
Article

Use of sodium polytungstate solution in the purification of volcanic glass shards for bulk chemical analysis

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Abstract

The sodium polytungstate ($3\text{Na}_2\text{WO}_4 \cdot 9\text{WO}_3 \cdot \text{H}_2\text{O}$) solution (SPT solution) is a nontoxic water-based heavy-liquid medium first introduced in the 1980s. Although this solution has been used in heavy/light mineral separation and in conodont extraction, it has been avoided in bulk chemical analyses of tephra due to the possibility of chemical influence. In order to examine for such complications, we prepared pairs of samples of pure volcanic glass shards from two East African tephra layers. Glass shards were purified either by standard magnetic separation or by using the SPT solution. The major and trace element compositions of the four samples were analyzed by Direct Current Argon Plasma Atomic Emission Spectrometry (DCP-AES). The resultant chemical compositions of the samples derived from each of the two separation methods exhibited remarkable correlation. This confirms that no significant chemical influence occurs with the use of the SPT solution, and thus indicates that the method is applicable to sample preparation for bulk chemical analyses of tephra.

Key Words: Sodium polytungstate (SPT) solution, heavy liquids, purification of volcanic glass shards, chemical influence, Direct Current Argon Plasma Atomic Emission Spectrometry (DCP-AES)

Introduction

Heavy liquids are routinely used to separate mixtures on the basis of difference in specific gravity. Halogenated hydrocarbons, such as tetrabromoethane ($\text{C}_2\text{H}_2\text{Br}_4$) and bromoform (CHBr_3), and carbon tetrachloride (CCl_4) are widely used heavy liquids, although they are toxic (Bretherick ed., 1981; Sax, 1984; Sax and Lewis, 1986) and hazardous (O'Connell, 1963). Organic solvents used for washing and recovery of these heavy liquids are volatile and flammable, and dangerous for the operators' health (Drake, 1971). Because of these problems, the aqueous sodium polytungstate ($3\text{Na}_2\text{WO}_4 \cdot 9\text{WO}_3 \cdot \text{H}_2\text{O}$) or sodium metatungstate ($\text{Na}_6[\text{H}_2\text{W}_{12}\text{O}_{40}]$) solution was introduced in the 1980s as a nontoxic substitute for the hazardous organic heavy liquids (Plewinsky and Kamp, 1984; Merrill, 1985).

Sodium polytungstate (SPT) readily dissolves in water, and density of the SPT solution is easily adjusted by adding or evaporating water. In addition to these advantages, no significant difference in effectiveness was recognized between the organic heavy liquids and the SPT solution in separating heavy/light minerals (Gregory and Johnston, 1987). A better recovery rate of nearly 100% was found for conodont separation using the SPT solution (Krukowski, 1988). In Japan, Danhara et al. (1992) first proposed the use of the SPT solution for mineral separation, and Tsuruta et al. (1995) attempted separation of clay minerals.

Purification of volcanic glass shards is a basic preparatory step in bulk chemical analysis of glass shards of tephra layers. In preparation for Instrumental Neutron Activation Analysis (INAA), the use of heavy liquids has been avoided because the liquids remaining in or on the

shards may act as a pollution source (e.g., Fukuoka, 1993). Magnetic separation and/or hand picking are thus preferred for this analysis. In contrast, organic heavy liquids contain no metal elements, and have been applied to the glass separation for chemical analyses such as in Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES) and X-ray fluorescence analysis (e.g., Kikkawa, 1993). However, use of the SPT solution is generally avoided even in these analyses, in spite of the many advantages described above, probably because it consists of tungsten and sodium compounds and includes rather high contents of trace elements such as Nb, P, and U (Callahan, 1987).

In this study, we first prepare pairs of samples of pure volcanic glass shards from two East African tephra layers. Each pair consists of one sample prepared by standard magnetic separation and another by use of the SPT solution. Next, we analyze the major and trace element compositions of the four samples using Direct Current Argon Plasma Atomic Emission Spectrometry (DCP-AES). Lastly, we discuss the application of the solution to the purification of volcanic glass shards for bulk chemical analyses of tephra.

To evaluate the influence of the solution, we need a sample pair that is chemically equivalent. Some East African tephra layers are, however, known to consist of multiple chemically distinguishable glass populations (e.g., Brown et al., 1992). Pure glass samples prepared from such tephra layers may show different chemical compositions. In this study, we analyze the major element composition of glass shards of each unknown tephra by Electron Probe X-ray Microanalyzer (EPMA). We then compare this with the major element compositions analyzed by DCP-AES of the paired samples prepared from the same tephra, to confirm the chemical homogeneity between samples.

Materials

Two bulk samples (944-57 and 9312-39) were taken from the Plio-Pleistocene tephra layers at Konso in the southern Main Ethiopian Rift, East Africa (Kato et al., 1999). Petrologic characteristics of these samples were examined for the initially prepared sand-sized grains.

Sample 944-57 contains 53.3 wt% of volcanic glass shards which consist of dominant clear light gray bubble-walled and rare whitish pumiceous types; these glass shard types are after Machida and Arai (1978). The other portion is composed of mineral crystals and less abundant rock fragments (feldspar >> rock fragments, green horn-

blende > orthopyroxene > quartz). Sample 9312-39 is a relatively pure vitric ash that consists of clear light gray glass shards with 99.0 wt% in total grains. The shards are predominantly bubble-walled with the occurrence of a few pumiceous types. They also contain rare pale brown glass shards of both types less than 0.5 wt%. The remainder is mostly composed of feldspar crystals, and includes very rare opaque mineral and green hornblende crystals, and rock fragments.

The internal standard used for our DCP-AES is tuff sample TW-3A, from Bunketo in the Middle Awash area, Ethiopia (White et al., 1993). This tuff is also known as MA91-3 and corresponds to the VT-3/Wargolo Tuff. The internal standard glass separate was prepared from a relatively pure vitric tephra by standard methods including magnetic separation and hand picking. Estimated purity of the glass separate is likely to be in the 99 wt% range. Comparison of numerous analyses of this internal standard with replicate analyses of glass separates of TW-3A prepared with great care (> 99.5 wt% purity) shows excellent agreement, indicating a similarly high purity of the internal standard.

Methods

Purification of volcanic glass shards

The quality of minor and trace element analysis largely depends on the purity of glass shard fractions prepared from the original tephra sample. It is thus important to improve the purification procedure. Generally, this consists of three operations: 1) initial washing and etching, 2) separation and concentration of volcanic glass shards, and 3) final hand picking and powdering of the concentrated glass shards (Fig. 1).

1. Initial washing and etching

Initial washing and etching are very important steps, because they help to remove microcrystalline mineral aggregates attached to glass shards and raise efficiency in glass separation.

A portion of the dried bulk sample is repeatedly washed with water in ultrasonic bath, and decanted to remove silt and clay particles until the water is clear. The washed sample is dried and sieved to obtain two size fractions with diameters larger than 1/4 mm and from 1/4 to 1/16 mm. When the total weight of the fraction is less than 2.0 g, the above procedure is repeated until a sufficient amount is obtained. The latter fraction is put into a FEP beaker and added to 10% HCl solution and washed in ultrasonic bath for 5 minutes with frequent stirring. It is rinsed with

deionized water at least 5 times and dried.

The fraction is added to 7% HF solution, and reacted for 3 minutes in ultrasonic bath with frequent stirring. The reaction is then stopped adding deionized water and stirring. When the glass shards are fine-grained, the reaction time is limited to one minute to avoid loss of the shards. After the end of the reaction, it is rinsed with deionized water at least 5 times. The etched fraction is rinsed out into an evaporating dish and dried. It is sieved again to obtain an accurate size fraction of 1/4 to 1/16 mm grains.

2. Separation and concentration of volcanic glass shards

The fraction of 1/4 to 1/16 mm grains is used to separate and concentrate volcanic glass shards. This size of grains is adequate for the glass separation. In this operation, two different purification methods are applied: standard magnetic separation and the technique using the SPT solution (Fig. 2).

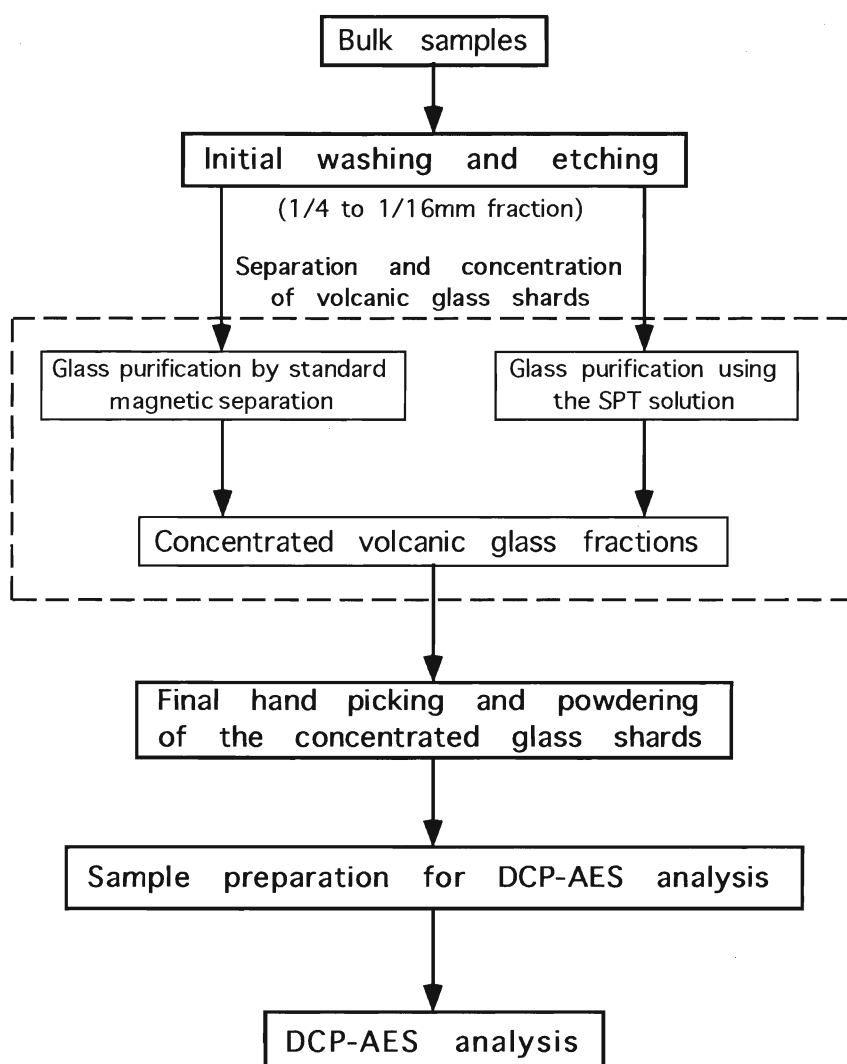


Fig.1. Flow chart of the analytical procedures including two purification methods of volcanic glass shards using either a magnetic separator or the SPT solution.

2-1. Standard magnetic separation

Magnetic grains are removed from the fraction with a hand magnet. Standard magnetic separation is then applied to the fraction using the Frantz isodynamic magnetic separator. The separation is repeated until a sufficient amount of pure glass shards (> 0.3 g) is obtained.

Glass shards are concentrated in either the magnetic or the nonmagnetic fraction. They are washed with deionized water in ultrasonic bath, and rinsed out into an evaporating dish and dried. The glass fraction is used as the unknown sample for DCP-AES analysis.

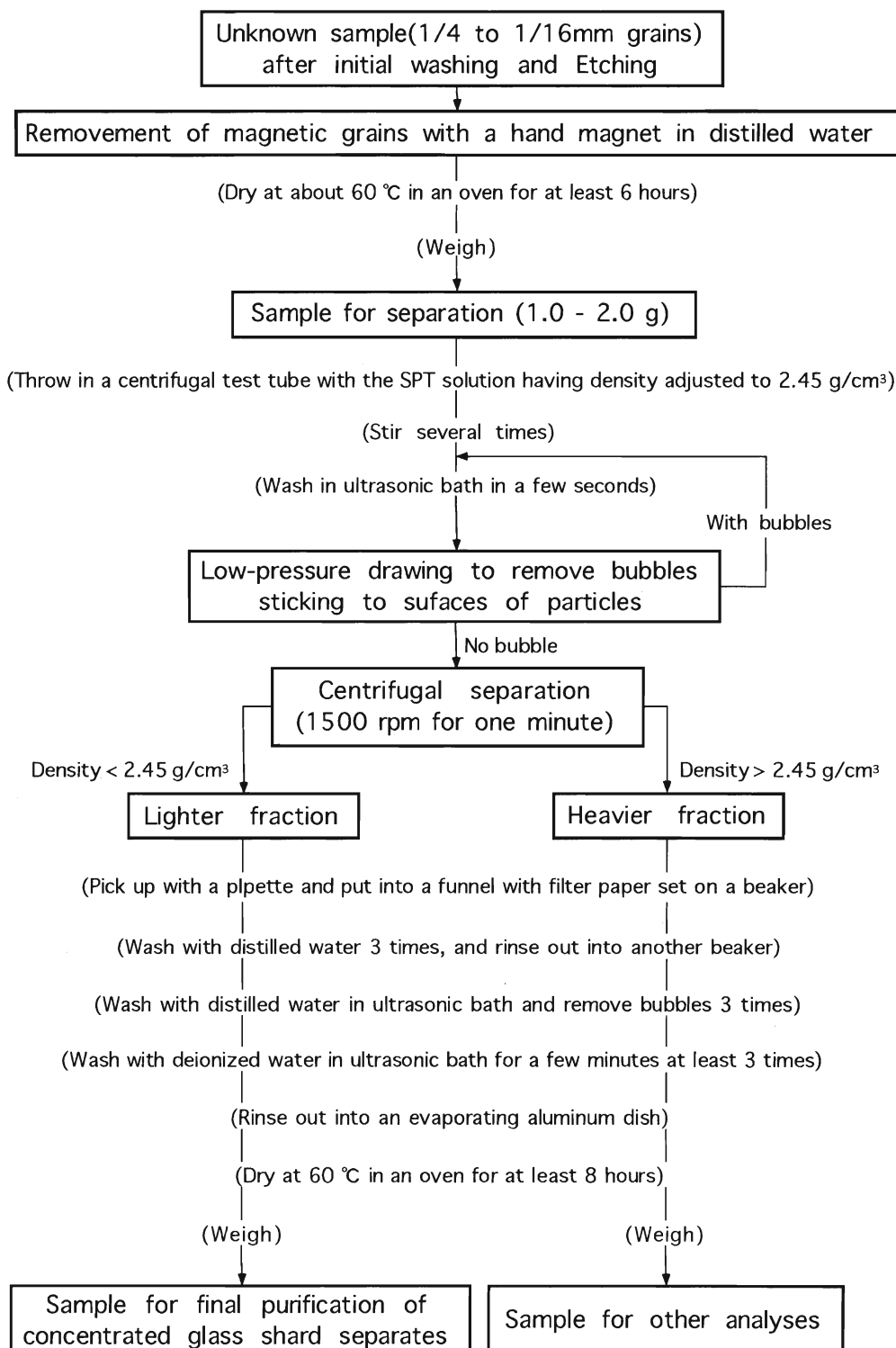


Fig.2. Flow chart of the glass shard separation method using the SPT solution.

Table 1. Compositions of four analytical solutions of unknown samples used for DCP-AES. TESS, SSRB, PMSS, and D.F. indicate trace element stock solution, spike solution reagent blank (5% HNO₃), pre-mixed spike solution (6% HNO₃ solution enriched with 3000 ppm Li and 30 ppm Ge), and dilution factor, respectively.

Analytical solutions	TESS	SSRB	PMSS	D.F.
Major element				
1	1ml (1.050±0.005g)		24ml (25.30±0.03g)	~6600
Trace element				
1	10.00±0.01g	0.600±0.004g		~280
2	10.00±0.01g	0.300±0.002g	0.300±0.002g	~280
3	10.00±0.01g		0.600±0.004g	~280

2-2. Glass purification using the SPT solution

Magnetic grains are removed from the fraction with a hand magnet in distilled water. The fraction is rinsed out into an evaporating dish, and dried and weighed. The fraction of 1.0 to 2.0 g is put into a centrifugal test tube with the SPT solution adjusted to a density of 2.45 g/cm³. This density is critical to separate volcanic glass shards (most < 2.45 g/cm³) from light minerals like feldspar and quartz (> 2.45 g/cm³). The adjusting method follows the procedure of Danhara et al. (1992). The mixture is stirred and washed in ultrasonic bath for a few seconds with low-pressure drawing to remove bubbles attached to particles. This operation is repeated until no bubbles are observed. The removal of attached bubbles raises efficiency in the glass separation using the SPT solution.

Centrifugal separation is then applied to the mixture at 1500 rpm for one minute to divide into the heavier (> 2.45 g/cm³) and the lighter (< 2.45 g/cm³) fractions. Each of the fractions is picked with a pipette and put into a funnel with filter paper set on a beaker, with caution not to contaminate with each other. The fractions on the filter paper are washed with distilled water several times, and then rinsed out into other beakers. The lighter fraction is added to distilled water, stirred and decanted at least three times. It is washed with deionized water in ultrasonic bath at least three times, and then rinsed out into an evaporating dish and dried. The same operation is applied to the heavier fraction. Repeated washing is necessary for complete removal of the SPT solution.

The purity of glass shards in the lighter fraction is then estimated before final hand picking. A very small amount of the fraction is prepared using Canada Balsam on a slideglass topped with coverglass. More than 2000 grains can be prepared on a slide for the 1/4 to 1/16 mm particles. The number of non-glass grains on the entire slide is identified under a polarization microscope and counted using a point counter. The approximate number of glass

shards on the slide is estimated by subtracting the number of the non-glass grains from 2000. The approximate purity of glass shards is then determined by dividing this number by 2000. When the purity is below the acceptable level, the above separation procedure is repeatedly applied to the lighter fraction. Usually, replicating the separation procedure twice is sufficient to attain a purity level of 98%.

Finally, the dried lighter fraction is weighed. When the quantity of the fraction is less than 0.3 g, the above procedure is repeated until a large enough quantity is obtained. The final lighter fraction is used as the unknown sample for DCP-AES analysis.

3. Final hand picking and powdering of the concentrated glass shards

To raise the purity as high as possible, obvious contaminating materials are further removed by hand picking from the 0.3 to 0.8 g of the fractions, prior to powdering with a boron carbide mortar and pestle. A very small amount of the fraction is first powdered and the purity of this material is estimated in oil under a polarization microscope. If significant birefringence like mineral contaminants and rare-type glass shards is still present, they are further hand picked before continuing with the final powdering. Ultimately, the powdered glass from all unknown samples are dried at 110 °C to remove non-structural volatile, and then stored in a desiccator until DCP-AES analysis.

Major and trace element analysis using DCP-AES

1. Sample preparation

The unknown powdered sample of 0.150 ± 0.001 g is combined with 0.450 ± 0.005 g of lithium metaborate (LiBO₂) in a pre-fired graphite crucible. This mixture is then fused at 950°C for 15 minutes. The resultant molten bead is added to 38 ml (i.e. 39.4 ± 0.1 g) of 6% HNO₃

Table 2. Data of the DCP rock standard cassettes 1 and 2. WL, PM, acc., mean, and s.d. indicate wavelengths (nanometer), precise measurement limits (wt % or ppm), accepted values from Govindaraju (1994), and mean values and standard deviations given as 1-sigma of n replicate analyses, respectively. STM-1, GSP-1, and NIM-G are all internationally recognized rock standards.

DCP rock standard cassette 1 data

	WL (nm)	PM (wt %)	STM-1			GSP-1			NIM-G		
			acc.	mean	s.d.	acc.	mean	s.d.	acc.	mean	s.d.
SiO ₂	288.158	1.20	59.64	59.50	0.47	67.22	67.29	0.31	75.70	75.55	0.23
TiO ₂	334.941	0.09	0.135	0.138	0.007	0.65	0.67	0.01	0.09	0.09	0.01
Al ₂ O ₃	396.152	0.20	18.39	18.33	0.14	15.10	15.04	0.10	12.08	12.14	0.14
Fe ₂ O ₃	371.994	0.30	5.22	5.24	0.06	4.29	4.30	0.06	2.02	2.02	0.09
MnO	257.610	0.03	0.220	0.220	0.003	0.040	0.040	0.003	0.021	0.020	0.001
MgO	279.553	0.05	0.10	0.12	0.01	0.96	0.98	0.02	0.06	0.05	0.01
CaO	317.993	0.15	1.09	1.13	0.02	2.07	2.01	0.03	0.78	0.77	0.02
Na ₂ O	589.592	0.10	8.94	8.78	0.31	2.80	2.80	0.03	3.36	3.37	0.03
K ₂ O	769.896	0.10	4.28	4.27	0.03	5.51	5.48	0.04	4.99	4.99	0.05
P ₂ O ₅	213.618	0.15	0.158	0.157	0.021	0.28	0.28	0.03	0.01	0.01	0.03
Total			98.17	97.89		98.92	98.90		99.11	99.00	
Sr (ppm)	407.771	10	700	696	15	234	236	4	10	12	4

DCP rock standard cassette 2 data

	WL (nm)	PM (ppm)	STM-1			GSP-1			NIM-G		
			acc.	mean	s.d.	acc.	mean	s.d.	acc.	mean	s.d.
Ni	341.476	10	3	4	2	8.8	9.7	2.5	8	6	3
Zn	206.200	27	235	239	4	104	106	5	50	50	3
Cu	324.754	10	4.6	4.3	0.4	33	33	2.5	12	10	1
Cr	425.435	10	4.3	4.1	0.6	13	11	1	12	12	2
Zr	339.198	20	1210	1220	16	530	538	23	300	285	4
V	437.924	15	8.7	9.1	3.3	53	54	4	2	3	3
Sc	361.384	15	0.61	0.65	0.10	6.2	6.7	0.4	1	0.8	0.2
Nb	309.418	20	268	271	12	27.9	28.2	2.5	53	51	4
Ba	455.403	4	560	572	11	1310	1301	24	120	113	2
Sr	407.771	4	700	nd		234	236	8	10	10.1	0.2
Rb	780.023	55	118	116	5	254	254	15	320	334	17
Y	371.030	10	46	46	1	26	27	1	143	140	4

solution enriched with 3000 ppm Li, 30 ppm Ge and 10 ppm Cd, and shaken until dissolved. The solution so produced is referred to as the trace element stock solution (TESS), and represents a dilution factor of approximately 260 with respect to the original concentration in the solid.

From the TESS, four analytical solutions are prepared; one is for major element analysis, and others for trace element analysis (Table 1). At least six internationally recognized rock standards and one procedure blank (LiBO₂ only) are prepared along with the unknown samples following the same procedures. Throughout the above steps, precise weights of all solids and solutions are recorded for final concentration determinations. As a result, these procedures can be tailored to sample sizes other than 0.150 g.

2. Instruments and data acquisition

All elemental analyses are accomplished using a Beckman Spectra Span V plasma source and spectrometer, and Interface Designs electronics module at the geologic laboratory of the Miami University. Two multi-element cassettes 1 and 2 are used for simultaneous determinations of major and trace elements. The cassette 1 is for typical silicate rock major elements (SiO₂, TiO₂, Al₂O₃, Fe₂O₃, MnO, MgO, CaO, Na₂O, K₂O, P₂O₅, and Sr), and the cassette 2 for typical silicate rock trace elements (Ni, Zn, Cu, Cr, Zr, V, Sc, Nb, Ba, Sr, Rb, and Y). Our results on replicate analyses of selected international rock standards (STM-1, GSP-1, and NIM-G) are shown in Table 2, together with wavelengths (WL) and estimated precise measurement limits (PM) for individual elements.

Data is gathered for each element (wavelength) in 10 to 20 sets of background-peak-background measurements with each intensity reading integrated for one second. Unknown solutions are subjected to this measurement routine three times and standard and blank solutions four times. Upon introduction of each new solution, the plasma stability is monitored and data acquisition begins only when repetitive readings on the peak of the internal standard elements (Ge and Cd) differ by less than 20%.

Major element concentrations are determined by comparison of unknown background corrected intensity ratios to calibration curves with each batch of unknowns. The calibration curves are constructed from rock standards and a blank (zero standard) analyzed. Trace element concentrations are determined by the method of standard addition using sets of three solutions per unknown (plus a blank) prepared as described above (e.g., Bader, 1980).

Major element analysis using EPMA

A sample for EPMA analysis is taken from the 1/4 to 1/16 mm fraction prepared from the same bulk sample only through washing and sieving. A small amount of the fraction is prepared for EPMA analysis by the standard method (e.g., Okumura, 1993). Major element compositions of the glass shards, randomly selected on the preparation, are analyzed by use of the EPMA facilities of Los Alamos National Laboratory, following the analytical procedure of WoldeGabriel et al. (1994). The number of glass shards analyzed for each tephra sample is more than 30. Major element oxides analyzed are SiO₂, TiO₂, Al₂O₃, Fe₂O₃, MnO, MgO, CaO, Na₂O, and K₂O. Mean contents and standard deviations of individual element oxides are calculated following the procedure of Katoh et al. (1999).

Results and Discussion

With bulk samples 9312-39 and 944-57 of the present study, glass shards were found to comprise at least 99.5% of the lighter fraction separated by use of the SPT solution. This high purity in our method was achieved by the application of centrifugal separation and removal of attached bubbles. The purity of the glass separates prepared by standard magnetic separation, in the present study, was estimated to be around 98%, also of sufficient purity level according to the criteria suggested by Kikkawa (1993) for minor and trace element analysis using ICP-AES. The results of DCP-AES and EPMA analyses of the present study are provided in Table 3 with respect to major and trace elements.

Influence of the SPT solution

The apparent systematic disagreements in SiO₂, Na₂O, and K₂O contents are typical between DCP-AES and EPMA data (Table 3). The same disagreements apply to the analytical totals. These inconsistencies, however, can be explained by the difference of the two analytical methods (Okumura, 1991, 1993). In EPMA analysis, the contents of Na₂O and K₂O are measured lower than their actual contents and this decreases analytical totals, while SiO₂ content is measured higher.

In contrast, the contents of Al₂O₃, Fe₂O₃, TiO₂, MnO, and CaO are measured independent of the difference of the two methods. The contents of these major element oxides analyzed by DCP-AES for the paired samples purified by the two methods agree well with those analyzed by EPMA (Table 3). This agreement indicates that the pair of samples is composed of the same glass population chemically with that of the original unknown tephra. Thus, we consider that major and trace element contents provided by DCP-AES are comparable between the paired samples.

The major element compositions of the paired samples, that purified by the magnetic operation (run-1) and that prepared by use of the SPT solution (run-2), as determined by the DCP-AES analysis are in good agreement (Table 3). The results of trace element analysis of the two runs agree well, especially in Zn, Zr, Nb, Ba, Rb, and Y contents at levels much higher than PM. The contents of Sc and Sr are also consistent between the two runs, although the measured contents are a little below PM. There are some disagreement in Cu and V contents only for sample 944-57, but we cannot place much weight on this because of their much lower levels compared with PM. These results indicate that there was no significant difference in major and trace element contents analyzed by DCP-AES between the paired samples.

Callahan (1987) suggested that the rather high contents of trace elements (Nb 6 ppm, P 8 ppm, and U 10 ppm) in the SPT solution could interfere with later chemical analysis of concentrates. He also stated that this should be obviated through washing with distilled water, but did not clarify its feasibility. According to the elemental composition of the SPT, such chemical influence should be expressed as difference in contents of Na₂O and Nb between the run-1 and run-2 columns of Table 3. Nevertheless, no such difference was recognized in our results. Accordingly, we conclude that the SPT solution has no significant influence on the major and trace element analysis using DCP-AES.

Table 3. Major and trace element compositions of two unknown tephra samples (9312-39 and 944-57) and those of the simultaneously and previously measured internal standard (TW-3A). Hydrous wt % with Fe₂O₃, and Total* is unnormalized analytical total. Trace element composition is in ppm. s.d. and nd are standard deviation and "not determined", respectively. Run-1 columns of the unknown samples show the chemical compositions of glass shards prepared by standard magnetic separation, while run-2 columns indicate those of glass shards purified using the SPT solution. These chemical compositions of the unknown samples and those of the TW-3A were all analyzed by DCP-AES. For comparison, the major element compositions of glass shards of the two samples analyzed by EPMA are shown in MP columns.

Samples	9312-39 (run-1)	9312-39 (run-2)	9312-39(n=40) (MP)	s.d.	944-57 (run-1)	944-57 (run-2)	944-57(n=36) (MP)	s.d.	TW-3A (run-1)	TW-3A (run-2)	TW-3A(n=4) (previous)	
Major element												
SiO ₂	71.81	72.28	72.15	0.63	70.58	71.42	70.41	0.79	72.00	72.63	72.79	0.59
TiO ₂	0.17	0.17	0.16	0.04	0.18	0.18	0.17	0.04	0.14	0.14	0.14	0.00
Al ₂ O ₃	10.35	10.49	10.60	0.10	10.56	10.50	10.28	0.07	10.59	10.62	10.64	0.04
Fe ₂ O ₃	2.74	2.72	2.74	0.06	2.96	2.98	2.88	0.08	2.33	2.38	2.36	0.03
MnO	0.07	0.08	0.07	0.02	0.10	0.10	0.10	0.03	0.06	0.07	0.06	0.00
MgO	0.01	0.01	0.00	0.00	0.03	0.03	0.06	0.05	0.01	0.01	0.02	0.01
CaO	0.21	0.18	0.17	0.01	0.21	0.18	0.17	0.02	0.20	0.19	0.20	0.01
Na ₂ O	3.60	3.60	2.72	0.24	4.52	4.31	3.81	0.24	4.16	4.03	4.11	0.05
K ₂ O	5.12	4.97	4.24	0.42	4.82	4.67	4.39	0.29	3.08	2.99	3.04	0.04
Total*	94.06	94.49	92.89	1.03	93.95	94.38	92.26	0.82	92.57	93.05	93.36	

Samples	9312-39 (run-1)	9312-39 (run-2)		944-57 (run-1)	944-57 (run-2)		TW-3A (run-1)	TW-3A (run-2)	TW-3A(n=5) (previous)	s.d.
Trace element										
Zn	217	195		252	248		169	180	175	5
Cu	2	2		19	1		4	4	3.7	0.1
Zr	1022	954		1161	1118		757	750	756	6
V	2	nd		4	nd		1	nd	1.4	0.5
Sc	1.5	1.3		2.4	2.4		1.1	0.9	0.9	0.2
Nb	102	98		194	201		118	120	117	2
Ba	247	240		24	21		70	70	70	1
Sr	3.4	3.1		0.8	0.7		2.4	2.5	2.4	0.1
Rb	92	101		162	163		123	116	123	4
Y	120	110		146	140		121	120	119	2

Application of the SPT solution to preparatory steps for bulk chemical analyses

The SPT solution has not been widely used as a heavy-liquid medium mainly due to its high viscosity and cost, although it is nontoxic. However, the higher cost of the SPT is not serious because it is fully compensated by the higher recovery rate of the solution and the lower cost of using deionized or distilled water as solvent and washer (Danbara et al., 1992). Innovation and labor can also improve the low filtration rate of the solution resulting from high viscosity. Such improvement is achieved by the correct adjustment of its density to 2.78 g/cm³ (Savage, 1988), the use of a coffee filter (Callahan, 1987; Gregory and Johnston, 1987), low-pressure drawing (Danbara et al., 1992), and the combination of all or some of these operations. Furthermore, samples wetted more easily with the

solution cause less aggregation or raft on the surface than common with other organic heavy liquids, and decrease frequency of stirring (Gregory and Johnston, 1987).

Repeated washing with deionized or distilled water is necessary to remove the SPT completely, and this takes much time. However, the density of the SPT solution is easily and accurately adjusted, and the adjusted SPT solution becomes available for all glass dominant samples. Thus, many samples can be treated together to enhance efficiency. In contrast, a magnetic separator must be set up for every sample, and the magnetic intensity and slope angles of the separator must also be repeatedly adjusted. As a result, magnetic separation is as time consuming as the SPT solution separation.

Furthermore, the purity of glass shard separates attained by our method using the SPT solution is higher

than that of the separates by standard magnetic separation. This is because magnetic separation of feldspar crystals is difficult due to its similar magnetic intensity to that of glass shards.

Our results revealed no significant chemical influence of the SPT solution on DCP-AES analysis of volcanic glass shards. This suggests that the SPT solution method is applicable to the purification of glass shards for other bulk chemical analyses like ICP-AES. Taking into consideration the advantages of using the SPT solution as mentioned above, we emphasize that this solution should be used more frequently in preparatory steps, in part to keep geologic laboratories safe.

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