACCURACY

The precision and accuracy measurements for the general procedure were made using two sets of solutions. Each set had one solution containing only NaOH while every other solution contained $\text{Al}(\text{OH})_4^-$ in addition to the OH^- . Each set was prepared so that the OH^- concentration would remain constant for each solution. A combination pH electrode with an E-2 glass bulb was used to determine the OH^- concentration. The results of this work are shown in Table V. All of the values given in the table are based upon at least 10 determinations.

As can be seen from the results in Table V the addition of aluminum to the hydroxide solution does not significantly affect the total hydroxide concentration. The small differences that arose in the first set may have been caused by sample preparation rather than by an erroneous determination. However, even if that were not the case, all of the values are within 1.4% of the calculated OH^- concentration.

TABLE IV

DETERMINATION OF $[\text{OH}^-]$ OF SOLUTIONS CONTAINING NO_3^- , NO_2^- , $\text{Al}(\text{OH})_4^-$, OH^- ,
AND VARYING AMOUNTS OF PO_4^{3-} , CO_3^{2-} , AND SO_4^{2-} (E-2 ELECTRODE, BaCl_2 ADDED)

SAMPLE	SAMPLE SIZE (ml)	$[\text{CO}_3^{2-}]$ (M)	$[\text{PO}_4^{3-}]$ (M)	$[\text{SO}_4^{2-}]$ (M)	$[\text{OH}^-]$ (M)		% ERROR
					GRAN'S PLOT	CALCULATED	
1	1.000	0.250	0	0	0.964	0.957	0.731
2	1.000	0.250	0.250	0	0.958	0.957	0.104
3	1.000	0.250	0.250	0.250	0.954	0.957	0.313
4	1.000	0	0.250	0	0.963	0.957	0.627
5	1.000	0	0.250	0.250	0.964	0.957	0.731
6	1.000	0	0	0.250	0.958	0.957	0.104
7	1.000	0.250	0	0.250	0.958	0.957	0.104
8	5.000	0.049	0	0.101	0.160	0.162	1.23
9	5.000	0.112	0	0.153	0.319	0.324	1.25

TABLE V
PRECISION AND ACCURACY MEASUREMENTS ON TWO SETS OF SOLUTIONS
(95% CONFIDENCE LEVEL)

SAMPLE NO.	$[\text{Al}(\text{OH})_4^-]$ (M)	$[\text{OH}^-]$ (M)		% RECOVERY
		CALCULATED	GRAN'S PLOT	
1	0	0.9535	0.948 ± 0.011	$99.4 \pm 1.1\%$
2	0.037	0.9535	0.945 ± 0.010	$99.1 \pm 1.0\%$
3	0.067	0.9535	0.940 ± 0.007	$98.6 \pm 0.7\%$
4	0.146	0.9535	0.952 ± 0.008	$99.8 \pm 0.8\%$
5	0.210	0.9535	0.961 ± 0.005	$100.8 \pm 0.5\%$
6	0	1.907	1.905 ± 0.008	$99.9 \pm 0.4\%$
7	0.029	1.907	1.898 ± 0.010	$99.5 \pm 0.5\%$
8	0.071	1.907	1.911 ± 0.015	$100.2 \pm 0.8\%$
9	0.150	1.907	1.904 ± 0.012	$99.8 \pm 0.6\%$
10	0.201	1.907	1.900 ± 0.013	$99.6 \pm 0.7\%$

TABLE VI
PRECISION AND ACCURACY MEASUREMENTS ON SOLUTIONS CONTAINING OTHER IONS
IN ADDITION TO OH^- AND $\text{Al}(\text{OH})_4^-$ (95% CONFIDENCE LEVEL)

ADDITIONAL IONS PRESENT	$[\text{OH}^-]$ (M)		% RECOVERY
	CALCULATED	GRAN'S PLOT	
$\text{NO}_2^-, \text{NO}_3^-$	1.011	1.009 ± 0.007	$99.9 \pm 0.7\%$
$\text{NO}_2^-, \text{NO}_3^-, \text{CO}_3^{2-}$	0.957	0.964 ± 0.005	$100.7 \pm 0.5\%$
$\text{NO}_2^-, \text{NO}_3^-, \text{PO}_4^{3-}$	0.957	0.963 ± 0.011	$100.6 \pm 1.1\%$
$\text{NO}_2^-, \text{NO}_3^-, \text{SO}_4^{2-}$	0.951	0.958 ± 0.010	$100.1 \pm 1.0\%$
$\text{CO}_3^{2-}, \text{PO}_4^{3-}, \text{SO}_4^{2-}$	0.9995	1.001 ± 0.008	$100.2 \pm 0.8\%$

The precision of the measurements of OH^- concentration in the presence of other ions remained essentially the same. The results of these determinations are shown in Table VI and each is based upon 10 determinations. As can be seen from Table VI, none of the ions checked affected the precision significantly.

APPLICATIONS

This procedure was developed specifically to determine hydroxide concentration in the presence of aluminate in nuclear waste solutions. It works extremely well for that type of solution and the same procedure can be applied to almost any system where there are competing reactions which might mask the endpoint. An example of such a system would be one which contains both a weak and a strong base. Work on this type of procedure has already been performed and gives excellent results. In principle the same procedure can be used for acid systems containing hydrolyzable metal ions. It is hoped that work in this area can be carried out in the future.

The primary advantage of this procedure is its versatility and applicability to a number of different matrices. Because interference from hydrolyzable metal ions is eliminated, this procedure should be helpful to anyone interested in the hydroxide concentration of such a system.

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APPENDIX A

COMPUTER PROGRAM FOR DETERMINING POTENTIOMETRIC ENDPOINT

```

0080 LET A2=1
0090 DIM W$(20)
0100 REM PROGRAM TITLE "GRABER"
0160 GOTO 0260
0170 FOR I=1 TO 3
0180 PRINT
0190 NEXT I
0200 PRINT "NEW SAMPLE? (YES=1, END=0)";
0210 INPUT A1
0220 IF A1=0 THEN GOTO 0850
0230 PRINT "DO YOU WANT TO CHANGE ANY INPUT PARAMETERS?"
0240 PRINT "(YES=1, NO=0)";
0250 INPUT A2
0260 PRINT "SAMPLE NUMBER";
0270 INPUT W$
0280 IF A2=0 THEN GOTO 0380
0290 PRINT "WHAT IS THE SLOPE (- FOR ANIONS, + FOR CATIONS)";
0300 INPUT S
0310 DIM X(100), Y(100), E(100), Z(1,200)
0320 PRINT "INITIAL VOLUME (ML)";
0330 INPUT V1
0340 PRINT "DILUTION FACTOR";
0350 INPUT Z2
0360 PRINT "CONCENTRATION OF STANDARD. (MOLES/LITER)";
0370 INPUT Z3
0380 PRINT "NO. OF DATA PAIRS";
0390 INPUT N
0400 PRINT "ENTER DATA (V,E PAIRS)"
0410 MAT Z=ZER(1,2*N)
0420 MAT INPUT Z
0430 FOR I=1 TO N
0440 LET X(I)=Z(1,2*I-1)
0450 LET E(I)=Z(1,2*I)
0460 LET Y(I)=((V1+X(I))/V1)*10**((E(I)-400)/S)
0470 NEXT I
0480 LET S1=0
0490 LET S2=0
0500 LET S3=0
0510 LET S4=0
0520 LET S5=0
0530 FOR I=N TO 1 STEP -1
0540 LET S1=S1+X(I)
0550 LET S2=S2+Y(I)
0560 LET S3=S3+X(I)*Y(I)
0570 LET S4=S4+X(I)**2
0580 LET S5=S5+Y(I)**2
0590 NEXT I
0600 LET V2=S1/N-(S2/N)/((N*S3-S1*S2)/(N*S4-S1**2))
0610 LET D=(S5-(S2**2)/N)/(N-1)
0620 LET C=(N*S3-S1*S2)**2/((N*S4-S1**2)*(N*S5-S2**2))

```

```
0630 LET R=SQR(C)
0640 PRINT
0650 PRINT
0660 PRINT "SAMPLE NUMBER ";W$
0670 PRINT
0680 PRINT "INITIAL VOLUME"; V1; "ML" SLOPE=";S
0690 PRINT
0700 PRINT "DILUTION FACTOR";Z2
0710 PRINT "CONCENTRATION STANDARD (MOLES/L)";Z3
0720 PRINT
0730 PRINT "VOLUME ADDED" MILLIVOLTS"
0740 FOR I=1 TO N
0750 PRINT X[I]," ";E[I]
0760 NEXT I
0770 PRINT
0780 PRINT "!!!!!! RESULTS !!!!!!"
0790 PRINT
0800 PRINT "THE EQUIVALENCE VOLUME IS ";V2;"ML"
0810 PRINT "COEF. OF DETM. =";R
0820 PRINT "RESULT IN MOLES/LITER IS ";V2*Z2*Z3/V1
0830 PRINT "!!!!!!!!!!!!!!!!!!!!!!!!!!!!"
0840 GOTO 0170
0850 GOTO 0880
0870 GOTO 0260
0880 END
```


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