NASA
National Aeronautics and
Space Administration

Planetary Materials Branch

Lyndon B. Johnson Space Center
Houston, Texas 77058

Publication 65

JSC 18928

COSMIC DUST CATALOG

(PARTICLES FROM COLLECTION FLAG W7027)

COMPILED BY

COSMIC DUST PRELIMINARY EXAMINATION TEAM (CDPET)

APRIL 1983

Volume 4
Number 1

September 12, 1983

Dear Reader:

Please place this notice at the front of your copy of Cosmic Dust Catalog, Vol. 4. The following information updates the catalogs, in general, and Vol. 4, in particular:

1. Catalogs and Newsletters Published

   With this mailing, the publications issued by the NASA/JSC Cosmic Dust Program comprise the following:

   Cosmic Dust Catalogs, Vol. 1 (1 and 2)
   Vol. 2 (1 and 2)
   Vol. 3 (1)
   Vol. 4 (1 and 2)

   Cosmic Dust Courier, No. 1, 2, and 3.

   No catalog was published under the title of Vol. 3 (2).

2. Samples Allocated

   To date, the following sample particles described in Catalog Vol. 4 have been allocated or are pending allocation:

   W7027A1 (pending)
   W7027A11 (allocated)
   W7027B5 (pending)
   W7027B8 (pending)
   W7027B15 (pending)
   W7027C4 (allocated)
   W7027C7 (pending)
   W7027C12 (pending)
   W7027E17 (pending)

   W7027 particles not listed above are still available for allocation. Allocations of particles described in other catalogs are summarized in Courier No. 3.

3. EDS Spectra of Standards

   Catalog 4 (2) includes new pages with spectra of three standard minerals and a standard bulk meteorite. Please make the following page substitutions:

   new xxi and xxii/8-83 for old xxi and xxii
   new xxiii/8-83 and xxiv for old xxiii and xxiv.

   The new pages represent 20-kV spectra obtained during preliminary examination of samples in the W7027F, G, H, and I series. In addition, page xxiii/8-83 includes important corrections to the bulk composition of Diopside JLC 99-63.

CDPET

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Volume 4/Number 1

(Particles from Collection Flag W7027)

Compiled by

Cosmic Dust Preliminary Examination Team (CDPET)*

NASA Johnson Space Center
Houston, Texas 77058 U.S.A.

April 1983

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CONTENTS

1. INTRODUCTION

Since May, 1981, the National Aeronautics and Space Administration (NASA) has used aircraft to collect cosmic dust (CD) particles from Earth's stratosphere (altitude $\sim$18 km). Specially designed dust collectors experience pre- and post-flight handling in an ultraclean laboratory constructed for this purpose at the Lyndon B. Johnson Space Center (JSC) in Houston, Texas. Particles are individually retrieved from the collectors, examined and cataloged, and then made available to the scientific community for research. Cosmic dust thereby joins lunar samples and meteorites as an additional source of extraterrestrial materials for scientific study.

This catalog summarizes preliminary observations on some of the particles retrieved from collection surface W7027. W7027 was one of eight flat plate "flags" (each with $\sim$30 cm^2 surface area) which were coated with silicone oil and then flown aboard a NASA WB57F aircraft during a series of flights across the western United States from September 15, 1981, to December 2, 1981. The flags were installed in specially constructed wing pylons which ensured that the necessary level of cleanliness was maintained between periods of active sampling. During successive periods of high-altitude ($\sim$60,000 ft.) cruise, the flags were exposed to the atmosphere by pilot command and then retracted into sealed storage containers prior to descent. In this manner, a total of 35 hours of stratospheric exposure was accumulated for Flag W7027. Flag W7027 was a member of the same set which included W7029, particles from which were described in Cosmic Dust Catalog, Vol. 2.

Details of particle collection, processing, and examination techniques will be published in the future. However, the following information summarizes these techniques so that the catalog can be more fully understood and utilized.

2. PROCESSING OF PARTICLES

Particle mounts designed for the JEOL 100CX scanning transmission electron microscope (STEM) are currently the standard receptacles for CD particles in the JSC laboratory. Each mount consists of a graphite frame (size $\sim$ 3x6x24 mm) onto which a Nucleopore^{TM} filter (0.4-μm pore size) is attached. A conductive coat of carbon is vacuum-evaporated onto the mount and then a microscopic reference pattern is "stenciled" onto the carbon-coated filter by vacuum evaporation of aluminum through an appropriately sized template. CD particles are individually removed from collection flags using glass-needle micromanipulators under a binocular stereo-microscope. Each particle is positioned on an aluminum-free area of a Freon-cleaned, carbon-coated mount filter and washed in-place with hexane to remove silicone oil. Each mount is normally limited to 16 particles. All processing and storage of each particle is performed in a Class-100 clean room.

3. PRELIMINARY EXAMINATION OF PARTICLES

Each rinsed particle is examined, before leaving the Class-100 clean room processing area, with a petrographic research microscope equipped with transmitted, reflected and oblique light illuminators. At a magnification to 500X, size, shape, transparency, color, and luster are determined and recorded for each particle.

After optical description, each mount (with uncoated particles) is examined by scanning electron microscopy (SEM) and x-ray energy-dispersive spectrometry (EDS). Secondary-electron imaging of each particle is performed with a JEOL-100CX STEM operated in the SEM mode and at an accelerating voltage of 40 kV. Images are necessarily of relatively low resolution due to deliberate avoidance of conventionally applied conductive coats (carbon or gold-palladium) which might interfere with later elemental analyses of particles. EDS data are collected with a JEOL-35CF SEM equipped with PGT-6000 analyzer. Using an accelerating voltage of 20 kV, each particle is raster-scanned and its x-ray spectrum recorded over the 0-10 keV range by counting for 100 sec. No system (artifact) peaks of significance appear in the spectra.

It should be pointed out that the SEM/EDS procedure used in preparing this catalog is different than that used in preparing Cosmic Dust Catalogs, Volumes 1, 2, and 3. In the earlier catalogs, both SEM imaging and EDS analysis were performed using the JEOL-100CX STEM operated at 40 kV. The new procedure retains the superior imaging capability of the JEOL-100CX but incorporates the superior EDS capabilities of the JEOL-35CF. The new, two-step process provides the best possible preliminary-quality data while minimizing the electron-beam exposure experienced by the samples. The only

changes likely to be noticed by readers occur in the EDS spectra. However, the same comparison standard spectra published in previous catalogs were re-collected under the new procedure and are included in this catalog. Please refer to Section 5 for a more complete discussion.

Following SEM/EDS examination, each particle mount is stored in a dry nitrogen gas atmosphere in a sealed cabinet.

4. CATALOG FORMAT

Each page in the main body of the catalog is devoted to one particle and consists of an SEM image, an EDS spectrum, and a brief summary of preliminary examination data obtained by optical microscopy. The unique identification number assigned to the particle appears at the top of the page. Sources of the descriptive data are as follows:

SIZE (μm) is measured using the original SEM image and its known magnification factor. For an irregularly shaped particle, the minimum dimension in the plane of the field of view is located and determined; then a second (maximum) dimension is measured at a right angle to the first. For a spherical or equidimensional particle, only a single size is recorded.

SHAPE is generalized to be spherical (S), equidimensional (E), or irregular (I). Particles having shape intermediate between S and E, or E and I, are not uncommon and may be denoted as S/E or E/I, etc.

TRANSPARENCY (abbreviated TRANS.) is determined by optical microscopy to be transparent (T), transulcent (TL), or opaque (O). Significant variations in transparency within a particle are annotated on the SEM image.

COLOR is determined by optical microscopy using oblique (fiber-optic, quartz-halogen) illumination supplemented with normal reflected (tungsten-lamp) illumination. Although color perception may vary with observer, the distinction of dark (Dk.) from light (Lt.) particles is unambiguous. Similarly, the distinction of colorless (CL) from colored particles is only occasionally in doubt. Complex colorations of individual particles may be noted in the "COMMENTS" column and annotated on the SEM image.

LUSTER is determined by optical microscopy using reflected normal (tungsten-lamp) illumination and supplemented with oblique (fiber-optic, quartz-halogen) illumination. Commonly applied descriptions, adopted from mineralogical usage, include dull (D), metallic (M), submetallic (SM), subvitreous (SV), and vitreous (V). Lusters transitional between categories or difficult to identify are indicated accordingly (D/SM, SV/V, etc.).

TYPE indicates a provisional first-order identification of each particle based on its morphology (from SEM image), elemental composition (from EDS spectrum), and optical properties. We emphasize that, for catalog purposes, types are defined for their descriptive and curatorial utility, not as scientific classifications. These tentative categorizations, which reflect judgements based on the collective experience of the CDPET, should not be construed to be firm identifications and should not dissuade any investigator from requesting any given particle for detailed study and proper identification. In the absence of any generally accepted taxonomy for stratospheric dust, the precise identification of each particle in our inventory is beyond the scope and intent of our collection and curation program. Indeed, the reliable identification and scientific classification of cosmic dust is one of many important research tasks which we hope our program will stimulate. We indicate particle "TYPE" only to aid the users of this catalog (especially those new to small-particle analysis) in distinguishing possible cosmic dust particles from other particles which are invariably collected during stratospheric dust sampling. Categories used in this catalog are defined as follows:

AOS: Aluminum oxide sphere. An AOS is transparent, subvitreous to vitreous in luster, colorless to pale yellow and at least approximately spherical. However, shape may range from nearly perfect sphericity to pronounced ellipticity and surface texture may range from very smooth to rough. Other spheres or irregularly shaped material may be attached to its surface. Al is the distinctively dominant (or only) peak in its EDS spectrum. A sphere displaying the attributes of an AOS except with major elements in addition to Al may be listed as "AOS?" or "?". Transparent Al-rich particles of irregular shape would probably be listed as "?" or "TCA?". (AOS particles are thought to be products of solid-fuel rocket exhausts.)

C: Cosmic dust (variety unspecified) or other extraterrestrial material. In the strict sense, "cosmic dust" refers only to those particles which have not been modified during passage from interplanetary space to Earth's stratosphere. In this catalog, though, particle type "C" is used to conveniently group together all particles which are judged to be of extra-terrestrial origin, including those that have apparently experienced strong ablational heating or melting. Type "C" particles are provisionally identified as those having one of the three following sets of attributes:

(a) irregular to spherical, opaque, dark-colored particles composed mostly of Fe with minor Ni or S.

(b) irregular to spherical, translucent to opaque, dark-colored particles containing various proportions of Mg, Si, and Fe with traces of Al, Ca, S, or Ni.

(c) irregular to faceted or blocky, transparent to translucent particles containing mostly Mg, Si, and Fe but with traces of Al or Ca.

Category (a) and (b) particles commonly display either complex, porous aggregate-type morphologies or distinctively spherical shapes and dull to metallic lusters which distinguish them from terrestrial minerals. Their EDS spectra are reminiscent of those exhibited by meteoritic Fe-Ni or FeS minerals, or combinations of Fe-Ni-S phases with olivine and/or pyroxene. Category (c) particles display morphologies and EDS spectra which suggest that they are fragments of olivine or pyroxene crystals, neither of which are significant components of stratospheric volcanic ash. Particles which do not fall easily into categories (a), (b), or (c) but which possess some of the same attributes may be classified here as "C?".

TCA: Terrestrial contamination (artificial or man-made). Particles included in the "TCA" category are commonly irregular in shape (though a few may be spherical) and may be transparent, translucent, or opaque. Their EDS spectra commonly show Al, Fe, or Si as the principal peaks but with a variety of minor peaks including those of Ti, V, Cr, Mn, Ni, Cu, or Zn and at abundances which are frequently much greater

than those expected in common minerals. However, such compositions are similar to those expected for certain metal alloys. In some cases, a high intensity (relative to intensities of characteristic x-ray peaks) of continuum radiation occurs in the EDS spectrum, suggesting that low atomic number elements not detectable by the EDS (e.g., H, C, N, O) are abundant in the particle. Such "TCA" particles are tacitly inferred to by synthetic carbon-based materials. (This category probably includes particles produced by or derived from aircraft operation or collector hardware, or possibly spacecraft debris.)

TCN: Terrestrial contamination (natural). "TCN" particles may be transparent to opaque and may exhibit a variety of colors. However, they are commonly irregular in shape and distinctively rich in Si and Al with minor abundances of Na, K, Ca, or Fe. Morphologies and EDS spectra of most "TCN" particles compare favorably with respective properties of silica polymorphs, feldspar, or silicic volcanic glass, three materials which are principal components of stratospheric volcanic ash. In addition, platy or porous aggregate-type particles of light color and Si, Al-rich composition may be silicic clay minerals, common phases in Earth's surface soils. Irregular, reddish Fe-rich particles may also be products of terrestrial rock weathering. Recognition of these and other phases as "TCN" particles is based mostly on CDPET's collective minera-

logical experience and comparison with some of the reference particles described in Section 5. Less commonly, the "TCN" category may include distinctive particles with apparently non-random shapes which are rich in low atomic number elements (as inferred from their EDS spectra having high levels of continuum x-radiation and relatively small peaks for characteristic x-rays). Those rare particles are distinguished from "TCA" particles by their unusual, organized morphologies and probably represent biological contaminants.

?: Identification uncertain. This category includes particles which do not unequivocally resemble those grouped together as AOS, C, TCA, or TCN. In addition, the "?" symbol is liberally used to reiterate the tentative identifications of other types of particles.

Again, this system for provisional classification of particles is presented only as a first-order attempt to distinguish particles which are probably extraterrestrial in origin from those which are probably contaminants. Many particles, especially those cataloged as type "?", will require careful research examination before they can be satisfactorily identified.

COMMENTS are included for particles with special features or histories. Particles lost during or after preliminary SEM examination, or particles with possible genetic relationships to other particles are noted here.

5. ANALYSES OF REFERENCE MATERIALS

The usefulness of the SEM images and EDS spectra provided for particles in this catalog is enhanced by comparison with similar data products obtained for comparably sized particles of known composition. Accordingly, the next several pages summarize data acquired by EDS analysis of reference particles under the same conditions used in the preliminary examination of particles from the stratospheric dust collections. Each reference particle represents material which has proven useful as a reference (which may be distinct from an analytical standard) in SEM and/or electron microprobe work at JSC or elsewhere. Included in this group are several members of the excellent series of microprobe standards prepared by Eugene Jarosewich (Smithsonian Institution) and identified by their USNM numbers. Other materials will be added to our reference suite in future catalogs. However, those included here provide a sampling of minerals common in meteorites (olivine, pyroxene, ilmenite) or their ablation products (magnetite). A representative EDS spectrum obtained from a pressed pellet of Jarosewich's homogenized Allende chondrite powder is included as an example of a spectrum which should be typical of bulk carbonaceous chondrite material. In addition, reasonable analogs of stratospheric volcanic ash (rhyolite glass, sodic plagioclase) are included. For completeness, the currently accepted bulk composition (expressed as oxide weight percent) of each reference sample is also provided.

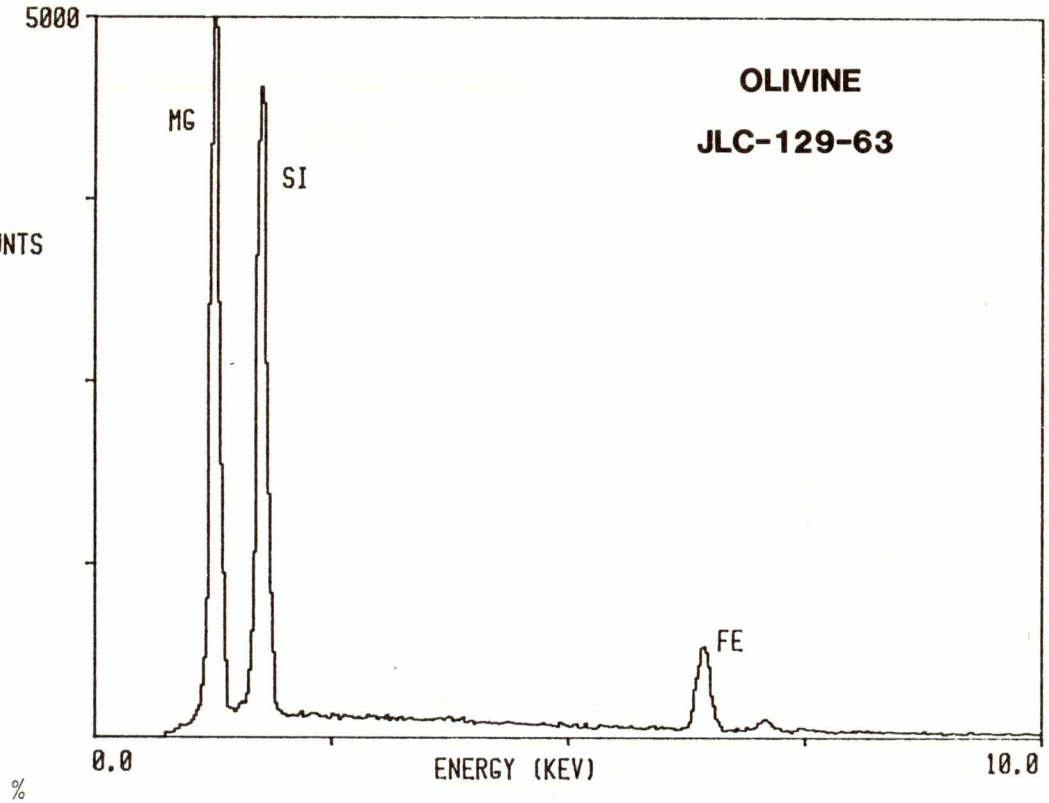
The EDS spectra included in this catalog are of quality equal to that which is routinely obtained in other state-of-the-art SEM laboratories. However, well-known geometrical and differential matrix effects prevent

these raw spectra from being interpreted as quantitative analyses. Hence, we have avoided the use of peak-height ratios as diagnostic compositional indicators.

In addition to the EDS spectra of whole reference particles, a typical EDS spectrum is presented for each of three standard minerals prepared as polished grain mounts (San Carlos olivine, USNM 111312/444; diopside JLC-99-63; Kakanui hornblende, USNM 143965). Analyses of these optically flat surfaces eliminate inter-sample geometrical variations so that effects of detection limits and compositional variations, in general, on relative peak heights in the raw spectra can be more readily assessed. Even so, the polished-grain spectra should not be over-interpreted because no corrections have been attempted for atomic number, absorption, or fluorescence effects. The spectra are presented simply as additional aids to the meaningful use of the sample particle EDS spectra. Investigators who might wish to compare performance characteristics of their EDS analytical systems with those of the system used by CDPET in preparing these catalog data should contact Curator/Cosmic Dust at the address given in Section 6. A short-term loan of a polished-grain mineral standard can then be arranged.

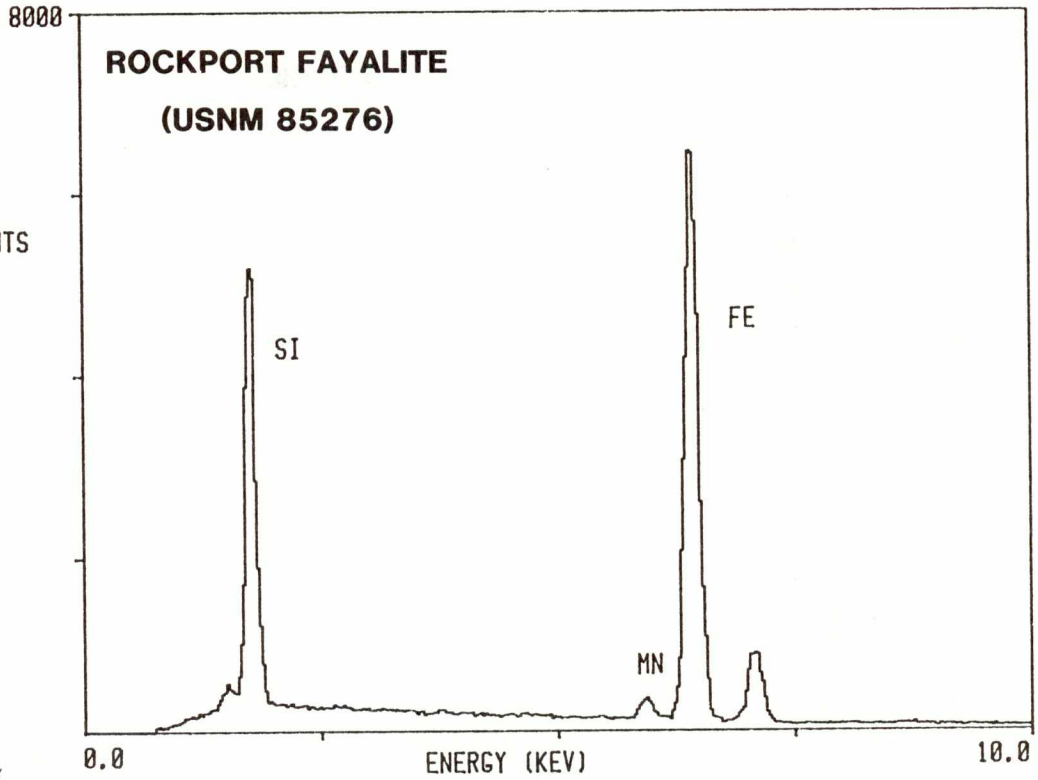
As pointed out in Section 3, the EDS spectra included in this catalog were obtained using a primary electron energy of 20 kV whereas spectra in previous catalogs were obtained with a different instrument operated at 40 kV. Although the effects on EDS spectra to be expected from such a change are well known from x-ray spectrometric analysis, they are worth pointing out to avoid confusion among the readers of this catalog. The major effects of concern to Cosmic Dust Catalog users can be seen by comparing the two "Allende (C3) Meteorite Bulk Powder" spectra, one of which was

obtained at 20 kV and the other at 40 kV. In the 20 kV spectrum, the Si peak is more intense than the principal peak of Fe whereas the opposite is true for the 40 kV spectrum. In general, the 20 kV spectra in this catalog will show peaks of light elements enhanced relative to peaks of heavy elements when compared with 40 kV spectra published in previous catalogs. The explanation is based both on geometrical differences between x-ray paths in the two EDS systems (the JEOL-35CF system is actually more favorable for light element analysis) and on electron and x-ray physics (x-ray emission by heavy elements is more intense at 40 kV than at 20 kV). Thus, readers are cautioned against attempting to quantitatively intercompare 20 kV spectra in this catalog with 40 kV spectra in previous catalogs. Still, the spectra in each catalog should continue to serve as originally intended. Namely, the sample and standard spectra in any given catalog will represent a self-consistent data set.



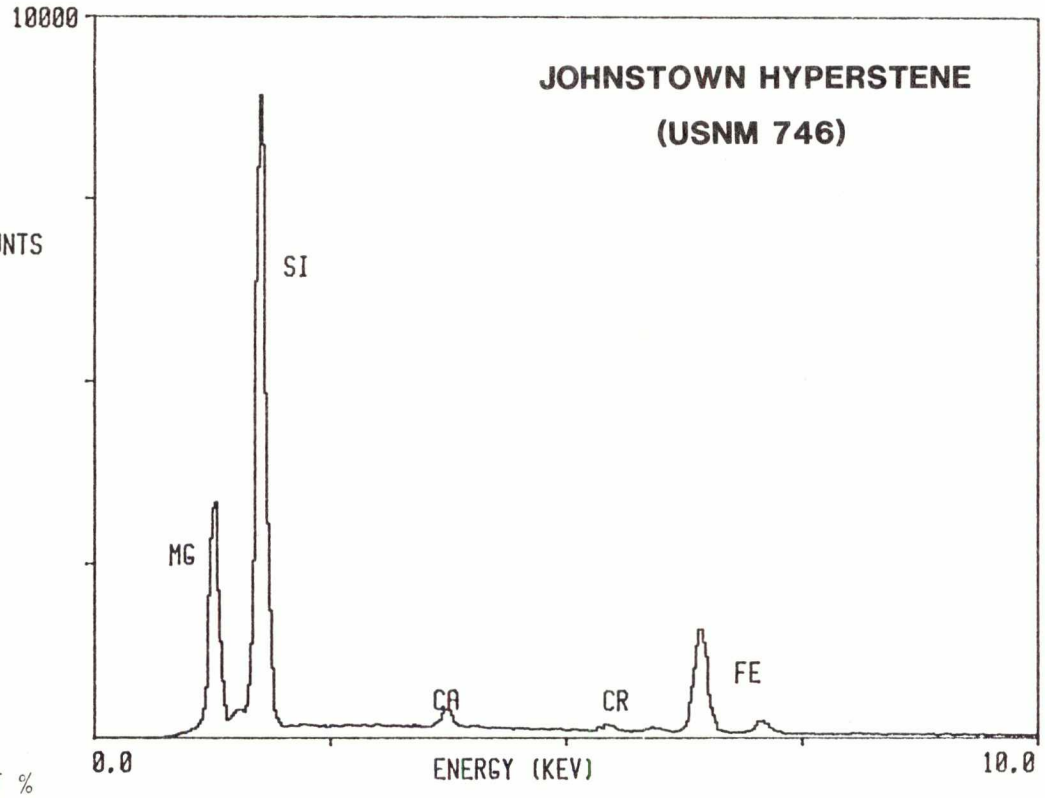
WEIGHT %

SiO_2	TiO_2	Al_2O_3	Cr_2O_3	Fe_2O_3	FeO	NiO	MnO	MgO	CaO	Na_2O	K_2O	TOTAL
40.94	0.01	0.07	0.01	-	8.74	0.35	0.12	49.64	0.10	-	-	99.98



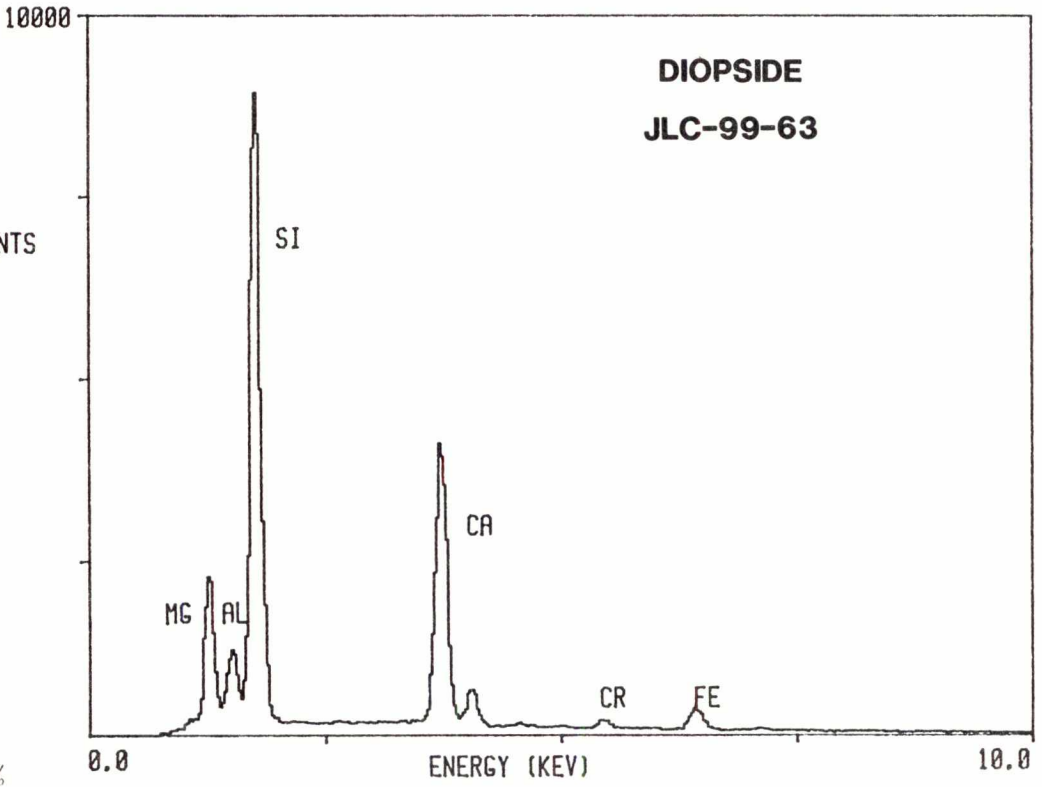
WEIGHT %

SiO_2	TiO_2	Al_2O_3	Cr_2O_3	Fe_2O_3	FeO	NiO	MnO	MgO	CaO	Na_2O	K_2O	TOTAL
29.22	0.04	-	-	1.32	66.36	-	2.14	-	-	-	-	99.08



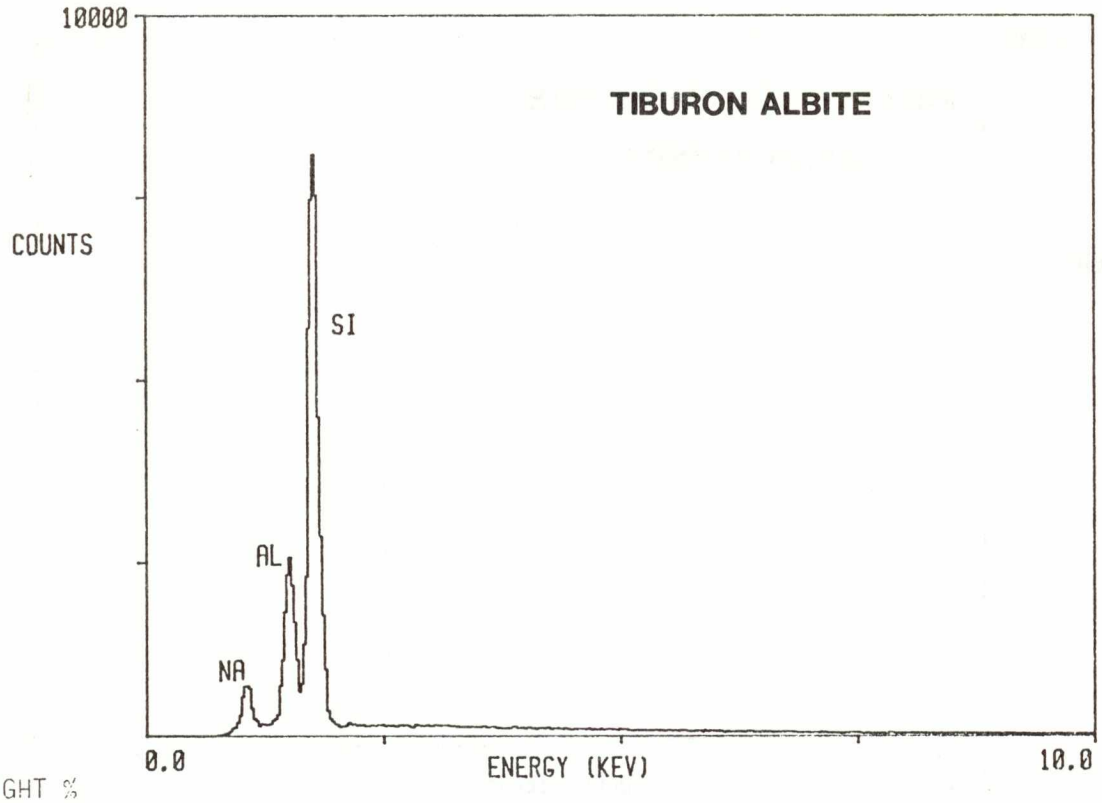
WEIGHT %

SiO_2	TiO_2	Al_2O_3	Cr_2O_3	Fe_2O_3	FeO	NiO	MnO	MgO	CaO	Na_2O	K_2O	TOTAL
54.09	0.16	1.23	0.75	-	15.22	-	0.49	26.79	1.52	<0.05	<0.05	100.25



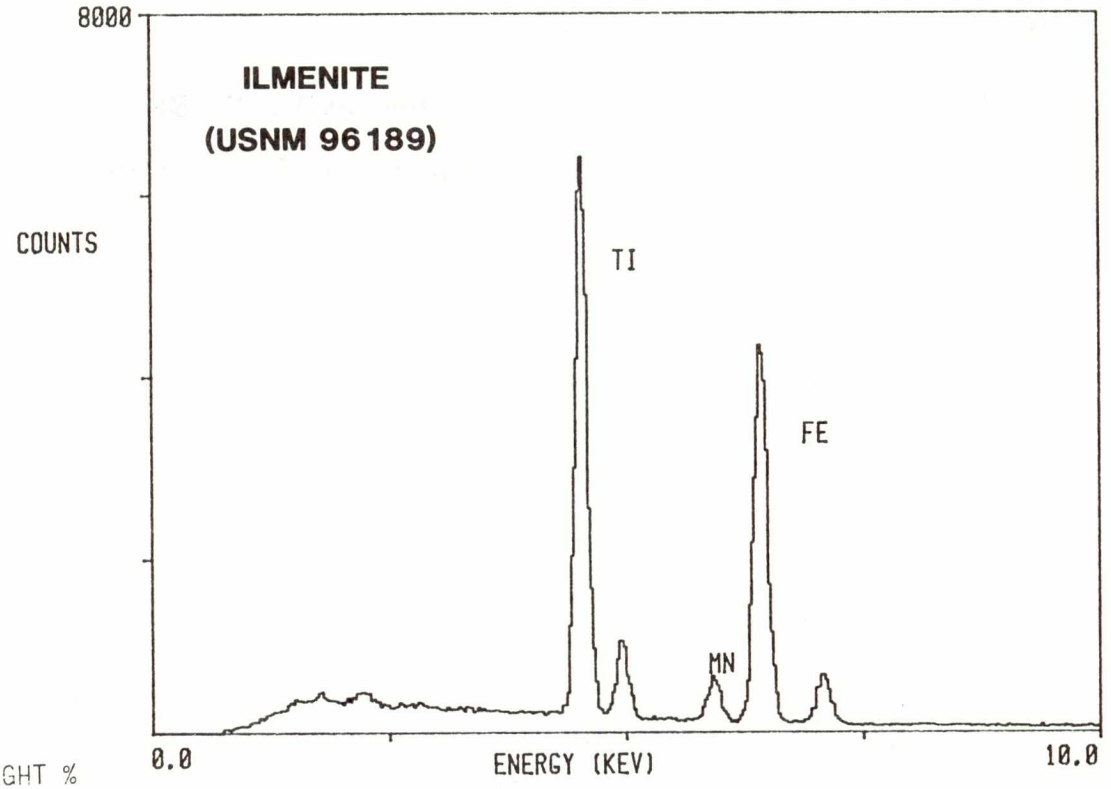
WEIGHT %

SiO_2	TiO_2	Al_2O_3	Cr_2O_3	Fe_2O_3	FeO	NiO	MnO	MgO	CaO	Na_2O	K_2O	TOTAL
51.93	0.46	6.31	0.96	1.80	2.34	0.04	0.07	16.05	18.64	1.39	-	99.99



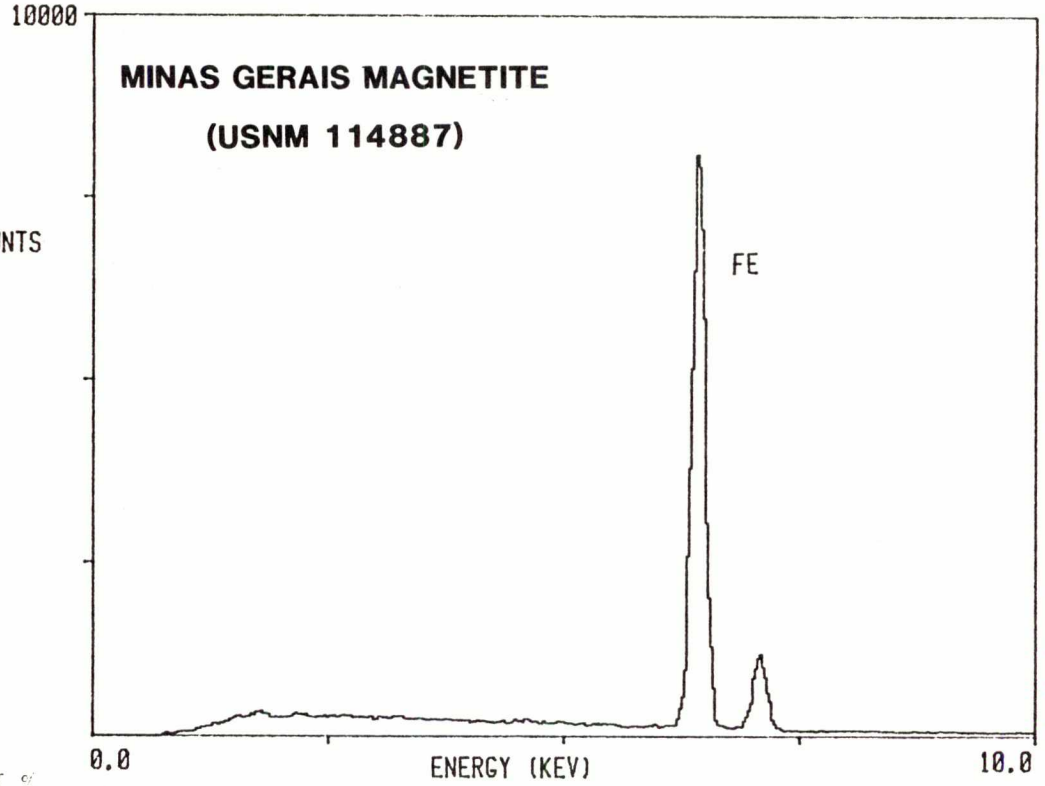
WEIGHT %

SiO_2	TiO_2	Al_2O_3	Cr_2O_3	Fe_2O_3	FeO	NiO	MnO	MgO	CaO	Na_2O	K_2O	TOTAL
68.22	-	19.90	-	0.06	-	-	-	-	0.00	11.65	0.03	99.86



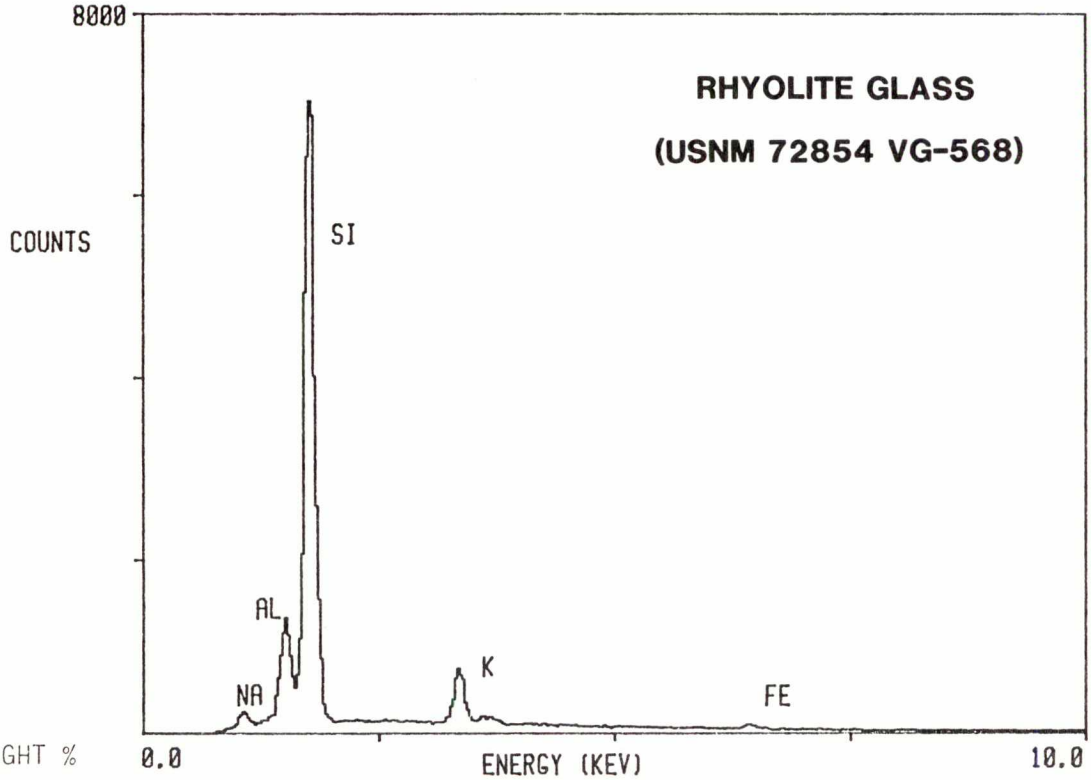
WEIGHT %

SiO_2	TiO_2	Al_2O_3	Cr_2O_3	Fe_2O_3	FeO	NiO	MnO	MgO	CaO	Na_2O	Nb_2O_5	TOTAL
-	45.7	-	-	11.6	36.1	-	4.77	0.31	-	-	0.92	99.40



WEIGHT %

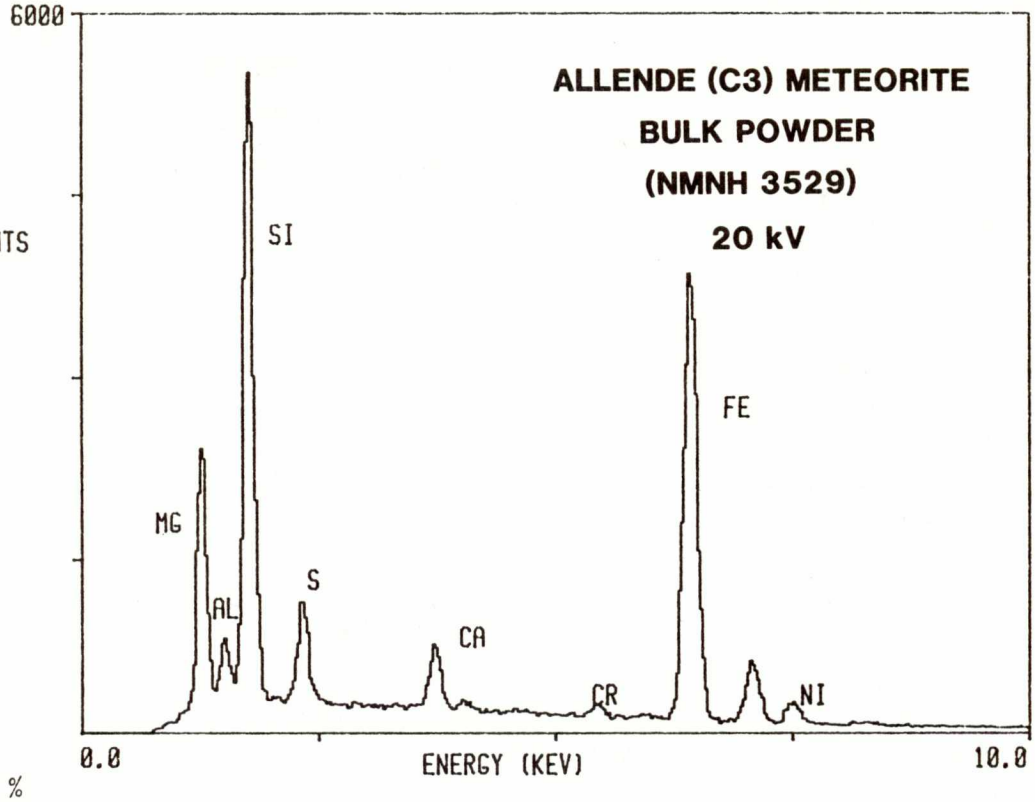
SiO_2	TiO_2	Al_2O_3	Cr_2O_3	Fe_2O_3	FeO	NiO	MnO	MgO	CaO	Na_2O	K_2O	TOTAL
-	0.16	-	0.25	67.5	30.2	-	<0.01	0.05	-	-	-	98.16



WEIGHT %

SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	Cl	H_2O	TOTAL
76.71	0.12	12.06	0.48	0.80	0.03	0.1	0.50	3.75	4.89	0.13	0.12	99.56

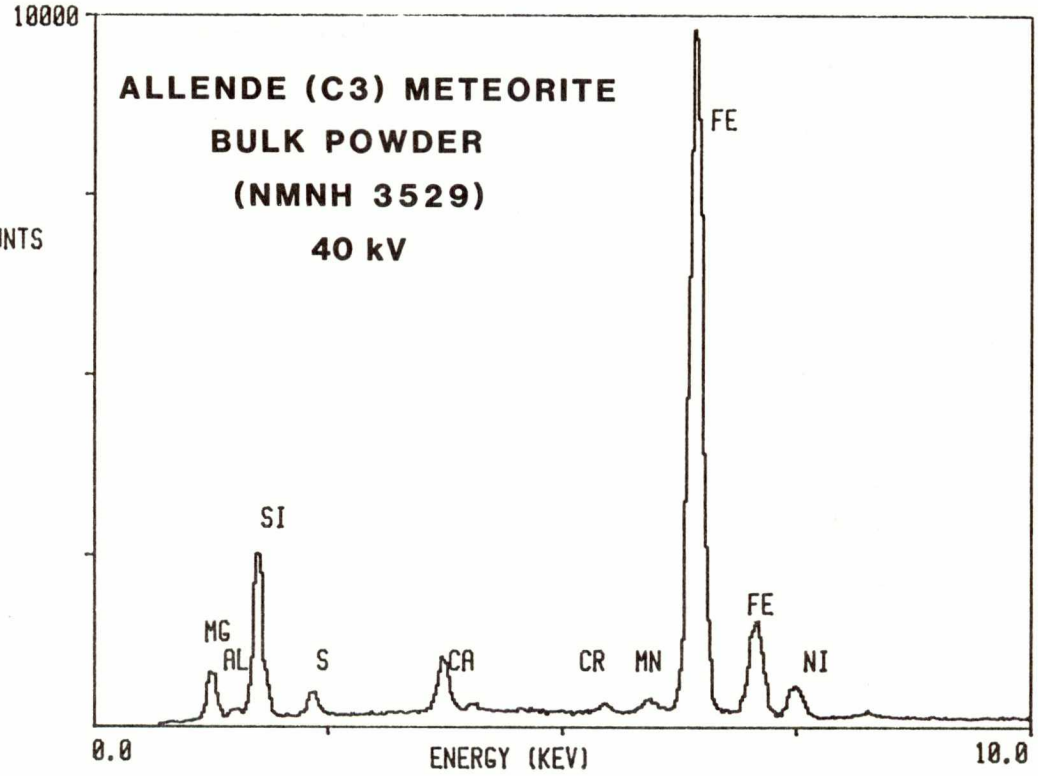
xx

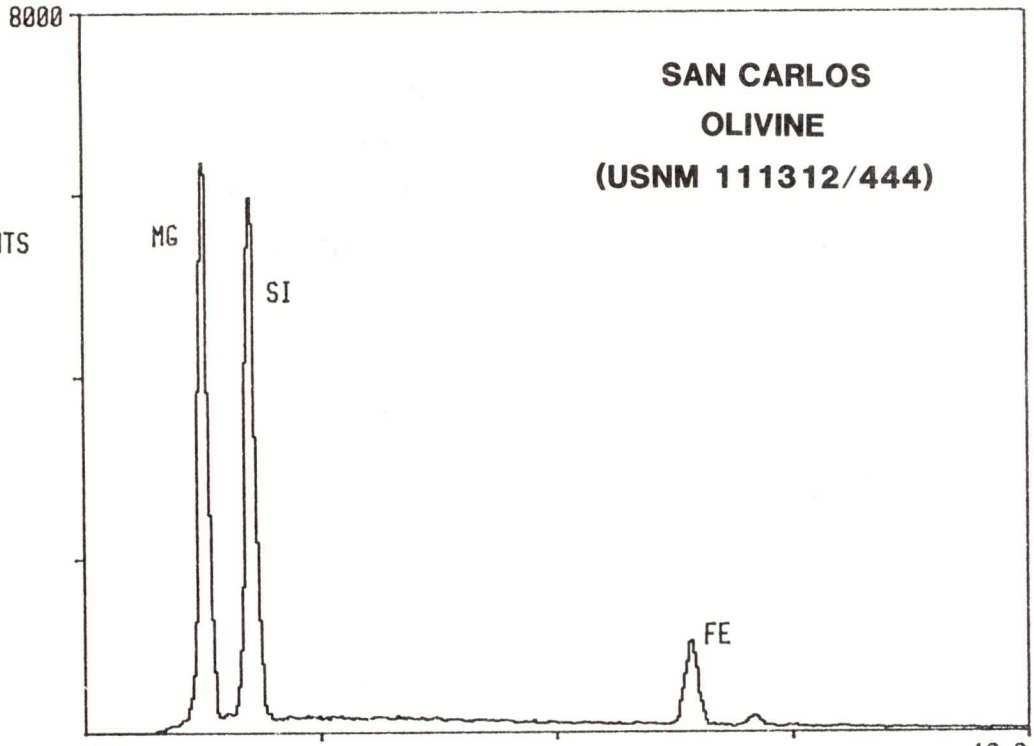


WEIGHT %

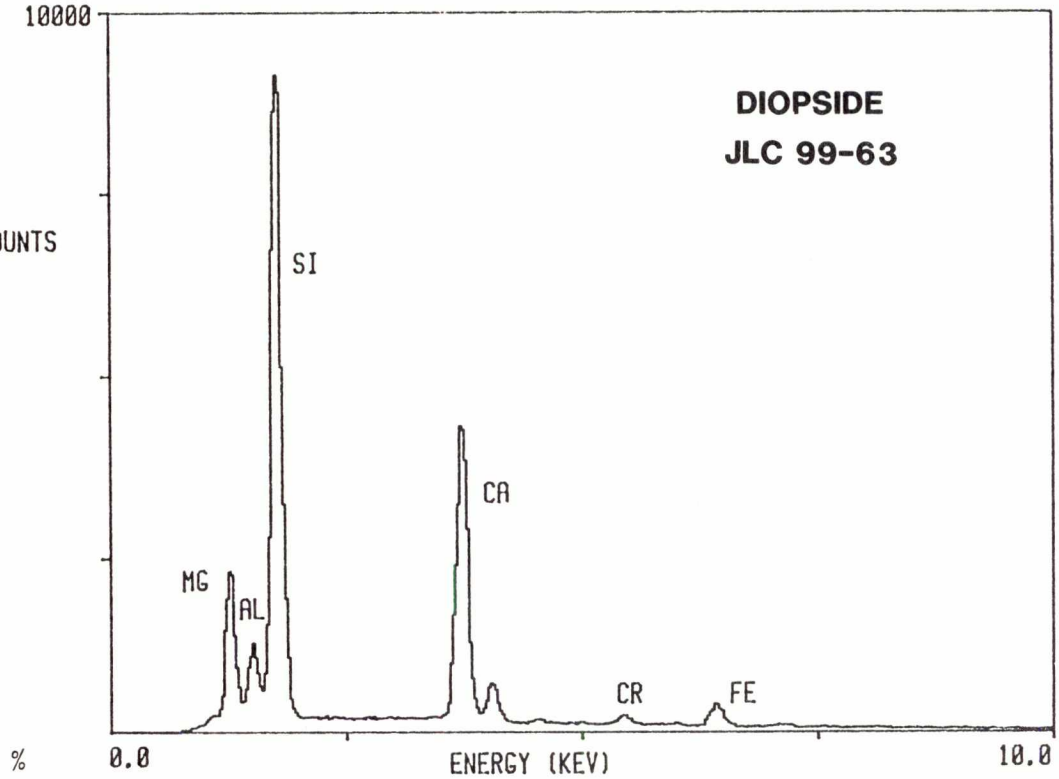
SiO_2	TiO_2	Al_2O_3	Cr_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	C
34.23	0.15	3.27	0.52	27.15	0.18	24.62	2.61	0.45	0.03	0.23	0.29

FeS	NiS	CoS	Fe^{O}	Ni^{O}	Co^{O}	TOTAL
4.03	1.60	0.08	0.17	0.36	0.01	99.98

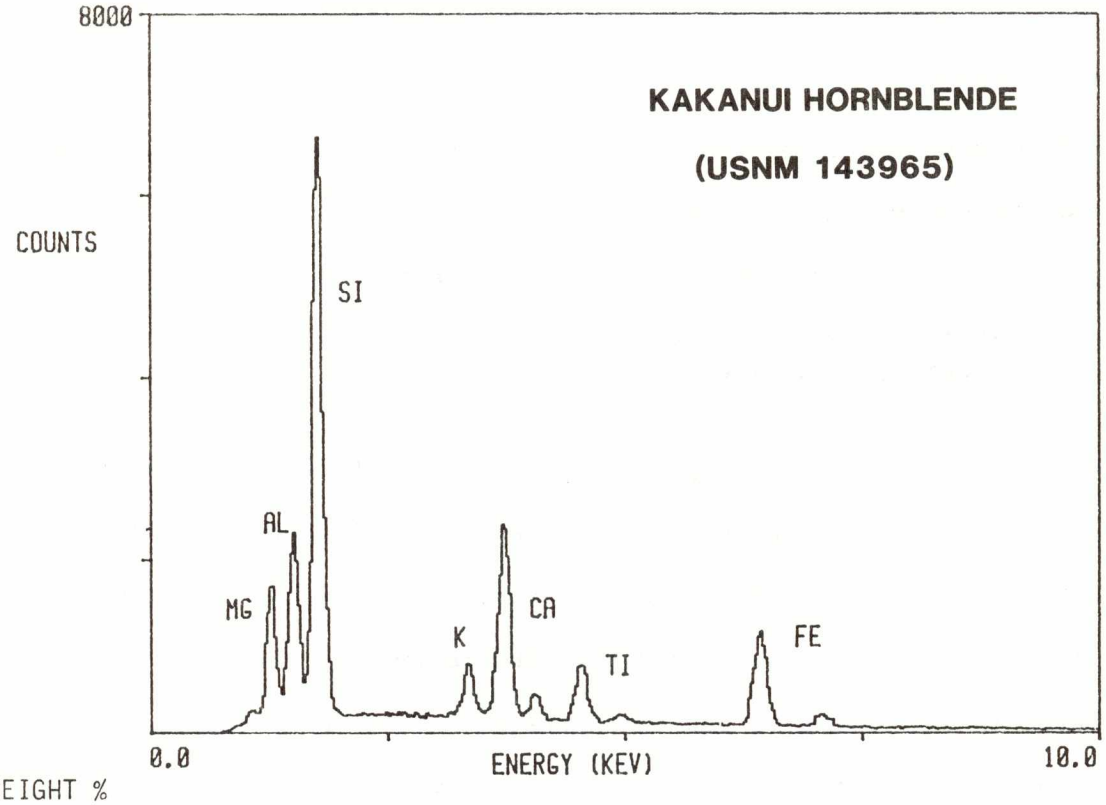




WEIGHT %												
SiO_2	TiO_2	Al_2O_3	Cr_2O_3	Fe_2O_3	FeO	NiO	MnO	MgO	CaO	Na_2O	K_2O	H_2O	TOTAL
40.81	-	-	-	-	9.55	0.37	0.14	49.42	<0.05	-	-	-	100.29



WEIGHT %													
SiO_2	TiO_2	Al_2O_3	Cr_2O_3	Fe_2O_3	FeO	NiO	MnO	MgO	CaO	Na_2O	K_2O	H_2O	TOTAL
51.93	0.46	6.31	9.96	1.80	2.34	0.04	0.07	16.05	19.64	1.39	-	-	99.99



WEIGHT %

SiO_2	TiO_2	Al_2O_3	Cr_2O_3	Fe_2O_3	FeO	NiO	MnO	MgO	CaO	Na_2O	K_2O	H_2O	TOTAL
40.37	4.72	14.90	-	3.30	7.95	-	0.09	12.80	10.30	2.60	2.05	0.94	100.02

6. SAMPLE REQUESTS

Scientists desiring to perform detailed research on particles described in this catalog should apply in writing to:

Curator/Cosmic Dust
Code SN2
NASA/Johnson Space Center
Houston, Texas 77058
U.S.A.

Telephone: (713) 483-6241
or -3274

Sample requests should refer to specific particle identification numbers and should describe the research being proposed as well as the qualifications and facilities of the investigator making the request. Additionally, requests for particles not yet passed through preliminary examination will be considered if the requester can demonstrate a strong need for them. NASA will arrange for a review of the scientific merits of each request and will inform the requester of the results. Approval of a sample does not imply or include funding for the proposed research. Questions about NASA funding should be directed to:

Discipline Scientist, Planetary Materials
Code EL-4
NASA Headquarters
Washington, D.C. 20546

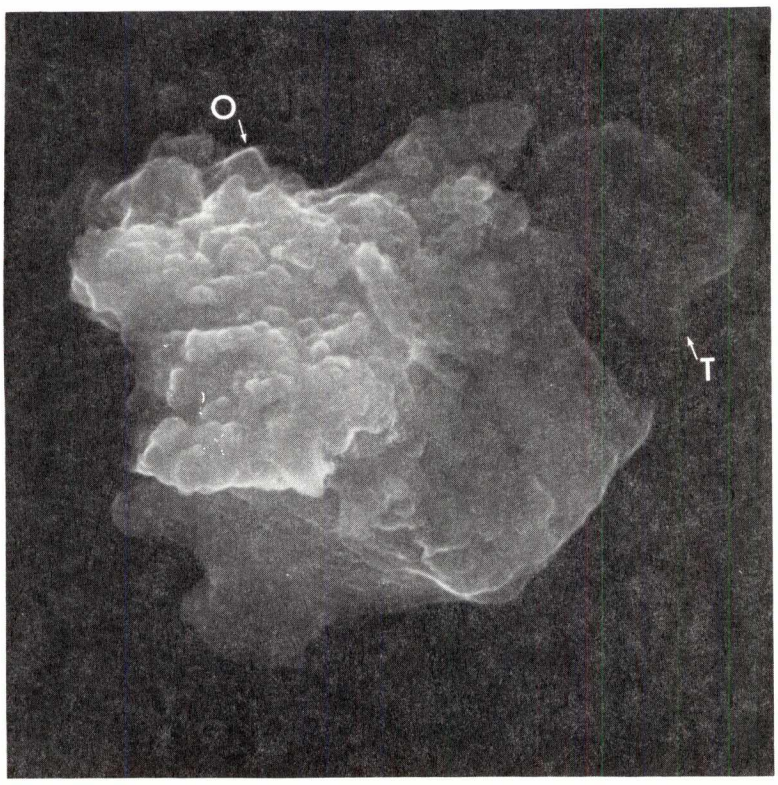
Although foreign scientists are welcome to request samples, NASA cannot provide funds to be spent outside the U.S.A. by citizens of other countries.

7. ACKNOWLEDGEMENTS

Eugene Jarosewich (Smithsonian Institution, Washington, D.C.) kindly provided several mineral standards and Roy S. Clarke, Jr. (also of Smithsonian Institution) generously supplied the Allende chondrite powder.

W7027A

W7027A1



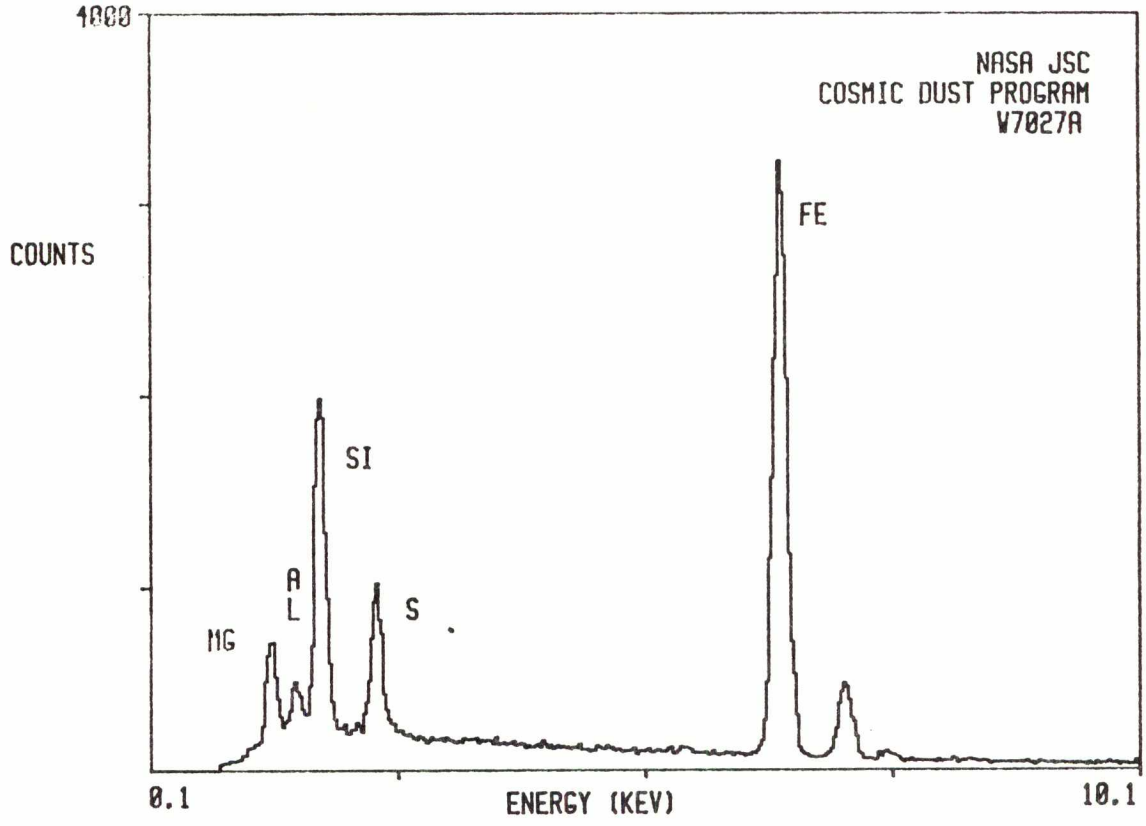
A0101

S-83-26372

SIZE	SHAPE	TRANS.
11x14	I	0

COLOR	LUSTER
Dk. Gray to Black	SV/SM

TYPE	COMMENTS
C	T grain attached



W7027A4

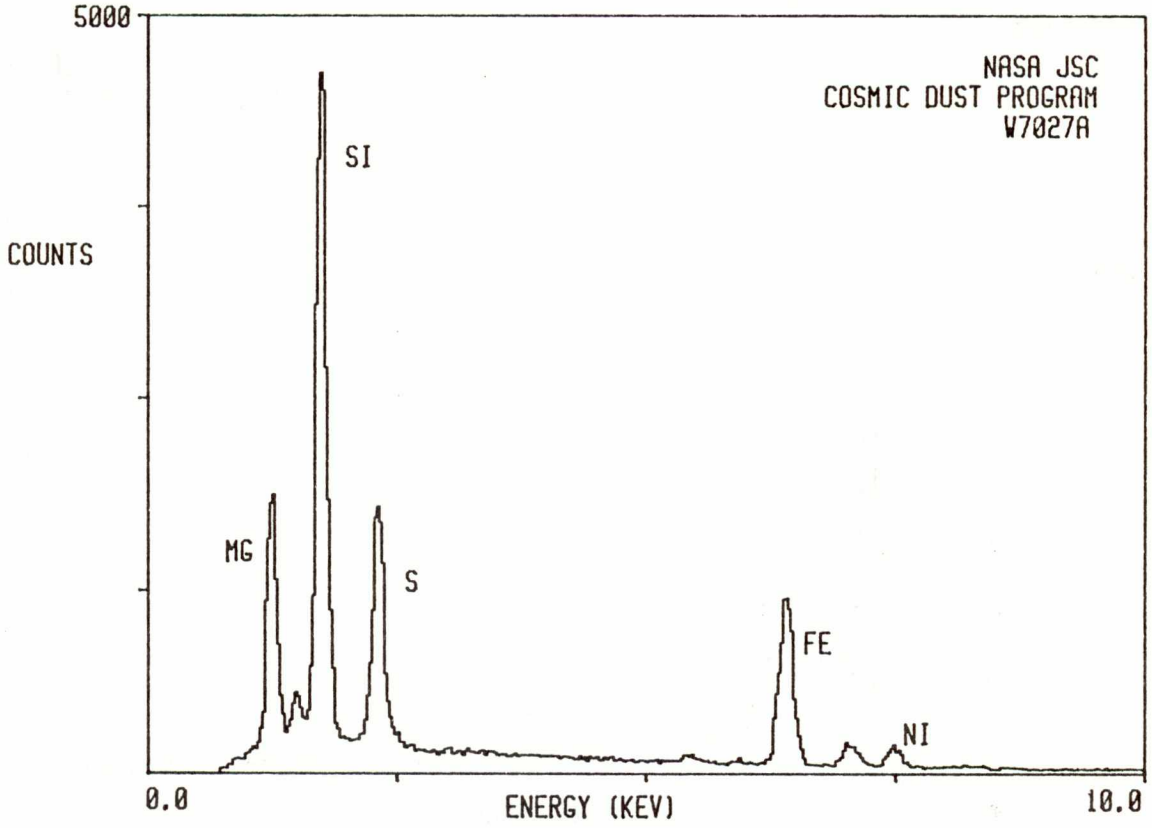
SIZE	SHAPE	TRANS.
17x20	I	0

COLOR	LUSTER
Dk. Gray to Black	D/SM

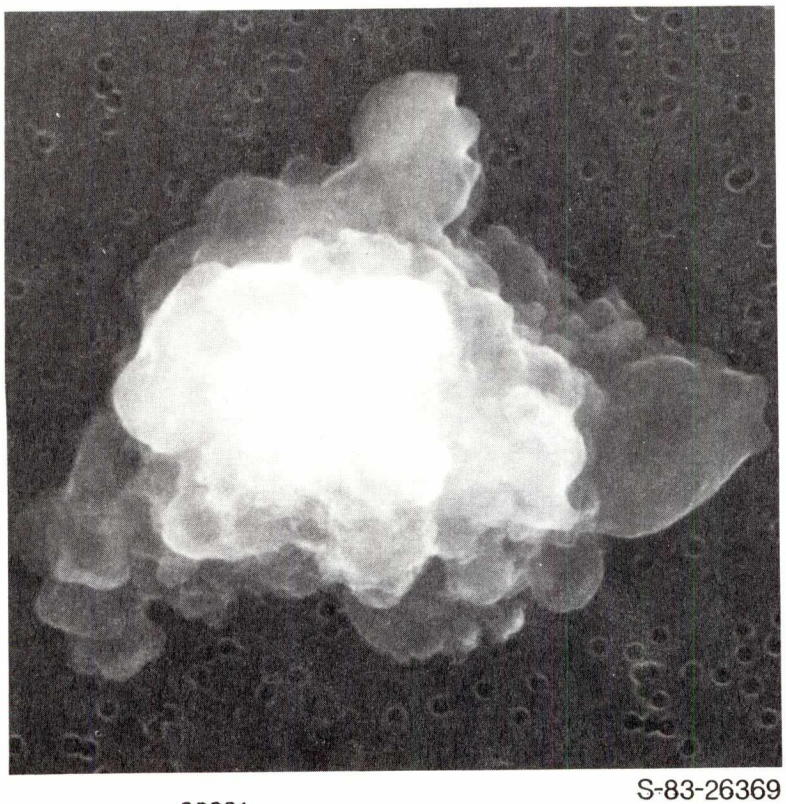
TYPE	COMMENTS
C	

A0401

S-83-26370



W7027A6



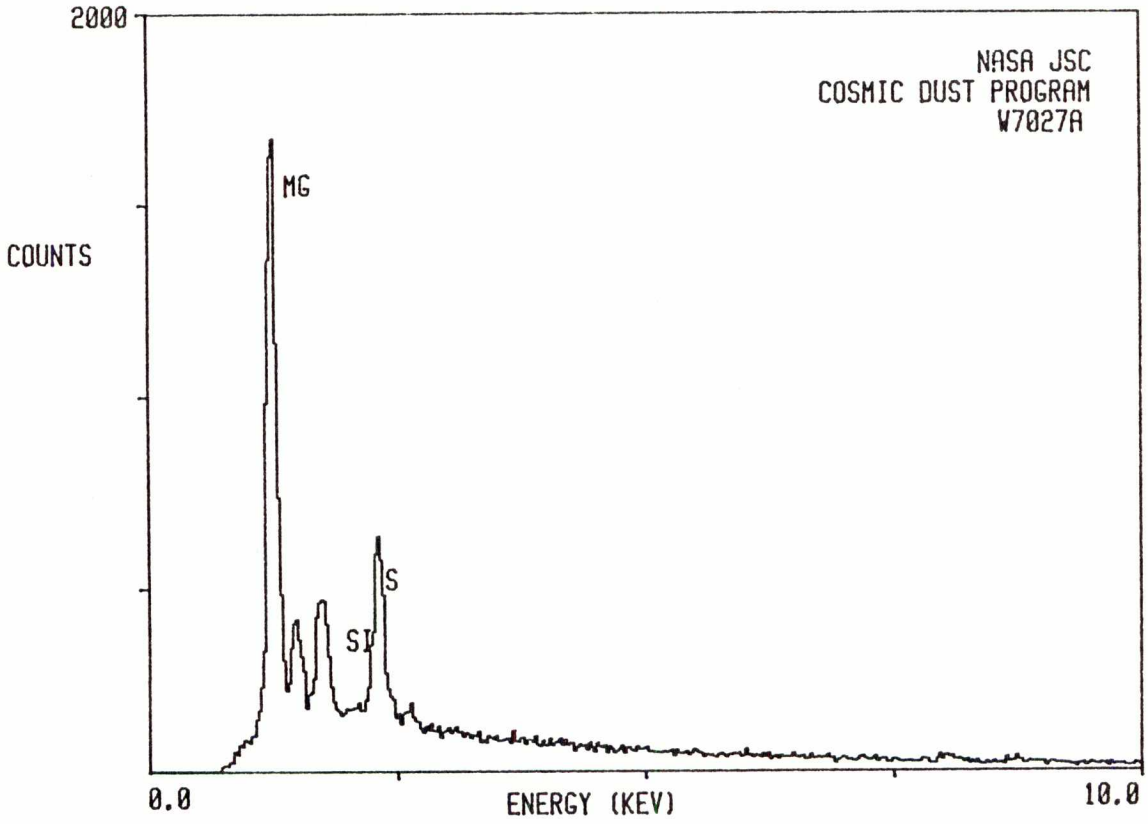
S-83-26369

A0601

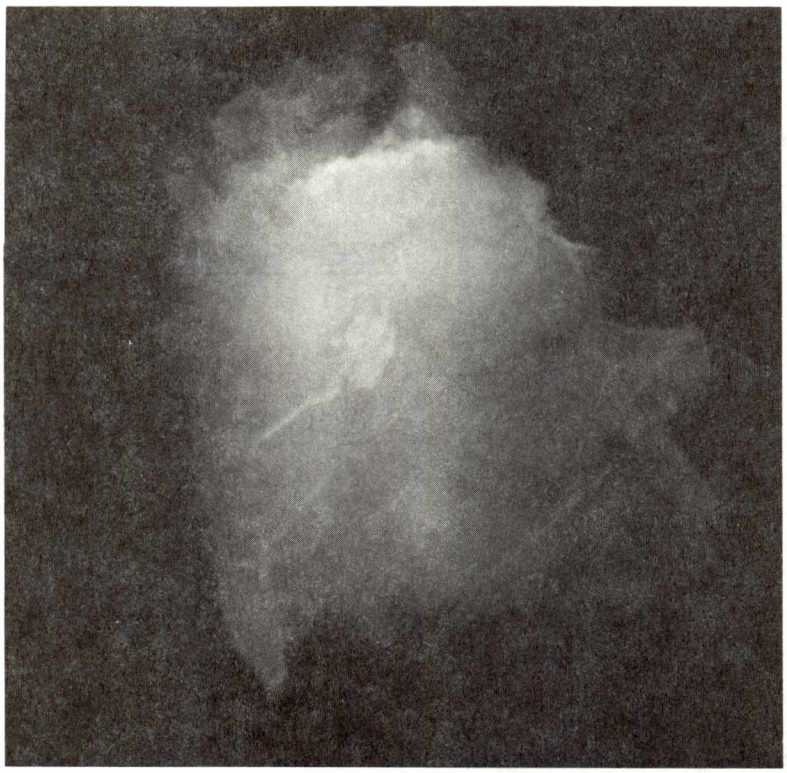
SIZE	SHAPE	TRANS.
12x16	I	O/TL

COLOR	LUSTER
CL to Pale Yellow-Gray	SV/V

TYPE	COMMENTS
?	



W7027A7



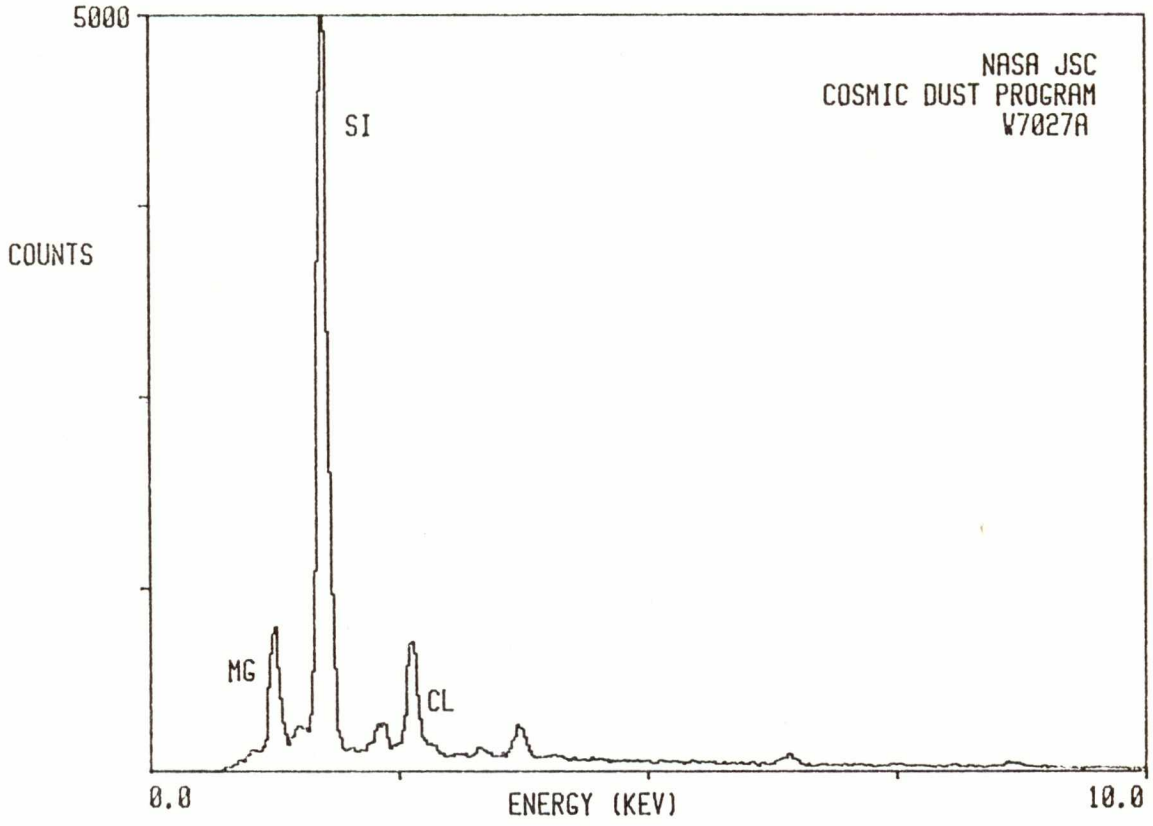
S-83-26368

SIZE	SHAPE	TRANS.
28x33	I	TL

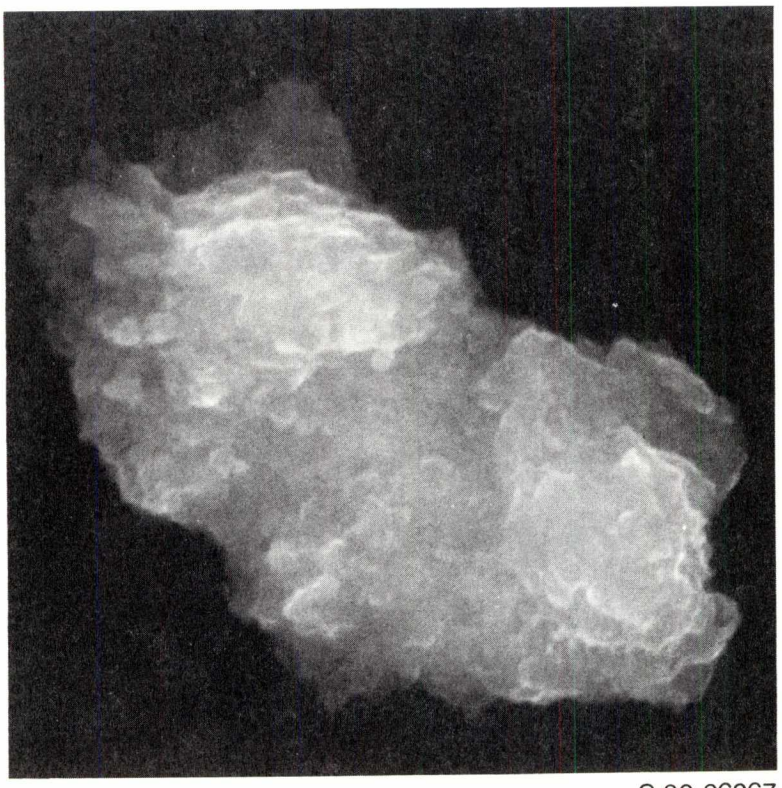
COLOR	LUSTER
CL to Pale Yellow-Gray	SV/V

TYPE	COMMENTS
?	

A0701



W7027A8



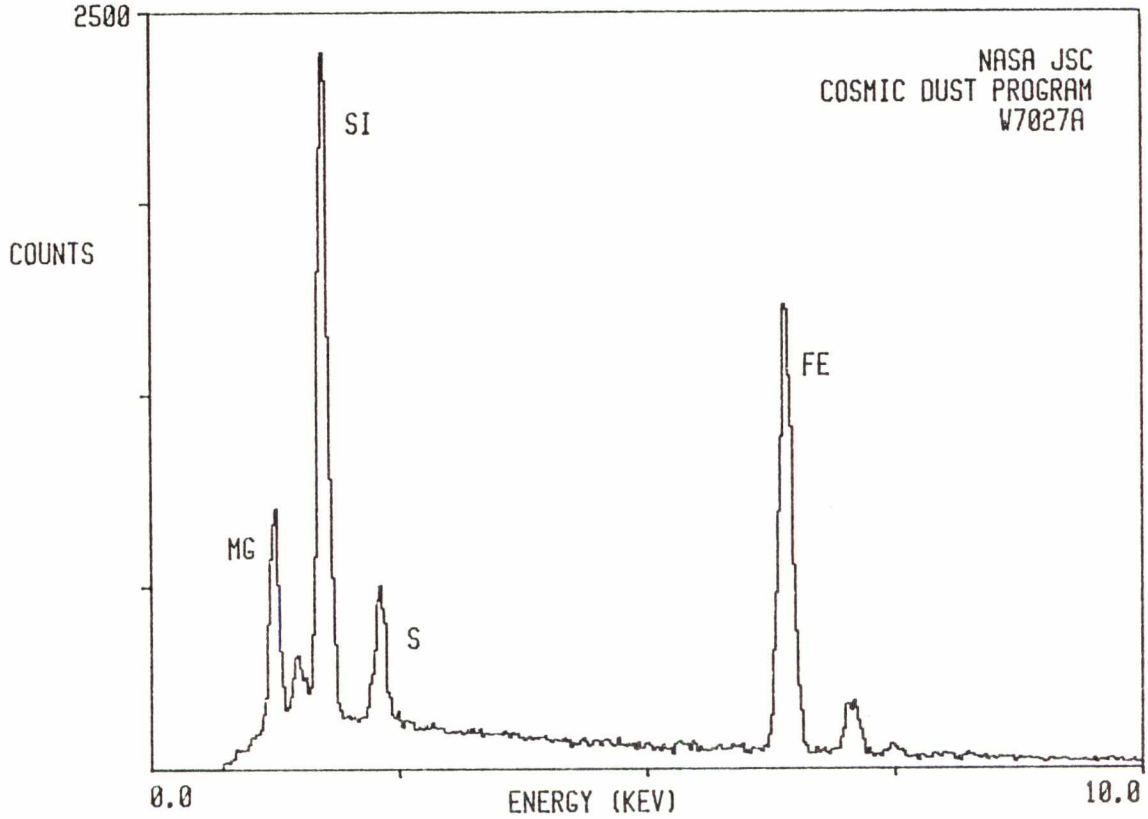
A0801

S-83-26367

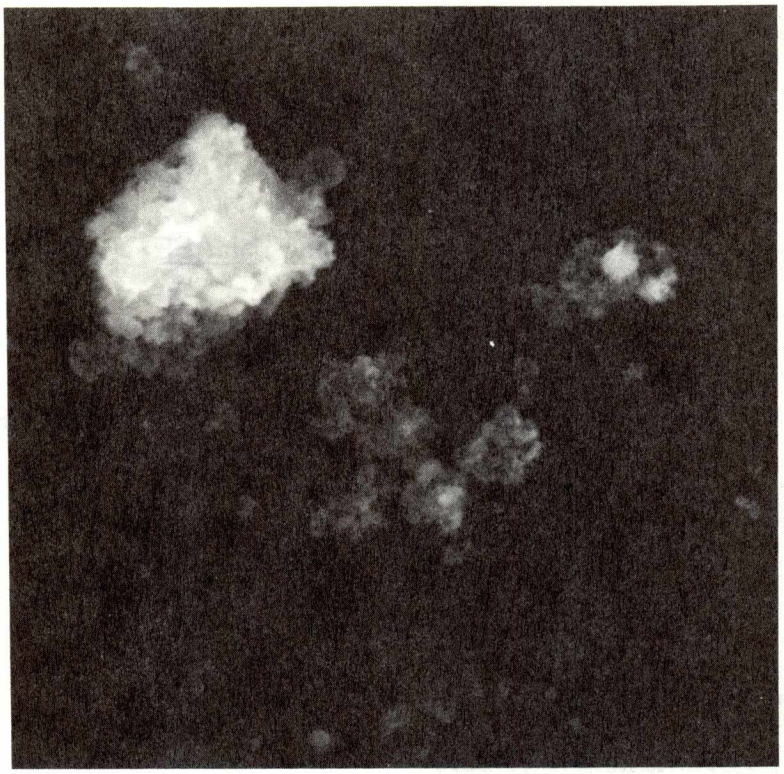
SIZE	SHAPE	TRANS.
12x21	I	0

COLOR	LUSTER
Dk. Brown to Black	D/SM

TYPE	COMMENTS
C	



W7027A11



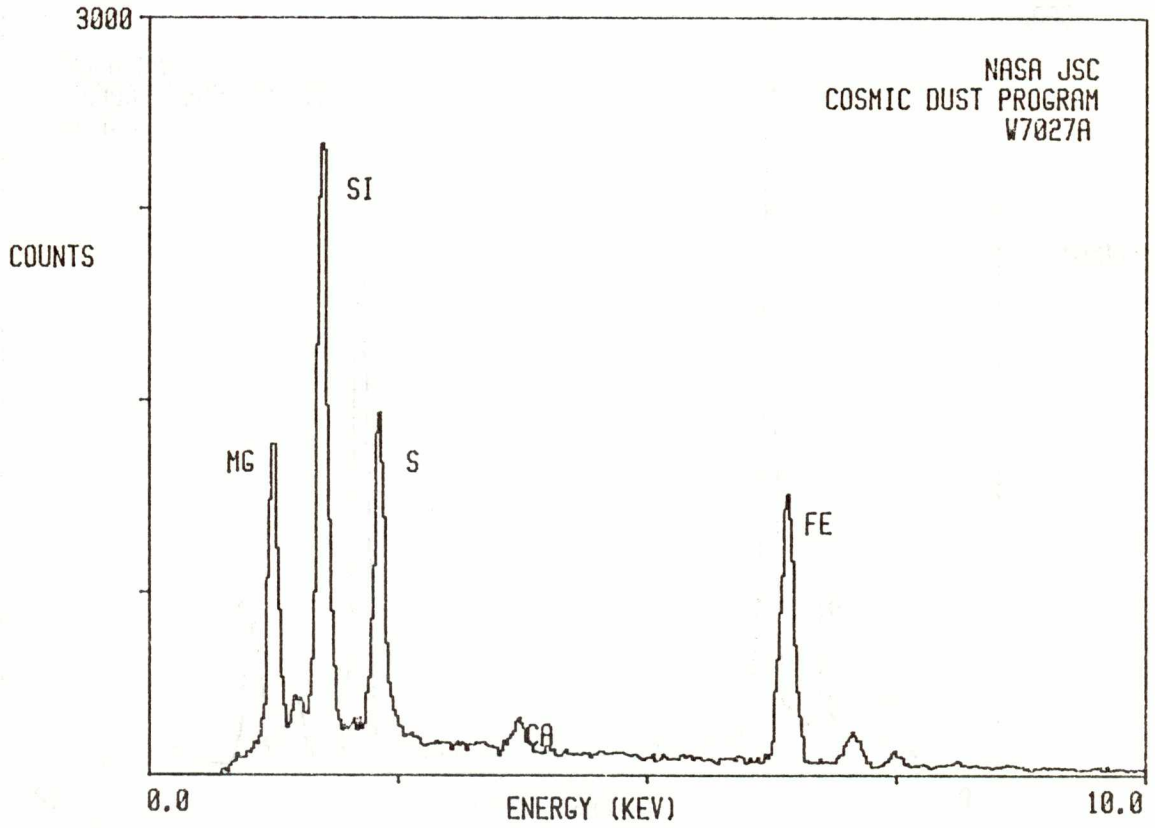
S-83-26366

A1101

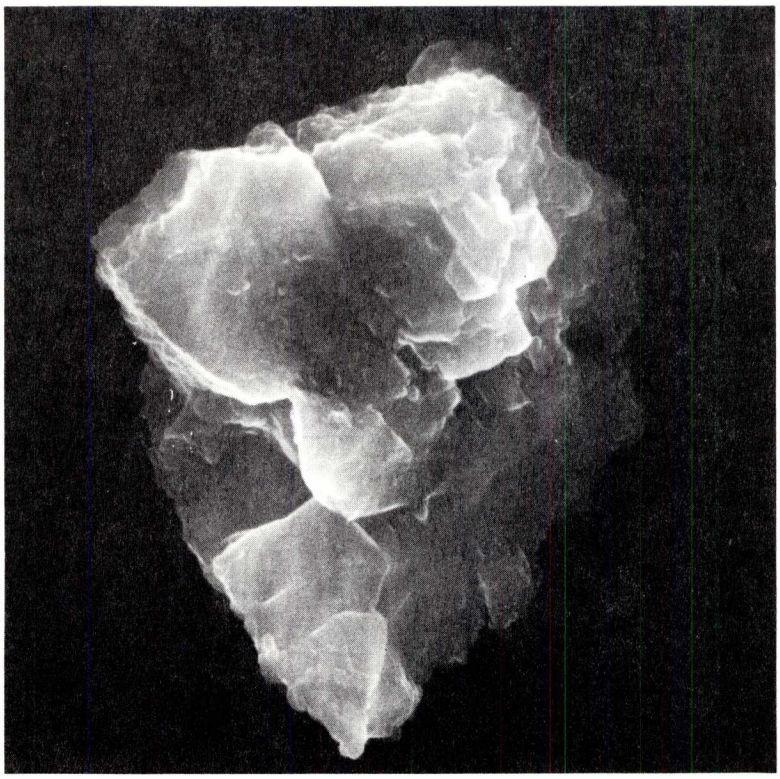
SIZE	SHAPE	TRANS.
17x23	I	0

COLOR	LUSTER
Dk. Gray to Black	SV/SM

TYPE	COMMENTS
C	Friable; size applies to largest fragment



W7027A12



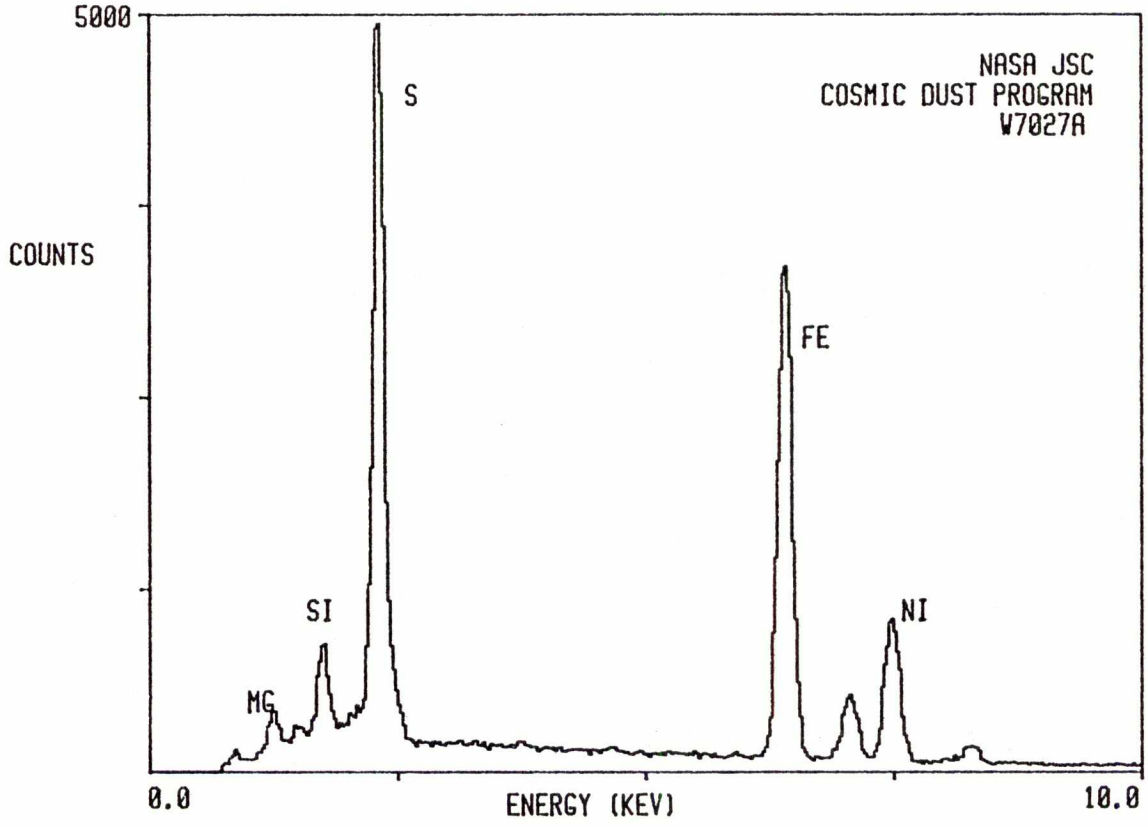
A1201

S-83-26365

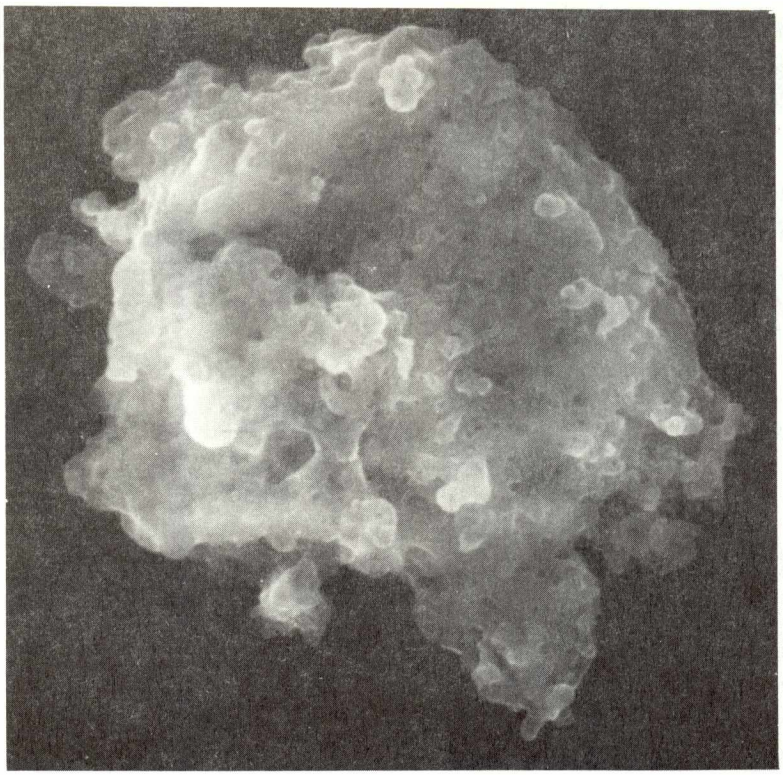
SIZE	SHAPE	TRANS.
18x24	I	O

COLOR	LUSTER
Black	SV/SM

TYPE	COMMENTS
C	



W7027A13



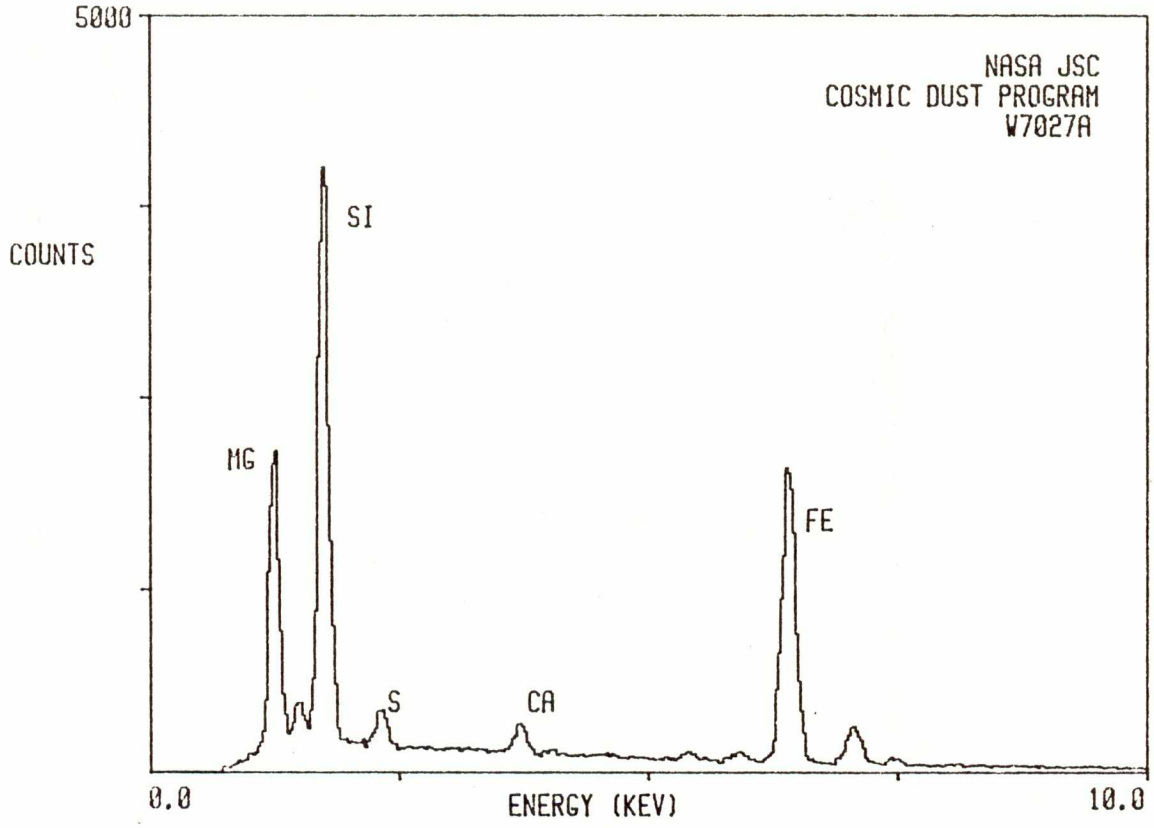
A1301

S-83-26364

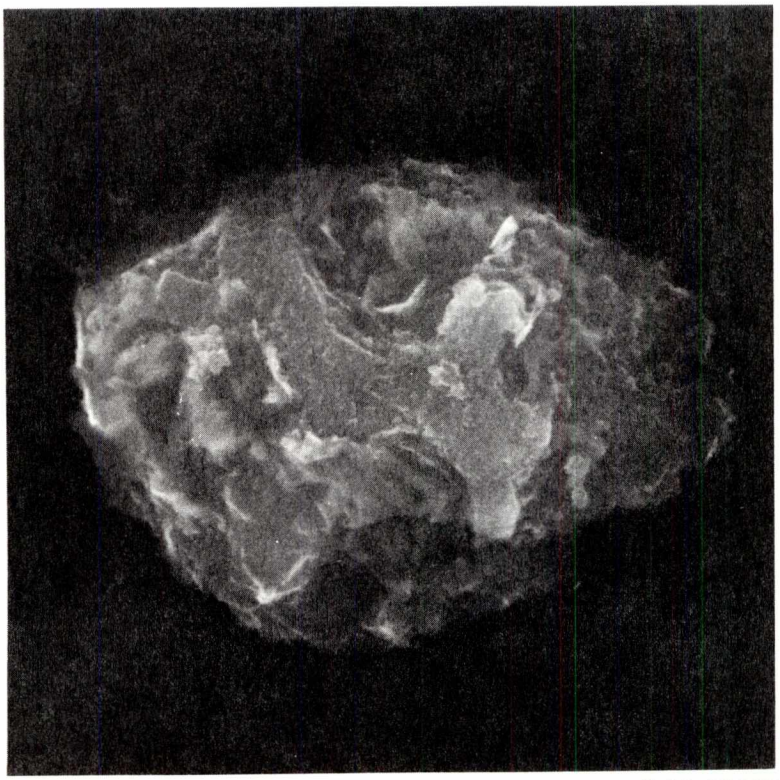
SIZE	SHAPE	TRANS.
25x31	I	0

COLOR	LUSTER
Dk. Brown to Black	SM

TYPE	COMMENTS
C	



W7027A14



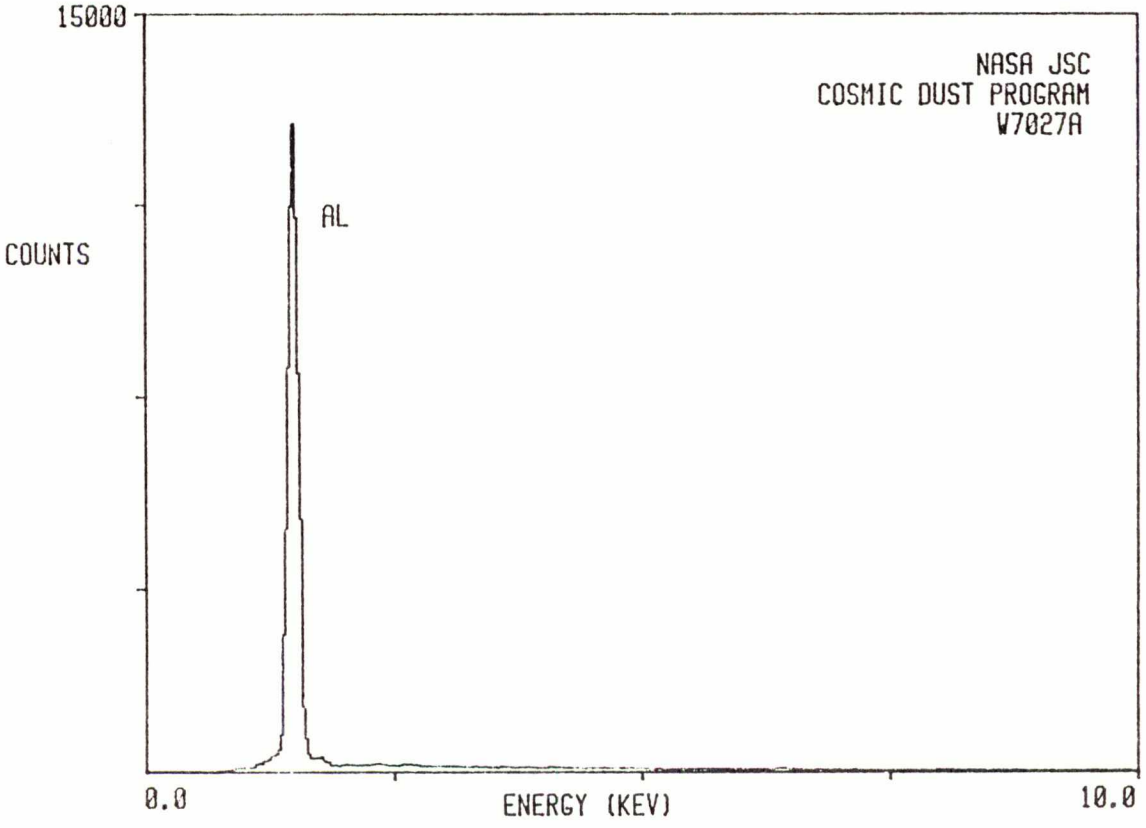
A1401

S-83-26363

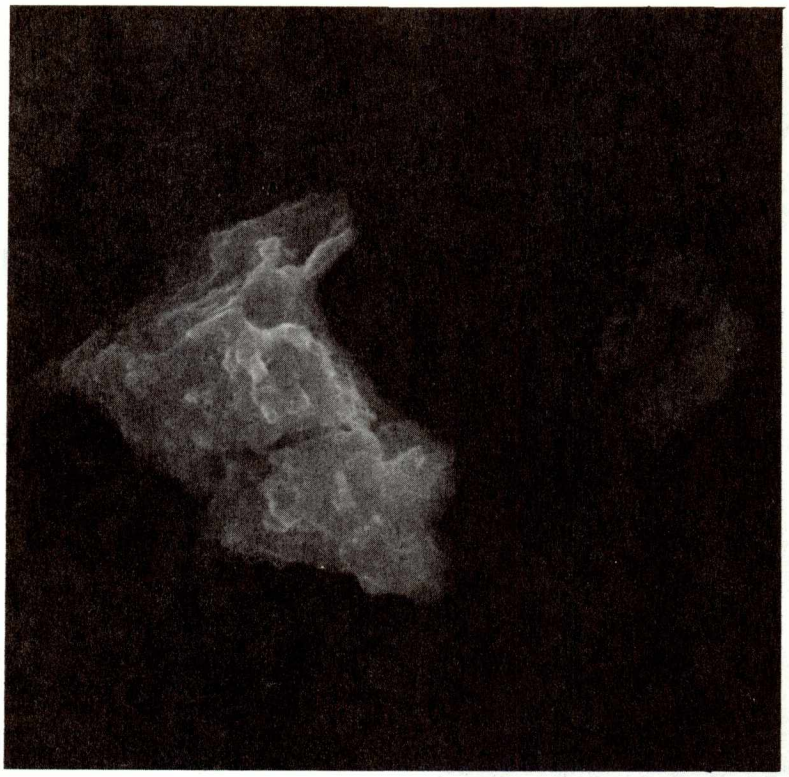
SIZE	SHAPE	TRANS.
13x18	I	0

COLOR	LUSTER
Dk. Gray to Black	D/SV

TYPE	COMMENTS
TCA	



W7027A15



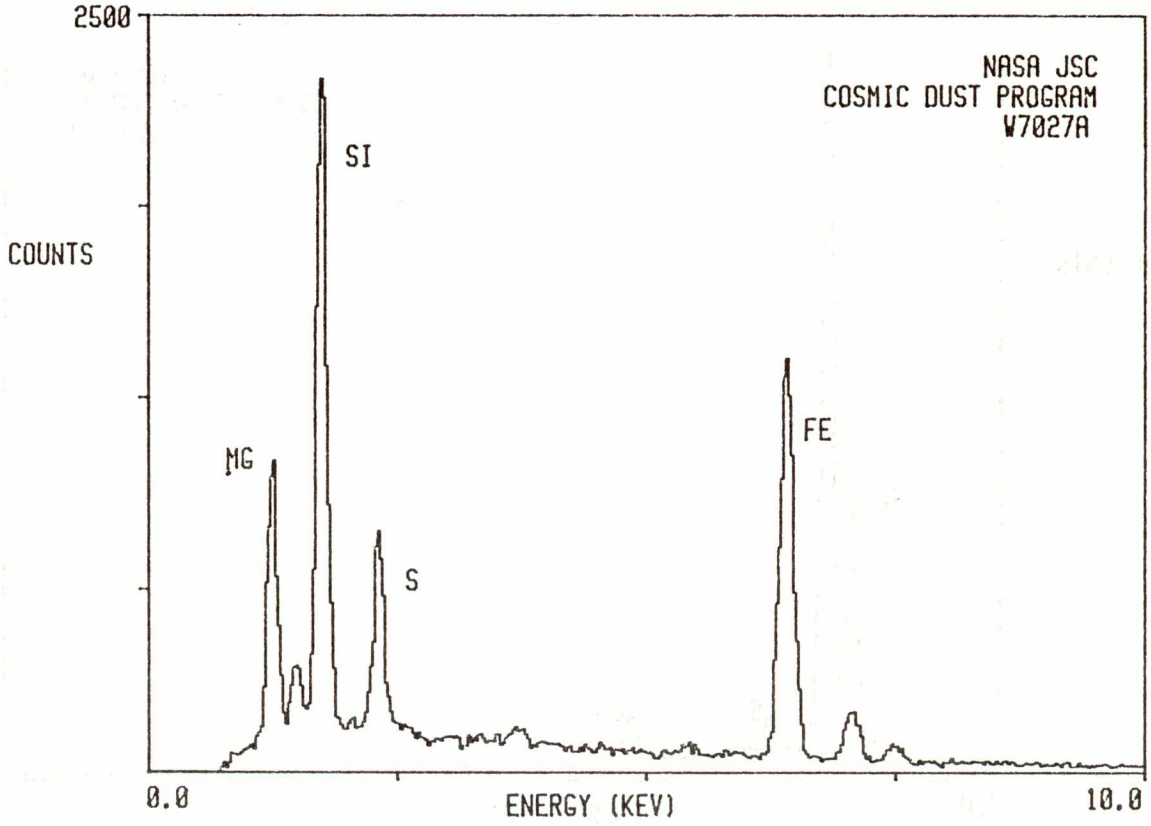
A1501B

S-83-26362

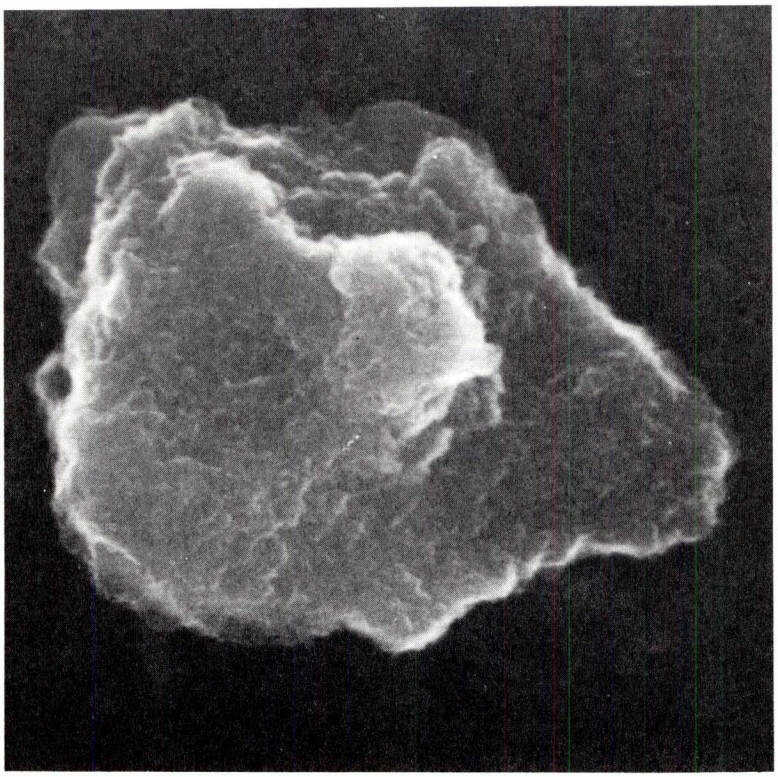
SIZE	SHAPE	TRANS.
9x10, 24x28	I	0

COLOR	LUSTER
Dk. Gray to Black	D/SV

TYPE	COMMENTS
C	Two fragments



W7027A16



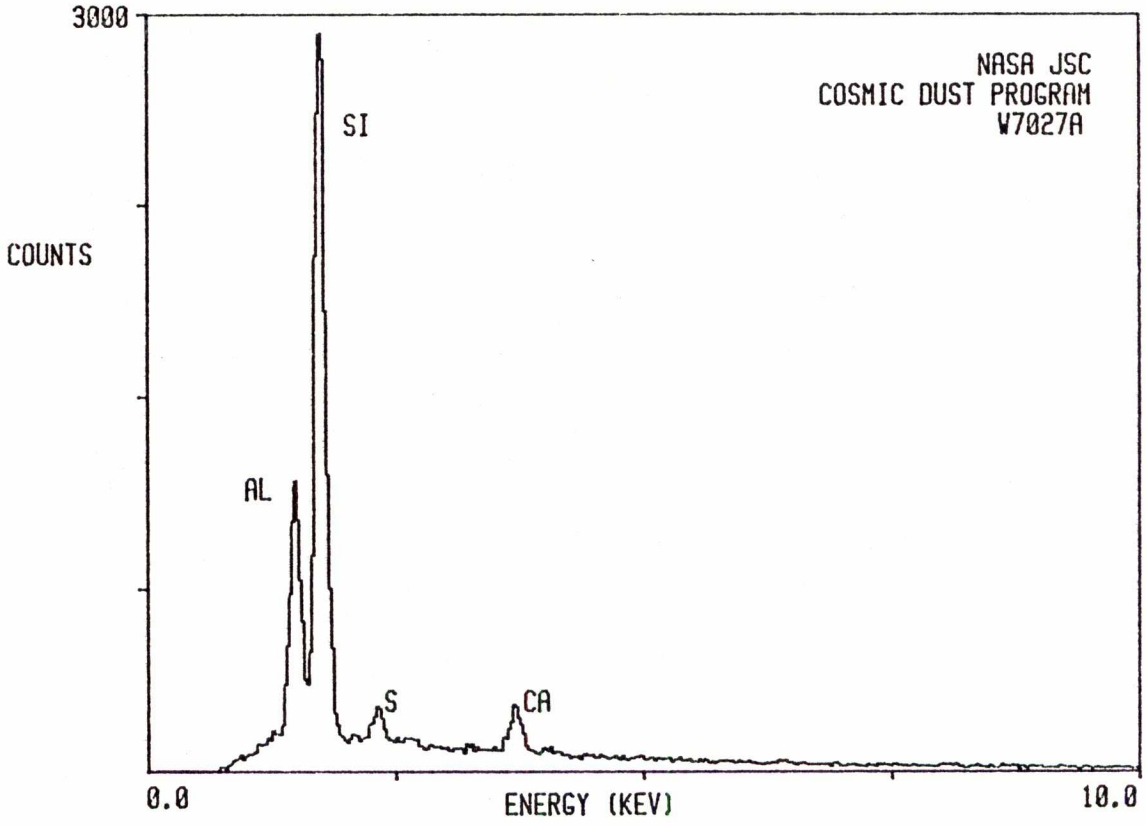
SIZE	SHAPE	TRANS.
13x17	I	O

COLOR	LUSTER
Black	D/SV

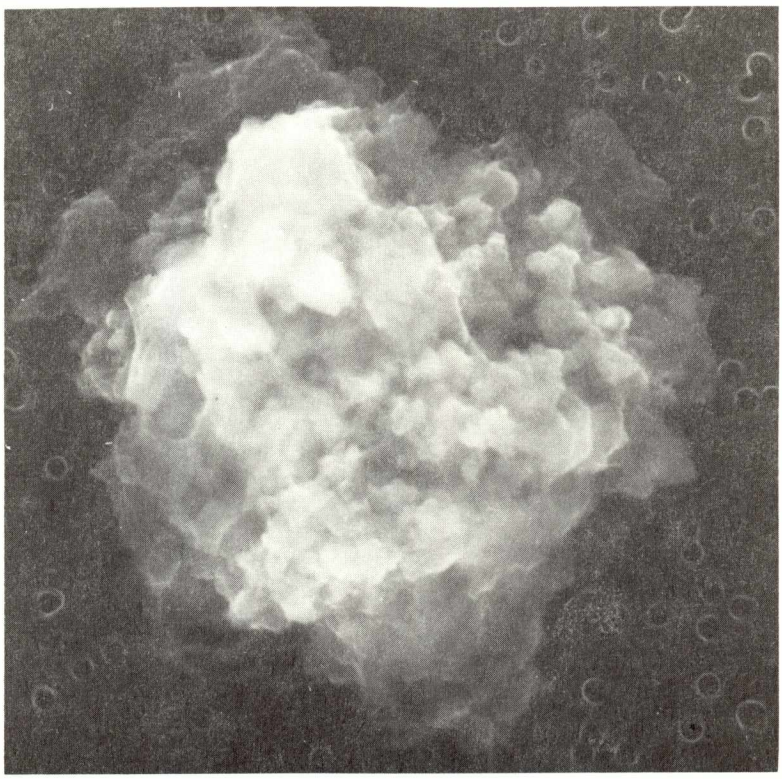
TYPE	COMMENTS
TCN?	

A1601

S-83-26361



W7027A17



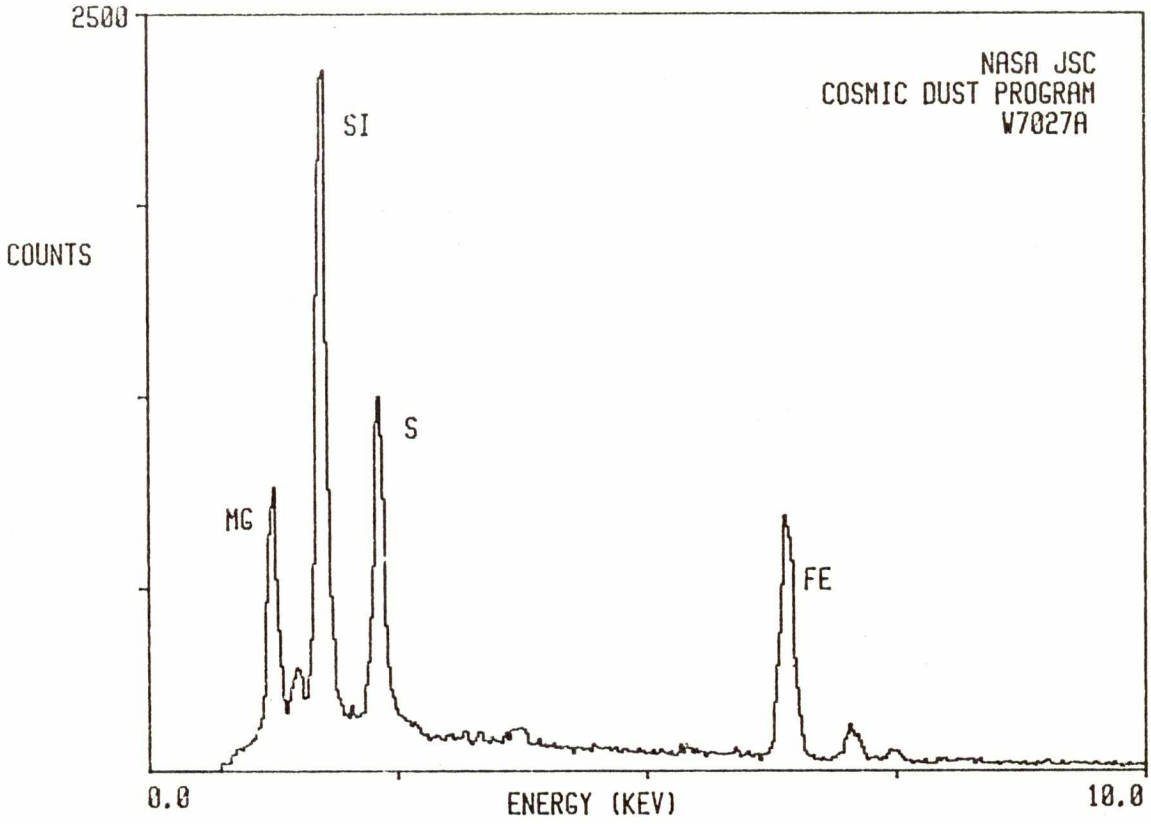
A1701

S-83-26360

SIZE	SHAPE	TRANS.
10x12	I	O

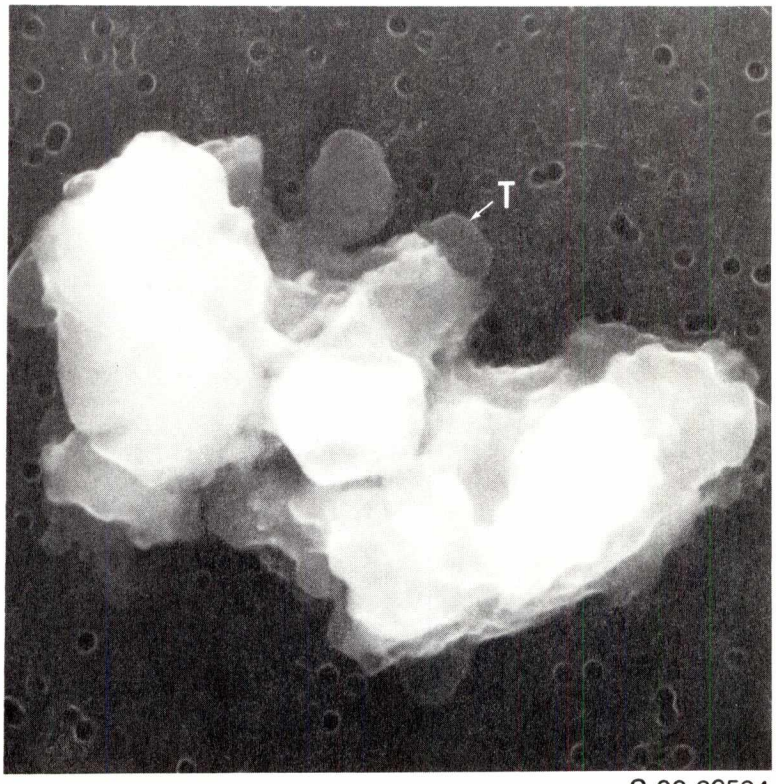
COLOR	LUSTER
Dk. Gray to Black	D/SV

TYPE	COMMENTS
C	



W7027B

W7027B1



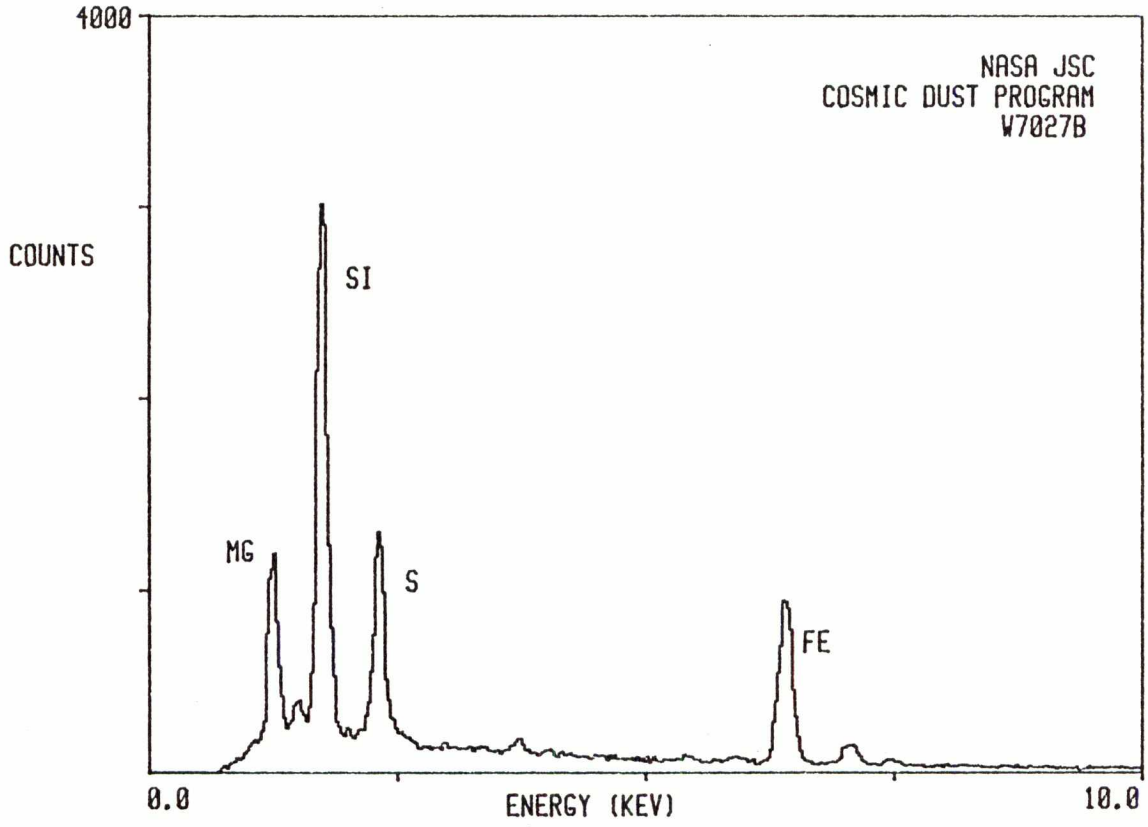
S-83-26584

B0101

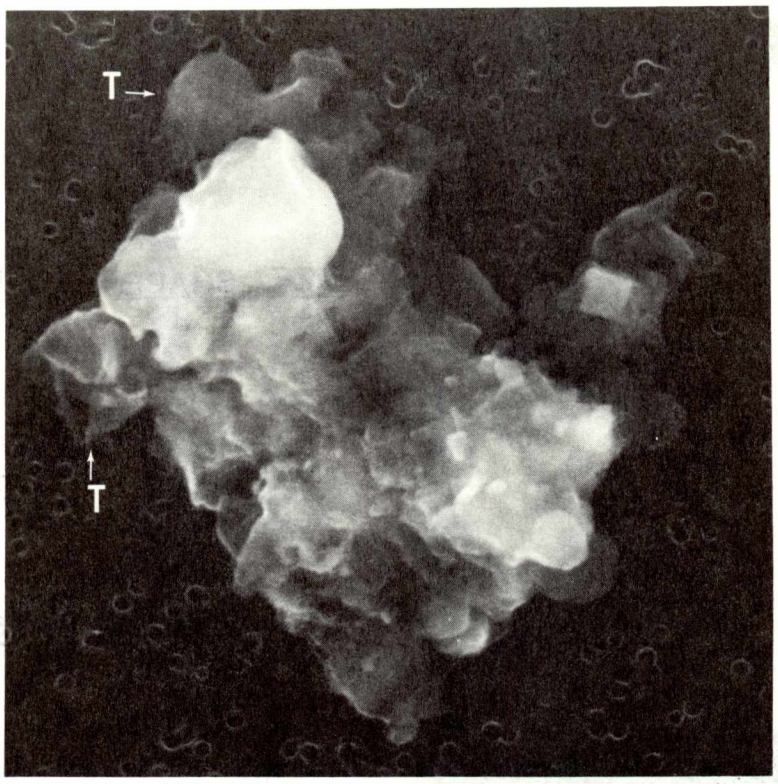
SIZE	SHAPE	TRANS.
8x13	I	O

COLOR	LUSTER
Dk. Gray to Black	D/SV

TYPE	COMMENTS
C	T grain attached



W7027B2

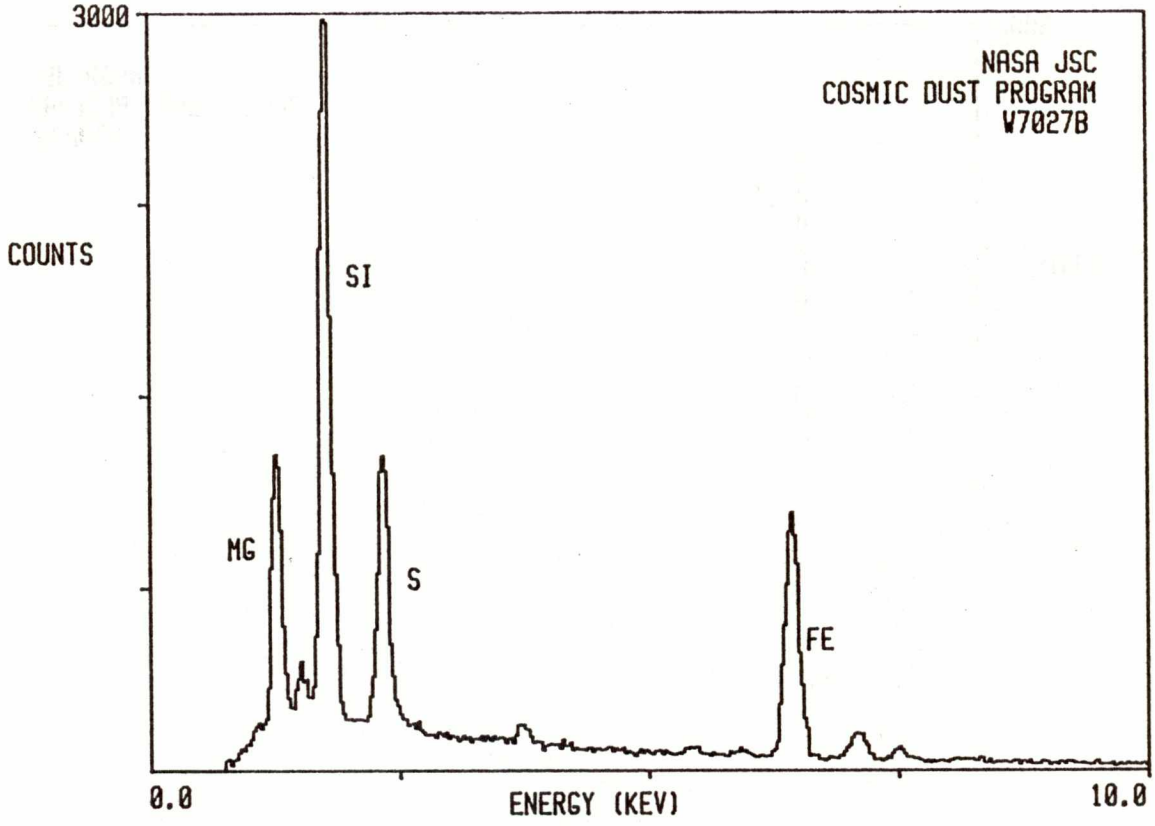


B0201 S-83-26588

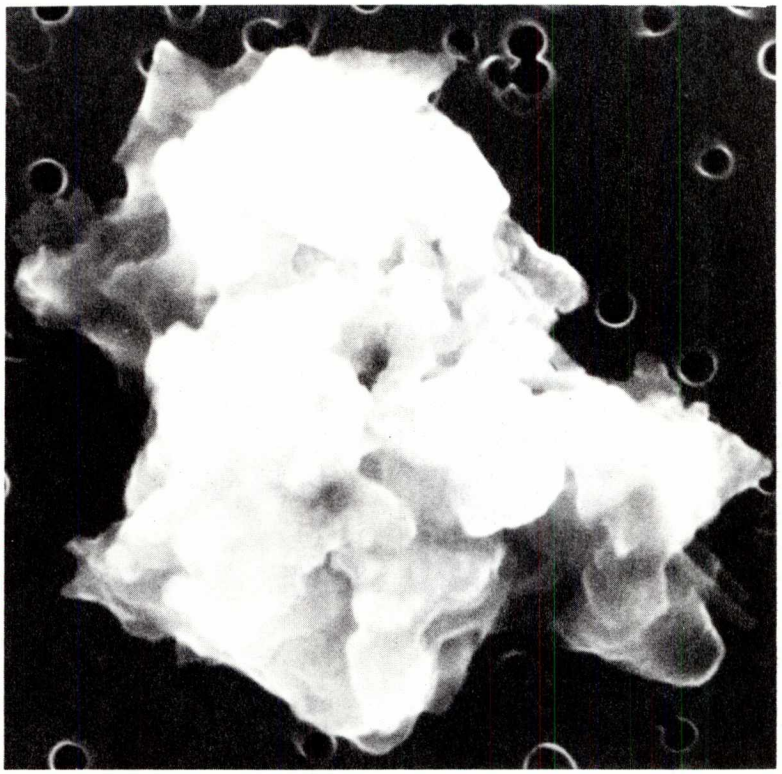
SIZE	SHAPE	TRANS.
12x14	I	O

COLOR	LUSTER
Dk. Brown to Black	D/SV

TYPE	COMMENTS
C	T grains attached



W7027B3



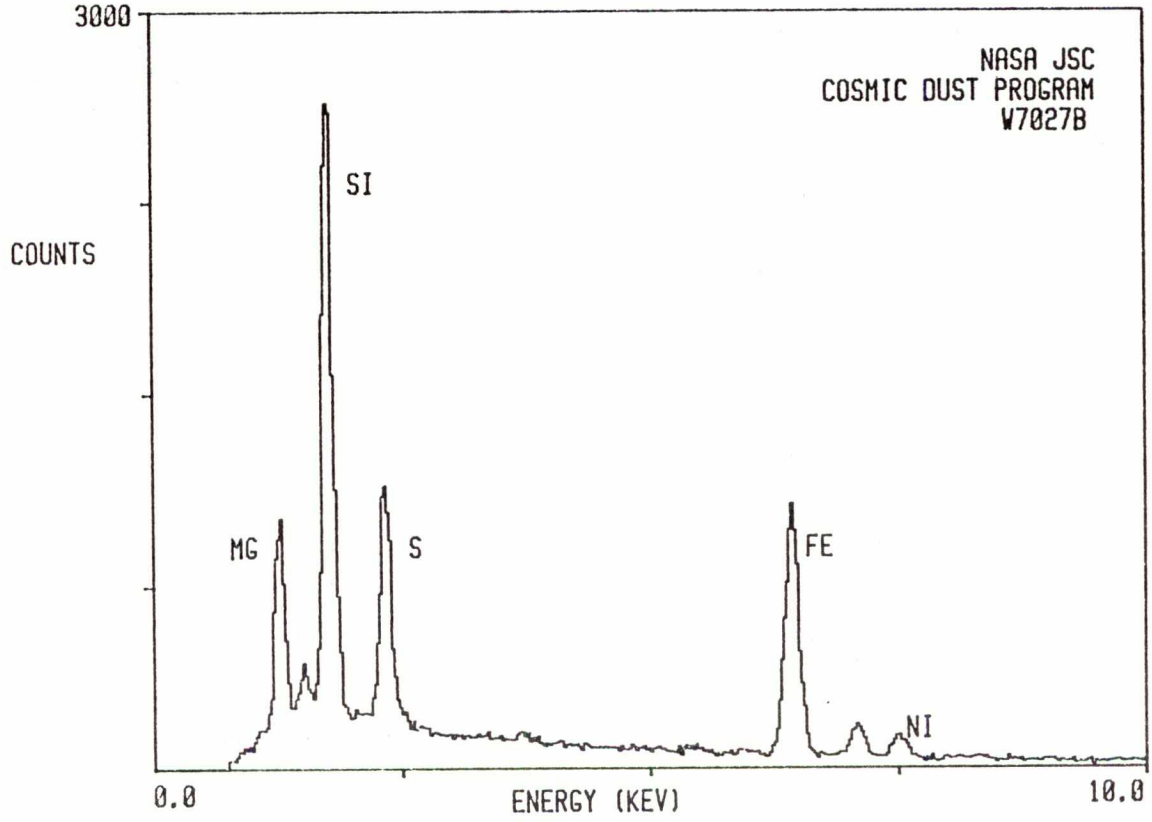
B0301

S-83-26587

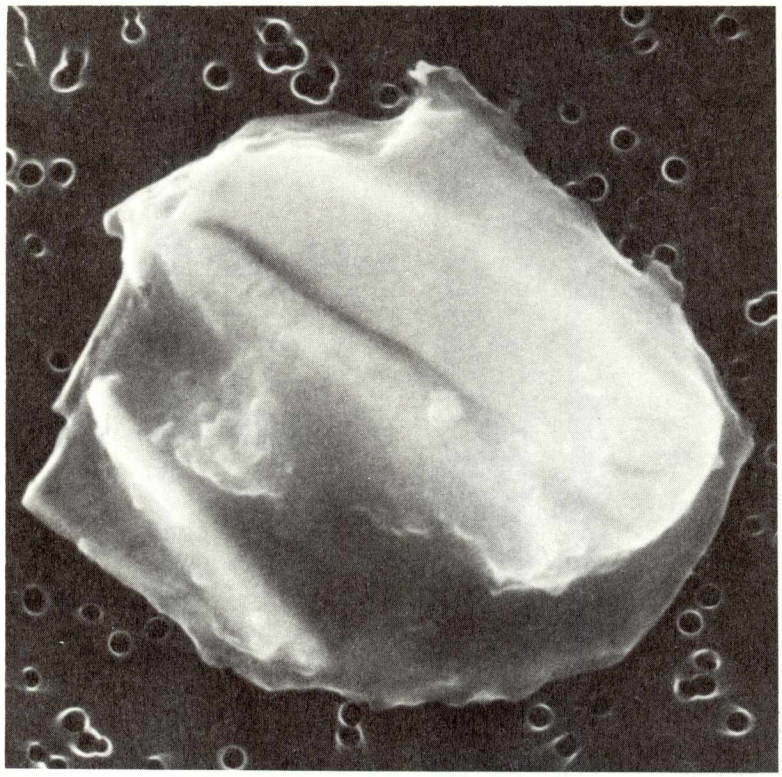
SIZE	SHAPE	TRANS.
6x9	I	0

COLOR	LUSTER
Dk. Gray to Black	D/SM

TYPE	COMMENTS
C	



W7027B4



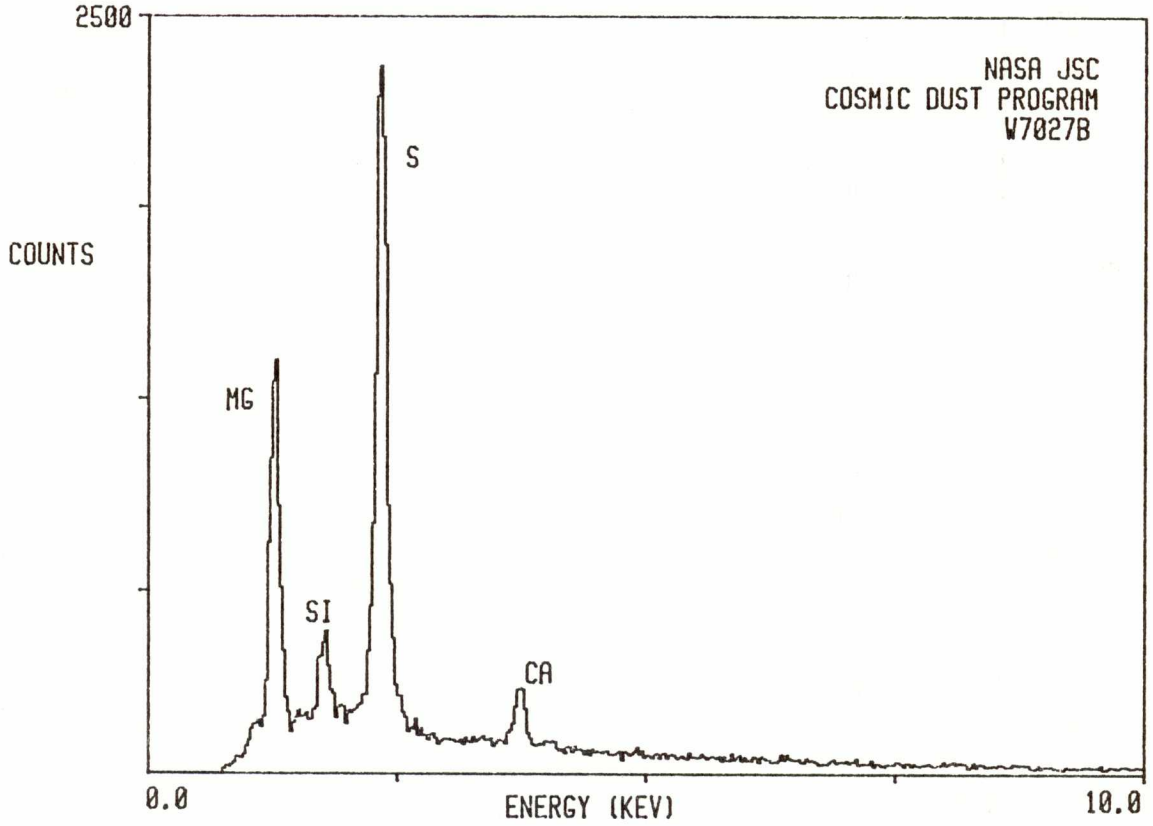
B0401

S-83-26586

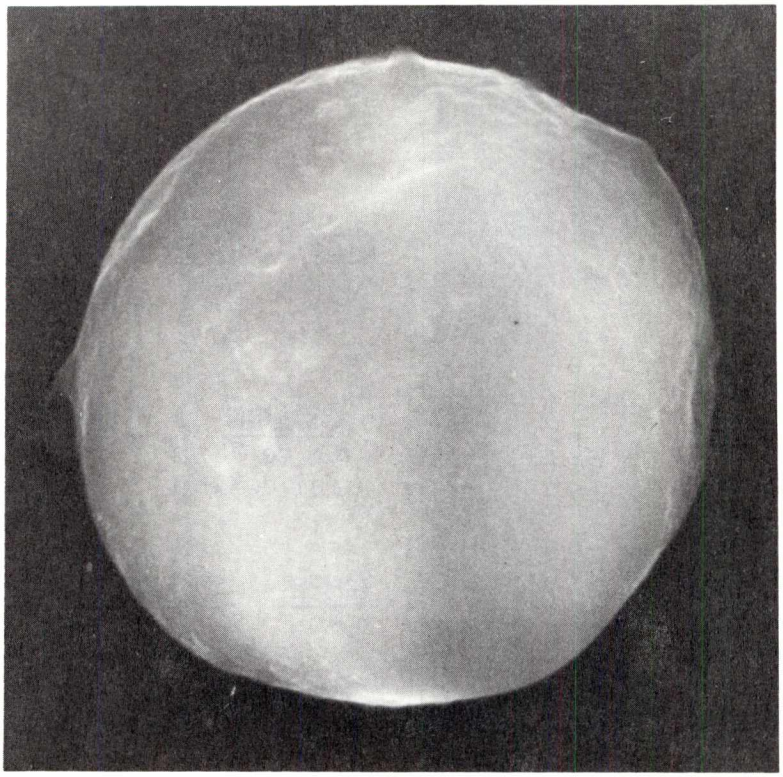
SIZE	SHAPE	TRANS.
9x10	E	T/TL

COLOR	LUSTER
CL to Pale Yellow-Gray	SV

TYPE	COMMENTS
?	



W7027B5



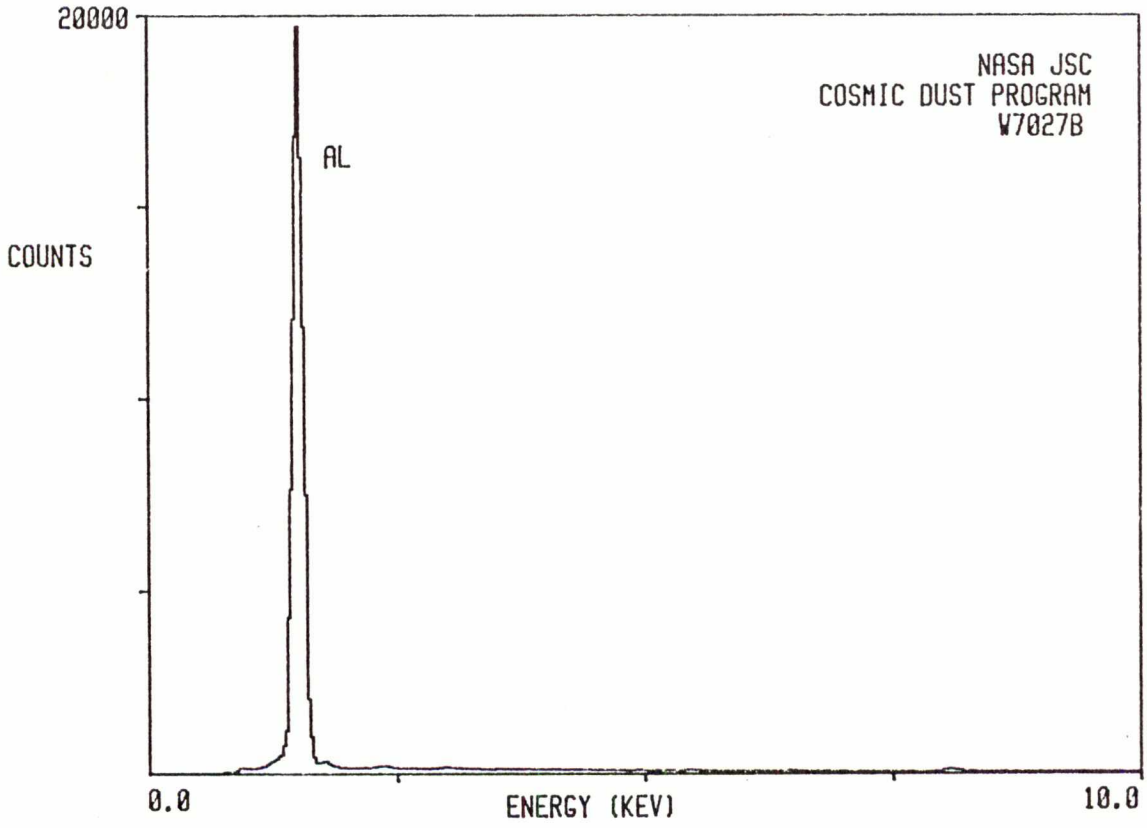
B0501

S-83-26585

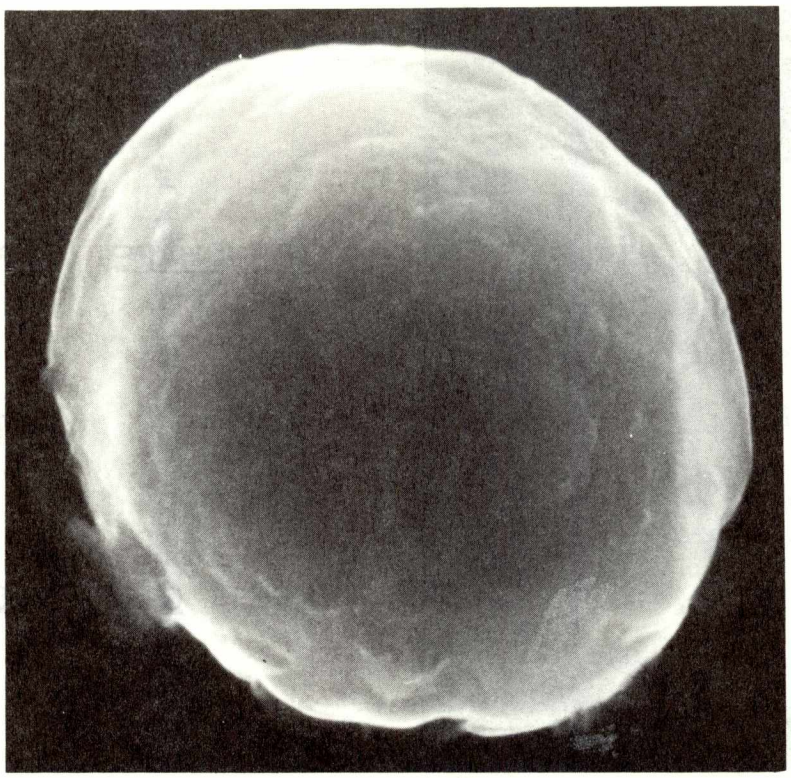
SIZE	SHAPE	TRANS.
13	S	0

COLOR	LUSTER
Steel Gray to Black	M

TYPE	COMMENTS
TCA	



W7027B6



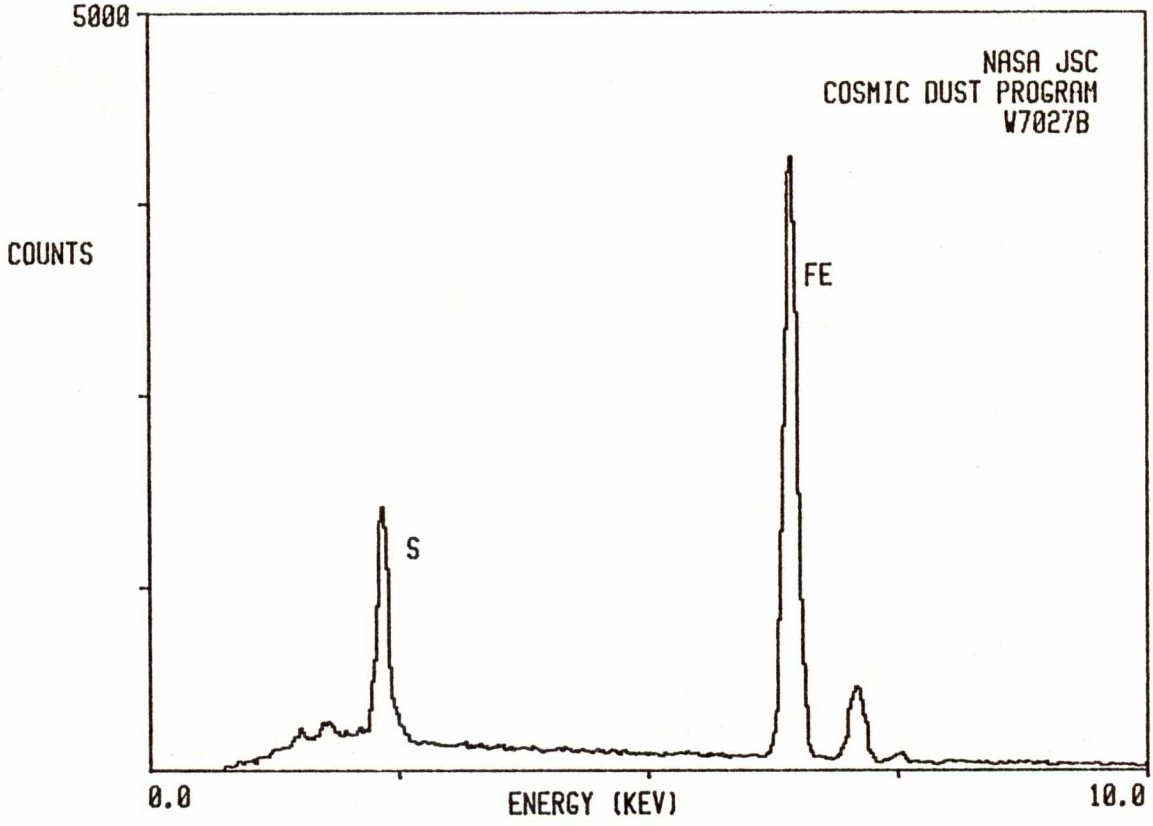
S-83-26589

SIZE	SHAPE	TRANS.
10	S	O

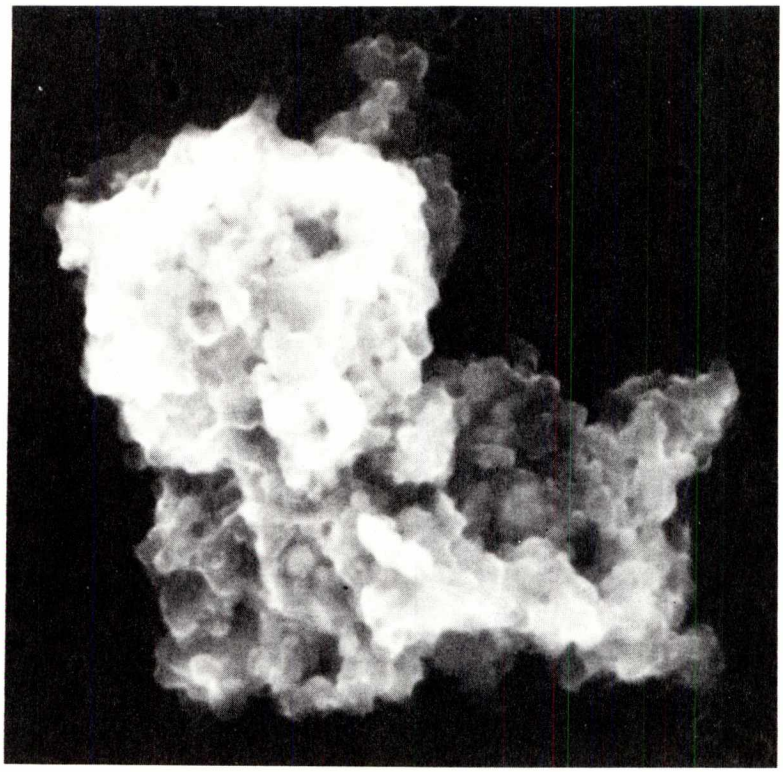
COLOR	LUSTER
Dk. Brown to Black	M

TYPE	COMMENTS
C	

B0601



W7027B7



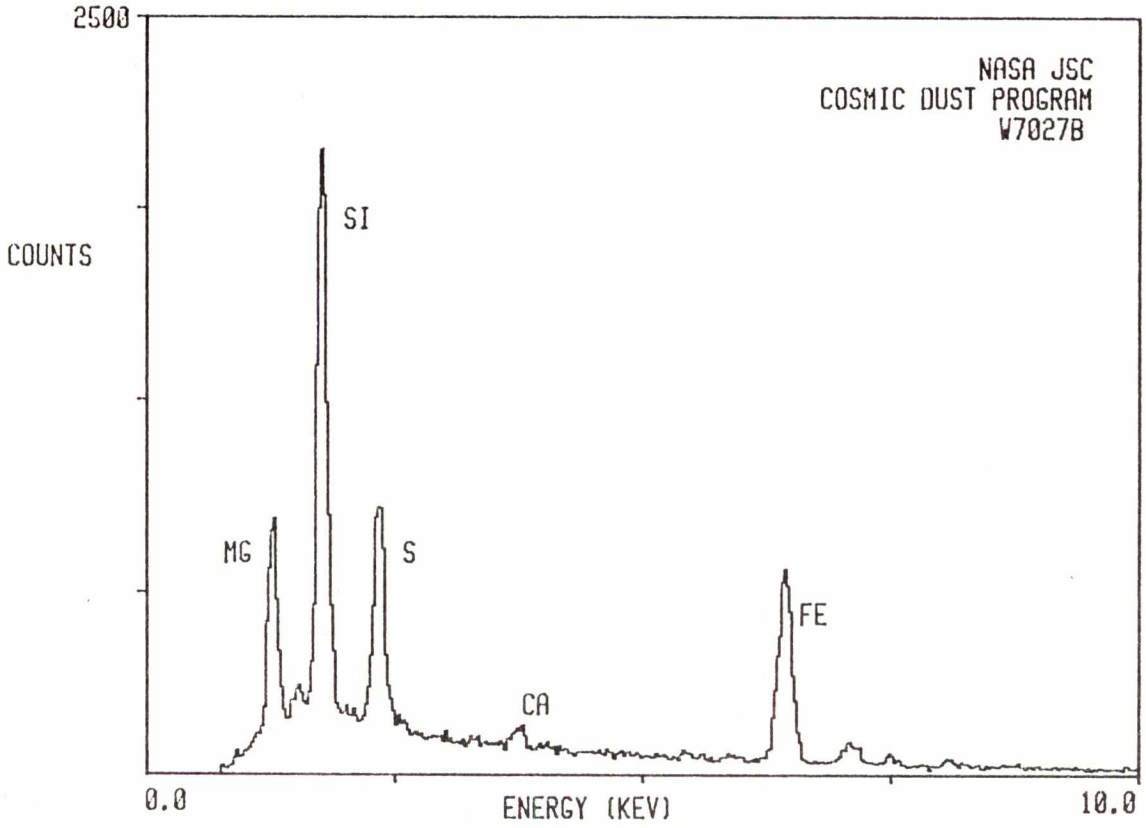
S-83-26583

B0701A

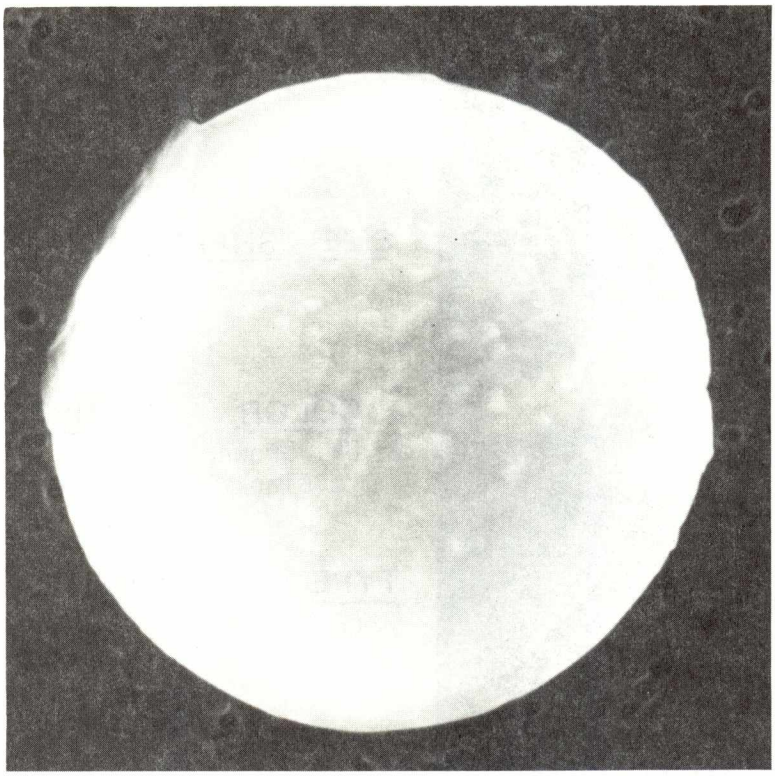
SIZE	SHAPE	TRANS.
12x13	I	0

COLOR	LUSTER
Dk. Gray to Black	D/SM

TYPE	COMMENTS
C	



W7O27B11



S-83-26578

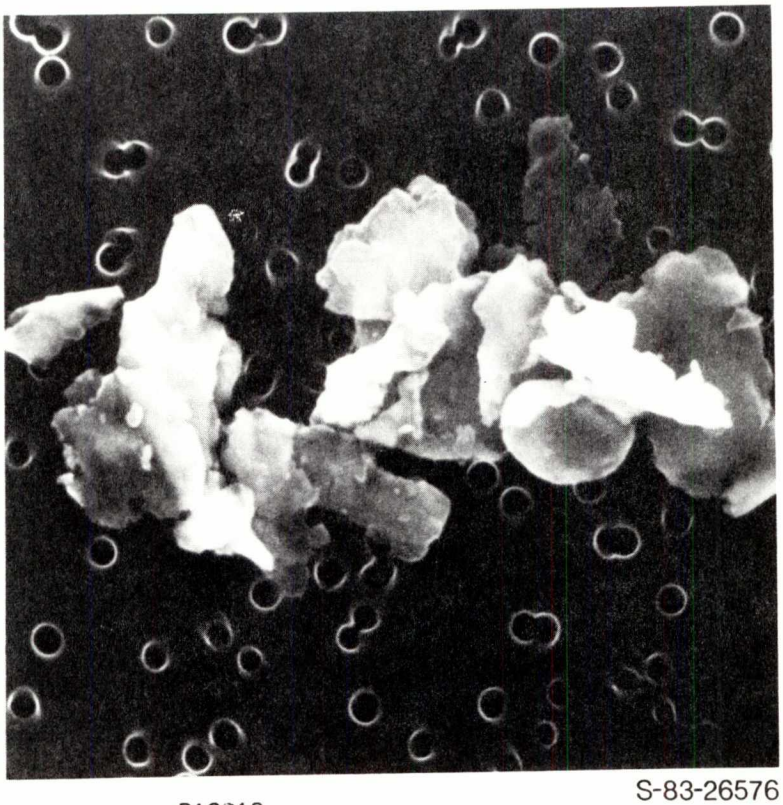
SIZE	SHAPE	TRANS.
9	S	O

COLOR	LUSTER
Dk. Gray to Black	SM/M

TYPE	COMMENTS
?	Lost

SAMPLE LOST PRIOR TO EDS

W7027B13



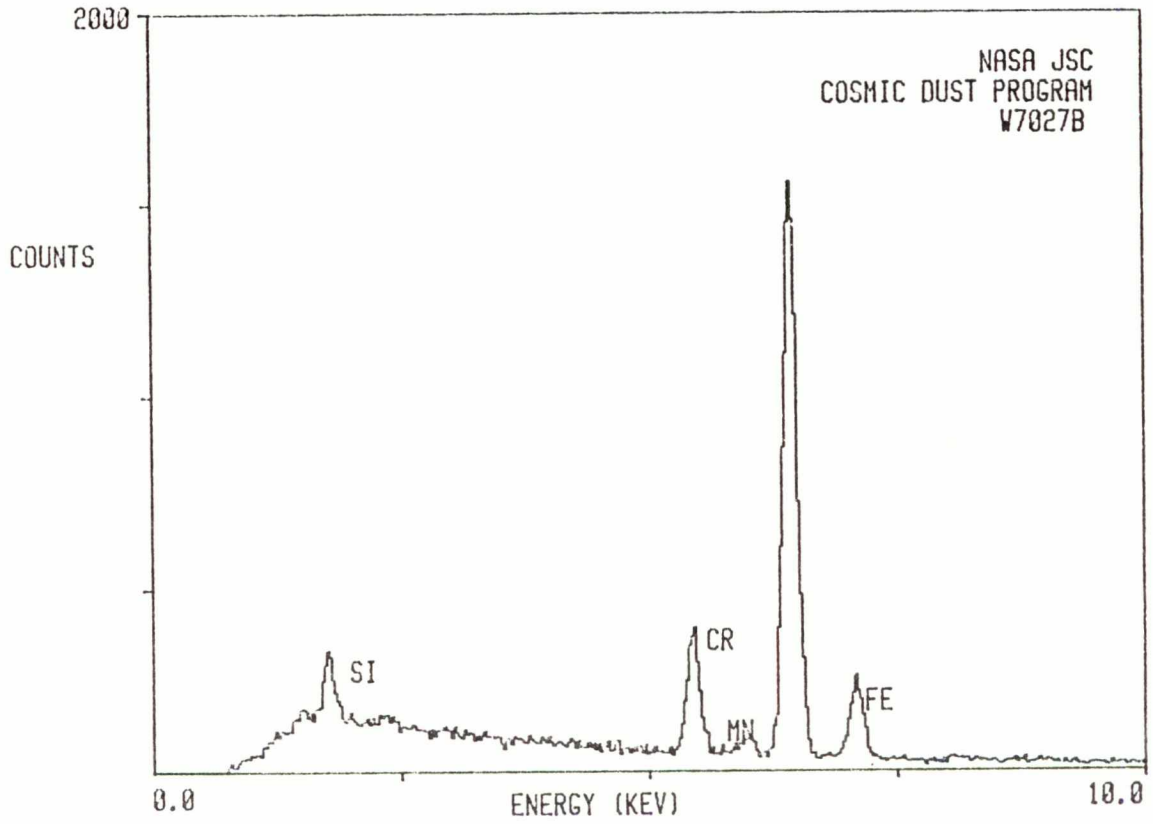
S-83-26576

B1301A

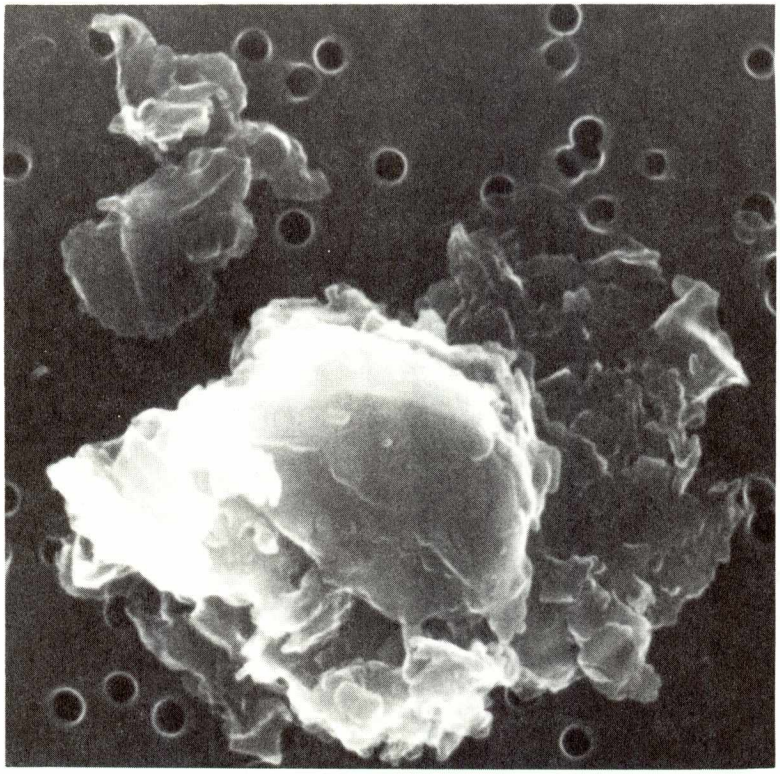
SIZE	SHAPE	TRANS.
∿5	I	O

COLOR	LUSTER
Dk. Brown to Black	M

TYPE	COMMENTS
TCA?	Many small fragments of the type shown, each ≤5 microns



W7027B14

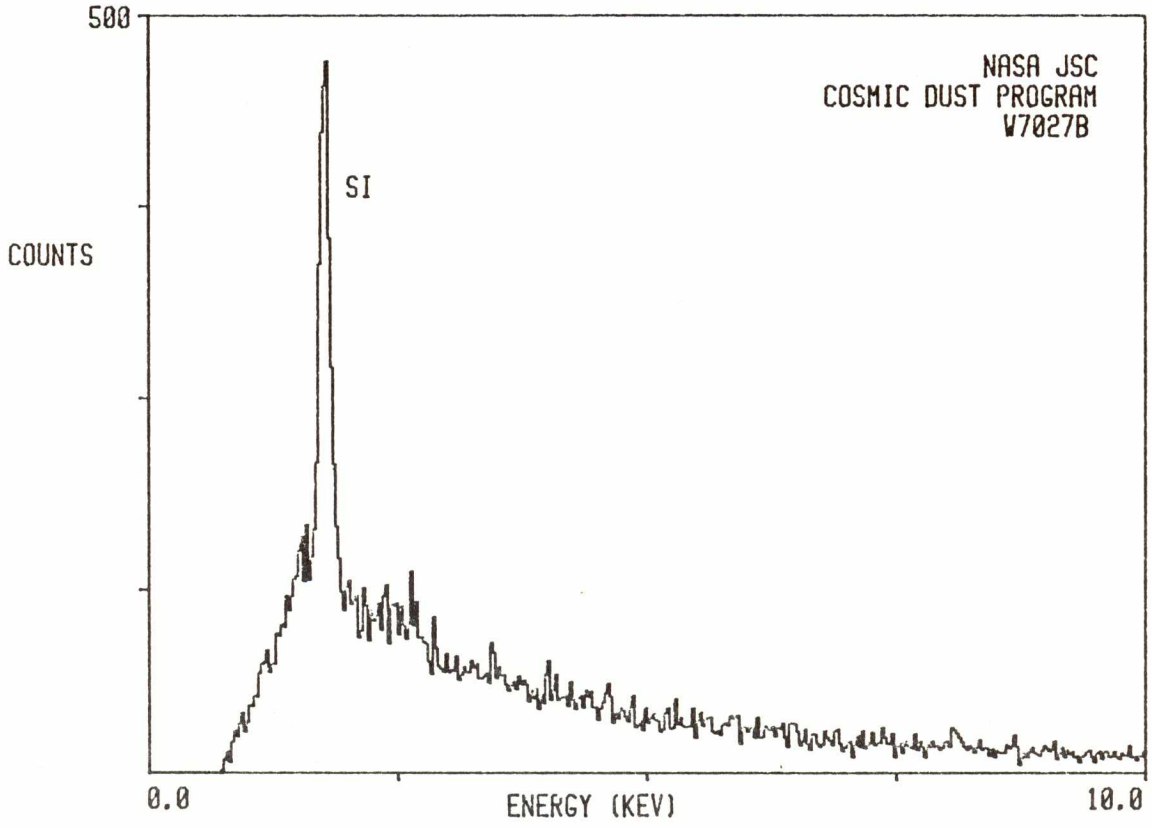


B1401 S-83-26573

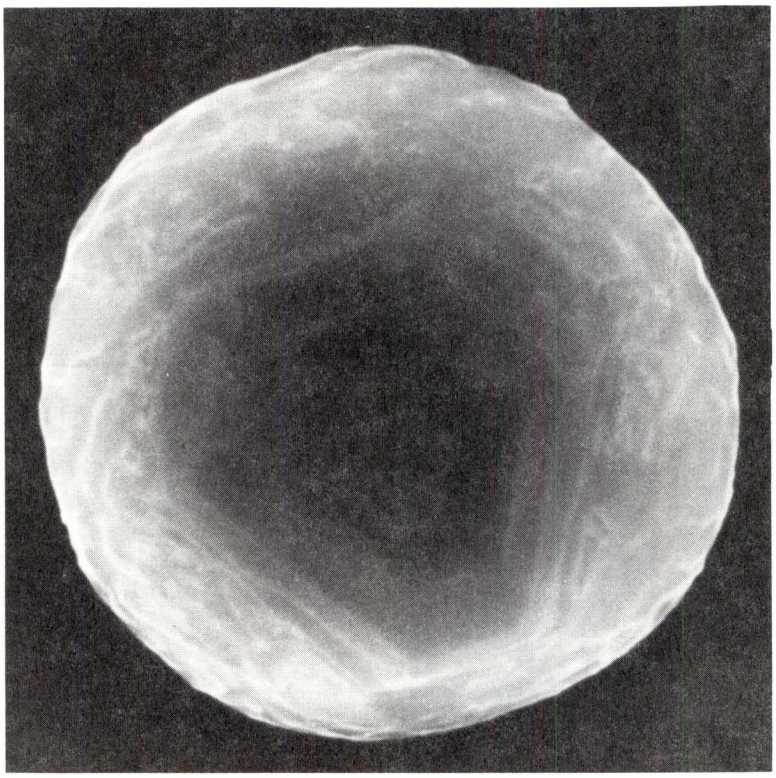
SIZE	SHAPE	TRANS.
6x8	I	0

COLOR	LUSTER
Dk. Brown to Black	M

TYPE	COMMENTS
?	



W7027B15



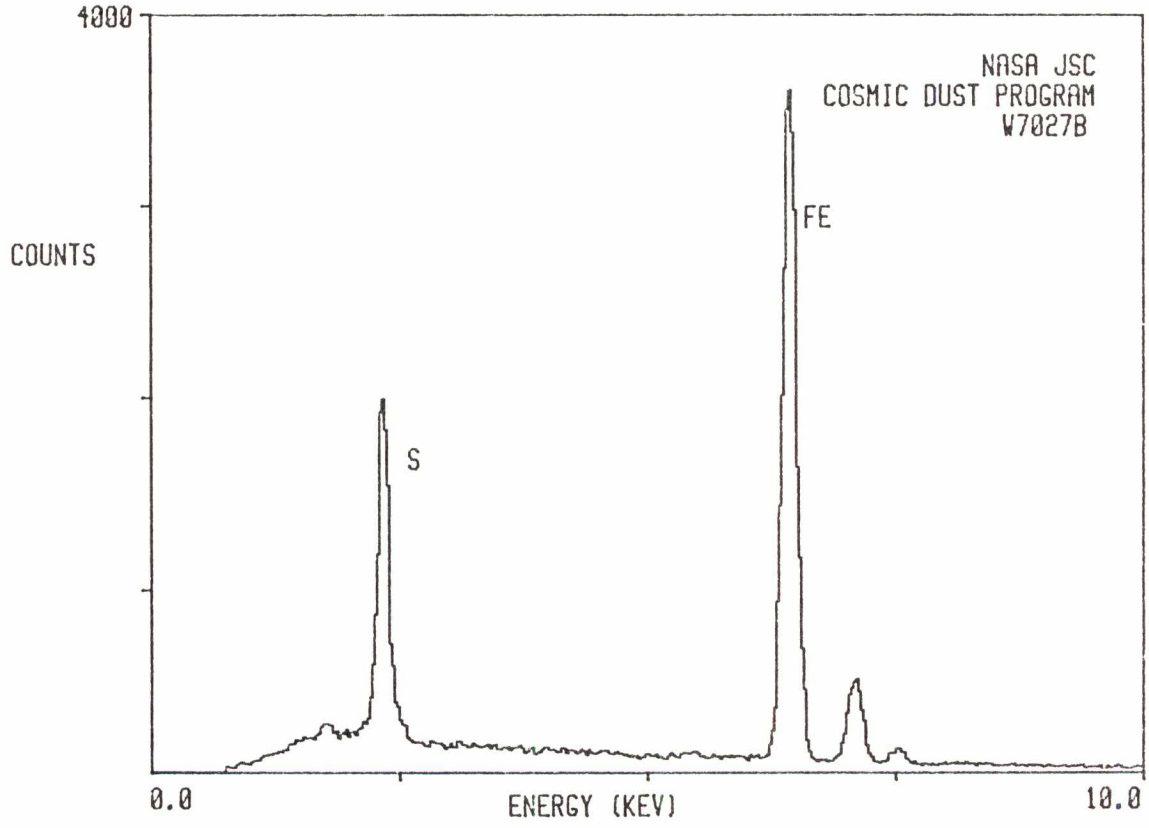
B1501

S-83-26574

SIZE	SHAPE	TRANS.
12	S	O

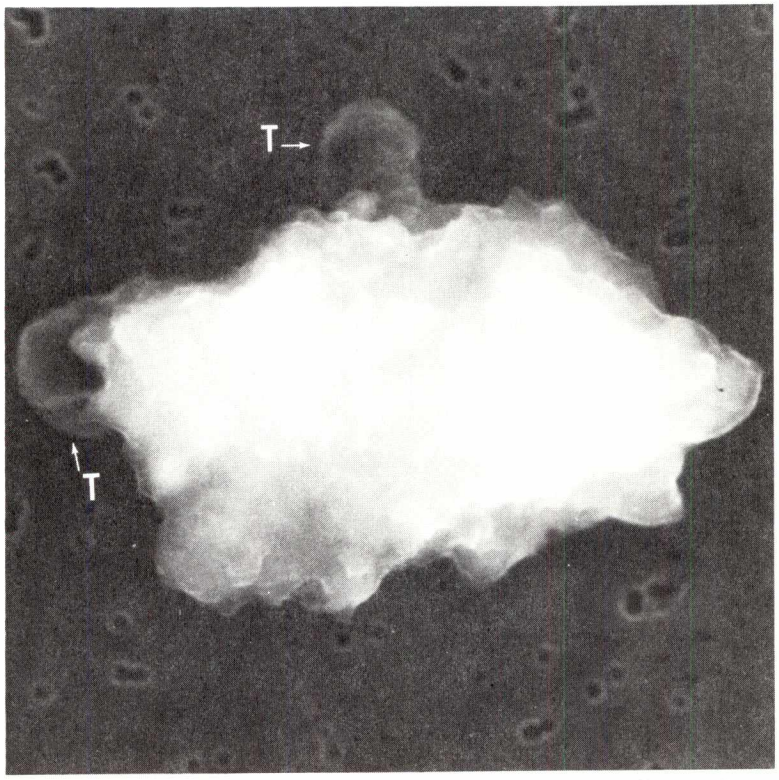
COLOR	LUSTER
Dk. Brown to Black	M

TYPE	COMMENTS
C	



W7027C

W7027C2



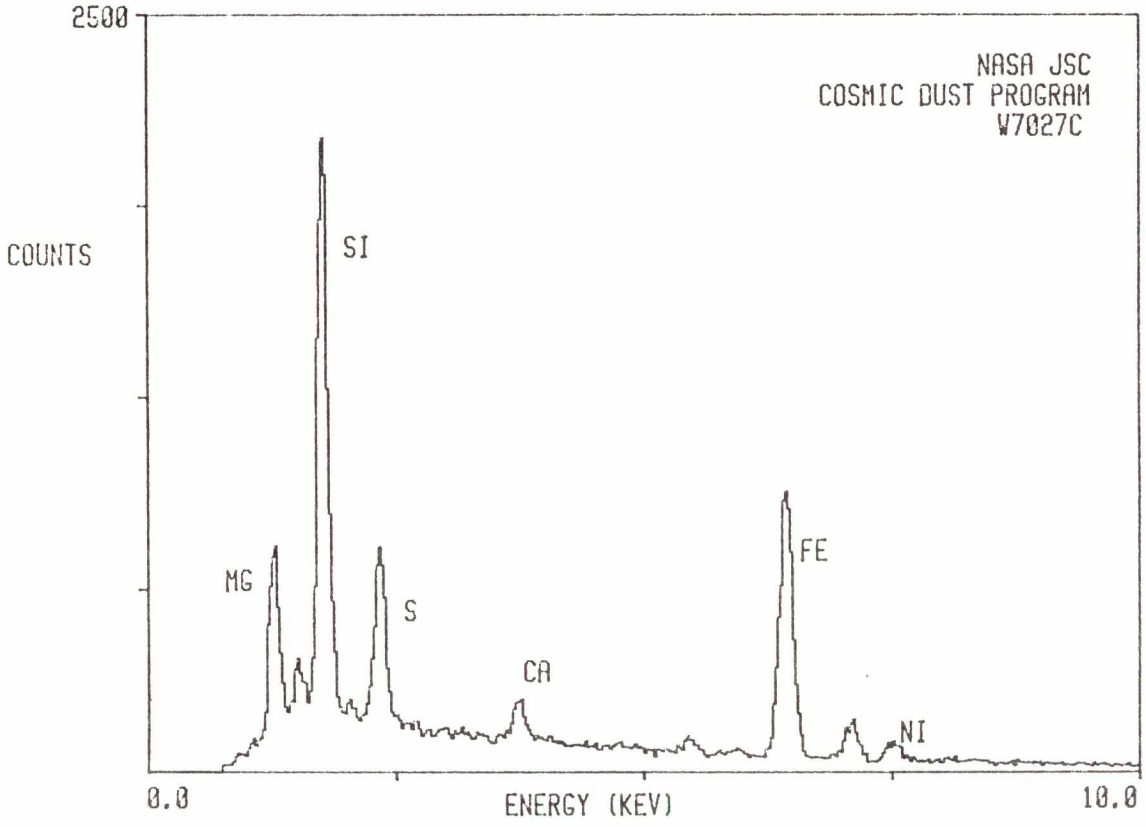
C0201

S-83-26558

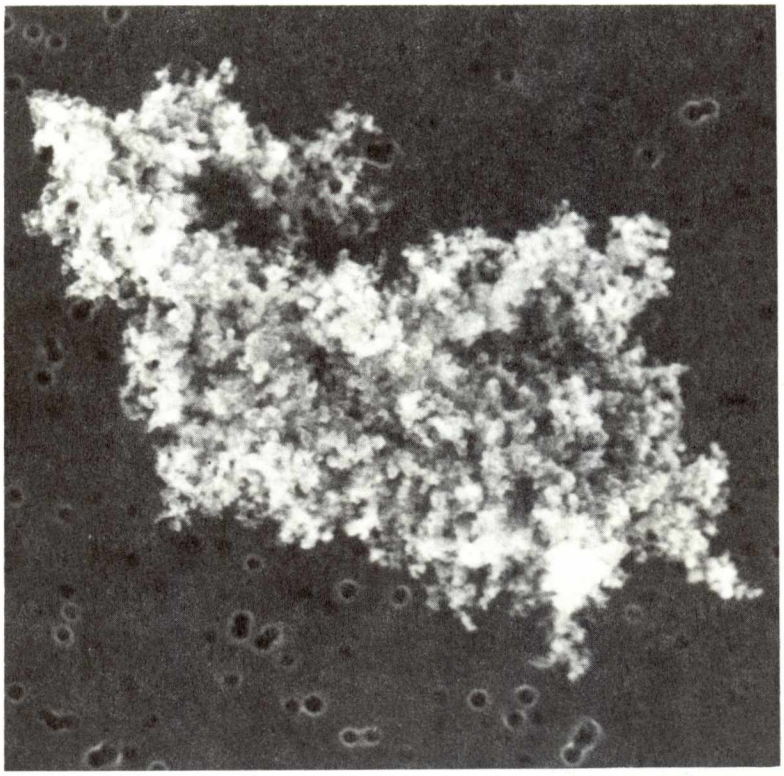
SIZE	SHAPE	TRANS.
9x13	I	O

COLOR	LUSTER
Dk. Gray to Black	D/SM

TYPE	COMMENTS
C	T grains attached



W7027C3



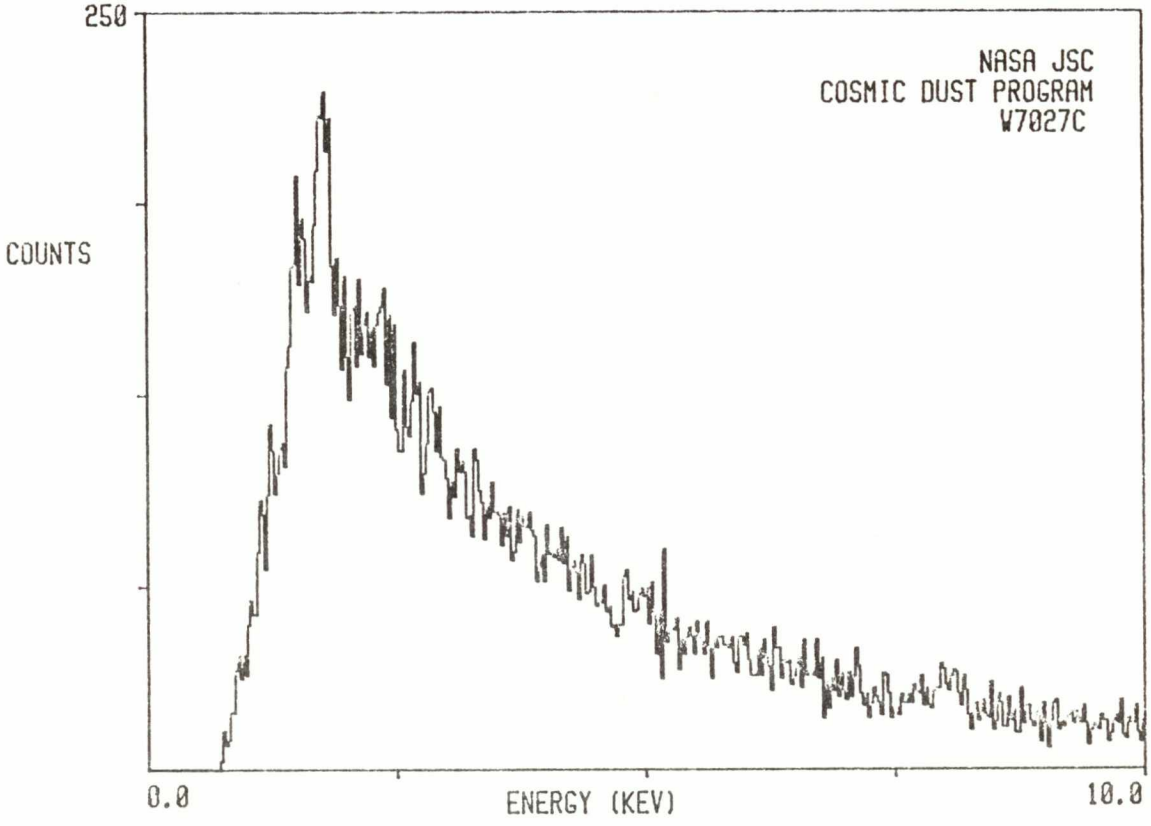
C0301

S-83-26559

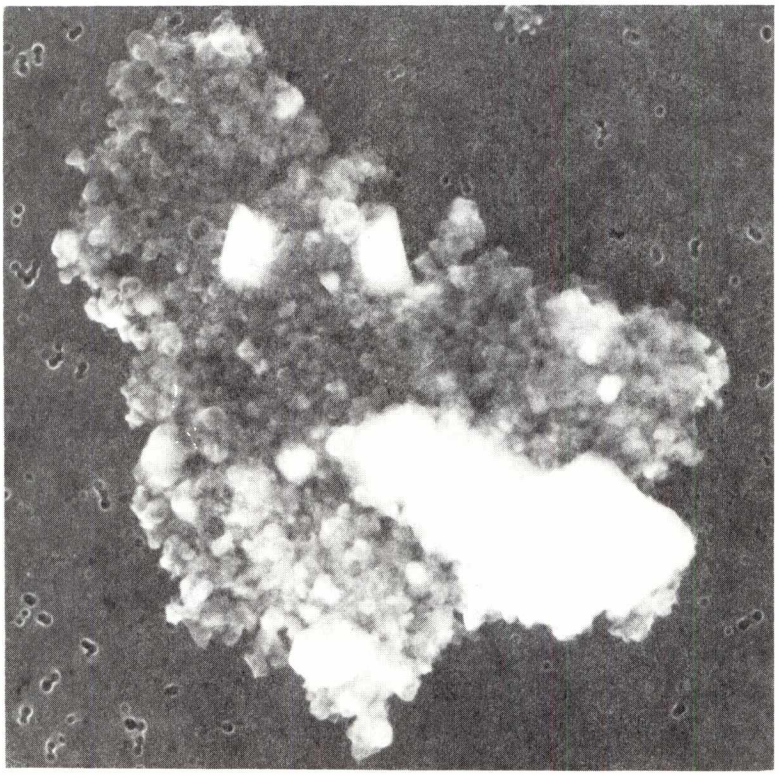
SIZE	SHAPE	TRANS.
8x16	I	0

COLOR	LUSTER
Dk. Gray to Black	D/SM

TYPE	COMMENTS
?	



W7027C4



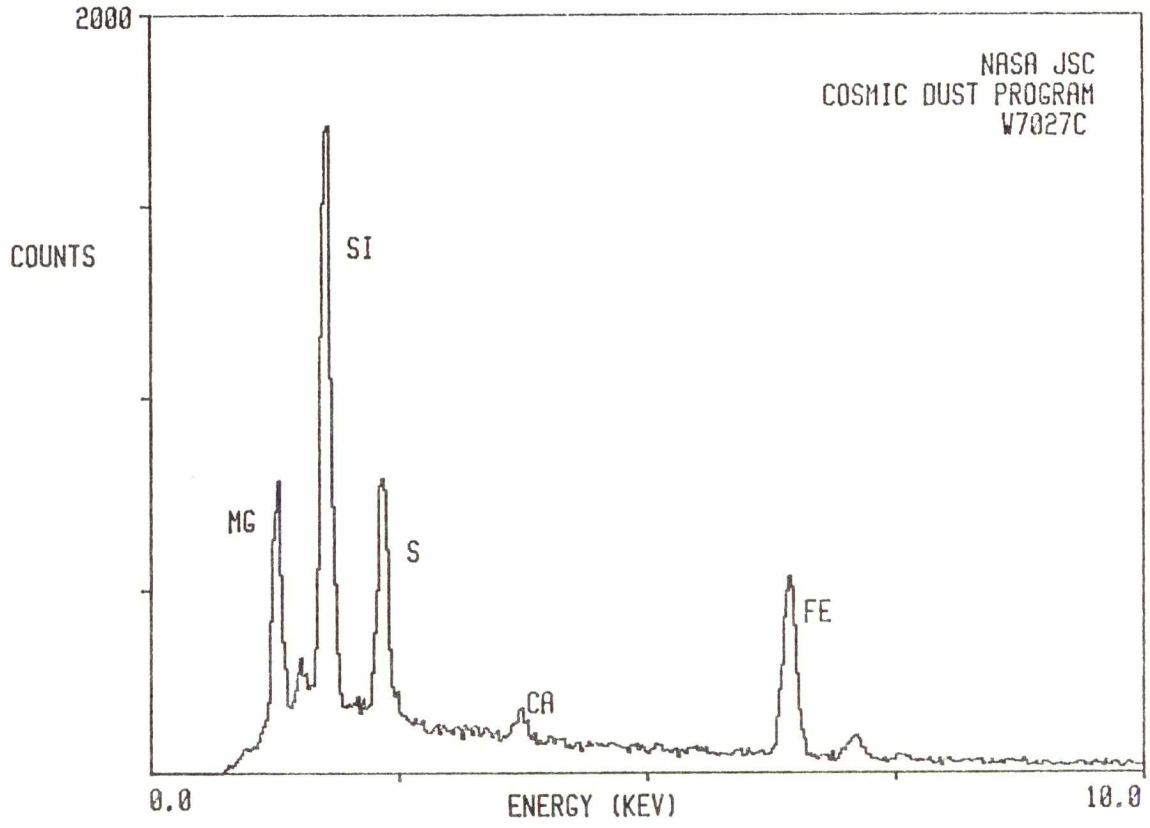
SIZE	SHAPE	TRANS.
19x24	I	0

COLOR	LUSTER
Dk. Gray to Black	D/SM

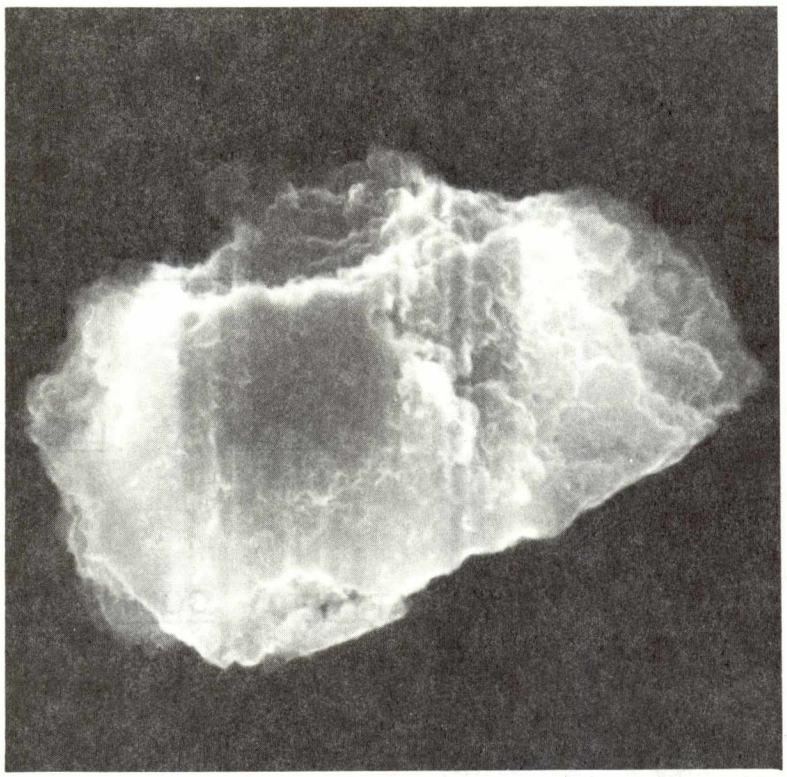
TYPE	COMMENTS
C	Friable

C0401

S-83-26560



W7027C5



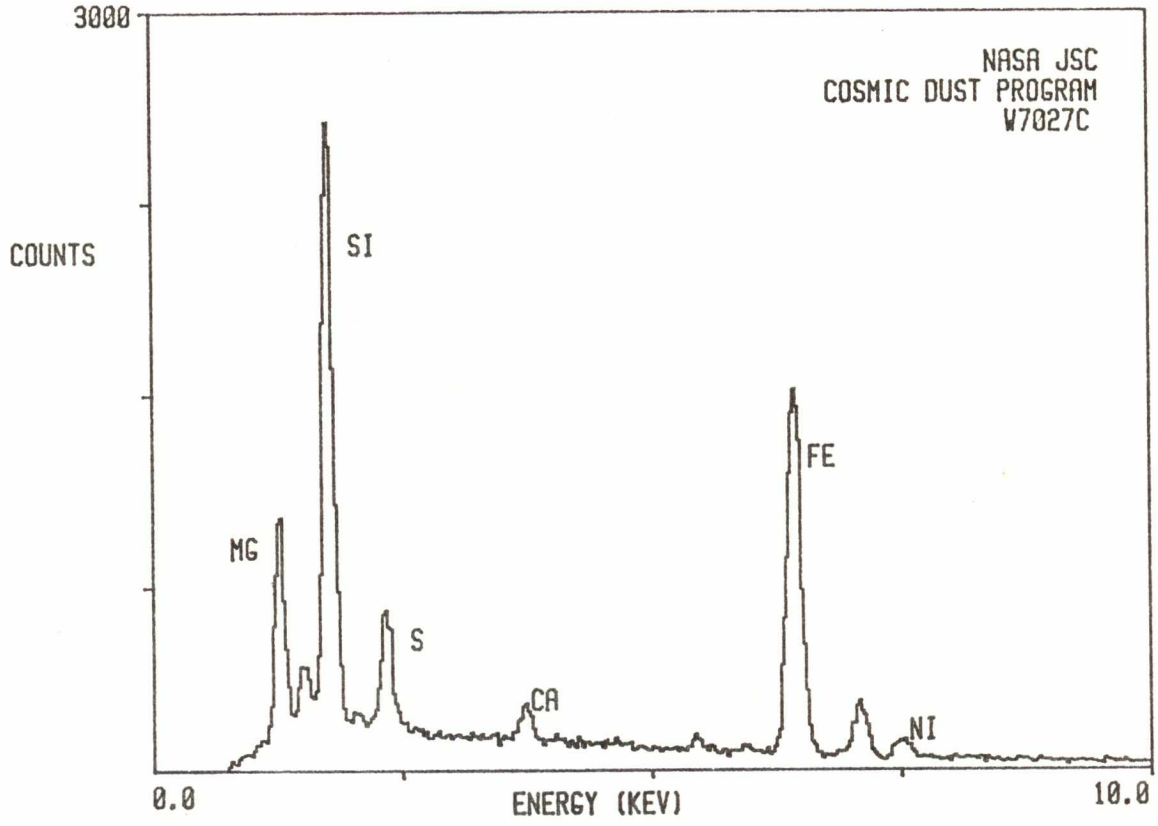
C0501

S-83-26561

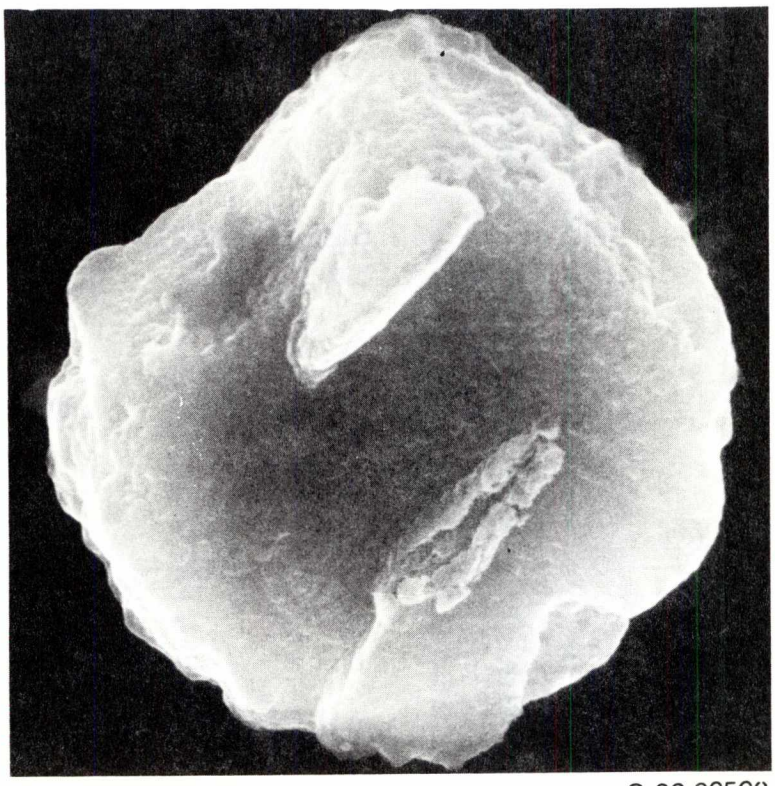
SIZE	SHAPE	TRANS.
18x29	I	0

COLOR	LUSTER
Dk. Gray to Black	D/SM

TYPE	COMMENTS
C	"Tall" in third dimension; a genuine "large" particle



W7O27C6



S-83-26562

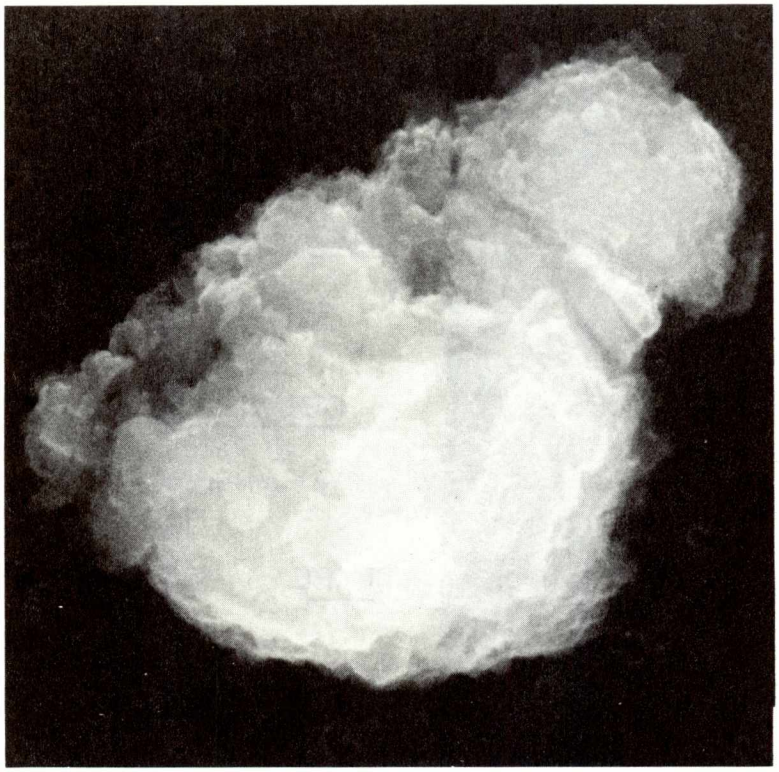
SIZE	SHAPE	TRANS.
19x20	I/E	O

COLOR	LUSTER
Black	SM

TYPE	COMMENTS
?	Lost

SAMPLE LOST PRIOR TO EDS

W7027C7



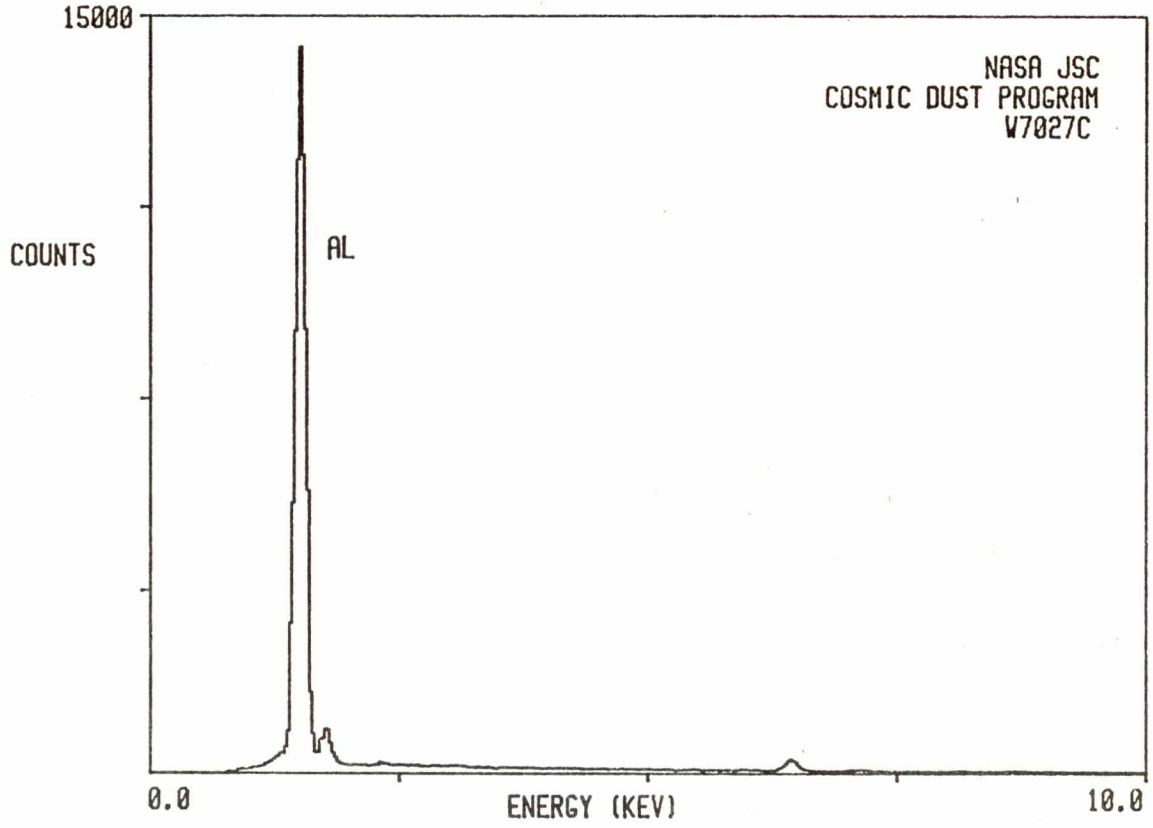
S-83-26563

C0701

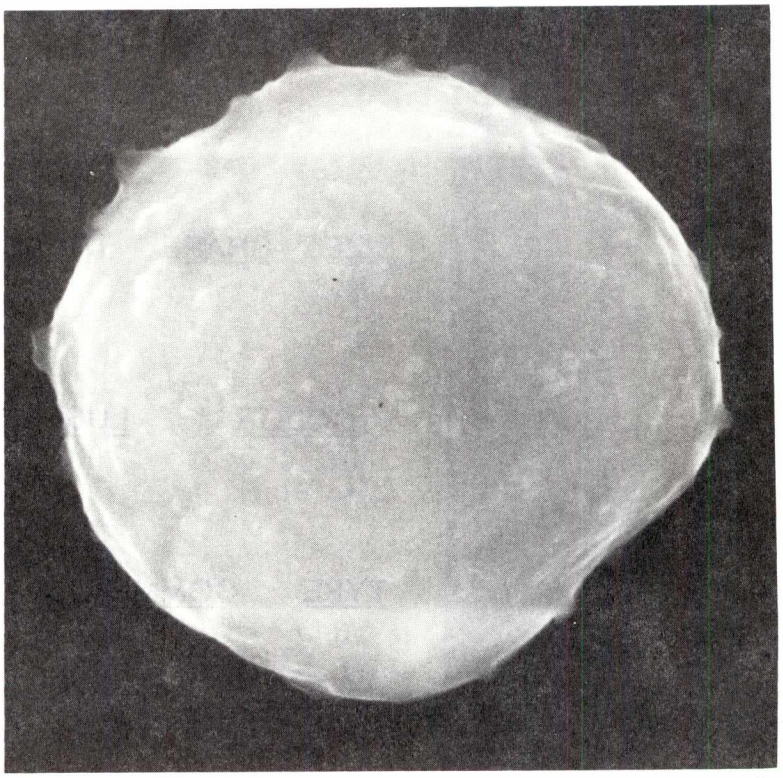
SIZE	SHAPE	TRANS.
13x18	I	0

COLOR	LUSTER
Dk. Gray to Black	D/SM

TYPE	COMMENTS
TCA?	



W7027C8



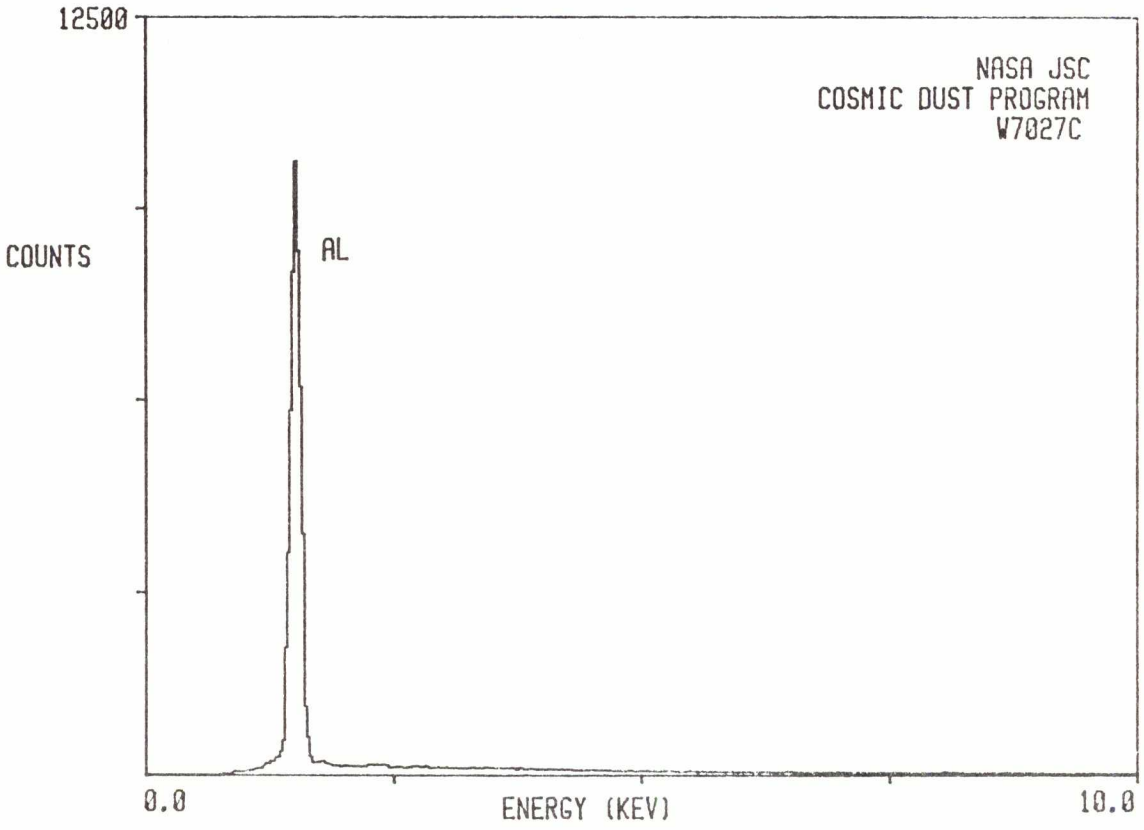
C0801

S-83-26564

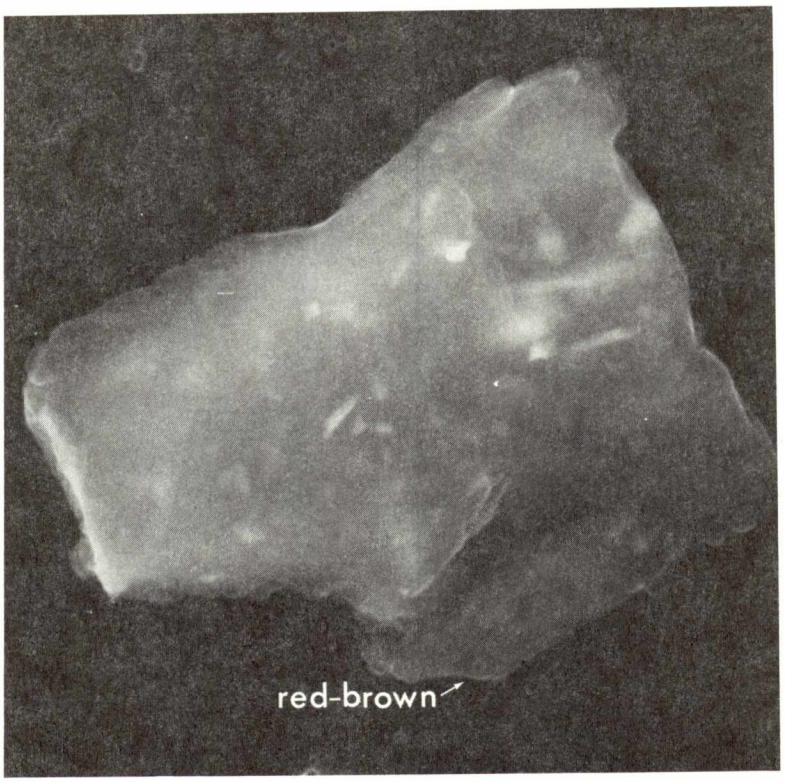
SIZE	SHAPE	TRANS.
12	S	TL

COLOR	LUSTER
CL to Pale Yellow-Gray	SV/V

TYPE	COMMENTS
AOS	



W7027C9

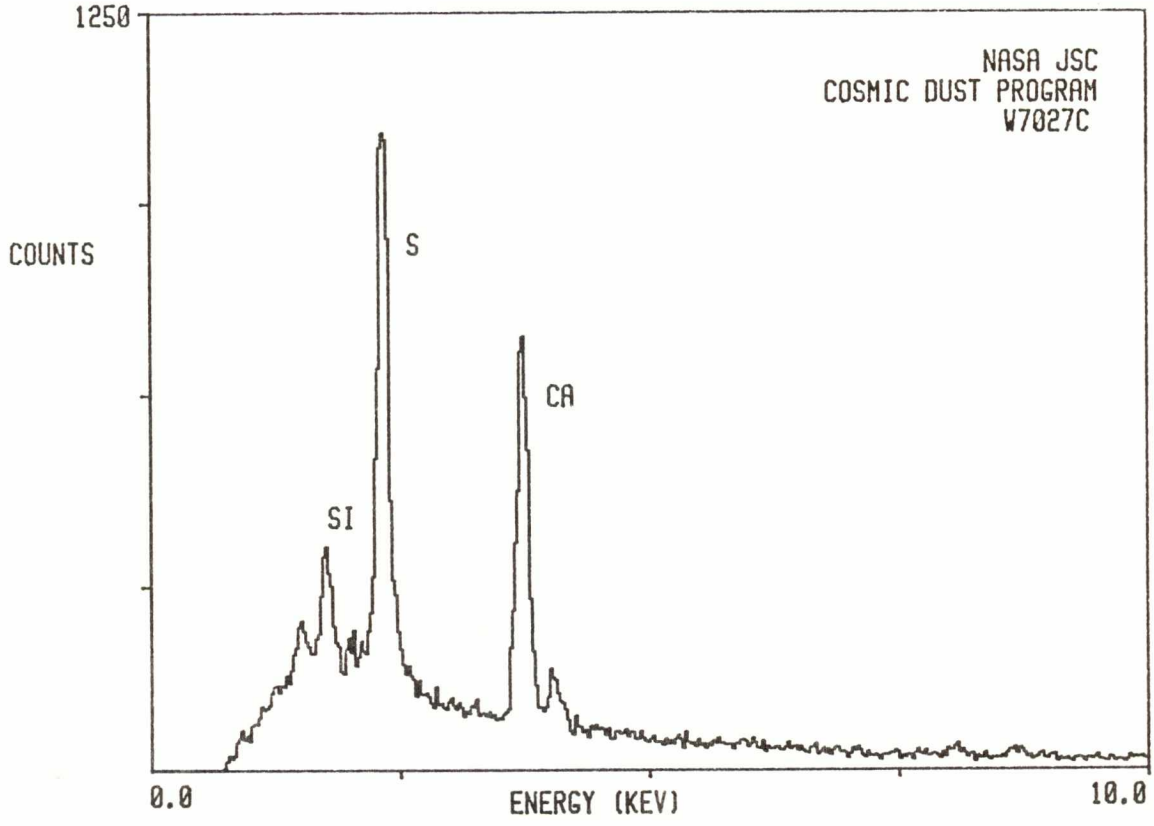


C0901 S-83-26565

SIZE	SHAPE	TRANS.
16x21	I	O/TL

COLOR	LUSTER
Dk. Brown	SV/SM

TYPE	COMMENTS
TCN?	



W7027C10

NO SEM

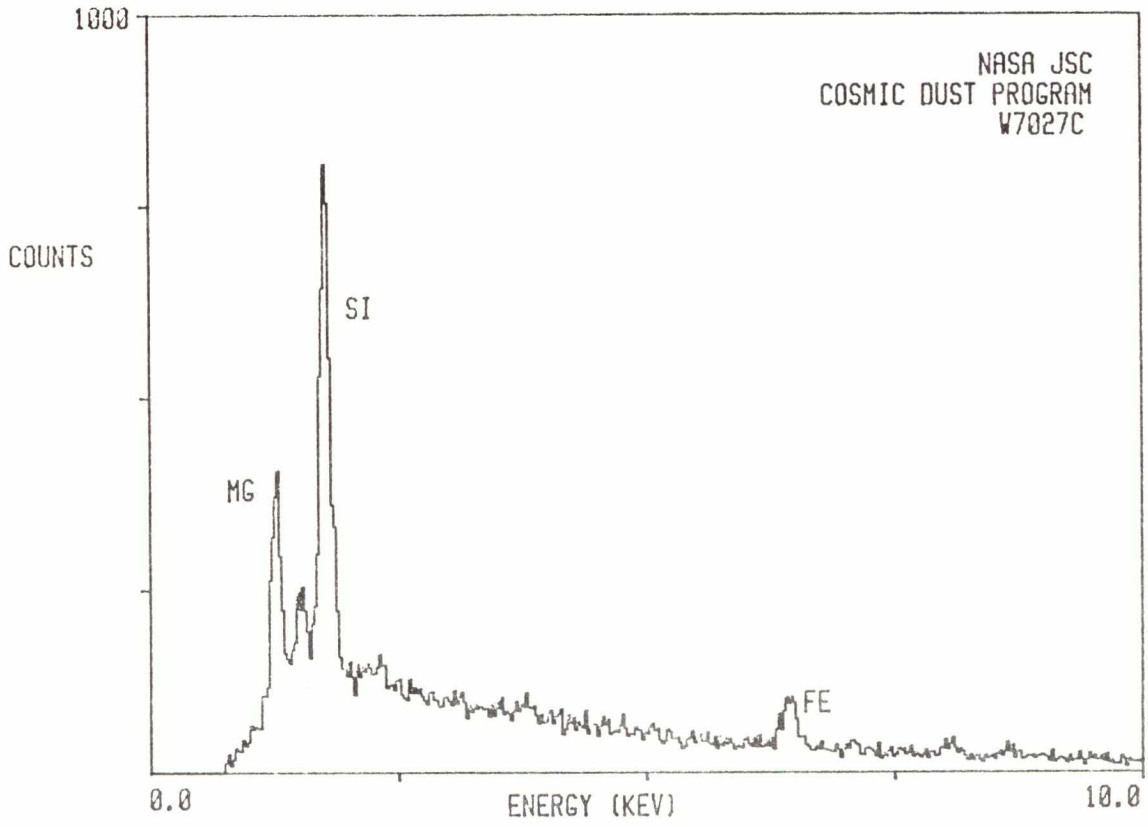
Photomicrograph Available
(Electron Charging Prevented
Acquisition of Acceptable Image)

SIZE	SHAPE	TRANS.
14	S	T

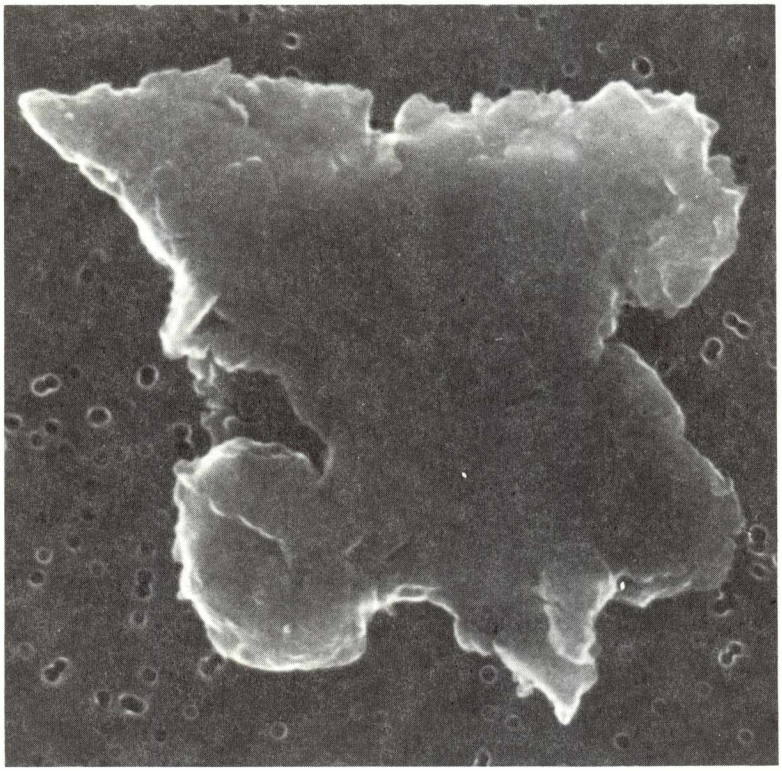
COLOR	LUSTER
CL to Pale Blue-Gray	V

TYPE	COMMENTS
C?	

C1001



W7027C11



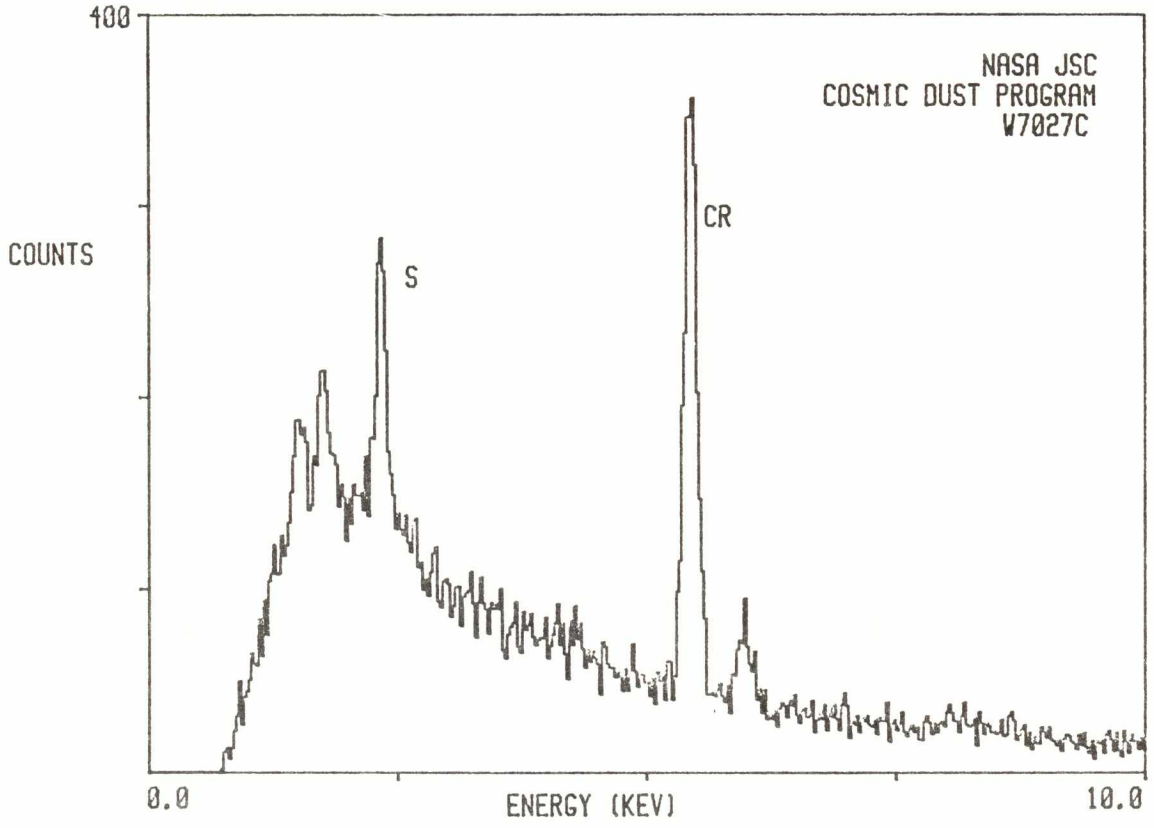
C1101

S-83-26567

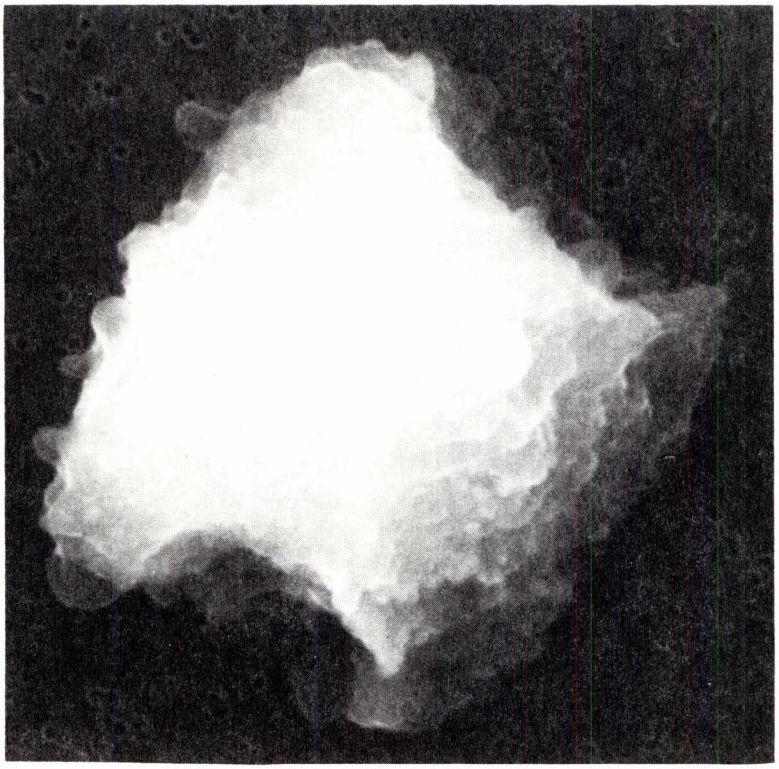
SIZE	SHAPE	TRANS.
15x18	I	TL/T

COLOR	LUSTER
Pale Gray to Brown	SM/M

TYPE	COMMENTS
TCA?	



W7027C12



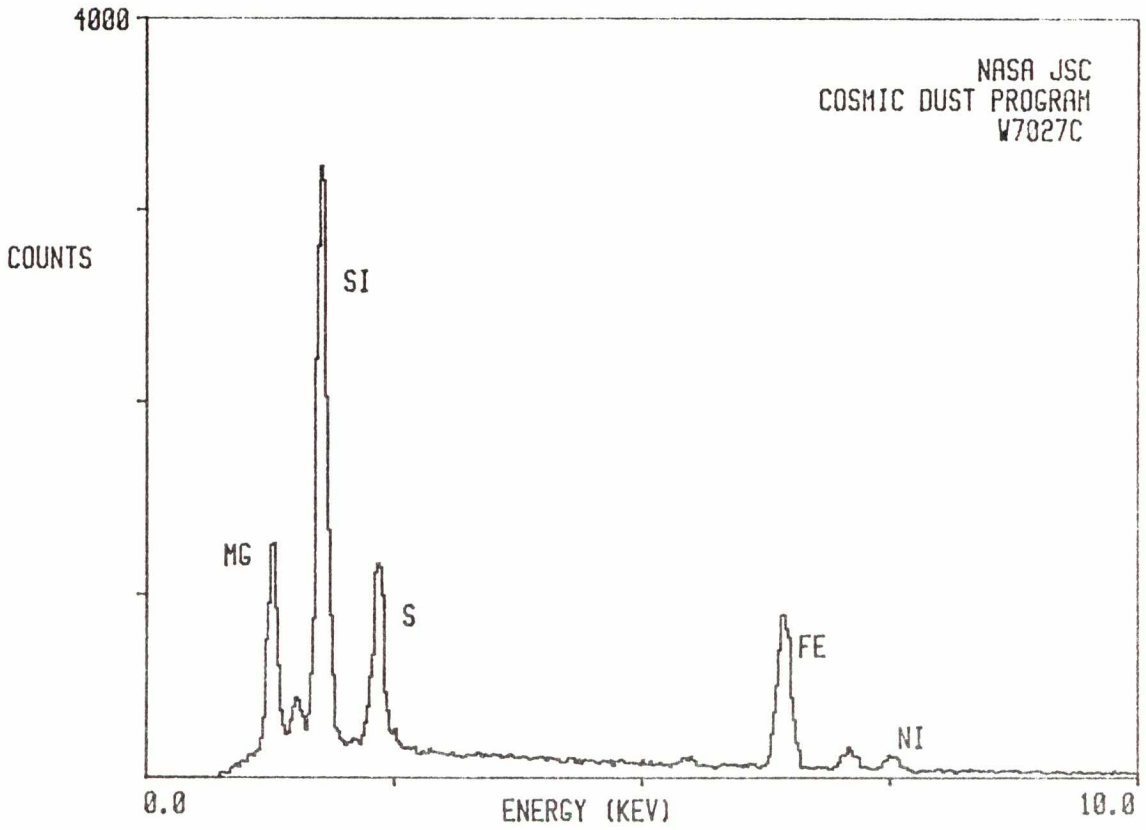
C1201

S-83-26568

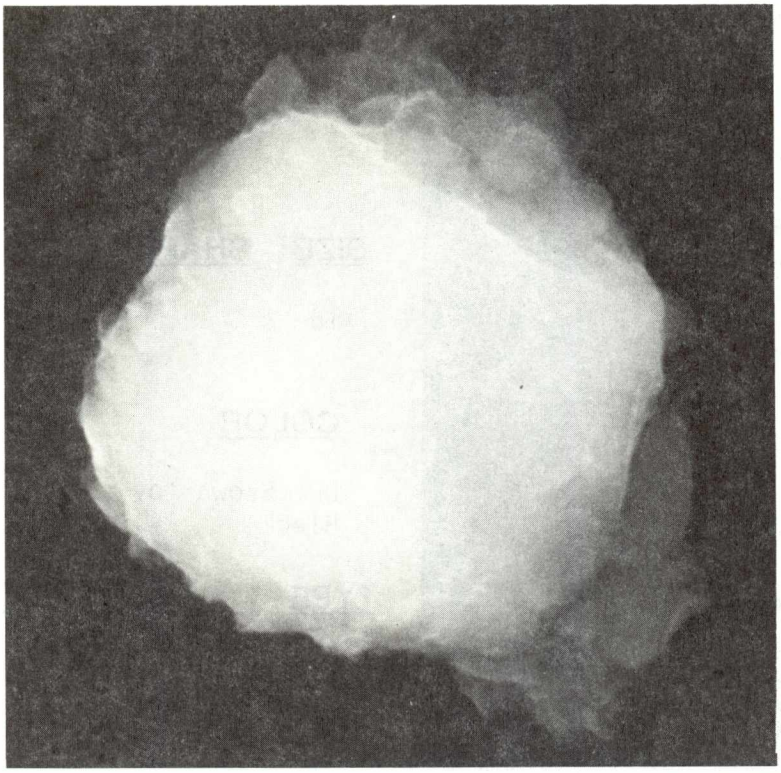
SIZE	SHAPE	TRANS.
14x15	I/E	O

COLOR	LUSTER
Dk. Gray to Black	D/SM

TYPE	COMMENTS
C	



W7027C13



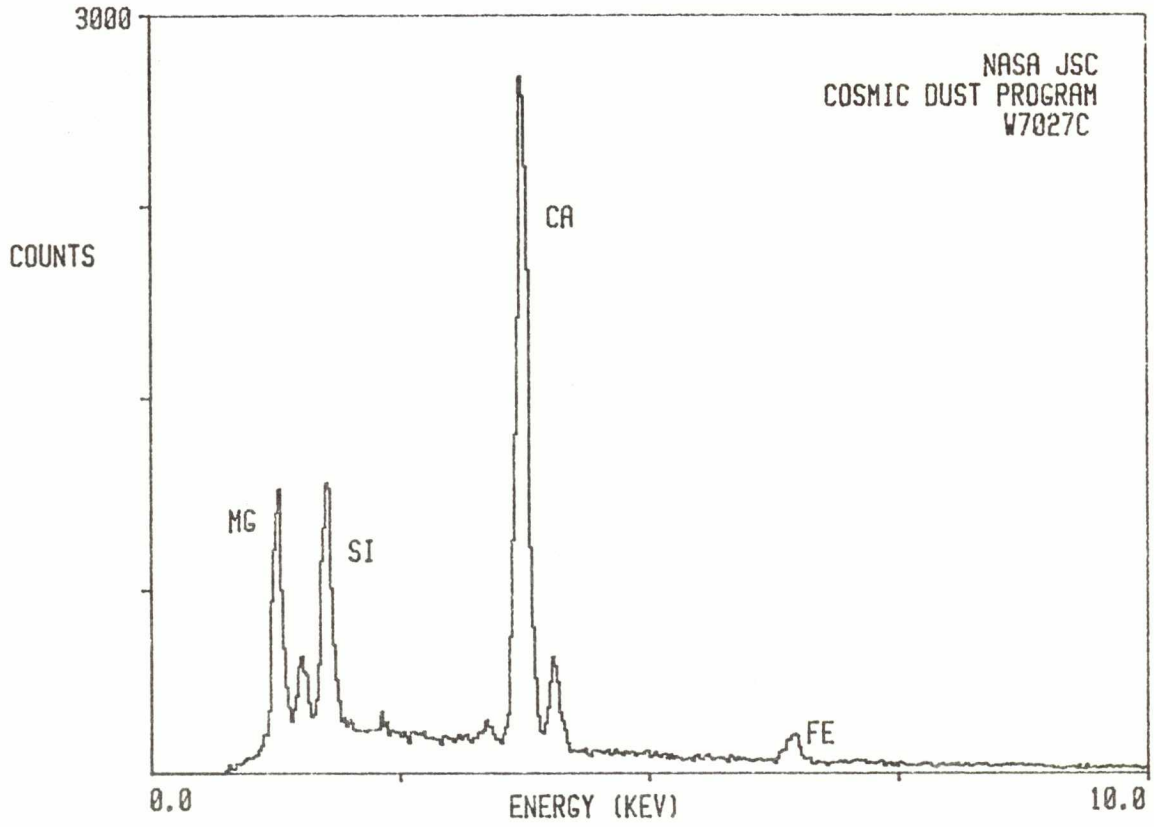
C1301

S-83-26569

SIZE	SHAPE	TRANS.
16x17	I/E	TL

COLOR	LUSTER
CL to Pale Yellow-Gray	SV/V

TYPE	COMMENTS
?	



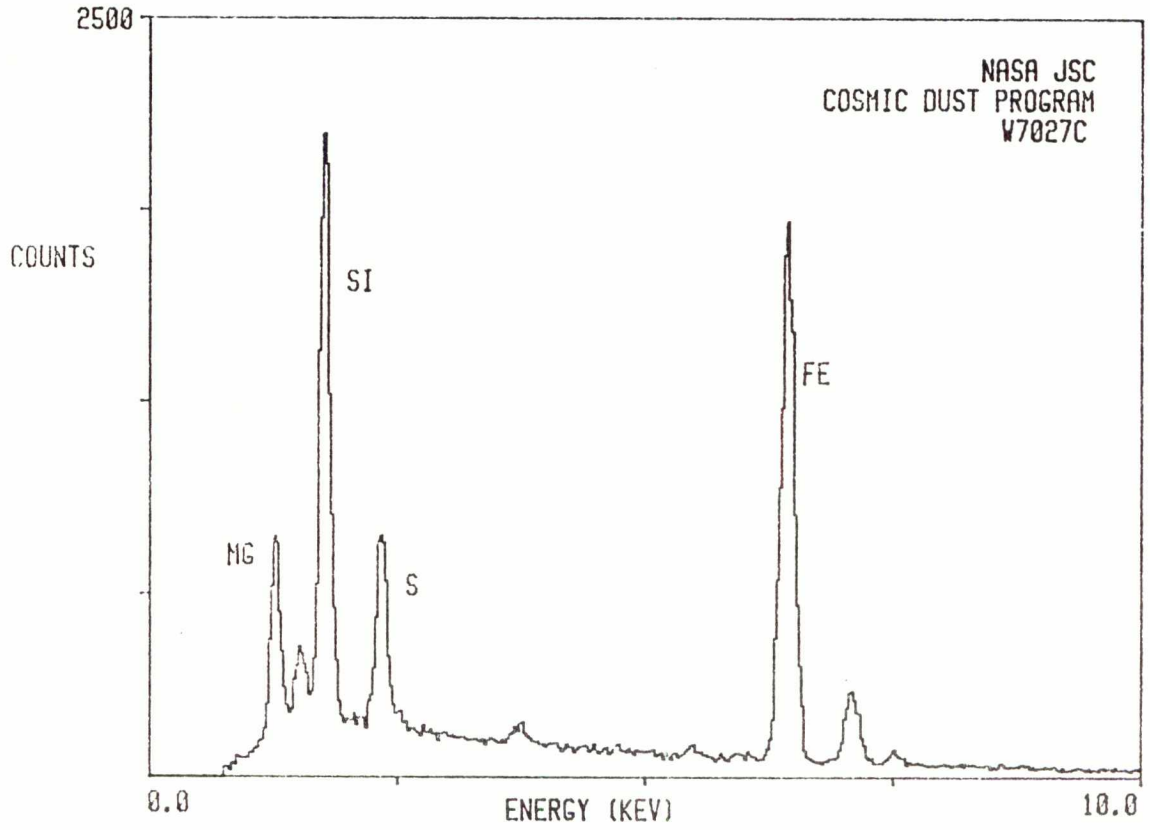
W7027C14

SIZE	SHAPE	TRANS.
7X16	I	O

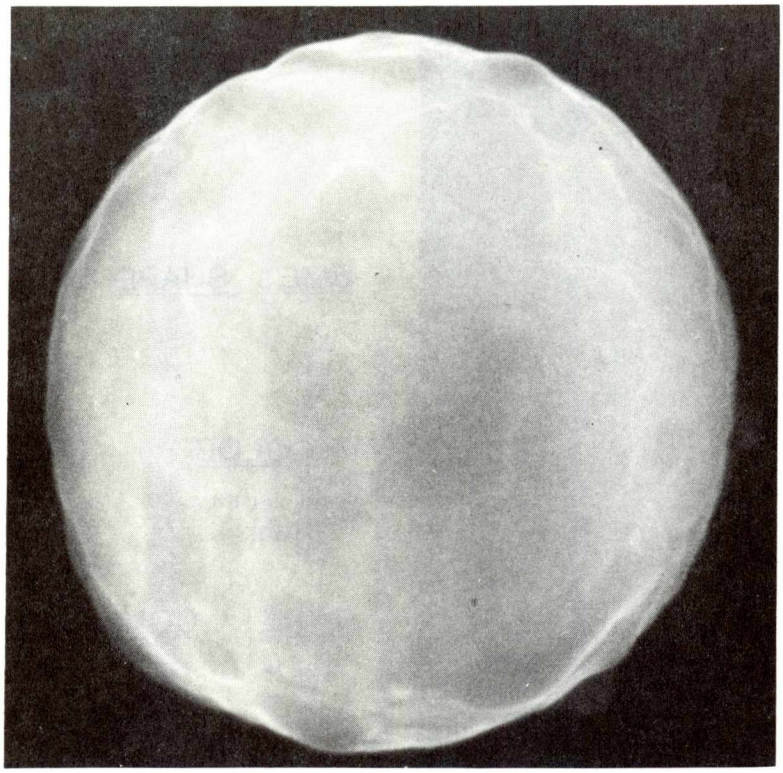
COLOR	LUSTER
Dk. Brown to Black	D/SM

TYPE	COMMENTS
C	

C1401 S-83-26570



W7027C15



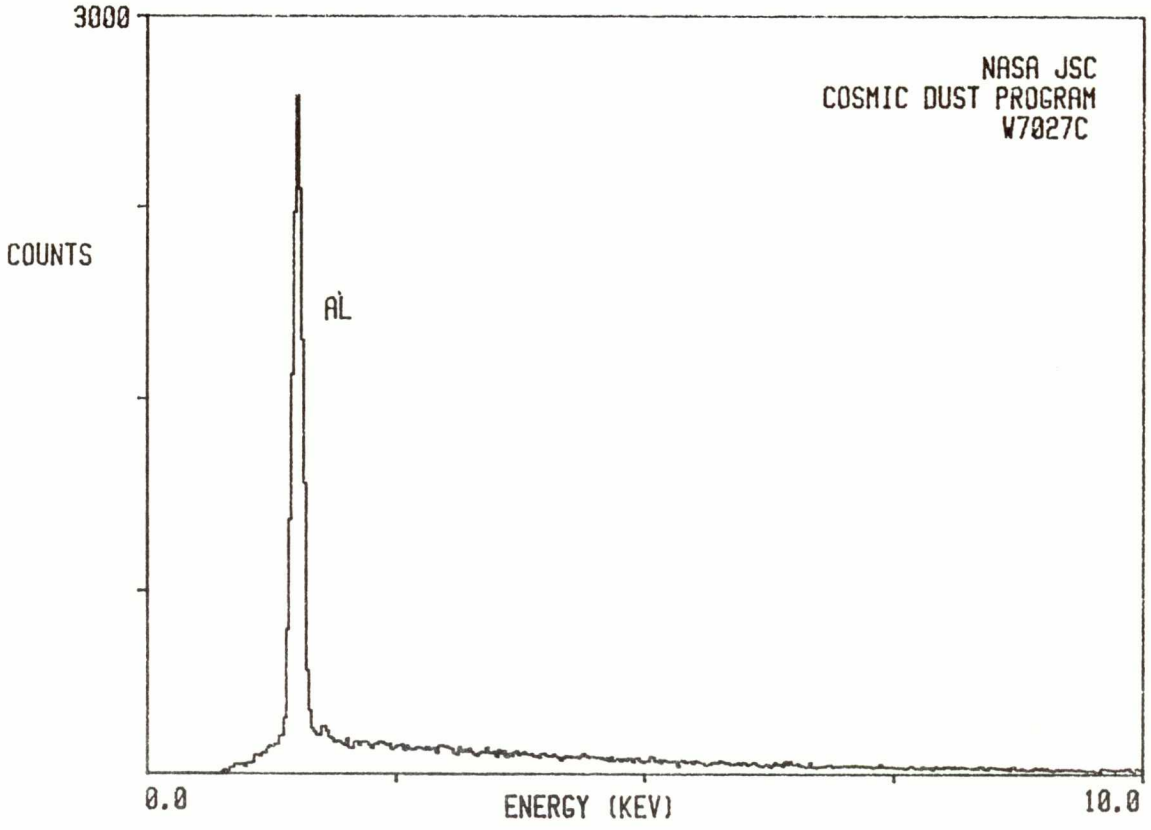
C1501

S-83-26571

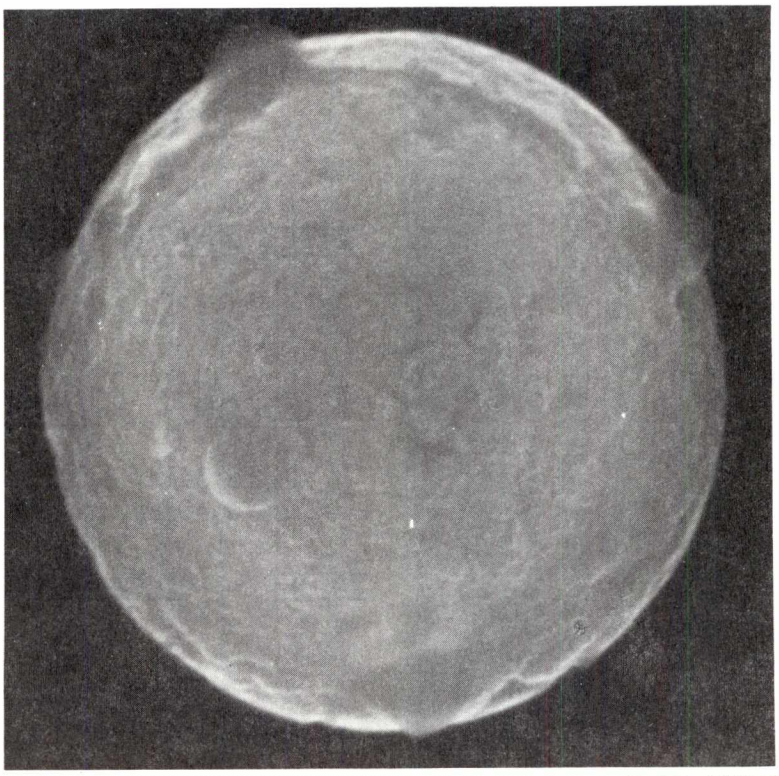
SIZE	SHAPE	TRANS.
12	S	T/TL

COLOR	LUSTER
CL to Pale Yellow-Gray	SV/V

TYPE	COMMENTS
AOS	



W7027C16



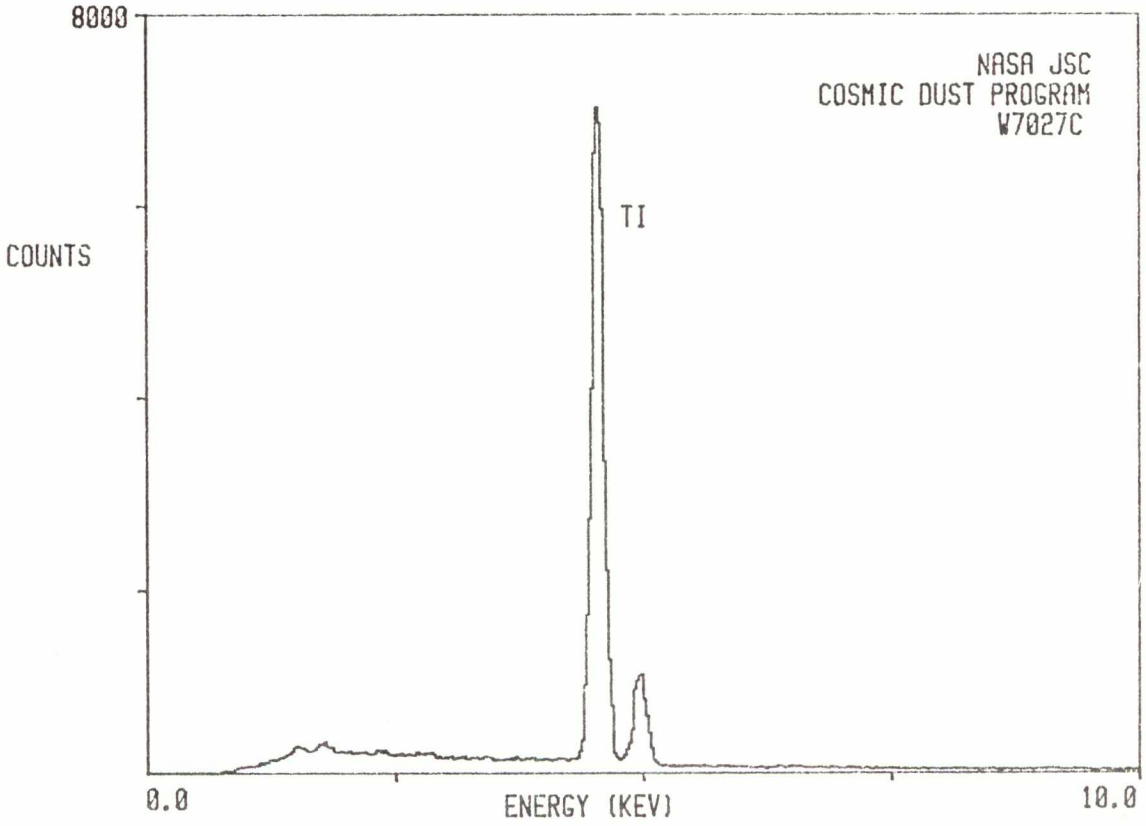
C1601

S-83-26572

SIZE	SHAPE	TRANS.
9	S	0

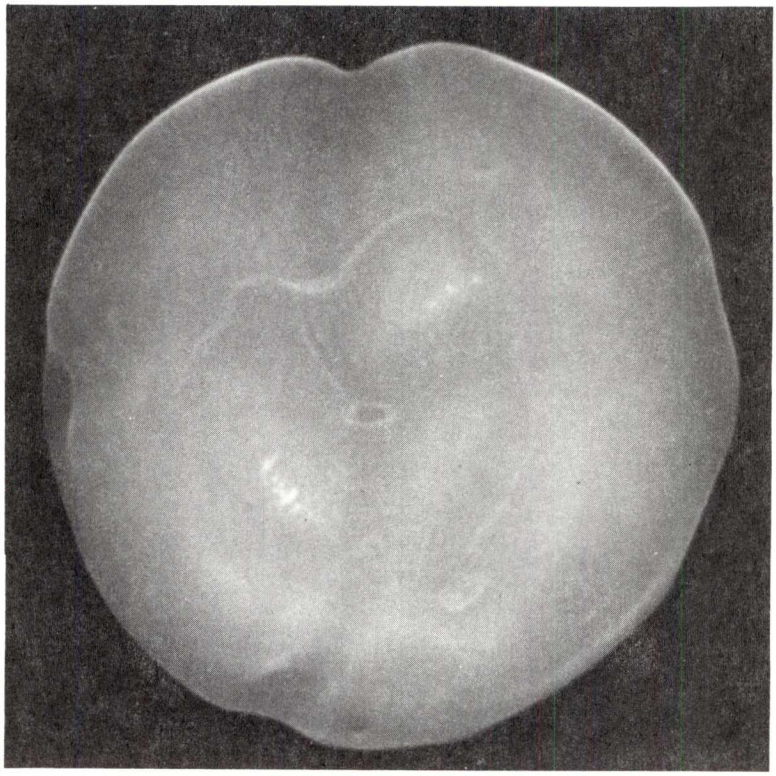
COLOR	LUSTER
Dk. Gray to Black	SM/M

TYPE	COMMENTS
TCA?	



W7027D

W7027D1

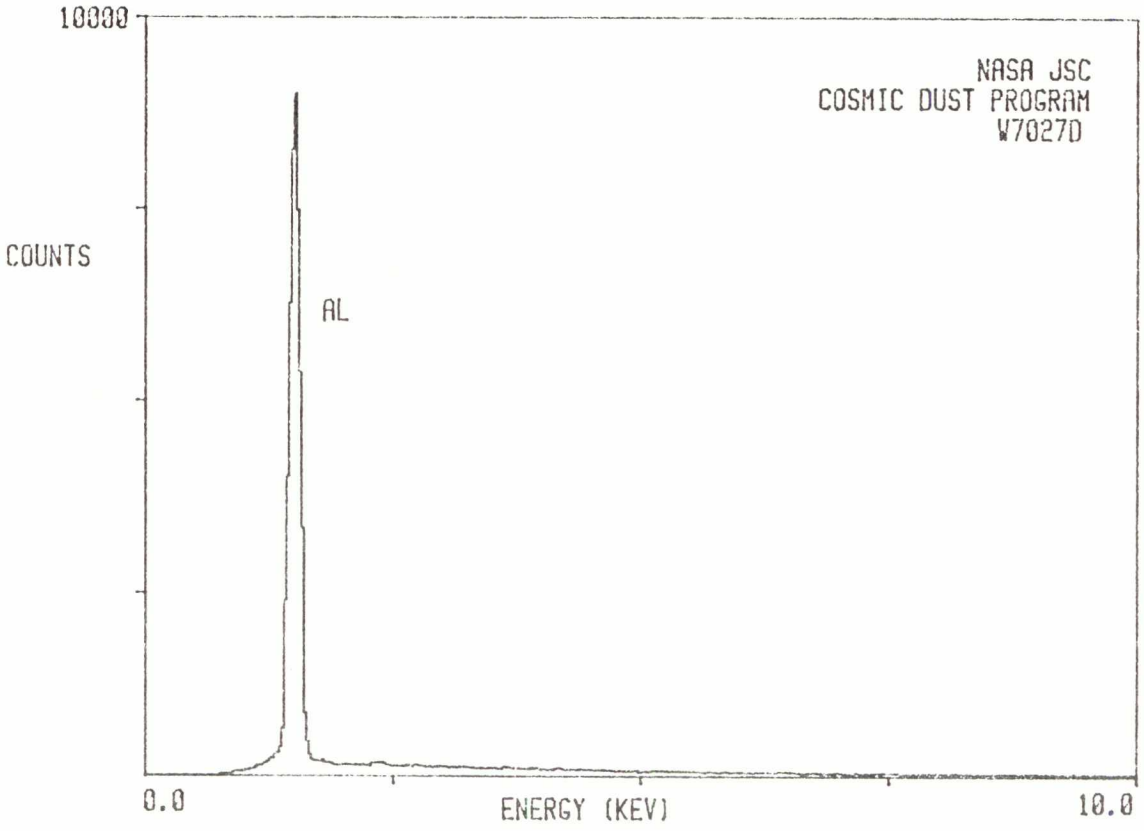


D0101 S-83-26612

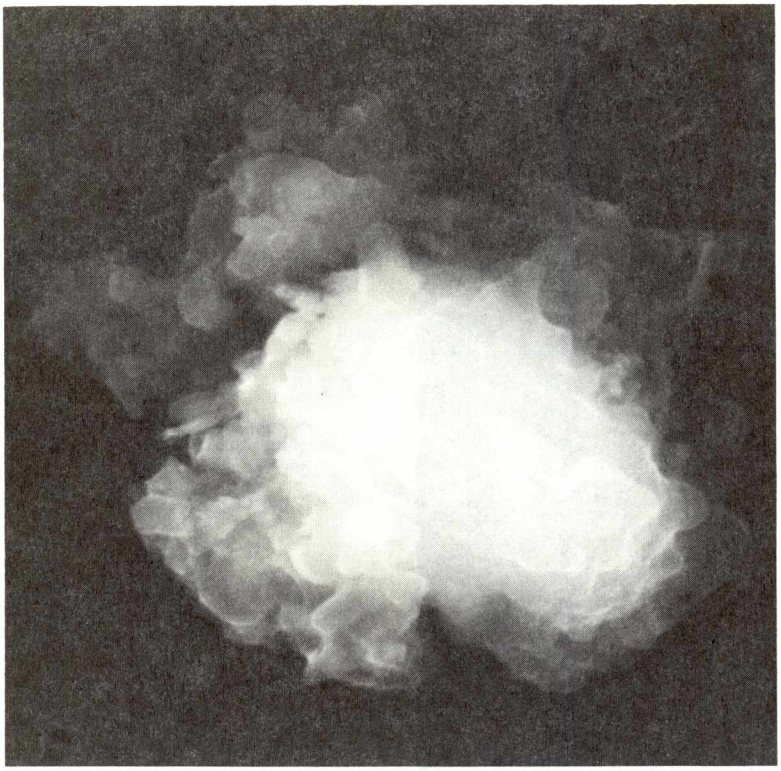
SIZE	SHAPE	TRANS.
8	S	T

COLOR	LUSTER
CL to Pale Yellow-Gray	SV/V

TYPE	COMMENTS
AOS	



W7027D2



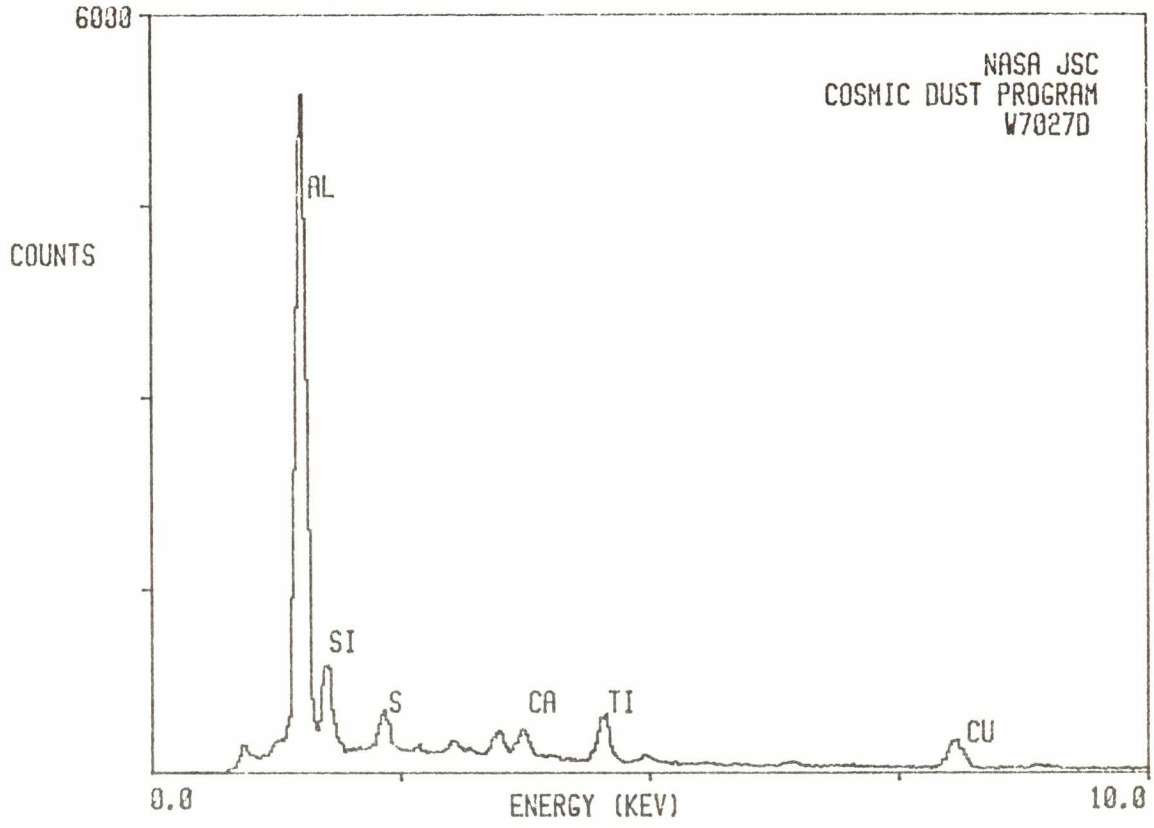
D0201

S-83-26613

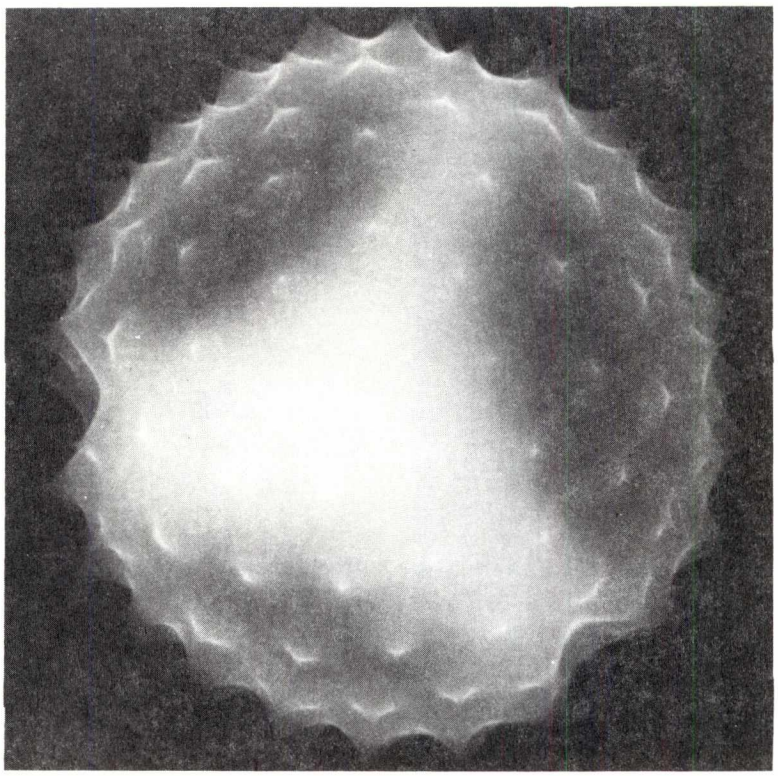
SIZE	SHAPE	TRANS.
10x12	I	0

COLOR	LUSTER
Dk. Gray to Black	D/SM

TYPE	COMMENTS
TCA?	



W7027D7



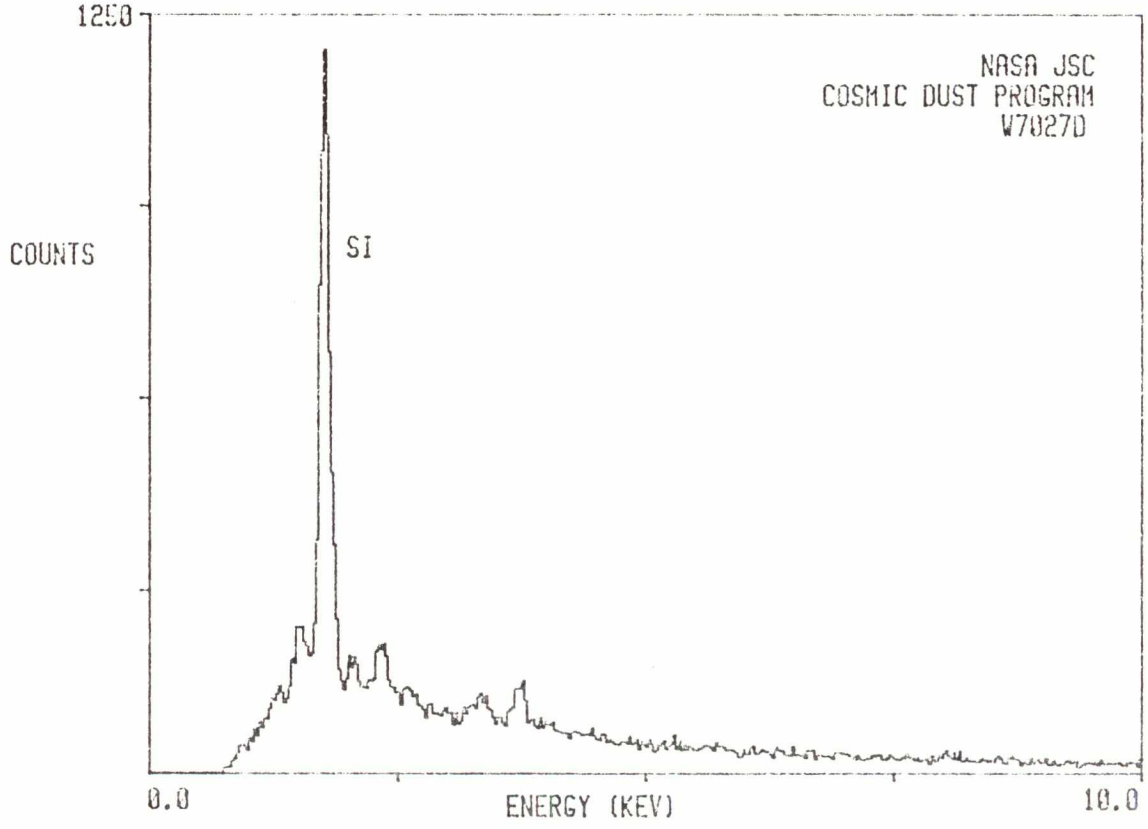
D0701

S-83-26621

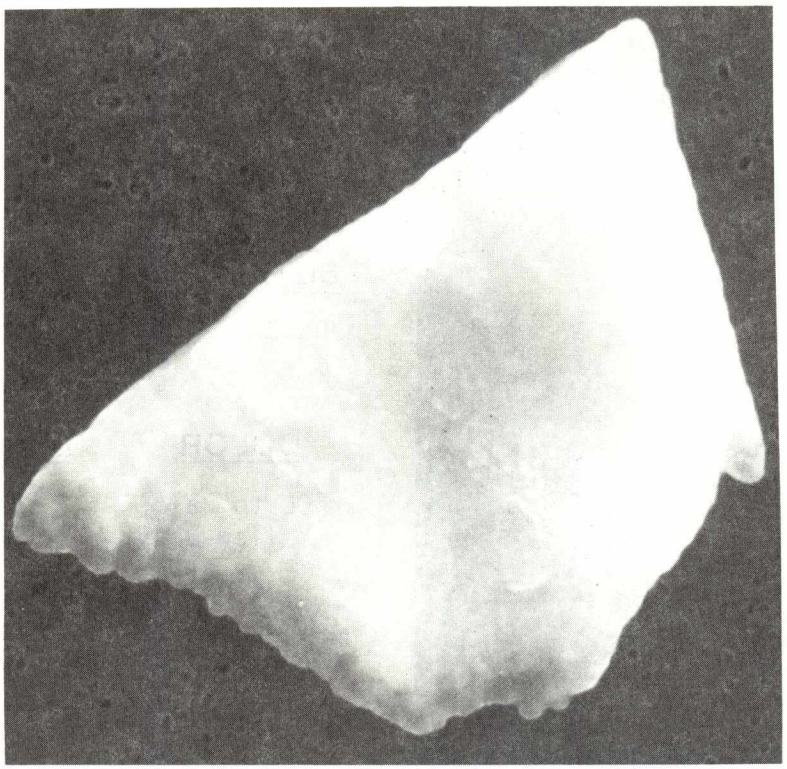
SIZE	SHAPE	TRANS.
21	S	TL

COLOR	LUSTER
CL to Pale Yellow-Gray	SV

TYPE	COMMENTS
TCN?	



W7027D8



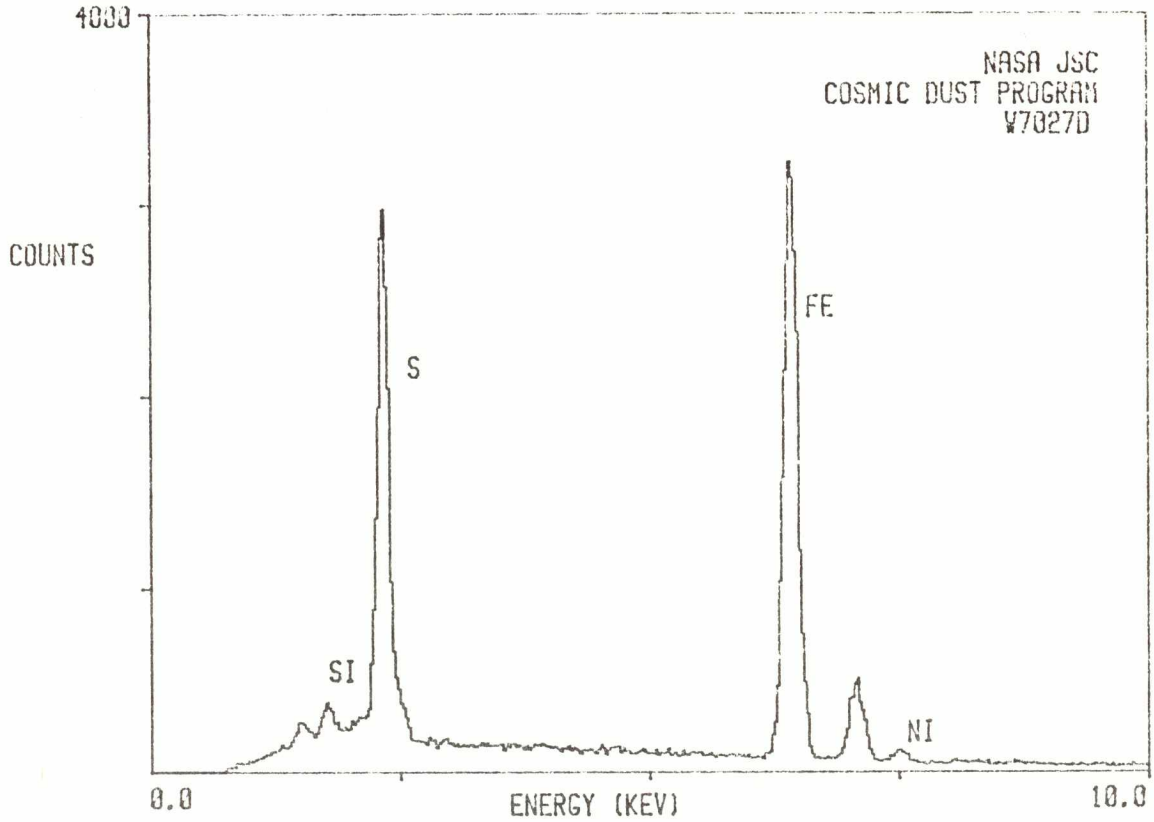
S-83-26622

D0801

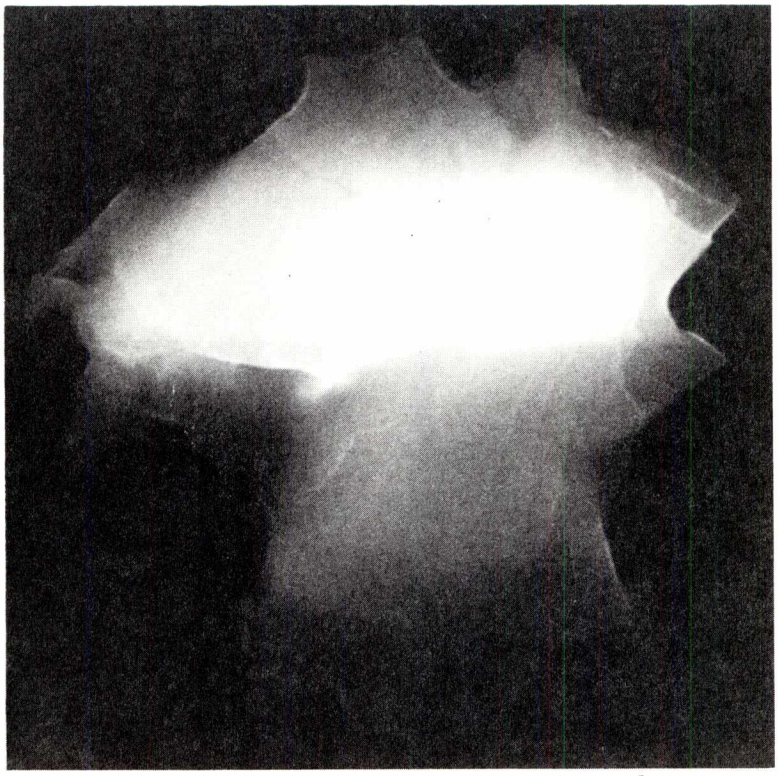
SIZE	SHAPE	TRANS.
13X21	I	O

COLOR	LUSTER
Dk. Brown to Black	SM

TYPE	COMMENTS
C	



W7027D9



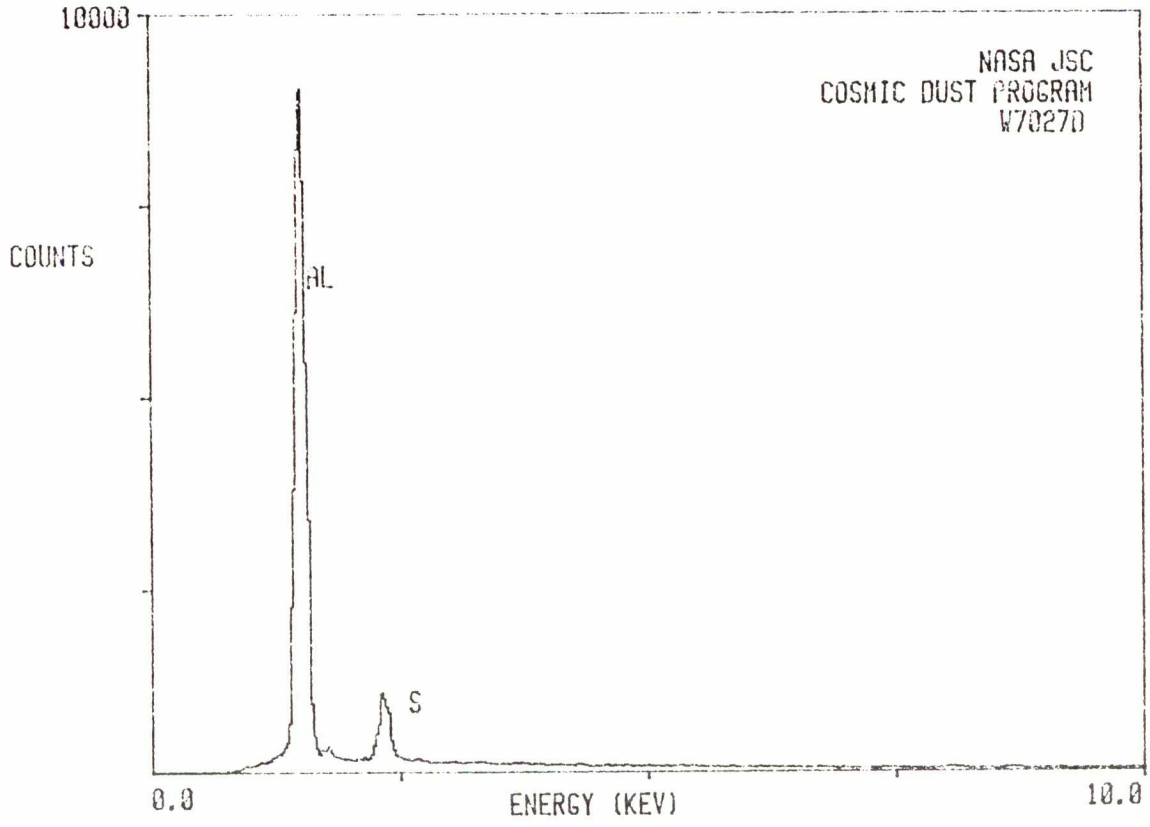
D0901

S-83-26623

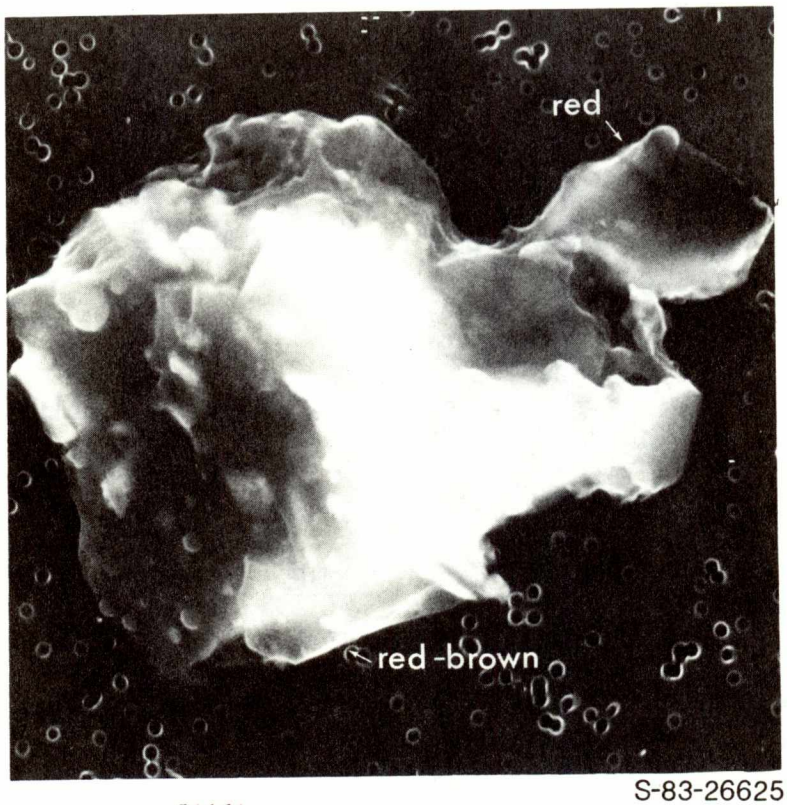
SIZE	SHAPE	TRANS.
29X30	I	TL

COLOR	LUSTER
CL to Pale Yellow-Gray	SV

TYPE	COMMENTS
TCA?	



W7027D11



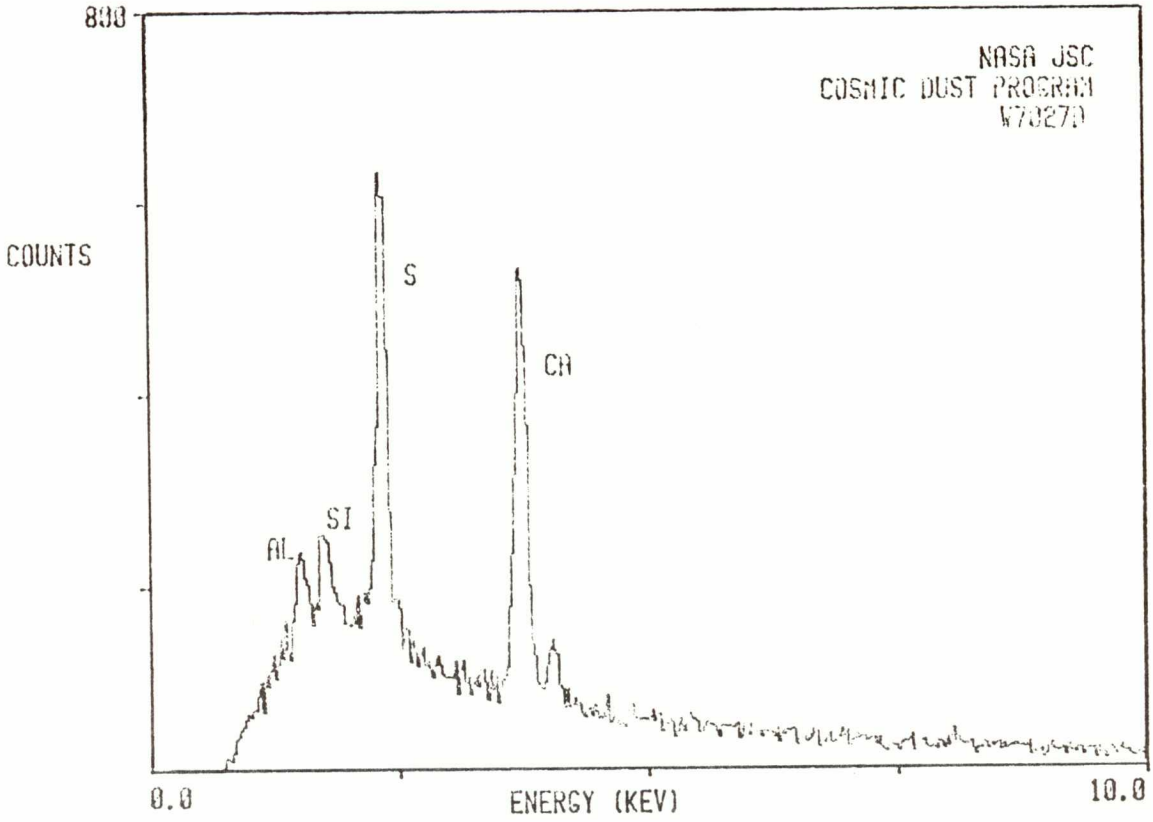
S-83-26625

D1101

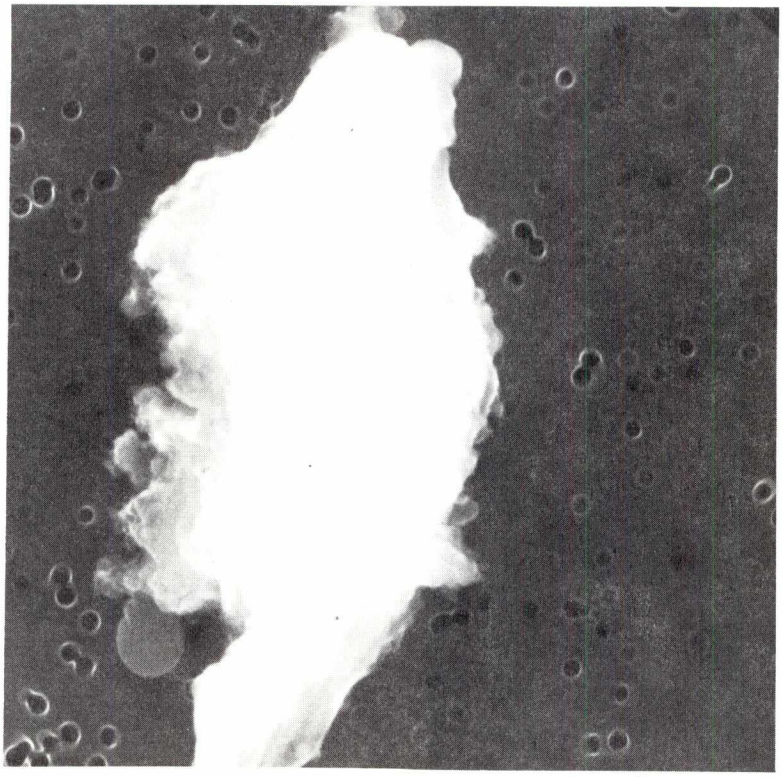
SIZE	SHAPE	TRANS.
14X18	I	O/TL

COLOR	LUSTER
Dk. Red-Brown	D/SM

TYPE	COMMENTS
TCN?	



W7027D12



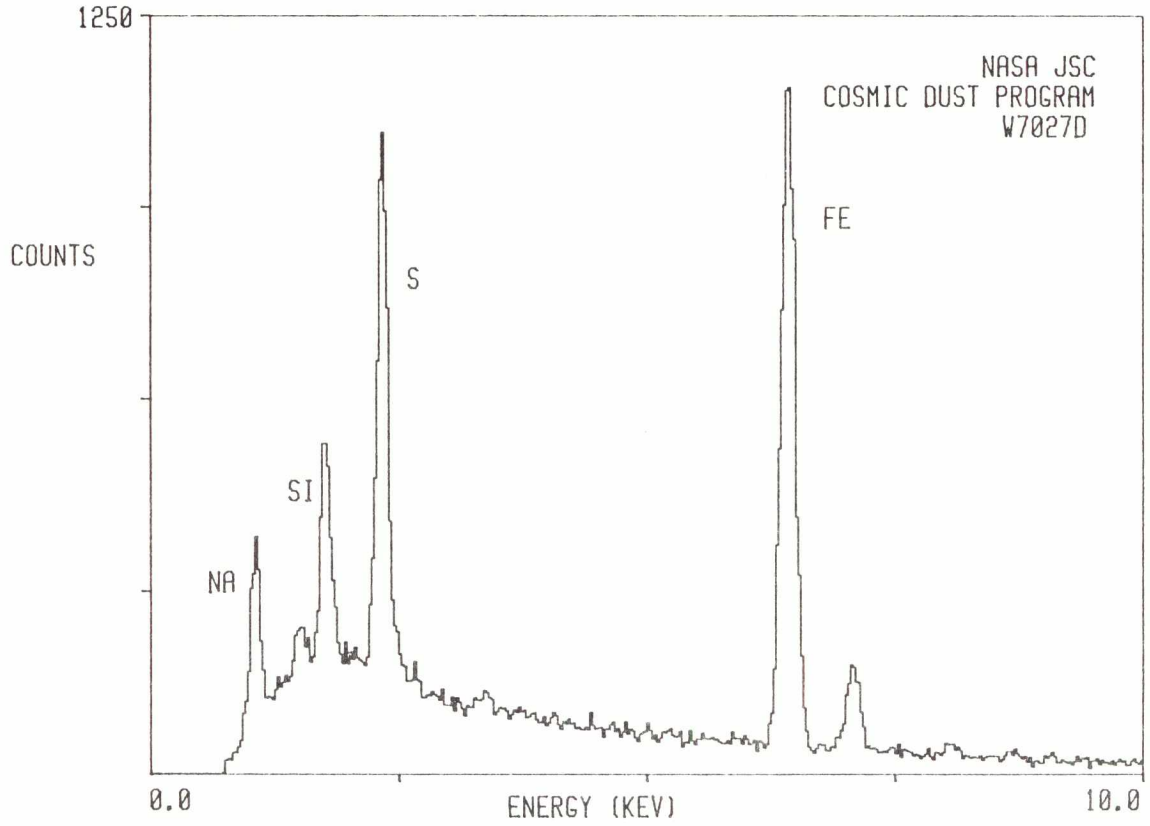
D1201

S-83-26626

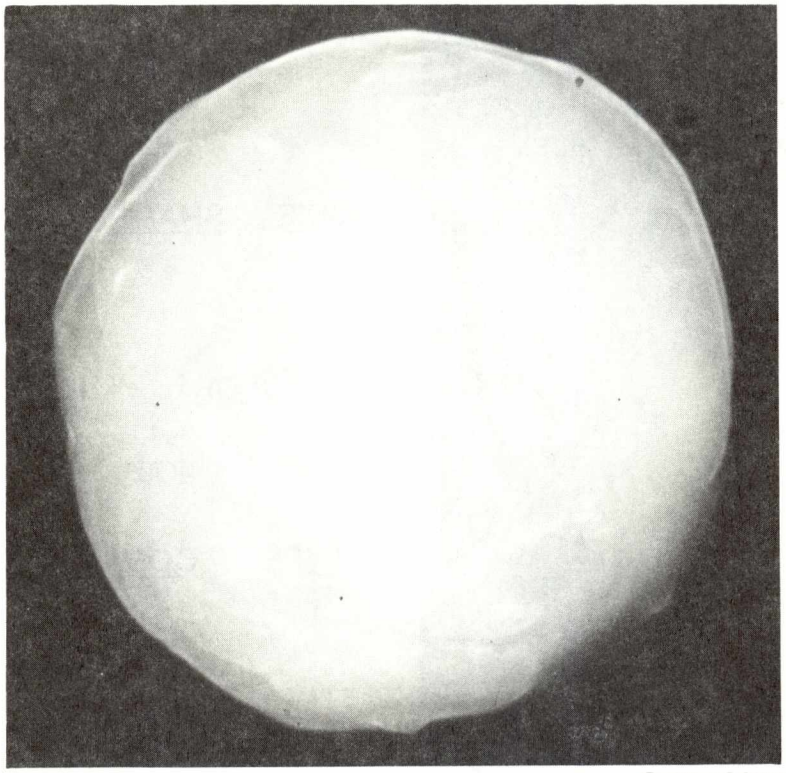
SIZE	SHAPE	TRANS.
6X14	I	O/TL

COLOR	LUSTER
Dk. Red-Brown	D/SM

TYPE	COMMENTS
TCN?	



W7027D13



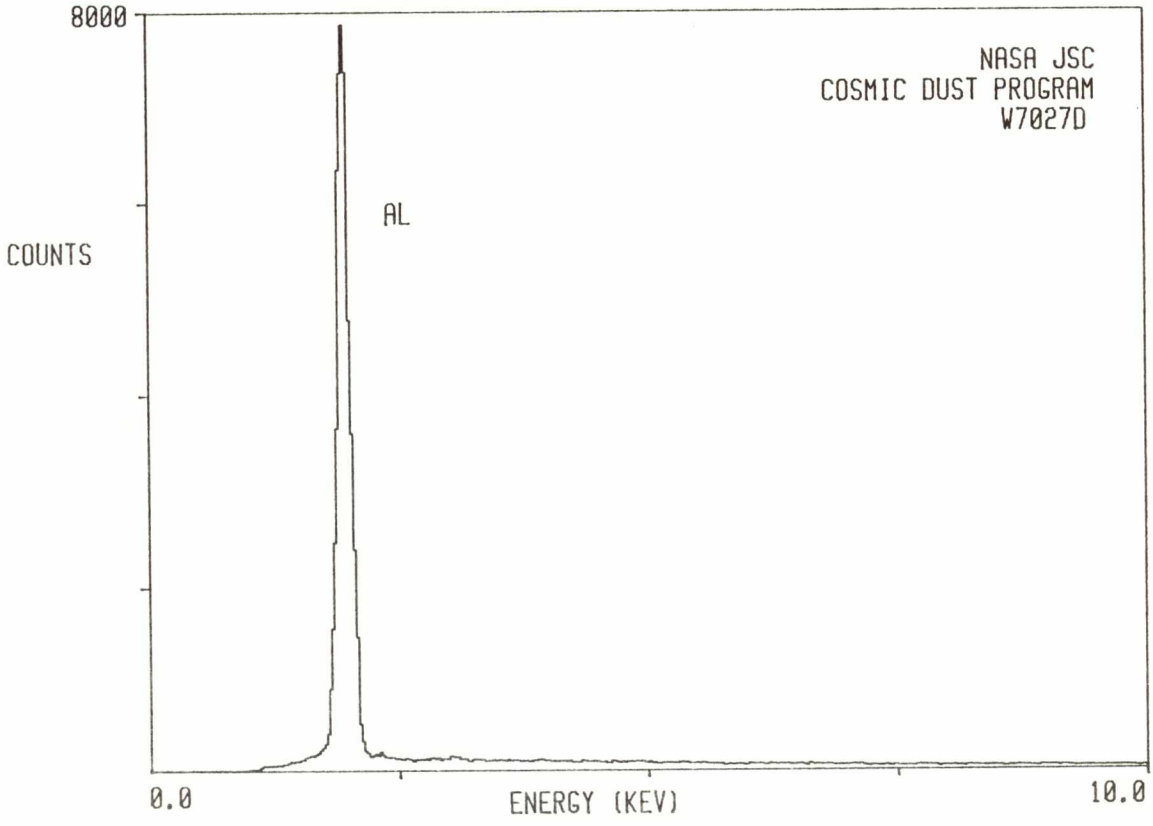
S-83-26627

D1301

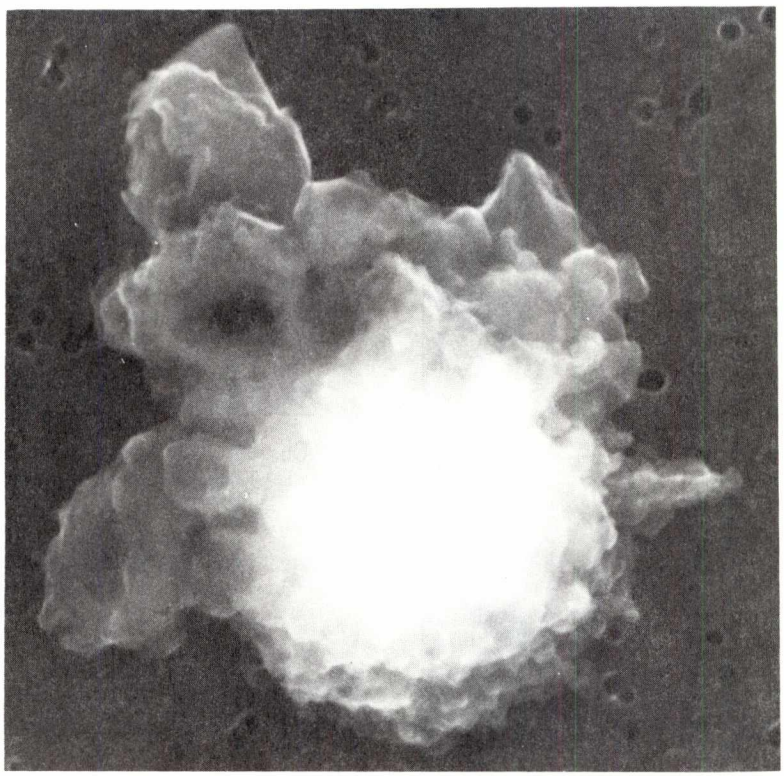
SIZE	SHAPE	TRANS.
8	S	TL

COLOR	LUSTER
CL to Pale Yellow-Gray	SV/V

TYPE	COMMENTS
AOS	



W7027D14



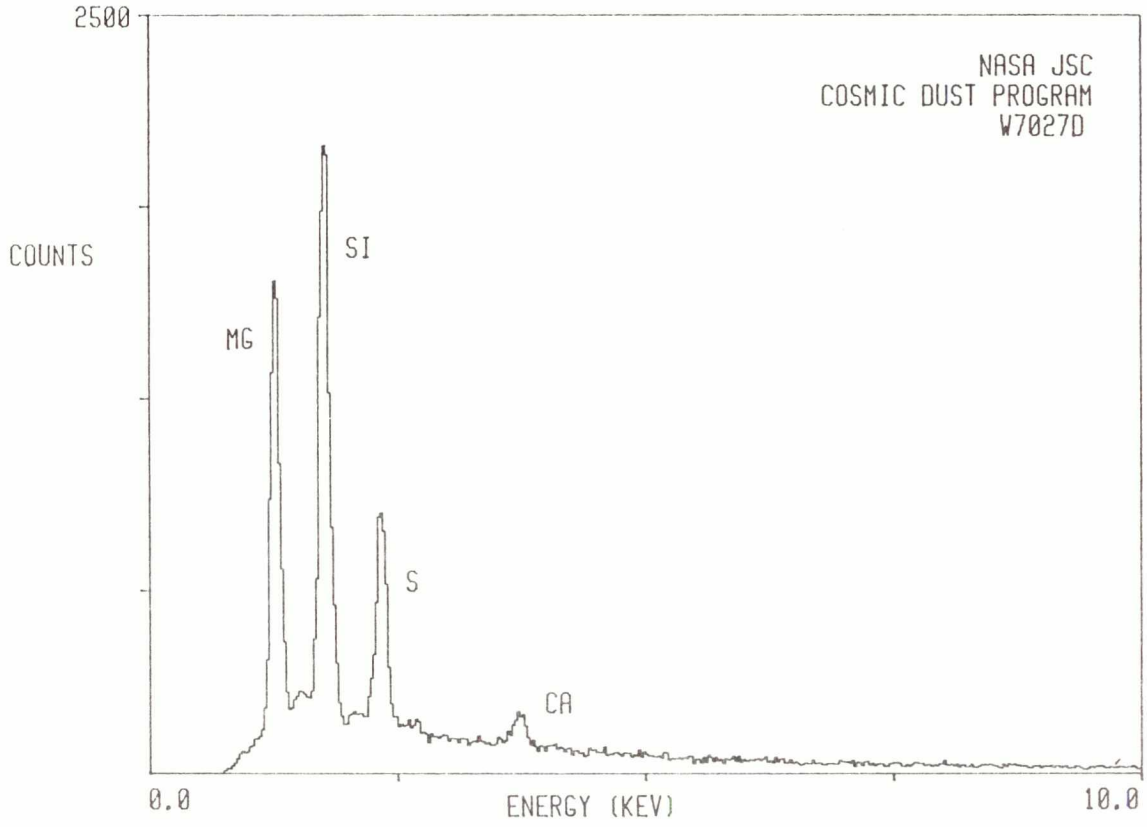
D1401

S-83-26628

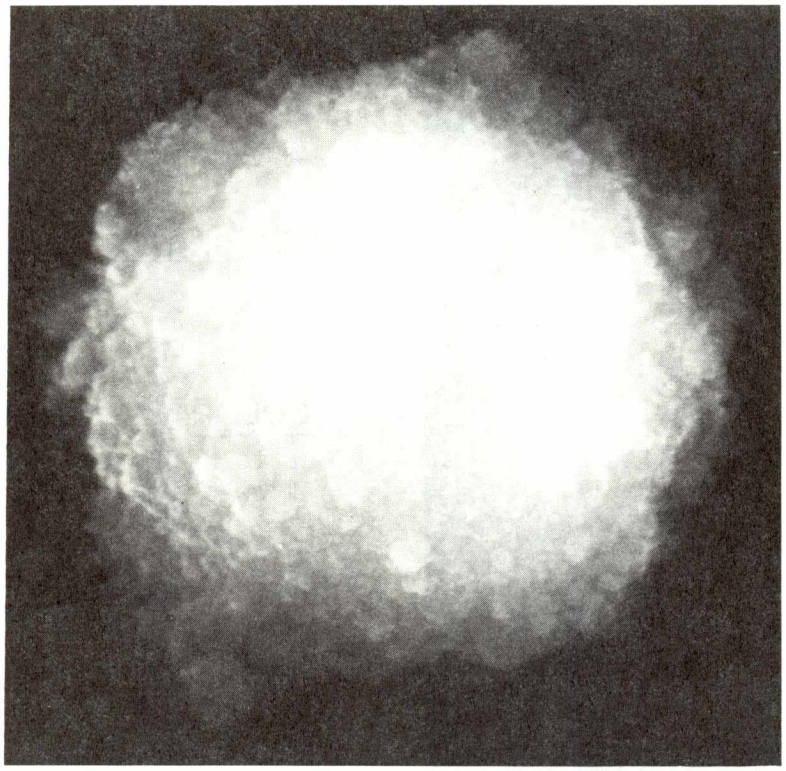
SIZE	SHAPE	TRANS.
10	I	TL

COLOR	LUSTER
CL to Pale Yellow-Gray	SV

TYPE	COMMENTS
?	



W7027D15



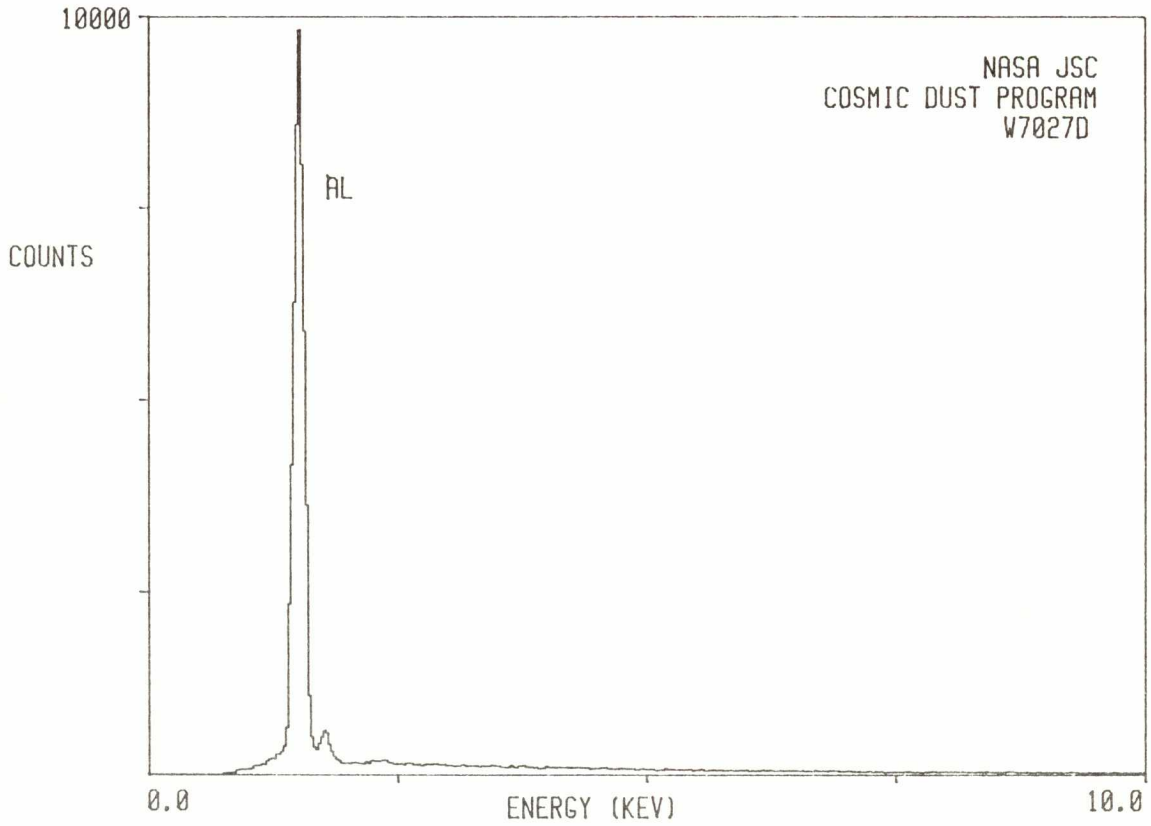
S-83-26629

SIZE	SHAPE	TRANS.
8	E/S	O/TL

COLOR	LUSTER
Dk. Brown-Gray	D/SM

TYPE	COMMENTS
TCA?	

D1501



W7027D17

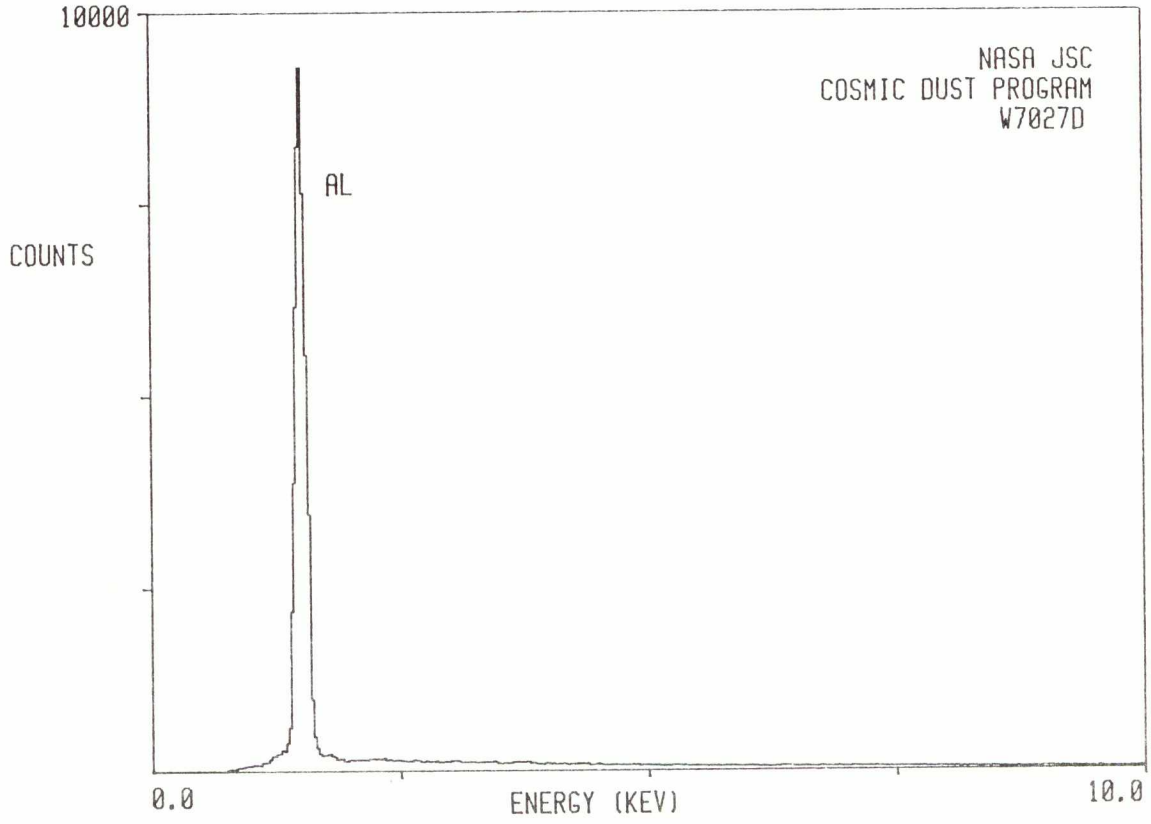
S-83-26631

SIZE	SHAPE	TRANS.
8	S	T

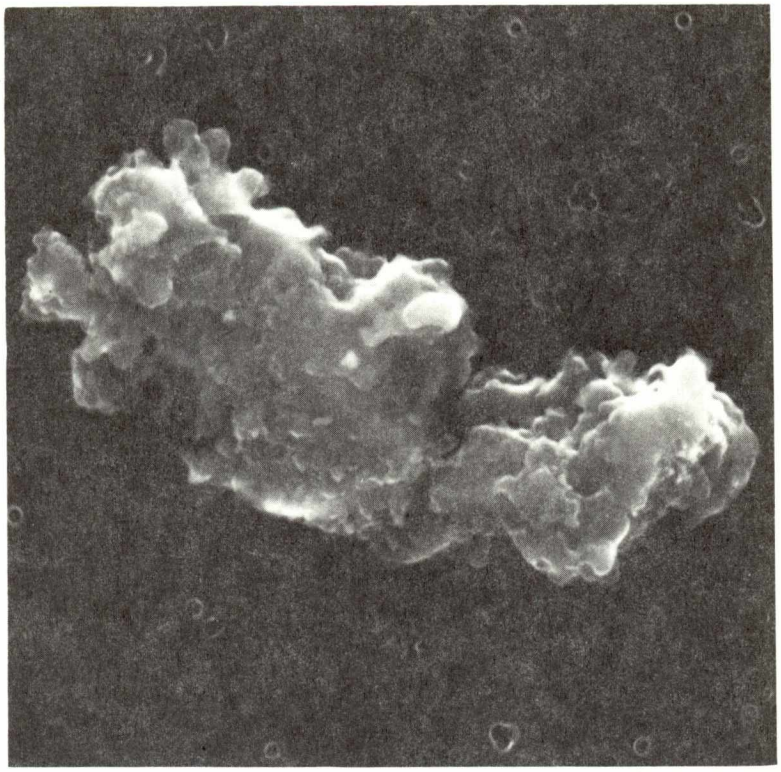
COLOR	LUSTER
CL to Pale Yellow-Gray	SV

TYPE	COMMENTS
AOS	

D1701



W7027D18



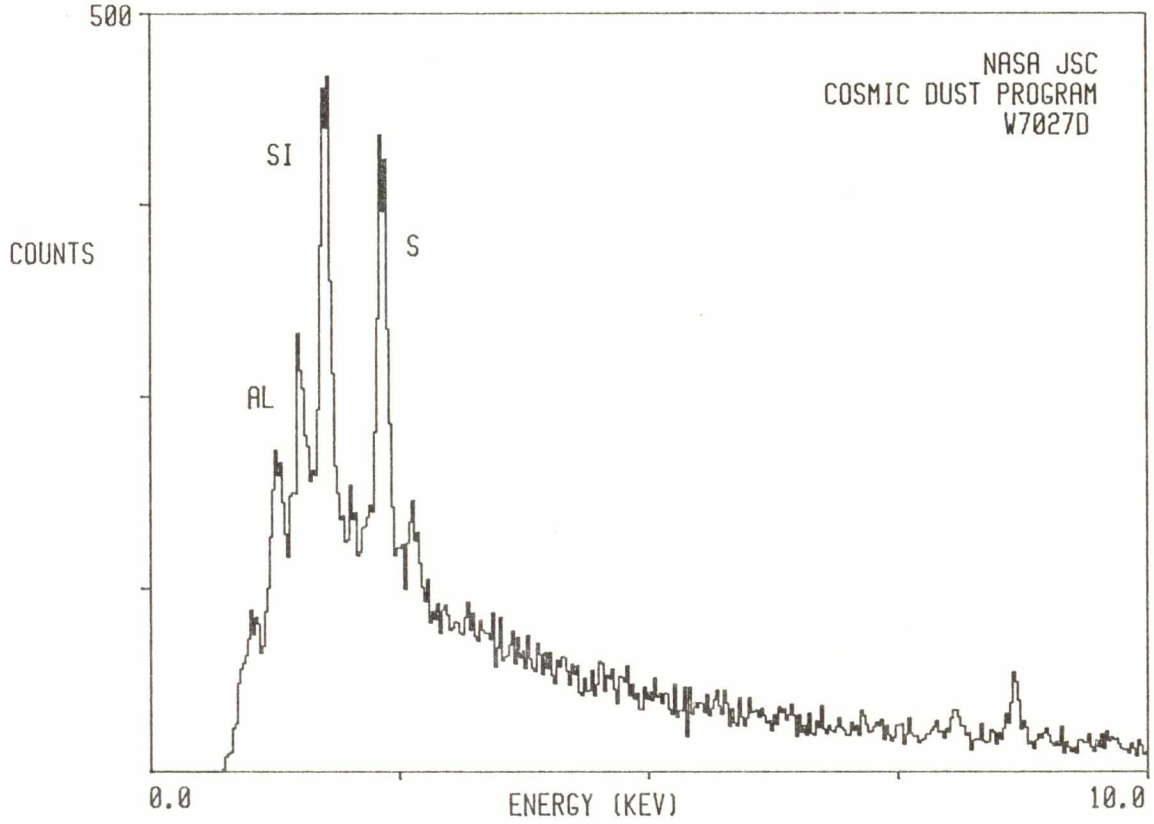
S-83-26632

D1801

SIZE	SHAPE	TRANS.
6X16	I	O

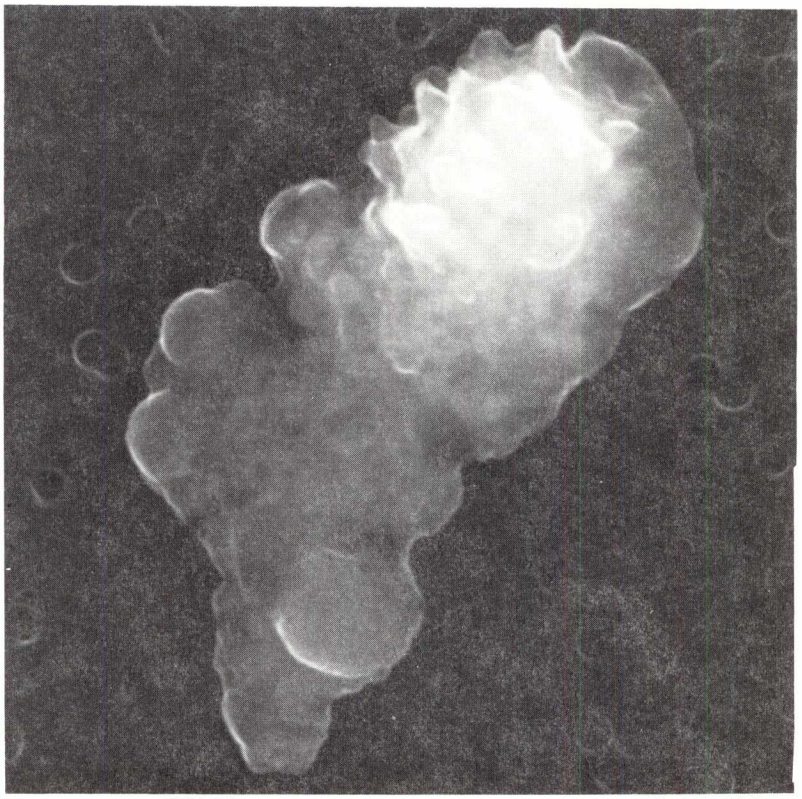
COLOR	LUSTER
Dk. Brown to Black	D/SM

TYPE	COMMENTS
?	



W7027E

W7027E1

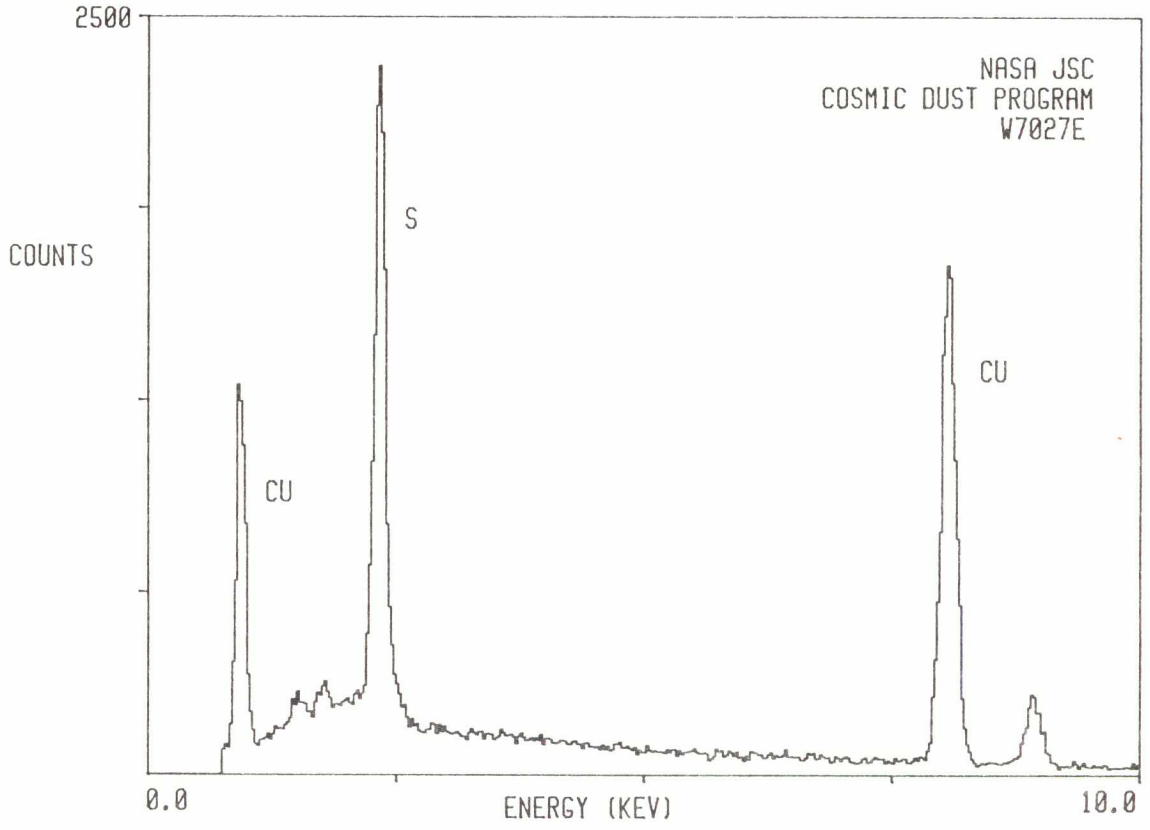


E0101 S-83-26600

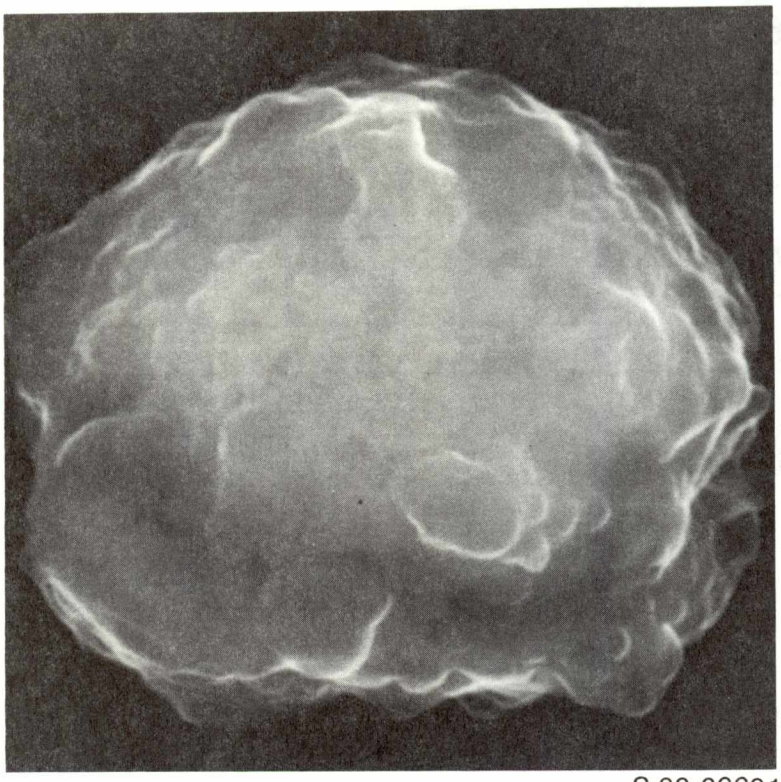
SIZE	SHAPE	TRANS.
4X8	I	O

COLOR	LUSTER
Dk. Red-Brown to Black	D/SM

TYPE	COMMENTS
TCA?	



W7027E2



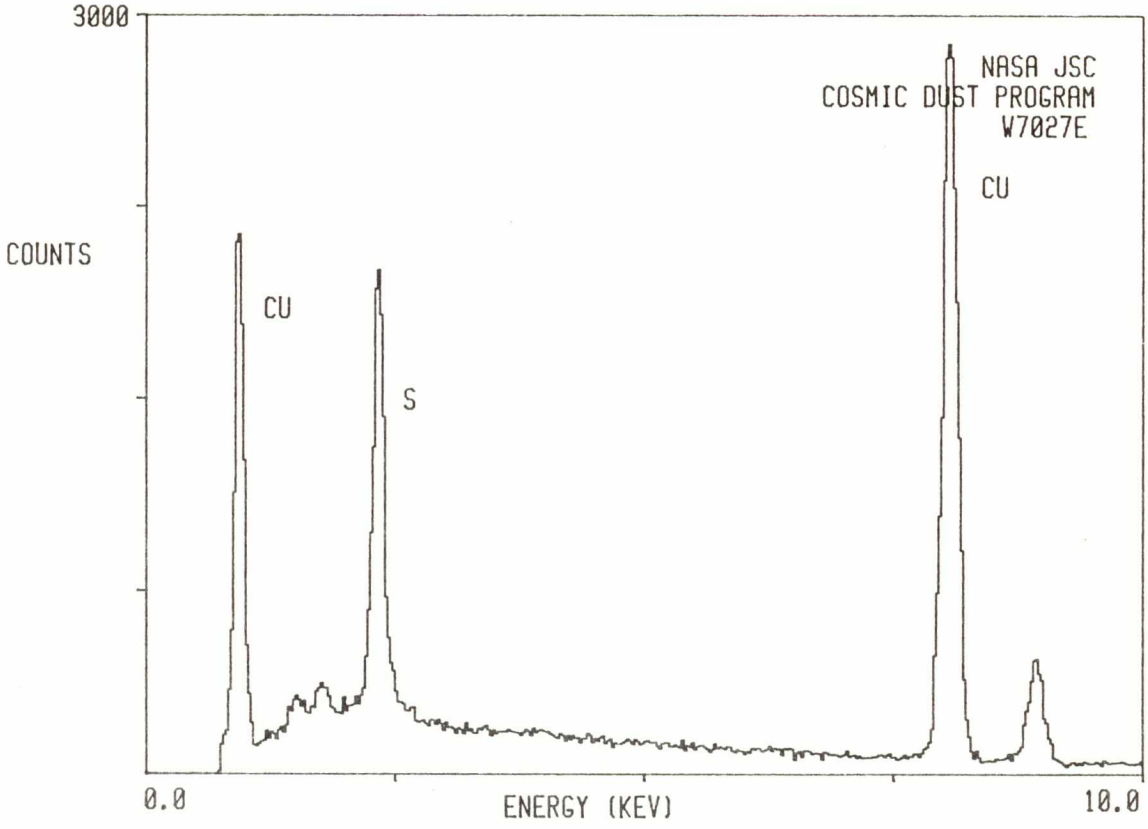
S-83-26601

E0201

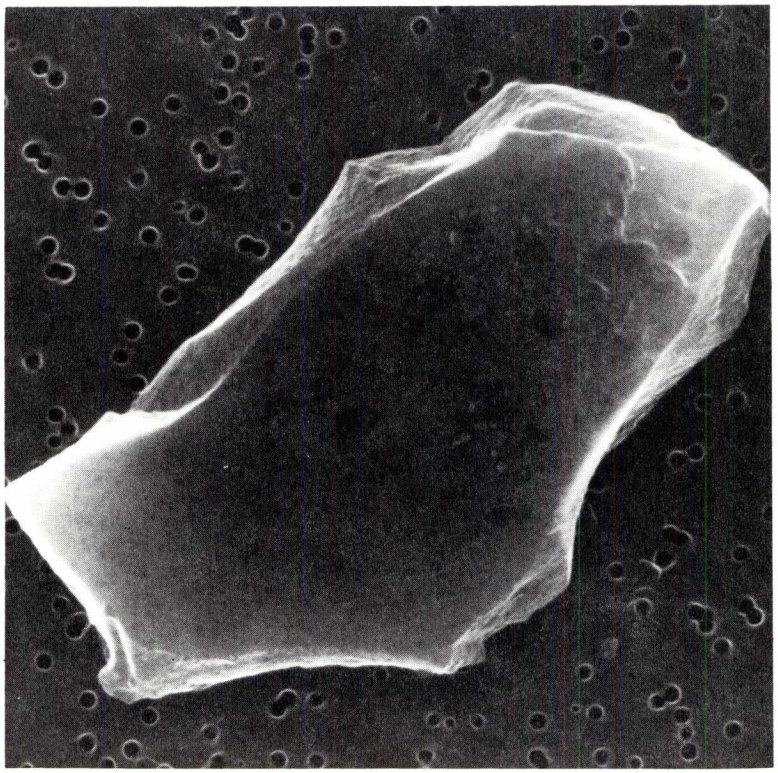
SIZE	SHAPE	TRANS.
4X5	I	O

COLOR	LUSTER
Dk. Brown to Black	SM

TYPE	COMMENTS
TCA?	Maybe related to W7027E1



W7027E3



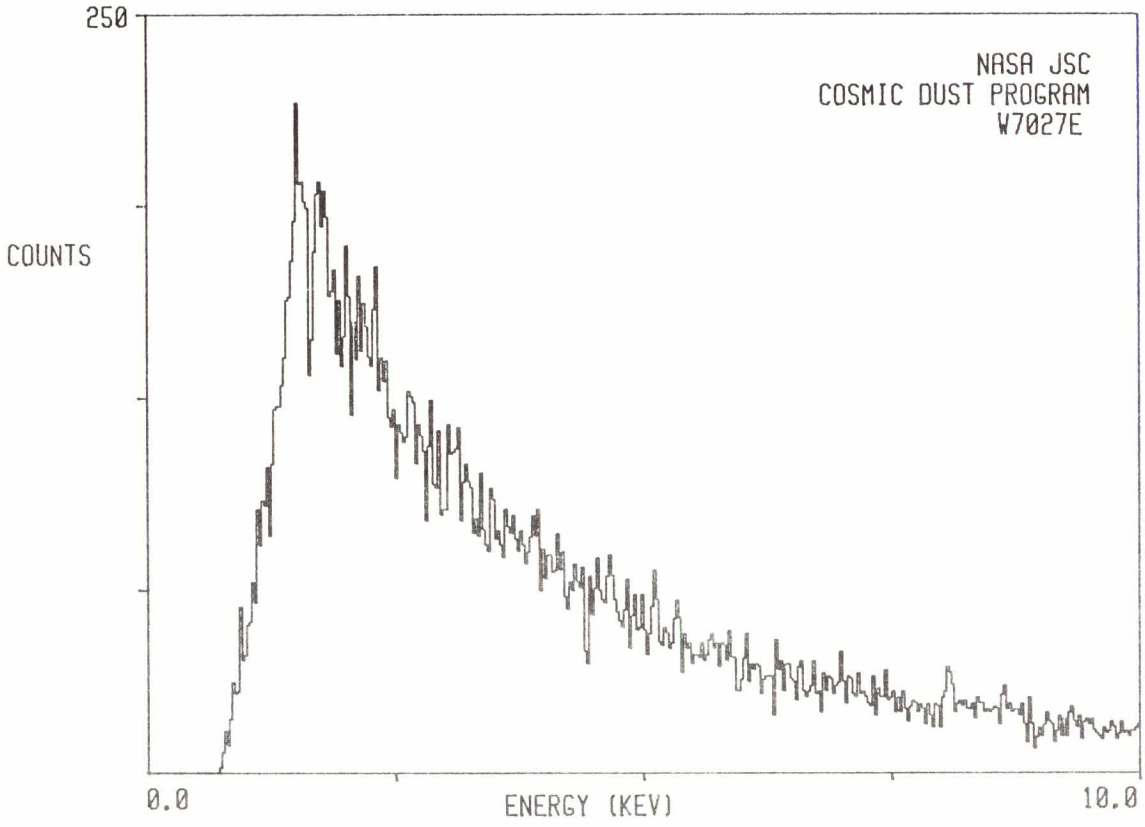
S-83-26602

E0301

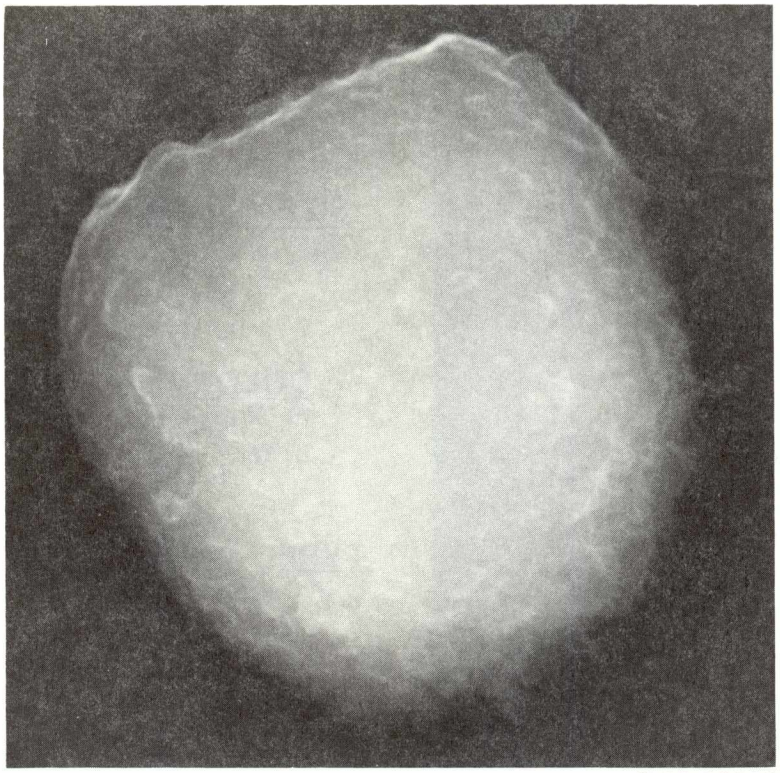
SIZE	SHAPE	TRANS.
10X17	I	0

COLOR	LUSTER
Dk. Brown to Black	SV/SM

TYPE	COMMENTS
?	



W7027E4



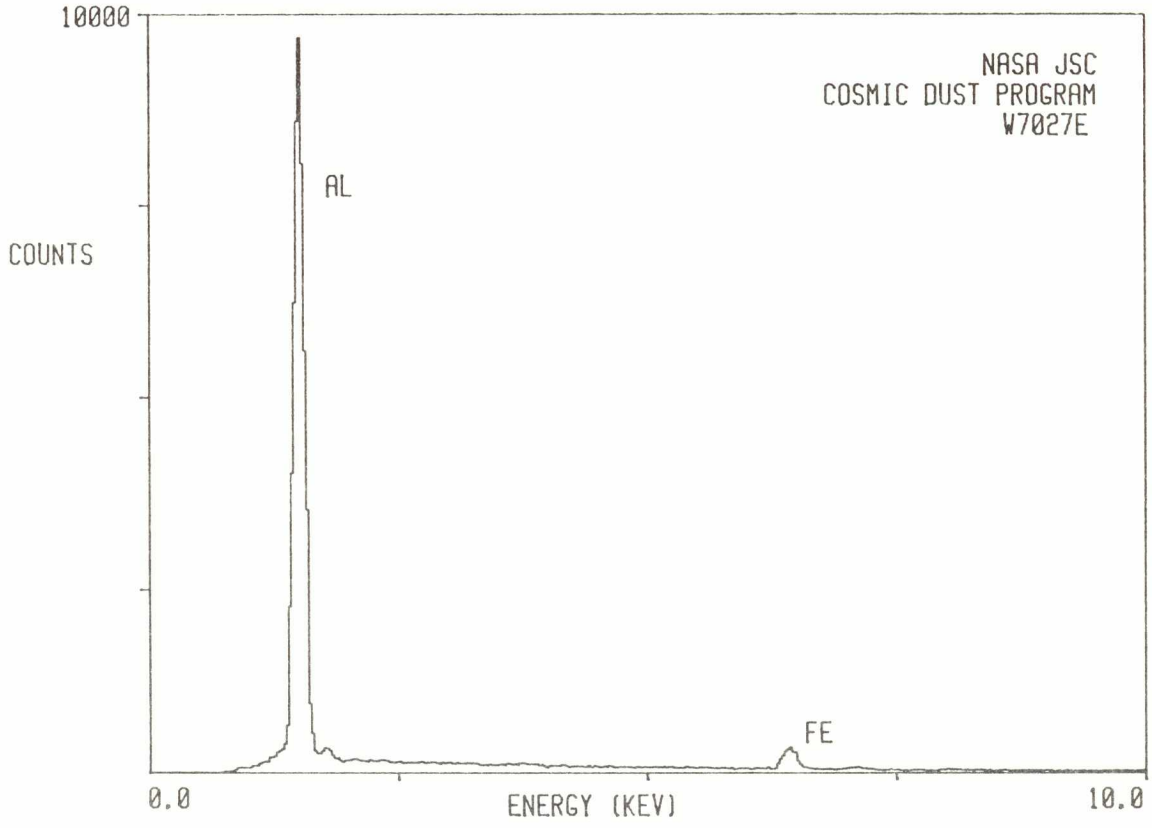
S-83-26603

E0401

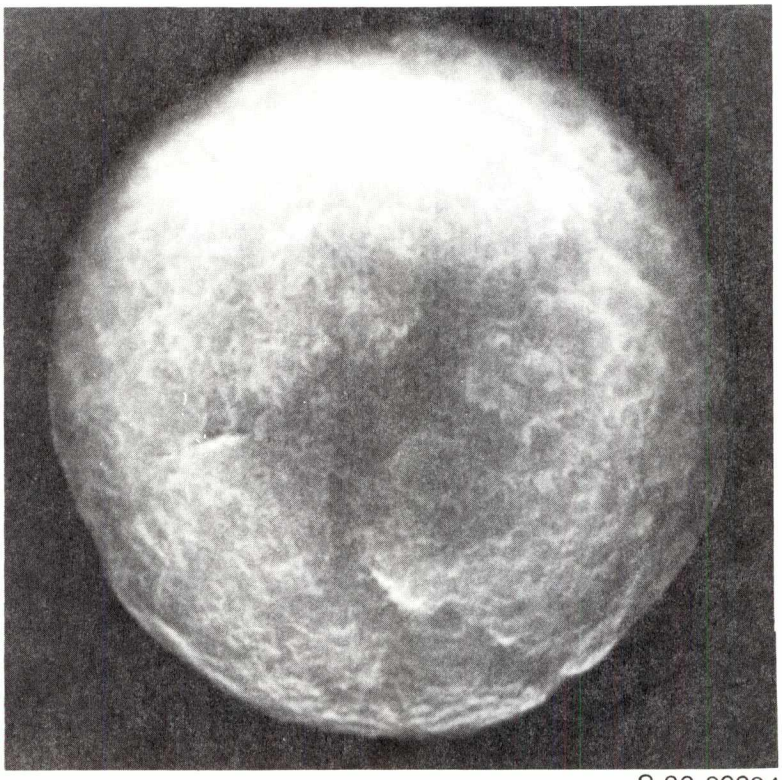
SIZE	SHAPE	TRANS.
8	S/E	TL/O

COLOR	LUSTER
Dk.Gray to Black	SM/M

TYPE	COMMENTS
AOS?	



W7027E5



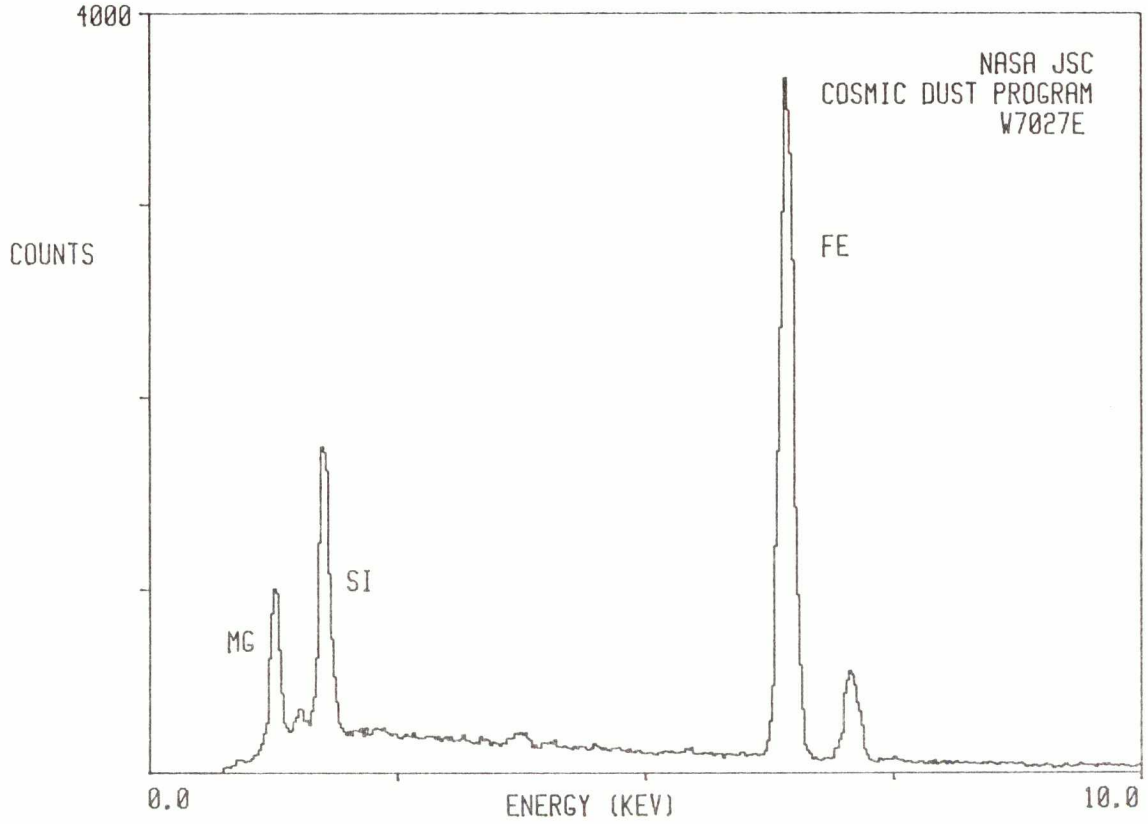
S-83-26604

E0501

SIZE	SHAPE	TRANS.
10	S	O

COLOR	LUSTER
Dk. Gray to Black	D/SM

TYPE	COMMENTS
C?	



W7027E6

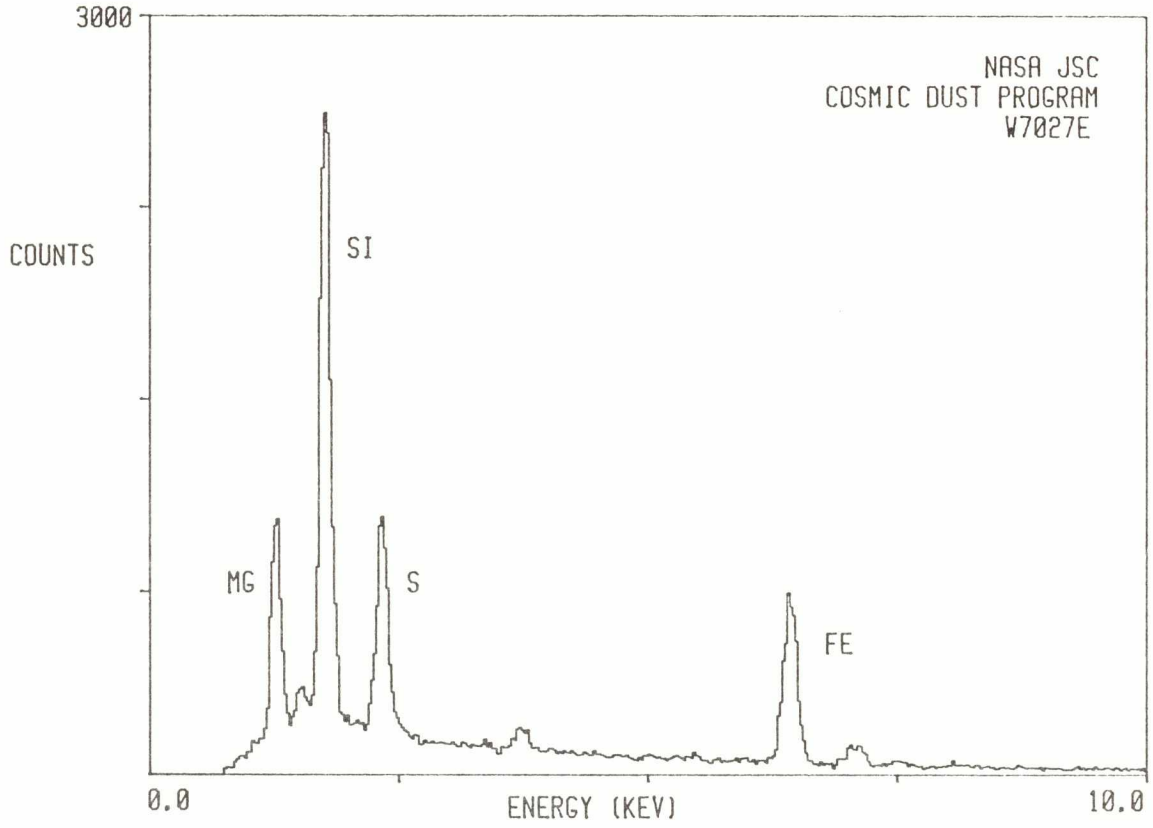
S-83-26605

E0601

SIZE	SHAPE	TRANS.
8X16	I	O

COLOR	LUSTER
Dk. Gray to Black	D/SM

TYPE	COMMENTS
C?	Friable



W7027E7

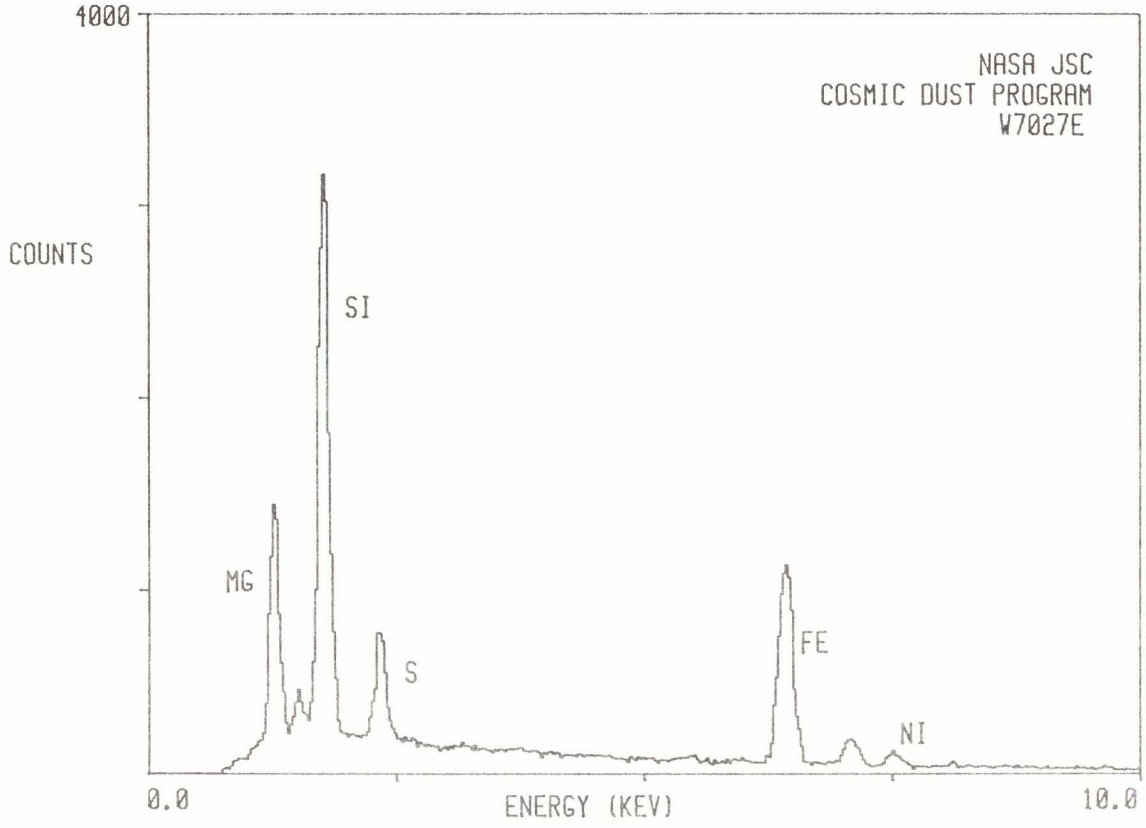
S-83-26606

E0701

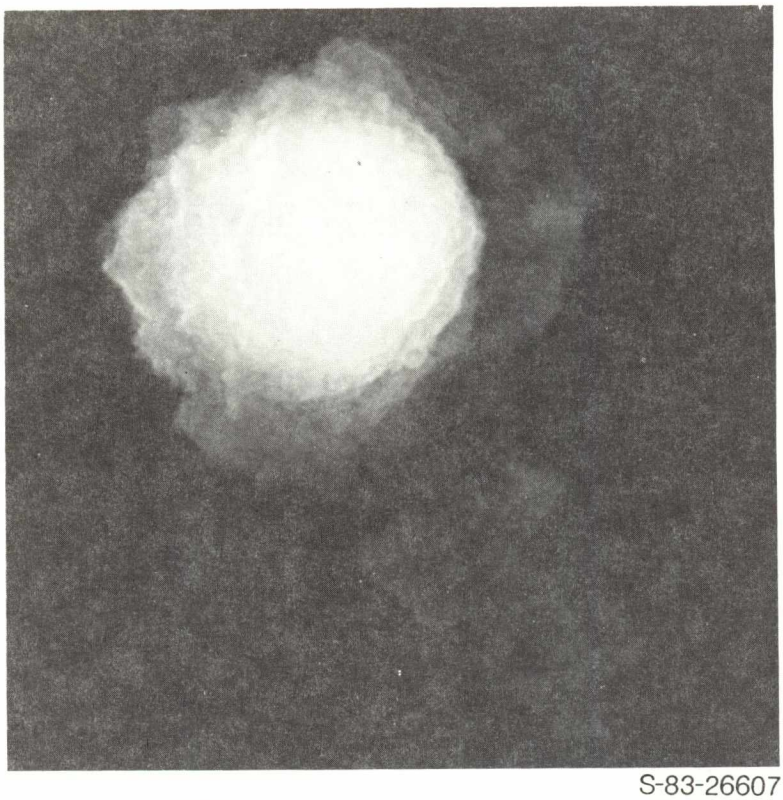
SIZE	SHAPE	TRANS.
10X17	I	O

COLOR	LUSTER
Dk. Gray to Black	D/SM

TYPE	COMMENTS
C?	



W7027E8



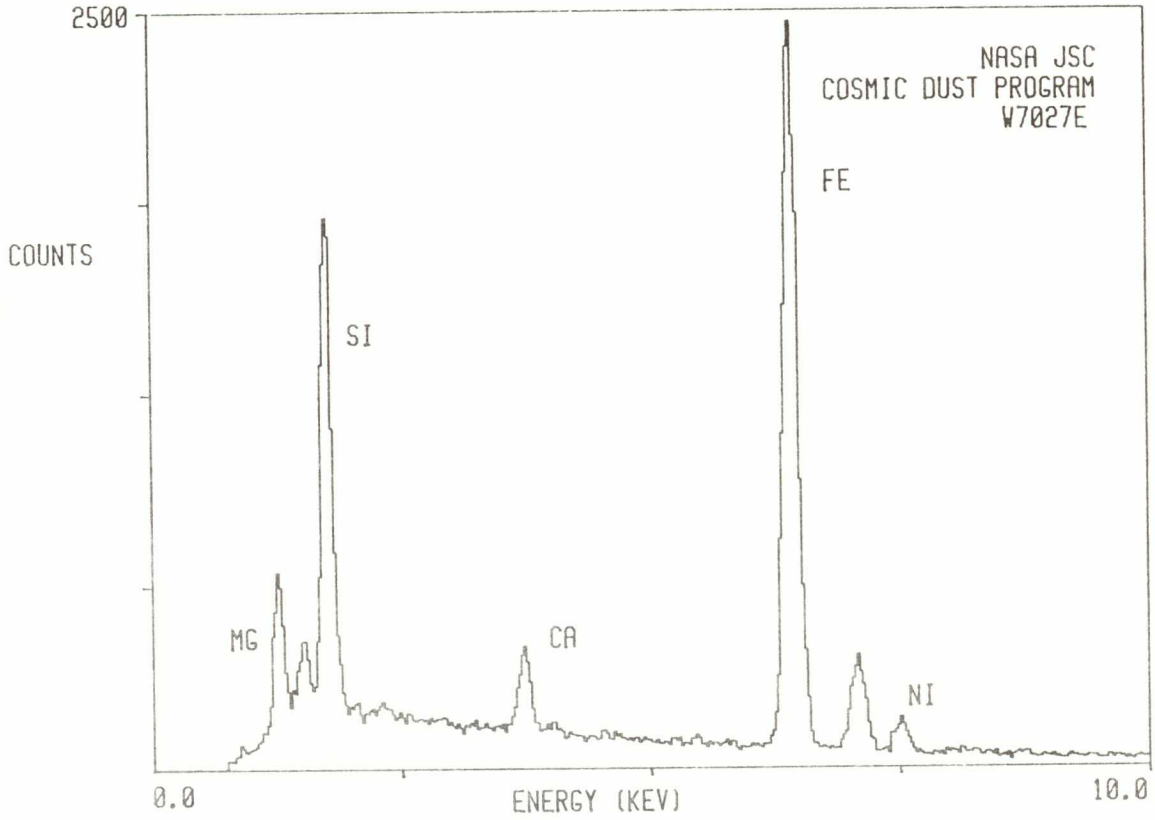
S-83-26607

SIZE	SHAPE	TRANS.
12X21	I	O

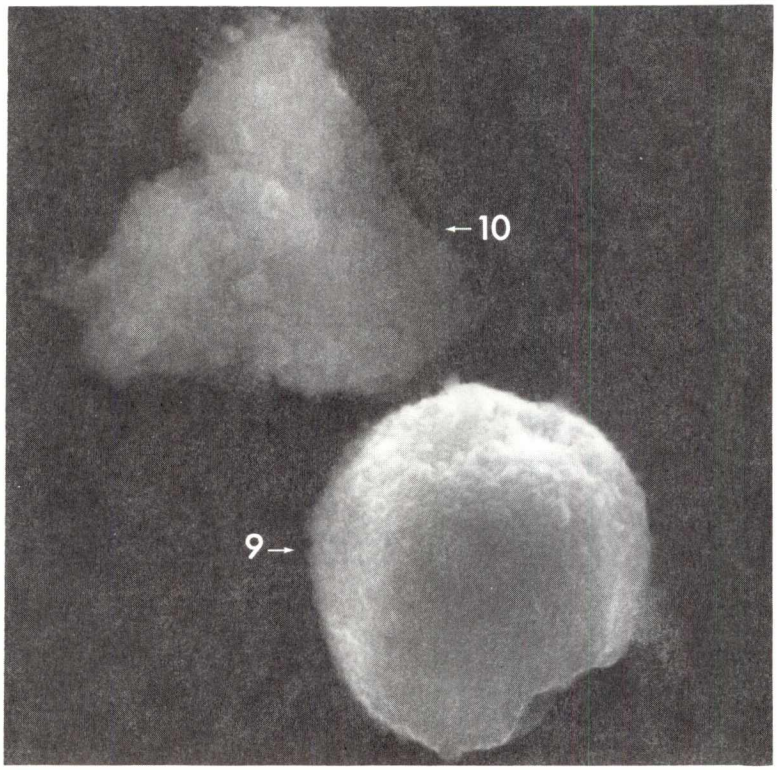
COLOR	LUSTER
Dk. Red-Brown to Black	D/SM

TYPE	COMMENTS
C	

E0801



W7027E9



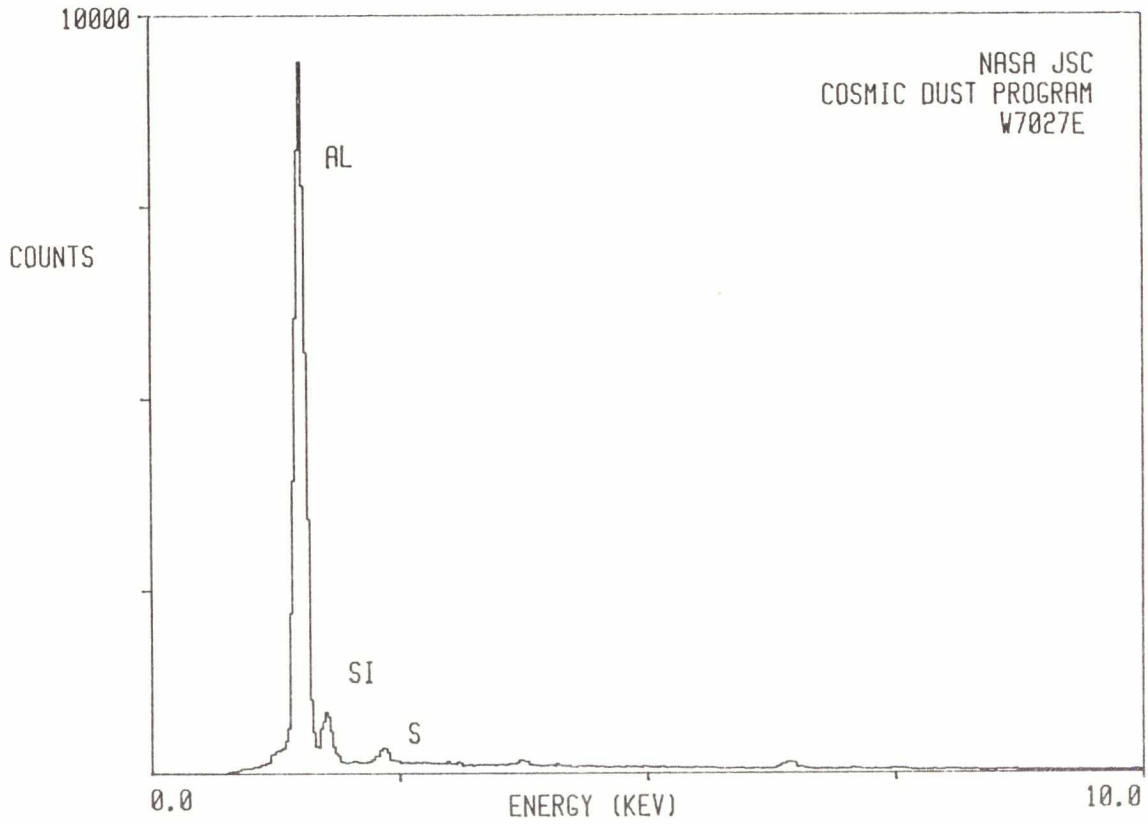
S-83-26608

E0901

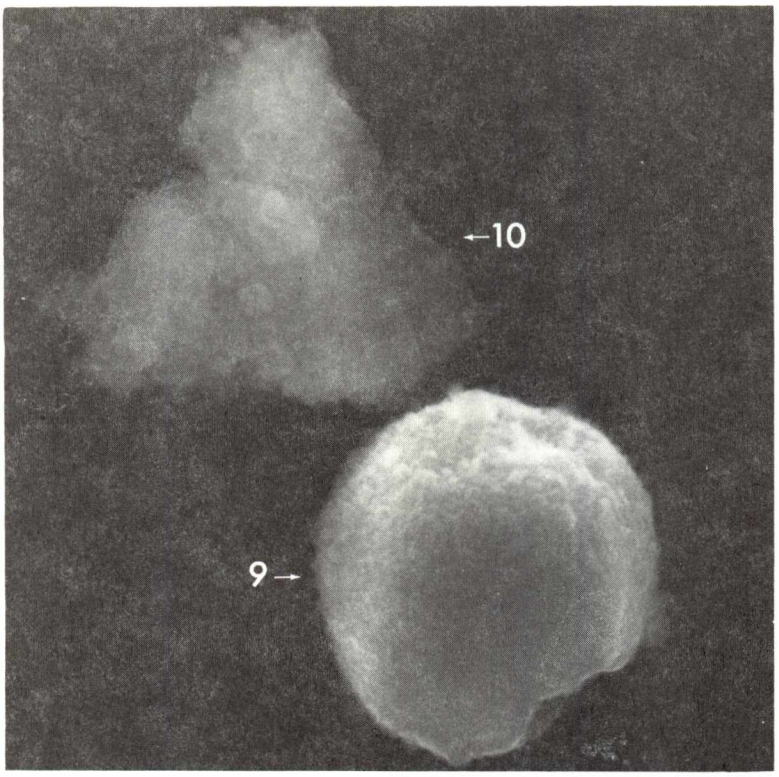
SIZE	SHAPE	TRANS.
17	S	0

COLOR	LUSTER
Dk. Gray to Black	D/SM

TYPE	COMMENTS
TCA?	Minor peaks in EDS spectrum may be attributable to adjacent particle, W7027E10



W7027E10



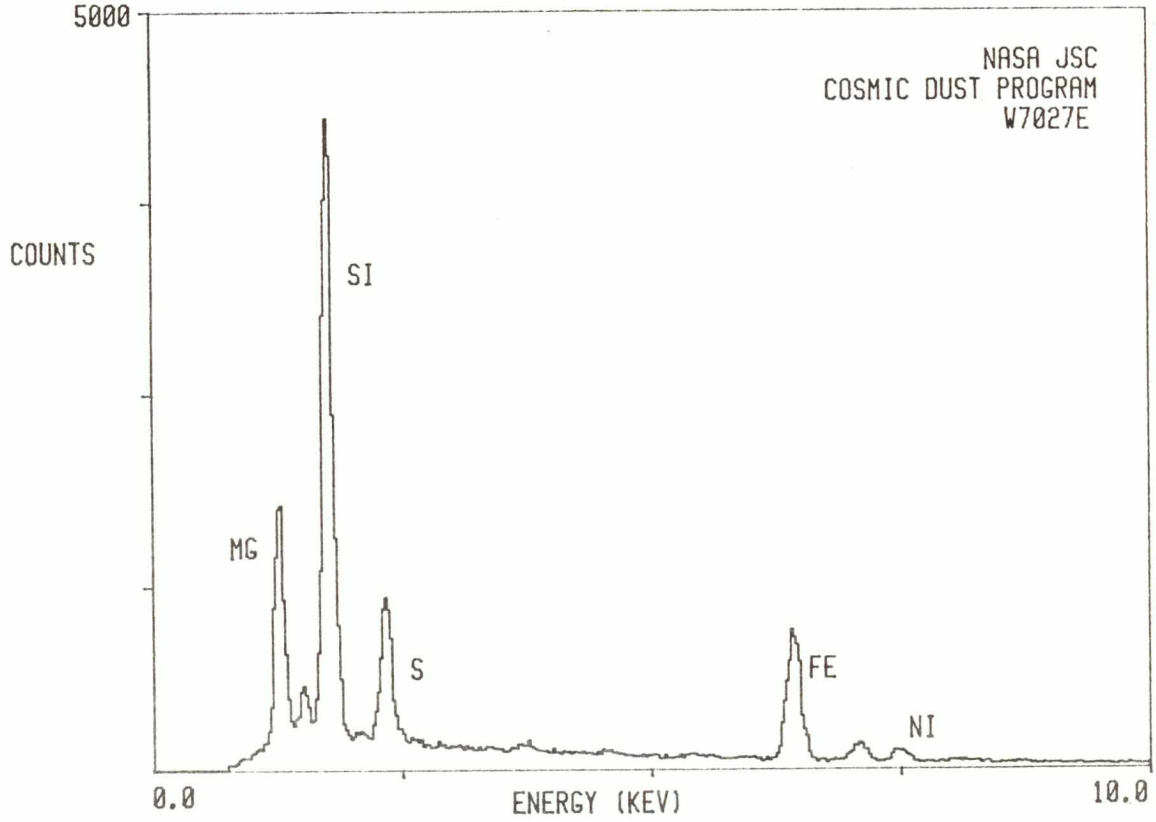
E1001

S-83-26608

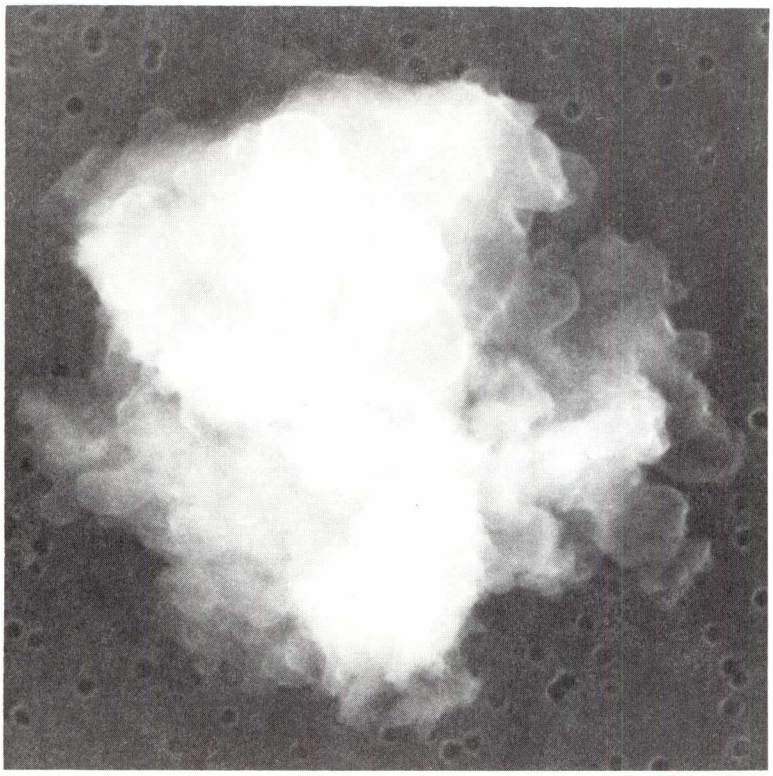
SIZE	SHAPE	TRANS.
18x19	I	O

COLOR	LUSTER
Dk. Gray to Black	D/SM

TYPE	COMMENTS
C?	Al peak in EDS spectrum may be partly attributable to W7027E9



W7027E11



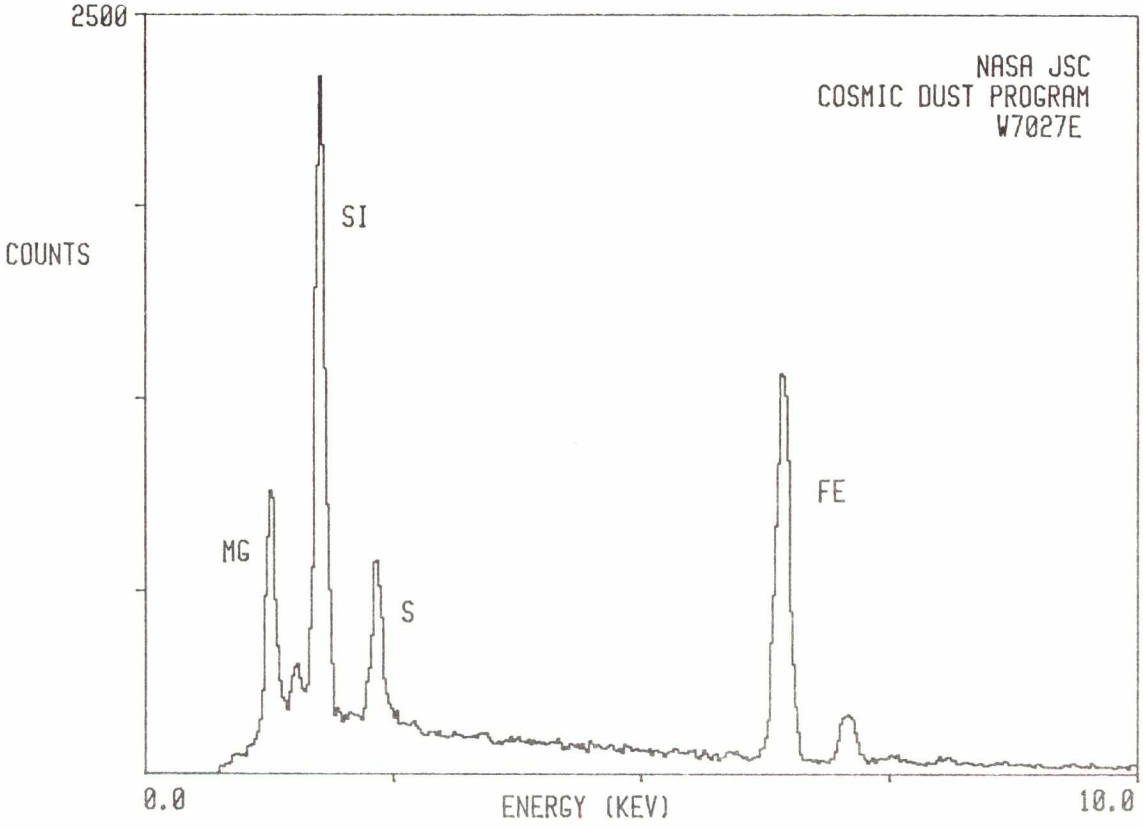
S-83-26609

E1101

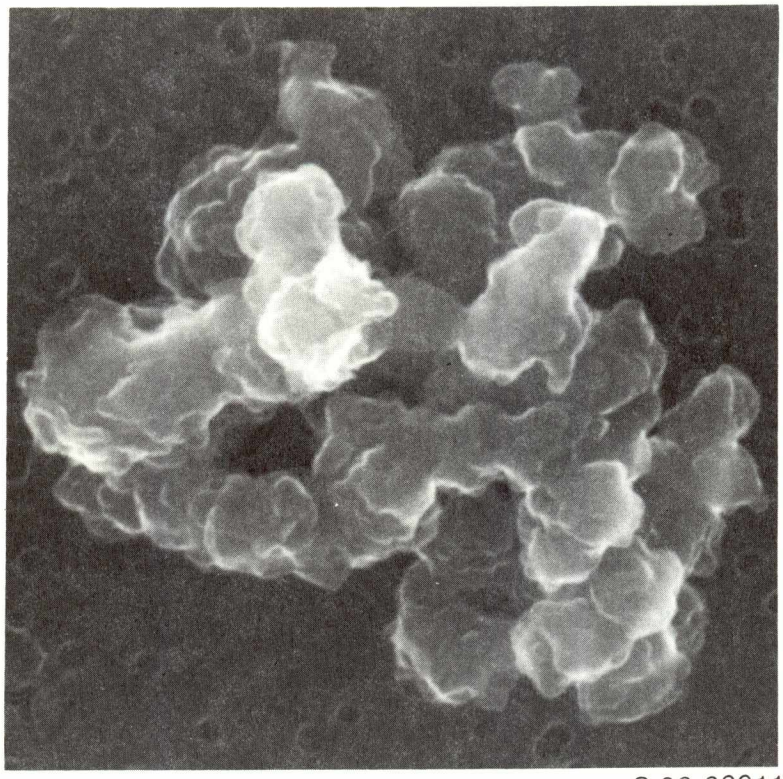
SIZE	SHAPE	TRANS.
12	E/I	O

COLOR	LUSTER
Dk. Gray to Black	D/SM

TYPE	COMMENTS
C?	



W7027E13



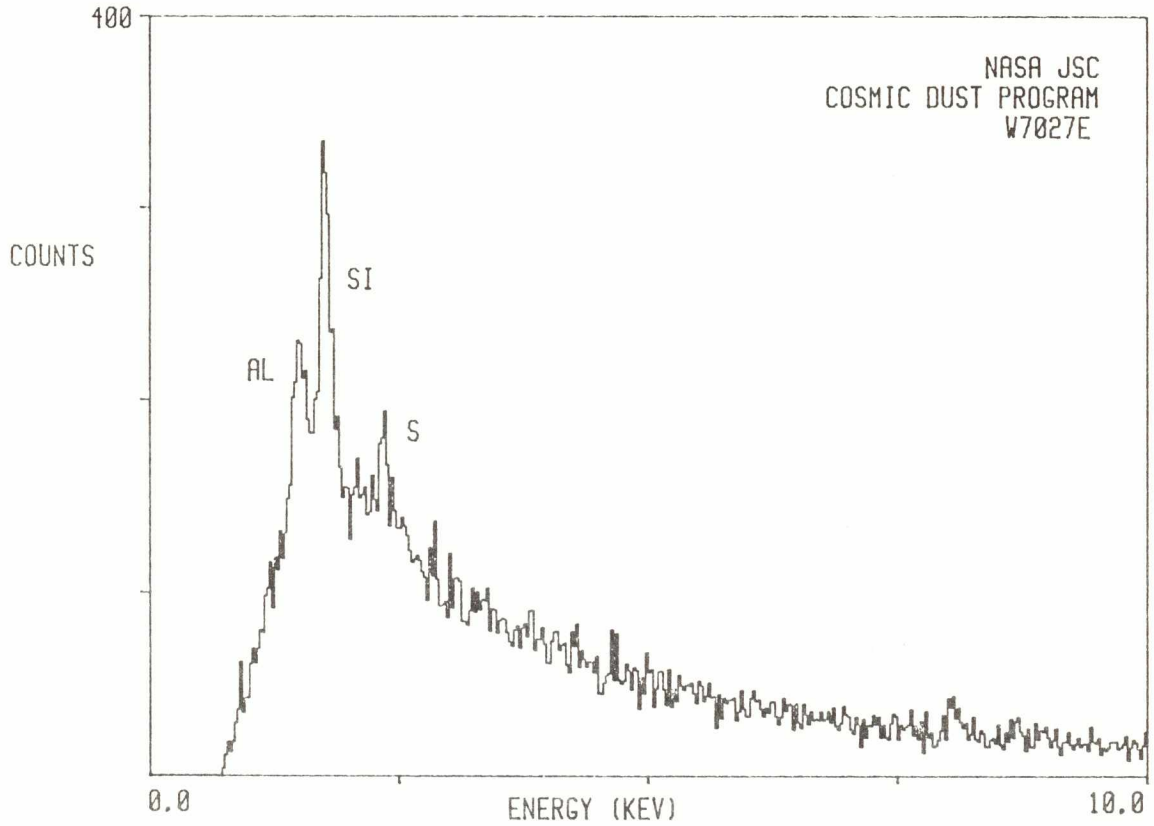
S-83-26611

E1301

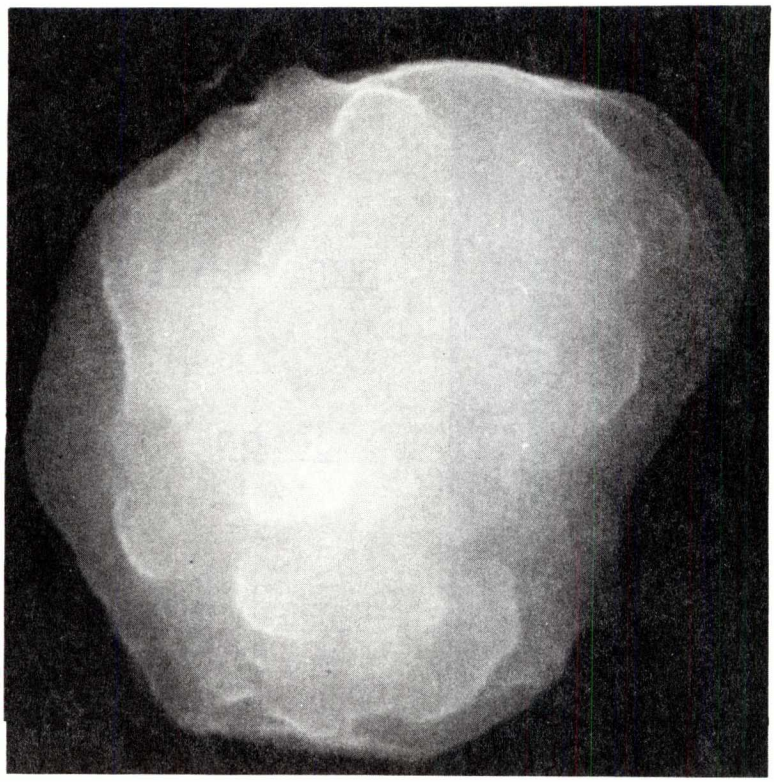
SIZE	SHAPE	TRANS.
8X9	I	O

COLOR	LUSTER
Black	D/SM

TYPE	COMMENTS
?	



W7027E14

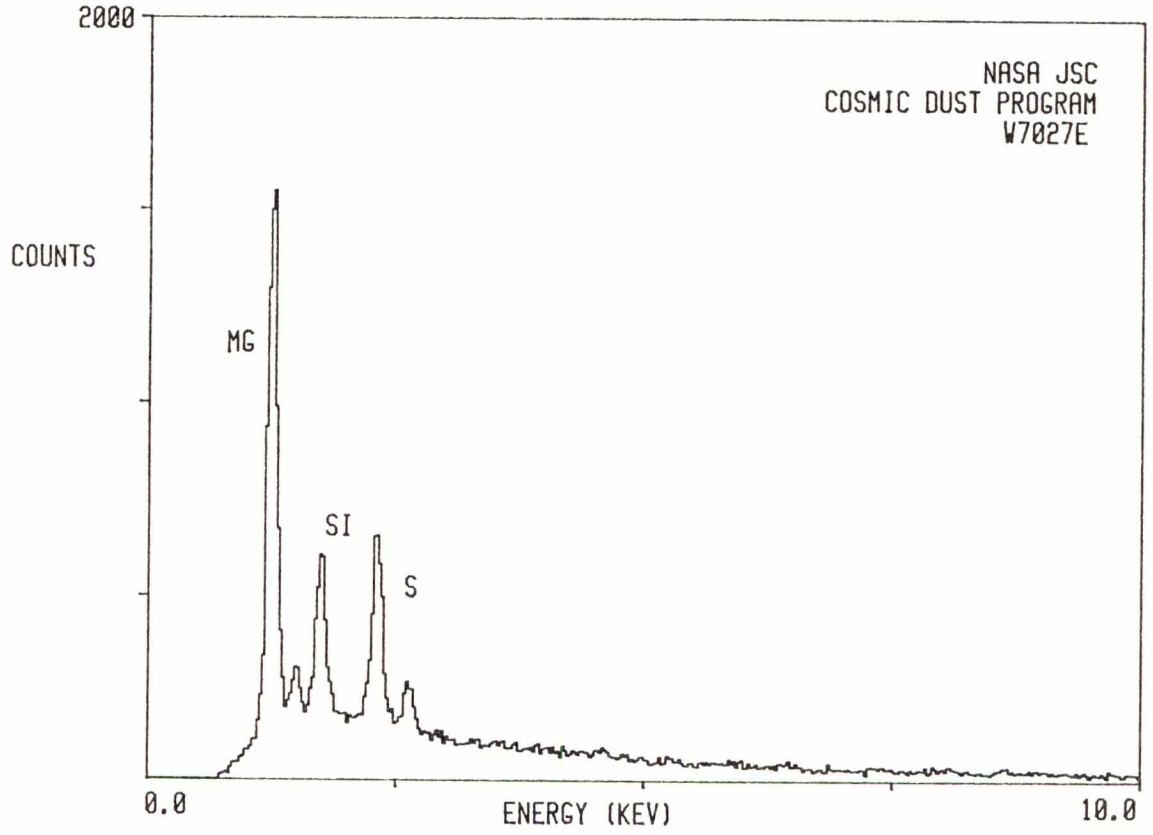


E1401 S-83-26594

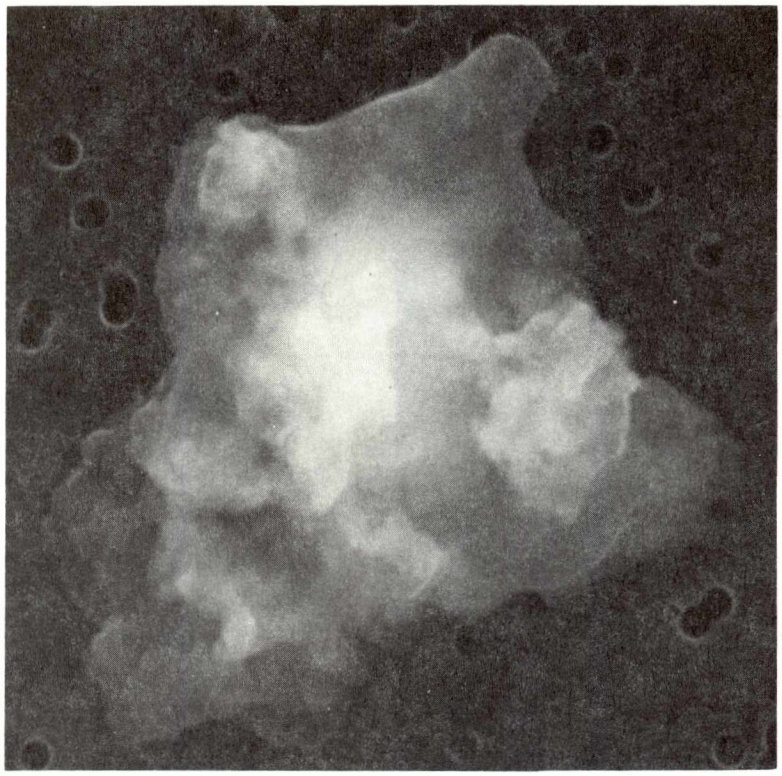
SIZE	SHAPE	TRANS.
12X15	I	TL

COLOR	LUSTER
Pale Yellow-Brown	SV

TYPE	COMMENTS
?	



W7027E15



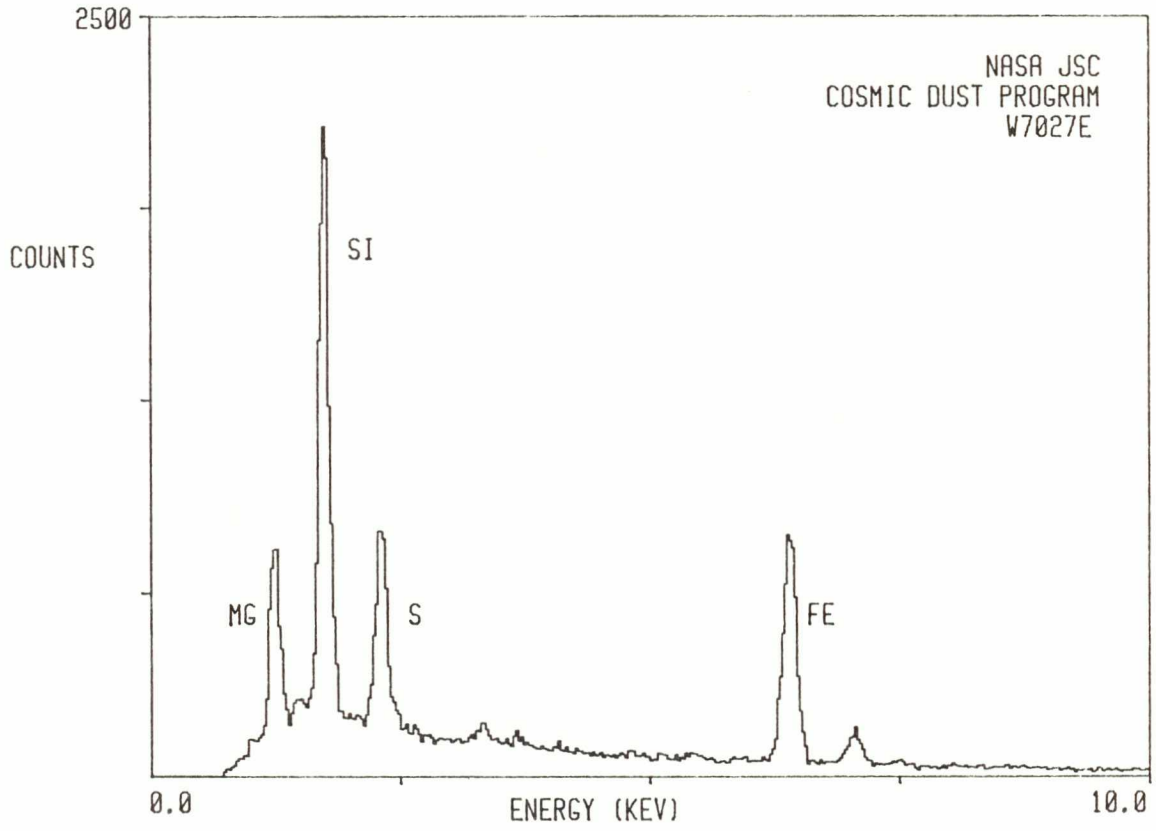
E1501

S-83-26595

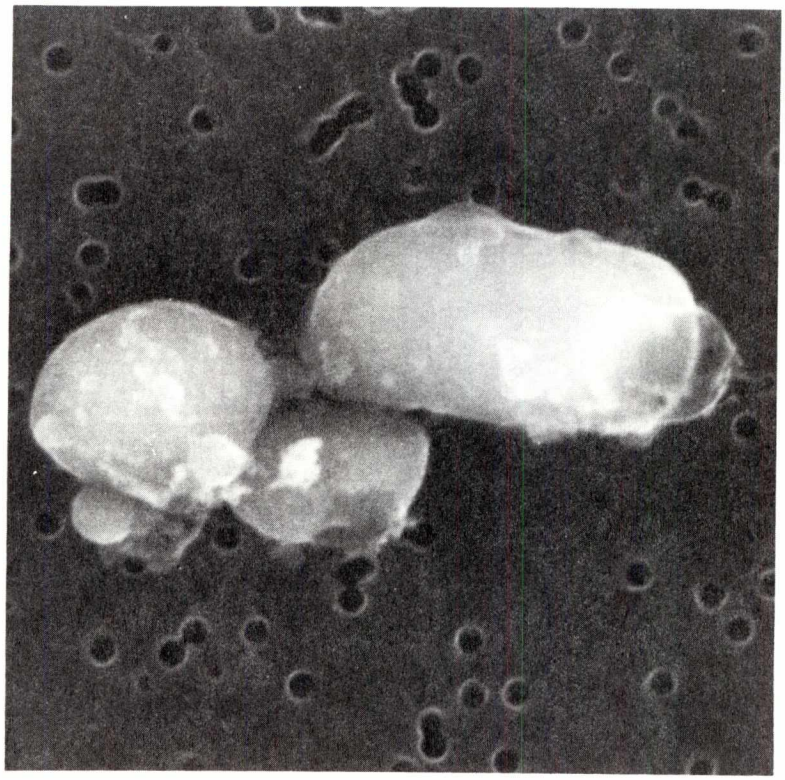
SIZE	SHAPE	TRANS.
7X8	I	O

COLOR	LUSTER
Yellow-Brown	D/SM

TYPE	COMMENTS
C?	



W7027E16



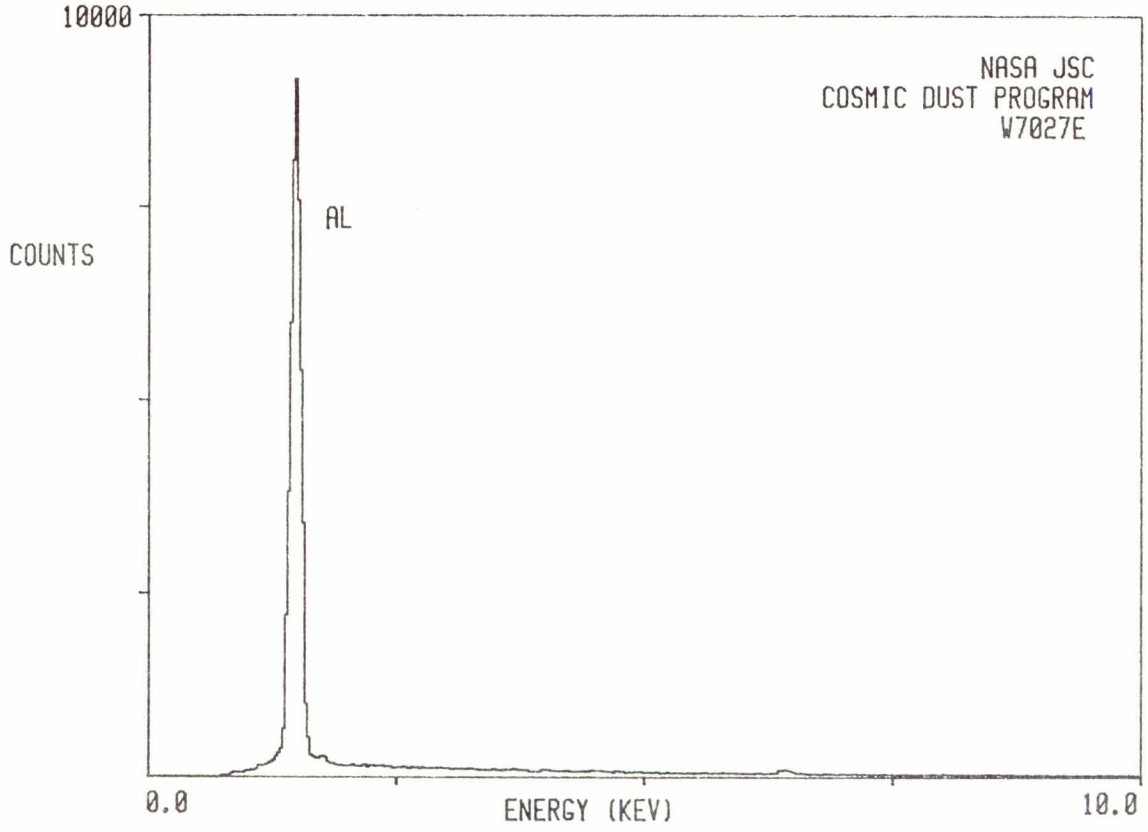
E1601

S-83-26597

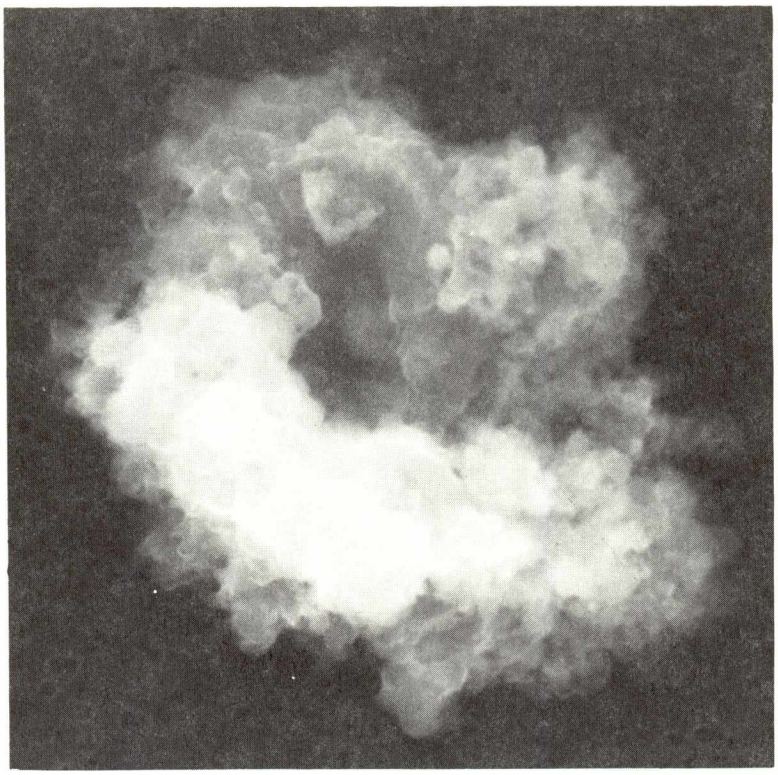
SIZE	SHAPE	TRANS.
~5	I	O

COLOR	LUSTER
Steel Gray to Black	M

TYPE	COMMENTS
TCA?	Several small fragments, each ≤ 5 microns



W7027E17



E1701

S-83-26610

SIZE	SHAPE	TRANS.
12X14	I	O

COLOR	LUSTER
Dk. Gray to Black	D/SM

TYPE	COMMENTS
C?