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NNDC Evaluated Charged Particle Reaction Data Library (1975)

S. Pearlstein

Abstract (H.D. Lemmel):

The US National Nuclear Data Center developed a "starter" library for charged particle induced nuclear reaction data in a trial ENDF/B format. It was issued in June 1974 and corrected in August 1975. It includes integral cross-section data for 306 nuclides between Z = 21 and 83 for the following reactions in the energy range from 0 to 20 MeV:

(p,n); (p,2n); (p,3n); (d,n); (d,2n); (d,3n); (d,p); (α,n); (α,2n); (α,3n); (α,p) and (α,np).

The data were calculated following the nuclear systematics developed by J. Lange and H. Münzel [KFK-767, May 1968]. The library serves to provide unmeasured cross sections and information that usually compares within an order of magnitude with actual data. It also serves as a convenient source for those requiring charged particle data in computerized form. The library contains 38 584 records.

The following documentation is a reprint of a report by S. Pearlstein, BNL-19148, May 1974.

September 1985

Starter Evaluated Charged Particle Data Library

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May 1974

I. Introduction

Cross section data for charged particle induced reaction data has been placed in the trial formats approved for the Evaluated Nuclear Data File (ENDF).[1] Data for 306 nuclides that span the range Z = 21 to 83 are included on one blocked magnetic tape labeled ENDF 875. These data were obtained from nuclear systematics, and therefore represent trends in the data rather than precise evaluations of specific experiments. The resultant file serves to predict unmeasured cross sections and provide information that usually compares within an order of magnitude with actual data. It also serves as a convenient source for those requiring charged particle data in computerized form.

This Starter Charged Particle Data Library is intended as a data base from which improvements can be made. These data sets should be replaced when necessary by a careful evaluation of measurements or nuclear model calculations performed for individual nuclides. Data for additional reaction types should be added. The Starter Charged Particle Data Library has been issued now since some time may pass before refined evaluations are available.

II. Library Description

Energy Range	-	0 to 20 MeV
Reactions	-	(p,n), (p,2n), (p,3n)
	-	(d,n), (d,2n), (d,3n), (d,p)
	-	(α,n), (α,2n), (α,3n), (α,p), (α,np)
Q Values	-	Wapstra 1971 Tables[a]
Nuclides	-	Z = 21-83, see Appendix I
MAT Nos.	-	Temporary numbers below 1000 assigned to each nuclide beginning with 21-Sc-45 having MAT = 0001
Format	-	Trial ENDF format, see Appendix II

III. Sample Evaluated Data

Sample evaluated data in the ENDF format is shown in Appendix III. The format has been annotated to facilitate comparison with the format described in Appendix II. The Starter Library generated entirely from nuclear systematics does not have a separate alphanumeric description of the evaluation with each nuclide since the same procedure was used for all nuclides.

IV. Method

The nuclear systematics follows that first described by Lange and Munzel.[3] The general features of an excitation cross section can be characterized by three parameters, the peak cross section σ_p, the energy at which the cross section occurs E_M, and the half-width at half maximum E_H. The dependence of these parameters on both the nuclear charge Z[3] and a statistical model parameter[4,5]

has been determined. Here, the dependence of σ_p on the assymetry parameter $\frac{N-Z}{N+Z}$ of the target nucleus has been determined. The data and curve fits are shown in Figures 1-12 of Appendix IV. In most cases a linear or quadratic least squares fit was selected.

Cross sections were generated by the CHAPIN code[6] using a 4 parameter transendental function fit to the excitation curve preserving E_M and E_H as described in Reference 3 and σ_p as obtained from Appendix IV. The effect of the Coulomb barrier on emitted particles was taken into account.

V. Sample Experimental Data

The assembly of carefully documented evaluations will take time. Extensive use can be made of the bibliography and data indices compiled by the Charged Particle Information Center at Oak Ridge. At the NNCSC it has been convenient to proceed to an evaluated data file by first compiling data in a generalized EXFOR, the format used to exchange experimental data between the world neutron data centers. A sample of experimental charged particle data in this format is shown in Appendix V.

gli

References

1. "Data Formats and Procedures for the ENDF Neutron Cross Section Library," BNL-50274 (ENDF-102, Vol. I) edited by M. K. Drake; and "ENDF Formats and Procedures for Photon Production and Interaction Data," LA-4549 (ENDF-102, Vol. II) compiled by D. J. Dudziak.

2. A. H. Wapstra and N. B. Gove, Nucl. Data A9 (1971) 267.

3. J. Lange, H. Munzel, KFK-767, May 1968.

4. H. F. Rohm, H. Munzel, and J. Lange, Nucl. Instruments and Methods 113 (1973) 101-107.

5. K. A. Keller, J. Lange, H. Munzel, G. Pfennig, Landolt-Börnstein Numerical Data and Functional Relationships in Science and Technology, Group I: Nuclear and Particle Physics, Volume 5, Q-Values and Excitation Functions of Nuclear Reactions Parts a, b, c (Sprinter-Verlag 1973).

6. S. Pearlstein, CHAPIN Code, Documentation in preparation.

APPENDIX I

Table of Contents

ENDF/B Tape 875

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ENDF/B Tape 875

(Starter Charged Particle Library)

6/4/74

(Revised 7/19/74)

Material	MAT #	No. of Records *	Material	MAT #	No. of Records *
21-Sc- 45	1	143	34-Se- 80	55	140
22-Ti- 46	2	113	34-Se- 82	56	152
22-Ti- 47	3	132	35-Br- 79	57	139
22-Ti- 48	4	133	35-Br- 81	58	146
22-Ti- 49	5	144	36-Kr- 78	59	110
22-Ti- 50	6	140	36-Kr- 80	60	121
23-V - 49	7	140	36-Kr- 81	61	134
23-V - 50	8	152	36-Kr- 82	62	128
23-V - 51	9	148	36-Kr- 83	63	141
24-Cr- 50	10	111	36-Kr- 84	64	137
24-Cr- 52	11	129	36-Kr- 85	65	146
24-Cr- 53	12	143	36-Kr- 86	66	141
24-Cr- 54	13	144	37-Rb- 85	67	142
25-Mn- 53	14	133	37-Rb- 87	68	144
25-Mn- 54	15	145	38-Sr- 84	69	112
25-Mn- 55	16	146	38-Sr- 86	70	125
26-Fe- 54	17	108	38-Sr- 87	71	134
26-Fe- 55	18	124	38-Sr- 88	72	127
26-Fe- 56	19	128	38-Sr- 90	73	148
26-Fe- 57	20	140	39-Y - 89	74	129
26-Fe- 58	21	137	40-Zr- 90	75	111
26-Fe- 60	22	156	40-Zr- 91	76	120
27-Co- 57	23	131	40-Zr- 92	77	131
27-Co- 59	24	143	40-Zr- 93	78	146
27-Co- 60	25	158	40-Zr- 94	79	142
28-Ni- 58	26	117	40-Zr- 96	80	146
28-Ni- 59	27	112	41-Nb- 91	81	123
28-Ni- 60	28	114	41-Nb- 92	82	135
28-Ni- 61	29	133	41-Nb- 93	83	137
28-Ni- 62	30	129	41-Nb- 94	84	151
28-Ni- 63	31	141	42-Mo- 92	85	103
28-Ni- 64	32	138	42-Mo- 93	86	115
29-Cu- 63	33	130	42-Mo- 94	87	123
29-Cu- 65	34	139	42-Mo- 95	88	130
30-Zn- 64	35	103	42-Mo- 96	89	128
30-Zn- 65	36	126	42-Mo- 97	90	142
30-Zn- 66	37	122	42-Mo- 98	91	134
30-Zn- 67	38	138	42-Mo-100	92	148
30-Zn- 68	39	133	43-Tc- 97	93	135
30-Zn- 70	40	143	43-Tc- 98	94	149
31-Ga- 69	41	138	43-Tc- 99	95	148
31-Ga- 71	42	146	44-Ru- 96	96	102
32-Ge- 68	43	102	44-Ru- 98	97	117
32-Ge- 70	44	118	44-Ru- 99	98	128
32-Ge- 72	45	127	44-Ru-100	99	125
32-Ge- 73	46	142	44-Ru-101	100	136
32-Ge- 74	47	136	44-Ru-102	101	130
32-Ge- 76	48	149	44-Ru-104	102	141
33-As- 75	49	142	45-Rh-101	103	132
34-Se- 74	50	110	45-Rh-102	104	146
34-Se- 76	51	124	45-Rh-103	105	139
34-Se- 77	52	136	46-Pd-102	106	114
34-Se- 78	53	134	46-Pd-104	107	121
34-Se- 79	54	144	46-Pd-105	108	136

Tape 875 (Cont'd.)

Material	MAT #	No. of Records *	Material	MAT #	No. of Records *
46-Pd-106	109	127	56-Ba-130	163	100
46-Pd-107	110	142	56-Ba-132	164	110
46-Pd-108	111	133	56-Ba-134	165	115
46-Pd-110	112	143	56-Ba-135	166	132
47-Ag-107	113	133	56-Ba-136	167	118
47-Ag-108	114	148	56-Ba-137	168	135
47-Ag-109	115	146	56-Ba-138	169	125
48-Cd-106	116	98	57-La-137	170	129
48-Cd-108	117	116	57-La-138	171	148
48-Cd-109	118	125	57-La-139	172	134
48-Cd-110	119	123	58-Ce-136	173	102
48-Cd-111	120	133	58-Ce-138	174	112
48-Cd-112	121	129	58-Ce-140	175	112
48-Cd-113	122	143	58-Ce-142	176	130
48-Cd-114	123	139	58-Ce-144	177	136
48-Cd-116	124	147	59-Pr-141	178	117
49-In-113	125	136	60-Nd-142	179	107
49-In-115	126	147	60-Nd-143	180	115
50-Sn-112	127	97	60-Nd-144	181	116
50-Sn-114	128	101	60-Nd-145	182	134
50-Sn-115	129	114	60-Nd-146	183	129
50-Sn-116	130	110	60-Nd-148	184	134
50-Sn-117	131	124	60-Nd-150	185	138
50-Sn-118	132	115	61-Pm-143	186	105
50-Sn-119	133	137	61-Pm-144	187	134
50-Sn-120	134	126	61-Pm-145	188	128
50-Sn-121	135	142	61-Pm-146	189	140
50-Sn-122	136	136	61-Pm-147	190	138
50-Sn-124	137	143	62-Sm-144	191	93
51-Sb-121	138	134	62-Sm-145	192	103
51-Sb-123	139	144	62-Sm-146	193	102
52-Te-120	140	108	62-Sm-147	194	121
52-Te-122	141	114	62-Sm-148	195	117
52-Te-123	142	128	62-Sm-149	196	126
52-Te-124	143	123	62-Sm-150	197	123
52-Te-125	144	139	62-Sm-151	198	138
52-Te-126	145	120	62-Sm-152	199	127
52-Te-128	146	137	62-Sm-154	200	131
52-Te-130	147	143	63-Eu-150	201	137
53-I -127	148	140	63-Eu-151	202	134
53-I -129	149	145	63-Eu-152	203	145
54-Xe-124	150	101	63-Eu-153	204	136
54-Xe-126	151	110	63-Eu-154	205	142
54-Xe-128	152	115	63-Eu-155	206	140
54-Xe-129	153	128	64-Gd-152	207	105
54-Xe-130	154	119	64-Gd-153	208	122
54-Xe-131	155	133	64-Gd-154	209	113
54-Xe-132	156	122	64-Gd-155	210	130
54-Xe-134	157	137	64-Gd-156	211	122
54-Xe-136	158	133	64-Gd-157	212	130
55-Cs-133	159	138	64-Gd-158	213	126
55-Cs-134	160	149	64-Gd-160	214	132
55-Cs-135	161	144	65-Tb-157	215	125
55-Cs-137	162	142	65-Tb-158	216	134

Tape 875 (Cont'd.)

Material	MAT #	No. of Records*
65-Tb-159	217	131
66-Dy-154	218	96
66-Dy-156	219	99
66-Dy-158	220	108
66-Dy-160	221	112
66-Dy-161	222	122
66-Dy-162	223	122
66-Dy-163	224	129
66-Dy-164	225	127
67-Ho-163	226	124
67-Ho-165	227	128
67-Ho-166	228	141
68-Er-162	229	98
68-Er-164	230	106
68-Er-166	231	112
68-Er-167	232	122
68-Er-168	233	123
68-Er-170	234	130
69-Tm-169	235	124
69-Tm-171	236	131
70-Yb-168	237	100
70-Yb-170	238	107
70-Yb-171	239	120
70-Yb-172	240	117
70-Yb-173	241	124
70-Yb-174	242	123
70-Yb-175	243	130
70-Yb-176	244	128
71-Lu-173	245	121
71-Lu-174	246	126
71-Lu-175	247	126
71-Lu-176	248	130
72-Hf-172	249	98
72-Hf-174	250	101
72-Hf-176	251	110
72-Hf-177	252	120
72-Hf-178	253	120
72-Hf-179	254	126
72-Hf-180	255	124
72-Hf-182	256	134
73-Ta-179	257	123
73-Ta-180	258	129
73-Ta-181	259	126
74-W -180	260	101
74-W -182	261	110
74-W -183	262	121
74-W -184	263	121
74-W -186	264	126
75-Re-185	265	120
75-Re-187	266	128
76-Os-184	267	95
76-Os-186	268	99
76-Os-187	269	112
76-Os-188	270	115
76-Os-189	271	123
76-Os-190	272	120
76-Os-192	273	124
76-Os-194	274	128
77-Ir-191	275	125
77-Ir-192	276	130
77-Ir-193	277	129
78-Pt-190	278	100
78-Pt-192	279	107
78-Pt-193	280	121
78-Pt-194	281	113
78-Pt-195	282	125
78-Pt-196	283	122
78-Pt-198	284	127
79-Au-197	285	125
80-Hg-194	286	95
80-Hg-196	287	98
80-Hg-198	288	100
80-Hg-199	289	118
80-Hg-200	290	116
80-Hg-201	291	123
80-Hg-202	292	123
80-Hg-204	293	126
81-Tl-203	294	115
81-Tl-205	295	124
82-Pb-202	296	86
82-Pb-204	297	97
82-Pb-205	298	105
82-Pb-206	299	97
82-Pb-207	300	100
82-Pb-208	301	98
82-Pb-210	302	116
83-Bi-207	303	104
83-Bi-208	304	108
83-Bi-209	305	99
83-Bi-210	306	114
		38540 Total**

*BCD card image records.

**Add two (TITLE record and TEND record) for total number of records on this tape.

APPENDIX II

Memo to Codes and Formats Subcommittee

December 11, 1973

Format Modification: 73-9

Date Approved: 12/12/73 (as "Experimental")

Proposer: Non-Neutron Data Subcommittee

Affected Files: 51-91

Purpose:

Purpose

It is desirable to expand the ENDF/B formats to include reactions relating to neutron physics and other applications such as fusion and space shielding studies. The major types needed are charged particle induced reactions arising in neutron source reactions, other inverse neutron reactions and reactions arising from intense charged particle fluxes produced by reactor, outer space, and common accelerator sources. It is also necessary to specify which secondary particle is designated in angular and energy distributions.

The solution proposed allows these data to be included with the following advantages:

1. No changes are required to existing neutron induced data formats.

2. The same MAT no. is used for both neutron and non-neutron induced data. This is desirable since ENDF/B should contain only one MAT per target material.

3. Where appropriate, the same MT numbers are used for both neutron and non-neutron data.

4. No changes are required to codes processing the neutron data files. If the non-neutron data files are merged with the neutron files only minimal changes are required to some of these peripheral codes (MT=700 series data = ?).

Proposed solution

Files 61-67 and 72-76 would be used in analogy to Files 1-7 and 12-16 (Add 60 to the present MF Nos.).

1. MT numbers plus new ones as required would designate the exit channel(s). The exceptions would be MT = 1, 2, 3, and 4 where the exit channel would be taken the same as the entrance channel.*

2. Field 6 of the HEAD record is blank for all Files according to ENDF 102, Volumes I and II. This field will specify the ZA as 1000*Z+A of the incident particle (IZA) as a fixed point number. An IZA of 0 will designate a neutron induced reaction. Other IZA's are:

Incident Particle	IZA
gamma	1111 (defined)
beta minus	-1000
beta plus	1000
proton	1001
deuteron	1002
triton	1003
He-3	2003
alpha	2004
C-12	6012
O-16	8016
S-32	16032

IZA's for molecules and strange particles can be invented as needed.

3. An MT number is repeated for as many sections as there are incident particles for which data are specified. The convention is followed that the neutron-induced section, if present, appears first and other sections, repeating the same MT numbers are arranged in order of ascending IZA. ENDF/B tapes can be supplied that do not contain merged neutron and non-neutron files.

4. According to ENDF 102 field 5 of the HEAD record is blank for all Files except File 5 for which Field 4 is blank. It is proposed that this field contain JZA, the 1000*Z+A of the particle designated in the angular or energy distribution following the same code as described above.

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*MT=4 would continue to equal the sum of MT=51,52...,91. New MT's 800-819 would be defined to describe (x,n_o), $(x,n_1)...(x,n_{18})$, (x,n_c), were x represents the incident particle. MT=15 would be used to define the total (x,n) cross section. Thus, for proton induced reactions field 6 of the HEAD record would contain 1001 and (p,p') total would be described by MT=4, (p,p') to discrete states and the continuum by MT=51-91, (p,n) total by MT=15, and (p,n') to discrete states and the continuum by MT=800-819. MT=15 and MT=800-819 cannot be used for neutron-induced reactions. Current MT assignments are attached.

5. The structure of File 1 would be changed to include IZA and JZA in the dictionary. The CONT record for a non-neutron data section would contain JZA and IZA as floating point numbers in the first and second fields, respectively, so as to maintain the order in which they appear on the HEAD card of each section.

6. The structure of File 2 could be constructed analogous to neutron induced widths with the incident particle designated as in item 4 and resonance energies, widths, and other data defined by new formats and procedures to be specified at a later time.

7. Photon-induced nuclear reactions are to be handled in the same way as other non-neutron induced reactions. The word atomic should be added to the definitions for MT=501, 502, and 504 and MF = 23-26. MT = 518, 532 and 533 should be cancelled.

Examples (In the examples add 60 to File numbers greater than 1 and less than 30.)

The structure of File 1 of a MAT containing File 3 sections for (n,np), (n,γ), and (p,γ) data and a File 4 section for (n,np) outgoing portion angular distribution data only is

[ZA,AWR,LRP,LFI,0,NXC]HEAD
[0.0,0.0,LDD,LFP,NWD,0/H(N)]LIST
[MAT,1,451,0.0,0.0,1,451,NC1,0]CONT
[MAT,1,451,0.0,0.0,3,28,NC2,0]CONT
[MAT,1,451,0.0,0.0,3,102,NC3,0]CONT
[MAT,1,451,0.0,1001.0,3,102,NC4,0]CONT
[MAT,1,451,1001.0,0,4,28,NC5,0]CONT
[MAT,1,0,0.0,0.0,0,0,0,0]SEND

The structure of File 3 containing both (n,γ) and (p,γ) data is

[MAT,3,MT=102/ZA,AWR,LIS,LFS,0,0]HEAD
[MAT,3,MT=102/T,Q,LT,0,NR,NP/E_{int}/σ(E)]TAB1
[MAT,3,0/0.0,0.0,0,0,0,0]SEND
[MAT,3,MT=102/ZA,AWR,LIS,LFS,0,IZA=1001]HEAD
[MAT,3,MT=102/T,Q,LT,0,NR,NP/E_{int}/σ(E)]TAB1
[MAT,3,0/0.0,0.0,0,0,0,0]SEND

The structure of File 4 containing both (n,np) and (p,pα) angular distribution for the emerging proton is

[MAT,4,MT=28,/ZA,AWT,LVT,LTT,JZA=1001,0]HEAD
.....
.....
.....
[MAT,4,0/0.0,0.0,00]SEND
[MAT,4,MT=112/ZA,AWR,LVT,LTT,JZA=1001,IZA=1001]HEAD
.....
.....
.....
[MAT,4,0/0.0,0.0,0,0,0,0]SEND

The differential elastic distributions would be rationed to Rutherford scattering. Angular distributions for inelastic scattering and reaction data integrate to unity.

The structure of File 5 containing both (n,np) and (p,pα) energy distribution data for the emerging proton is

[MAT,5,MT=28/ZA,AWR,0,JZA=1001,NK,0]HEAD
.....
.....
.....
[MAT,5,0/0.0,0.0,0,0,0,0]SEND
[MAT,5,MT=112/ZA,AWR,0,JZA=1001,NK,IZA=1001]HEAD
.....
.....
.....
[MAT,6,0/0.0,0.0,0,0,0,0]SEND

The structure of File 6 would follow the rules for File 4.

Limitations

Simple additional tests would be required to DICTION and RIGEL and dictionary expansions made to the display codes. RIGEL can be modified by the NNCSC to output only neutron data files or only neutron and gamma files, etc. There would be no limitation to the user receiving an ENDF tape containing only neutron-induced reaction and gamma-gamma interaction data. This will probably be the normal distribution recommended by CSEWG. However, for those users requiring other types of data these may be included in the ENDF system with a minimum of modification to formats and processing codes.

APPENDIX III

Sample Evaluated Data

```
CHARGED PARTICLE DATA IN THE ENDF FORMAT                                  0 0  0      0
39089.          1000*Z+A                0          0          0       49001 1451      1
0.0             0.0                     0          0          8       09001 1451      2
 YTTRIUM-89   EVALUATED 1974 BY S.PEARLSTEIN (BNL)                      9001 1451      3
 PRIM. REF.-PHYS. REV. 144(1966)962 SAHA, PORILE, AND JAFFE            9001 1451      4
            OTHER (P,XN) DATA AGREE TO ABOUT 60 PER CENT.               9001 1451      5
            NO INDIVIDUAL PARTICLE LEVEL EFFECTS INCLUDED.              9001 1451      6
            Q VALUES-NUC. DATA A9(1971)267, WAPSTRA AND GOVE.           9001 1451      7
            DATA NEAR THRESHOLD CALCULATED FROM SYSTEMATICS OF          9001 1451      8
             KFK-767, LANCE AND MUNZEL, MODIFIED BY PEARLSTEIN          9001 1451      9
             FOR NUCL. POTENTIAL EFFECTS AT LOW ENERGIES.               9001 1451     10
                                     1          451         14         9001 1451     11
                                    63 File     15 No.Cards 10         9001 1451     12
                                    63 Reaction 16         11         9001 1451     13
                                    63          17         10         9001 1451     14
0.0             0.0                     0          0          0       09001 1  0     15
0.0             0.0                     0          0          0       09001 0  0     16
39089.          89.877                  0          0          0    1001900163 15     17
                -3.6100E+06             0          0          2    2100900163 15     18
                     2                 21                             900163 15     19
3.5700E+06      0.0             4.0000E+06 0.007      4.5000E+06 0.020  900163 15     20
5.0000E+06      0.050           6.0000E+06 0.14       7.0000E+06 0.26   900163 15     21
8.0000E+06      0.36            1.0000E+07 0.56       1.2000E+07 0.73   900163 15     22
1.4000E+07      0.75            1.6000E+07 0.69       1.8000E+07 0.58   900163 15     23
2.0000E+07      0.46            2.2000E+07 0.32       2.4000E+07 0.20   900163 15     24
3.0000E+07      0.066           3.2000E+07 0.052      3.3000E+07 0.049  900163 15     25
3.4000E+07      0.047           5.0000E+07 0.030      1.0000E+08 0.0085 900163 15     26
0.0             0.0                     0          0          0       090 0163  0     27
39089.          89.877                  0          0          0    1001900163 16     28
0.0             -1.2900E+07             0          0          2    2390 0163 16     29
                     2                 23                             900163 16     30
1.2760E+07      0.0             1.3500E+07 0.0018     1.4000E+07 0.013  900163 16     31
1.4500E+07      0.038           1.5000E+07 0.060      1.6000E+07 0.110  900163 16     32
1.8000E+07      0.235           2.0000E+07 0.45       2.2000E+07 0.76   900163 16     33
2.4000E+07      1.13            2.5000E+07 1.28       2.6000E+07 1.32   900163 16     34
2.7000E+07      1.30            2.8000E+07 1.20       3.0000E+07 0.92   900163 16     35
3.4000E+07      0.18            3.8000E+07 0.28       4.0000E+07 0.23   900163 16     36
4.2000E+07      0.172           4.6000E+07 0.126      5.0000E+07 0.10   900163 16     37
5.5000E+07      0.08            1.0000E+08 0.03                         900163 16     38
0.0             0.0                     0          0          0       090 0163  0     39
39089.          89.877                  0          0          0    1001900163 17     40
0.0             -2.5100E+07             0          0          2    2090 0163 17     41
                     2                 20                             900163 17     42
2.4820E+07      0.0             2.7000E+07 0.001      2.8000E+07 0.007  900163 17     43
2.9000E+07      0.023           3.0000E+07 0.050      3.6000E+07 0.235  900163 17     44
3.8000E+07      0.35            4.0000E+07 0.37       4.2000E+07 0.37   900163 17     45
4.4000E+07      0.35            4.6000E+07 0.285      4.8000E+07 0.23   900163 17     46
5.2000E+07      0.12            5.4000E+07 0.093      5.6000E+07 0.082  900163 17     47
5.8000E+07      0.074           6.2000E+07 0.062      7.0000E+07 0.046  900163 17     48
8.0000E+07      0.035           1.0000E+08 0.023                        900163 17     49
0.0             0.0                     0          0          0       090 0163 17     50
0.0             0.0                     0          0          0       090 0163 17     51
0.0             0.0                     0          0          0       0   0 0  0     52
0.0             0.0                     0          0          0       0  -1 0  0      0
```

Threshold Energy

Q Value

Target Mass / Particle Mass

Table of Cont.

Lin X, Lin Y Int.

Lin X, Log Y Int.

No. of Reg.

No. of Points

Incident Particle

σ

(n,n') Reaction

(n,2n) Reaction

(n,3n) Reaction

APPENDIX IV

Variation of σ_p with Assymetry Parameter $\frac{N-Z}{N+Z}$

Figure	Reaction
1	α,n
2	α,2n
3	α,3n
4	α,p
5	α,pn
6	d,n
7	d,2n
8	d,3n
9	d,p
10	p,n
11	p,2n
12	p,3n

Fig. 1

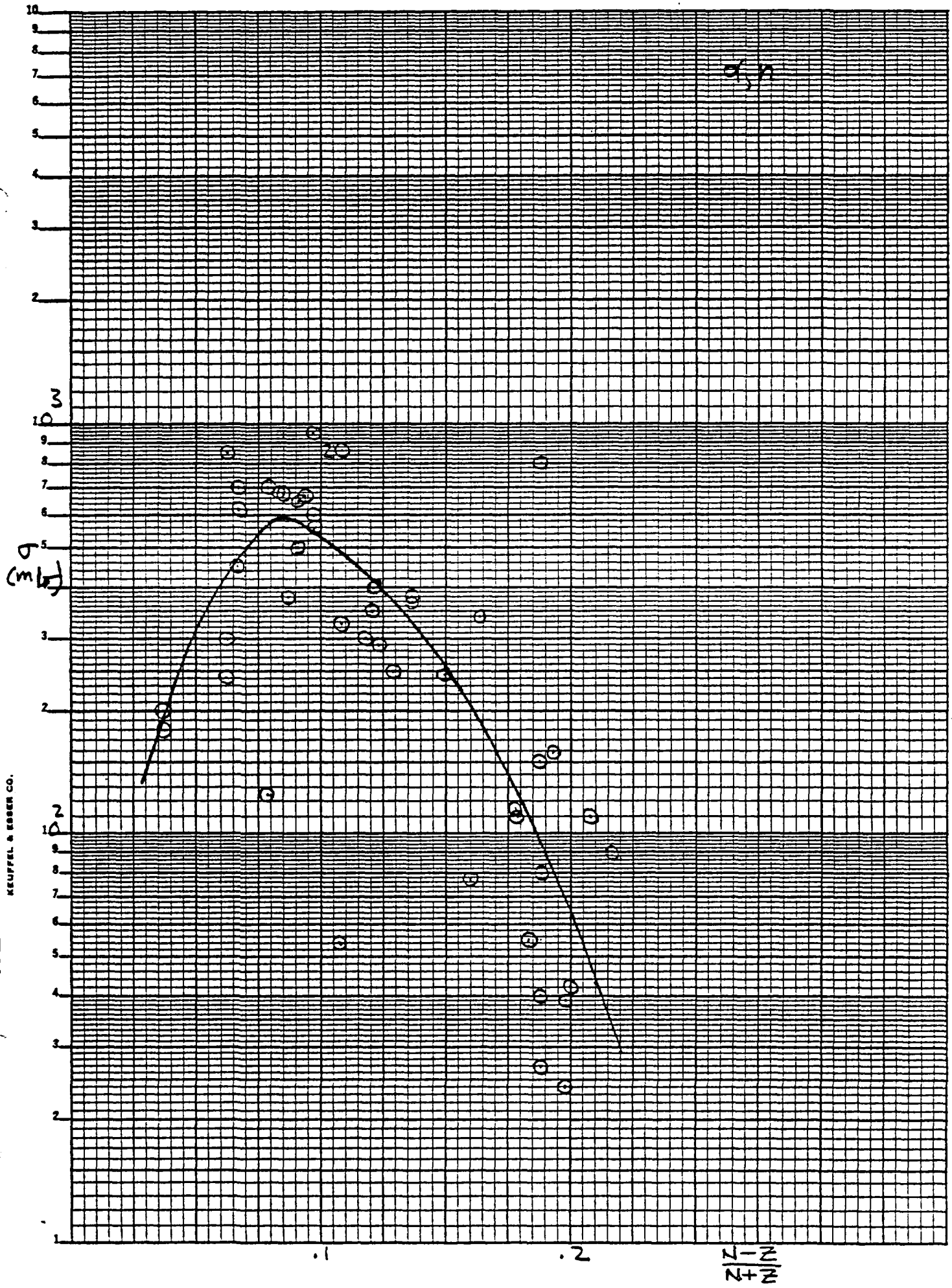

$\sigma_{3,n}$
ρ_3
ρ_2
σ (mb)
.1
.2
$\frac{N-Z}{N+Z}$
K&E SEMI-LOGARITHMIC 46 5493
3 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

Fig. 2

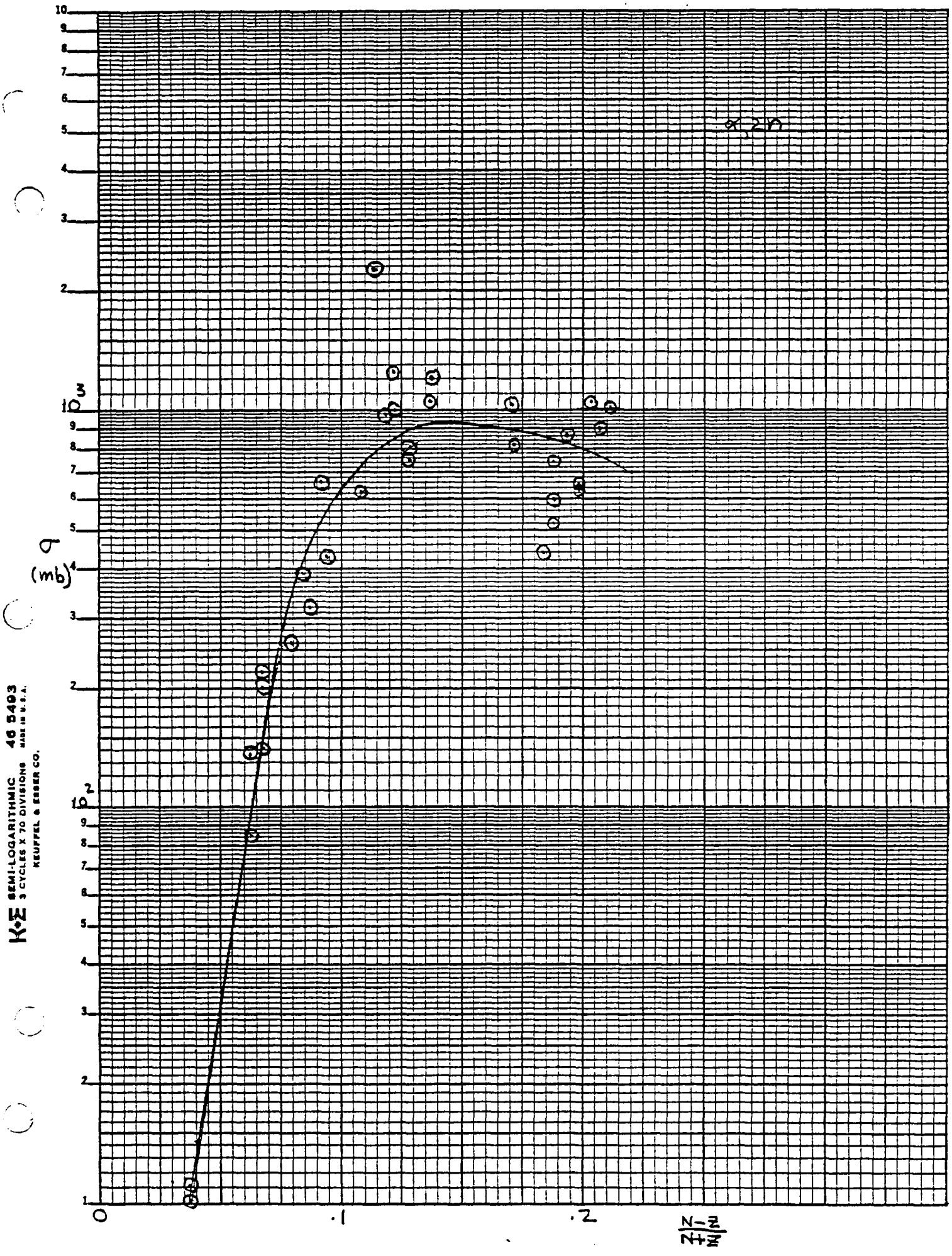

10
9
8
7
6
5
4
3
2
10^3
9
8
7
6
5
q
$(mb)^4$
3
2
10^2
9
8
7
6
5
4
3
2
1
0
.1
.2
$\frac{N-N_0}{N+N_0}$
K•E SEMI-LOGARITHMIC 46 5493
3 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

Fig. 3

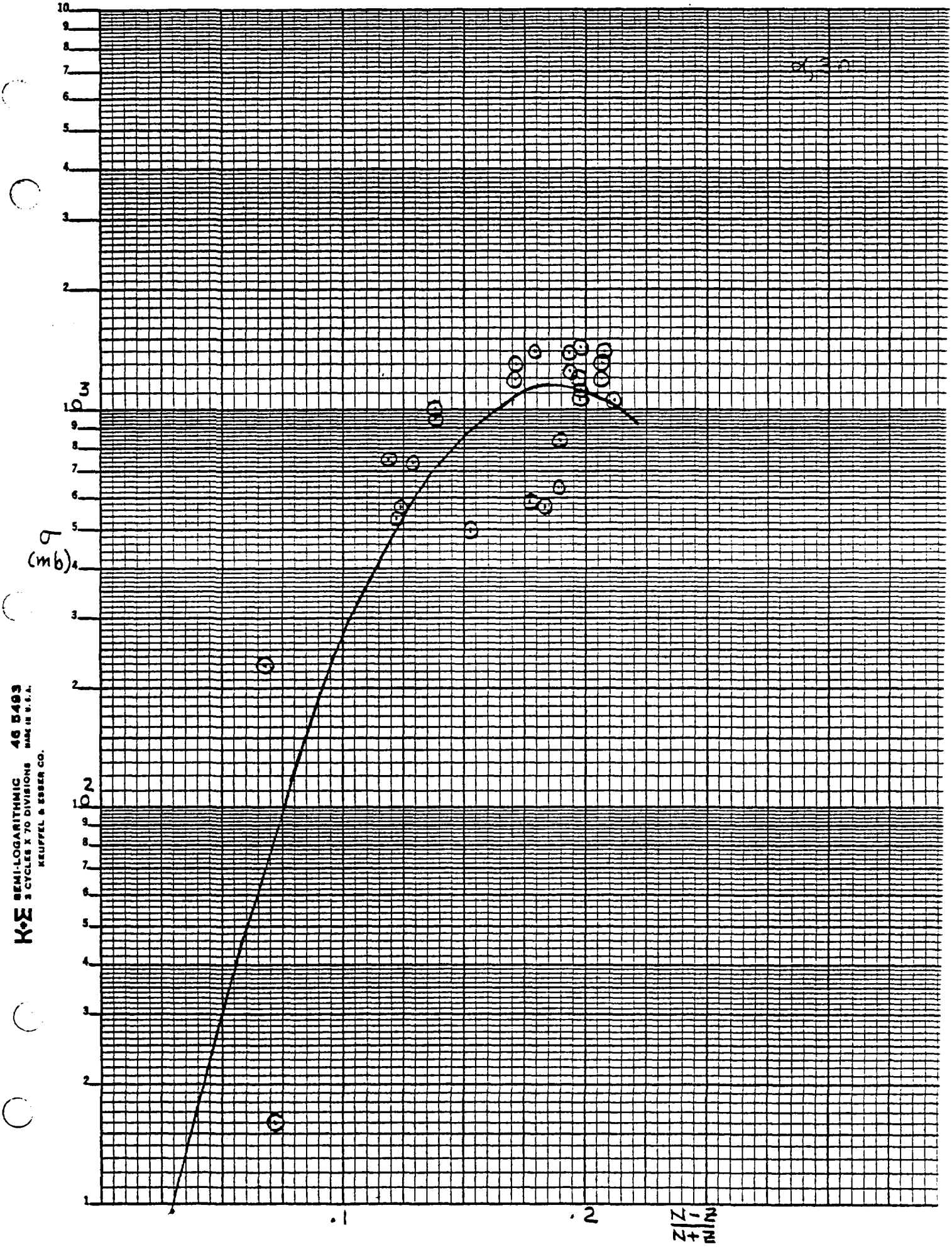

σ (mb)
10
9
8
7
6
5
4
3
2
10^3
10^2
.1
.2
(N-Z)/(N+Z)
K+E SEMI-LOGARITHMIC 46 5493
3 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

Fig. 4

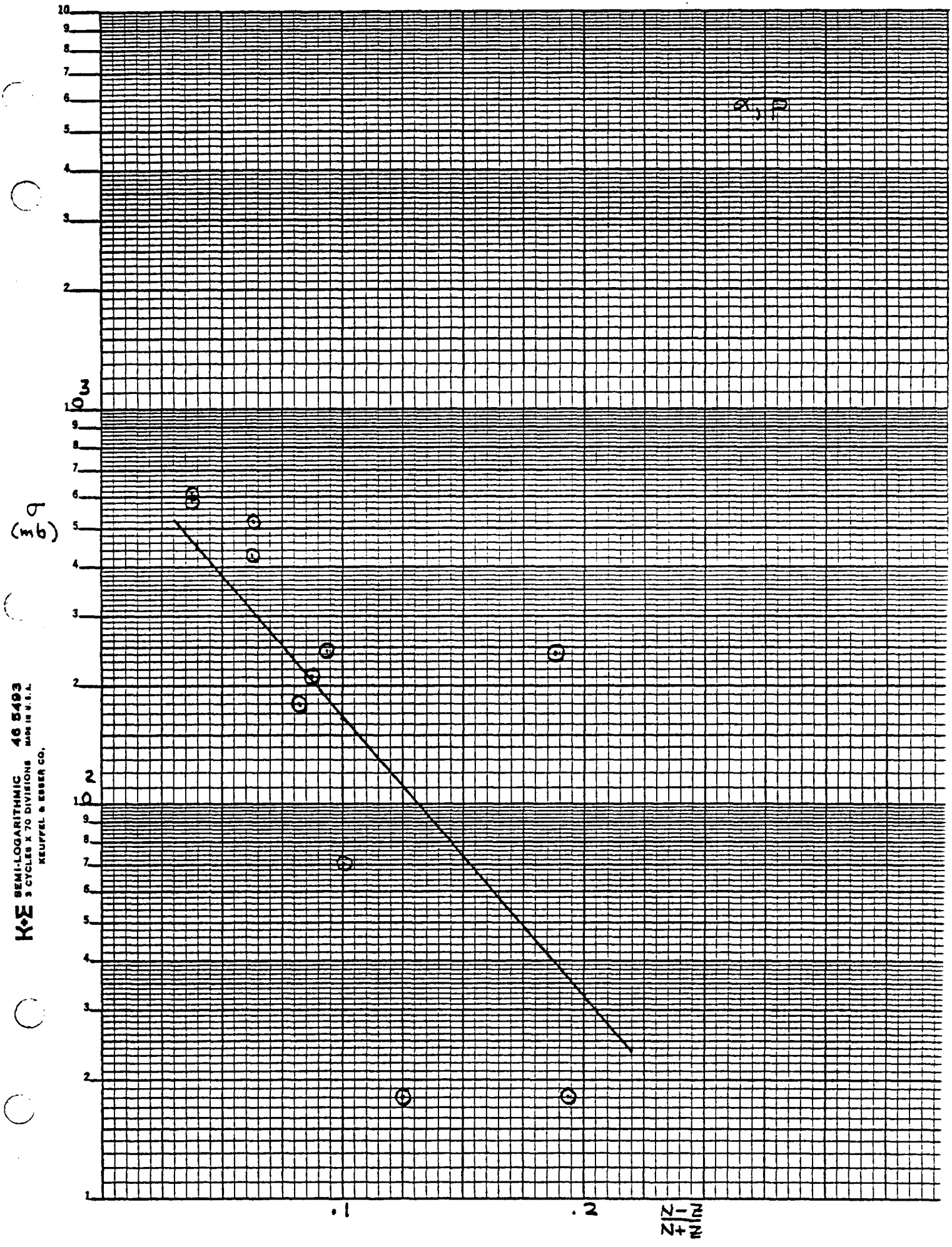

10
9
8
7
6
5
4
3
2
10 3
9
8
7
6
5
4
3
2
10 2
9
8
7
6
5
4
3
2
1
σ
(mb)
.1
.2
N−N / N+N
K+E 46 5493
SEMI-LOGARITHMIC
3 CYCLES X 70 DIVISIONS
MADE IN U.S.A.
KEUFFEL & ESSER CO.

Fig. 5

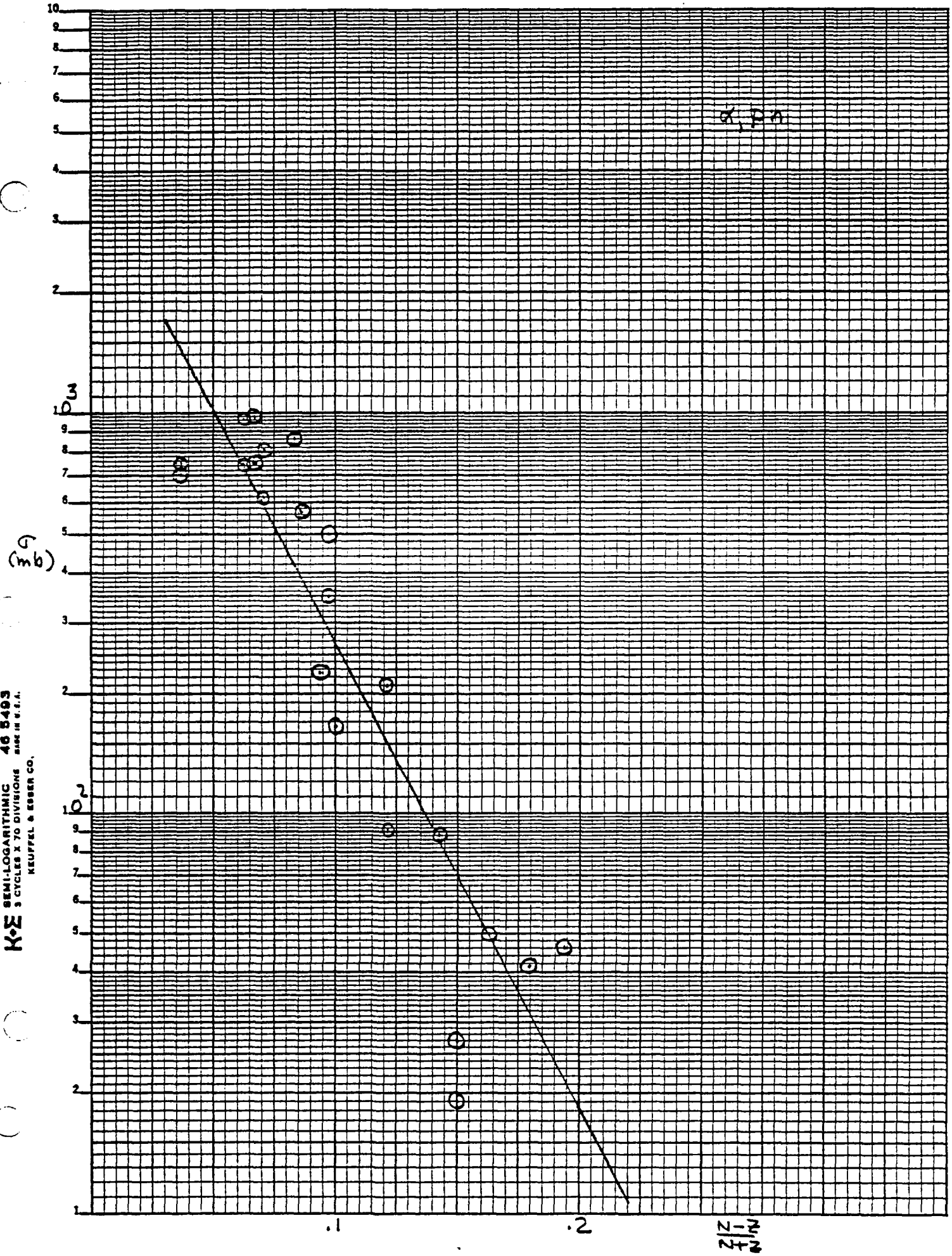

10
9
8
7
6
5
4
3
2
1
.1
.2
K&E SEMI-LOGARITHMIC 46 5493
3 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO.

Fig. 6

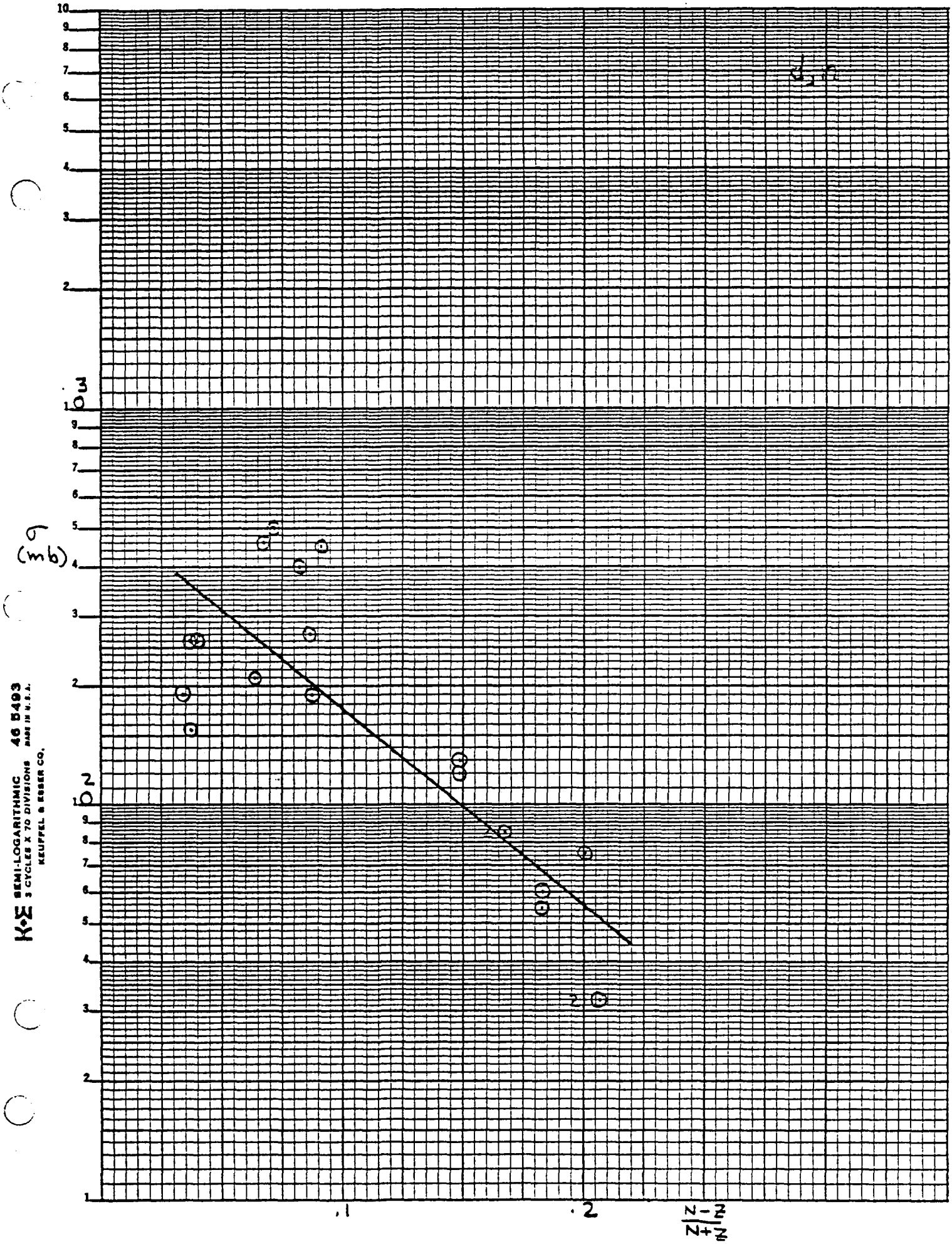

σ (mb)
$\frac{N-Z}{N+Z}$
.1
.2
K&E SEMI-LOGARITHMIC 46 5493
3 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO.

Fig. 7

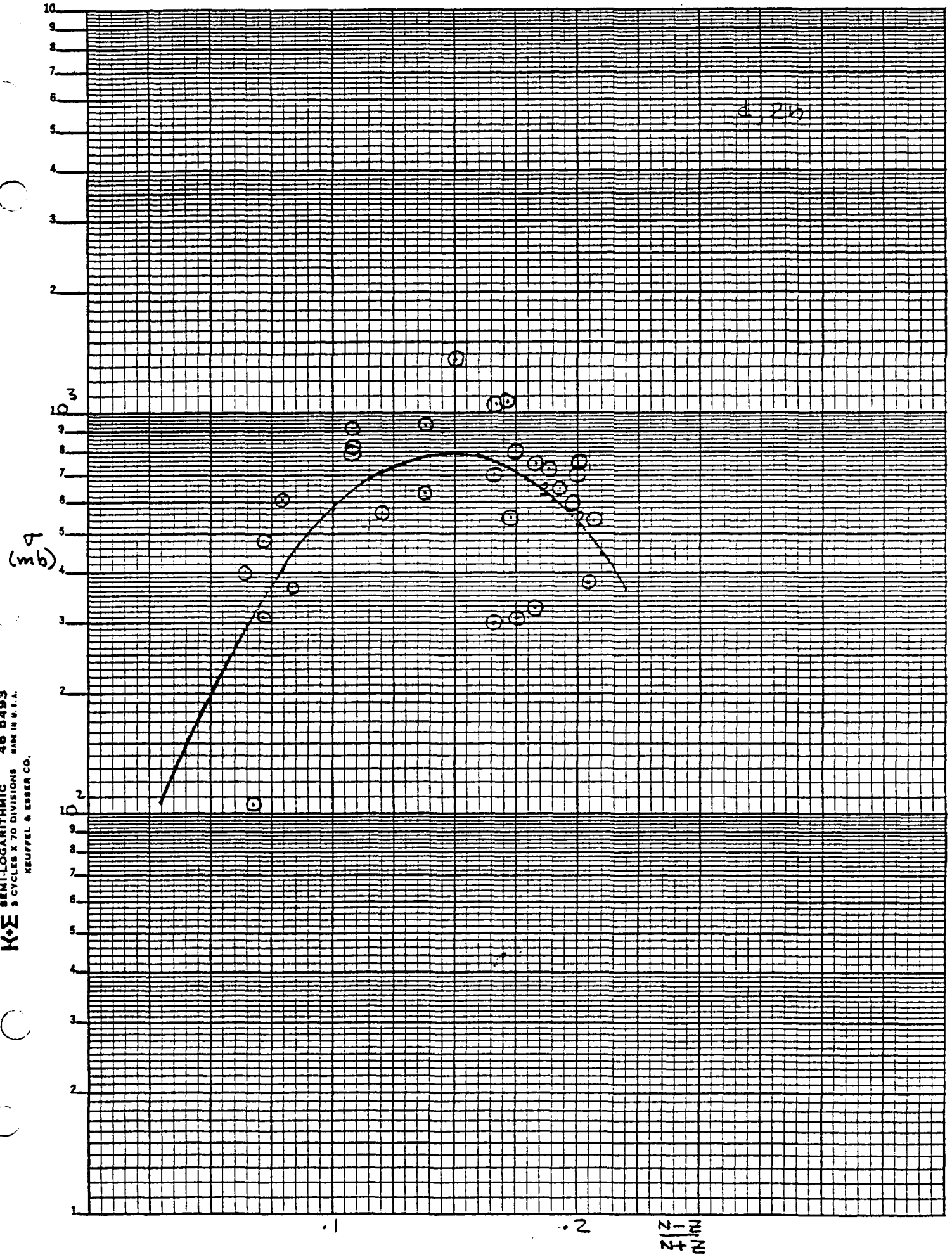

d, Pb
σ (mb)
$\frac{N-Z}{N+Z}$
.1
.2
10
9
8
7
6
5
4
3
2
1
10^3
10^2
K&E SEMI-LOGARITHMIC 46 5493
3 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

Fig. 8

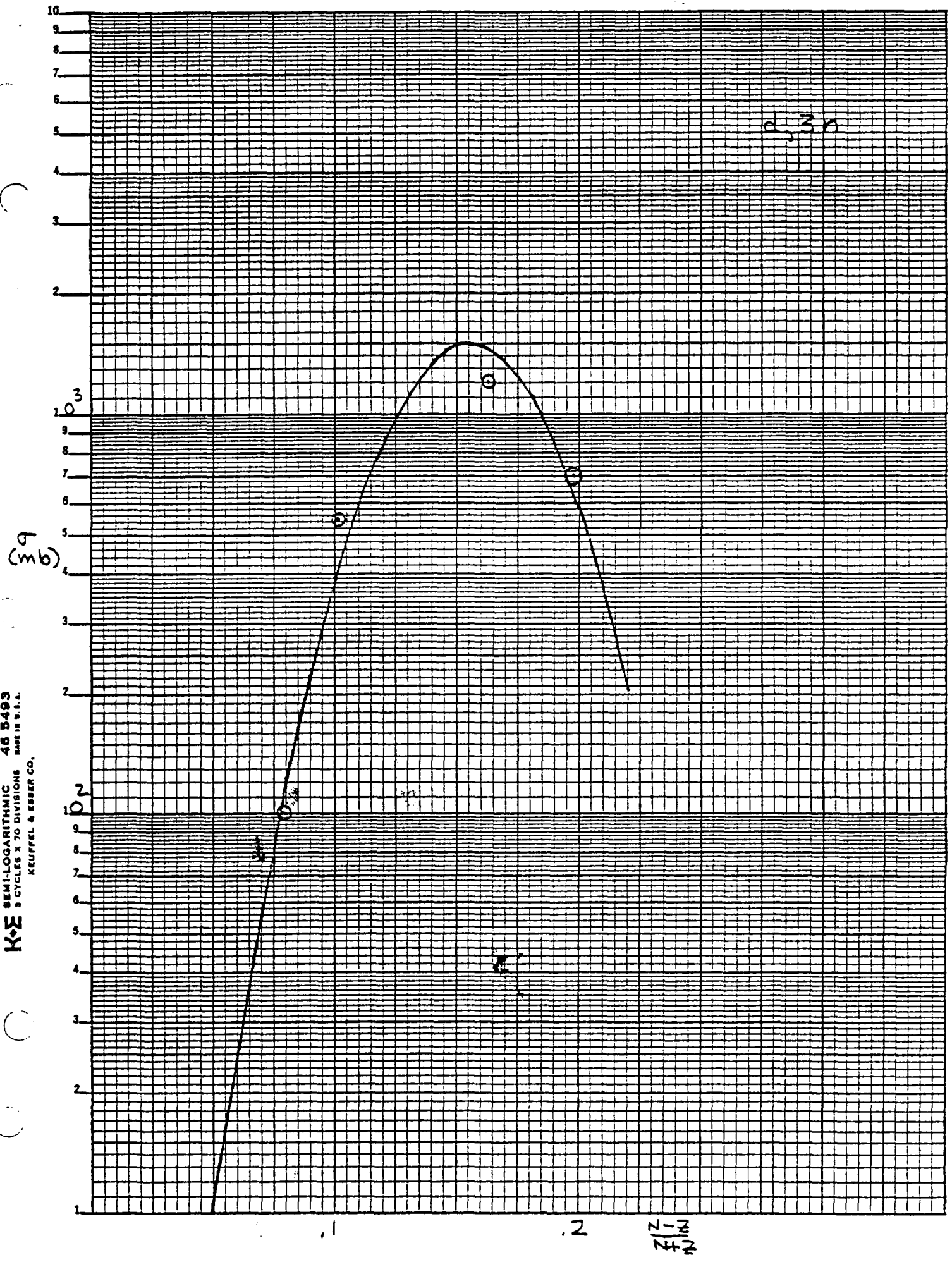

10
9
8
7
6
5
4
3
2
10 3
9
8
7
6
5
4
3
2
10 2
9
8
7
6
5
4
3
2
1
(mb)
.1
.2
K&E SEMI-LOGARITHMIC 46 5493
3 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO.

Fig. 9

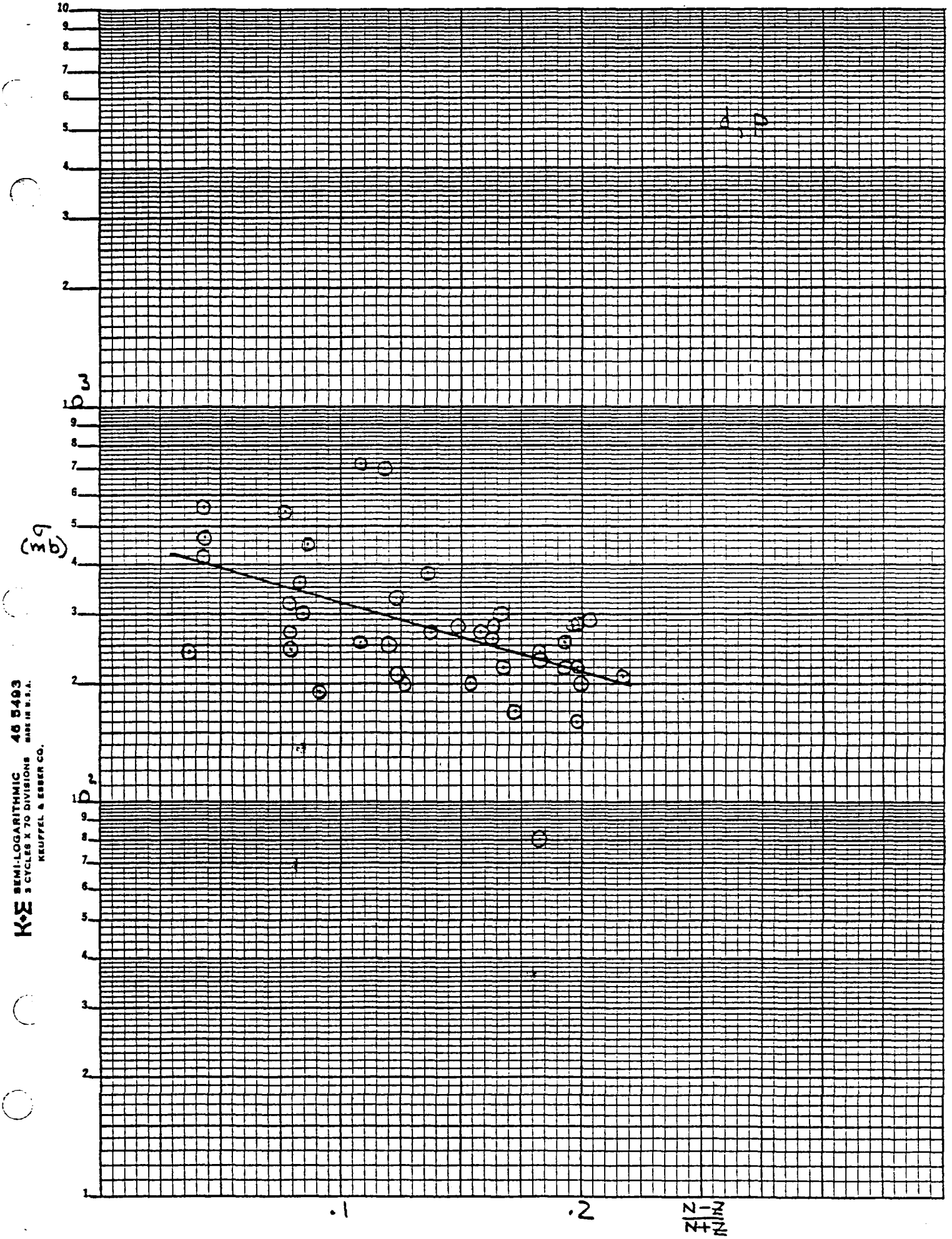

10
9
8
7
6
5
4
3
2
1
D_3
D_2
D_1
(mb)
.1
.2
$\frac{N-Z}{N+Z}$
K+E SEMI-LOGARITHMIC 46 5403
3 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

Fig. 10

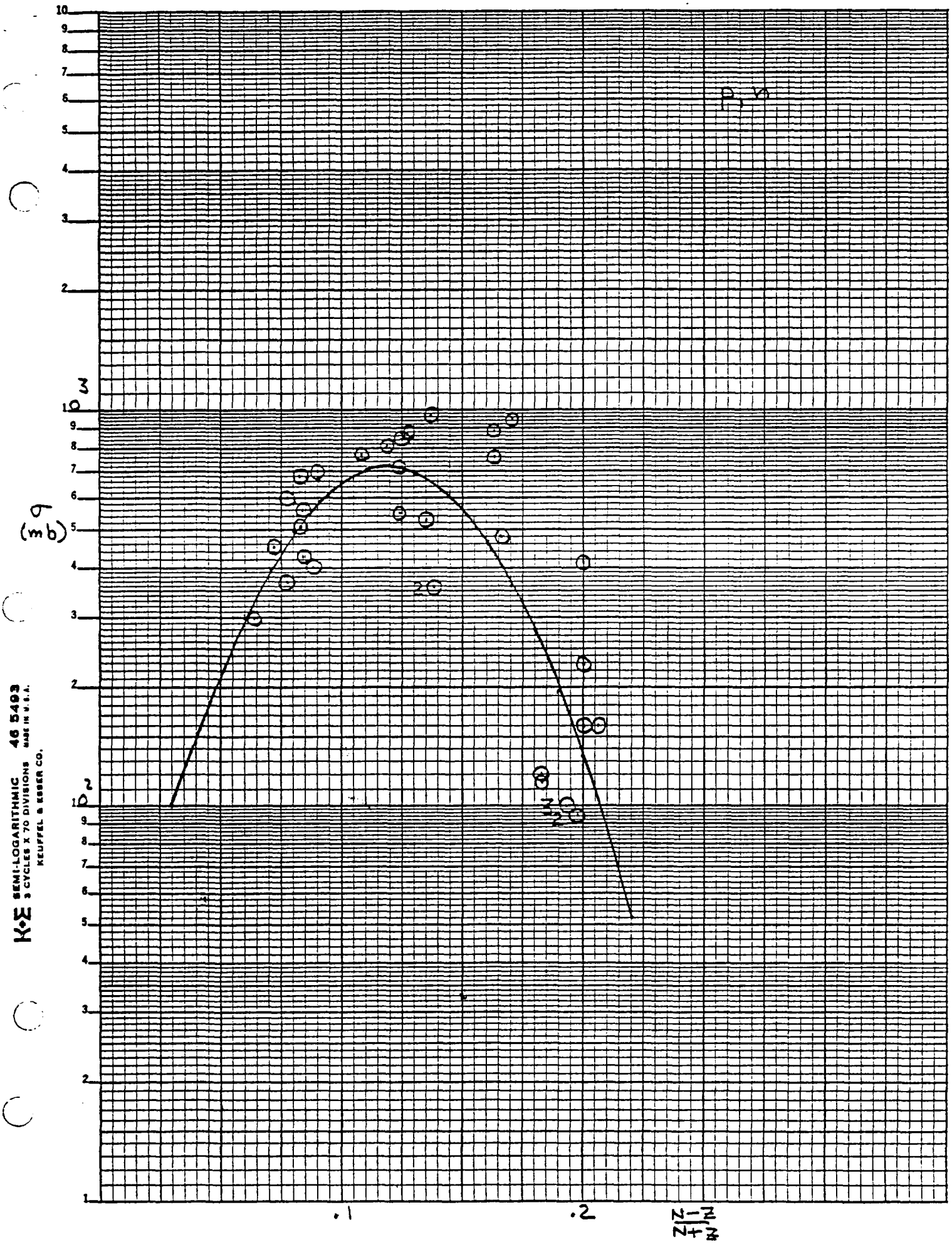

p, n
σ (mb)
10³
10²
20
32
.1
.2
(N−Z)/(N+Z)
K&E SEMI-LOGARITHMIC 46 5493
3 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

Fig. 11

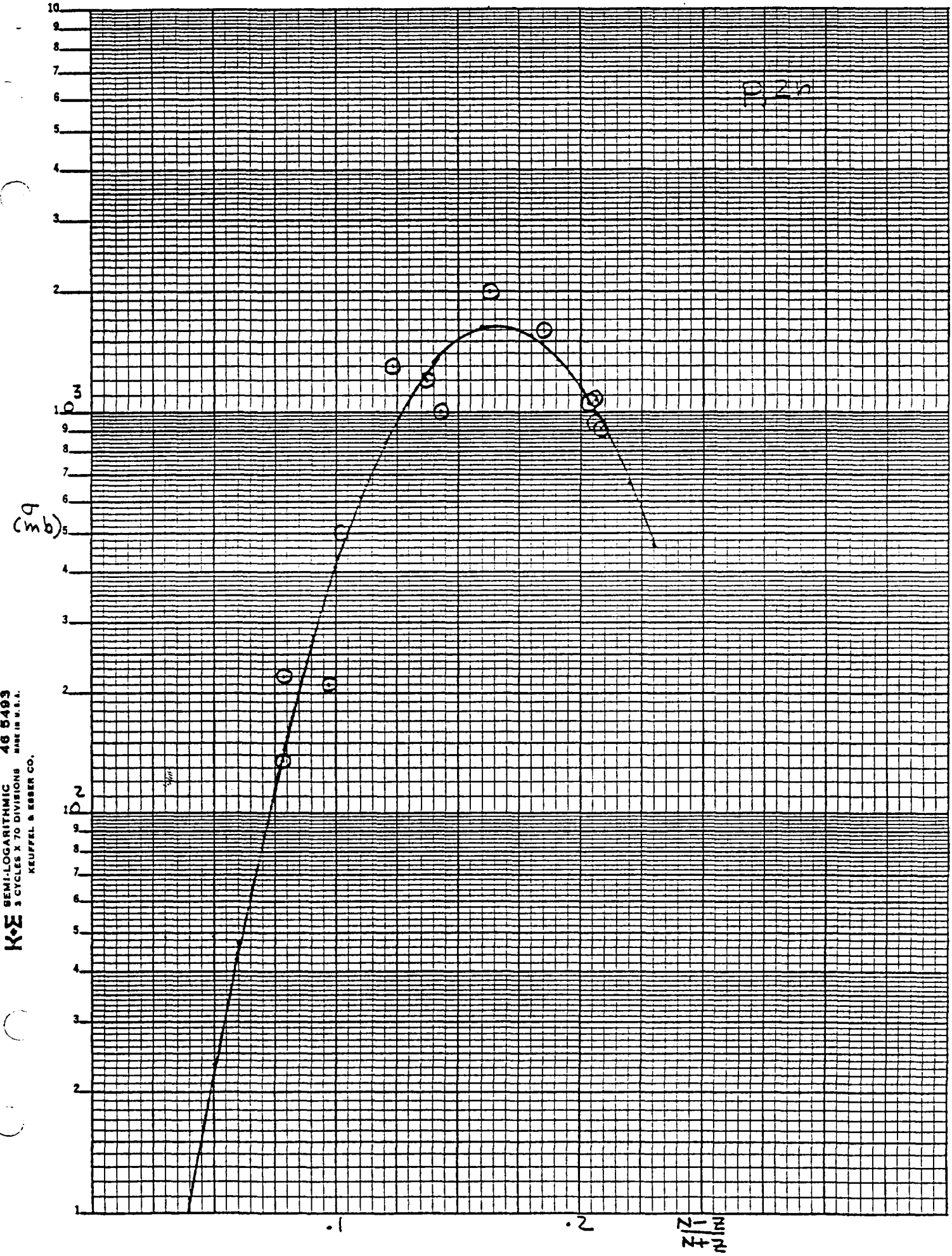
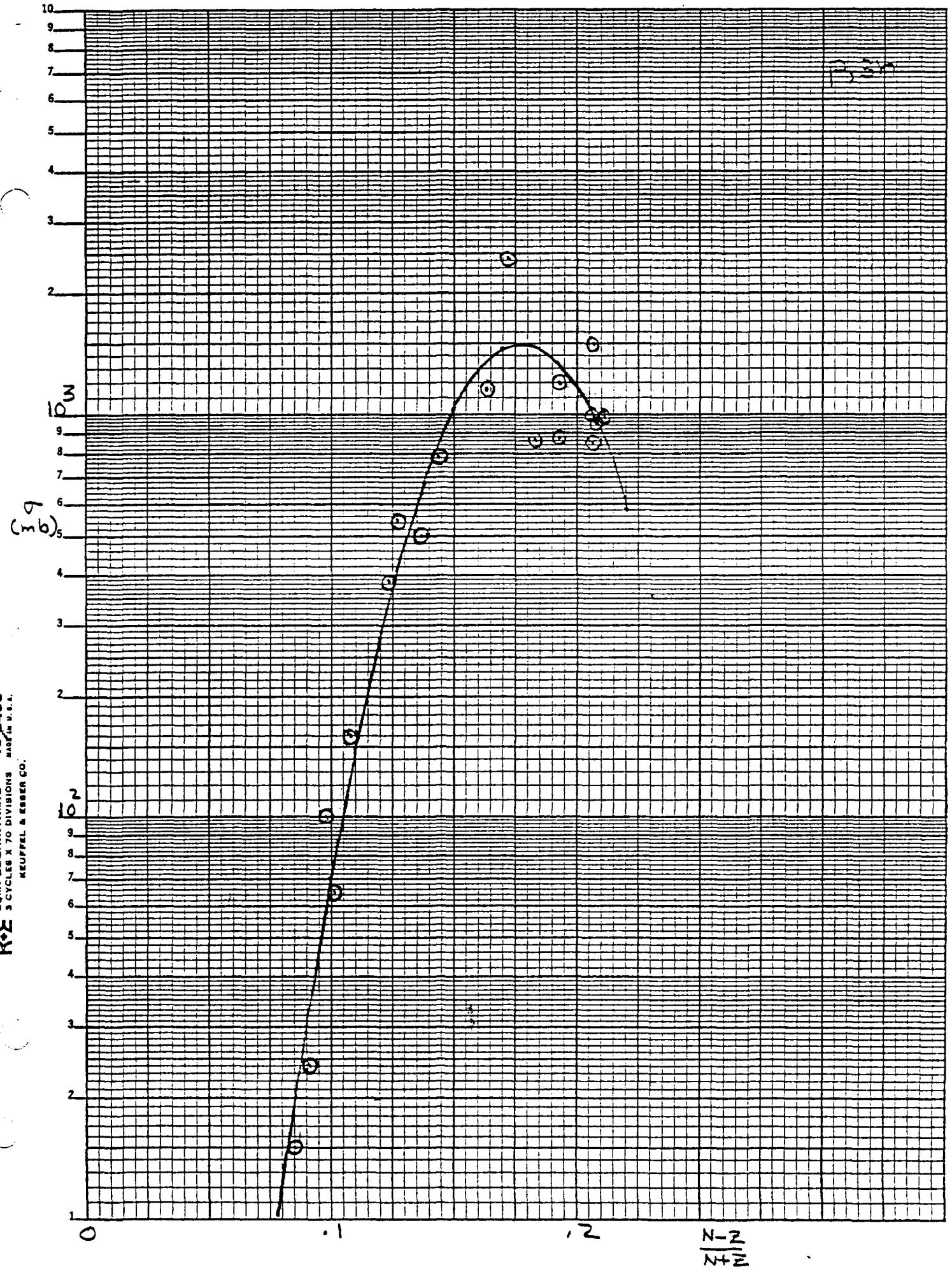

10
9
8
7
6
5
4
3
2
1
10³
10²
(mb)
.1
.2
(N−Z)/(N+Z)
K&E SEMI-LOGARITHMIC 46 5493
3 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

Fig. 12


10
9
8
7
6
5
4
3
2
10^3
9
8
7
6
$(3b)_5$
4
3
2
10^2
9
8
7
6
5
4
3
2
1
0
.1
.2
$\frac{N-Z}{N+Z}$
K+E SEMI-LOGARITHMIC 46 5493
3 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO.

APPENDIX V

Experimental Charged Particle Data in Generalized EXFOR

```
SUBENT        19001001      740301                                          19001  1      1
BIB                10            19                                        19001  1      2
TITLE         (P,XN) AND (P,PXN) REACTIONS OF YTTRIUM-89 WITH 5-85          19001  1      3
              MEV PROTONS                                                   19001  1      4
AUTHOR        (G.B.SAHA,N.T.PORILE,L.JAFFE)                                 19001  1      5
INSTITUTE     (1CANMOG) MCGILL UNIVERSITY,MONTREAL,QUEBEC                   19001  1      6
REFERENCE     (J,PR,144,962,6604)                                           19001  1      7
STANDARD      (29-CU-63,P*N) S.N.GHOSHAL,PR,80,939,5000                     19001  1      8
              (29-CU-65,P*NP) S.MEGHIR,L.YAFFE,UNPUBLISHED                  19001  1      9
PART-DET      (N) NEUTRONS                                                  19001  1     10
FACILITY      (SYNCY) MCGILL SYNCHROCYCLOTRON                               19001  1     11
METHOD        (CHSEP) CHEMICAL SEPARATION AND POSITRON COUNTING             19001  1     12
DETECTOR      (SCIN) TWO NAI(TL) COINCIDENT DETECTION OF 511 KEV            19001  1     13
              ANNIHILATION GAMMA RAYS.                                      19001  1     14
ERR-ANALYS    UNCERTAINTIES INCLUDE RANDOM ERRORS ASSOCIATED WITH THE       19001  1     15
              DETERMINATION OF PHOTO PEAK AREAS,DECAY CURVE ANALYSIS,       19001  1     16
              CHEMICAL YIELDS, AND SYSTEMATIC ERRORS ASSOCIATED WITH        19001  1     17
              COUNTER EFFICIENCIES AND SPREAD IN BEAM ENERGY. NO            19001  1     18
              ERRORS IN REFERENCE CROSS SECTION OR DECAY SCHEMES WERE       19001  1     19
              INCLUDED. RANDOM ERROR FROM SCATTER OF DATA IS MUCH           19001  1     20
              SMALLER THAN TOTAL ERROR WHICH RANGES 11-22 PERCENT.          19001  1     21
ENDBIB             19                                                       19001  1     22
NOCOMMON                                                                    19001  1     23
ENDSUBENT          22                                                       19001  199999
SUBENT        19001002      740301                                          19001  2      1
BIB                1             1                                         19001  2      2
ISO-QUANT     (39-Y-89,P*N)                                                 19001  2      3
ENDBIB             1                                                        19001  2      4
NOCOMMON                                                                    19001  2      5
DATA               3          19                                            19001  2      6
EN            DATA        DATA-ERR                                          19001  2      7
MEV           MB          MB                                                19001  2      8
 5.            50.          5.5                                            19001  2      9
 8.5          352.         39.                                             19001  2     10
 12.          720.         79.                                             19001  2     11
 15.          712.         78.                                             19001  2     12
 18.5         552.         61.                                             19001  2     13
 21.5         395.         43.                                             19001  2     14
 24.8         194.         21.                                             19001  2     15
 27.5         103.         11.                                             19001  2     16
 30.5         61.4          6.8                                            19001  2     17
 33.5         43.           4.7                                            19001  2     18
 36.8         45.           5.                                             19001  2     19
 42.          37.           4.1                                            19001  2     20
 48.          29.4          3.2                                            19001  2     21
 54.          29.7          3.3                                            19001  2     22
 60.          23.3          2.6                                            19001  2     23
 66.          19.7          2.2                                            19001  2     24
 72.          17.           1.9                                            19001  2     25
 78.          14.4          1.6                                            19001  2     26
 85.          12.           1.3                                            19001  2     27
ENDDATA            21                                                       19001  2     28
ENDSUBENT          27                                                       19001  299999
SUBENT        19001003      740301                                          19001  3      1
BIB                1             1                                         19001  3      2
ISO-QUANT     (39-Y-89,P*2N)                                                19001  3      3
ENDBIB             1                                                        19001  3      4
NOCOMMON                                                                    19001  3      5
DATA               3          18                                            19001  3      6
EN            DATA        DATA-ERR                                          19001  3      7
MEV           MB          MB                                                19001  3      8
```

```
 15.          68.          8.8
 18.5         352.         46.
 21.5         495.         64.
 24.8         1252.        163.
 27.          1248.        162.
 27.5         1318.        171.
 30.5         828.         108.
 30.5         896.         116.
 33.5         506.         66.
 36.8         329.         43.
 42.          172.         22.
 48.          112.         15.
 54.          82.5         11.
 60.          73.4         9.5
 66.          60.          7.8
 72.          54.          7.
 78.          46.          6.
 85.          41.          5.3
ENDDATA                20
ENDSUBENT              26
SUBENT          19001004      740301
BIB                     1           1
ISO-QUANT    (39-Y-89,P*3N)
ENDBIB                  1
NOCOMMON
DATA                    3          14
EN           DATA        DATA-ERR
MEV          MB          MB
 30.5         55.          4.6
 33.5         119.         14.
 36.8         313.         38.
 40.          385.         46.
 42.          333.         40.
 42.          349.         42.
 45.          299.         36.
 48.          168.         20.
 54.          91.          11.
 60.          55.4         6.6
 66.          54.          6.5
 72.          47.5         5.7
 78.          36.5         4.4
 85.          31.5         3.8
ENDDATA                16
ENDSUBENT              22
ENDENTRY
```

```
19001   3     9
19001   3    10
19001   3    11
19001   3    12
19001   3    13
19001   3    14
19001   3    15
19001   3    16
19001   3    17
19001   3    18
19001   3    19
19001   3    20
19001   3    21
19001   3    22
19001   3    23
19001   3    24
19001   3    25
19001   3    26
19001   3    27
19001 399999
19001   4     1
19001   4     2
19001   4     3
19001   4     4
19001   4     5
19001   4     6
19001   4     7
19001   4     8
19001   4     9
19001   4    10
19001   4    11
19001   4    12
19001   4    13
19001   4    14
19001   4    15
19001   4    16
19001   4    17
19001   4    18
19001   4    19
19001   4    20
19001   4    21
19001   4    22
19001   4    23
19001 499999
19001999999999
```