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DATA ON THE BACKSCATTERING COEFFICIENTS OF LIGHT IONS FROM SOLIDS*

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* This work was performed under the joint research program of data compilation at the Research Information Center, Institute of Plasma Physics.

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ABSTRACT

Experimental data on the backscattering of H, D and He ions from solids have been collected. The parameters considered are the number-backscattering coefficient R_N, the energy-backscattering coefficient R_E and the mean fractional energy r_E ($=R_E/R_N$) of backscattered particles. The data are compiled into tables, and are also shown in graphs together with the curves of the empirical formulas proposed by Tabata et al. Most of the data range in the region of incident energy from 1 to 50 keV. The empirical formulas, obtained by taking account of Monte Carlo results for energies below 1 keV as well, are plotted for energies from 10 eV to 100 keV. The rms deviations of the data from the empirical formulas lie between 6% (r_E of He ions) and 30% (R_N of He ions).

CONTENTS

I. INTRODUCTION

The backscattering of light ions from solids is one of the phenomena important for plasma-surface interaction, and is related to the so-called recycling of plasma particles from the first wall in a fusion reactor. Experimental and theoretical studies of this phenomenon have been accumulated during recent years.[1] Compilation and evaluation of data have also been made.[2,3] For the effective utilization of the knowledge obtained, however, further compilation of data are required as well as development of interpolation formulas valid in a wide region of incident energy. In the present joint research program of data compilation, empirical formulas for the following parameters have been developed[4]:

(1) the number-backscattering coefficient R_N defined as the ratio of the total number of backscattered particles, charged and neutrals, to the number of primary particles,

(2) the energy-backscattering coefficient R_E defined as the ratio of the total energy backscattered to the total incident energy,

(3) the mean fractional energy r_E of backscattered particles.

The last parameter is expressed by the ratio of the former two:

$$r_E = R_E/R_N \ . \tag{1}$$

The empirical formulas give values of these parameters for H, D and He ions normally incident on the amorphous or polycrystalline target of effectively semiinfinite thickness, and are valid in the region of incident energy from about 10^{-3} to 10^{2} in Thomas-Fermi reduced units.

This report presents a new compilation of the experimental data on these three parameters, and makes comparison of the data with the empirical formulas for all available combinations of the incident ions and target elements.

II. EMPIRICAL FORMULAS

A. Expressions

The empirical formulas have been developed on the basis of a modified scaling law, and values of constants in them have been determined from the least-squares fit to the experimental data collected and representative Monte Carlo data for energies below 1 keV.[3,5]

(1) The number-backscattering coefficient R_N

The empirical formula for R_N is written as

$$R_N = (S_e^{LSS}/S_t)\eta_N \ , \tag{2}$$

where S_e^{LSS} is the electronic stopping-power given by the theory of Lindhard, Scharff and Schiøtt[6] (LSS theory) when the ratio of the mass M_2 of the target atom to the mass M_1 of the projectile is much greater than unity, S_t is the total stopping-power, and η_N is a function only of the Thomas-Fermi reduced energy ε for a given projectile; η_N is called here the reduced number-backscattering coefficient. The expression for S_e^{LSS} is

$$S_e^{LSS} = 0.0793 Z_1^{2/3} M_1^{-1/2} \mu \varepsilon^{1/2} \quad , \tag{3}$$

where Z_1 is the atomic number of the projectile, ε is defined by

$$\varepsilon = 32.5 E M_2 / [(Z_1^{2/3}+Z_2^{2/3})(M_1+M_2) Z_1 Z_2] \quad (E \text{ in keV}) \quad , \tag{4}$$

E is the incident kinetic energy of the projectile, and Z_2 is the atomic number of the target material. The total stopping-power S_t is given by

$$S_t = S_n + S_e^0 \quad , \tag{5}$$

where S_n is the nuclear stopping-power, and S_e^0 is the electronic stopping-power including the Z_2-oscillations. For S_n, we use the formula proposed by Kalbitzer et al.[7] with the coefficients determined by Ziegler[8]; for S_e^0, we use the semiempirical formulas given by Andersen and Ziegler[9] and by Ziegler[8] (see Appendix). We express η_N in the form:

$$\eta_N = a_1 / [\varepsilon^{a_2} (1 + a_3 \varepsilon + a_4 \varepsilon^2)] \quad , \tag{6}$$

where the symbols a_i (i=1, 2, 3, 4) denote constants for a given projectile, and their values are listed in Table II.1.

(2) The energy-backscattering coefficient R_E

The empirical formula for R_E is written as

$$R_E = (S_e^{LSS}/S_t)\eta_E \ , \tag{7}$$

where η_E is called the reduced energy-backscattering coefficient, and is given by

$$\eta_E = r_E \eta_N \ . \tag{8}$$

Here r_E is expressed by a function only of ε for a given projectile (see the next paragraph).

(3) The mean fractional energy r_E of backscattered particles

The empirical formula for r_E is of the form:

$$r_E = 1-b_1/(1+b_2\varepsilon^{-b_3}) \ , \tag{9}$$

where b_1 is a constant independent of the projectile and target material, and b_2 and b_3 are constants for a given projectile. Values of these constants are also given in Table II.1.

B. Comparison with Data

The empirical formulas for η_N, η_E and r_E are compared with the corresponding experimental and Monte Carlo data in Figs. II.1-6. The experimental values of η_N and η_E have been obtained from the data on R_N and R_E by using the relations:

$$\eta_N = (S_t/S_e^{LSS})R_N \tag{10}$$

$$\eta_E = (S_t/S_e^{LSS})R_E \ , \tag{11}$$

respectively. In the case of the Monte Carlo data, these relations have been used by replacing S_t by the stopping power used in each simulation.

As can be seen from Figs. II.1-6, the empirical formulas for η_N, η_E and r_E fit generally well to the data, and are considered to be valid in the energy region $10^{-3} \lesssim \varepsilon \lesssim 10^2$.

The goodness of fit of the experimental data to the empirical formulas can be measured by the relative rms deviation δ defined by

$$\delta = \{(1/n) \sum_{i=1}^{n} [y_i/y(\varepsilon_i)-1]^2\}^{1/2} \ , \tag{12}$$

where n is the number of the data points, y_i is the ith data on the parameter y for the reduced energy ε_i, and $y(\varepsilon_i)$ is the corresponding value of the parameter given by the empirical formula.*

Values of δ for R_N, R_E and r_E of each projectile are given in Table II.2, and lie between 6 and 30%. Typical experimental errors stated in the sources of the data are given in Table II.3. The values of δ in Table II.2 are comparable to most of the

* In the least-squares fit to determine the values of the constants in the empirical formulas, the sum of squares of $\ln[y(\varepsilon_i)/y_i]$ has been minimized instead of δ. The reason is described in Appendix B of ref. 4.

experimental errors in Table II.3, indicating again that the fit is satisfactory. However, systematic deviations are seen for some values of Z_2. For example, the experimental data on R_N and R_E of H ions incident on Ta are lower than the values of the empirical formula by about 30% on the average (see Fig. 12 of MAIN FIGURES). The following three possible causes for these systematic deviations have been discussed in ref. 4: (1) errors in the formulas for S_e^0, (2) approximate nature of the scaling law assumed for η_N and η_E, and (3) experimental errors due to characteristics of targets. To evaluate and reduce each of these errors, further experimental and theoretical studies are required.

At low energies, the empirical formula for R_N of H and D ions incident on C predicts a slight increase of R_N with increasing energy (see Figs. 1 and 16 of MAIN FIGURES). This behavior is considered to be a spurious one due to the predominance of the nuclear stopping over the electronic stopping; this predominance might cause deviations of actual values of η_N from the simple universal curve expressed by eq. (6). Therefore, the errors in the empirical formulas for R_N and R_E are expected to be rather large below the energies where this spurious behavior appears in the formula for R_N.

III. COMPILATION OF DATA

The experimental data on R_N, R_E and r_E reported before the end of 1980 have been compiled and stored in the computer of Institute of Plasma Physics, Nagoya University. The combinations of the incident ions and the target elements available are shown in Table III.1. Numerical values of the data on the three parameters are given in MAIN TABLES, Tables 1-54, and the data on R_N and R_E are also shown in MAIN FIGURES, Figs. 1-54. These figures contain the curves of the empirical formulas plotted for energies from 10 eV to 100 keV.* Sources of the data are shwon in the tables and the figures by the use of abbreviations, and the corresponding references are listed in the alphabetical order at the end of this report.

All the data on R_N and R_E of each projectile are plotted in Figs. III.1-3 as a function of ε. The empirical formulas are also plotted in these figures for representative materials with high and low values of the parameters.

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* For D ions incident on the targets with $Z_2 \gtrsim 74$ and He ions incident on the targets with $Z_2 \gtrsim 29$, the empirical formulas for R_N and R_E give erroneous values greater than unity at low energies. In such cases, the plot of these curves is made only for the region where the value is less than unity.

APPENDIX

For the sake of the reader's convenience, the semiempirical formulas[8,9] for the nuclear stopping-power S_n and the electronic stopping-power S_e^0, which constitute part of the empirical formulas for R_N and R_E, are quoted here. The expressions for S_n and S_e^0 are given in LSS reduced stopping units.

(1) S_n (common to all incident ions)

$$S_n = 1.593\varepsilon^{1/2} \quad \text{for } \varepsilon<0.01 \qquad (A.1)$$

$$= 1.7\varepsilon^{1/2}\ln(\varepsilon+e)/(1+6.8\varepsilon+3.4\varepsilon^{3/2}) \quad \text{for } 0.01\leq\varepsilon\leq 10 \qquad (A.2)$$

$$= \ln(0.47\varepsilon)/2\varepsilon \quad \text{for } \varepsilon>10\ , \qquad (A.3)$$

where e is the base of the natural logarithm.

(2) S_e^0 for H and D ions

$$S_e^0 = A_1KE^{1/2} \quad \text{for } 1\leq E<10 \text{ keV/amu} \qquad (A.4)$$

$$1/S_e^0 = 1/S_{L1}+1/S_{H1} \quad \text{for } 10\leq E<1000 \text{ keV/amu}\ , \qquad (A.5)$$

where

$$S_{L1} = A_2KE^{0.45} \qquad (A.6)$$

$$S_{H1} = (A_3K/E)\ln(1+A_4/E+A_5E) \tag{A.7}$$

$$K = 0.118(M_1+M_2)(Z_1^{2/3}+Z_2^{2/3})^{1/2}/Z_1Z_2M_1 \ , \tag{A.8}$$

E is the incident energy per projectile mass expressed in units of keV/amu, and the symbols A_i (i=1, 2, ..., 5) denote coefficients whose values are given for each element in ref. 9.

(3) S_e^0 for He ion

$$1/S_e^0 = 1/S_{L2}+1/S_{H2} \quad \text{for } 1\le E<1000 \text{ keV} \ , \tag{A.9}$$

where

$$S_{L2} = B_1KE^{B_2} \tag{A.10}$$

$$S_{H2} = (B_3K/E')\ln(1+B_4/E'+B_5E') \tag{A.11}$$

$$E' = E/1000 \ , \tag{A.12}$$

E is the incident energy in keV, and the symbols B_i (i=1, 2, ..., 5) denote coefficients whose values are given for each element in ref. 8.

Examples of the values of A_i and B_i are quoted in Table A.1 for representative elements.

REFERENCES

1) See, for example, the review articles: H. Verbeek: in Radiation Effects on Solid Surfaces, Advances in Chemistry Series 158, M. Kaminsky ed. (American Chemical Soc., Washington, 1976) p. 245; G. M. McCracken and P. E. Stott: Nucl. Fusion 19 (1979) 889; E. S. Mashkova: Radiat. Effects 54 (1981) 1.

2) E. W. Thomas, S. W. Hawthorne, F. W. Meyer and B. J. Farmer: Atomic Data for Controlled Fusion Research, ORNL-5207/R1 (1979).

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4) T. Tabata, R. Ito, K. Morita and Y. Itikawa: Japan. J. Appl. Phys. 20, No. 10 (1981)

5) O. S. Oen and M. T. Robinson: Nucl. Instrum. & Methods 132 (1976) 647.

6) J. Lindhard, M. Scharff and H. E. Schiøtt: Kgl. Danske Videnskab. Selskab., Mat.-Fys. Medd. 33, No. 14 (1963).

7) S. Kalbitzer, H. Oetzmann, H. Grahmann and A. Feuerstein: Z. Phys. A 278 (1976) 223.

8) J. F. Ziegler: Helium Stopping Powers and Ranges in All Elements, Vol. 4 of The Stopping and Ranges of Ions in Matter (Pergamon Press, New York, 1978).

9) H. H. Andersen and J. F. Ziegler: Hydrogen Stopping Powers and Ranges in All Elements, Vol. 3 of The Stopping and Ranges of Ions in Matter (Pergamon Press, New York, 1977).

Table II.1. Values of the constants in the empirical formulas. Errors attached are those of least-squares fit.

Constant	H ion	D ion	He ion
a_1	0.375 ±0.037	0.300 ±0.023	0.197 ±0.009
a_2	0.107 ±0.030	0.316 ±0.023	0.416 ±0.021
a_3	0.64 ±0.13	0.282 ±0.077	0.148 ±0.029
a_4	0.0338±0.0091	0.0121±0.0040	0[a]
b_1	0.872 ±0.052	0.872[a]	0.872[a]
b_2	0.306 ±0.091	0.465 ±0.040	0.470 ±0.018
b_3	0.50 ±0.13	0.273 ±0.052	0.262 ±0.020

a) The value has been fixed in the fit.

Table II.2. Values of relative rms deviation δ of the experimental data on R_N, R_E and r_E from the empirical formulas are shown for each projectile. Numbers n of the experimental data collected are also given.

Projectile	R_N		R_E		r_E	
	n	δ (%)	n	δ (%)	n	δ (%)
H ion	96	26	133	17	79	22
D ion	38	22	27	13	26	10
He ion	16	30	140	28	13	6

Table II.3. Typical experimental errors. The references corresponding to the abbreviations for data sources are given at the end of this report.

Data source	Error
AN76	~10% for $R_E > 2\times10^{-3}$
EC79	~50% for R_N of 1.5-keV H on C
	~30% for R_N of 1.5-keV H on W
	~10% for R_N of 15-keV H on W
	~30% for R_N of 5-keV He on W
SI76	from 10% for high R_N and R_E values to 25% for low R_N and R_E values
VE80	2-20% for R_N of H
	5% for R_N of He

Table III.1. Combinations of the incident ions and the target elements available in the present compilation. The numbers in the second to the fourth column indicate the numbers of the tables and the figures in which the corresponding data are given.

Target	Incident ion			Target	Incident ion		
element	H	D	He	element	H	D	He
$_{6}C$	1	16	24	$_{34}Se$	-	-	39
$_{12}Mg$	-	-	25	$_{40}Zr$	8	-	40
$_{13}Al$	2	-	26	$_{41}Nb$	9	20	41
$_{14}Si$	3	-	27	$_{42}Mo$	10	21	42
$_{22}Ti$	4	17	28	$_{46}Pd$	-	-	43
$_{23}V$	-	-	29	$_{47}Ag$	11	-	44
$_{24}Cr$	-	-	30	$_{48}Cd$	-	-	45
$_{25}Mn$	-	-	31	$_{49}In$	-	-	46
$_{26}Fe$	5	18	32	$_{50}Sn$	-	-	47
$_{27}Co$	-	-	33	$_{51}Sb$	-	-	48
$_{28}Ni$	6	19	34	$_{52}Te$	-	-	49
$_{29}Cu$	7	-	35	$_{73}Ta$	12	-	50
$_{30}Zn$	-	-	36	$_{74}W$	13	22	51
$_{31}Ga$	-	-	37	$_{78}Pt$	-	-	52
$_{32}Ge$	-	-	38	$_{79}Au$	14	23	53
				$_{82}Pb$	15	-	54

Table A.1. Examples of the values of the coefficients A_i and B_i (i=1, 2, ..., 5) in the semiempirical formulas for S_e^0 (A_i from ref. 8; B_i from ref. 7).

Coefficient	Value $_6C$	$_{13}Al$	$_{26}Fe$
A_1	2.631E 00	4.154E 00	3.519E 00
A_2	2.989E 00	4.739E 00	3.963E 00
A_3	1.445E 03	2.766E 03	6.065E 03
A_4	9.572E 02	1.645E 02	1.243E 03
A_5	2.819E-02	2.023E-02	7.782E-03
B_1	4.232E 00	2.5 E 00	5.013E 00
B_2	3.877E-01	6.25 E-01	4.707E-01
B_3	2.299E 01	4.57 E 01	8.558E 01
B_4	3.5 E 01	1. E-01	1.655E 01
B_5	7.993E 00	4.359E 00	3.211E 00

Coefficient	Value $_{42}Mo$	$_{74}W$	$_{79}Au$
A_1	6.425E 00	4.574E 00	4.856E 00
A_2	7.248E 00	5.144E 00	5.46 E 00
A_3	9.545E 03	1.593E 04	1.832E 04
A_4	4.802E 02	4.424E 02	4.385E 02
A_5	5.367E-03	3.144E-03	2.542E-03
B_1	9.276E 00	6.335E 00	3.223E 00
B_2	4.18 E-01	4.825E-01	5.883E-01
B_3	1.571E 02	2.551E 02	2.327E 02
B_4	8.038E 00	2.834E 00	2.954E 00
B_5	1.29 E 00	8.228E-01	1.05 E 00

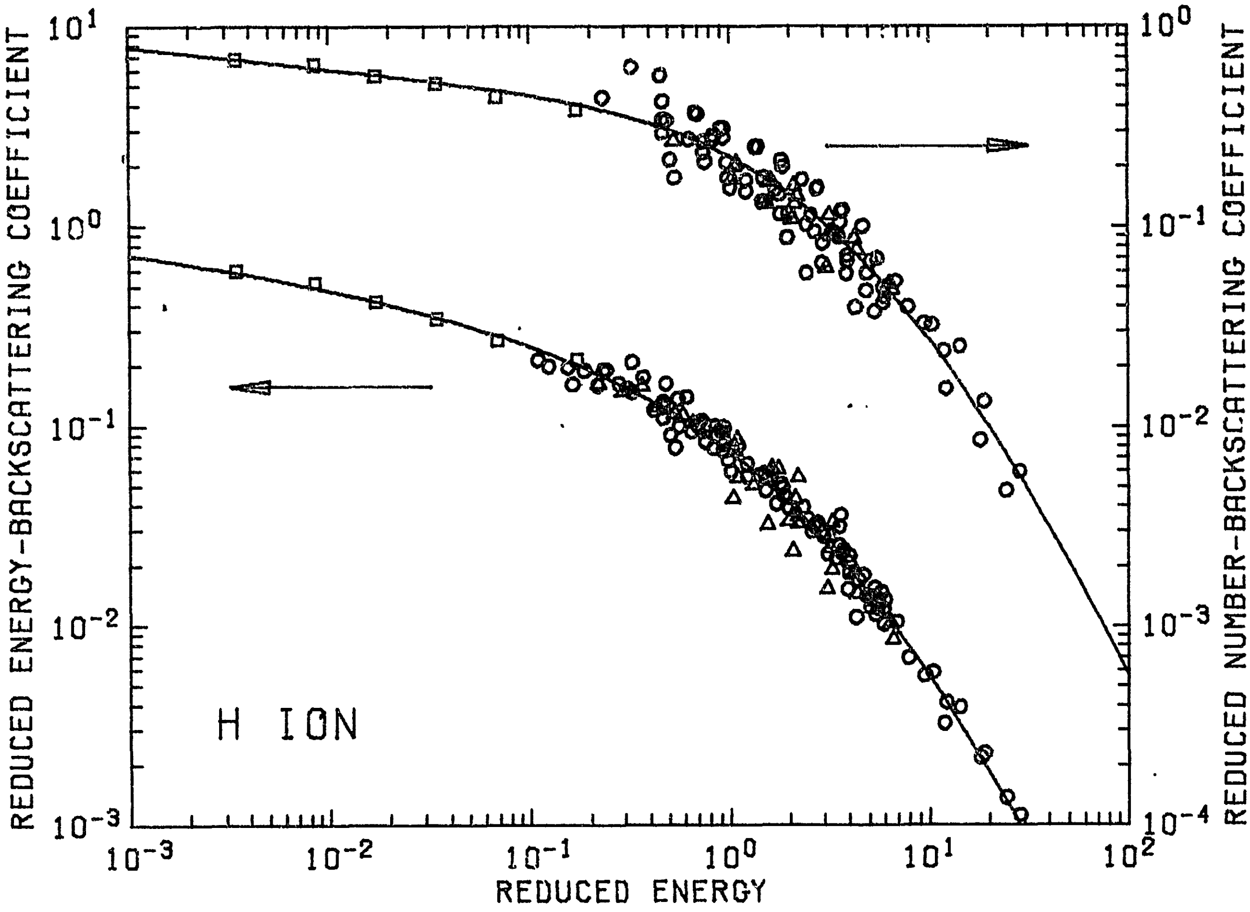

Fig. II.1. The reduced number-backscattering coefficient η_N and the reduced energy-backscattering coefficient η_E of H ions are plotted as a function of the Thomas-Fermi reduced energy ε. o: experimental results for the targets of C, Al, Si, Ti, stainless steel, Ni, Cu, Zr, Ag, W, Au and Pb; Δ: experimental results for the targets of Nb, Mo and Ta; squares: Monte Carlo results for the target of Cu (ref. 5); curves: the empirical formulas universal for all materials (ref. 4). All the experimental data are compiled in the present report. This figure includes additional experimental data other than those shown in Fig. 2 of ref. 4.

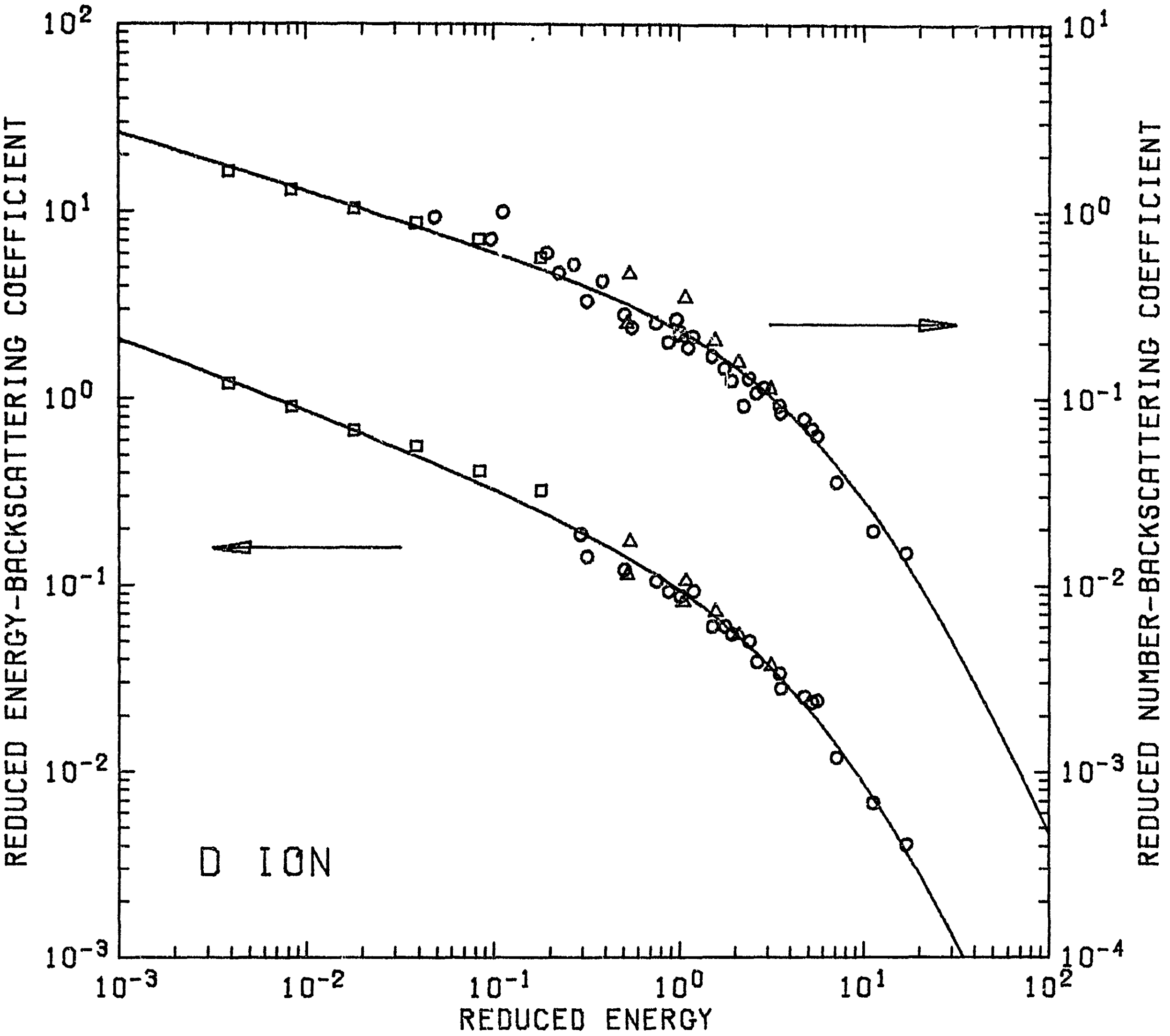

Fig. II.2. The reduced number-backscattering coefficient η_N and the reduced energy-backscattering coefficient η_E of D ions are plotted as a function of the Thomas-Fermi reduced energy ε. o: experimental results for the targets of C, Ti, stainless steel, Ni, W and Au; Δ: experimental results for the targets of Nb and Mo; squares: Monte Carlo results for the target of Fe (ref. 3); curves: the empirical formulas universal for all materials. All the experimental data are compiled in the present report. This figure includes additional experimental data other than those shown in Fig. 3 of ref. 4.

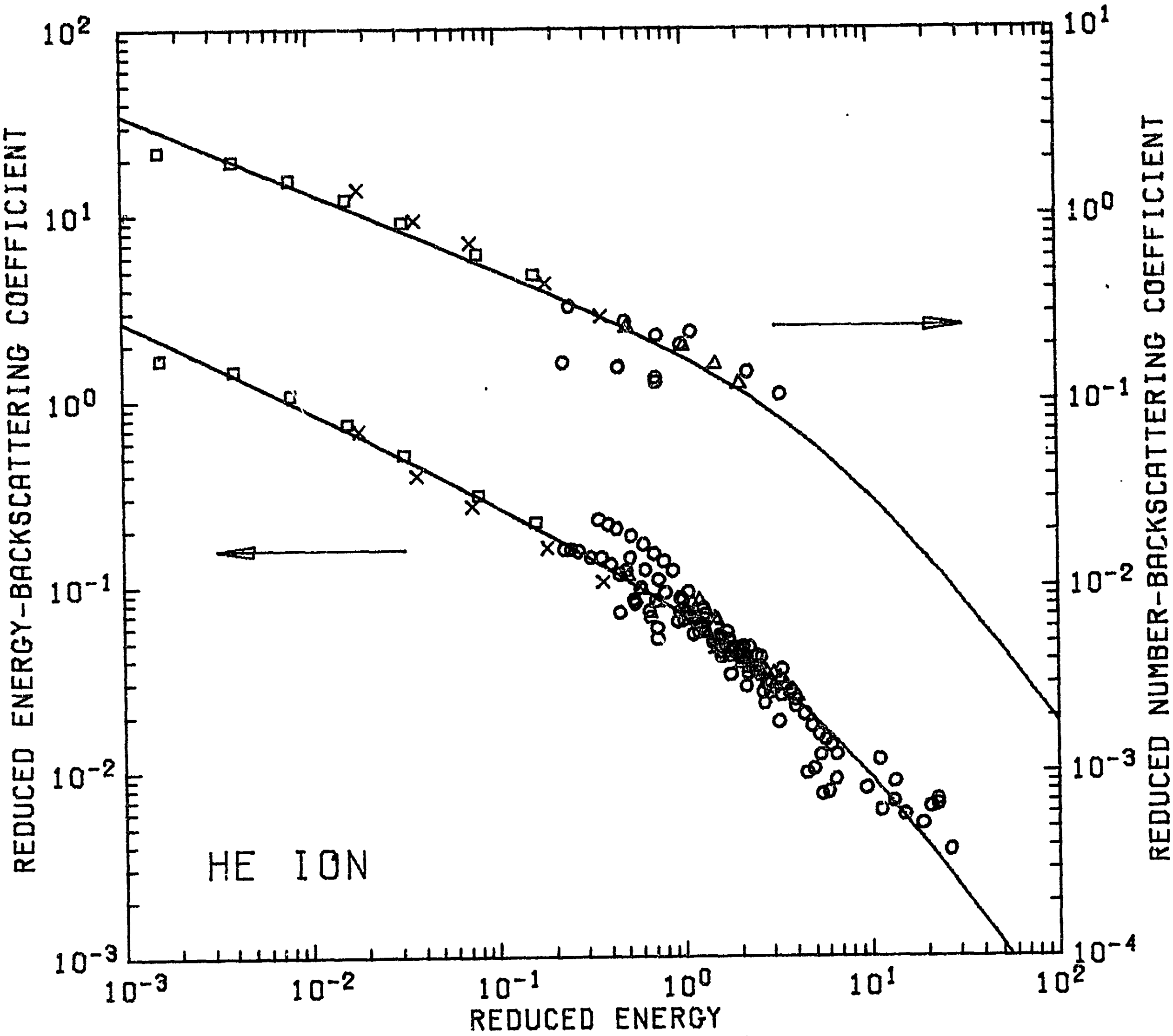

Fig. II.3. The reduced number-backscattering coefficient η_N and the reduced energy-backscattering coefficient η_E of He ions are plotted as a function of the Thomas-Fermi reduced energy ε. o: experimental results for the targets of Si, Ti, Cu, Ag, W, Au, Pb and other twenty-one elemental materials; Δ: experimental results for the targets of Nb, Mo and Ta; squares: Monte Carlo results for the targets of Cu (ref. 5); crosses: Monte Carlo results for the targets of Al (ref. 5); curves: the empirical formulas universal for all materials. All the experimental data are compiled in the present report. This figure has been taken from ref. 4.

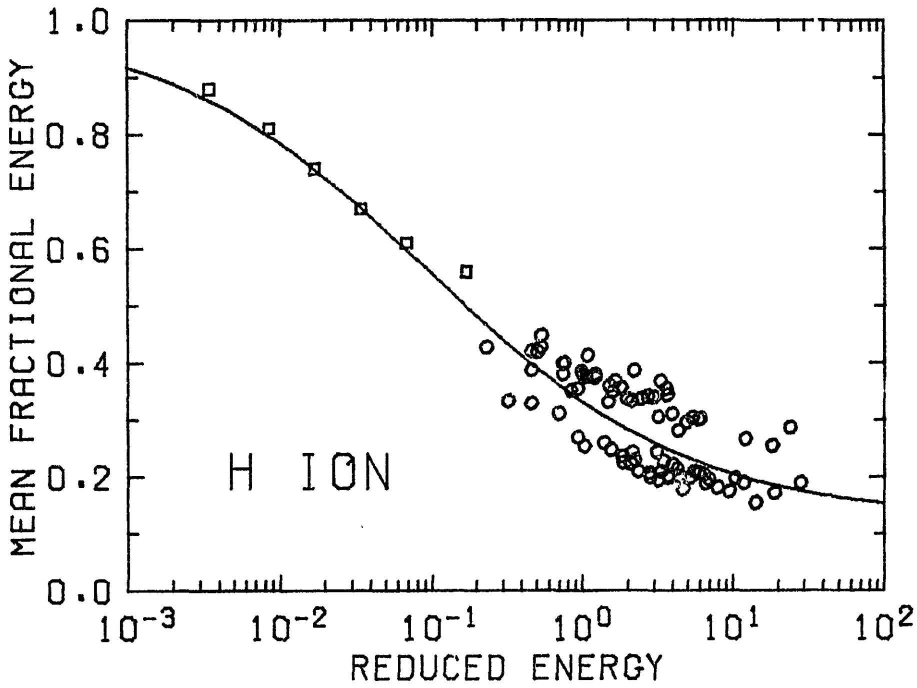

Fig. II.4. The mean fractional energy r_E of backscattered particles when H ions are incident is plotted as a function of the Thomas-Fermi reduced energy ε. o: experimental results; squares: Monte Carlo results (ref. 5); curve: the empirical formula. This figure includes additional experimental data other than those shown in Fig. 5 of ref. 4.

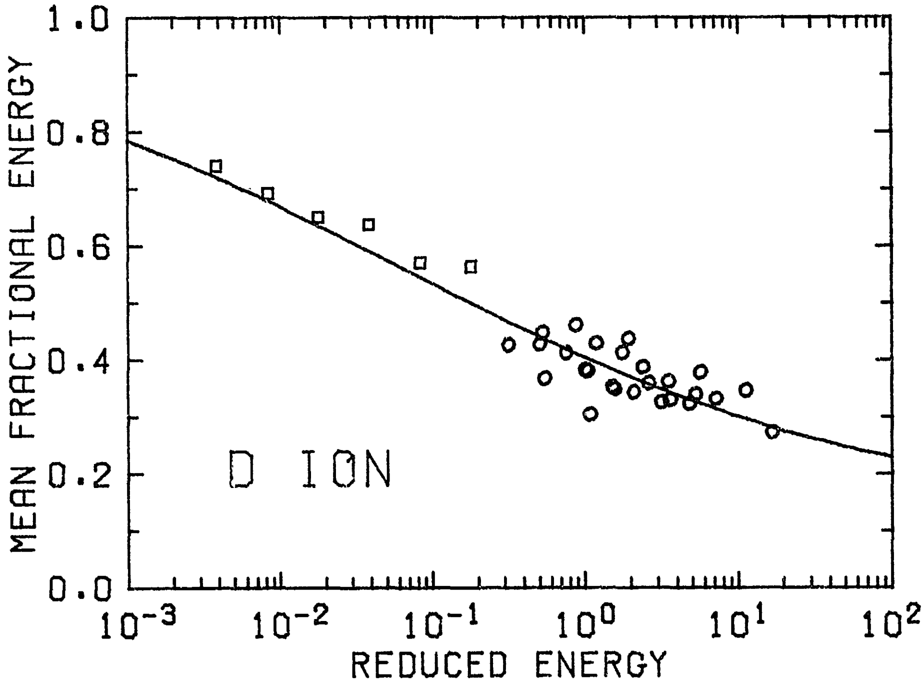

Fig. II.5. The mean fractional energy r_E of backscattered particles when D ions are incident is plotted as a function of the Thomas-Fermi reduced energy ε. o: experimental results; squares: Monte Carlo results (ref. 3); curve: the empirical formula. This figure includes additional experimental data other than those shown in Fig. 6 of ref. 4.

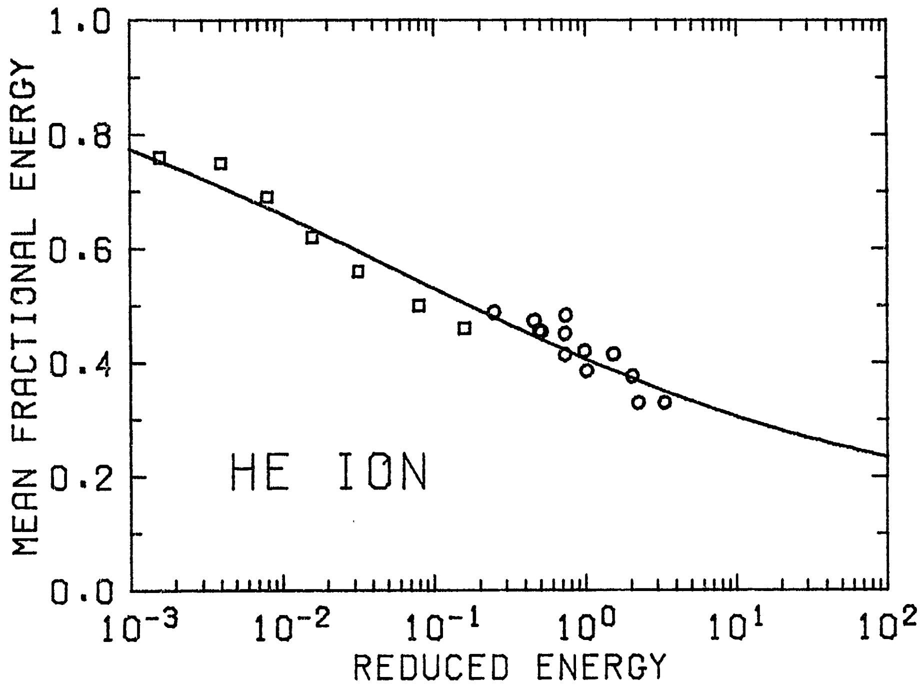

Fig. II.6. The mean fractional energy r_E of backscattered particles when He ions are incident is plotted as a function of the Thomas-Fermi reduced energy ε. o: experimental results; squares: Monte Carlo results (ref. 5); curve: the empirical formula. This figure has been taken from ref. 4.

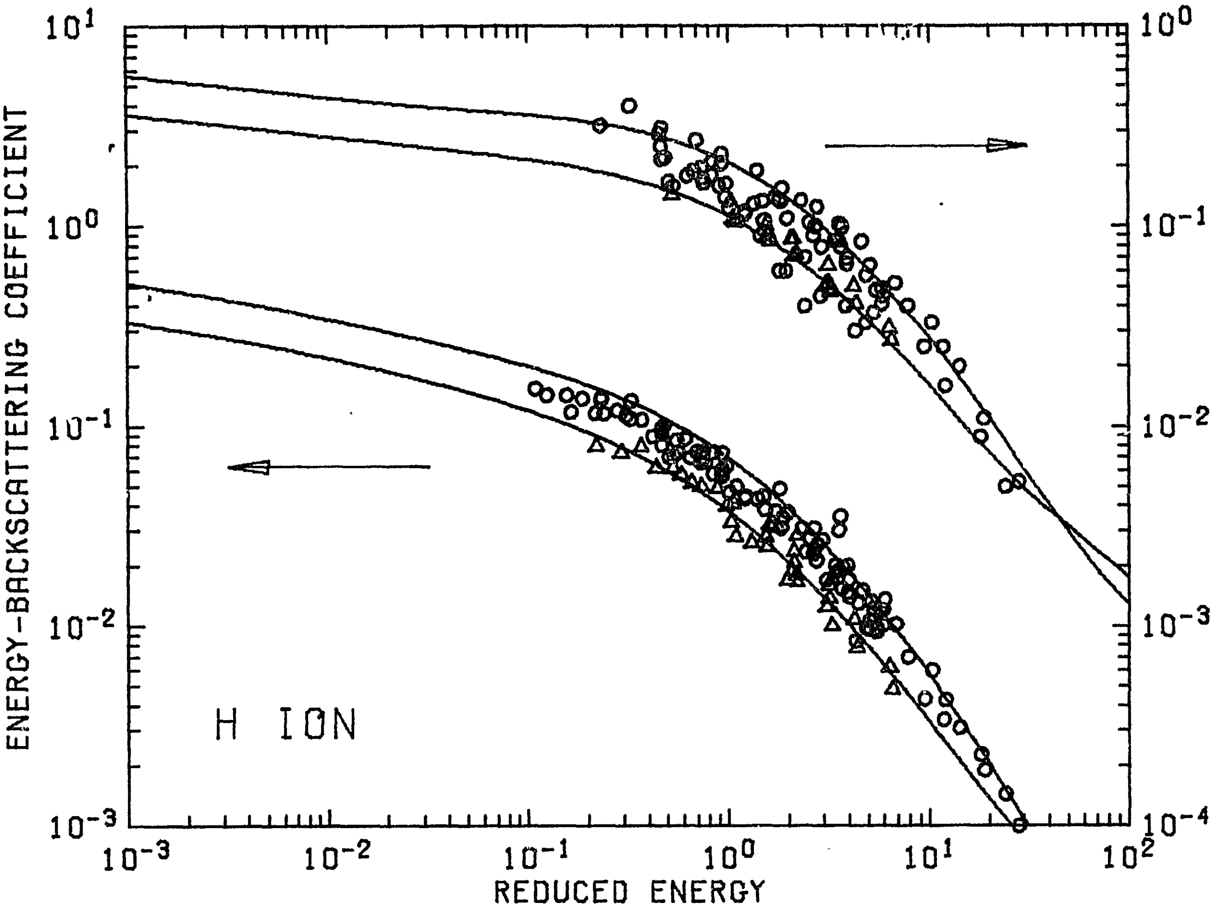

Fig. III.1. The number-backscattering coefficient R_N and the energy-backscattering coefficient R_E of H ions are plotted as a function of the Thomas-Fermi reduced energy ε. o: experimental results for the targets of C, Al, Si, Ti, stainless steel, Ni, Cu, Zr, Ag, W, Au and Pb; Δ: experimental results for the targets of Nb, Mo and Ta; curves: the empirical formulas for the targets of Fe (the upper of each pair) and Nb (the lower). This figure includes additional data points other than those shown in Fig. 1 of ref. 4.

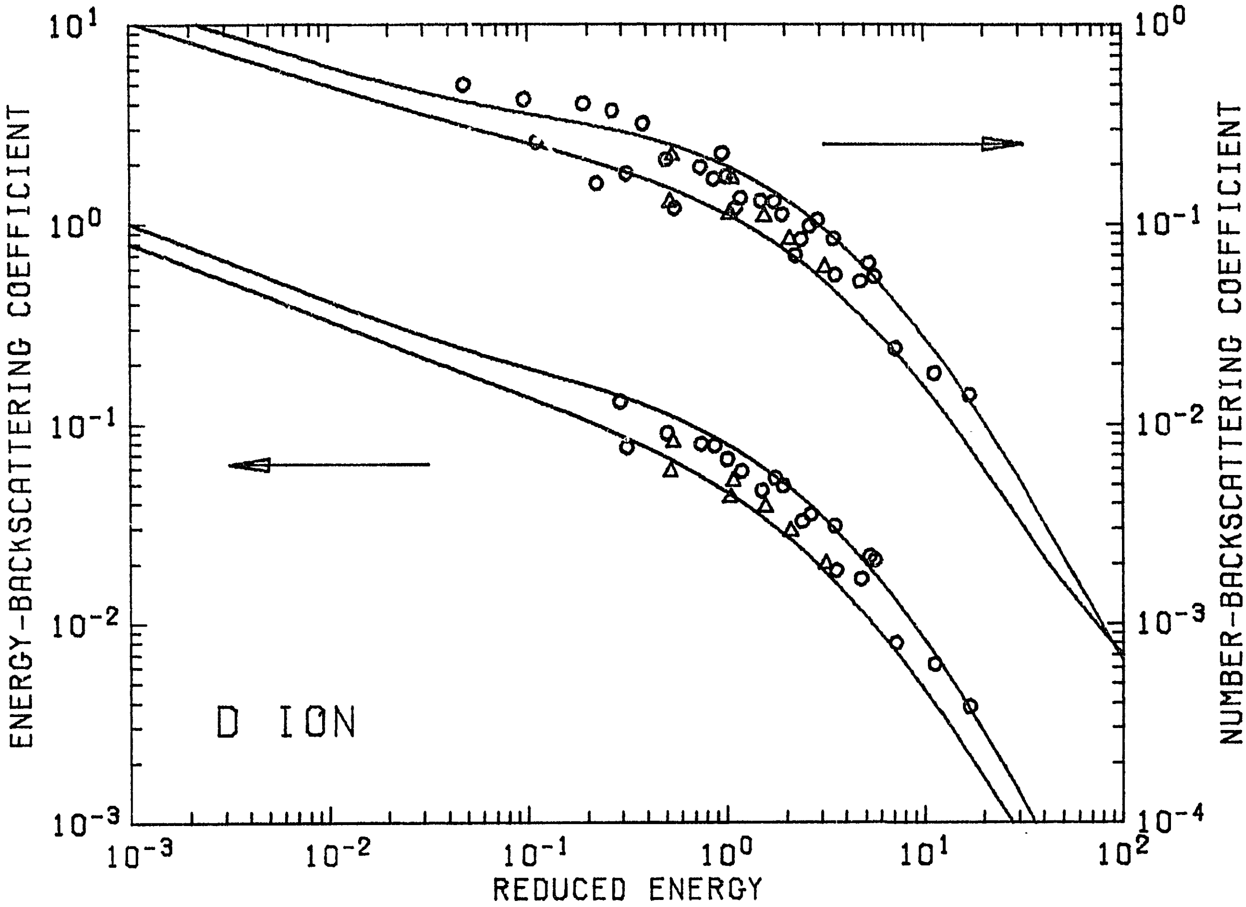

Fig. III.2. The number-backscattering coefficient R_N and the energy-backscattering coefficient R_E of D ions are plotted as a function of the Thomas-Fermi reduced energy ε. o: experimental results for the targets of C, Ti, stainless steel, Ni, W, and Au; Δ: experimental results for the targets of Nb and Mo; curves: the empirical formulas for the targets of Fe (the upper of each pair) and Nb (the lower).

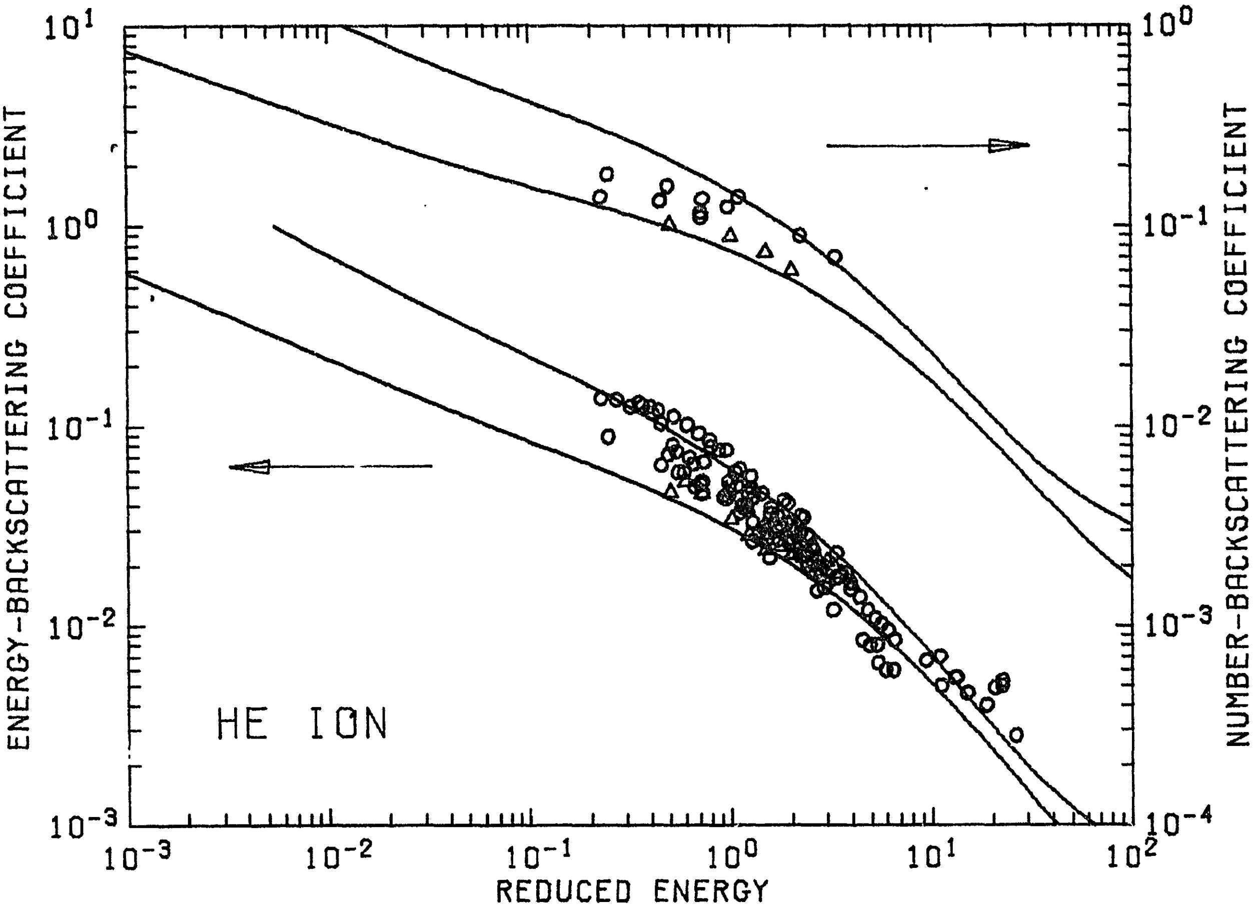

Fig. III.3. The number-backscattering coefficient R_N and the energy-backscattering coefficient R_E of He ions are plotted as a function of the Thomas-Fermi reduced energy ε. o: experimental results for the targets of Si, Ti, Cu, Ag, W, Au, Pb and other twenty-one elemental materials; Δ: experimental results for the targets of Nb, Mo and Ta; curves: the empirical formulas for the targets of Au (the upper of each pair) and Nb (the lower).

MAIN TABLES

Experimental data on the number-backscattering coefficient R_N, the energy-backscattering coefficient R_E and the mean fractional energy r_E of backscattered particles.

The order in which each combination of the incident ions and the target elements appears is given in the following list. Sources of the data are shown by the use of abbreviations, and the corresponding references are listed in the alphabetical order at the end of this report.

LIST OF TABLES / FIGURES FOR DATA

Table/Figure No.	Incident Ion	Target
26	He	Al
27	He	Si
28	He	Ti
29	He	V
30	He	Cr
31	He	Mn
32	He	Fe
33	He	Co
34	He	Ni
35	He	Cu
36	He	Zn
37	He	Ga
38	He	Ge
39	He	Se
40	He	Zr
41	He	Nb
42	He	Mo
43	He	Pd
44	He	Ag
45	He	Cd
46	He	In
47	He	Sn
48	He	Sb
49	He	Te
50	He	Ta
51	He	W
52	He	Pt
53	He	Au
54	He	Pb

Notes

1) As for AN76, only the data on R_E of H ions incident on Pb and those of He ions incident on Si, Ag, Ta and Pb have been adopted. Other data have originally or revisedly appeared in SI76 and SO76.

2) The data from EC79 include those reported earlier in the following publications:
W. Eckstein and H. Verbeek: J. Nucl. Mater. 76 & 77 (1978) 365.
W. Eckstein, F. E. P. Matschke and H. Verbeek: J. Nucl. Mater. 63 (1976) 199.

3) As for the following sources, numerical data have been provided by courtesy of the authors: HI76, SC78, SI76 and SO76.

4) The following data have been collected after determining the values of constants in the empirical formulas: BO76, ST79, TH80 and the data for stainless steel from EC79.

5) Reference ST79 presents two sets of data obtained by the nuclear-reaction method and by the re-emission method. The set by the former method has not been included in the present compilation because of larger errors.

Table 1. R_N, R_E and r_E of H ions on $_6C$.

Energy (eV)	R_N	R_E	r_E
Data source: EC79			
1.5 E 03	1.03E-01	3.54E-02	3.44E-01
2.5 E 03	4.5 E-02	1.36E-02	3.03E-01
5.0 E 03	1.6 E-02	4.27E-03	2.67E-01
7.5 E 03	8.9 E-03	2.27E-03	2.55E-01
1.0 E 04	5.0 E-03	1.44E-03	2.87E-01

Table 2. R_N, R_E and r_E of H ions on $_{13}Al$.

Energy (eV)	R_N	R_E	r_E
Data source: SI76			
1.0 E 04	2.5 E-02	4.3 E-03	1.75E-01
1.5 E 04	2.0 E-02	3.1 E-03	1.55E-01
2.0 E 04	1.1 E-02	1.9 E-03	1.72E-01
3.0 E 04	5.3 E-03	1.0 E-03	1.89E-01

Table 3. R_N, R_E and r_E of H ions on $_{14}Si$.

Energy (eV)	R_N	R_E	r_E
Data source: EC79			
5.0 E 03	3.0 E-02	8.42E-03	2.81E-01

Table 4. R_N, R_E and r_E of H ions on $_{22}Ti$.

Energy (eV)	R_N	R_E	r_E
Data source: BO76			
1.0 E 03	2.2 E-01		
1.3 E 03	1.8 E-01		
1.7 E 03	1.8 E-01		
2.0 E 03	1.4 E-01		
3.0 E 03	9. E-02		
4.0 E 03	6. E-02		
5.0 E 03	4. E-02		
6.0 E 03	4.5 E-02		
8.0 E 03	4. E-02		
Data source: EC79			
6.67E 02	4. E-01	1.34E-01	3.34E-01
2.5 E 03	1.15E-01	4.37E-02	3.80E-01
5.0 E 03	7.0 E-02	2.36E-02	3.37E-01
1.0 E 04	3.3 E-02	9.77E-03	2.96E-01

Table 5. R_N, R_E and r_E of H ions on $_{26}Fe$.

Energy (eV)	R_N	R_E	r_E
Data source: EC79 (data for stainless steel)			
2.5 E 03	1.63E-01	6.30E-02	3.86E-01
5.0 E 03	1.10E-01	3.72E-02	3.38E-01
7.5 E 03	7.9 E-02	2.7 E-02	3.40E-01
1.0 E 04	6.5 E-02	2.0 E-02	3.11E-01
1.25E 04	5.7 E-02		
1.5 E 04	4.1 E-02	1.2 E-02	3.01E-01
Data source: SI76 (data for stainless steel)			
1.0 E 04	6.9 E-02	1.47E-02	2.21E-01
1.5 E 04	4.9 E-02	1.01E-02	2.07E-01
2.0 E 04	4.0 E-02	7.0 E-03	1.81E-01
3.0 E 04	2.5 E-02	3.4 E-03	1.90E-01

Table 6. R_N, R_E and r_E of H ions on $_{28}Ni$.

Energy (eV)	R_N	R_E	r_E
Data source: EC79			
1.5 E 03	1.59E-01	7.12E-02	4.48E-01
5.0 E 03	1.37E-01	4.88E-02	3.56E-01
7.5 E 03	9.0 E-02	3.08E-02	3.42E-01
1.0 E 04	8.5 E-02	3.02E-02	3.55E-01
1.5 E 04	3.7 E-02	1.12E-02	3.04E-01

Table 7. R_N, R_E and r_E of H ions on $_{29}Cu$.

Energy (eV)	R_N	R_E	r_E
Data source: SI76			
5. E 03	1.40E-01	3.76E-02	
7.5 E 03	1.05E-01	2.75E-02	
1.0 E 04	8.5 E-02	2.01E-02	2.27E-01
1.5 E 04	6.4 E-02	1.33E-02	1.99E-01
2.0 E 04	5.2 E-02	1.02E-02	1.96E-01
3.0 E 04	3.3 E-02	6.0 E-03	1.98E-01

Table 8. R_N, R_E and r_E of H ions on $_{40}Zr$.

Energy (eV)	R_N	R_E	r_E
Data source: BO76			
2.0 E 03	2.9 E-01		
3.0 E 03	1.9 E-01		
4.0 E 03	1.6 E-01		
6.0 E 03	1.3 E-01		
8.0 E 03	6. E-02		

Table 9. R_N, R_E and r_E of H ions on $_{41}$Nb.

Energy (eV)	R_N	R_E	r_E
Data source: EC79			
5.0 E 03	1.05E-01	4.34E-02	4.13E-01
7.5 E 03	8.5 E-02	3.13E-02	3.68E-01
1.0 E 04	7.3 E-02	2.83E-02	3.87E-01
1.5 E 04	4.7 E-02	1.73E-02	3.68E-01
Data source: SI76			
1.0 E 04	7.21E-02	1.66E-02	2.30E-01
1.5 E 04	4.9 E-02	1.00E-02	2.10E-01
2.0 E 04	4.1 E-02	7.8 E-03	2.01E-01
3.0 E 04	2.7 E-02	4.8 E-03	1.89E-01
Data source: SO76			
1.00E 03		8.0 E-02	
1.34E 03		7.4 E-02	
1.67E 03		7.9 E-02	
2.00E 03		6.2 E-02	
2.66E 03		5.7 E-02	
3.00E 03		5.2 E-02	
3.33E 03		5.0 E-02	
4.00E 03		4.9 E-02	
4.50E 03		4.0 E-02	
5.00E 03		2.8 E-02	
6.00E 03		2.6 E-02	
7.00E 03		2.8 E-02	
8.00E 03		3.1 E-02	
9.00E 03		1.7 E-02	
1.00E 04		1.8 E-02	

Table 10. R_N, R_E and r_E of H ions on $_{42}$Mo.

Energy (eV)	R_N	R_E	r_E
Data source: EC79			
2.5 E 03	1.45E-01	6.21E-02	4.28E-01
5.0 E 03	1.09E-01	4.10E-02	3.76E-01
7.5 E 03	9.2 E-02	3.22E-02	3.50E-01
1.0 E 04	7.09E-02	2.37E-02	3.34E-01
1.5 E 04	5.2 E-02	1.59E-02	3.06E-01
Data source: SI76			
1.0 E 04	8.7 E-02	2.07E-02	2.43E-01
1.5 E 04	6.4 E-02	1.38E-02	1.95E-01
2.0 E 04	5.0 E-02	1.08E-02	2.15E-01
3.0 E 04	3.1 E-02	6.2 E-03	2.04E-01

Table 11. R_N, R_E and r_E of H ions on ${}_{47}Ag$.

Energy (eV)	R_N	R_E	r_E
Data source: SI76			
1.0 E 04	1.34E-01	3.10E-02	2.36E-01
1.5 E 04	1.00E-01	2.13E-02	2.07E-01
2.0 E 04	7.9 E-02	1.54E-02	2.01E-01
3.0 E 04	4.8 E-02	9.4 E-03	2.10E-01
Data source: SO76			
1.5 E 03		1.16E-01	
2.0 E 03		1.08E-01	
2.6 E 03		1.01E-01	
3.0 E 03		8.5 E-02	
3.3 E 03		8.7 E-02	
4.0 E 03		6.6 E-02	
5.0 E 03		5.8 E-02	
6.0 E 03		5.0 E-02	

Table 12. R_N, R_E and r_E of H ions on ${}_{73}Ta$.

Energy (eV)	R_N	R_E	r_E
Data source: SI76			
1.0 E 04	1.32E-01	3.30E-02	2.54E-01
1.5 E 04	1.01E-01	2.50E-02	2.48E-01
2.0 E 04	8.7 E-02	1.88E-02	2.24E-01
3.0 E 04	5.1 E-02	1.25E-02	2.44E-01

Table 13. R_N, R_E and r_E of H ions on $_{74}W$.

Energy (eV)	R_N	R_E	r_E
Data source: EC79			
5.0 E 03	1.68E-01	7.06E-02	4.20E-01
7.5 E 03	1.65E-01	6.60E-02	4.00E-01
1.0 E 04	1.23E-01	4.67E-02	3.80E-01
1.25E 04	1.19E-01	4.46E-02	3.75E-01
1.5 E 04	1.07E-01	3.85E-02	3.60E-01

Table 14. R_N, R_E and r_E of H ions on $_{79}Au$.

Energy (eV)	R_N	R_E	r_E
Data source: EC79			
2.5 E 03	3.20E-01	1.37E-01	4.28E-01
5.0 E 03	2.51E-01	9.74E-02	3.88E-01
8.0 E 03	1.97E-01	7.50E-02	3.81E-01
9.0 E 03	2.11E-01	7.42E-02	3.52E-01
1.0 E 04	2.07E-01	7.35E-02	3.55E-01
1.6 E 04	1.34E-01	4.45E-02	3.32E-01

Table 14 (Çontinued).

Energy (eV)	R_N	R_E	r_E
Data source: SI76			
5.0 E 03	3.10E-01	9.5 E-02	3.30E-01
7.5 E 03	2.70E-01	7.5 E-02	3.12E-01
1.0 E 04	2.30E-01	6.09E-02	2.70E-01
1.5 E 04	1.90E-01	4.33E-02	2.60E-01
2.0 E 04	1.55E-01	3.50E-02	2.25E-01
2.5 E 04	1.35E-01	3.10E-02	2.10E-01
3.0 E 04	1.25E-01	2.55E-02	2.00E-01
4.0 E 04	9.9 E-02	1.96E-02	1.99E-01
5.0 E 04	8.4 E-02	1.51E-02	1.79E-01
Data source: SO76			
1.17E 03		1.55E-01	
1.33E 03		1.44E-01	
1.67E 03		1.43E-01	
1.75E 03		1.18E-01	
2.00E 03		1.38E-01	
2.33E 03		1.17E-01	
2.51E 03		1.40E-01	
3.00E 03		1.20E-01	
3.3 E 03		1.13E-01	
3.51E 03		1.09E-01	
4.51E 03		8.9 E-02	
5.00E 03		8.1 E-02	
6.02E 03		7.4 E-02	
7.00E 03		7.0 E-02	
8.00E 03		7.4 E-02	
9.00E 03		5.8 E-02	
1.00E 04		5.6 E-02	
Data source: VE80			
5.0 E 03	2.17E-01	9.2 E-02	4.22E-01
8.0 E 03	1.74E-01	7.0 E-02	4.0 E-01

Table 15. R_N, R_E and r_E of H ions on $_{82}Pb$.

Energy (eV)	R_N	R_E	r_E
Data source: AN76			
3.0 E 04		2.3 E-02	
3.5 E 04		1.7 E-02	
4.0 E 04		1.9 E-02	
4.5 E 04		1.7 E-02	
4.5 E 04		1.4 E-02	
5.0 E 04		1.3 E-02	
5.7 E 04		1.06E-02	
5.7 E 04		9.7 E-03	
6.0 E 04		1.07E-02	
6.0 E 04		1.22E-02	
6.2 E 04		9.7 E-03	
6.5 E 04		1.17E-02	

Table 16. R_N, R_E and r_E of D ions on $_6C$.

Energy (eV)	R_N	R_E	r_E
Data source: EC79			
2.5 E 03	5.5 E-02	2.09E-02	3.79E-01
5.0 E 03	1.8 E-02	6.25E-03	3.47E-01
7.5 E 03	1.4 E-02	3.82E-03	2.73E-01
Data source: ST79			
5.0 E 01	2.6 E-01		
1.0 E 02	1.6 E-01		
2.5 E 02	1.2 E-01		
5.0 E 02	1.2 E-01		
1.0 E 03	7. E-02		

Table 17. R_N, R_E and r_E of D ions on $_{22}Ti$.

Energy (eV)	R_N	R_E	r_E
Data source: EC79			
6.67E 02	1.8 E-01	7.69E-02	4.27E-01
2.5 E 03	1.35E-01	5.81E-02	4.30E-01
5.0 E 03	8.4 E-02	3.26E-02	3.88E-01
7.5 E 03	5.6 E-02	1.85E-02	3.31E-01
1.0 E 04	5.2 E-02	1.68E-02	3.24E-01
1.5 E 04	2.4 E-02	7.98E-03	3.32E-01

Table 18. R_N, R_E and r_E of D ions on $_{26}Fe$.

Energy (eV)	R_N	R_E	r_E
Data source: EC79 (data for stainless steel)			
2.5 E 03	2.26E-01		
5.0 E 03	1.12E-01	4.90E-02	4.37E-01
7.5 E 03	1.05E-01		
Data source: TH80 (data for stainless steel)			
1.25E 02	5.0 E-01		
2.5 E 02	4.2 E-01		
5.0 E 02	4.0 E-01		
7.0 E 02	3.7 E-01		
1.0 E 03	3.2 E-01		

Table 19. R_N, R_E and r_E of D ions on $_{28}Ni$.

Energy (eV)	R_N	R_E	r_E
Data source: EC79			
2.5 E 03	1.69E-01	7.81E-02	4.62E-01
5.0 E 03	1.30E-01	5.37E-02	4.13E-01
7.5 E 03	9.8 E-02	3.53E-02	3.60E-01
1.0 E 04	8.5 E-02	3.09E-02	3.63E-01
1.5 E 04	6.4 E-02	2.18E-02	3.40E-01

Table 20. R_N, R_E and r_E of D ions on $_{41}$Nb.

Energy (eV)	R_N	R_E	r_E
Data source: EC79			
2.5 E 03	2.21E-01	8.14E-02	3.68E-01
5.0 E 03	1.69E-01	5.15E-02	3.05E-01

Table 21. R_N, R_E and r_E of D ions on $_{42}$Mo.

Energy (eV)	R_N	R_E	r_E
Data source: EC79			
2.5 E 03	1.29E-01	5.78E-02	4.48E-01
5.0 E 03	1.12E-01	4.27E-02	3.81E-01
7.5 E 03	1.09E-01	3.82E-02	3.50E-01
1.0 E 04	8.4 E-02	2.89E-02	3.44E-01
1.5 E 04	6.1 E-02	1.99E-02	3.27E-01

Table 22. R_N, R_E and r_E of D ions on $_{74}$W.

Energy (eV)	R_N	R_E	r_E
Data source: EC79			
5.0 E 03	2.11E-01	9.03E-02	4.28E-01
7.5 E 03	1.93E-01	7.97E-02	4.13E-01
1.0 E 04	1.74E-01	6.68E-02	3.84E-01
1.5 E 04	1.31E-01	4.64E-02	3.54E-01

Table 23. R_N, R_E and r_E of D ions on $_{79}Au$.

Energy (eV)	R_N	R_E	r_E
Data source: SO76			
3.17E 03		1.30E-01	

Table 24. R_N, R_E and r_E of He ions on $_6C$.

Energy (eV)	R_N	R_E	r_E
Data source: HI76			
1.2 E 04		7. E-03	
1.45E 04		5.5 E-03	

Table 25. R_N, R_E and r_E of He ions on $_{12}Mg$.

Energy (eV)	R_N	R_E	r_E
Data source: HI76			
1.2 E 04		8. E-03	
1.45E 04		6. E-03	

Table 26. R_N, R_E and r_E of He ions on $_{13}Al$.

Energy (eV)	R_N	R_E	r_E
Data source: HI76			
1.2 E 04		8. E-03	
1.45E 04		6. E-03	

Table 27. R_N, R_E and r_E of He ions on $_{14}Si$.

Energy (eV)	R_N	R_E	r_E
Data source: AN76			
2.5 E 04		6.7 E-03	
3.0 E 04		5.0 E-03	
3.5 E 04		5.5 E-03	
4.0 E 04		4.6 E-03	
5.0 E 04		4.0 E-03	
5.5 E 04		4.9 E-03	
6.0 E 04		5.3 E-03	
6.0 E 04		5.0 E-03	
7.0 E 04		2.8 E-03	
Data source: HI76			
1.2 E 04		8.5 E-03	
1.45E 04		6.5 E-03	

Table 28. R_N, R_E and r_E of He ions on $_{22}Ti$.

Energy (eV)	R_N	R_E	r_E
Data source: EC79			
5.0 E 03	1.4 E-01		
1.0 E 04	9.0 E-02	2.96E-02	3.29E-01
1.5 E 04	7.0 E-02	2.31E-02	3.30E-01
Data source: HI76			
1.2 E 04		1.5 E-02	
1.45E 04		1.2 E-02	

Table 29. R_N, R_E and r_E of He ions on $_{23}V$.

Energy (eV)	R_N	R_E	r_E
Data source: HI76			
1.2 E 04		2.1 E-02	
1.45E 04		1.65E-02	

Table 30. R_N, R_E and r_E of He ions on $_{24}Cr$.

Energy (eV)	R_N	R_E	r_E
Data source: HI76			
1.2 E 04		2.0 E-02	
1.45E 04		1.55E-02	

Table 31. R_N, R_E and r_E of He ions on $_{25}Mn$.

Energy (eV)	R_N	R_E	r_E
Data source: HI76			
1.2 E 04		2.3 E-02	
1.45E 04		1.9 E-02	

Table 32. R_N, R_E and r_E of He ions on $_{26}Fe$.

Energy (eV)	R_N	R_E	r_E
Data source: HI76			
1.2 E 04		2.3 E-02	
1.45E 04		1.85E-02	

Table 33. R_N, R_E and r_E of He ions on $_{27}Co$.

Energy (eV)	R_N	R_E	r_E
Data source: HI76			
1.2 E 04		3.0 E-02	
1.45E 04		2.5 E-02	

Table 34. R_N, R_E and r_E of He ions on $_{28}Ni$.

Energy (eV)	R_N	R_E	r_E
Data source: HI76			
1.2 E 04		3.35E-02	
1.45E 04		2.85E-02	

Table 35. R_N, R_E and r_E of He ions on $_{29}Cu$.

Energy (eV)	R_N	R_E	r_E
Data source: HI76			
1.2 E 04		4.1 E-02	
1.45E 04		3.5 E-02	
Data source: SC78			
5.0 E 03		7.9 E-02	
6.0 E 03		7.6 E-02	
7.0 E 03		6.1 E-02	
8.0 E 03		5.6 E-02	
9.0 E 03		4.6 E-02	
1.0 E 04		3.9 E-02	

Table 36. R_N, R_E and r_E of He ions on $_{30}Zn$.

Energy (eV)	R_N	R_E	r_E
Data source: HI76			
1.2 E 04		4.25E-02	
1.45E 04		3.55E-02	

Table 37. R_N, R_E and r_E of He ions on $_{31}Ga$.

Energy (eV)	R_N	R_E	r_E
Data source: HI76			
1.2 E 04		3.2 E-02	
1.45E 04		2.8 E-02	

Table 38. R_N, R_E and r_E of He ions on $_{32}$Ge.

Energy (eV)	R_N	R_E	r_E
Data source: HI76			
1.2 E 04		3.55E-02	
1.45E 04		3.0 E-02	

Table 39. R_N, R_E and r_E of He ions on $_{34}$Se.

Energy (eV)	R_N	R_E	r_E
Data source: HI76			
1.2 E 04		3.65E-02	
1.45E 04		3.25E-02	

Table 40. R_N, R_E and r_E of He ions on $_{40}$Zr.

Energy (eV)	R_N	R_E	r_E
Data source: HI76			
1.2 E 04		2.65E-02	
1.45E 04		2.2 E-02	

Table 41. R_N, R_E and r_E of He ions on $_{41}$Nb.

Energy (eV)	R_N	R_E	r_E
Data source: HI76			
1.2 E 04		2.85E-02	
1.45E 04		2.4 E-02	

Table 42. R_N, R_E and r_E of He ions on $_{42}$Mo.

Energy (eV)	R_N	R_E	r_E
Data source: EC79			
5.0 E 03	1.02E-01	4.63E-02	4.54E-01
1.0 E 04	8.9 E-02	3.43E-02	3.85E-01
1.5 E 04	7.4 E-02	3.07E-02	4.15E-01
2.0 E 04	6.0 E-02	2.26E-02	3.76E-01
Data source: HI76			
1.2 E 04		3.85E-02	
1.45E 04		3.15E-02	

Table 43. R_N, R_E and r_E of He ions on $_{46}$Pd.

Energy (eV)	R_N	R_E	r_E
Data source: HI76			
1.2 E 04		5.0 E-02	
1.45E 04		4.4 E-02	

Table 44. R_N, R_E and r_E of He ions on $_{47}$Ag.

Energy (eV)	R_N	R_E	r_E
Data source: AN76			
1.8 E 04		2.9 E-02	
2.3 E 04		2.7 E-02	
2.8 E 04		2.8 E-02	
3.3 E 04		2.0 E-02	
3.8 E 04		1.73E-02	
4.3 E 04		1.84E-02	
4.5 E 04		1.66E-02	
4.5 E 04		1.53E-02	
5.0 E 04		1.39E-02	
5.5 E 04		1.20E-02	
6.0 E 04		1.09E-02	
6.5 E 04		1.02E-02	
7.0 E 04		9.5 E-03	
7.5 E 04		8.5 E-03	
Data source: HI76			
1.2 E 04		5.9 E-02	
1.45E 04		4.9 E-02	
Data source: SC78			
4.0 E 03		1.31E-01	
4.5 E 03		1.25E-01	
5.0 E 03		1.20E-01	
6.0 E 03		1.12E-01	
7.0 E 03		1.02E-01	
8.0 E 03		9.2 E-02	
9.0 E 03		8.5 E-02	
1.0 E 04		7.6 E-02	

Table 45. R_N, R_E and r_E of He ions on $_{48}Cd$.

Energy (eV)	R_N	R_E	r_E
Data source: HI76			
1.2 E 04		5.4 E-02	
1.45E 04		4.6 E-02	

Table 46. R_N, R_E and r_E of He ions on $_{49}In$.

Energy (eV)	R_N	R_E	r_E
Data source: HI76			
1.2 E 04		4.7 E-02	
1.45E 04		4.0 E-02	

Table 47. R_N, R_E and r_E of He ions on $_{50}Sn$.

Energy (eV)	R_N	R_E	r_E
Data source: HI76			
1.2 E 04		4.4 E-02	
1.45E 04		3.9 E-02	

Table 48. R_N, R_E and r_E of He ions on $_{51}$Sb.

Energy (eV)	R_N	R_E	r_E
Data source: HI76			
1.2 E 04		4.5 E-02	
1.45E 04		4.0 E-02	

Table 49. R_N, R_E and r_E of He ions on $_{52}$Te.

Energy (eV)	R_N	R_E	r_E
Data source: HI76			
1.2 E 04		4.4 E-02	
1.45E 04		3.7 E-02	

Table 50. R_N, R_E and r_E of He ions on $_{73}$Ta.

Energy (eV)	R_N	R_E	r_E
Data source: AN76			
3.0 E 04		2.7 E-02	
3.5 E 04		2.5 E-02	
4.0 E 04		2.3 E-02	
4.5 E 04		2.3 E-02	
4.5 E 04		2.2 E-02	
5.0 E 04		2.2 E-02	
5.5 E 04		2.1 E-02	
6.0 E 04		2.1 E-02	
6.5 E 04		1.98E-02	
7.0 E 04		1.82E-02	
7.5 E 04		1.72E-02	
8.0 E 04		1.60E-02	
Data source: HI76			
1.2 E 04		5.3 E-02	
1.45E 04		4.6 E-02	

Table 51. R_N, R_E and r_E of He ions on $_{74}$W.

Energy (eV)	R_N	R_E	r_E
Data source: EC79			
5.0 E 03	1.82E-01	8.87E-02	4.88E-01
1.0 E 04	1.59E-01	7.23E-02	4.55E-01
1.5 E 04	1.37E-01	6.62E-02	4.83E-01
2.0 E 04	1.25E-01	5.25E-02	4.20E-01
Data source: HI76			
1.2 E 04		5.9 E-02	
1.45E 04		5.1 E-02	

Table 52. R_N, R_E and r_E of He ions on $_{78}$Pt.

Energy (eV)	R_N	R_E	r_E
Data source: HI76			
1.2 E 04		5.9 E-02	
1.45E 04		5.0 E-02	

Table 53. R_N, R_E and r_E of He ions on $_{79}$Au.

Energy (eV)	R_N	R_E	r_E
Data source: EC79			
5.0 E 03	1.40E-01		
1.0 E 04	1.35E-01	6.39E-02	4.73E-01
1.6 E 04	1.17E-01	5.27E-02	4.51E-01
Data source: HI76			
1.2 E 04		7.5 E-02	
1.45E 04		6.5 E-02	
Data source: SC78			
5.0 E 03		1.38E-01	
6.0 E 03		1.36E-01	
7.0 E 03		1.26E-01	
8.0 E 03		1.26E-01	
9.0 E 03		1.16E-01	
1.0 E 04		1.03E-01	
Data source: VE80			
1.0 E 04	1.34E-01		
1.6 E 04	1.11E-01	4.6 E-02	4.14E-01

Table 54. R_N, R_E and r_E of He ions on $_{82}Pb$.

Energy (eV)	R_N	R_E	r_E
Data source: AN76			
3.0 E 04		3.3 E-02	
3.5 E 04		2.9 E-02	
3.5 E 04		2.7 E-02	
4.0 E 04		2.7 E-02	
4.0 E 04		3.0 E-02	
4.5 E 04		2.6 E-02	
5.0 E 04		2.4 E-02	
5.5 E 04		2.1 E-02	
6.0 E 04		2.4 E-02	
6.5 E 04		1.8 E-02	
Data source: HI76			
1.2 E 04		8.1 E-02	
1.45E 04		7.0 E-02	

MAIN FIGURES

Dependence on energy of the number-backscattering coefficient R_N and the energy-backscattering coefficient R_E. Points represent experimental data, and curves show the empirical formulas of Tabata et al.*

The order in which each combination of the incident ions and the target elements appears is given in the following list. Sources of the data are shown by the use of abbreviations, and the corresponding references are listed in the alphabetical order at the end of this report.

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* For D ions incident on the targets with $Z_2 \gtrsim 74$ and He ions incident on the targets with $Z_2 \gtrsim 29$, the empirical formulas for R_N and R_E give erroneous values greater than unity at low energies. In such cases, the plot of these curves is made only for the region where the value is less than unity.

LIST OF TABLES / FIGURES FOR DATA

Table/Figure No.	Incident Ion	Target
1	H	C
2	H	Al
3	H	Si
4	H	Ti
5	H	Fe
6	H	Ni
7	H	Cu
8	H	Zr
9	H	Nb
10	H	Mo
11	H	Ag
12	H	Ta
13	H	W
14	H	Au
15	H	Pb
16	D	C
17	D	Ti
18	D	Fe
19	D	Ni
20	D	Nb
21	D	Mo
22	D	W
23	D	Au
24	He	C
25	He	Mg

Table/Figure No.	Incident Ion	Target
26	He	Al
27	He	Si
28	He	Ti
29	He	V
30	He	Cr
31	He	Mn
32	He	Fe
33	He	Co
34	He	Ni
35	He	Cu
36	He	Zn
37	He	Ga
38	He	Ge
39	He	Se
40	He	Zr
41	He	Nb
42	He	Mo
43	He	Pd
44	He	Ag
45	He	Cd
46	He	In
47	He	Sn
48	He	Sb
49	He	Te
50	He	Ta
51	He	W
52	He	Pt
53	He	Au
54	He	Pb

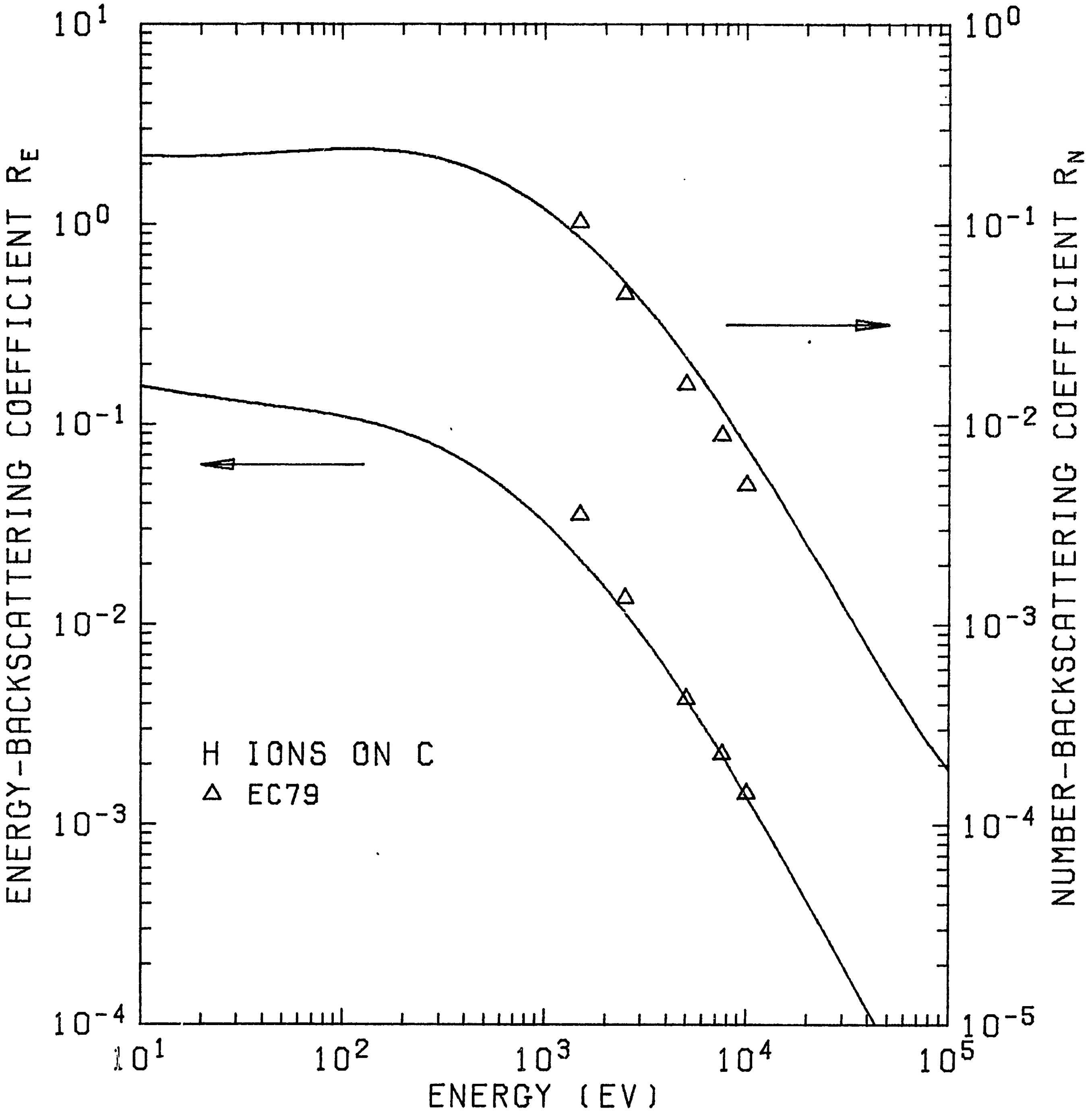

Fig. 1. R_N and R_E of H ions on $_6C$.

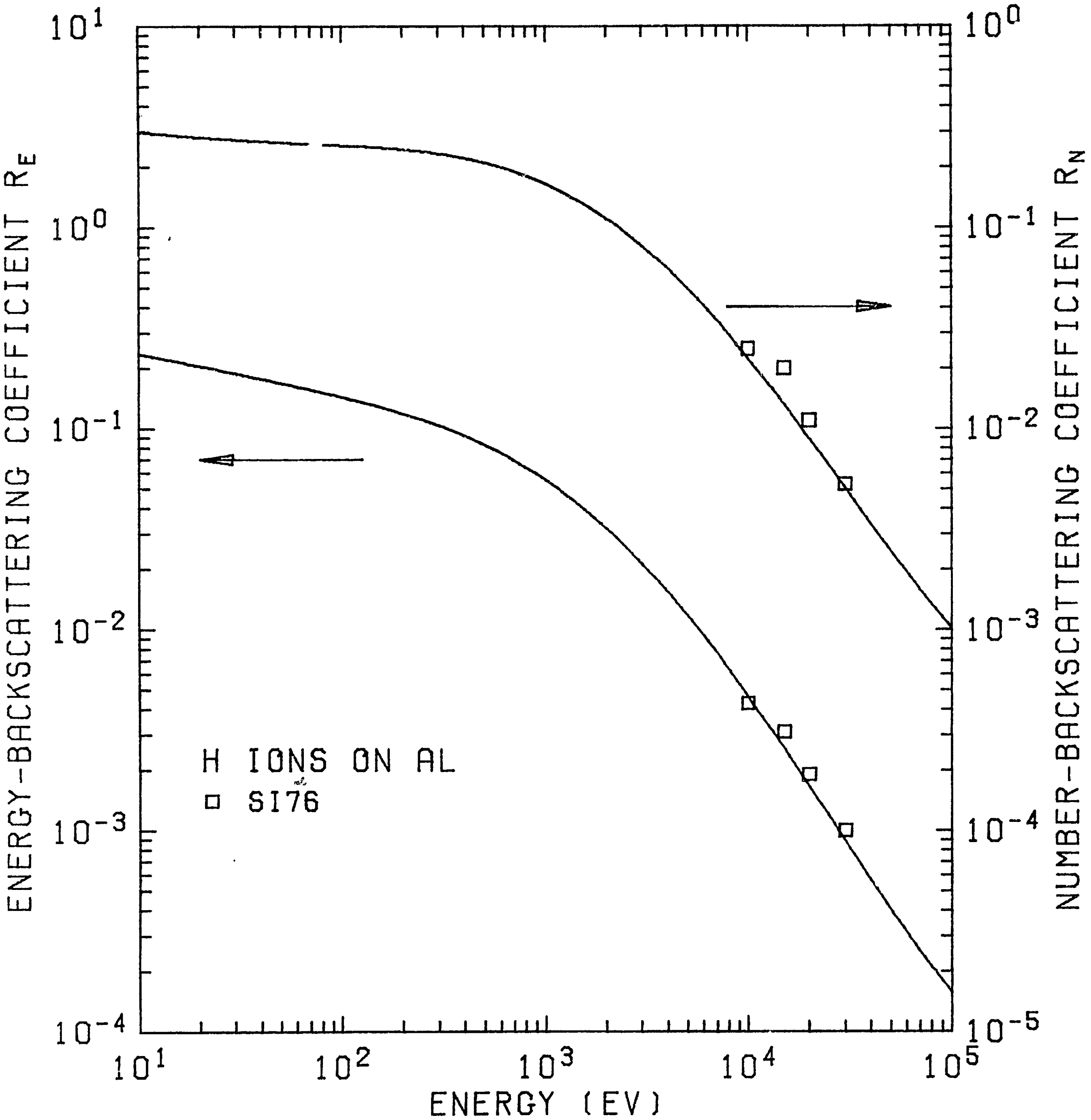

Fig. 2. R_N and R_E of H ions on $_{13}Al$.

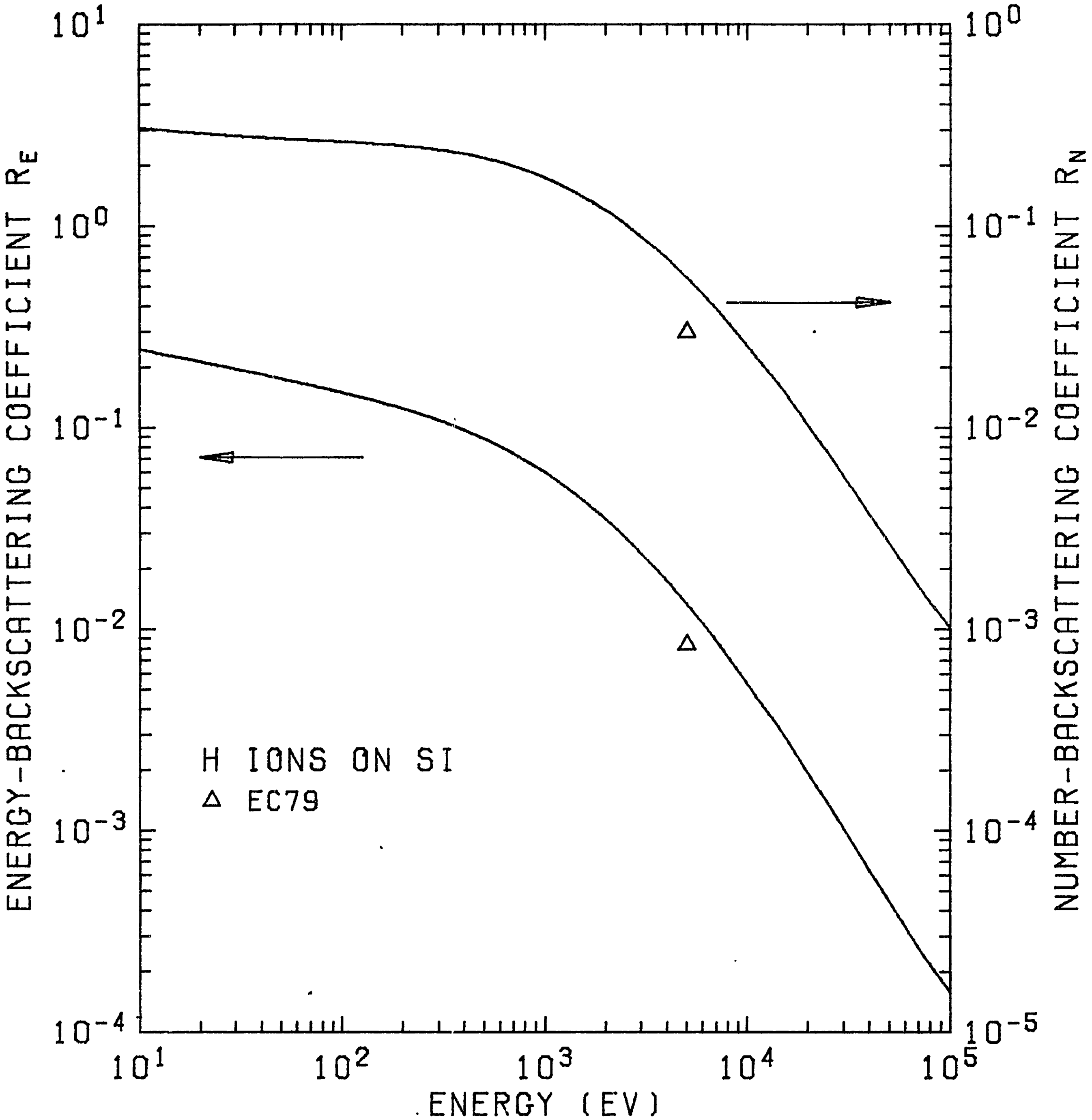

Fig. 3. R_N and R_E of H ions on $_{14}Si$.

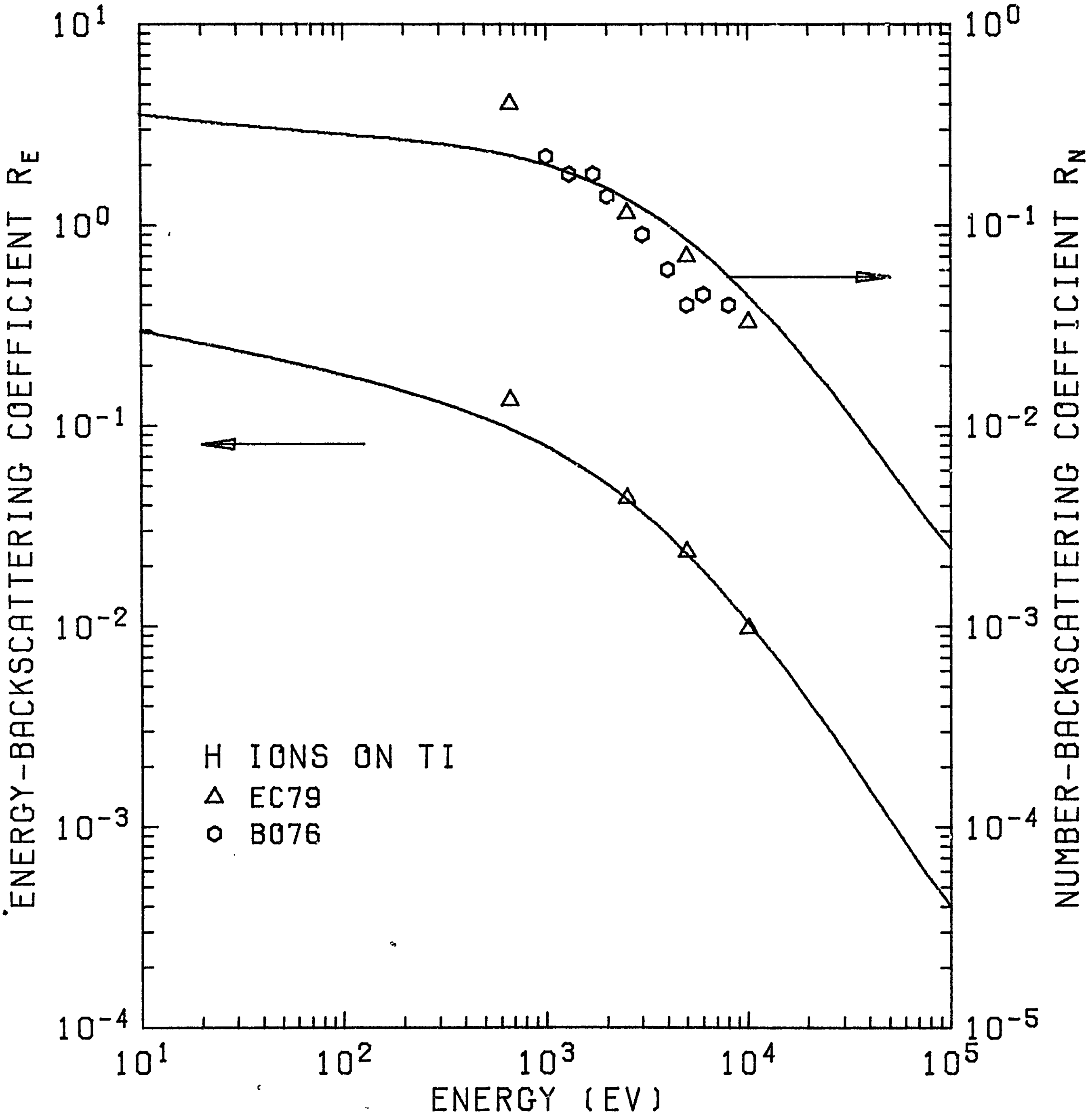

Fig. 4. R_N and R_E of H ions on $_{22}$Ti.

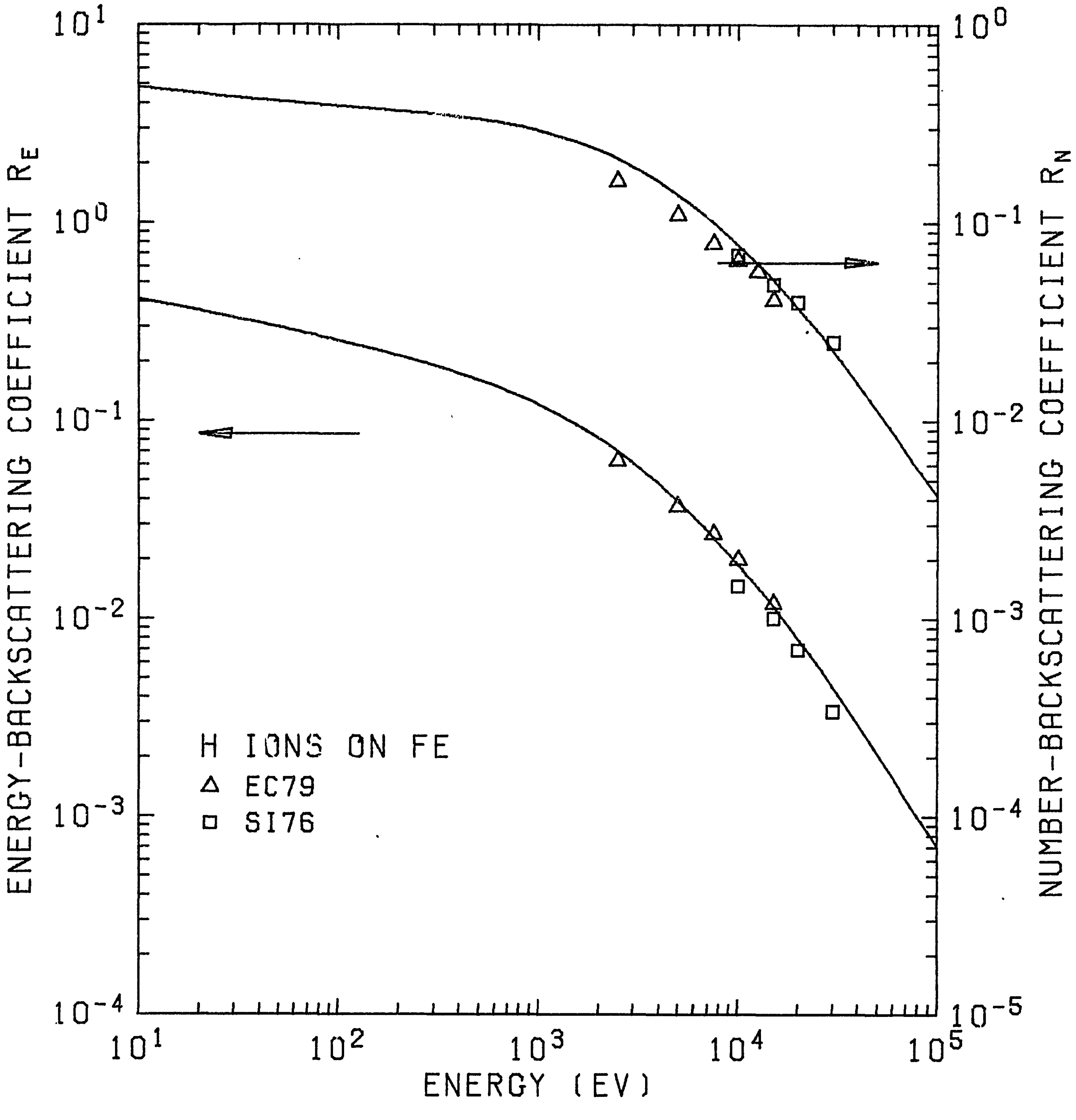

Fig. 5. R_N and R_E of H ions on $_{26}Fe$.

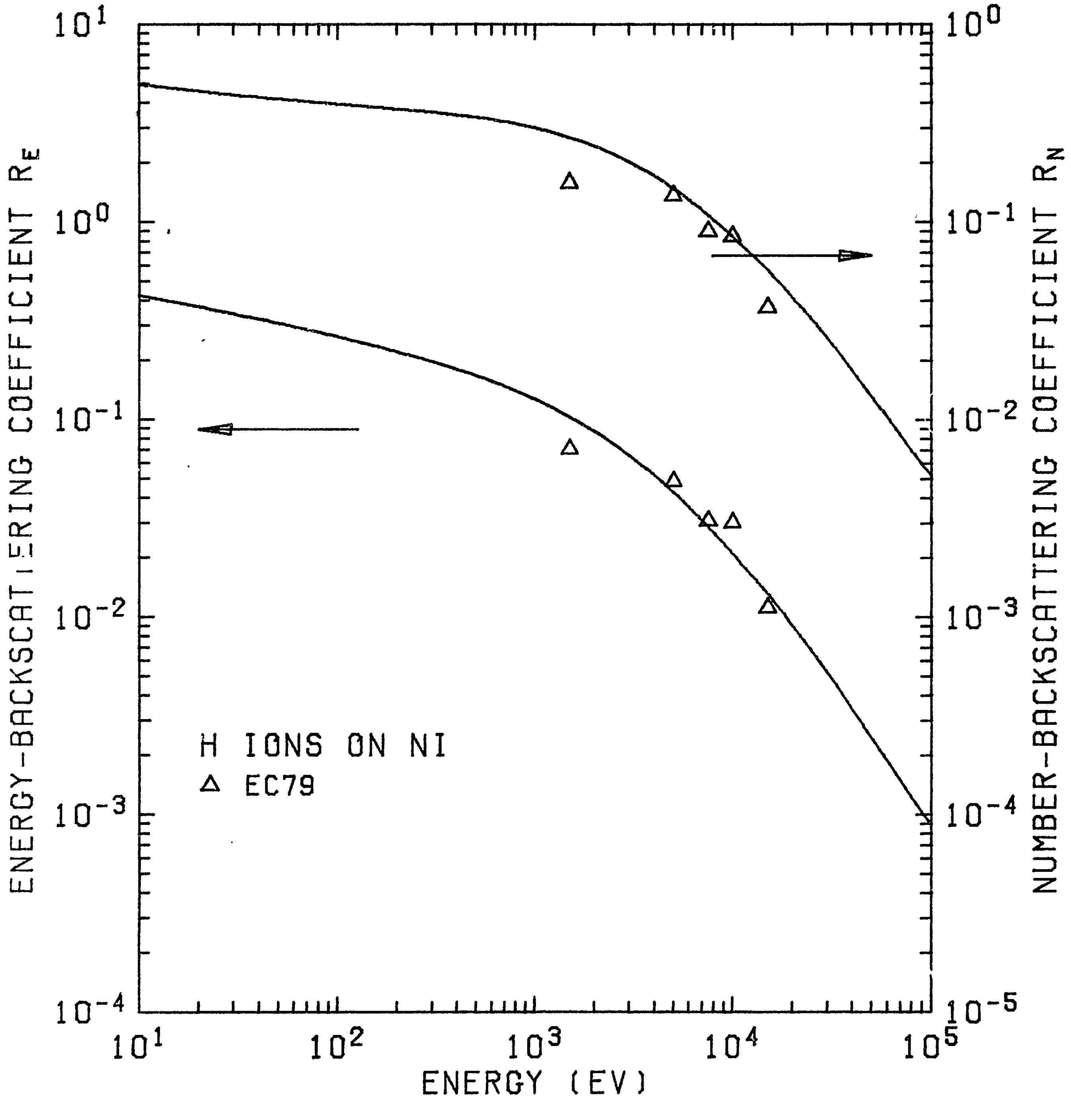

Fig. 6. R_N and R_E of H ions on $_{28}Ni$.

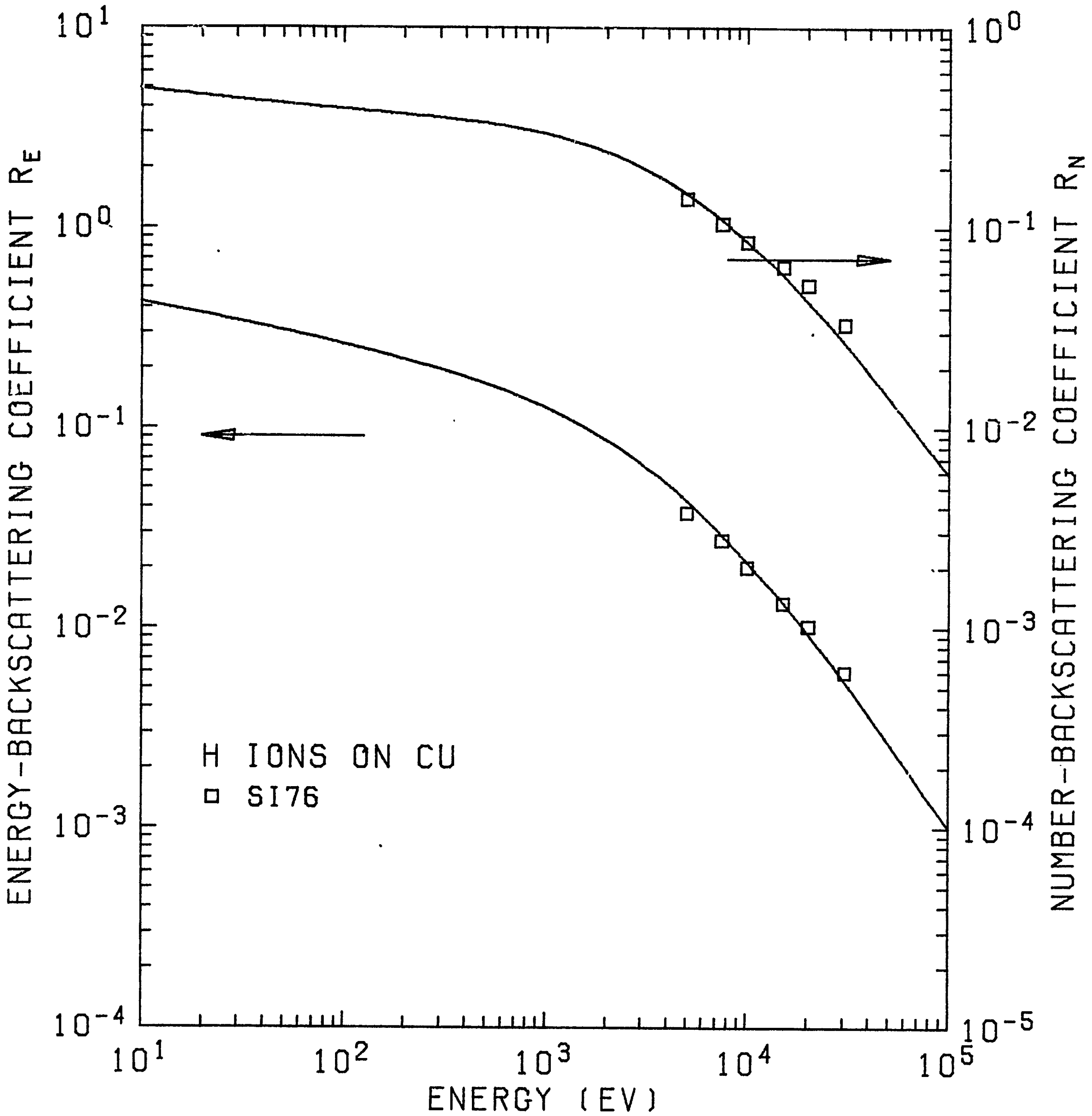

Fig. 7. R_N and R_E of H ions on $_{29}Cu$.

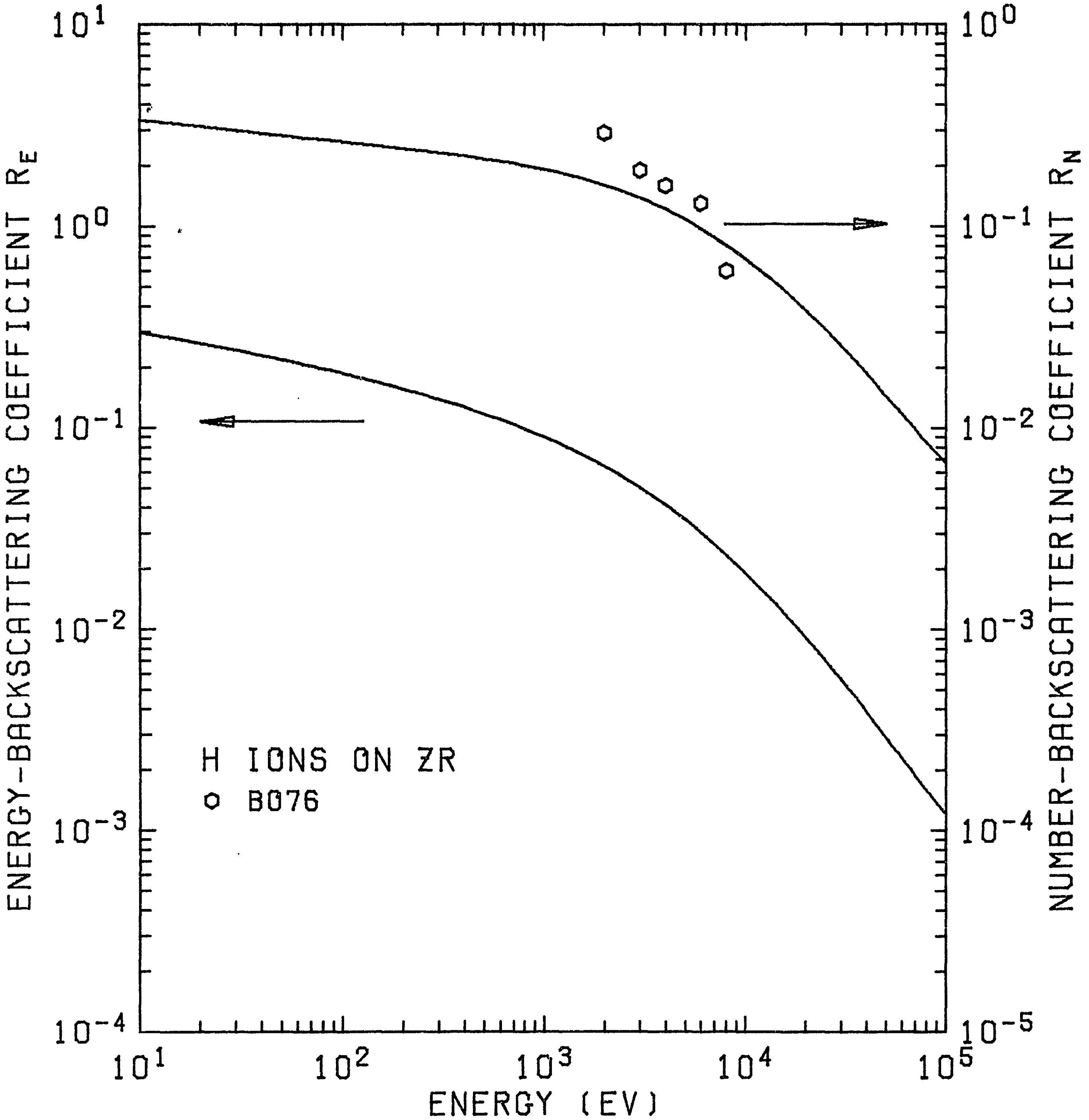

Fig. 8. R_N and R_E of H ions on $_{40}Zr$.

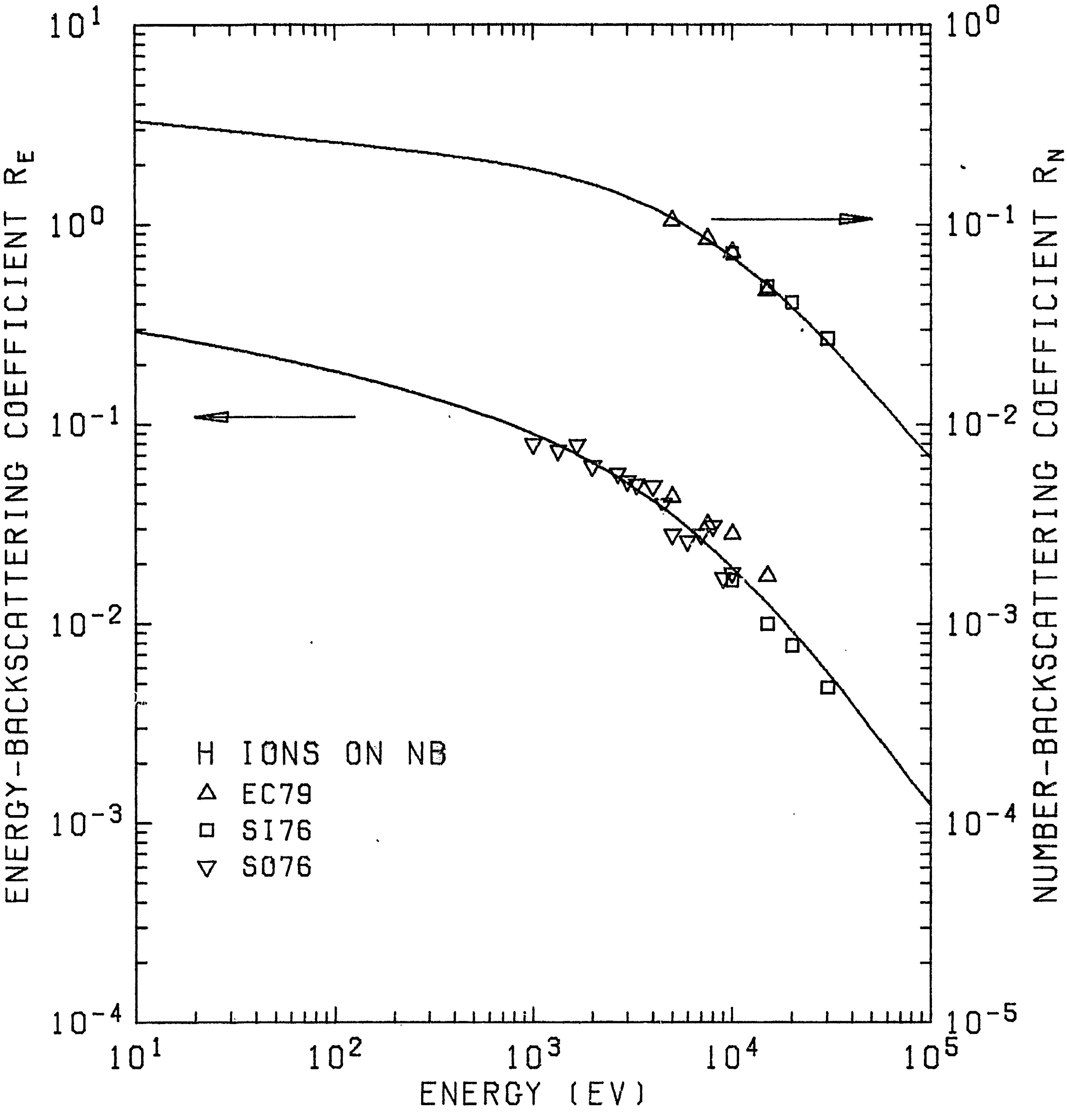

Fig. 9. R_N and R_E of H ions on $_{41}$Nb.

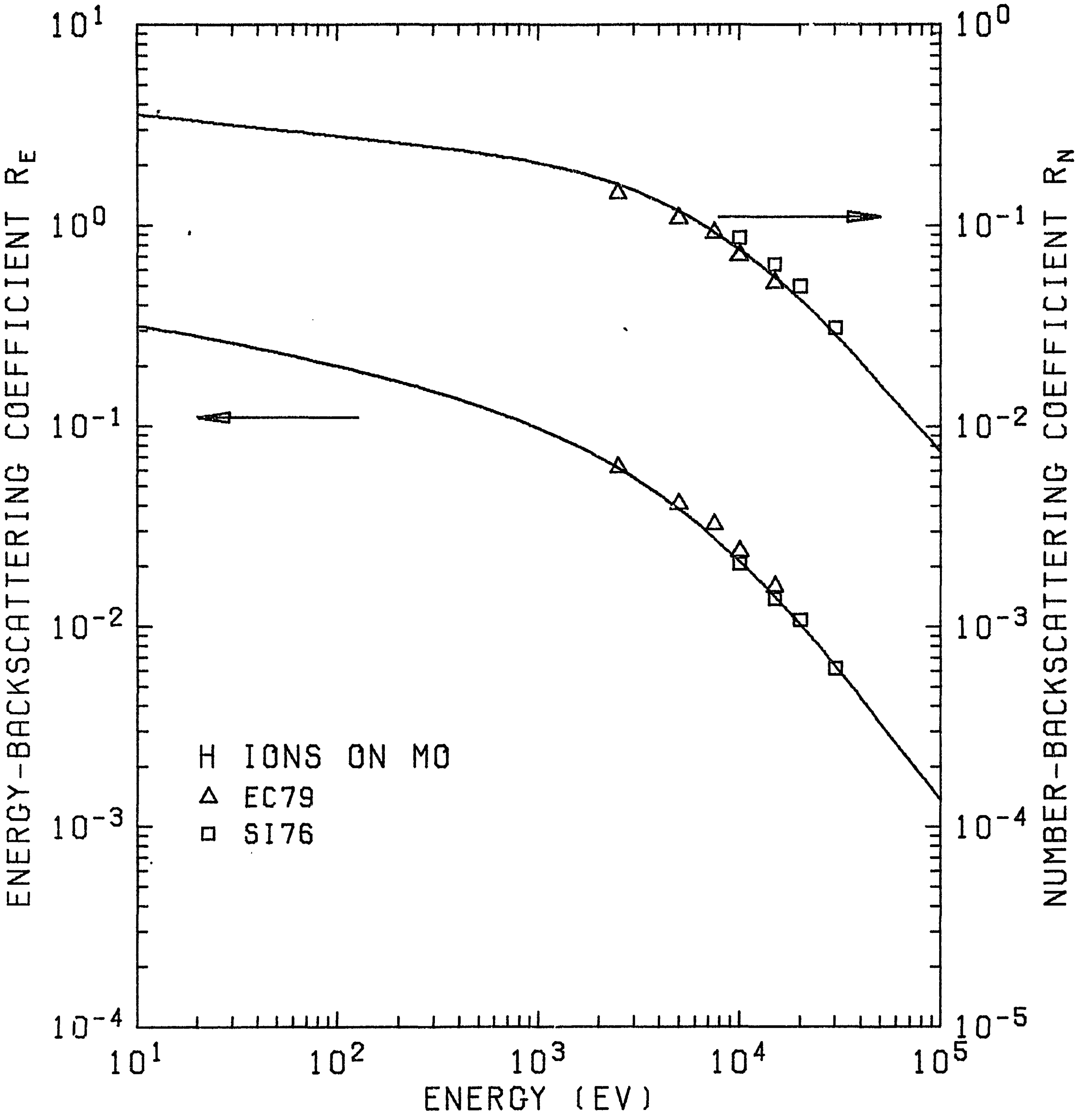

Fig. 10. R_N and R_E of H ions on $_{42}$Mo.

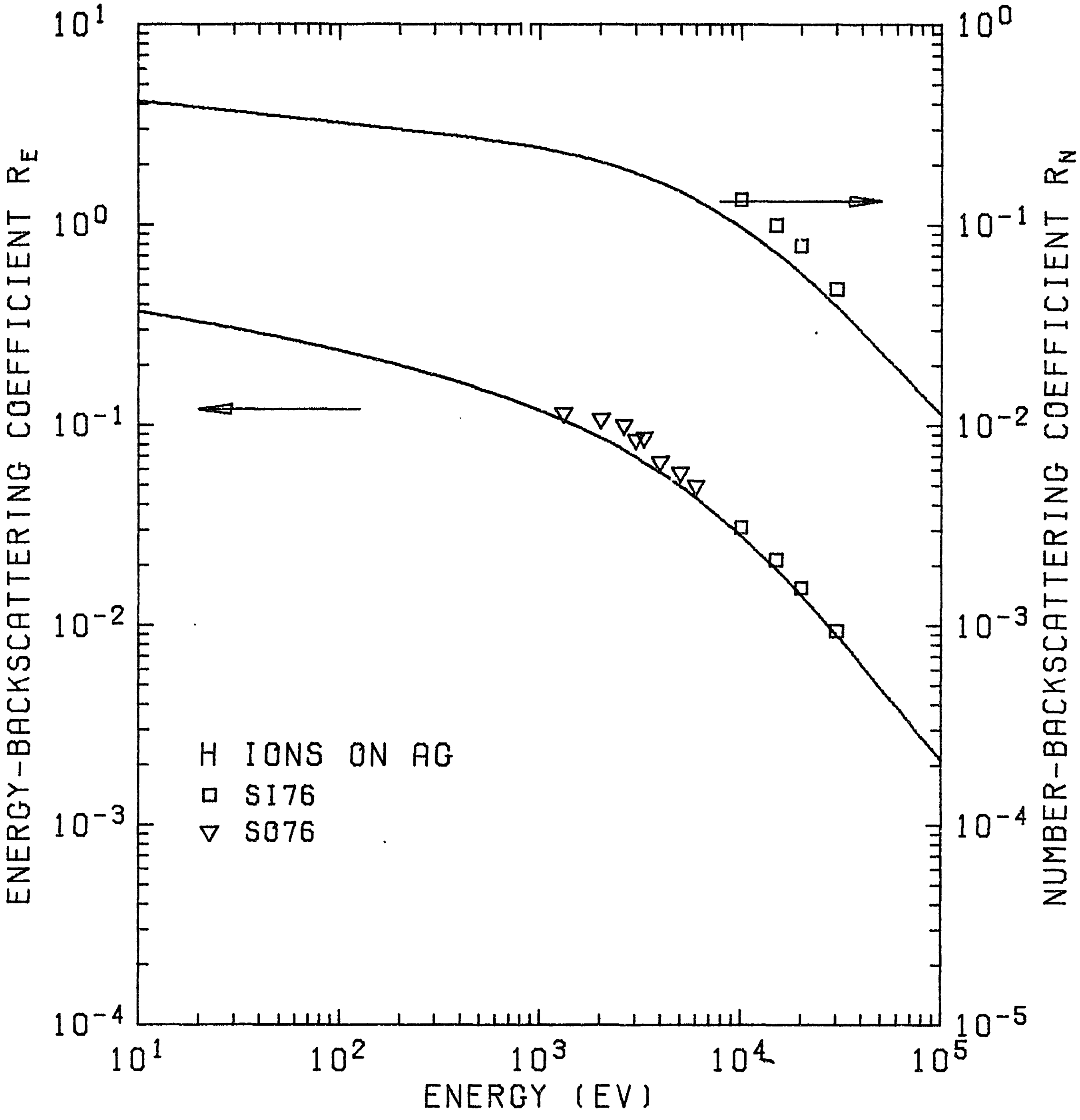

Fig. 11. R_N and R_E of H ions on $_{47}Ag$.

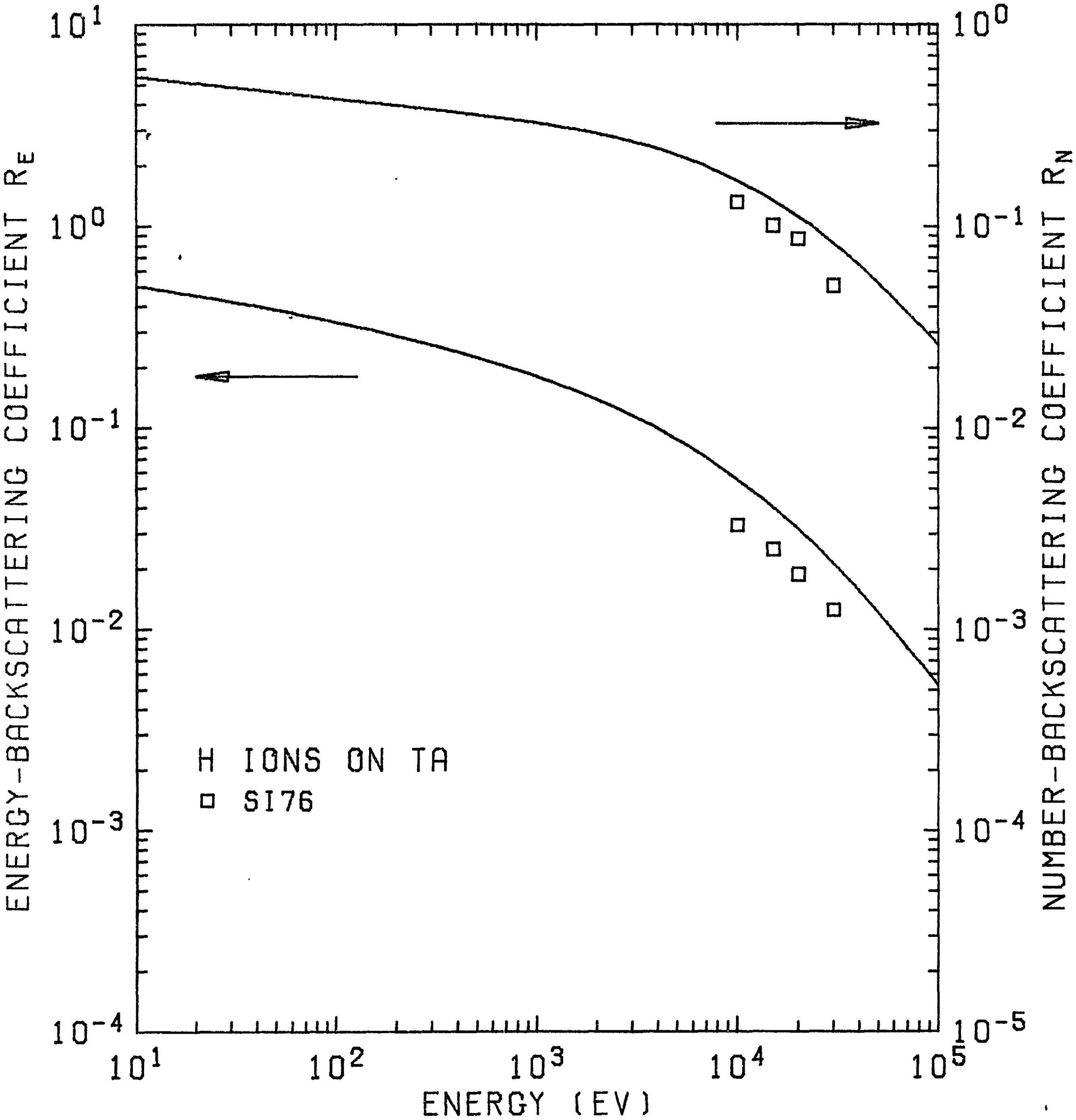

Fig. 12. R_N and R_E of H ions on $_{73}Ta$.

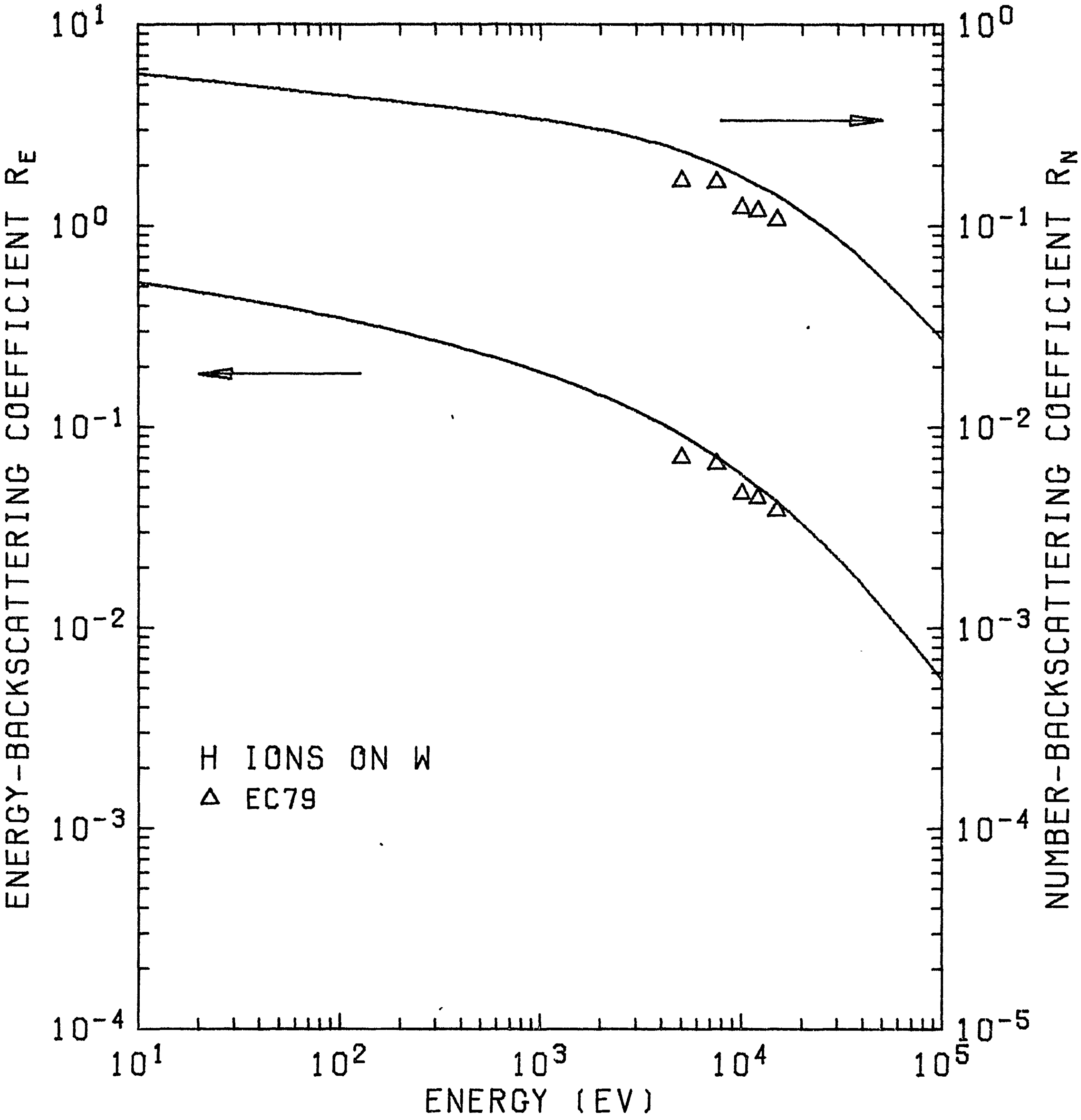

Fig. 13. R_N and R_E of H ions on $_{74}W$.

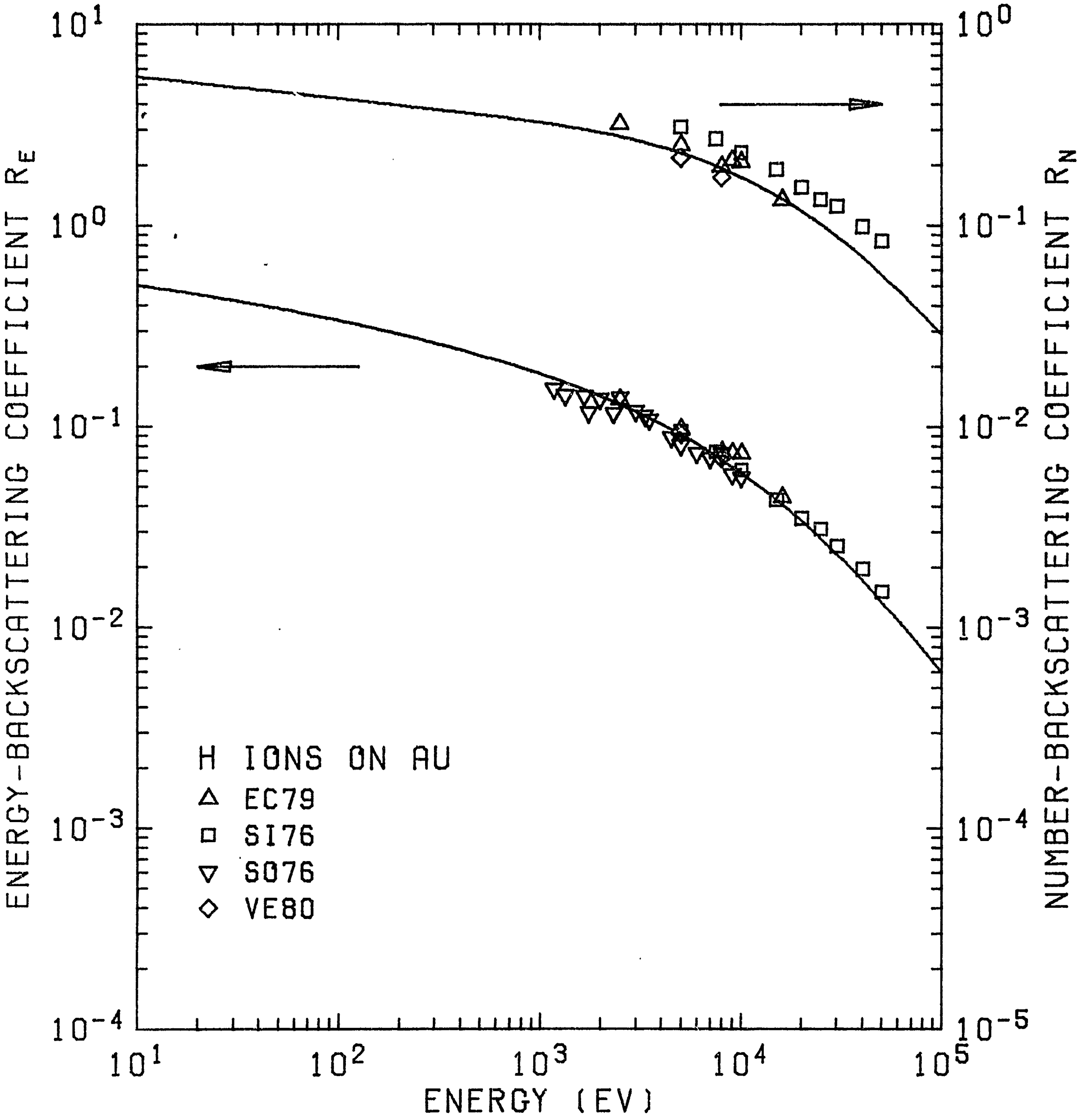

Fig. 14. R_N and R_E of H ions on $_{79}$Au.

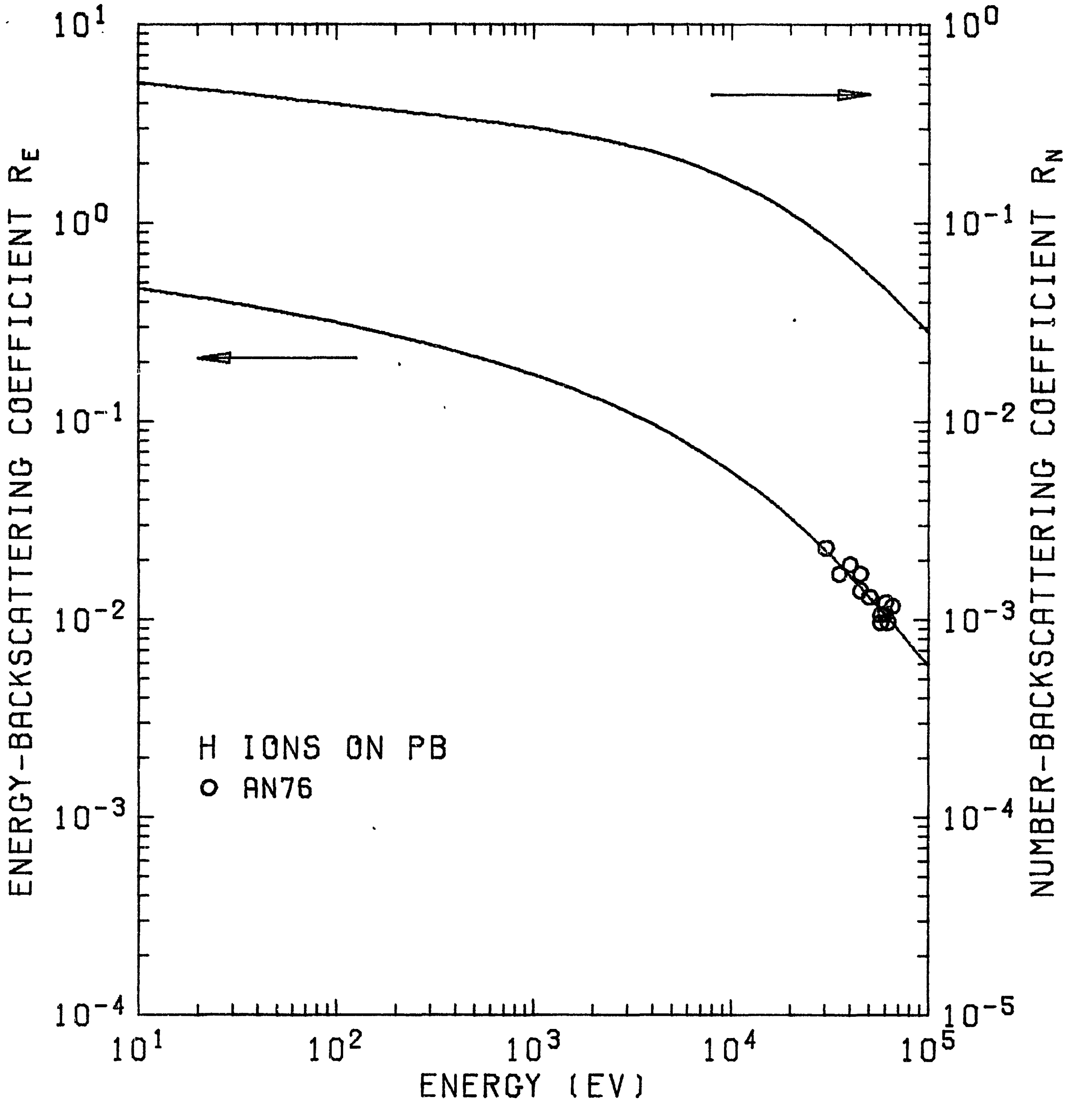

Fig. 15. R_N and R_E of H ions on $_{82}Pb$.

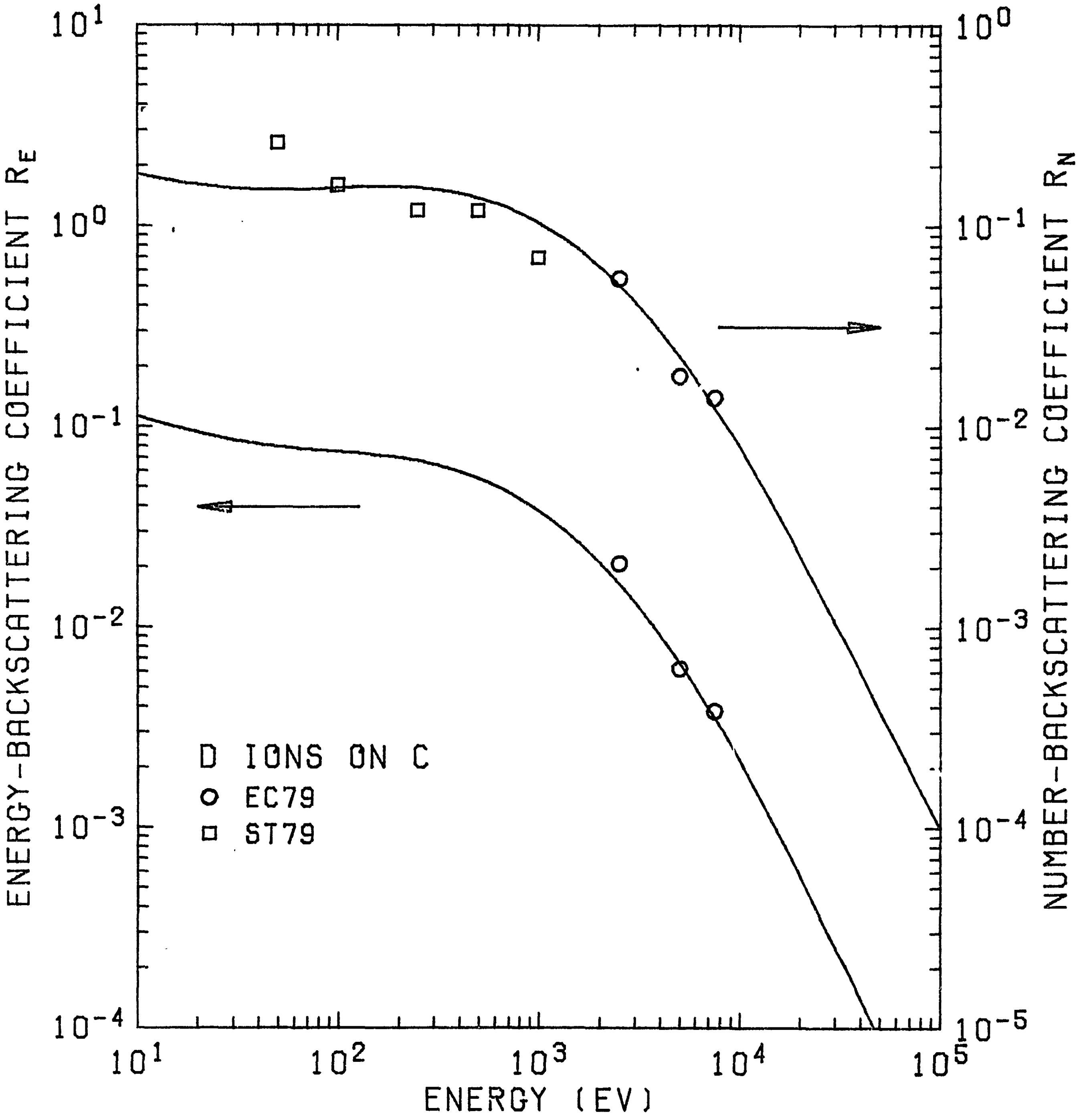

Fig. 16. R_N and R_E of D ions on $_6C$.

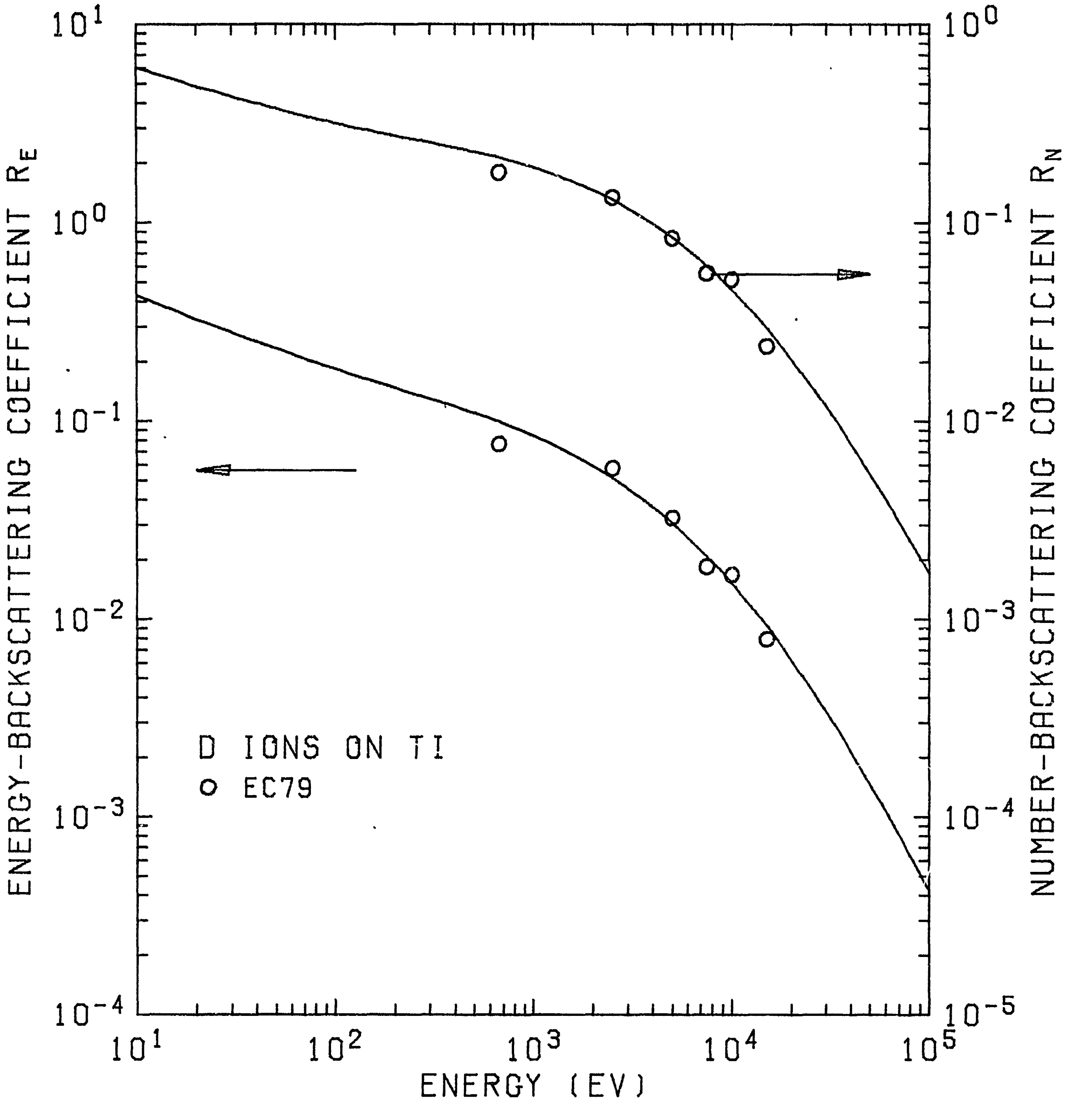

Fig. 17. R_N and R_E of D ions on $_{22}Ti$.

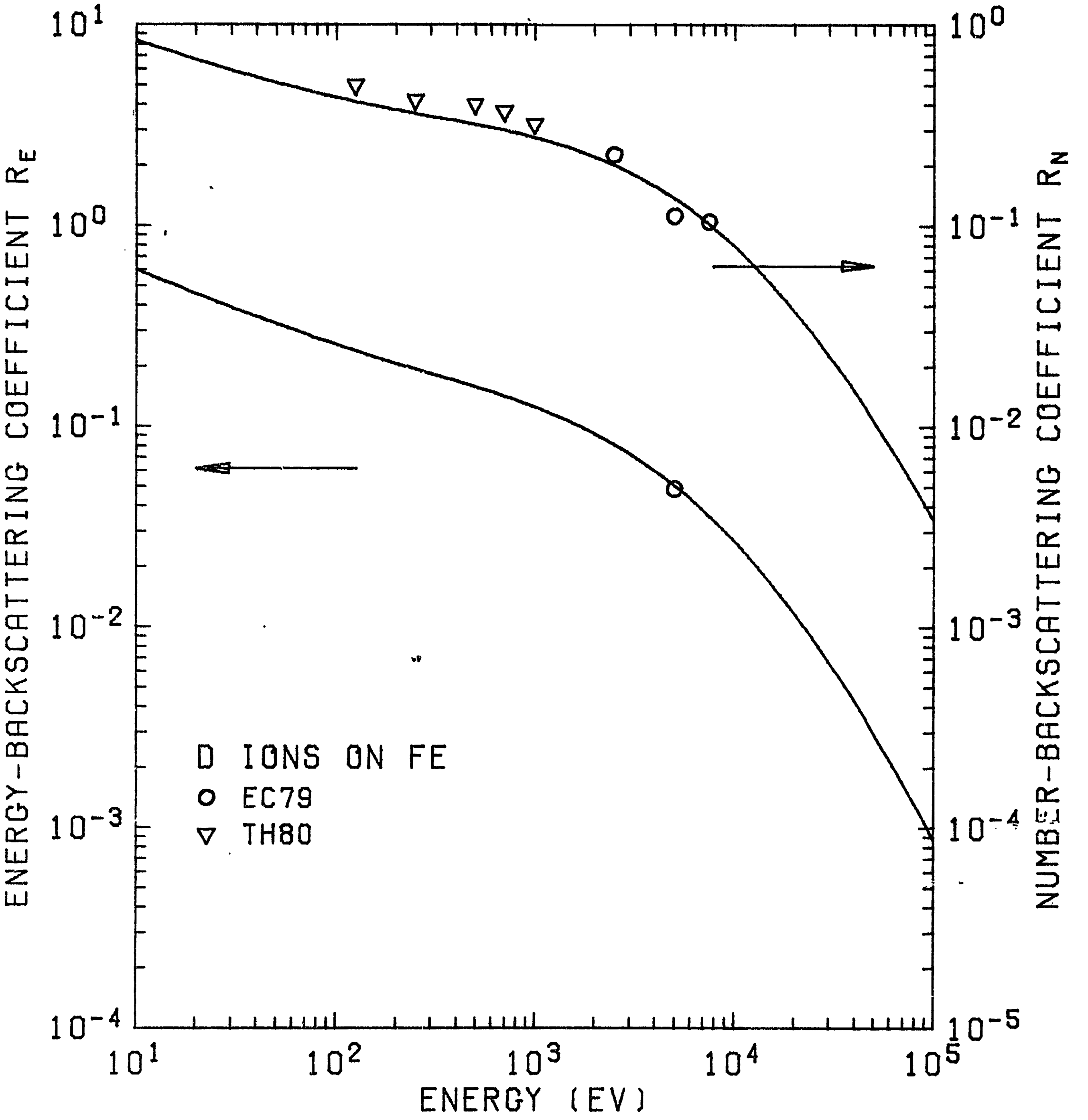

Fig. 18. R_N and R_E of D ions on $_{26}Fe$.

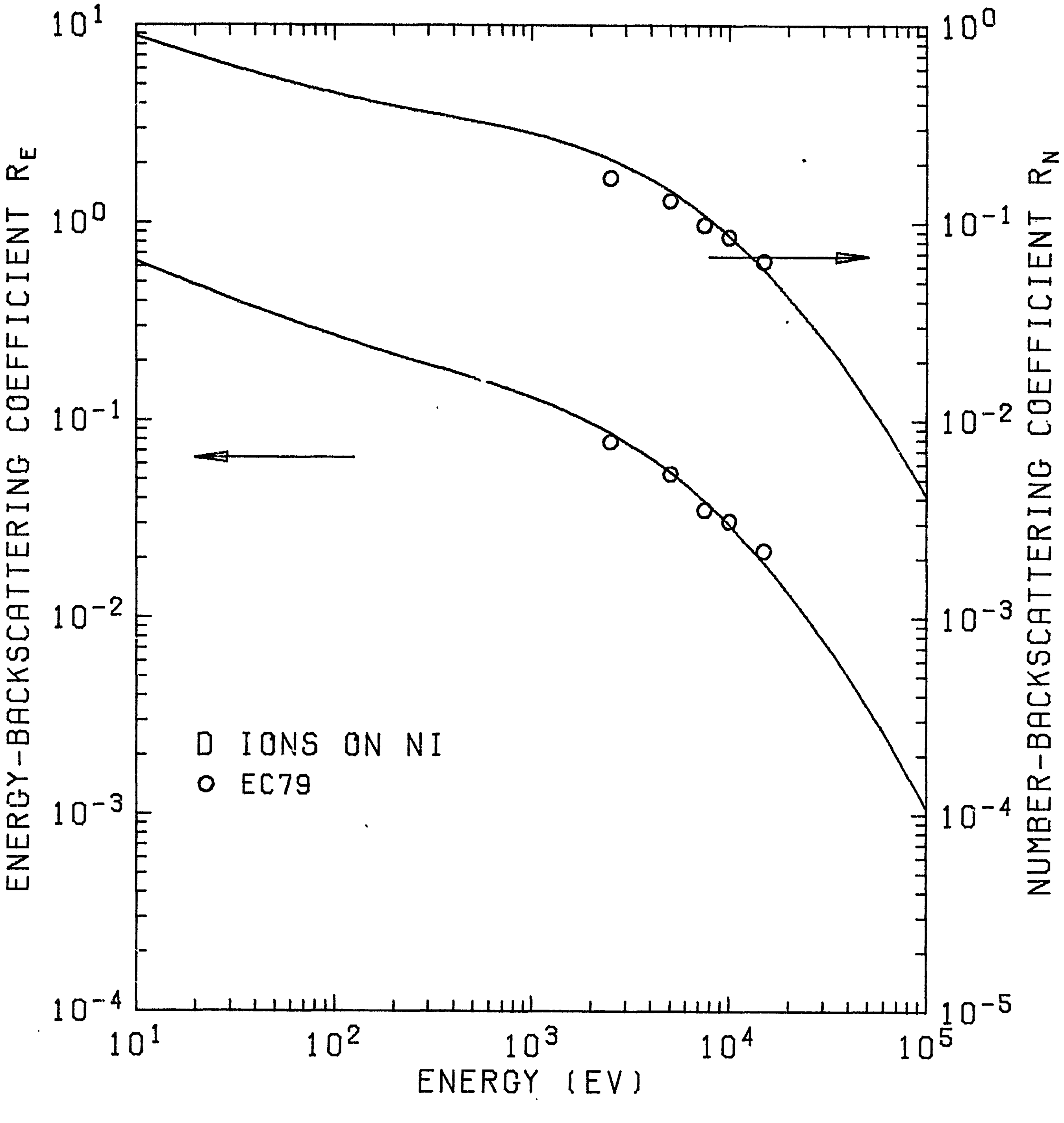

Fig. 19. R_N and R_E of D ions on $_{28}Ni$.

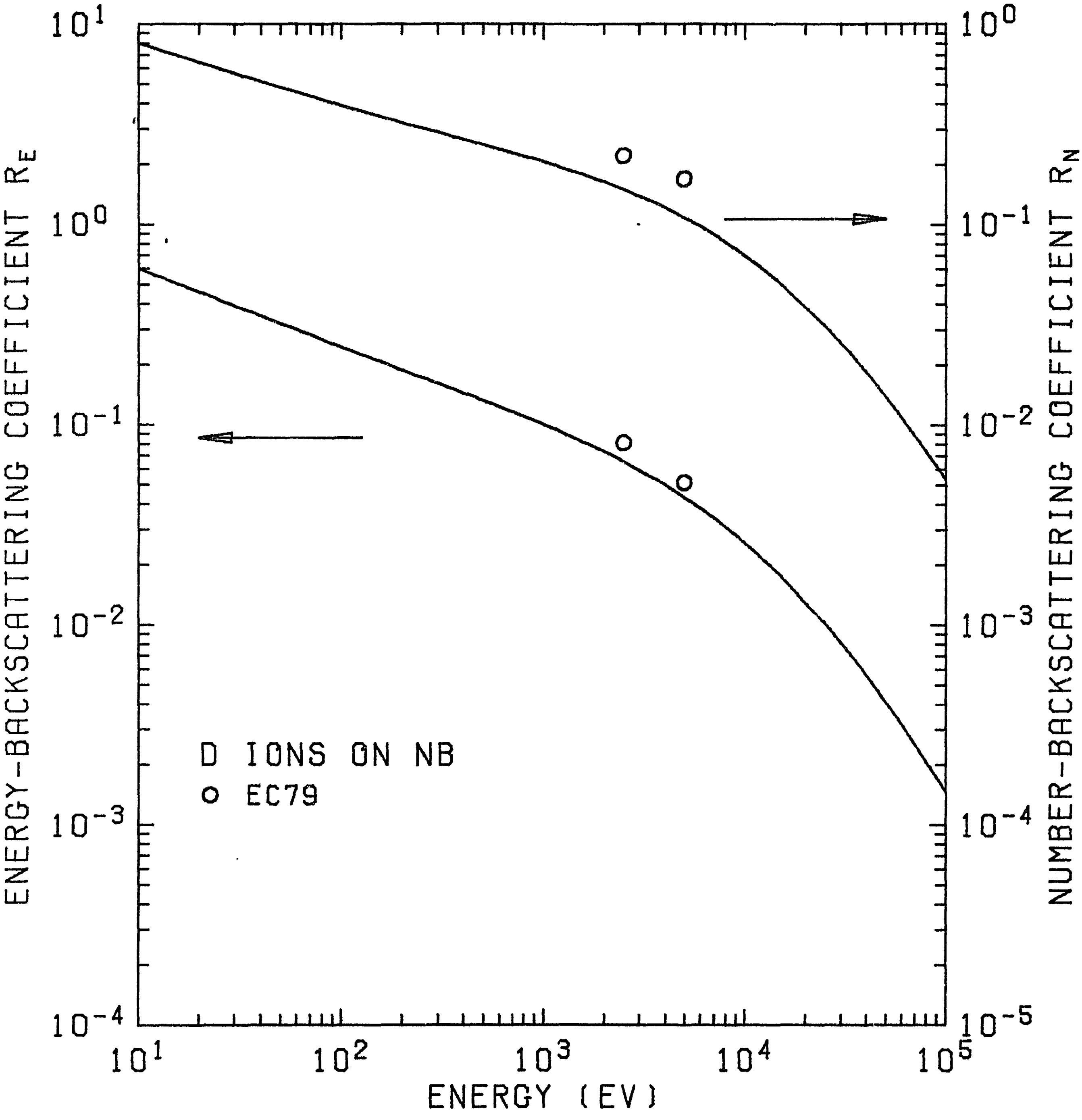

Fig. 20. R_N and R_E of D ions on $_{41}Nb$.

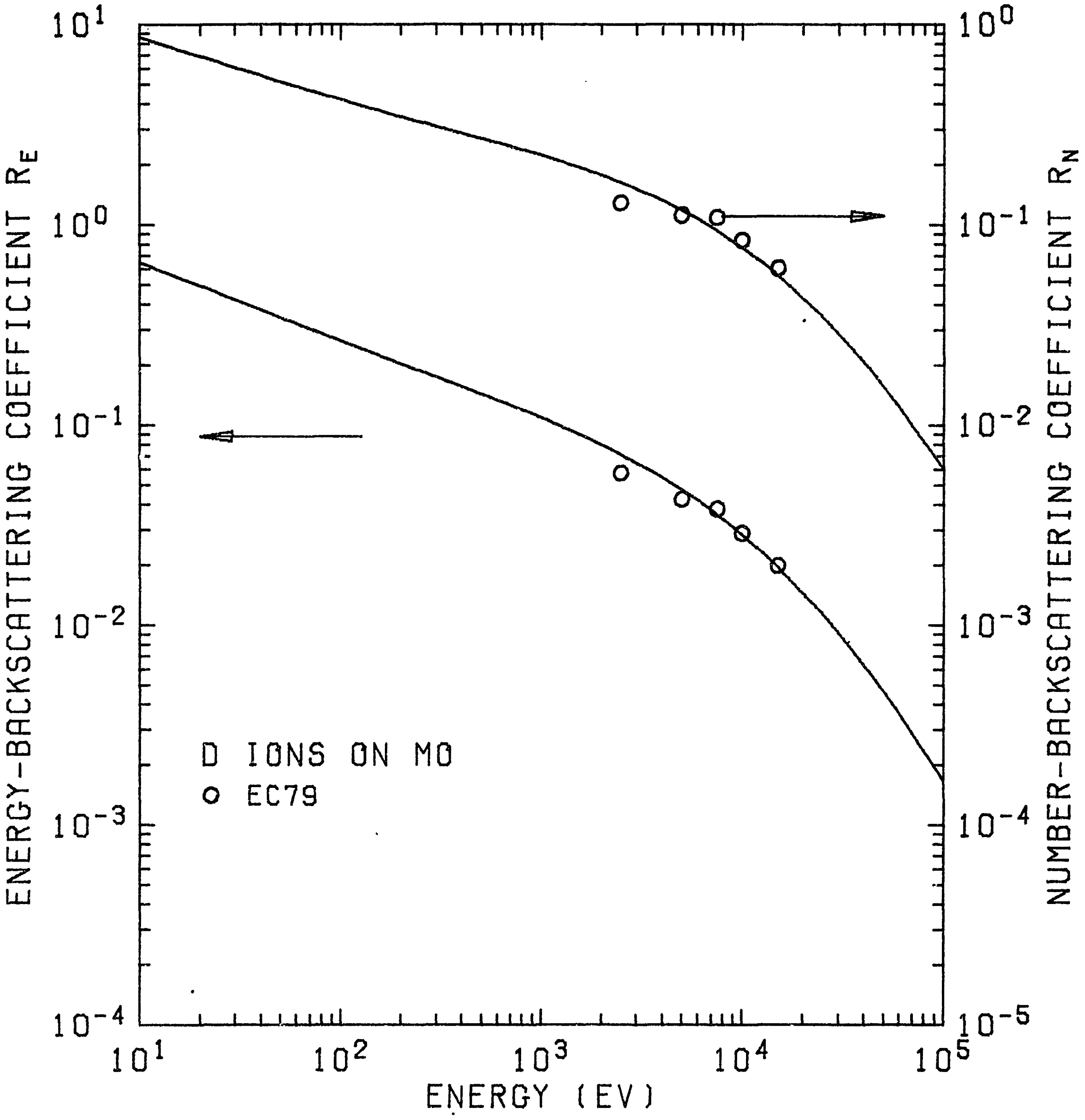

Fig. 21. R_N and R_E of D ions on $_{42}$Mo.

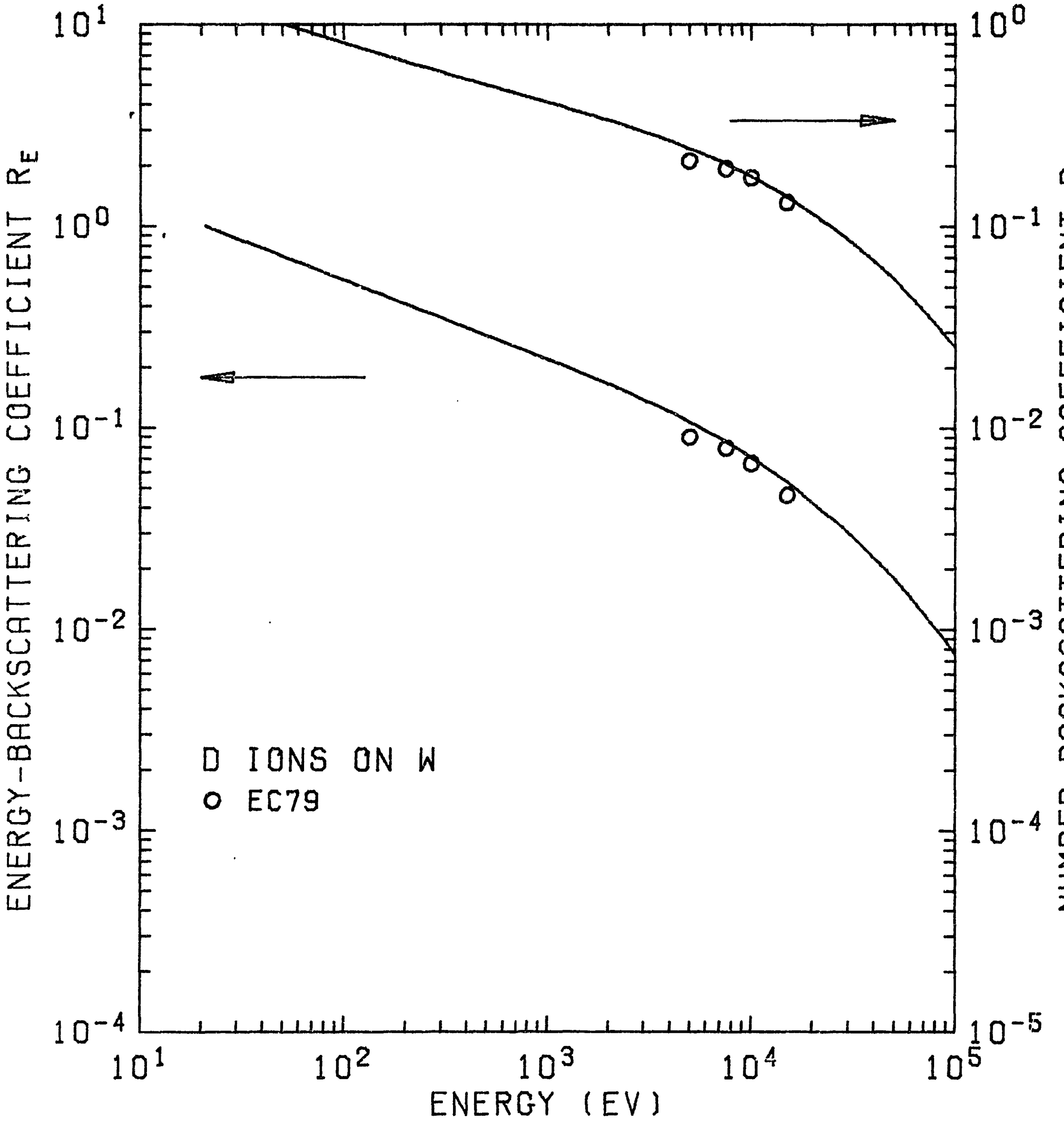

Fig. 22. R_N and R_E of D ions on $_{74}W$.

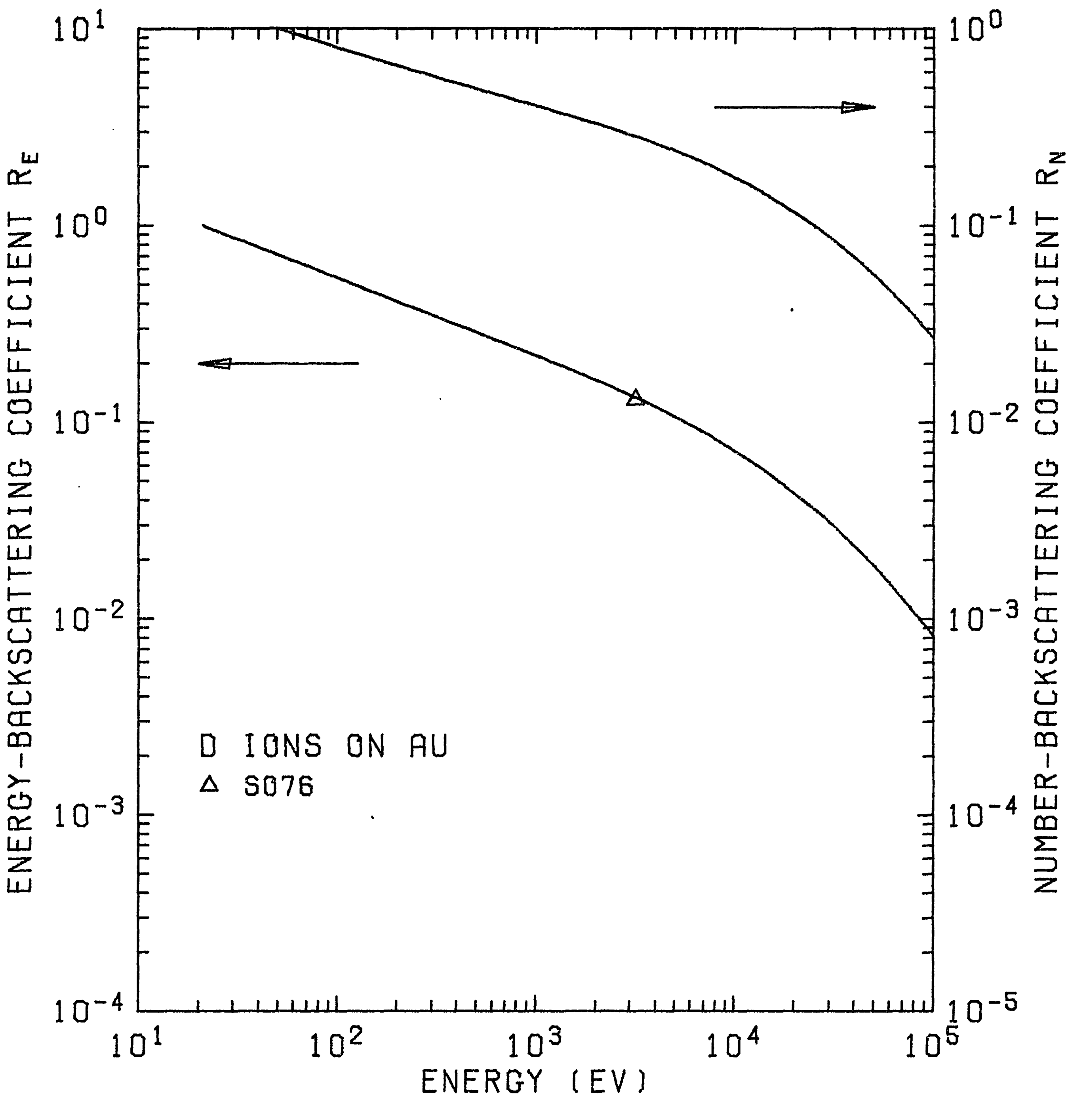

Fig. 23. R_N and R_E of D ions on $_{79}Au$.

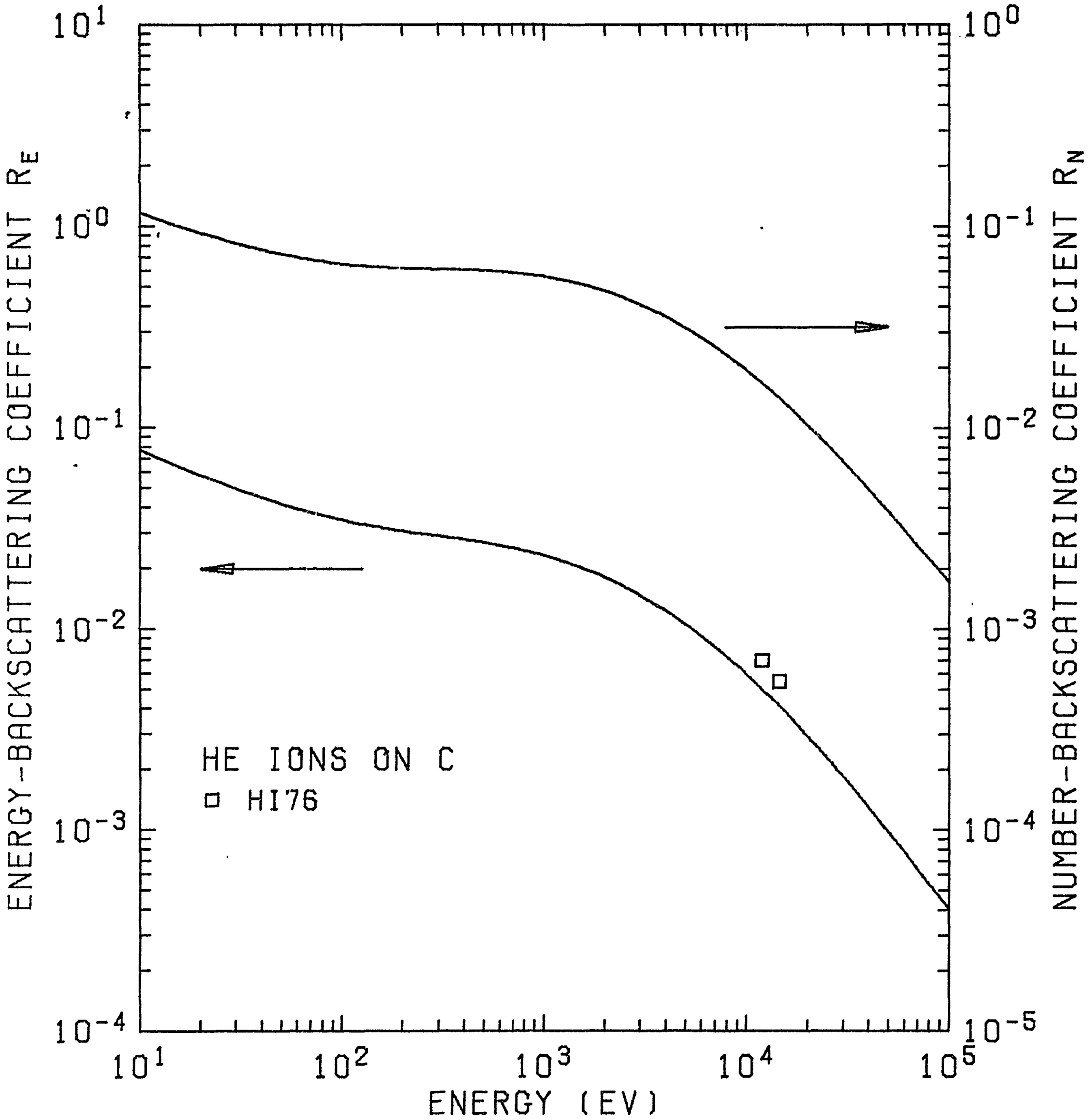

Fig. 24. R_N and R_E of He ions on $_6C$.

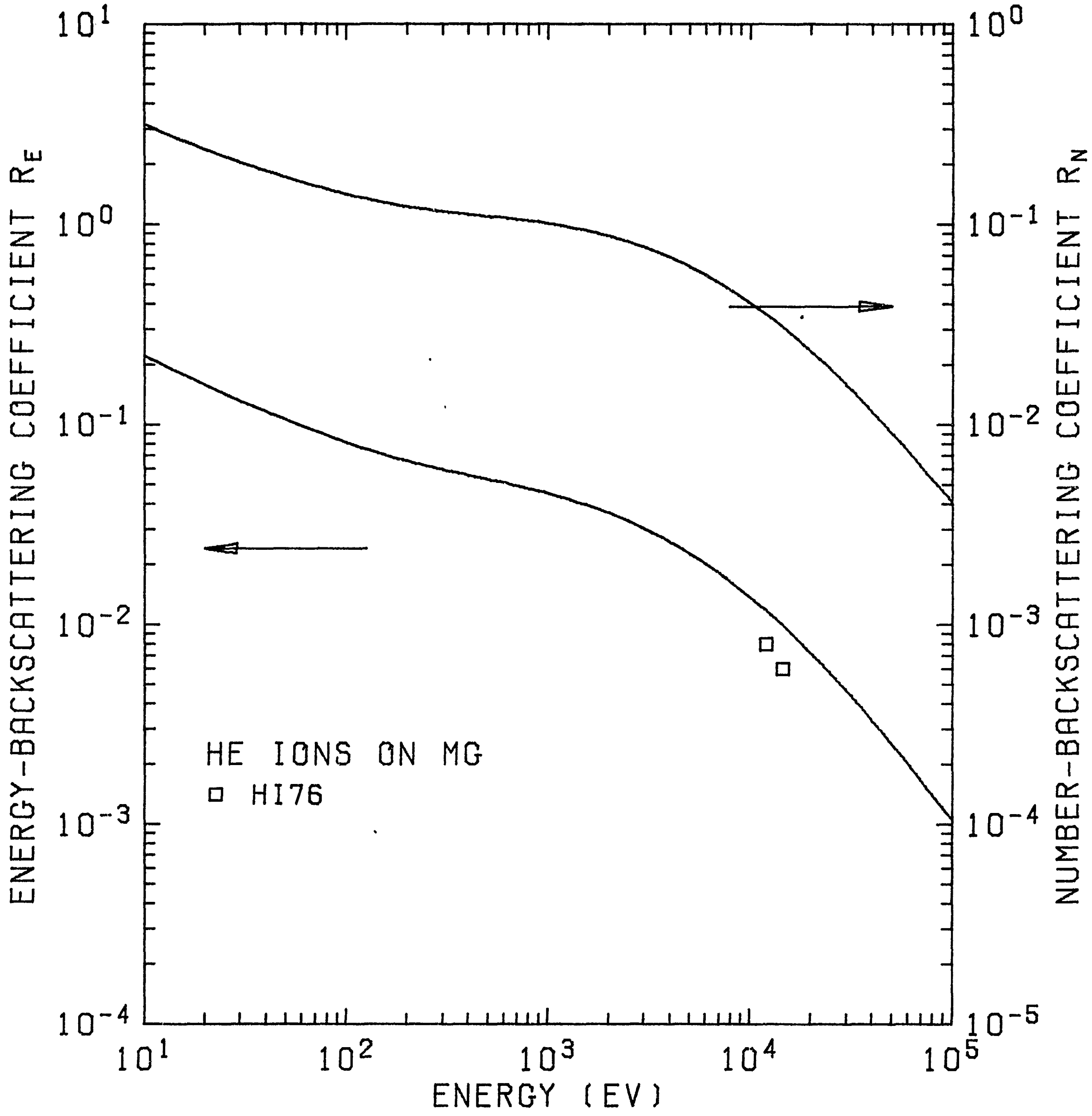

Fig. 25. R_N and R_E of He ions on $_{12}$Mg.

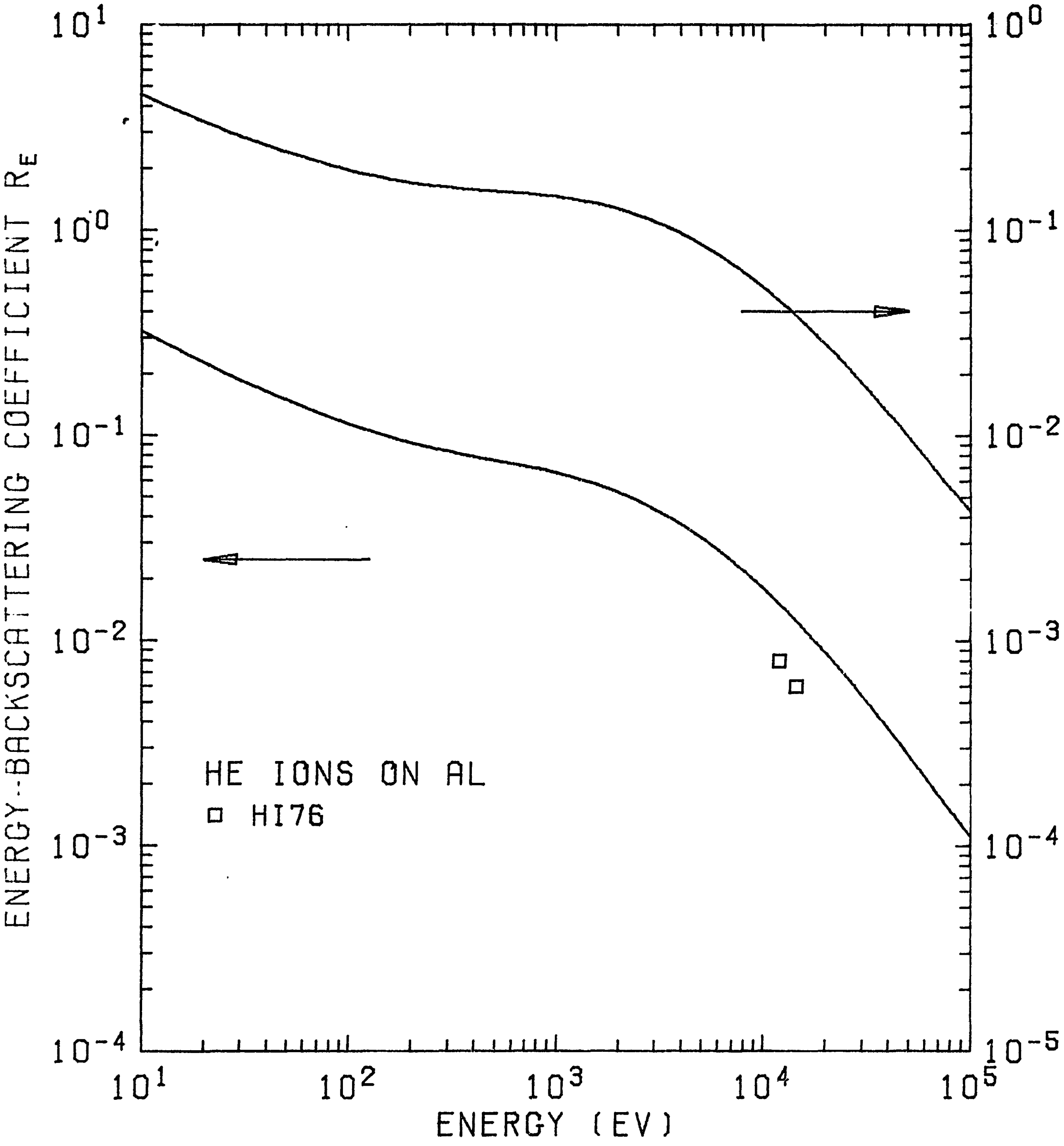

Fig. 26. R_N and R_E of He ions on $_{13}$Al.

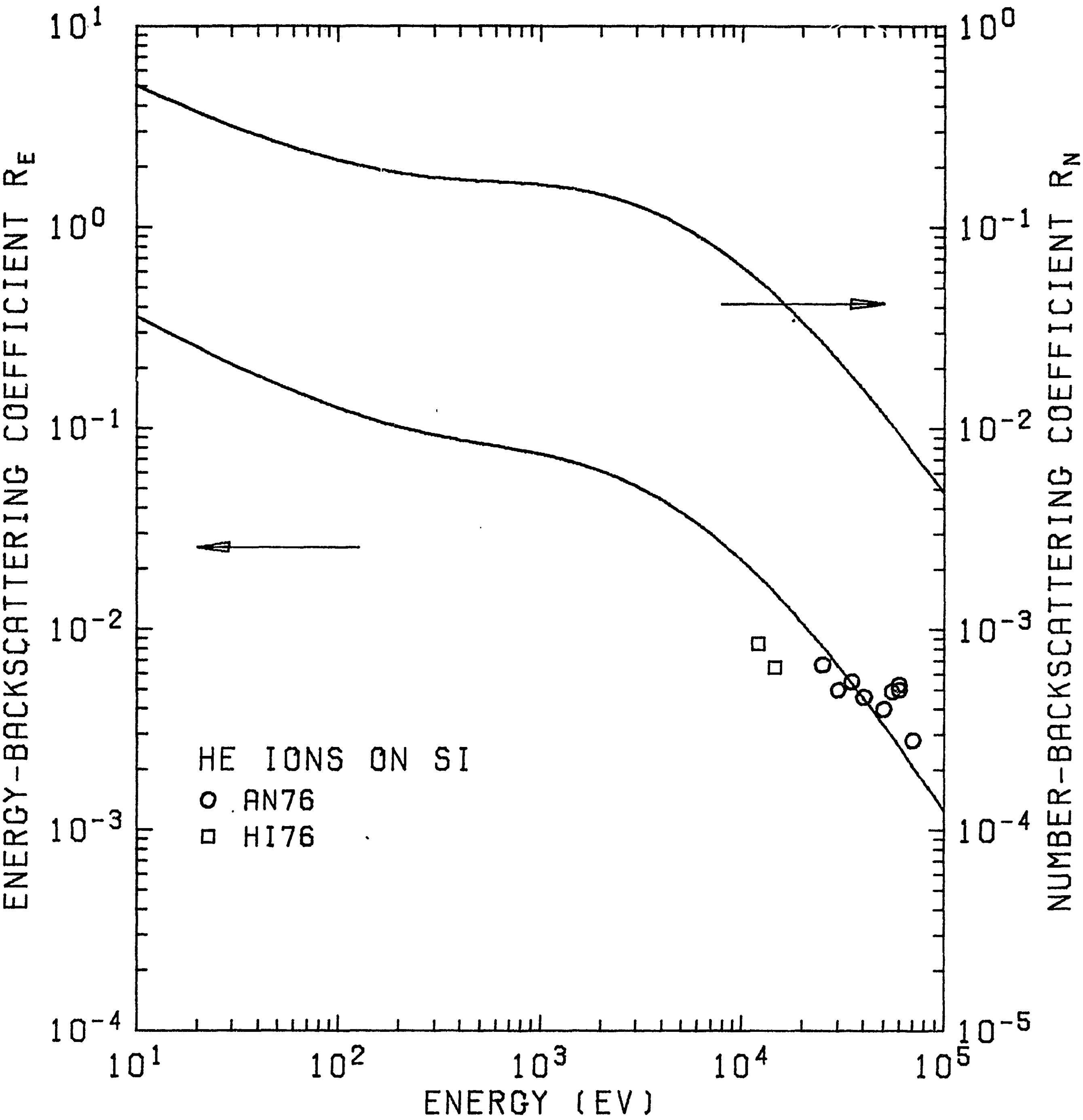

Fig. 27. R_N and R_E of He ions on $_{14}Si$.

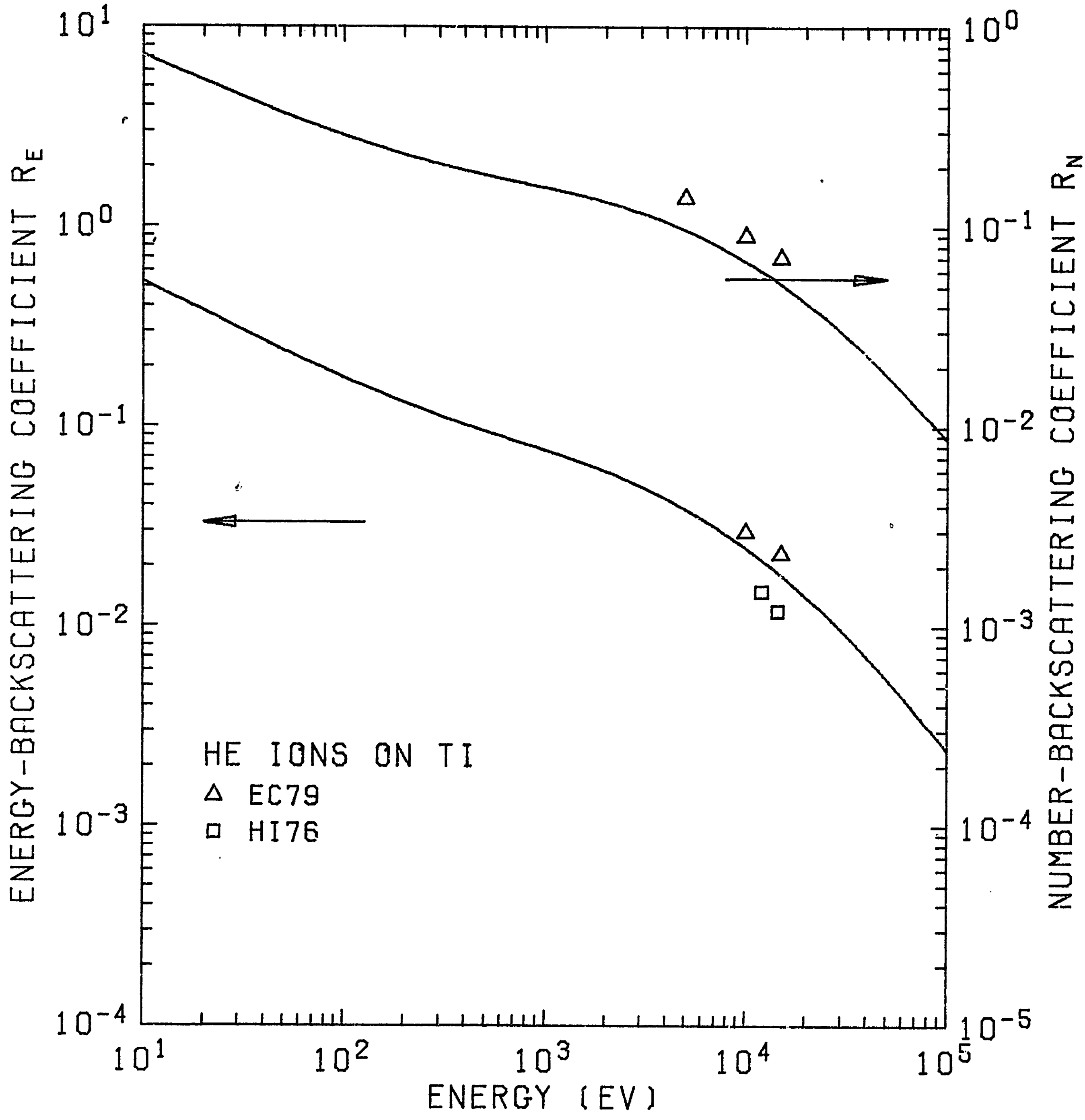

Fig. 28. R_N and R_E of He ions on $_{22}$Ti.

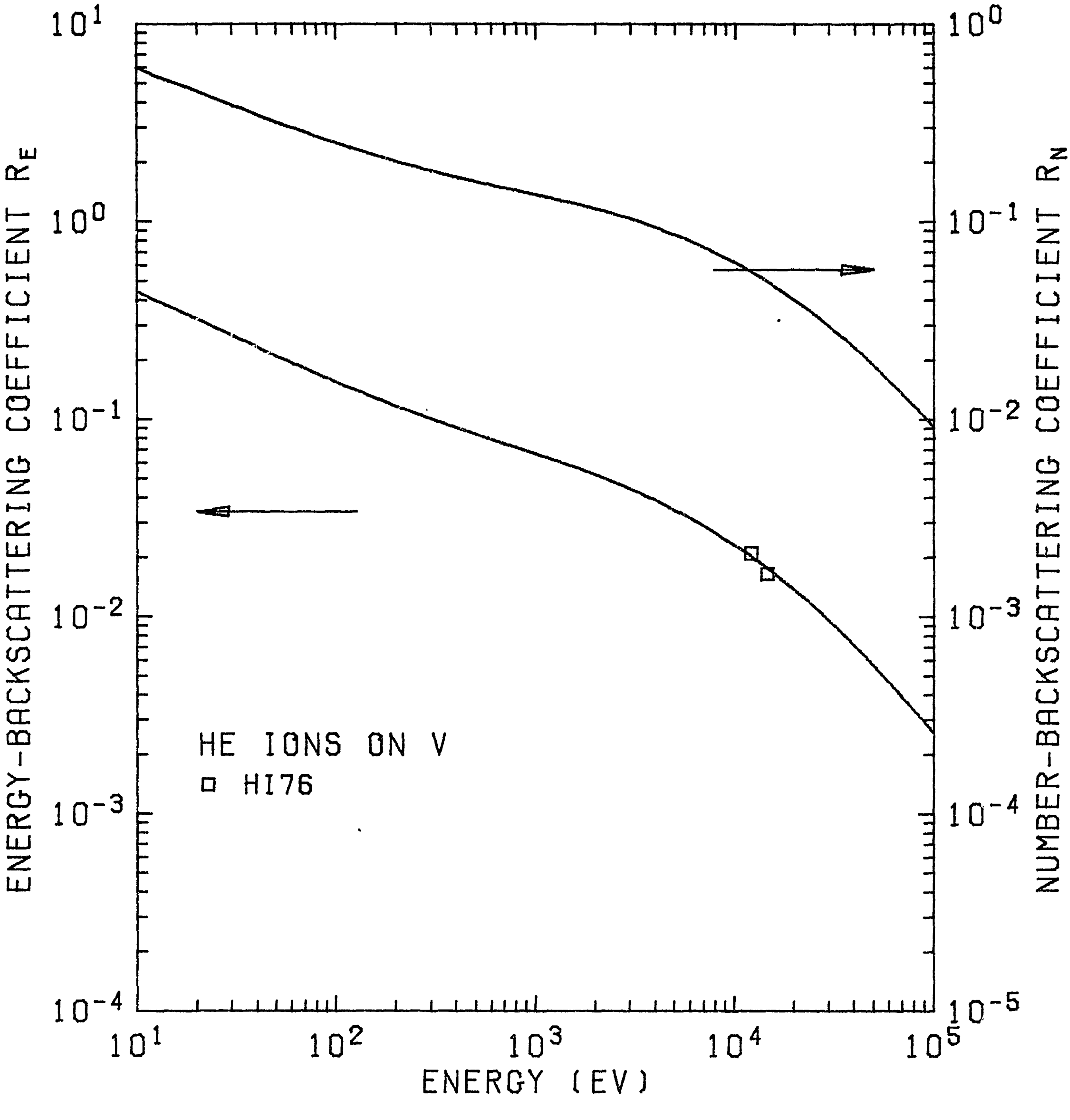

Fig. 29. R_N and R_E of He ions on $_{23}V$.

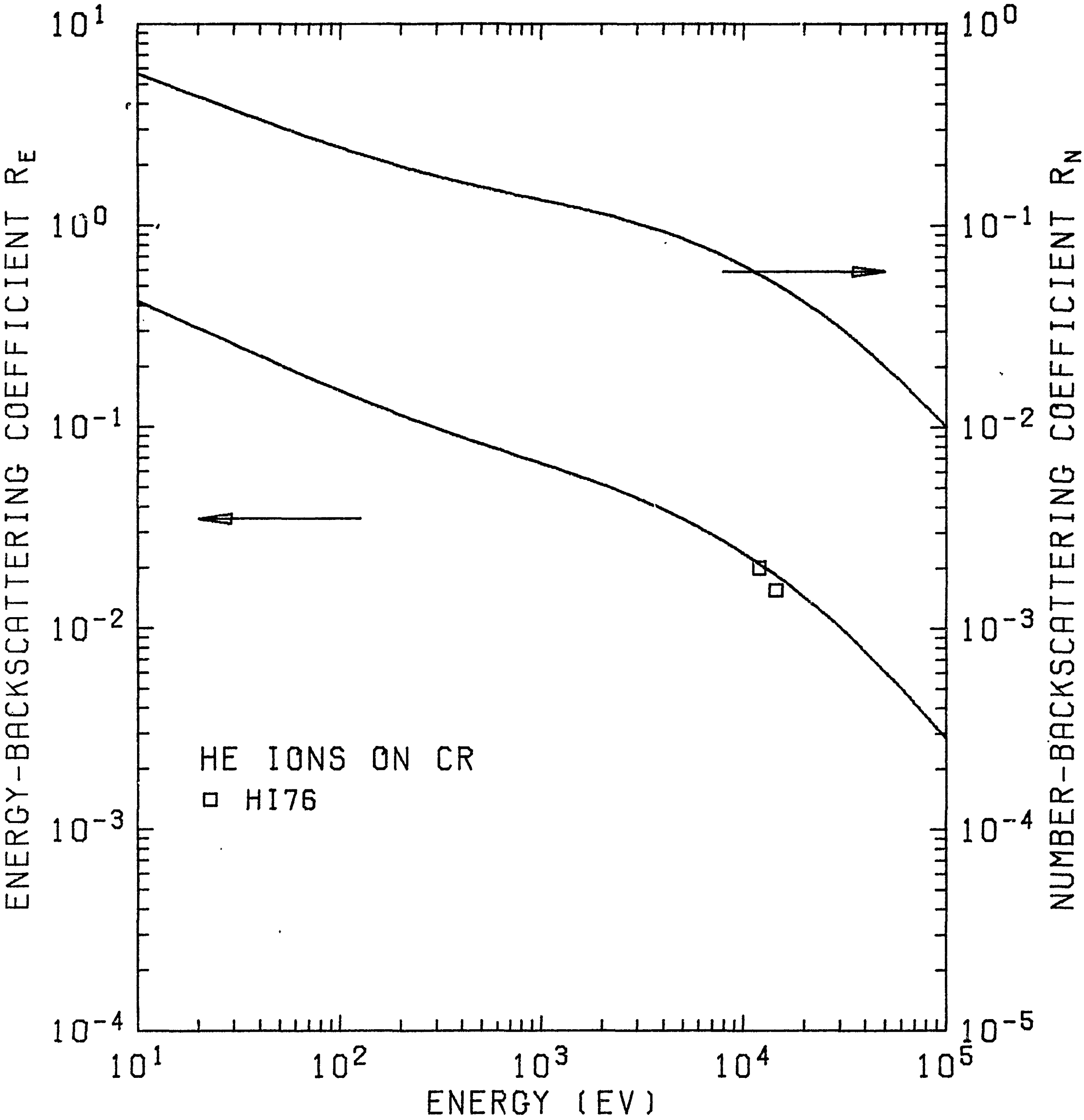

Fig. 30. R_N and R_E of He ions on $_{24}Cr$.

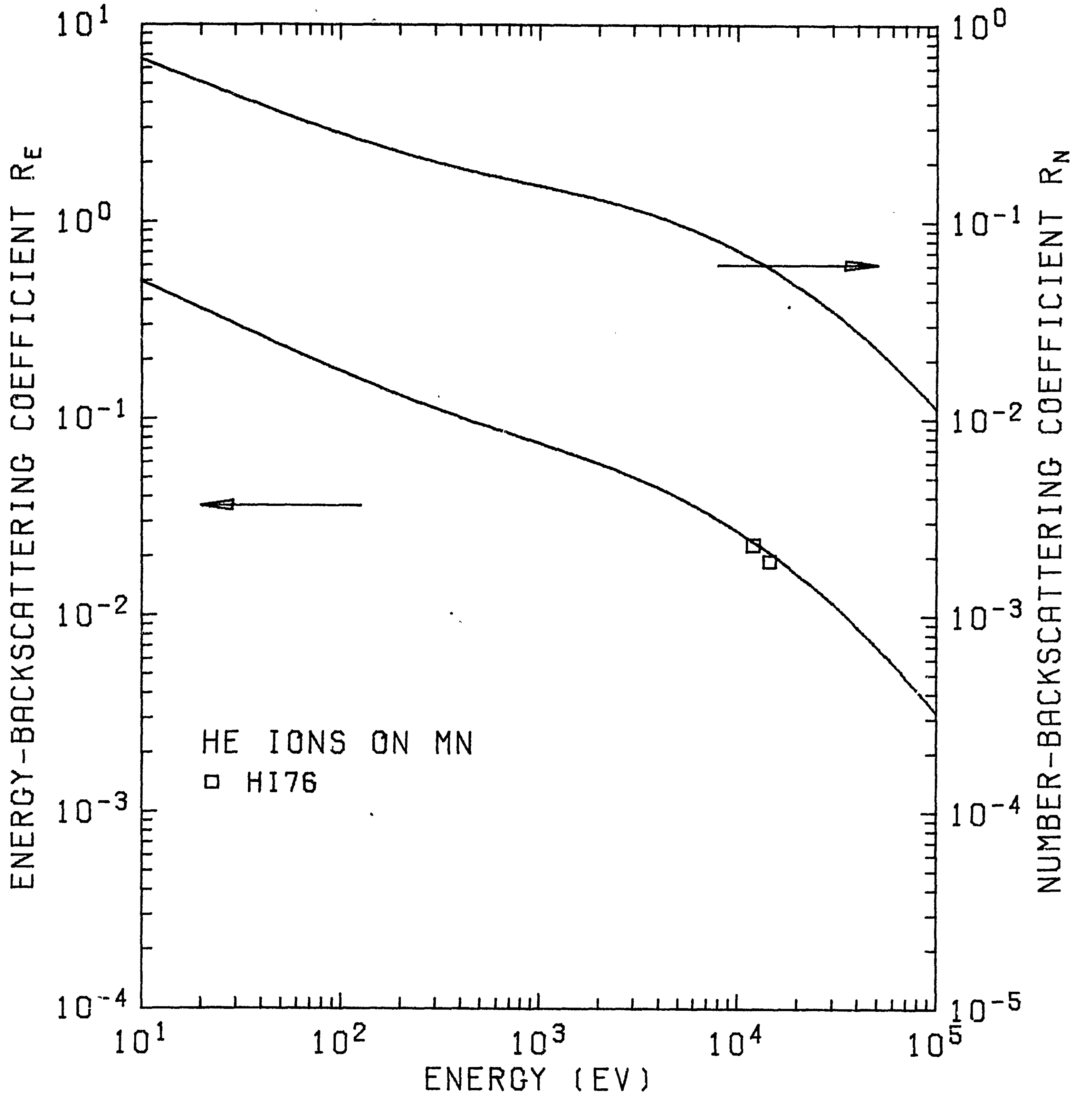

Fig. 31. R_N and R_E of He ions on $_{25}$Mn.

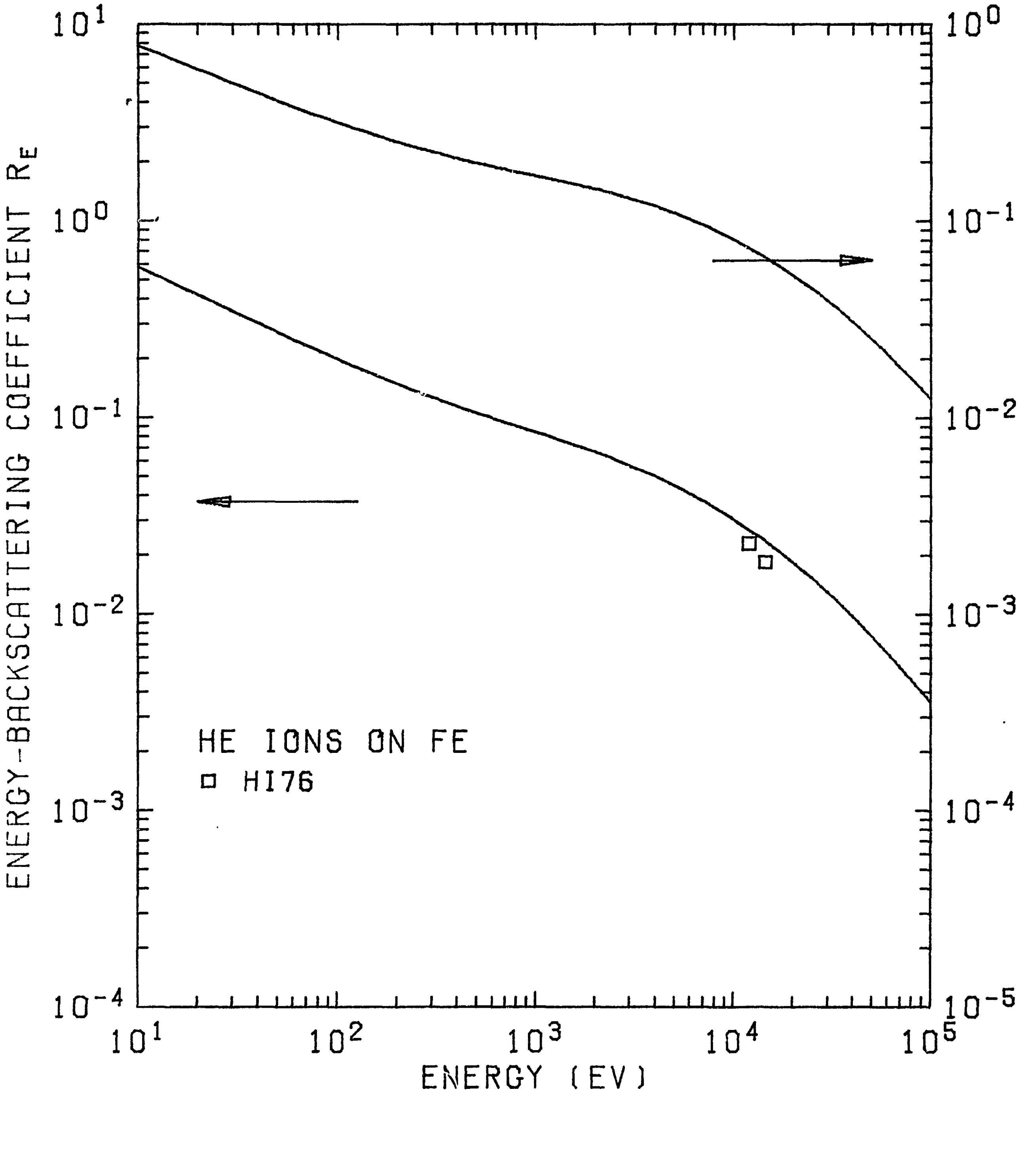

Fig. 32. R_N and R_E of He ions on $_{26}Fe$.

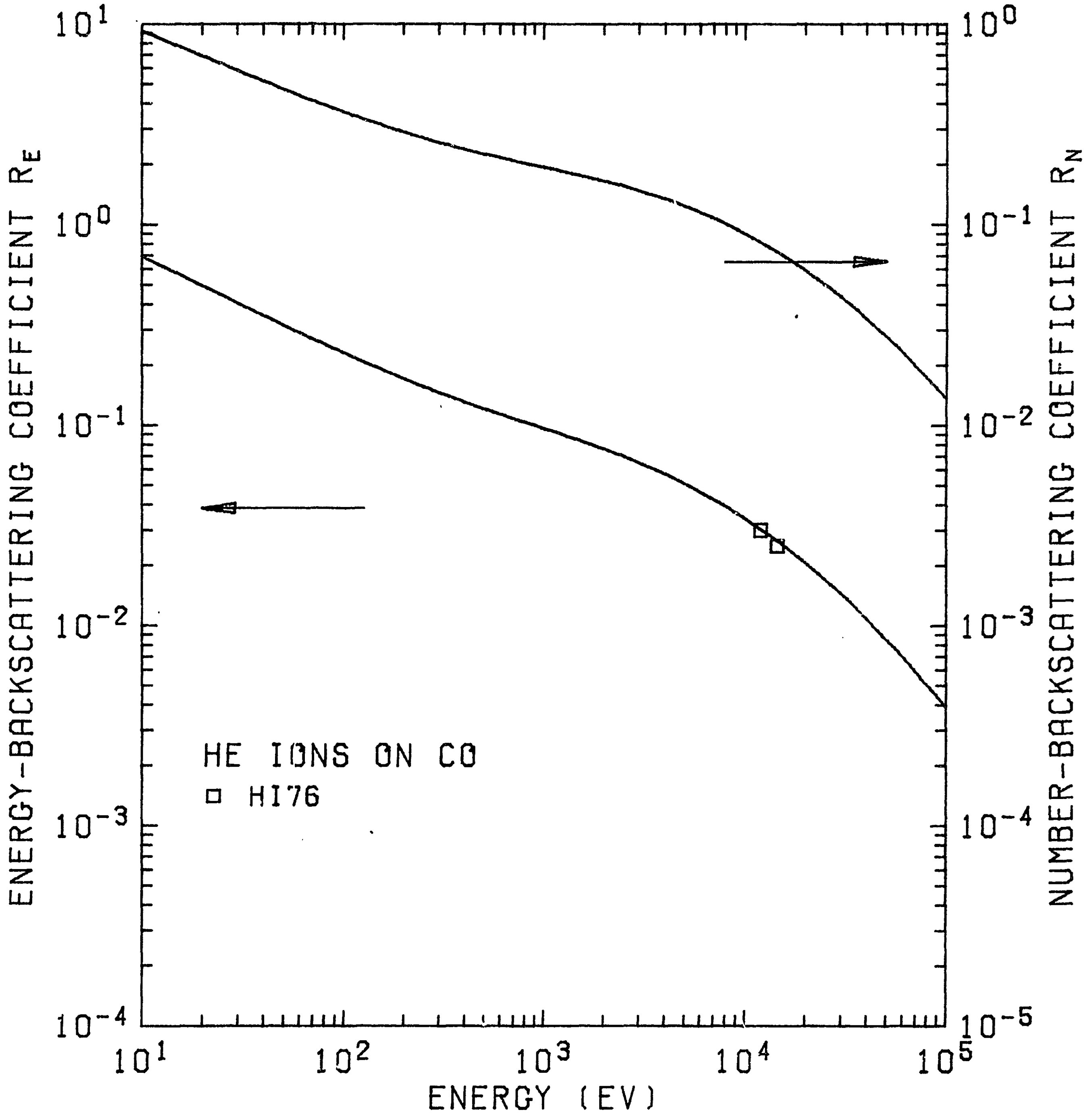

Fig. 33. R_N and R_E of He ions on $_{27}Co$.

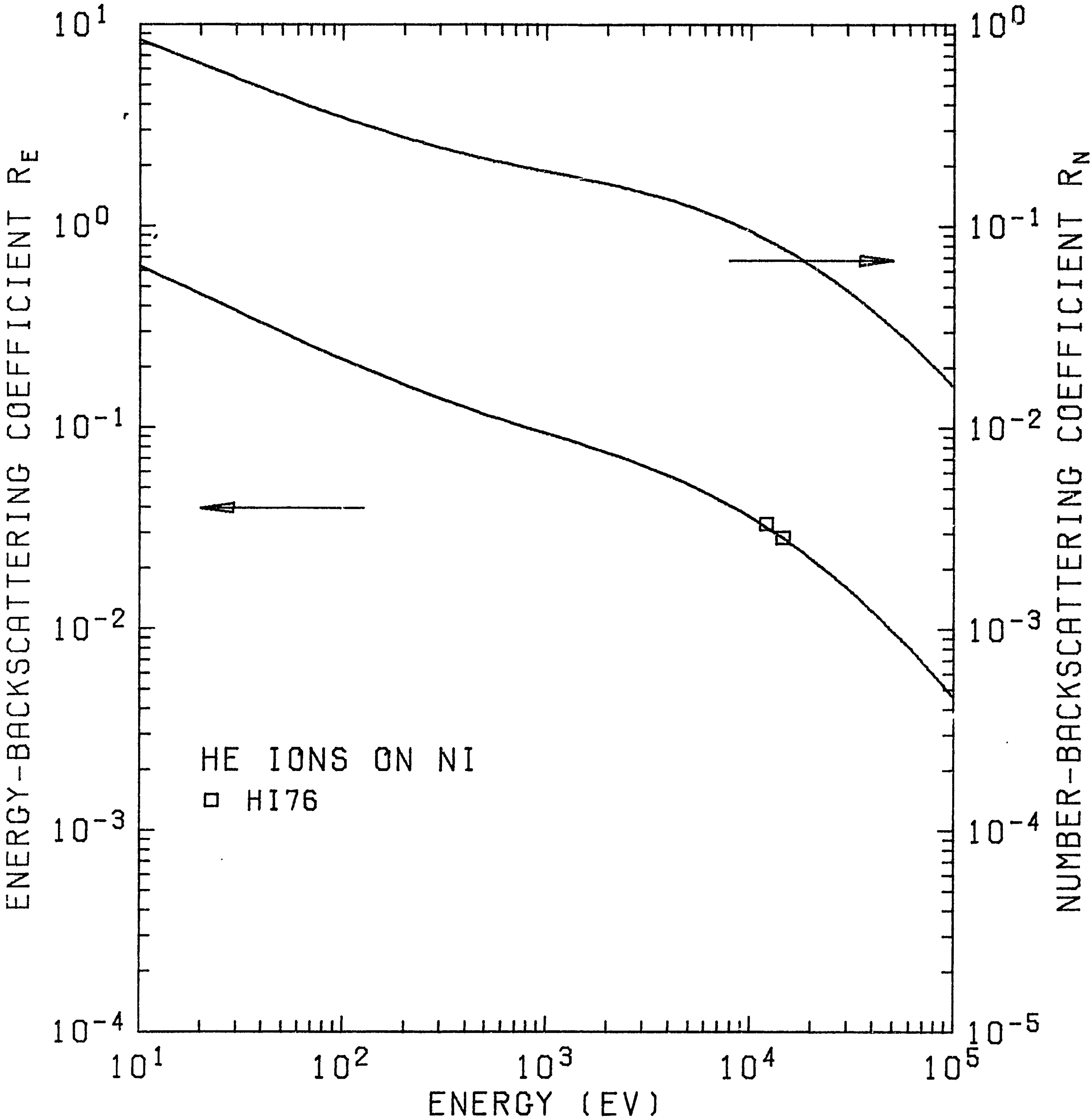

Fig. 34. R_N and R_E of He ions on $_{28}$Ni.

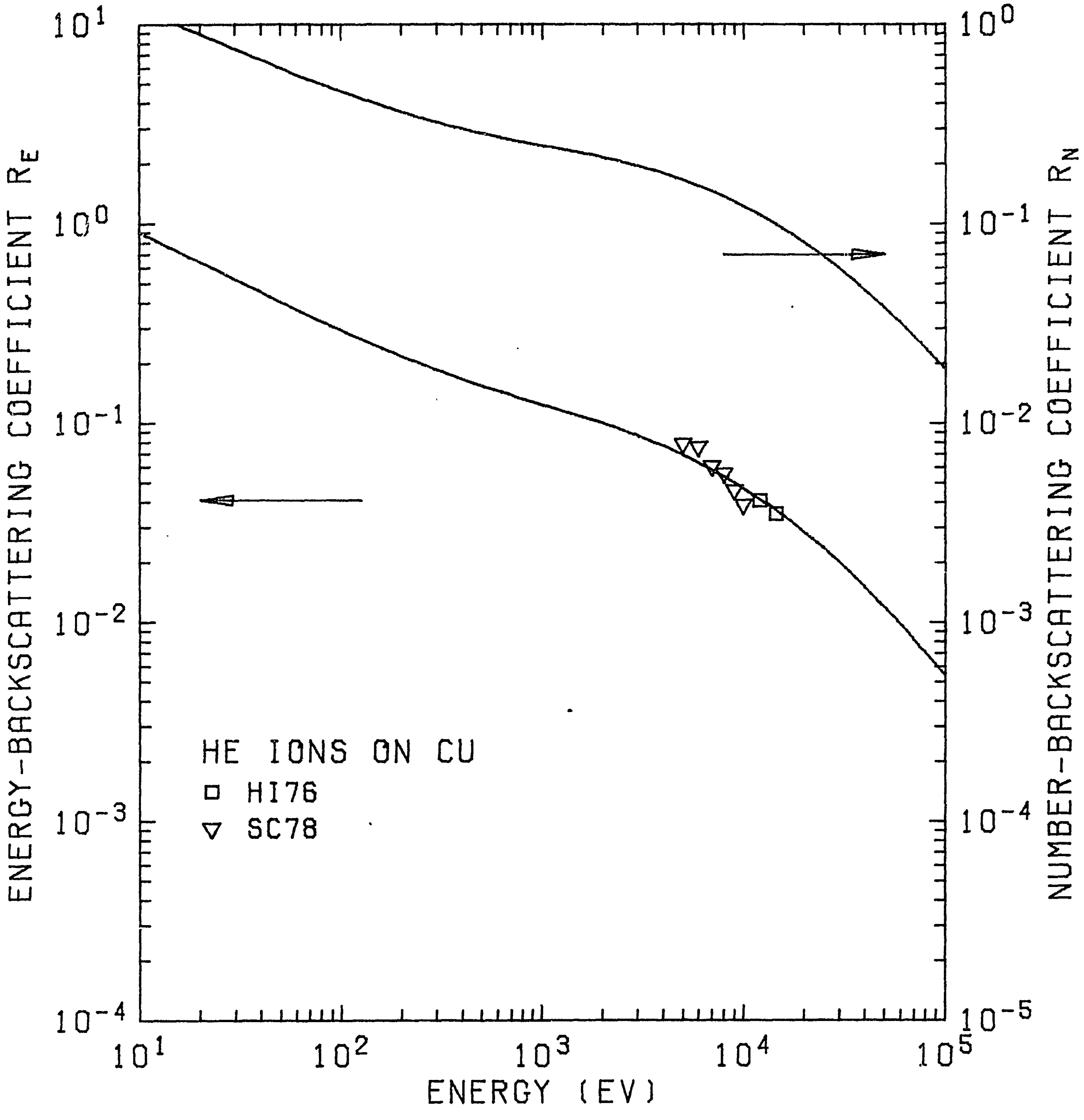

Fig. 35. R_N and R_E of He ions on $_{29}Cu$.

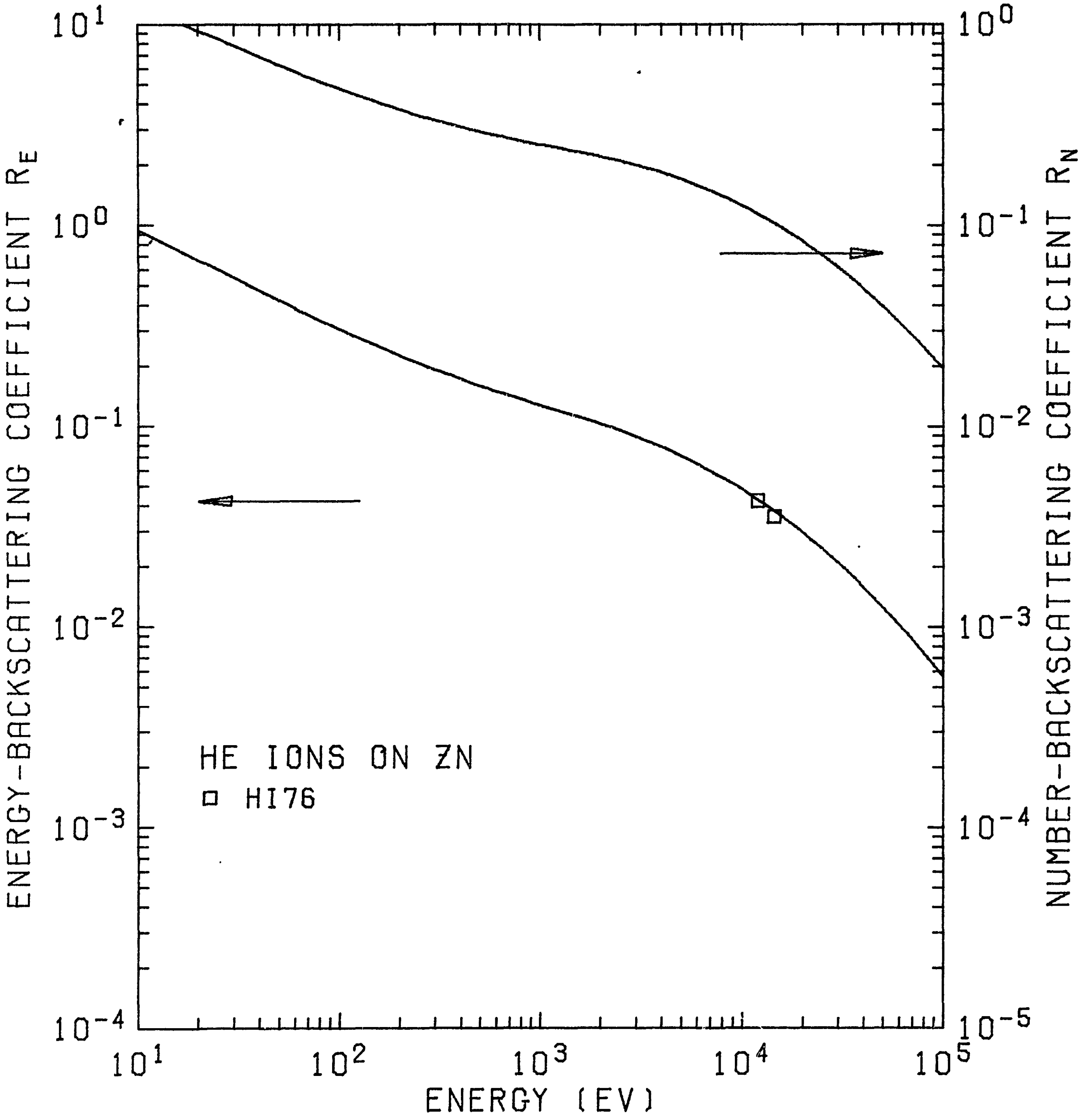

Fig. 36. R_N and R_E of He ions on $_{30}Zn$.

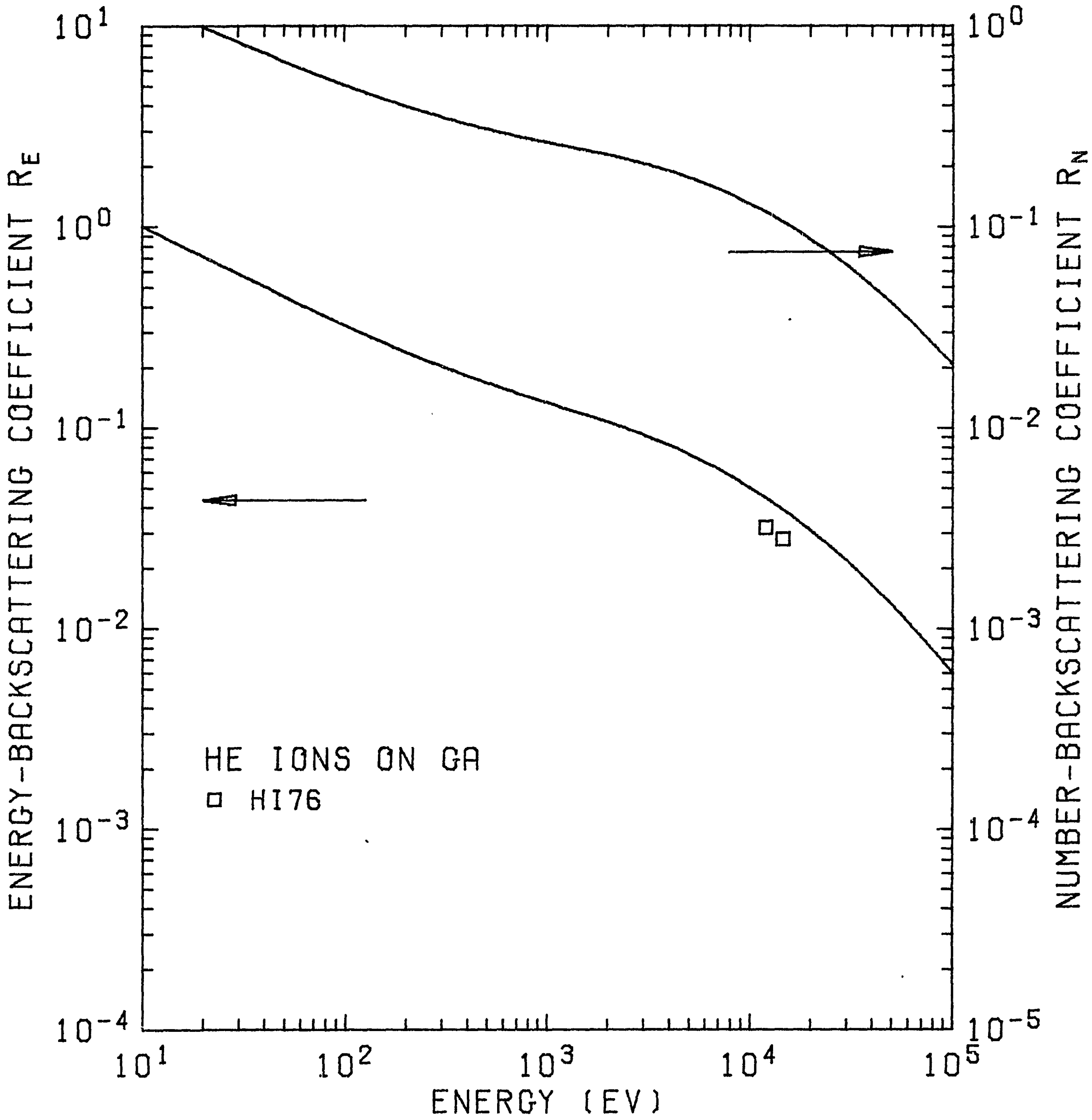

Fig. 37. R_N and R_E of He ions on $_{31}$Ga.

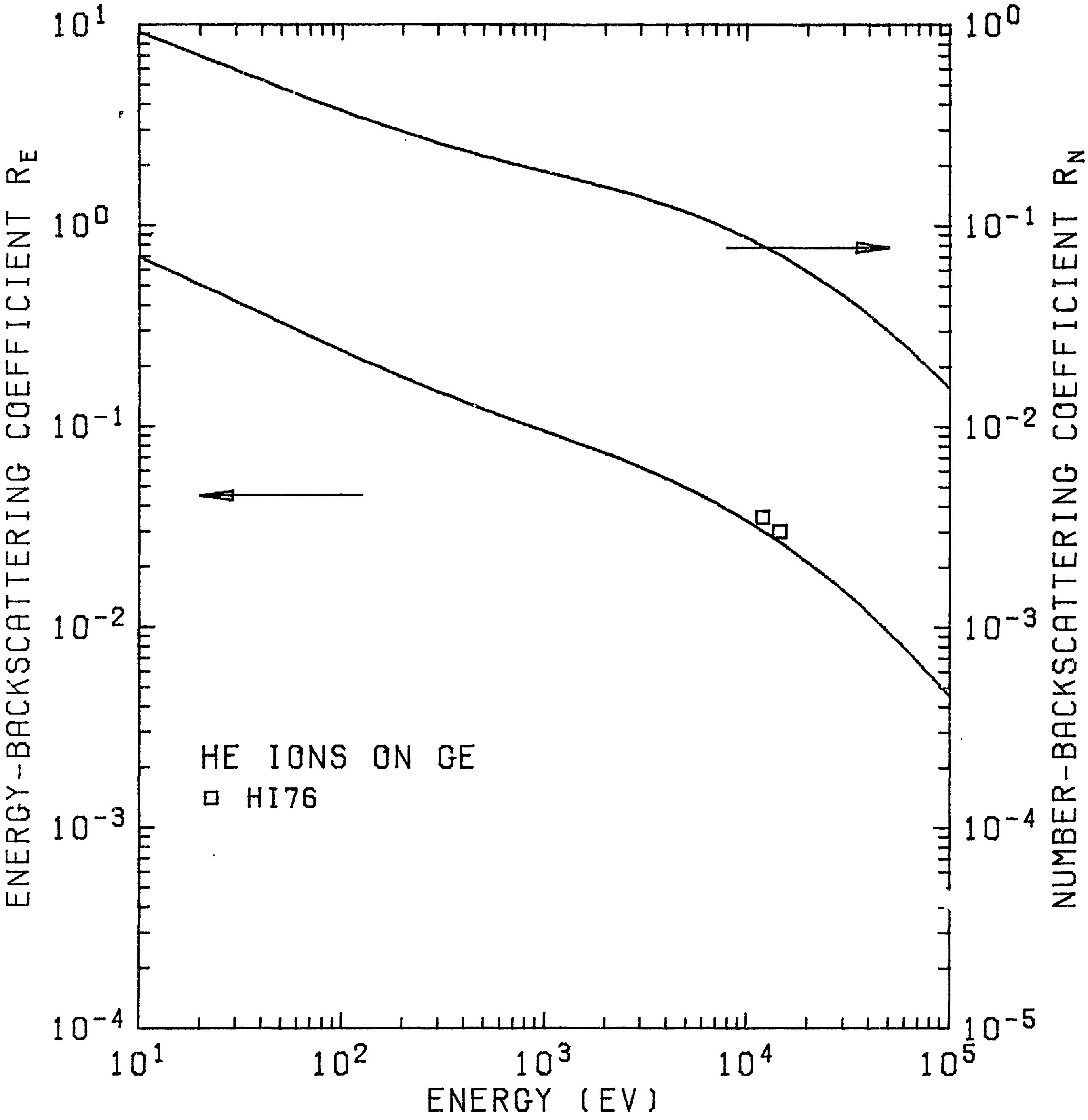

Fig. 38. R_N and R_E of He ions on $_{32}$Ge.

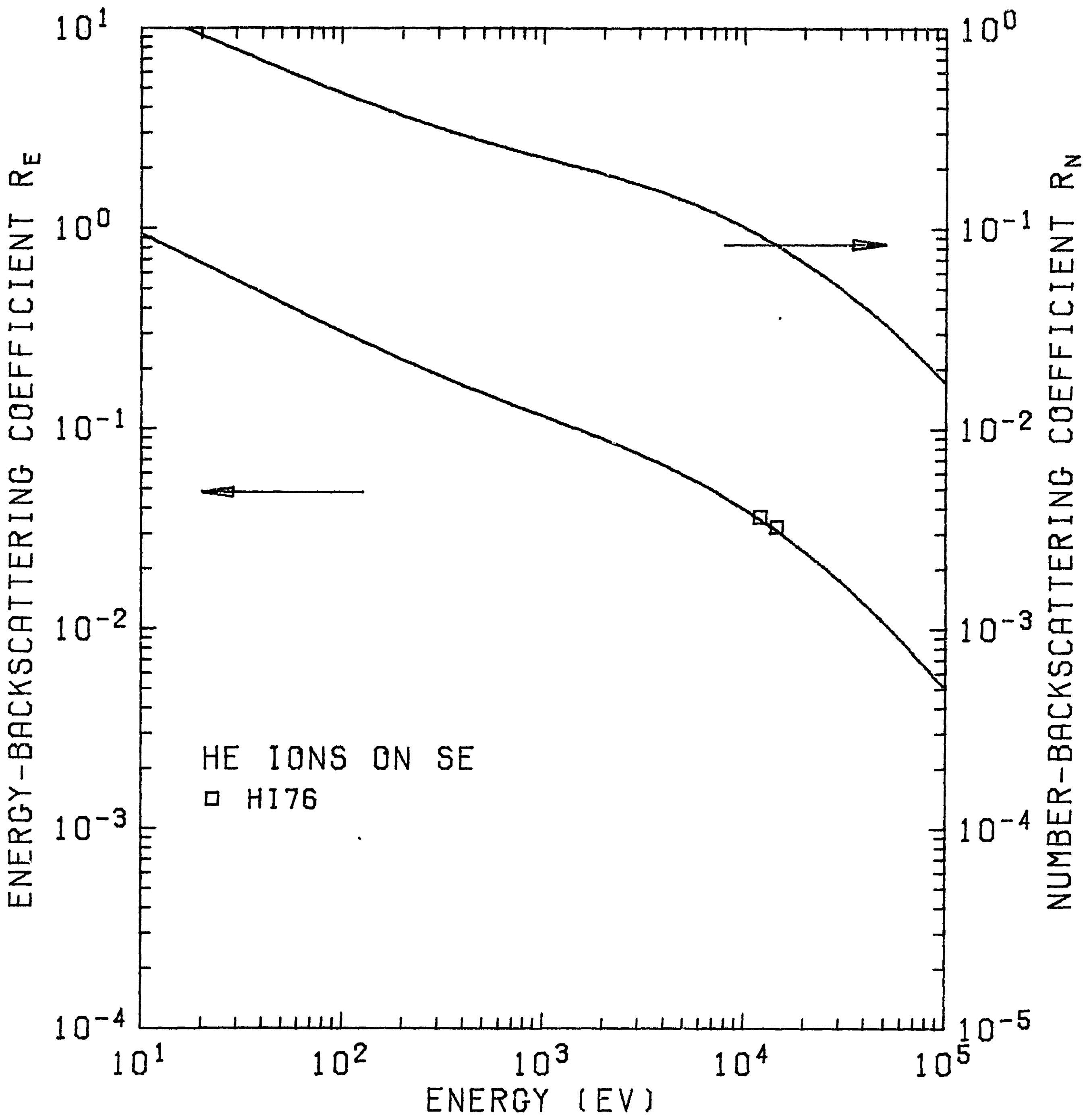

Fig. 39. R_N and R_E of He ions on $_{34}$Se.

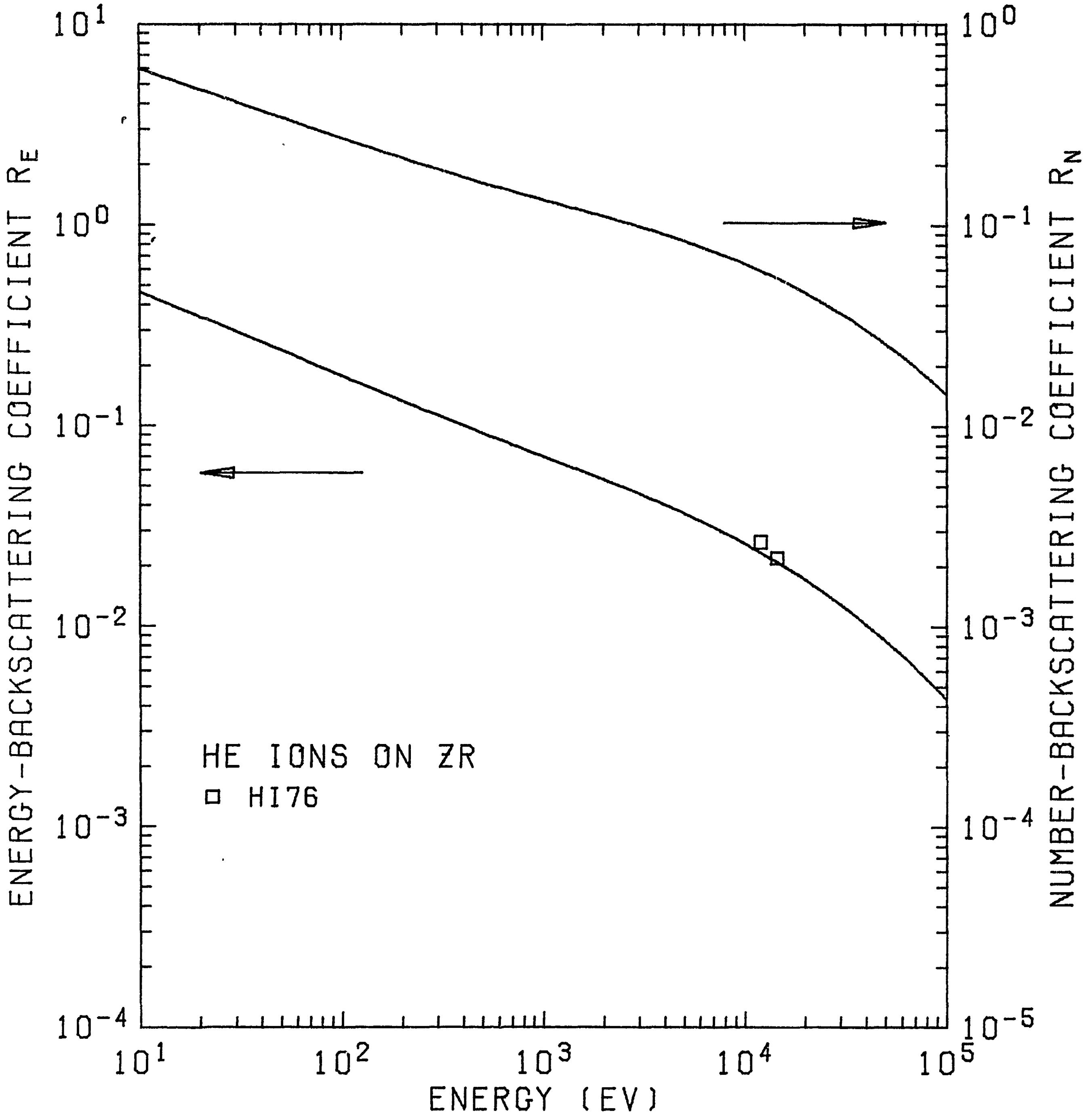

Fig. 40. R_N and R_E of He ions on $_{40}Zr$.

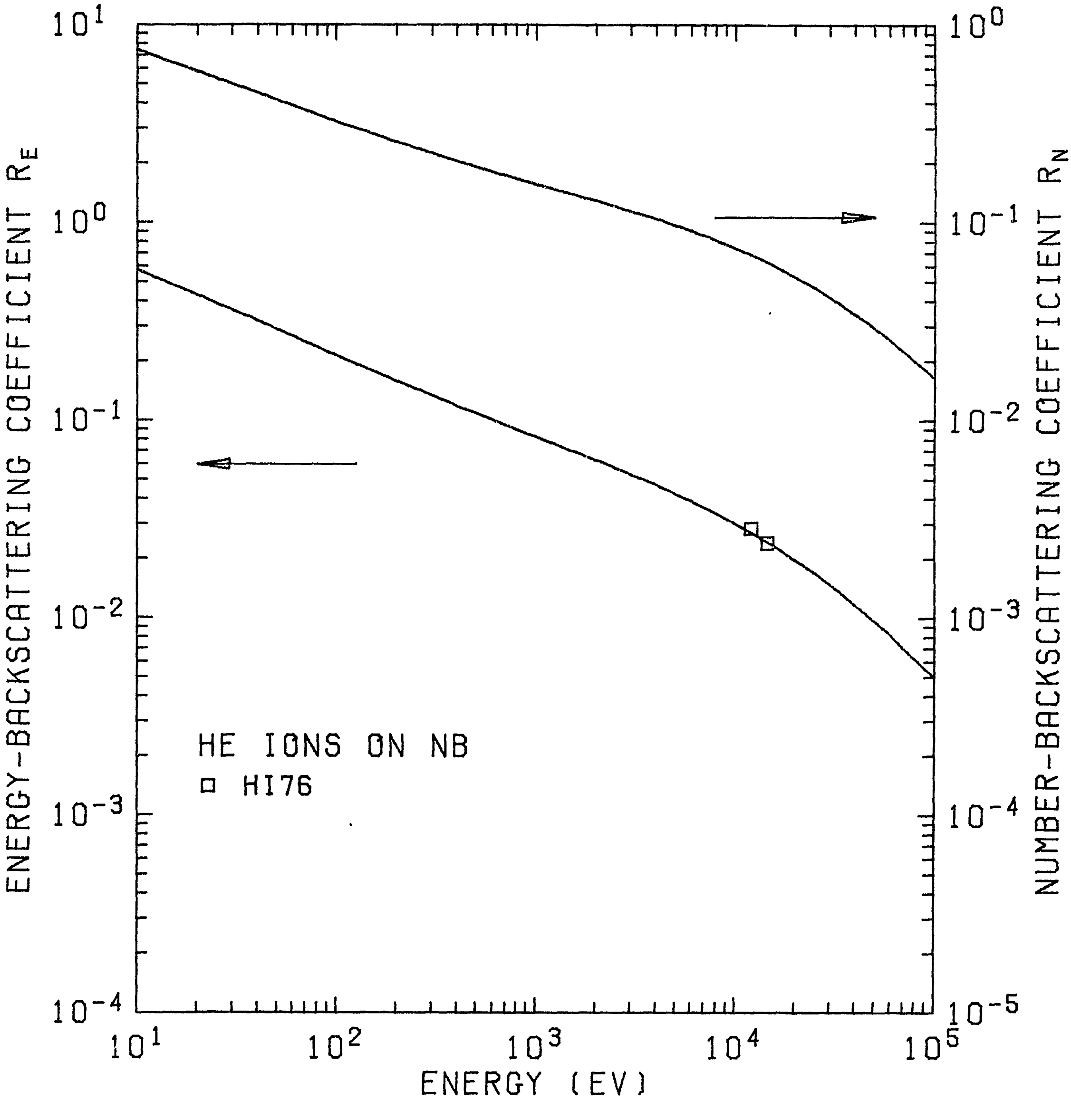

Fig. 41. R_N and R_E of He ions on $_{41}Nb$.

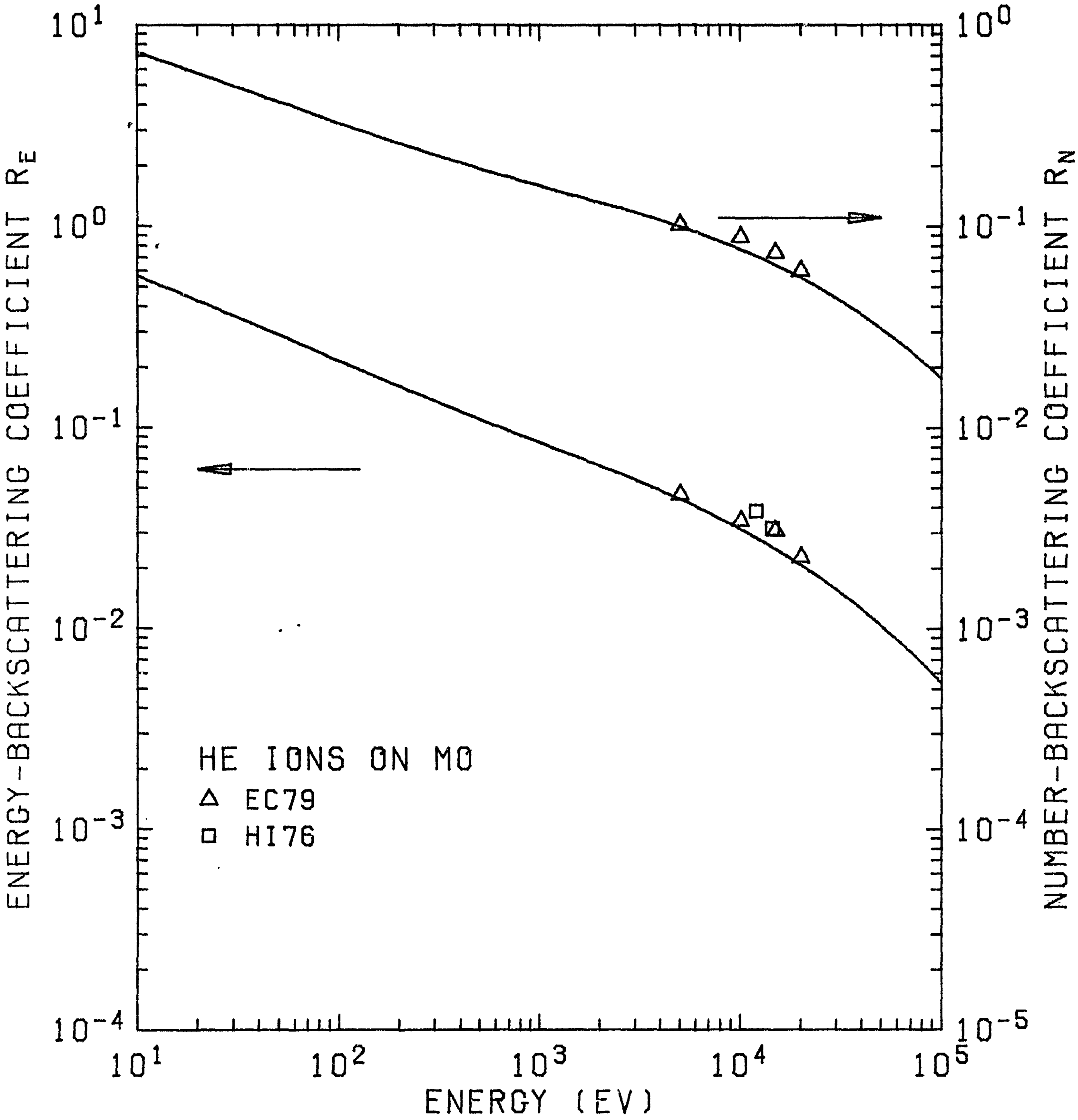

Fig. 42. R_N and R_E of He ions on $_{42}Mo$.

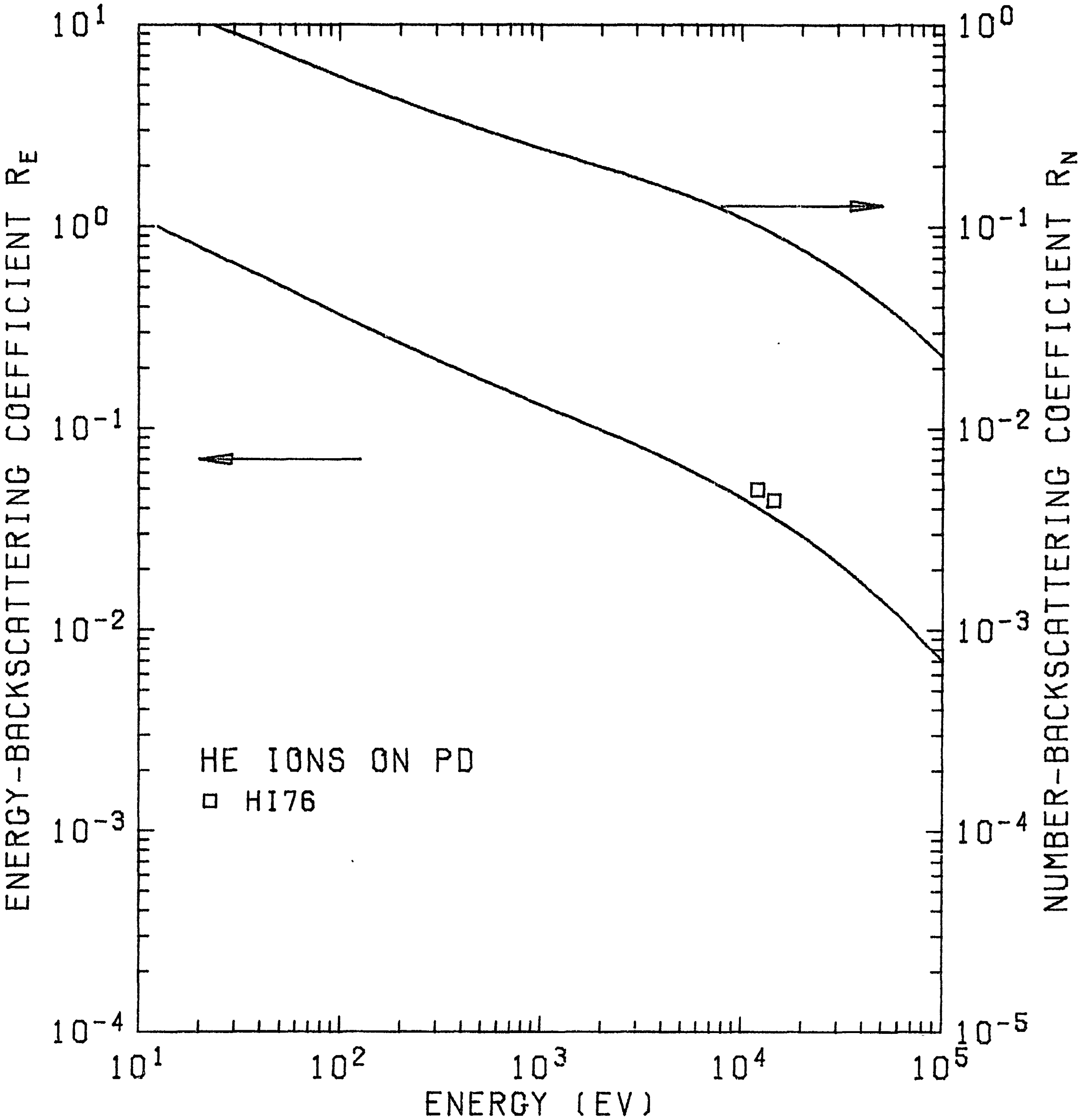

Fig. 43. R_N and R_E of He ions on $_{46}$Pd.

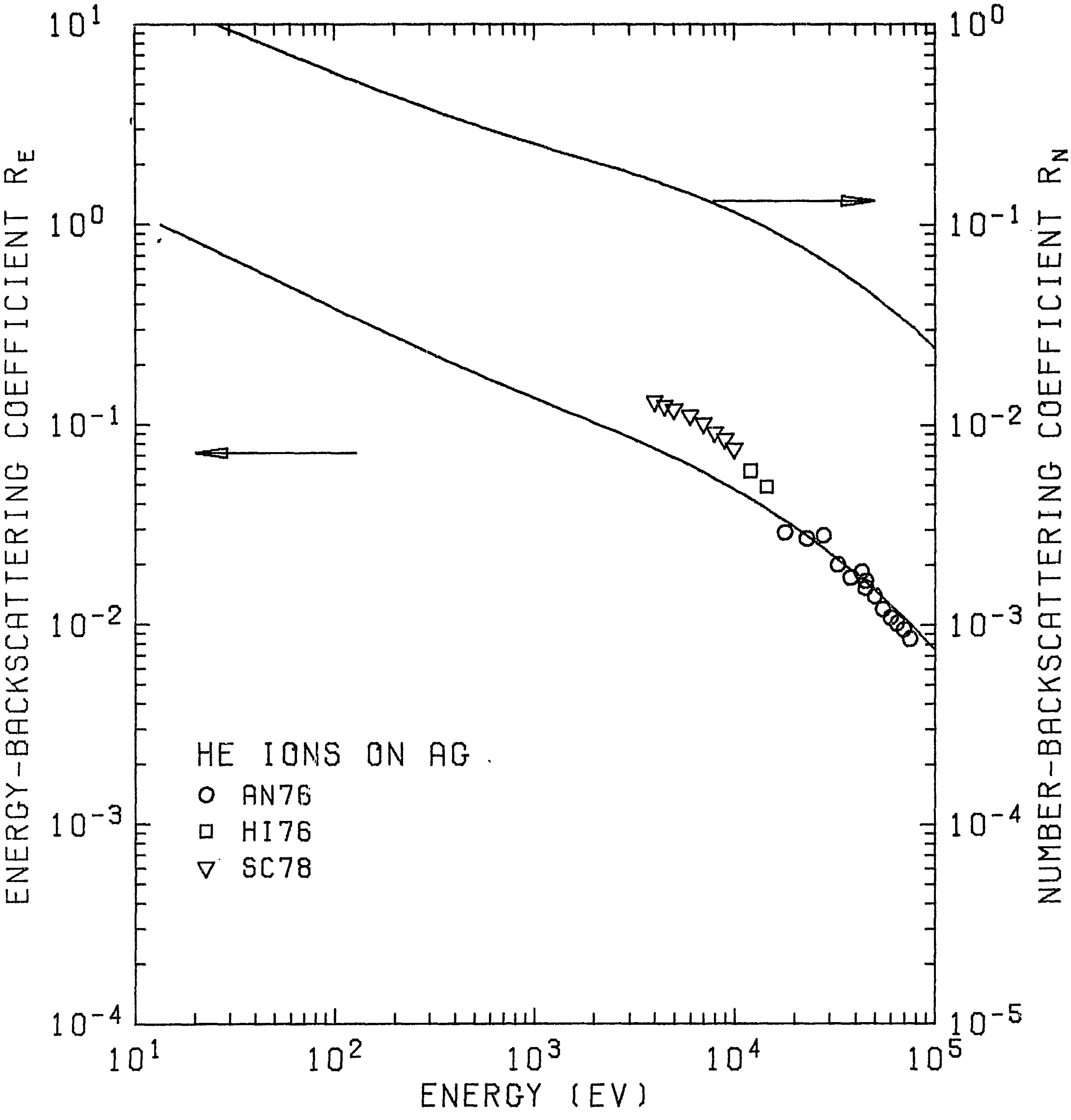

Fig. 44. R_N and R_E of He ions on $_{47}Ag$.

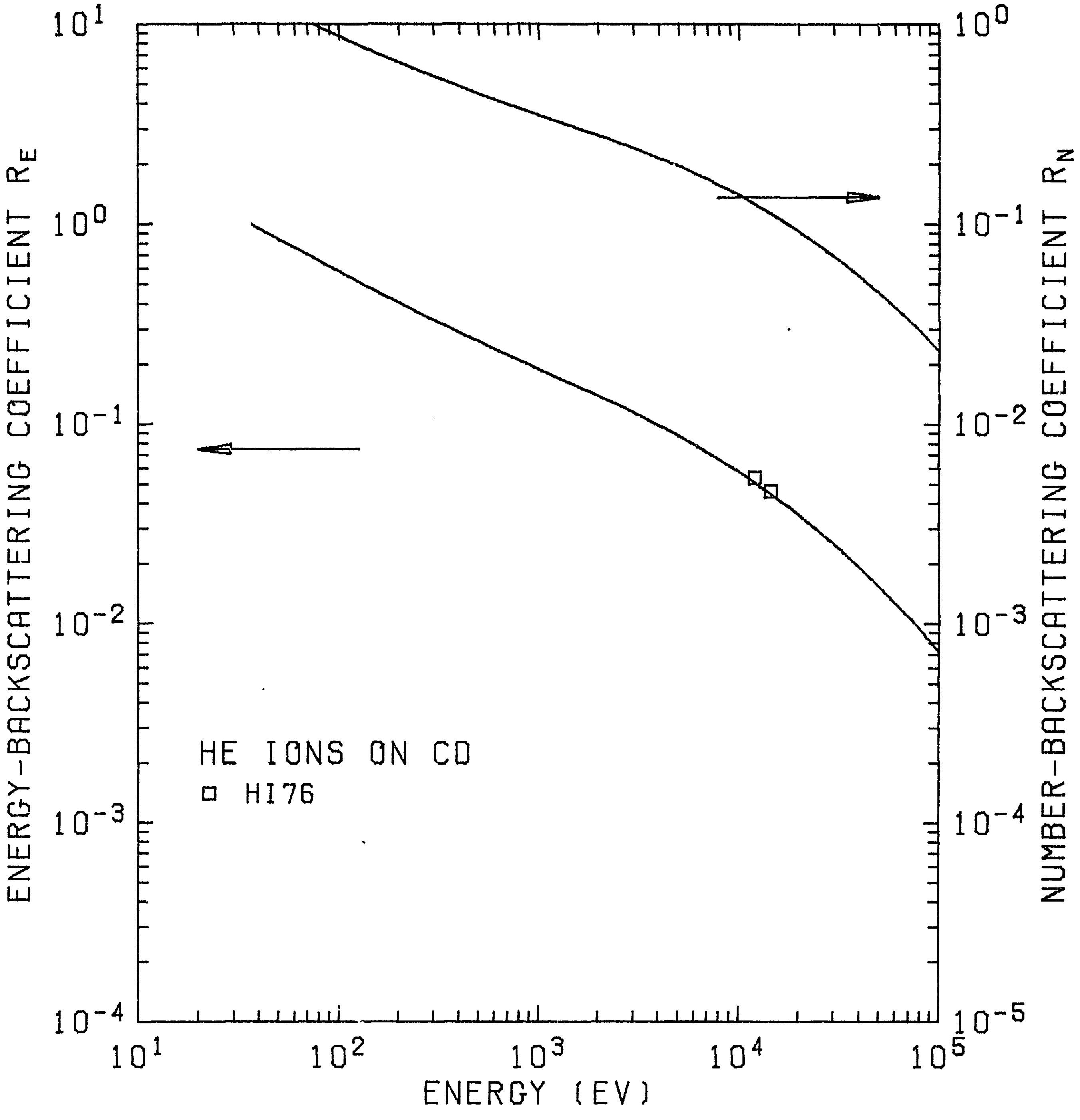

Fig. 45. R_N and R_E of He ions on $_{48}$Cd.

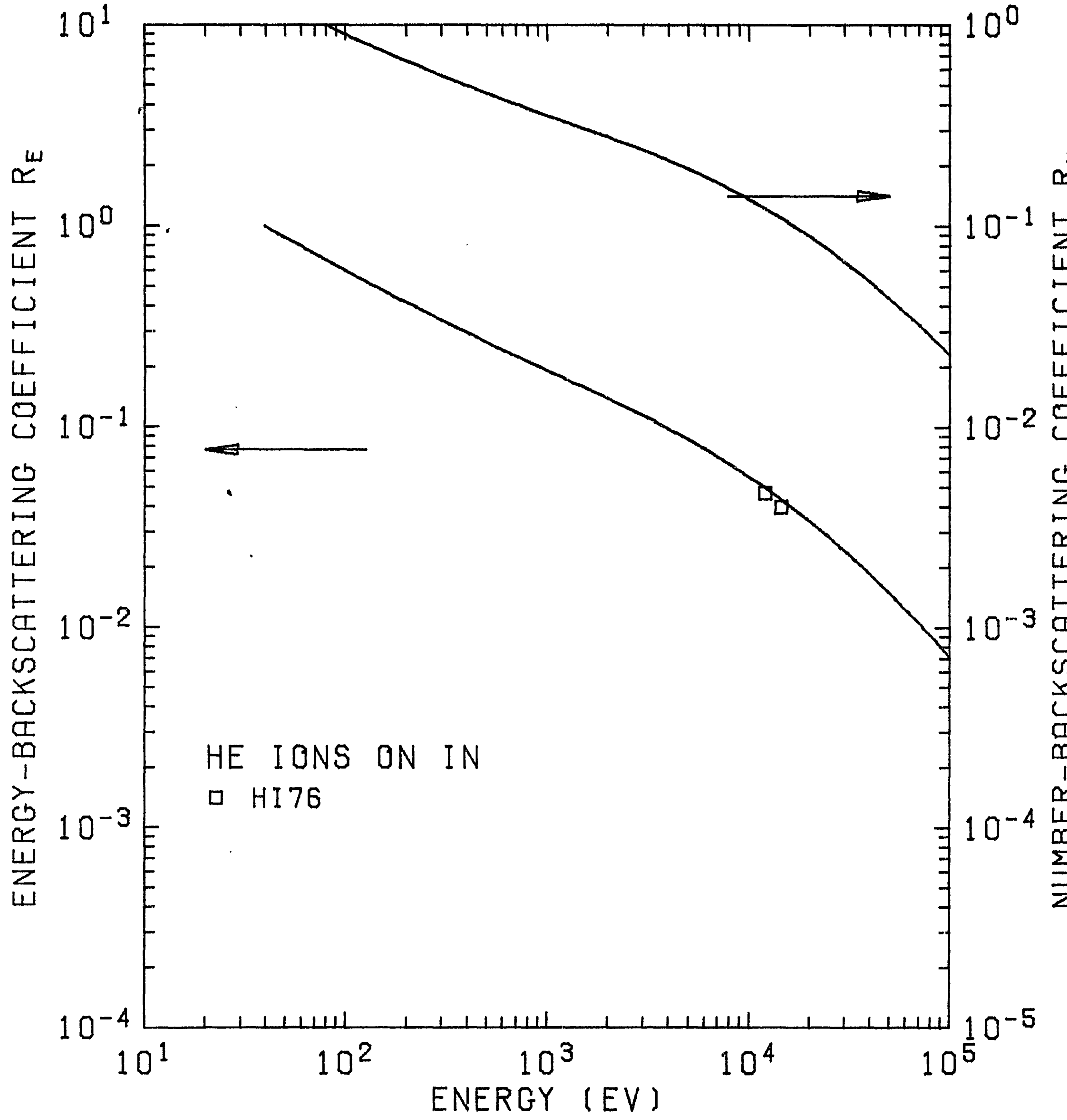

Fig. 46. R_N and R_E of He ions on $_{49}In$.

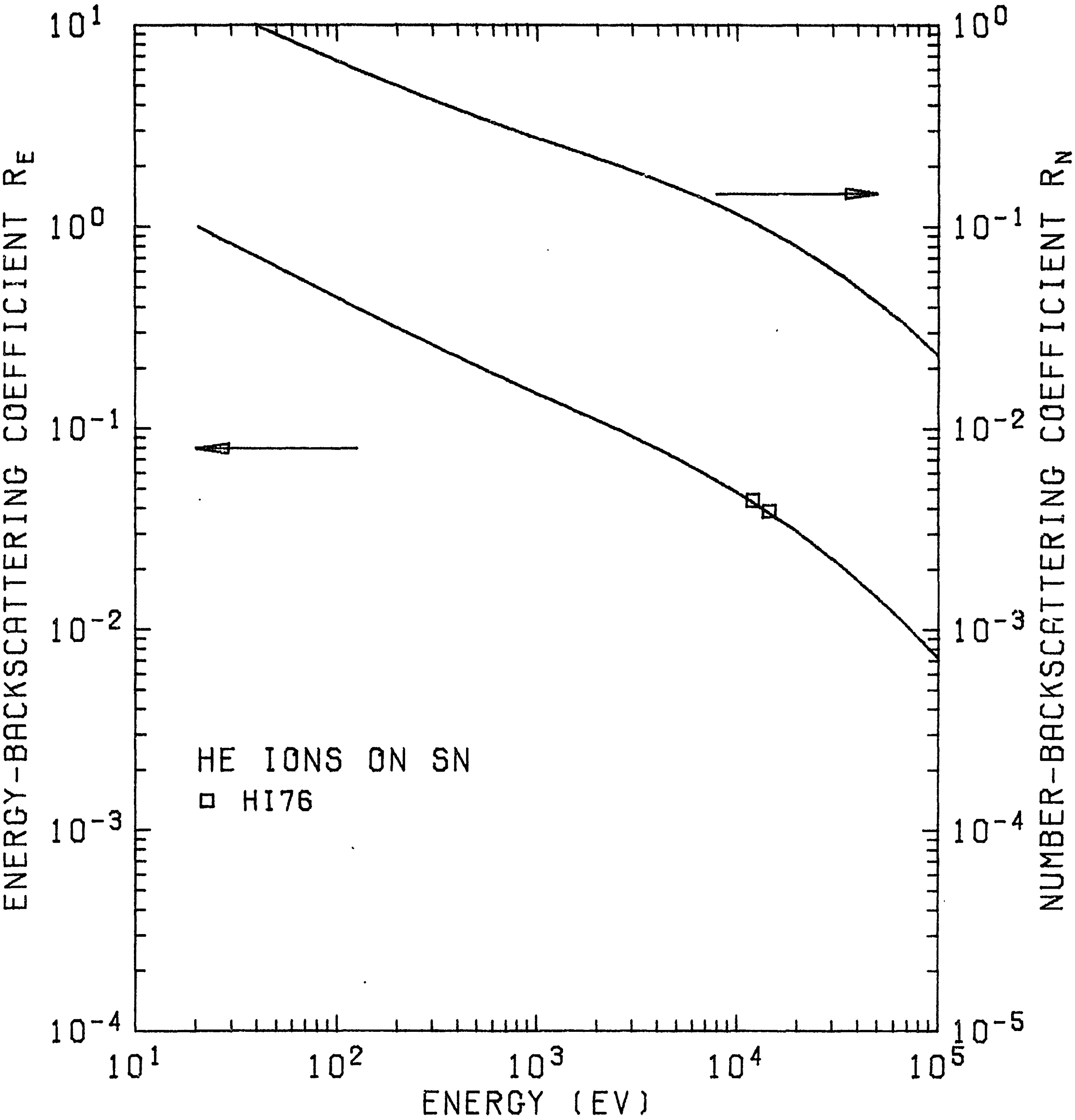

Fig. 47. R_N and R_E of He ions on $_{50}Sn$.

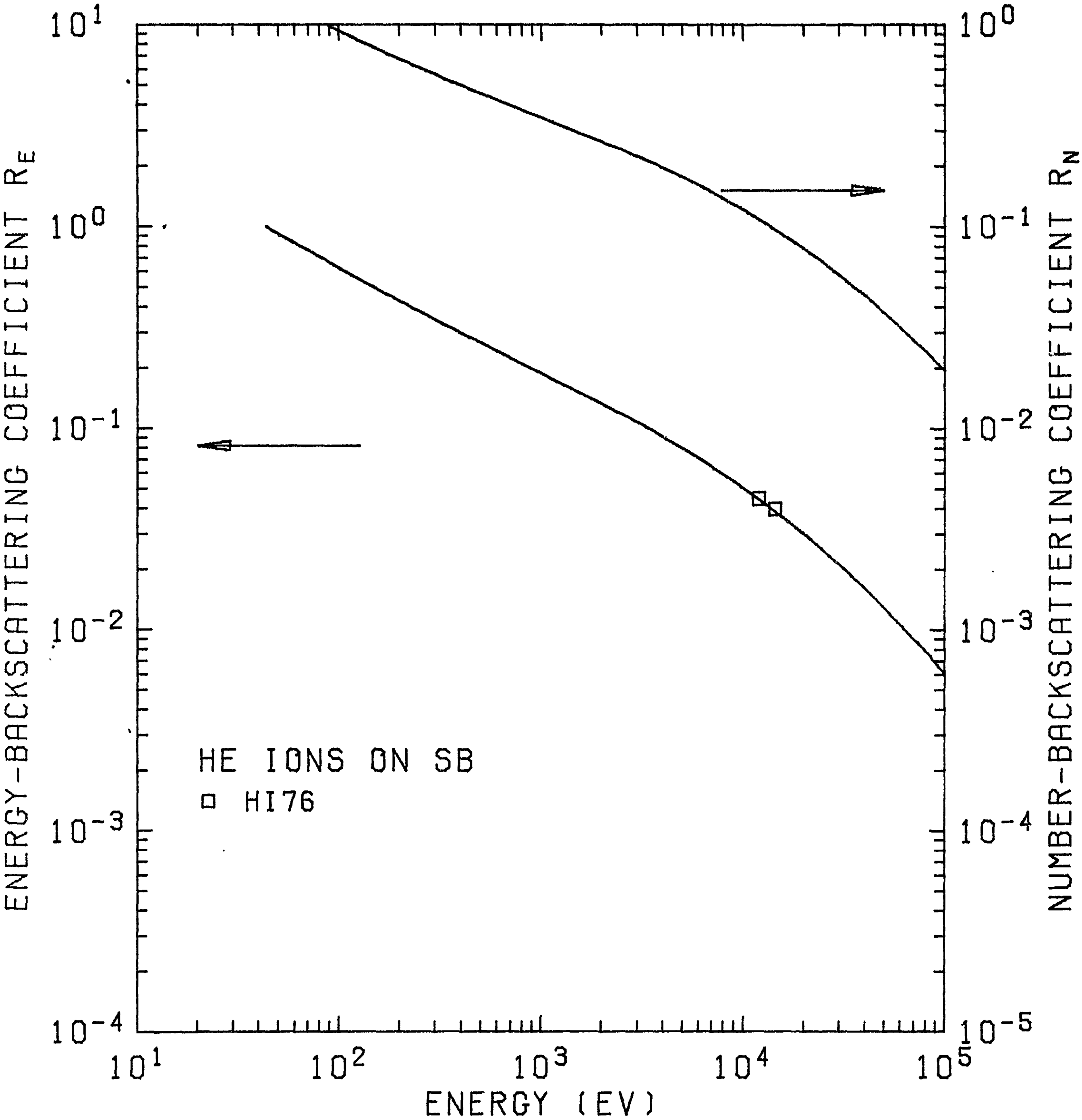

Fig. 48. R_N and R_E of He ions on $_{51}Sb$.

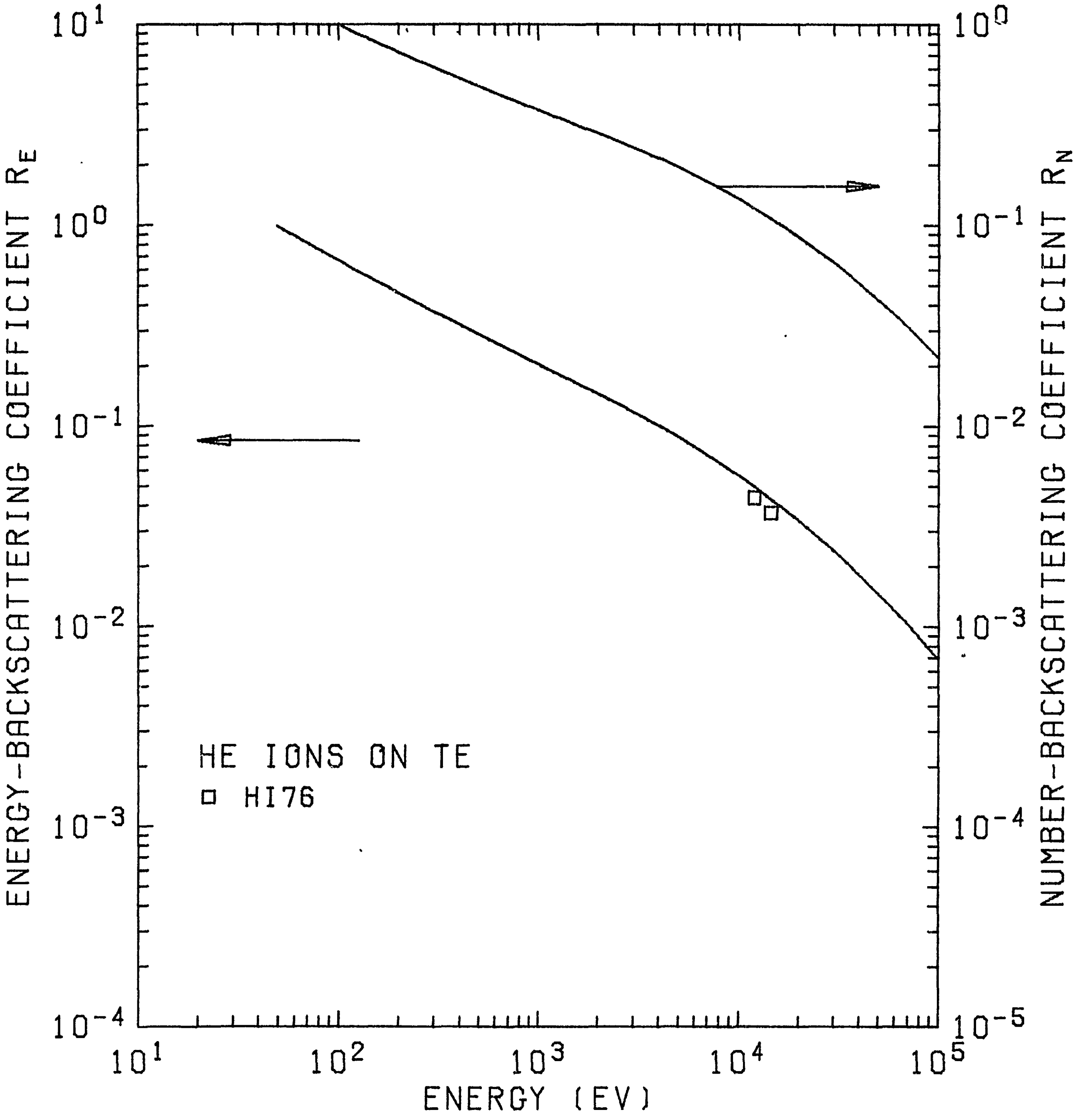

Fig. 49. R_N and R_E of He ions on $_{52}Te$.

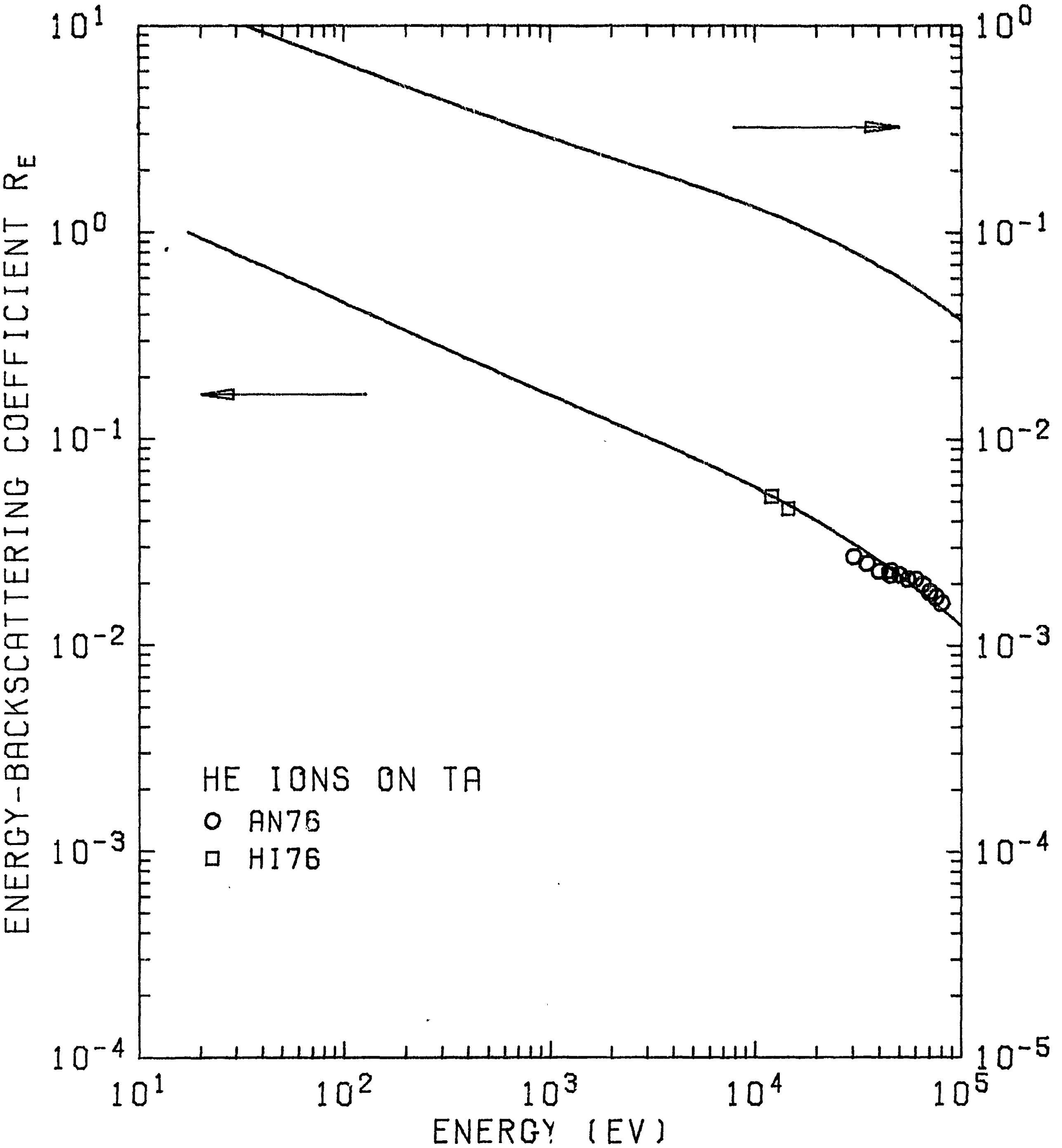

Fig. 50. R_N and R_E of He ions on $_{73}$Ta.

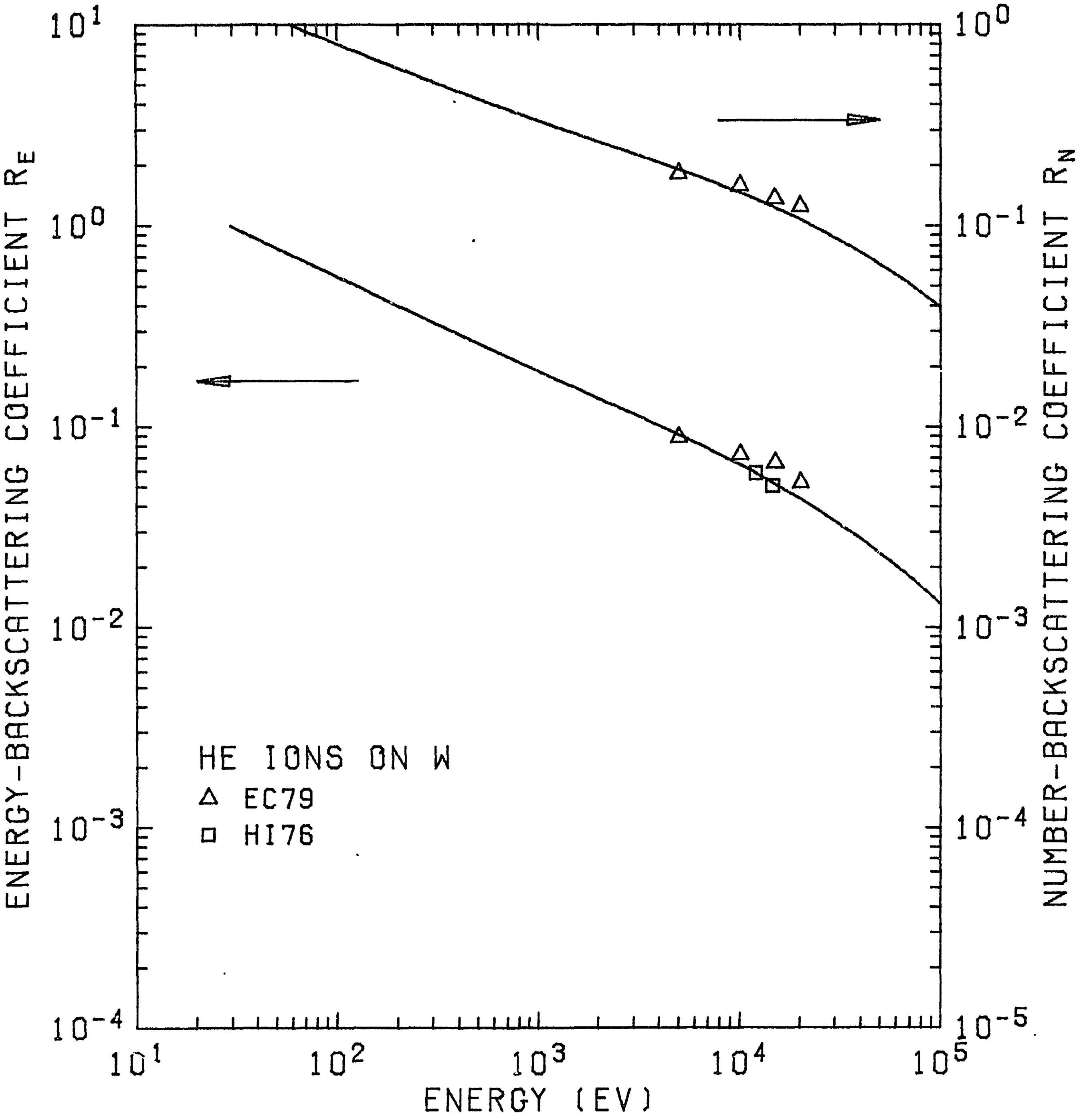

Fig. 51. R_N and R_E of He ions on $_{74}W$.

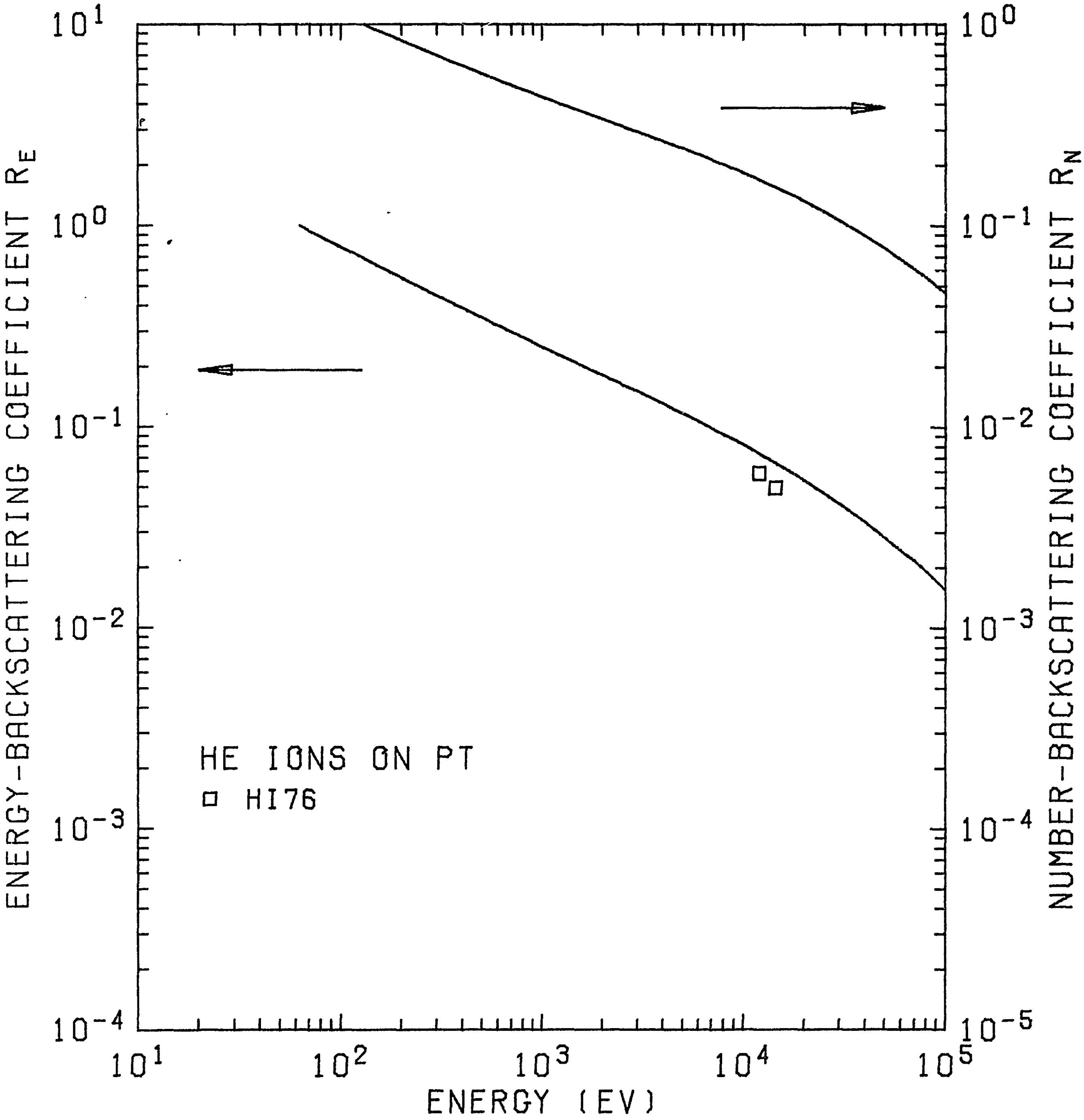

Fig. 52. R_N and R_E of He ions on $_{78}$Pt.

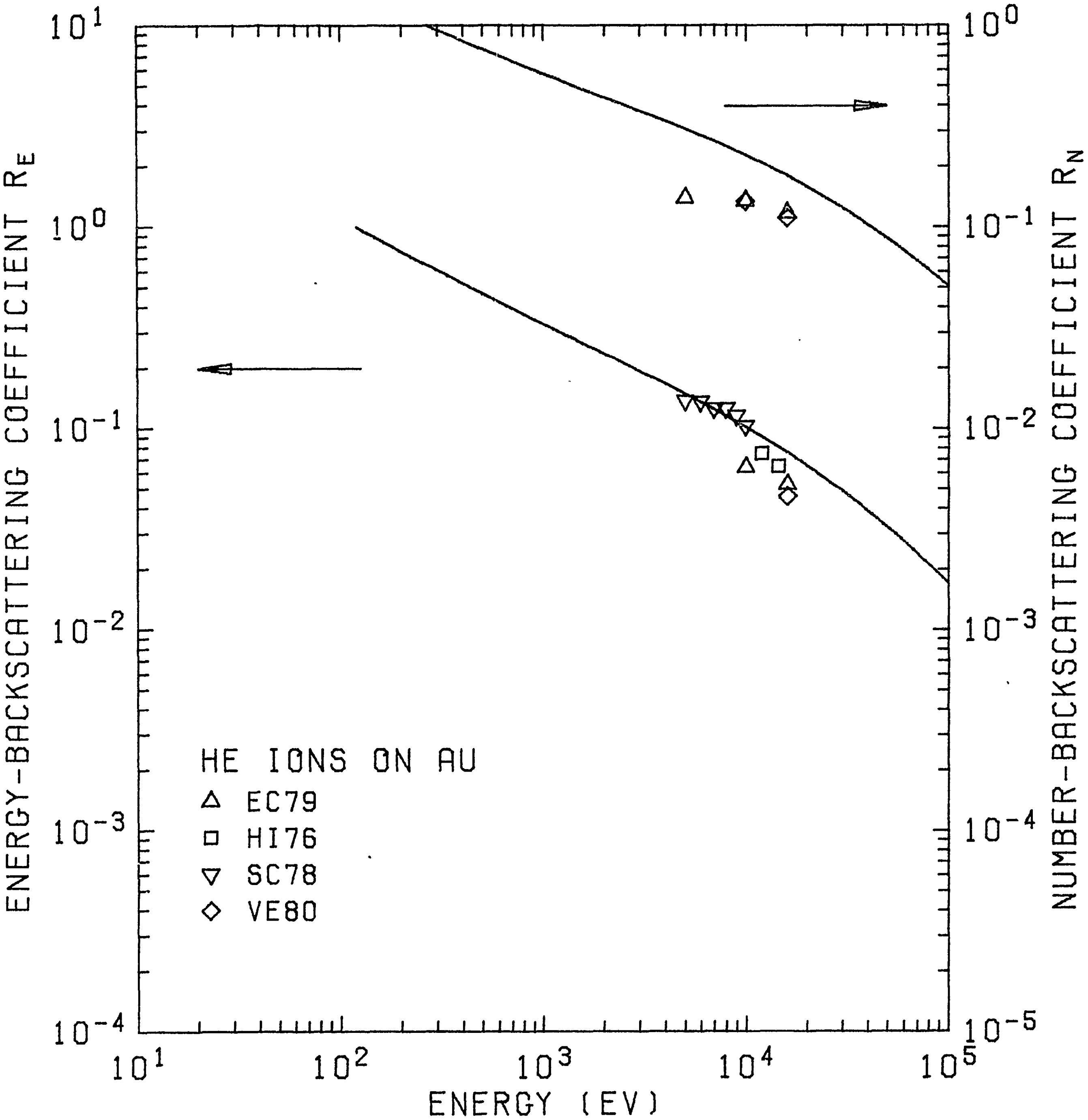

Fig. 53. R_N and R_E of He ions on $_{79}$Au.

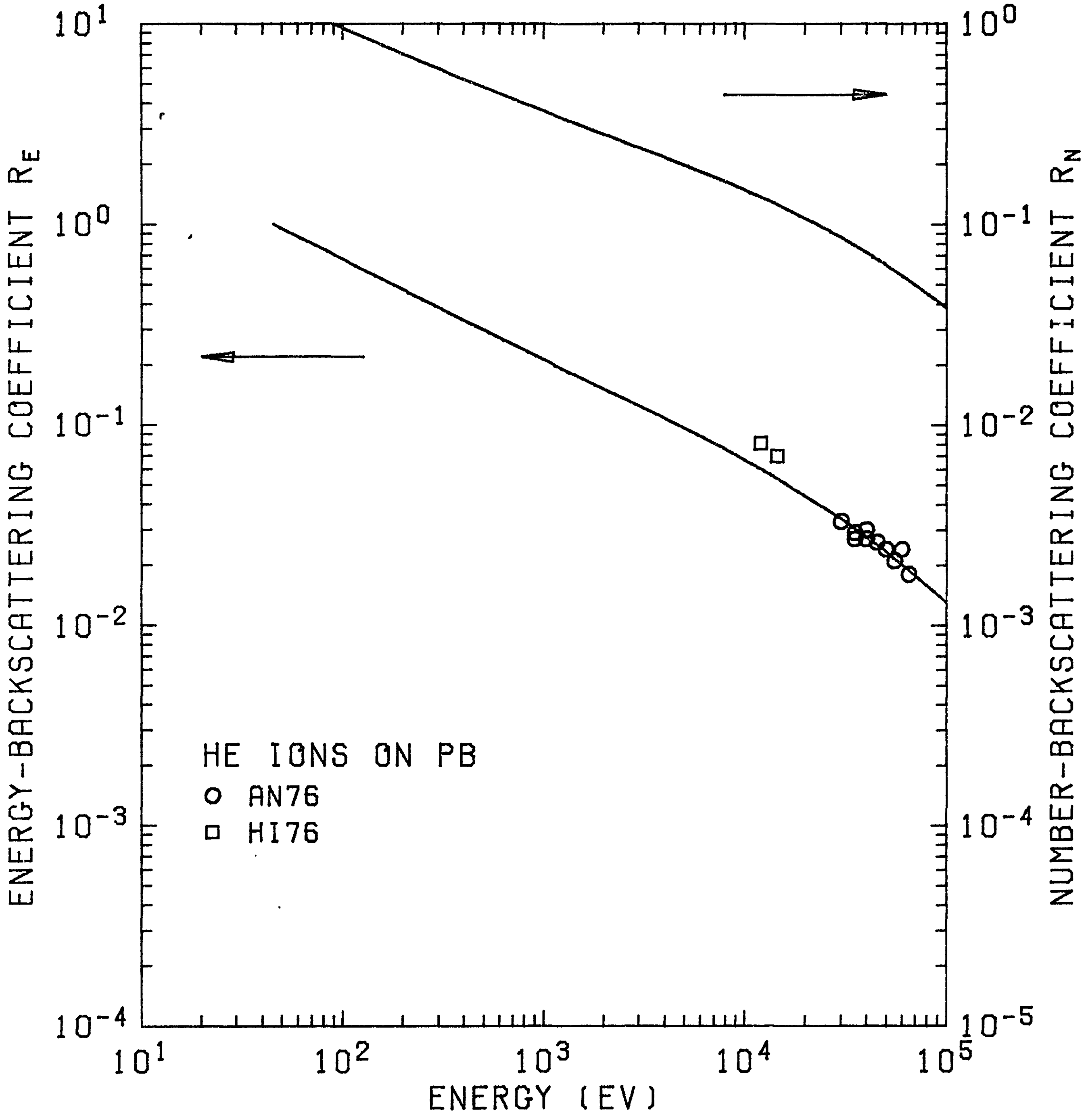

Fig. 54. R_N and R_E of He ions on $_{82}Pb$.

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