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ABSTRACT

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 are tabulated for H, D, ^3He, and ^4He ions normally incident on elemental solids. References through 1984 are covered. The dependence of R_N and R_E on incident energy is shown graphically for energies from 10 eV to 100 keV by plotting the experimental data, computer-simulation data, and new empirical formulas. Graphs are provided for the projectiles of H, D, T, ^3He, and ^4He ions incident on 40 elemental targets of atomic numbers from 3 to 92, and for H and ^4He ions incident on compound targets. The listings of the computer programs to evaluate the empirical formulas are also given. The programs can be used for elemental and compound targets and for arbitrary angles of incidence. This compilation is a revision of the previous publications: Institute of Plasma Physics Nagoya University Report IPPJ-AM-18; Atomic Data and Nuclear Data Tables **28**, 493 (1983).

CONTENTS

INTRODUCTION

Data on the backscattering (also called reflection) of light ions are important in various fields of research and application including the development of thermonuclear-fusion reactor.[1] Recent reviews of studies on the backscattering are given by Mashkova[2] and by Eckstein and Verbeek.[3] The parameters useful for describing the backscattering are:

(1) the number-backscattering (also called particle-reflection) 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 first two:

$$r_E = R_E/R_N. \quad (1)$$

Experimental data on these parameters were compiled in Refs. 4 and 5 for normal incidence of ions, and in Ref. 6 for oblique incidence. In these references, empirical formulas[7,8] were also given to facilitate the evaluation of the parameters.

For normal incidence, new experimental data have been published,[9-12] and attempts have been made to improve the empirical formulas.[13,14] In this report, we give a revised compilation of the data for normal incidence along with the new empirical formulas. These formulas are a further revision of those given in Ref. 14.

Experimental data on R_N, R_E, and r_E are compiled in tabular form. Additionally, graphs of R_N and R_E vs incident energy are presented in which the experimental data are plotted together with the curves given by the empirical formulas. The computer-simulation data generated by the codes MARLOWE[15,16] and TRIM[17] and given in literature are also shown in the graphs. The data compiled in this report and a FORTRAN code for the empirical formulas are contained in the data base of Research Information Center, Institute of Plasma Physics, Nagoya University.

We consider the light ions of atomic numbers 1 and 2, that is H, D, T, ^{3}He, and ^{4}He ions, incident on a target of effectively semi-infinite thickness. For T ions, no experimental data is available. No particular limit has been set on the incident energy in compiling the data. The targets considered for compilation in tabular form are amorphous or polycrystalline solid of elemental materials aside from the following cases: (1) The data for stainless steel have been compiled when the data for iron is deficient, and (2) the data for crystalline tungsten reported by Amano and Seidman[9] have been compiled to give a measure at the lowest energies. Experimental data for compound targets have also been compiled, and are given only in graphs.

References up to the end of 1984 have been covered. The list of data sets not included for definite reasons has been given in Ref. 5. An additional entry to the list is:

Part of the data (incident energies of 3 and 10 keV) on R_N of D ions on C by Chen et al.[12]: these authors used the method based on the measurement of the trapping coefficient T_N, and determined values by $R_N=1-T_N$, so that the errors in R_N was large for T_N close to unity.

As for various methods of measuring R_N and R_E, we refer the reader to the aforementioned review articles.

The Empirical Formulas

The previous empirical formulas[7] for R_N and R_E had the following deficiencies: (1) A separate expression is given for each species of incident ion without allowing interpolation for T or ^{3}He ions. (2) Extrapolation cannot always be made to energies below 0.3 keV or above 100 keV. In later formulas,[13,14] a unified scaling valid for all the light ions of atomic numbers up to two and an improved fitting function were used to remove these deficiencies. The new formulas used in the present report were obtained by revising those of Ref. 14, and are given in Appendix.

The revision was made in the following respects:

(1) As suggested in Ref. 14, the ratio of path lengths (ranges) of ions in the target material was used in the scaling factor instead of the ratio of stopping cross-sections.
(2) An additional factor depending on the ratio of the projectile mass to the target atomic weight and on the reduced energy was included in the scaling factor.
(3) A universal fitting function was used to fit the reduced energy-backscattering coefficient instead of the reduced number-backscattering coefficient (see Appendix for the definition of the reduced backscattering coefficients), and the functional form was simplified.

Putting the present empirical formulas into the relation given in Ref. 8 (see Appendix II), we obtain improved formulas for the backscattering coefficients at arbitrary angles of incidence. A FORTRAN subprogram to evaluate these empirical formulas is given in Table A. A BASIC program for the same purpose is given in Table B.

The empirical formulas at normal incidence were plotted in the graphs of the present report for the region of energies from 10 eV to 100 keV.

Discussion of Results

Experimental data on R_N and R_E of light ions are available, in favorable cases, for incident energies down to 33 eV and up to 80 keV. Below 1 keV, data are scarce in spite of their importance in fusion research. To predict the data in this energy region, several authors performed Monte Carlo simulations using the binary collision approximation. In the energy region where experimental and Monte Carlo studies overlap, the results show moderately good agreement as can be seen in the graphs of this report.

For elemental targets, the new empirical formulas are reasonably in good agreement with the experimental and the computer-simulation data, covering almost the whole energy region above 10 eV for various combinations of the projectile and the target (validity at energies above 100 keV can be seen from Fig. A on p. 23). The relative deviations of the data from the empirical formulas follow approximately the normal distribution; the standard deviation is 26% for the total of 525 experimental data, and 28% for the total of 695 computer-simulation data. No significant difference in the standard devaiation can be seen for the different projectiles. Applicability of the formulas to projectiles of mass number greater than four is being investigated. As shown in Graphs VI and VII, the formulas can also be used to evaluate R_N and R_E for compound targets.

Few data are presently available for incident energies below 10 eV. It should be noted that, using the computer simulation called the embedded atom method,[18] Baskes[19] has found a drastic decrease, due to the effect of chemical interactions, of R_N with decreasing energy below several eV. Data in this energy region are urgently needed in designing the divertors of tokamak-type fusion devices.

Appendix I

In this appendix we present the empirical formulas used for R_E and r_E. The formula for R_N can be obtained from these formulas by use of Eq. (1).

(1) Meaning of Symbols and Definitions

R_N =number-backscattering coefficient.

R_E =energy-backscattering coefficient.

r_E =mean fractional energy of the backscattered particles $=R_E/R_N$.

η_N =reduced number-backscattering coefficient $=fR_N$.

η_E =reduced energy-backscattering coefficient $=fR_E$.

E =incident kinetic energy of the projectile in eV.

Z_1 =atomic number of the projectile.

Z_2 =atomic number of the target.

M_1 =mass of the projectile.

M_2 =atomic weight of the target.

μ $=M_2/M_1$.

α $=1+1/\mu$.

ζ $=[1+(Z_1/Z_2)^{2/3}]^{1/2}$.

f =scaling factor for the backscattering coefficients.

ε =Thomas-Fermi reduced energy $=0.032534E/(Z_1Z_2^{4/3}\alpha\zeta)$.

S_L =low-energy electronic stopping cross-section in LSS units; the formula of Lindhard et al.[20] corrected for the Z_2-oscillations is used.

S_B =high-energy electronic stopping cross-section in LSS units. The Bethe-Bloch formula modified by Biersack and Haggmark[17] is used; the modification was made so that the relation $(1/S_L+1/S_B)$ gives the electronic stopping cross-section in the intermediate energy region.

S_a =electronic stopping cross-section given by the formula of

Lindhard et al.[20] when μ is much greater than unity.

ρ_a ="virtual" path length (range) of the incident ion in the target material when the stopping cross section is assumed to be given by S_a for the whole energy region.

ρ_t ="true" path length of the incident ion in the target material.

ρ_n =path length, determined by nuclear stopping only, of the incident ion in the target material; the formula of Wilson et al.[21] is used.

$$\Gamma(\nu, x) = \int_x^{\infty} e^{-t} t^{\nu-1} dt$$

D =correction factor for the low-energy electronic stopping cross-section.

A_1 =coefficient in the semiempirical formula of Andersen and Ziegler[22] for the electronic stopping cross-section.

β =ratio of the projectile velocity to the velocity of light.

$m_e c^2$ =rest energy of the electron.

$Z_2 I_0$ =mean excitation energy of target atoms.

Z_c =effective atomic number of the compound target.

M_c =effective atomic weight of the compound target.

(2) Formulas

The formula for R_E is written as

$$R_E = (0.705/f)/[1+(\varepsilon/0.047)^{0.597}+(\varepsilon/0.619)^{1.5}], \tag{A1}$$

where

$$f = Z_1^{2/3} M_1^{-1/2} \alpha^{(2\varepsilon-3)/(\varepsilon+1)} \rho_a/\rho_t, \tag{A2}$$

$$\rho_a/\rho_t = \{2\varepsilon/\rho_n+[1/S_L+1/(4S_B)]^{-1}\}/S_a, \tag{A3}$$

$$\rho_n = \{\Gamma[0,(C-1)\ln(B\varepsilon)]-\Gamma[0,-2\ln(B\varepsilon)]\}/(AB), \tag{A4}$$

$$A = 0.56258, \tag{A5}$$

$$B = 1.1776, \tag{A6}$$

$$C = 0.62680, \tag{A7}$$

$$S_L = D(\alpha/\zeta)^{3/2} S_a, \tag{A8}$$

$$S_B = 61.47 Z_1 \alpha\mu\zeta Z_2^{-2/3} \{\ln[\varepsilon_B/(1-\beta^2)+1+G/\varepsilon_B]-\beta^2\}/(I_0\varepsilon_B), \tag{A9}$$

$$S_a = 0.0793 Z_1^{2/3} \mu M_1^{-1/2} \varepsilon^{1/2}, \tag{A10}$$

$$D = 0.2617(1+Z_2^{2/3})^{3/2} Z_2^{-1} A_1, \tag{A11}$$

$$\varepsilon_B = 2m_e c^2 \beta^2/(Z_2 I_0), \tag{A12}$$

$$I_0 = \begin{cases} 12+7Z_2^{-1} & \text{for } Z_2<13, \\ 9.76+58.5Z_2^{-1.19} & \text{for } Z_2\geqq 13, \end{cases} \tag{A13}$$

$$G = \begin{cases} 100Z_1/Z_2 & \text{for } Z_1<3, \\ 5 & \text{for } Z_1\geqq 3. \end{cases} \tag{A14}$$

The formula for r_E is given by[12]

$$r_E = 1/[1+(\varepsilon/0.133)^{0.285}]+0.530/[1+(\varepsilon/85)^{-1.46}]. \tag{A15}$$

For the compound target, Z_c and M_c defined by the following formula[3] are used instead of Z_2 and M_2 to evaluate the value of ε appearing explicitly in Eqs. (A1), (A2), and (A15):

$$Z_c,\ M_c = (mX+nY+\ldots)/(m+n+\ldots), \tag{A16}$$

where X, Y, ... are the atomic numbers or the atomic weights of the constituent elements in the compound $X_mY_n\ldots$. Values of $2\varepsilon/\rho$, S_L, S_B, and S_a for the compound target are evaluated by applying the Bragg rule.

(3) Comments on Formulas

At high energies η_N and η_E behave as $\varepsilon^{-1.5}$ in accord with theoretical prediction (see Appendix 1 of Ref. 14). When the exponent of the last term in Eq. (A1) was adjusted, we obtained the value of 1.486±0.027; therefore, the exponent was fixed to 1.5 in the final fit. The curves of η_N and η_E versus ε are shown in Fig. A together with the experimental and computer-simulation data used for the fit.

Another feature to be noted at high energies is that the factor $\alpha^{(2\varepsilon-3)/(\varepsilon+1)}$ in f is approximately equal to α^2; then f is approximately equal to the scaling factor derived from the single-collision model by Morita et al.[13] A similar dependence of the scaling factor on α at high energies is implied by Wedell's single-collision approximation result,[23] which gives $\alpha^3/[1+5/(8\mu)]$ in place of α^2 when the terms of the second and higher orders in $1/\mu$ are neglected (note that $\alpha=1+1/\mu$).

The dependence of the exponent of α on ε at low and intermediate energies was determined by inspection so as to reduce the deviation of the formulas from the data for D ions incident on the carbon target.

To obtain the expression for ρ_t at high energies, the factor in {} of Eq. (A9) was assumed to be a constant and β much smaller than unity.

Appendix II

In this appendix we give an empirical relation[8] between the backscattering coefficients of light ions at oblique incidence and those at normal incidence.

(1) Meaning of Symbols

$R(0)$ =number- or energy-backscattering coefficient of ions normally incident on the target (denoted by R_N or R_E in other part of this report).

$R(\theta)$ =number- or energy-backscattering coefficient of ions impinging on the target at the angle of incidence θ.

(2) Relation

$$R(\theta) = R(0)+[1-R(0)]/(1+a_1\cot^{2a_2}\theta), \quad (A17)$$

where a_1 and a_2 are given as follows:
For the number-backscattering coefficient,

$$a_1 = 7.38\varepsilon^{0.359}, \quad (A18)$$

$$a_2 = 0.836/\varepsilon^{0.087}. \quad (A19)$$

For the energy-backscattering coefficient,

$$a_1 = 17.9\varepsilon^{0.453}, \quad (A20)$$

$$a_2 = 0.771/\varepsilon^{0.014}. \quad (A21)$$

(3) Comments on the Relation

The combination of Eq. (A17) with the present empirical formulas for the backscattering coefficients at normal incidence gives formulas for arbitrary values of θ. The standard deviation of the relevant data* from these formulas is 21% for experiment (130 data points), and 15% for computer simulation (494 data points).

* The data obtained to show the dependence of the backscattering coefficients on θ. Those compiled in Ref. 6 and the new ones in Ref. 12 were used.

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TABLE A. FORTRAN Subprogram to Evaluate Empirical Formulas for Number- and Energy-Backscattering Coefficients of Light Ions Incident on Elemental and Compound Targets

[Call RNION for the Number-Backscattering Coefficient and REION for Energy-Backscattering Coefficient]

```
      FUNCTION RNION(THETA,ENERGY,NZ1,M1,NE,NZ2,NW)
C
C       NUMBER-BACKSCATTERING COEFFICIENT OF LIGHT IONS
C
C       MEANING OF INPUT VARIABLES
C
C         THETA   ANGLE OF INCIDENCE IN DEGREE
C         ENERGY  INCIDENT KINETIC ENERGY IN EV
C         NZ1     ATOMIC NUMBER OF THE PROJECTILE
C         M1      MASS NUMBER OF THE PROJECTILE
C         NE      NUMBER OF CONSTITUENT ELEMENTS IN THE TARGET
C         NZ2     ARRAY FOR ATOMIC NUMBERS OF THE CONSTITUENTS
C         NW      ARRAY FOR RELATIVE NUMBERS OF ATOMS OF THE
C                   CONSTITUENTS
C
C         EXAMPLE: FOR TRITIUM IONS OF 1-KEV ENERGY INCIDENT ON THE
C           TIO2 (TITANIUM DIOXIDE) TARGET, ENERGY=1000, NZ1=1, M1=3,
C           NE=2, NZ2(1)=22, NW(1)=1, NZ2(2)=8 AND NW(2)=2
C
C       TABLES PREPARED
C         A1T     TABLE OF MASSES OF PROJECTILES
C         A2T     TABLE OF ATOMIC WEIGHTS OF ELEMENTAL TARGETS
C                   IUPAC (1983), C12=12
C         D       TABLE OF CORRECTION FACTORS FOR THE LOW-ENERGY
C                   ELECTRONIC STOPPING CROSS-SECTION
C
      DIMENSION A1T(5),A2T(92),D(92),NZ2(NE),NW(NE)
      DATA A1T/
C       Z1= 1
     +1.0072766,2.0135536,3.0155011,
C       Z1= 2
     +3.0149325,4.0015059/
      DATA A2T/
C       Z2= 1-10
     +1.00794,4.002602,6.941,9.01218,10.811,12.011,14.0067,15.9994,
     +18.998403,20.179,
C       Z2=11-20
     +22.98977,24.305,26.98154,28.0855,30.97376,32.066,35.453,39.948,
     +39.0983,40.078,
C       Z2=21-30
     +44.95591,47.88,50.9415,51.9961,54.9380,55.847,58.9332,58.69,
     +63.546,65.39,
C       Z2=31-40
     +69.723,72.59,74.9216,78.96,79.904,83.80,85.4678,87.62,88.9059,
     +91.224,
C       Z2=41-50
     +92.9064,95.94,99.,101.07,102.9055,106.42,107.8682,112.41,114.82,
     +118.710,
C       Z2=51-60
     +121.75,127.60,126.9045,131.29,132.9054,137.33,138.9055,140.12,
     +140.9077,144.24,
C       Z2=61-70
     +145.,150.36,151.96,157.25,158.9254,162.50,164.9304,167.26,
     +168.9342,173.04,
C       Z2=71-80
```

```
     +174.967,178.49,180.9479,183.85,186.207,190.2,192.22,195.08,
     +196.9665,200.59,
C       Z2=81-90
     +204.383,207.2,208.9804,210.,210.,222.,223.,226.,227.,232.0,
C       Z2=91-92
     +231.,238.0289/
      DATA D/
C       Z2= 1-10
     +.9341,.6693,.6654,.9712,1.007,1.024,1.111,.9699,.7357,.6842,
C       Z2=11-20
     +.8769,1.290,1.395,1.378,1.063,1.123,1.632,1.839,1.642,1.749,
C       Z2=21-30
     +1.638,1.523,1.396,1.236,1.072,1.083,.9624,1.085,1.125,1.277,
C       Z2=31-40
     +1.525,1.675,1.601,1.762,1.679,1.914,1.696,1.884,1.900,1.993,
C       Z2=41-50
     +2.039,1.894,2.001,1.795,1.738,1.534,1.644,1.698,1.816,1.866,
C       Z2=51-60
     +2.181,2.027,2.240,2.384,2.108,2.283,2.321,2.159,2.100,2.042,
C       Z2=61-70
     +1.986,1.932,1.879,1.931,1.779,1.578,1.492,1.448,1.406,1.365,
C       Z2=71-80
     +1.394,1.431,1.348,1.300,1.477,1.439,1.403,1.269,1.376,1.220,
C       Z2=81-90
     +1.336,1.504,1.683,1.739,1.751,1.744,1.959,2.115,2.167,2.170,
C       Z2=91-92
     +2.084,2.050/
      F(Z1,Z2)=SQRT(Z1**.6666667+Z2**.6666667)
      FNEPS(E,Z1,A1,Z2,A2)=.032534*E/(Z1*Z2*(1.+A1/A2)*F(Z1,Z2))
      RNE(TH)=R0+(1.-R0)/(1.+AS1*(COTAN(TH))**(2.*AS2))
  600 FORMAT('  UNDEFINED PROJECTILE IS CALLED.')
      N=1
      GO TO 1
      ENTRY REION(THETA,ENERGY,NZ1,M1,NE,NZ2,NW)
C
C       ENERGY-BACKSCATTERING COEFFICIENT OF LIGHT IONS
C
      N=0
    1 IF(NZ1.EQ.1) GO TO 3
      IF(NZ1.EQ.2) GO TO 4
    2 WRITE(6,600)
      RETURN
    3 IF(M1.LT.1.OR.M1.GT.3) GO TO 2
      A1=A1T(M1)
      GO TO 5
    4 IF(M1.LT.3.OR.M1.GT.4) GO TO 2
      A1=A1T(M1+1)
    5 Z1=NZ1
      Z1P=Z1**.6666667
      Z2EFF=0.
      A2EFF=0.
      SAEFF=0.
      SBEFF=0.
      SUM=0.
      DO 70 I=1,NE
```

```
      Z2=NZ2(I)
      A2=A2T(NZ2(I))
      WI=NW(I)
      Z2EFF=Z2EFF+WI*Z2
      A2EFF=A2EFF+WI*A2
      SUM=SUM+WI
      FMU=A1/A2
      AA=1.+FMU
      Z2P=Z2**.6666667
      ZZ=SQRT(1.+Z1P/Z2P)
      EPS=FNEPS(ENERGY,Z1,A1,Z2,A2)
      SA=.0793*SQRT(EPS)/FMU
      W=Z1*ZZ*AA/Z2P
      WI=WI*Z1/W/A2
      SAEFF=SAEFF+WI*SA
      SL=D(NZ2(I))*Z1P*(AA/ZZ)**1.5*SA/SQRT(A1)
      IF(Z2-12.9) 10,10,20
   10 FI0=12.+7./Z2
      GO TO 30
   20 FI0=9.76+58.5/Z2**1.19
   30 TAU=EPS*Z2**2*W/A1/3.03055E7
      BETA2=TAU*(TAU+2.)/(TAU+1.)**2
      EPSB=1.022E6*BETA2/Z2/FI0
      IF(Z1-2.9) 40,40,50
   40 C=100.*Z1/Z2
      GO TO 60
   50 C=5.
   60 SB=61.474/FMU*W*(ALOG(EPSB/(1.-BETA2)+1.+C/EPSB)-BETA2)/FI0/EPSB
      SB=2.*EPS/RANGEN(EPS)+SL*SB/(.25*SL+SB)
      SBEFF=SBEFF+WI*SB
   70 CONTINUE
      Z2=Z2EFF/SUM
      A2=A2EFF/SUM
      SA=SAEFF
      SB=SBEFF
      EPS=FNEPS(ENERGY,Z1,A1,Z2,A2)
      FEPS=(2.*EPS-3.)/(EPS+1.)
      R0=.705*SA/SB/(1.+A1/A2)**FEPS
      R0=R0/(1.+(EPS/.047)**.597+(EPS/.619)**1.5)
      TH=THETA*1.745329E-2
      IF(N.EQ.1) GO TO 80
      IF(TH.EQ.0.) GO TO 78
      AS1=17.9*EPS**.453
      AS2=.771/EPS**.014
      REION=RNE(TH)
      RETURN
   78 REION=R0
      RETURN
   80 R=1./(1.+(EPS/0.133)**0.285)+0.530/(1.+(85./EPS)**1.46)
      R0=R0/R
      IF(TH.EQ.0.) GO TO 88
      AS1=7.38*EPS**.359
      AS2=.836/EPS**.087
      RNION=RNE(TH)
      RETURN
```

```
   88 RNION=R0
      RETURN
      END
C
      FUNCTION RANGEN(EPSILN)
C       REDUCED RANGE OF IONS FOR NUCLEAR STOPPING ONLY.
C       W. D. WILSON, L. G. HAGGMARK AND J. P. BIERSACK,
C       PHYS. REV. B 15, 2458 (1977).
      DATA A,B,C/.56258,1.1776,.62680/
      X=LOG(B*EPSILN)
      X1=(C-1.)*X
      X2=-2.*X
      RANGEN=(EXPINT(X1)-EXPINT(X2))/A/B
      RETURN
      END
C
      FUNCTION EXPINT(X)
C       INCOMPLETE GAMMA FUNCTION: GAMMA(0,X)
C         GAMMA(0,X)=-EI(-X)     FOR X>0
C         GAMMA(0,X)=-EIBAR(-X)  FOR X<0
      DOUBLE PRECISION A,B,CONV,F,P,Q,T,Z
      DIMENSION A(4),B(4)
      DATA A/.2677737343,8.6347608925,18.0590169730,8.5733287401/
      DATA B/3.9584969228,21.0996530827,25.6329561486,9.5733223454/
      DATA CONV/1.D-7/
      Z=DBLE(X)
      IF(X-1.) 10,40,40
   10 P=.57721566490153
      IF(X) 12,30,15
   12 IF(X+83.5) 13,15,15
   13 EXPINT=-1.E75
      RETURN
   15 P=P+LOG(ABS(Z))
      F=1.D0
      T=-Z
   20 Q=T+P
      IF(ABS(P-Q)-CONV) 30,30,22
   22 P=Q
      T=-Z*F*T
      F=F+1.D0
      T=T/F**2
      GO TO 20
   30 EXPINT=-P
      RETURN
   40 IF(X-84.) 43,43,41
   41 EXPINT=1.E-75
      RETURN
   43 P=((((Z+A(4))*Z+A(3))*Z+A(2))*Z+A(1))/
     +   ((((Z+B(4))*Z+B(3))*Z+B(2))*Z+B(1))
      EXPINT=EXP(-Z)*P/Z
      RETURN
      END
```

TABLE B. BASIC Program to Evaluate Empirical Formulas for Number- and Energy-Backscattering Coefficients of Light Ions Incident on Elemental and Compound Targets

```
10 '  PROGRAM NAME: RNEION
20 '
30 '  PURPOSE: TO CALCULATE NUMBER- AND ENERGY-BACKSCATTERING COEFFICIENTS
40 '              OF LIGHT IONS
50 '
60 '  MACHINE: ANY ONE OPERATING UNDER BASIC INTERPRETER WITH DOUBLE
70 '              PRECISION FUNCTIONS: ABS, EXP AND LOG
80 '           FOR EXAMPLE, PC-9801 SERIES
90 '
100 ' MEANING OF INPUT VARIABLES
110 '
120 '           THETA   ANGLE OF INCIDENCE IN DEGREE
130 '           ENERGY  INCIDENT KINETIC ENERGY IN EV
140 '           NZ1%    ATOMIC NUMBER OF THE PROJECTILE
150 '           M1%     MASS NUMBER OF THE PROJECTILE
160 '           NE%     NUMBER OF CONSTITUENT ELEMENTS IN THE TARGET
170 '           NZ2%    ARRAY FOR ATOMIC NUMBERS OF THE CONSTITUENTS
180 '           NW%     ARRAY FOR RELATIVE NUMBERS OF ATOMS OF THE
190 '                     CONSTITUENTS
200 '
210 '           EXAMPLE: FOR TRITIUM IONS OF 1-KEV ENERGY INCIDENT ON THE
220 '             TIO2 (TITANIUM DIOXIDE) TARGET, ENERGY=1000, NZ1%=1, M1%=3,
230 '             NE%=2, NZ2%(1)=22, NW%(1)=1, NZ2%(2)=8 AND NW%(2)=2
240 '
250 ' TABLES PREPARED:
260 '           A1T     TABLE OF MASSES OF PROJECTILES
270 '           A2T     TABLE OF ATOMIC WEIGHTS OF ELEMENTAL TARGETS
280 '                     IUPAC (1983), C12=12
290 '           D       TABLE OF CORRECTION FACTORS FOR THE LOW-ENERGY
300 '                     ELECTRONIC STOPPING CROSS-SECTION
310 '
320 ' TO TEST THE PROGRAM:
330 '           PUSH RETURN KEY FOR ALL REQUESTS.
340 '             RESULTS SHOULD BE:
350 '               NUMBER-BACKSCATTERING COEFFICIENT= .56425
360 '               ENERGY-BACKSCATTERING COEFFICIENT= .453919.
370 '
380 WIDTH 80,25:CONSOLE 2,25,0,1:COLOR 7:ON ERROR GOTO *WRITEMES
390 DIM A1T(5),A2T(92),D(92),A#(4),B#(4)
400 DEF FNF(Z1,Z2)=SQR(Z1^.666667+Z2^.666667)
410 DEF FNEPS(E,Z1,A1,Z2,A2)=.032534*E/(Z1*Z2*(1!+A1/A2)*FNF(Z1,Z2))
420 DEF FNRNE(TH)=R0+(1!-R0)/(1!+AS1/TAN(TH)^(2!*AS2))
430 RESTORE 440 :FOR I=1 TO 5:READ A1T(I):NEXT:
440 '       Z1= 1
450 DATA 1.0072766,2.0135536,3.0155011
460 '       Z1= 2
470 DATA 3.0149325,4.0015059
480 RESTORE 490 :FOR I=1 TO 92:READ A2T(I):NEXT:
490 '       Z2= 1-10
500 DATA 1.00794,4.002602,6.941,9.01218,10.811,12.011,14.0067,15.9994
510 DATA 18.998403,20.179
520 '       Z2=11-20
530 DATA 22.98977,24.305,26.98154,28.0855,30.97376,32.066,35.453,39.948
540 DATA 39.0983,40.078
550 '       Z2=21-30
```

```
560 DATA 44.95591,47.88,50.9415,51.9961,54.9380,55.847,58.9332,58.69
570 DATA 63.546,65.39
580 '        Z2=31-40
590 DATA 69.723,72.59,74.9216,78.96,79.904,83.80,85.4678,87.62,88.9059
600 DATA 91.224
610 '        Z2=41-50
620 DATA 92.9064,95.94,99.,101.07,102.9055,106.42,107.8682,112.41,114.82
630 DATA 118.710
640 '        Z2=51-60
650 DATA 121.75,127.60,126.9045,131.29,132.9054,137.33,138.9055,140.12
660 DATA 140.9077,144.24
670 '        Z2=61-70
680 DATA 145.,150.36,151.96,157.25,158.9254,162.50,164.9304,167.26
690 DATA 168.9342,173.04
700 '        Z2=71-80
710 DATA 174.967,178.49,180.9479,183.85,186.207,190.2,192.22,195.08
720 DATA 196.9665,200.59
730 '        Z2=81-90
740 DATA 204.383,207.2,208.9804,210.,210.,222.,223.,226.,227.,232.0
750 '        Z2=91-92
760 DATA 231.,238.0289
770 RESTORE 780 :FOR I=1 TO 92:READ D(I):NEXT:
780 '        Z2= 1-10
790 DATA .9341,.6693,.6654,.9712,1.007,1.024,1.111,.9699,.7357,.6842
800 '        Z2=11-20
810 DATA .8769,1.290,1.395,1.378,1.063,1.123,1.632,1.839,1.642,1.749
820 '        Z2=21-30
830 DATA 1.638,1.523,1.396,1.236,1.072,1.083,.9624,1.085,1.125,1.277
840 '        Z2=31-40
850 DATA 1.525,1.675,1.601,1.762,1.679,1.914,1.696,1.884,1.900,1.993
860 '        Z2=41-50
870 DATA 2.039,1.894,2.001,1.795,1.738,1.534,1.644,1.698,1.816,1.866
880 '        Z2=51-60
890 DATA 2.181,2.027,2.240,2.384,2.108,2.283,2.321,2.159,2.100,2.042
900 '        Z2=61-70
910 DATA 1.986,1.932,1.879,1.931,1.779,1.578,1.492,1.448,1.406,1.365
920 '        Z2=71-80
930 DATA 1.394,1.431,1.348,1.300,1.477,1.439,1.403,1.269,1.376,1.220
940 '        Z2=81-90
950 DATA 1.336,1.504,1.683,1.739,1.751,1.744,1.959,2.115,2.167,2.170
960 '        Z2=91-92
970 DATA 2.084,2.050
980 '
990 RESTORE 990 :FOR I=1 TO 4:READ A#(I):NEXT:
1000 DATA .2677737343,8.6347608925,18.0590169730,8.5733287401
1010 RESTORE 1010 :FOR I=1 TO 4:READ B#(I):NEXT:READ CONV#
1020 DATA 3.9584969228,21.0996530827,25.6329561486,9.5733223454,1.D-7
1030 '
1040 LOCATE 0,0:COLOR 5:PRINT" CALCULATION OF NUMBER- AND ENERGY-BACKSCATT
ERING COEFFICIENTS OF LIGHT IONS"
1050 *PROJECTILE:LOCATE 0,2:COLOR 5:PRINT"Parameters of the projectile"
1060 *INDT1:LOCATE 0,3:COLOR 6:INPUT"  Angle of incidence in degree: (Defau
lt value=0) ", THETA
1070 COLOR@(0,3)-(79,3)
1080 *INDT2:LOCATE 0,4:COLOR 6:INPUT"  Incident kinetic energy in eV: (Defa
```

```
ult value=10) ", ENERGY:IF ENERGY=<0 THEN ENERGY=10
1090 COLOR@(0,4)-(79,4)
1100 *INDT3:LOCATE 0,5:INPUT"  Atomic number: (Default value=1) ", NZ1%:IF
NZ1%=0 THEN NZ1%=1
1110 IF NZ1%<1 OR NZ1%>2 THEN ERROR 100
1120 COLOR@(0,5)-(79,5):GOSUB *ERASEMES
1130 *INDT4:LOCATE 0,6:INPUT"  Mass number: (Default value=1) ", M1%:IF M1%
=0 THEN M1%=1
1140 IF NZ1%=1 AND (M1%<1 OR M1%>3) OR NZ1%=2 AND (M1%<3 OR M1%>4) THEN ERR
OR 101
1150 COLOR@(0,6)-(79,6):GOSUB *ERASEMES
1160 LOCATE 0,8:COLOR 5:PRINT"Parameters of the target":COLOR 6
1170 *INDT5:LOCATE 0,9:INPUT"  Number of the constituent elements in the ta
rget: (Default value=1) ", NE%:IF NE%=0 THEN NE%=1
1180 COLOR@(0,9)-(79,9)
1190 DIM NZ2%(NE%),NW%(NE%)
1200 FOR I=1 TO NE%
1210 *INDT6:LOCATE 0,CSRLIN:INPUT"  Atomic number: (Default value=79) ", NZ
2%(I):IF NZ2%(I)=<0 THEN NZ2%(I)=79
1220 COLOR@(0,CSRLIN-1)-(79,CSRLIN-1)
1230 *INDT7:LOCATE 0,CSRLIN:INPUT"  Relative numbers of the constituent ele
ments: (Default value=1) ", NW%(I):IF NW%(I)=0 THEN NW%(I)=1
1240 COLOR@(0,CSRLIN-1)-(79,CSRLIN-1)
1250 NEXT I
1260 PRINT:PRINT"Input data all right?  Answer with 'y' or 'n'. ";
1270 ANS$=INPUT$(1):IF INP(&HE5)=&HFD THEN *EXECUTE ELSE IF INP(&HE3)<>&HBF
 THEN 1270
1280 COLOR@(0,CSRLIN)-(79,CSRLIN):PRINT:PRINT"Push any key to restart. ";:A
NS$=INPUT$(1):COLOR 7:CLS:ERASE NZ2%,NW%:GOTO *PROJECTILE
1290 *EXECUTE:LOCATE 47,CSRLIN:PRINT ANS$;:COLOR@(0,CSRLIN)-(79,CSRLIN):GOS
UB *REION
1300 LOCATE 0,CSRLIN+2:COLOR 7:PRINT"Number backscattering coefficient =";R
NION
1310 PRINT"Energy backscattering coefficient =";REION
1320 LOCATE 0,22:COLOR 7:PRINT"Push 'y' key to continue, or 'n' key to end.
 ";
1330 ANS$=INPUT$(1):IF INP(&HE5)=&HFD THEN CLS:ERASE NW%,NZ2%:GOTO *PROJECT
ILE ELSE IF INP(&HE3)=&HBF THEN CONSOLE 0,25,1,1:CLS:END ELSE 1330
1340 *WRITEMES:IF ERR<75 THEN *WRITEMES1
1350 BEEP:LOCATE 20,25:COLOR 2:PRINT"Undefined projectile is called.";:COLO
R 6
1360 IF ERR<100 OR ERR>101 THEN *WRITEMES1
1370 Y=(ERL-1100)/40+5:LOCATE 0,Y:PRINT SPACE$(79):IF ERR=100 THEN RESUME *
INDT3 ELSE RESUME *INDT4
1380 *WRITEMES1:ON ERROR GOTO 0:RESUME
1390 *ERASEMES:LOCATE 0,25:PRINT SPACE$(79);:RETURN
1400 '
1410 *RNION:'FUNCTION RNION(THETA,ENERGY,NZ1,M1,NE,NZ2,NW)
1420 '
1430 '          NUMBER-BACKSCATTERING COEFFICIENT OF LIGHT IONS
1440 '
1450 N%=1:GOTO *REION.1
1460 '
1470 *REION:'ENTRY REION(THETA,ENERGY,NZ1,M1,NE,NZ2,NW)
1480 '
```

```
1490 '          ENERGY-BACKSCATTERING COEFFICIENT OF LIGHT IONS
1500 '
1510 N%=0
1520 *REION.1:IF NZ1%=2 THEN *REION.4
1530 A1=A1T(M1%):GOTO *REION.5
1540 *REION.4:A1=A1T(M1%+1)
1550 *REION.5:Z1=NZ1%:Z1P=Z1^.666667
1560 Z2EFF=0!:A2EFF=0!:SAEFF=0!:SBEFF=0!:SUM=0!
1570 FOR I%=1 TO NE%
1580 Z2=NZ2%(I%):A2=A2T(NZ2%(I%)):WI=NW%(I%)
1590 Z2EFF=Z2EFF+WI*Z2:A2EFF=A2EFF+WI*A2:SUM=SUM+WI
1600 FMU=A1/A2:AA=1!+FMU:Z2P=Z2^.666667:ZZ=SQR(1!+Z1P/Z2P)
1610 EPS=FNEPS(ENERGY,Z1,A1,Z2,A2)
1620 SA=.0793*SQR(EPS)/FMU
1630 W=Z1*ZZ*AA/Z2P:WI=WI*Z1/W/A2:SAEFF=SAEFF+WI*SA
1640 SL=D(NZ2%(I%))*Z1P*(AA/ZZ)^1.5*SA/SQR(A1)
1650 IF Z2>12.9 THEN FI0=9.76+58.5/Z2^1.19 ELSE FI0=12!+7!/Z2
1660 TAU=EPS*Z2^2*W/A1/3.03055E+07:BETA2=TAU*(TAU+2!)/(TAU+1!)^2
1670 EPSB=1.022E+06*BETA2/Z2/FI0
1680 IF Z1>2.9 THEN C=5! ELSE C=100!*Z1/Z2
1690 SB=61.474/FMU*W*(LOG(EPSB/(1!-BETA2)+1!+C/EPSB)-BETA2)/FI0/EPSB
1700 EPSILN=EPS:GOSUB *RANGEN:SB=2!*EPS/RANGEN+SL*SB/(.25*SL+SB)
1710 SBEFF=SBEFF+WI*SB
1720 NEXT I%
1730 Z2=Z2EFF/SUM:A2=A2EFF/SUM:SA=SAEFF:SB=SBEFF
1740 EPS=FNEPS(ENERGY,Z1,A1,Z2,A2):FEPS=(2!*EPS-3!)/(EPS+1!)
1750 R0=.705*SA/SB/(1!+A1/A2)^FEPS
1760 R0=R0/(1!+(EPS/.047)^.597+(EPS/.619)^1.5)
1770 TH=THETA*.0174532:IF N%=1 THEN  *RNION.80
1780 IF TH=0! THEN *RNION.78
1790 AS1=17.9*EPS^.453:AS2=.771/EPS^.014:REION=FNRNE(TH):GOTO *RNION.80
1800 *RNION.78:REION=R0
1810 *RNION.80:R=1!/(1!+(EPS/.133)^.285)+.53/(1!+(85!/EPS)^1.46):R0=R0/R
1820 IF TH=0! THEN *RNION.88
1830 AS1=7.38*EPS^.359:AS2=.836/EPS^.087:RNION=FNRNE(TH):RETURN
1840 *RNION.88:RNION=R0:RETURN
1850 '
1860 *RANGEN:'FUNCTION RANGEN(EPSILN)
1870 '         REDUCED RANGE OF IONS FOR NUCLEAR STOPPING ONLY.
1880 '         W. D. WILSON, L. G. HAGGMARK AND J. P. BIERSACK,
1890 '         PHYS. REV. B 15, 2458 (1977).
1900 X=LOG(1.1776*EPSILN):X1=-.3732*X:X2=-2!*X
1910 X=X1:GOSUB *EXPINT:RANGEN=EXPINT:X=X2:GOSUB *EXPINT
1920 RANGEN=1.50945*(RANGEN-EXPINT):RETURN
1930 '
1940 *EXPINT:'FUNCTION EXPINT(X)
1950 '         INCOMPLETE GAMMA FUNCTION: GAMMA(0,X)
1960 '           GAMMA(0,X)=-EI(-X)    FOR X>0
1970 '           GAMMA(0,X)=-EIBAR(-X) FOR X<0
1980 Z#=CDBL(X)
1990 IF X=>1! THEN *EXPINT.40
2000 P#=.57721566490153#
2010 IF X<-86.7 THEN EXPINT=-1.70141E+38:RETURN
2020 IF X = 0 THEN *EXPINT.30
2030 P#=P#+LOG(ABS(Z#)):F#=1#:T#=-Z#
```

```
2040 *EXPINT.20:Q#=T#+P#:IF ABS(P#-Q#)=<CONV# THEN *EXPINT.30
2050 P#=Q#:T#=-Z#*F#*T#:F#=F#+1#:T#=T#/F#^2:GOTO *EXPINT.20
2060 *EXPINT.30:EXPINT=-P#:RETURN
2070 *EXPINT.40:IF X>83.8 THEN EXPINT=0!:RETURN
2080 P#=((((Z#+A#(4))*Z#+A#(3))*Z#+A#(2))*Z#+A#(1))/((((Z#+B#(4))*Z#+B#(3))
*Z#+B#(2))*Z#+B#(1))
2090 EXPINT=EXP(-Z#)*P#/Z#:RETURN
```

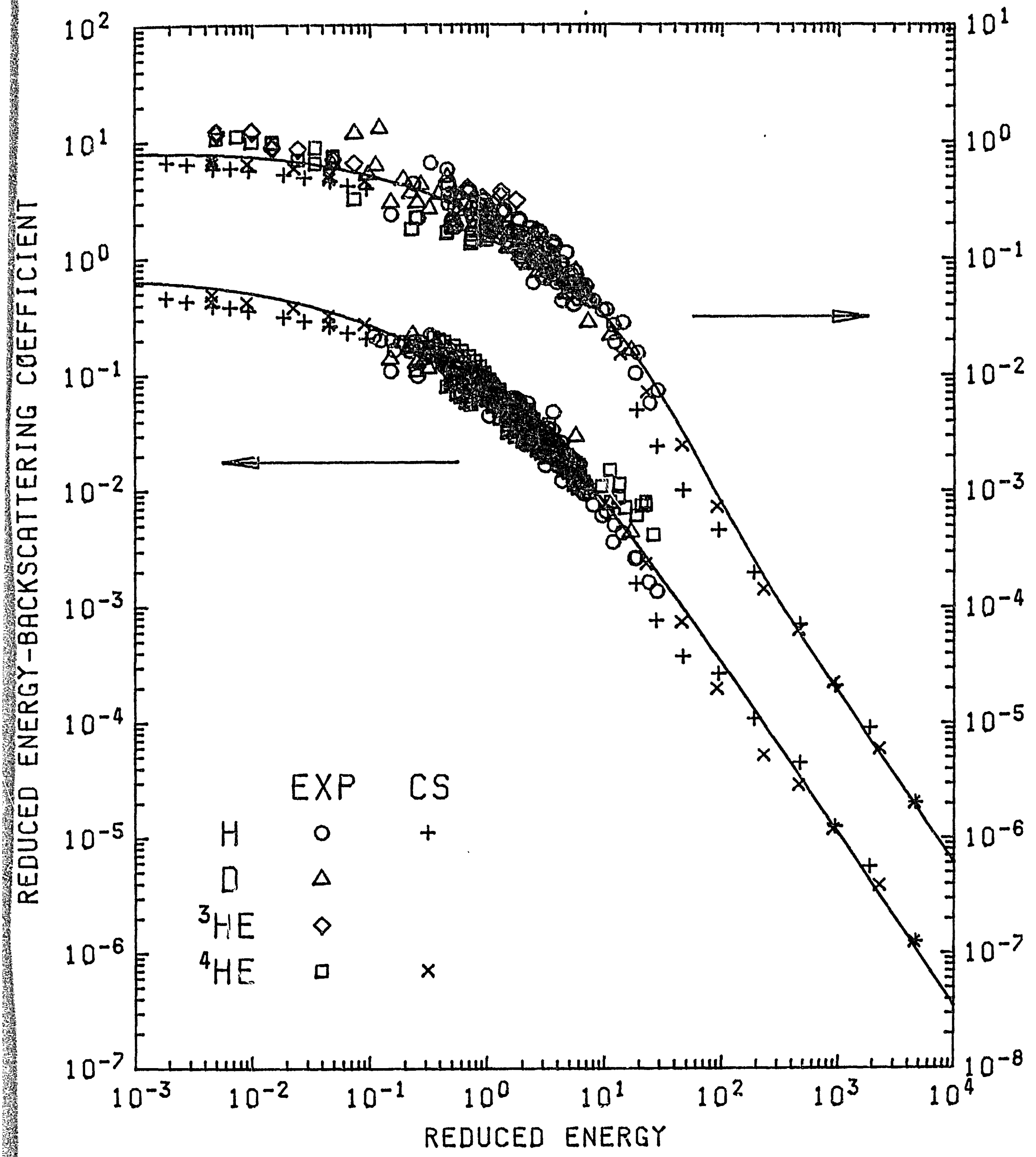

FIGURE A. Reduced Number- and Energy-Backscattering Coefficients as a Function of Thomas-Fermi Reduced Energy [Points: Experiment (EXP) and Computer Simulation (CS); Curves: Present Empirical Expressions]

EXPLANATION OF TABLES

TABLE I. **Experimental Data on R_N, R_E, and r_E for H Ions on C to Pb**

TABLE II. **Experimental Data on R_N, R_E, and r_E for D Ions on C to Au**

TABLE III. **Experimental Data on R_N, R_E, and r_E for ^{3}He Ions on Ag to Au**

TABLE IV. **Experimental Data on R_N, R_E, and r_E for ^{4}He Ions on C to Pb**

Target and Data Source	Chemical symbol of target and reference code for data source (see References for Tables and Graphs)
Energy	Energy for incident ion in eV
R_N	Number-backscattering coefficient
R_E	Energy-backscattering coefficient
r_E	Mean fractional energy of backscattered particles; $r_E = R_E/R_N$

EXPLANATION OF GRAPHS

Number- and Energy-Backscattering Coefficients R_N and R_E

GRAPH I. R_N **and** R_E **vs Energy for H ions on Li to U**

GRAPH II. R_N **and** R_E **vs Energy for D Ions on Li to U**

GRAPH III. R_N **and** R_E **vs Energy for T Ions on Li to U**

GRAPH IV. R_N **and** R_E **vs Energy for** ^{3}**He Ions on Li to U**

GRAPH V. R_N **and** R_E **vs Energy for** ^{4}**He Ions on Li to U**

GRAPH VI. R_N **and** R_E **vs Energy for H Ions on Compounds**

GRAPH VII. R_N **and** R_E **vs Energy for** ^{4}**He Ions on Compounds**

Ordinate	Number-backscattering coefficient R_N (right-hand scale)
	Energy-backscattering coefficient R_E (left-hand scale)
Abscissa	Incident ion energy in eV
Legend	Incident ion-target combination and symbol with reference code for data source (see References for Tables and Graphs) and code for method (EXP: experiment; CSM:computer simulation with MARLOWE; CST: computer simulation with TRIM)

REFERENCES FOR TABLES AND GRAPHS

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TABLE I. Experimental Data on R_N, R_E, and r_E of H Ions on C to Fe
See page 24 for Explanation of Tables

Target & Data Source		Energy (eV)	R_N	R_E	r_E
C	EC79	1.5 E 3	1.03E-1	3.54E-2	3.44E-1
		2.5 E 3	4.5 E-2	1.36E-2	3.03E-1
		5.0 E 3	1.6 E-2	4.27E-3	2.67E-1
		7.5 E 3	8.9 E-3	2.27E-3	2.55E-1
		1.0 E 4	5.0 E-3	1.44E-3	2.87E-1
C	OV80	1.0 E 3	1.13E-1		
		1.2 E 3	7.5 E-2		
		1.5 E 3	6.4 E-2		
		2.0 E 3	5.5 E-2		
		2.5 E 3	4.7 E-2		
		3.0 E 3	3.5 E-2		
Al	SI76	1.0 E 4	2.5 E-2	4.3 E-3	1.75E-1
		1.5 E 4	2.0 E-2	3.1 E-3	1.55E-1
		2.0 E 4	1.1 E-2	1.9 E-3	1.72E-1
		3.0 E 4	5.3 E-3	1.0 E-3	1.89E-1
Si	EC79	5.0 E 3	3.0 E-2	8.42E-3	2.81E-1
Ti	BO76	1.0 E 3	2.2 E-1		
		1.3 E 3	1.8 E-1		
		1.7 E 3	1.8 E-1		
		2.0 E 3	1.4 E-1		
		3.0 E 3	9. E-2		
		4.0 E 3	6. E-2		
		5.0 E 3	4. E-2		
		6.0 E 3	4.5 E-2		
		8.0 E 3	4. E-2		
Ti	EC79	6.67E 2	4. E-1	1.34E-1	3.34E-1
		2.5 E 3	1.15E-1	4.37E-2	3.80E-1
		5.0 E 3	7.0 E-2	2.36E-2	3.37E-1
		1.0 E 4	3.3 E-2	9.77E-3	2.96E-1
Fe	EC79	2.5 E 3	1.63E-1	6.30E-2	3.86E-1
		5.0 E 3	1.10E-1	3.72E-2	3.38E-1
		7.5 E 3	7.9 E-2	2.7 E-2	3.40E-1
		1.0 E 4	6.5 E-2	2.0 E-2	3.11E-1
		1.25E 4	5.7 E-2		
		1.5 E 4	4.1 E-2	1.2 E-2	3.01E-1
Fe	SI76	1.0 E 4	6.9 E-2	1.47E-2	2.21E-1
		1.5 E 4	4.9 E-2	1.01E-2	2.07E-1
		2.0 E 4	4.0 E-2	7.0 E-3	1.81E-1
		3.0 E 4	2.5 E-2	3.4 E-3	1.90E-1
Fe	TA78	1.0 E 4		1.5 E-2	

TABLE I. Experimental Data on R_N, R_E, and r_E of H Ions on Fe to Nb
See page 24 for Explanation of Tables

Target & Data Source		Energy (eV)	R_N	R_E	r_E
Fe	TA78	1.5 E 4		1.2 E-2	
Ni	EC79	1.5 E 3	1.59E-1	7.12E-2	4.48E-1
		5.0 E 3	1.37E-1	4.88E-2	3.56E-1
		7.5 E 3	9.0 E-2	3.08E-2	3.42E-1
		1.0 E 4	8.5 E-2	3.02E-2	3.55E-1
		1.5 E 4	3.7 E-2	1.12E-2	3.04E-1
Cu	SI76	5. E 3	1.40E-1	3.76E-2	
		7.5 E 3	1.05E-1	2.75E-2	
		1.0 E 4	8.5 E-2	2.01E-2	2.27E-1
		1.5 E 4	6.4 E-2	1.33E-2	1.99E-1
		2.0 E 4	5.2 E-2	1.02E-2	1.96E-1
		3.0 E 4	3.3 E-2	6.0 E-3	1.98E-1
Cu	TA78	1.0 E 4		2.0 E-2	
		1.5 E 4		1.6 E-2	
Zr	BO76	2.0 E 3	2.9 E-1		
		3.0 E 3	1.9 E-1		
		4.0 E 3	1.6 E-1		
		6.0 E 3	1.3 E-1		
		8.0 E 3	6. E-2		
Nb	EC79	5.0 E 3	1.05E-1	4.34E-2	4.13E-1
		7.5 E 3	8.5 E-2	3.13E-2	3.68E-1
		1.0 E 4	7.3 E-2	2.83E-2	3.87E-1
		1.5 E 4	4.7 E-2	1.73E-2	3.68E-1
Nb	SI76	1.0 E 4	7.21E-2	1.66E-2	2.30E-1
		1.5 E 4	4.9 E-2	1.00E-2	2.10E-1
		2.0 E 4	4.1 E-2	7.8 E-3	2.01E-1
		3.0 E 4	2.7 E-2	4.8 E-3	1.89E-1
Nb	SO76	1.00E 3		8.0 E-2	
		1.34E 3		7.4 E-2	
		1.67E 3		7.9 E-2	
		2.00E 3		6.2 E-2	
		2.66E 3		5.7 E-2	
		3.00E 3		5.2 E-2	
		3.33E 3		5.0 E-2	
		4.00E 3		4.9 E-2	
		4.50E 3		4.0 E-2	
		5.00E 3		2.8 E-2	

All the data listed for the Fe target are actually for stainless steel.

TABLE I. Experimental Data on R_N, R_E, and r_E of H Ions on Nb to W
See page 24 for Explanation of Tables

Target & Data Source		Energy (eV)	R_N	R_E	r_E
Nb	So76	6.00E 3		2.6 E-2	
		7.00E 3		2.8 E-2	
		8.00E 3		3.1 E-2	
		9.00E 3		1.7 E-2	
		1.00E 4		1.8 E-2	
Mo	EC79	2.5 E 3	1.45E-1	6.21E-2	4.28E-1
		5.0 E 3	1.09E-1	4.10E-2	3.76E-1
		7.5 E 3	9.2 E-2	3.22E-2	3.50E-1
		1.0 E 4	7.09E-2	2.37E-2	3.34E-1
		1.5 E 4	5.2 E-2	1.59E-2	3.06E-1
Mo	SI76	1.0 E 4	8.7 E-2	2.07E-2	2.43E-1
		1.5 E 4	6.4 E-2	1.38E-2	1.95E-1
		2.0 E 4	5.0 E-2	1.08E-2	2.15E-1
		3.0 E 4	3.1 E-2	6.2 E-3	2.04E-1
Mo	TA78	1.0 E 4		2.1 E-2	
		1.5 E 4		1.7 E-2	
		2.0 E 4		1.4 E-2	
		2.5 E 4		1.0 E-2	
Ag	SI76	1.0 E 4	1.34E-1	3.10E-2	2.36E-1
		1.5 E 4	1.00E-1	2.13E-2	2.07E-1
		2.0 E 4	7.9 E-2	1.54E-2	2.01E-1
		3.0 E 4	4.8 E-2	9.4 E-3	2.10E-1
Ag	SO76	1.5 E 3		1.16E-1	
		2.0 E 3		1.08E-1	
		2.6 E 3		1.01E-1	
		3.0 E 3		8.5 E-2	
		3.3 E 3		8.7 E-2	
		4.0 E 3		6.6 E-2	
		5.0 E 3		5.8 E-2	
		6.0 E 3		5.0 E-2	
Ta	SI76	1.0 E 4	1.32E-1	3.30E-2	2.54E-1
		1.5 E 4	1.01E-1	2.50E-2	2.48E-1
		2.0 E 4	8.7 E-2	1.88E-2	2.24E-1
		3.0 E 4	5.1 E-2	1.25E-2	2.44E-1
W	EC79	1.5 E 3	1.82E-1	8.19E-2	4.50E-1
		2.5 E 3	1.71E-1	7.52E-2	4.40E-1
		5.0 E 3	1.68E-1	7.06E-2	4.20E-1
		7.5 E 3	1.65E-1	6.60E-2	4.00E-1
		1.0 E 4	1.23E-1	4.67E-2	3.80E-1
		1.25E 4	1.19E-1	4.46E-2	3.75E-1
		1.5 E 4	1.07E-1	3.85E-2	3.60E-1

TABLE I. Experimental Data on R_N, R_E, and r_E of H Ions on Au to Pb
See page 24 for Explanation of Tables

Target & Data Source		Energy (eV)	R_N	R_E	r_E
Au	EC79	2.5 E 3	3.20E-1	1.37E-1	4.28E-1
		5.0 E 3	2.51E-1	9.74E-2	3.88E-1
		8.0 E 3	1.97E-1	7.50E-2	3.81E-1
		9.0 E 3	2.11E-1	7.42E-2	3.52E-1
		1.0 E 4	2.07E-1	7.35E-2	3.55E-1
		1.6 E 4	1.34E-1	4.45E-2	3.32E-1
Au	SI76	5.0 E 3	3.10E-1	9.5 E-2	3.30E-1
		7.5 E 3	2.70E-1	7.5 E-2	3.12E-1
		1.0 E 4	2.30E-1	6.09E-2	2.70E-1
		1.5 E 4	1.90E-1	4.33E-2	2.60E-1
		2.0 E 4	1.55E-1	3.50E-2	2.25E-1
		2.5 E 4	1.35E-1	3.10E-2	2.10E-1
		3.0 E 4	1.25E-1	2.55E-2	2.00E-1
		4.0 E 4	9.9 E-2	1.96E-2	1.99E-1
		5.0 E 4	8.4 E-2	1.51E-2	1.79E-1
Au	SO76	1.17E 3		1.55E-1	
		1.33E 3		1.44E-1	
		1.67E 3		1.43E-1	
		1.75E 3		1.18E-1	
		2.00E 3		1.38E-1	
		2.33E 3		1.17E-1	
		2.51E 3		1.40E-1	
		3.00E 3		1.20E-1	
		3.3 E 3		1.13E-1	
		3.51E 3		1.09E-1	
		4.51E 3		8.9 E-2	
		5.00E 3		8.1 E-2	
		6.02E 3		7.4 E-2	
		7.00E 3		7.0 E-2	
		8.00E 3		7.4 E-2	
		9.00E 3		5.8 E-2	
		1.00E 4		5.6 E-2	
Au	VE80	5.0 E 3	2.17E-1	9.2 E-2	4.22E-1
		8.0 E 3	1.74E-1	7.0 E-2	4.0 E-1
Pb	AN76	3.0 E 4		2.3 E-2	
		3.5 E 4		1.7 E-2	
		4.0 E 4		1.9 E-2	
		4.5 E 4		1.7 E-2	
		4.5 E 4		1.4 E-2	
		5.0 E 4		1.3 E-2	
		5.7 E 4		1.06E-2	
		5.7 E 4		9.7 E-3	
		6.0 E 4		1.07E-2	
		6.0 E 4		1.22E-2	

TABLE I. Experimental Data on R_N, R_E, and r_E of H Ions on Pb
See page 24 for Explanation of Tables

Target & Data Source		Energy (eV)	R_N	R_E	r_E
Pb	AN76	6.2 E 4		9.7 E-3	
		6.5 E 4		1.17E-2	

TABLE II. Experimental Data on R_N, R_E, and r_E of D Ions on C to Ni
See page 24 for Explanation of Tables

Target & Data Source		Energy (eV)	R_N	R_E	r_E
C	BR82	3.30E 1	4.8 E-1		
		5.40E 1	5.5 E-1		
		2.05E 2	2.3 E-1		
		3.30E 2	1.4 E-1		
		4.48E 2	1.3 E-1		
		5.00E 2	1.0 E-1		
		1.00E 3	7.3 E-2		
		2.10E 3	3.4 E-2		
C	CH84	4.0 E 2	1.0 E-1		
		1.0 E 3	5.1 E-2		
		3.0 E 3	7.0 E-3		
C	EC79	2.5 E 3	5.5 E-2	2.09E-2	3.79E-1
		5.0 E 3	1.8 E-2	6.25E-3	3.47E-1
		7.5 E 3	1.4 E-2	3.82E-3	2.73E-1
C	OV80	1.0 E 3	6.7 E-2		
		1.2 E 3	4.6 E-2		
		1.5 E 3	5.0 E-2		
		2.0 E 3	4.4 E-2		
		2.5 E 3	4.1 E-2		
		3.0 E 3	3.6 E-2		
C	ST79	5.0 E 1	2.6 E-1		
		1.0 E 2	1.6 E-1		
		2.5 E 2	1.2 E-1		
		5.0 E 2	1.2 E-1		
		1.0 E 3	7. E-2		
Ti	EC79	6.67E 2	1.8 E-1	7.69E-2	4.27E-1
		2.5 E 3	1.35E-1	5.81E-2	4.30E-1
		5.0 E 3	8.4 E-2	3.26E-2	3.88E-1
		7.5 E 3	5.6 E-2	1.85E-2	3.31E-1
		1.0 E 4	5.2 E-2	1.68E-2	3.24E-1
		1.5 E 4	2.4 E-2	7.98E-3	3.32E-1
Fe	EC79	2.5 E 3	2.26E-1		
		5.0 E 3	1.12E-1	4.90E-2	4.37E-1
		7.5 E 3	1.05E-1		
Fe	TH80	1.25E 2	5.0 E-1		
		2.5 E 2	4.2 E-1		
		5.0 E 2	4.0 E-1		
		7.0 E 2	3.7 E-1		
		1.0 E 3	3.2 E-1		
Ni	EC79	2.5 E 3	1.69E-1	7.81E-2	4.62E-1

TABLE II. Experimental Data on R_N, R_E, and r_E of D Ions on Ni to Au
See page 24 for Explanation of Tables

Target & Data Source		Energy (eV)	R_N	R_E	r_E
Ni	EC79	5.0 E 3	1.30E-1	5.37E-2	4.13E-1
		7.5 E 3	9.8 E-2	3.53E-2	3.60E-1
		1.0 E 4	8.5 E-2	3.09E-2	3.63E-1
		1.5 E 4	6.4 E-2	2.18E-2	3.40E-1
Nb	EC79	2.5 E 3	2.21E-1	8.14E-2	3.68E-1
		5.0 E 3	1.69E-1	5.15E-2	3.05E-1
Mo	EC79	2.5 E 3	1.29E-1	5.78E-2	4.48E-1
		5.0 E 3	1.12E-1	4.27E-2	3.81E-1
		7.5 E 3	1.09E-1	3.82E-2	3.50E-1
		1.0 E 4	8.4 E-2	2.89E-2	3.44E-1
		1.5 E 4	6.1 E-2	1.99E-2	3.27E-1
W	EC79	1.5 E 3	2.92E-1	1.33E-1	4.56E-1
		2.5 E 3	2.99E-1	1.25E-1	4.19E-1
		5.0 E 3	2.11E-1	9.03E-2	4.28E-1
		7.5 E 3	1.93E-1	7.97E-2	4.13E-1
		1.0 E 4	1.74E-1	6.68E-2	3.84E-1
		1.5 E 4	1.31E-1	4.64E-2	3.54E-1
Au	KO83	2.5 E 3		2.1 E-1	
		5.0 E 3		1.6 E-1	
		8.3 E 3		8. E-2	
		8.3 E 3		1.1 E-1	
Au	SO76	3.17E 3		1.30E-1	

All the data listed for the Fe target are actually for stainless steel.

TABLE III. Experimental Data on R_N, R_E, and r_E of ^3He Ions on Ag to Au
See page 24 for Explanation of Tables

Target & Data Source		Energy (eV)	R_N	R_E	r_E
Ag	BT76	1.5 E 4	2.3 E-1		
		1.5 E 4	2.1 E-1		
		2.0 E 4	1.95E-1		
		3.0 E 4	1.1 E-1		
		3.0 E 4	9. E-2		
W	AM81	1.0 E 2	8.2 E-1		
		1.0 E 2	8.6 E-1		
		2.0 E 2	8.6 E-1		
		2.0 E 2	8.7 E-1		
		3.0 E 2	6.2 E-1		
		3.0 E 2	6.4 E-1		
		5.0 E 2	6.2 E-1		
		1.0 E 3	5.1 E-1		
		1.5 E 3	4.8 E-1		
Au	BT76	1.5 E 4	3.0 E-1		
		1.5 E 4	2.9 E-1		
		2.0 E 4	2.5 E-1		
		3.0 E 4	1.9 E-1		

TABLE IV. Experimental Data on R_N, R_E, and r_E of ^4He Ions on C to Ni
See page 24 for Explanation of Tables

Target & Data Source		Energy (eV)	R_N	R_E	r_E
C	HI76	1.2 E 4		7. E-3	
		1.45E 4		5.5 E-3	
Mg	HI76	1.2 E 4		8. E-3	
		1.45E 4		6. E-3	
Al	HI76	1.2 E 4		8. E-3	
		1.45E 4		6. E-3	
Si	AN76	2.5 E 4		6.7 E-3	
		3.0 E 4		5.0 E-3	
		3.5 E 4		5.5 E-3	
		4.0 E 4		4.6 E-3	
		5.0 E 4		4.0 E-3	
		5.5 E 4		4.9 E-3	
		6.0 E 4		5.3 E-3	
		6.0 E 4		5.0 E-3	
		7.0 E 4		2.8 E-3	
Si	HI76	1.2 E 4		8.5 E-3	
		1.45E 4		6.5 E-3	
Ti	EC79	5.0 E 3	1.4 E-1		
		1.0 E 4	9.0 E-2	2.96E-2	3.29E-1
		1.5 E 4	7.0 E-2	2.31E-2	3.30E-1
Ti	HI76	1.2 E 4		1.5 E-2	
		1.45E 4		1.2 E-2	
Ti	KO83	5.0 E 3		3. E-2	
V	HI76	1.2 E 4		2.1 E-2	
		1.45E 4		1.65E-2	
Cr	HI76	1.2 E 4		2.0 E-2	
		1.45E 4		1.55E-2	
Mn	HI76	1.2 E 4		2.3 E-2	
		1.45E 4		1.9 E-2	
Fe	HI76	1.2 E 4		2.3 E-2	
		1.45E 4		1.85E-2	
Co	HI76	1.2 E 4		3.0 E-2	
		1.45E 4		2.5 E-2	
Ni	HI76	1.2 E 4		3.35E-2	
		1.45E 4		2.85E-2	

TABLE IV. Experimental Data on R_N, R_E, and r_E of ^{4}He Ions on Cu to Ag
See page 24 for Explanation of Tables

Target & Data Source		Energy (eV)	R_N	R_E	r_E
Cu	HI76	1.2 E 4		4.1 E-2	
		1.45E 4		3.5 E-2	
Cu	KO83	4.0 E 3		9. E-2	
Cu	SC78	5.0 E 3		7.9 E-2	
		6.0 E 3		7.6 E-2	
		7.0 E 3		6.1 E-2	
		8.0 E 3		5.6 E-2	
		9.0 E 3		4.6 E-2	
		1.0 E 4		3.9 E-2	
Zn	HI76	1.2 E 4		4.25E-2	
		1.45E 4		3.55E-2	
Ga	HI76	1.2 E 4		3.2 E-2	
		1.45E 4		2.8 E-2	
Ge	HI76	1.2 E 4		3.55E-2	
		1.45E 4		3.0 E-2	
Se	HI76	1.2 E 4		3.65E-2	
		1.45E 4		3.25E-2	
Zr	HI76	1.2 E 4		2.65E-2	
		1.45E 4		2.2 E-2	
Nb	HI76	1.2 E 4		2.85E-2	
		1.45E 4		2.4 E-2	
Mo	EC79	5.0 E 3	1.02E-1	4.63E-2	4.54E-1
		1.0 E 4	8.9 E-2	3.43E-2	3.85E-1
		1.5 E 4	7.4 E-2	3.07E-2	4.15E-1
		2.0 E 4	6.0 E-2	2.26E-2	3.76E-1
Mo	HI76	1.2 E 4		3.85E-2	
		1.45E 4		3.15E-2	
Pd	HI76	1.2 E 4		5.0 E-2	
		1.45E 4		4.4 E-2	
Ag	AN76	1.8 E 4		2.9 E-2	
		2.3 E 4		2.7 E-2	
		2.8 E 4		2.8 E-2	
		3.3 E 4		2.0 E-2	
		3.8 E 4		1.73E-2	
		4.3 E 4		1.84E-2	
		4.5 E 4		1.66E-2	

TABLE IV. Experimental Data on R_N, R_E, and r_E of ^4He Ions on Ag to Ta

See page 24 for Explanation of Tables

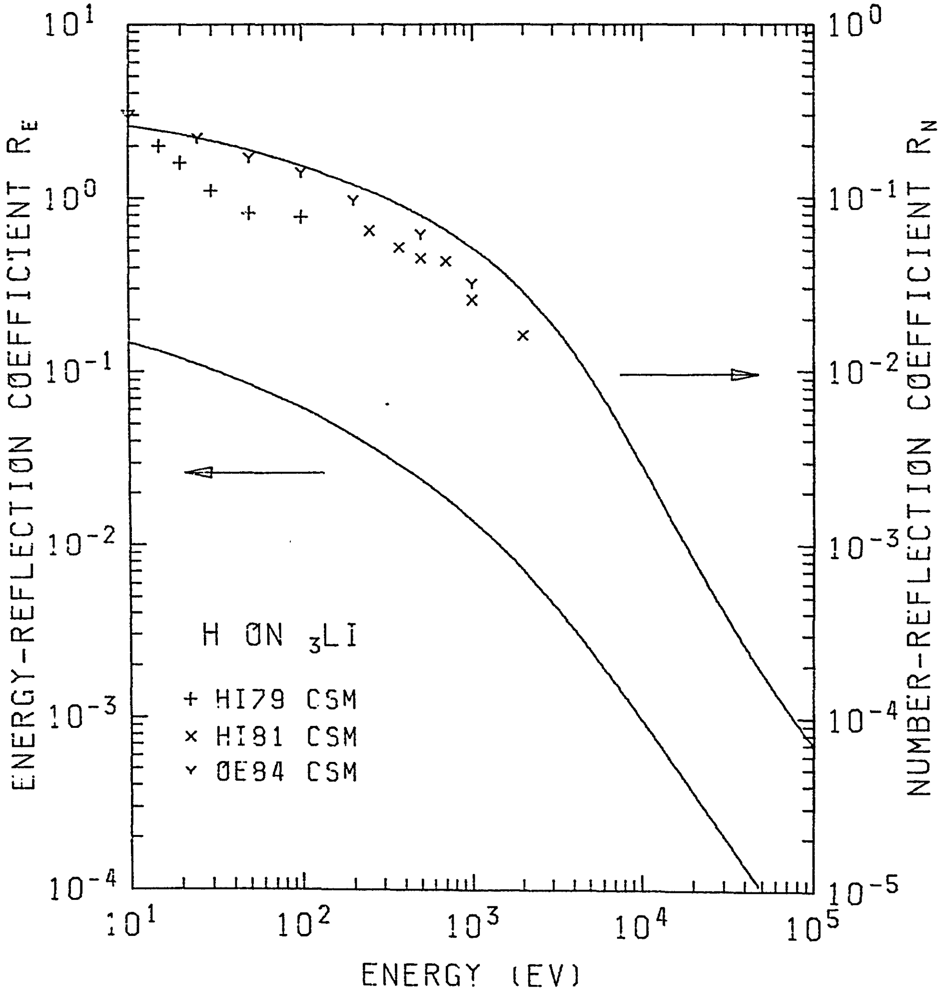
Target & Data Source		Energy (eV)	R_N	R_E	r_E
Ag	AN76	4.5 E 4		1.53E-2	
		5.0 E 4		1.39E-2	
		5.5 E 4		1.20E-2	
		6.0 E 4		1.09E-2	
		6.5 E 4		1.02E-2	
		7.0 E 4		9.5 E-3	
		7.5 E 4		8.5 E-3	
Ag	HI76	1.2 E 4		5.9 E-2	
		1.45E 4		4.9 E-2	
Ag	SC78	4.0 E 3		1.31E-1	
		4.5 E 3		1.25E-1	
		5.0 E 3		1.20E-1	
		6.0 E 3		1.12E-1	
		7.0 E 3		1.02E-1	
		8.0 E 3		9.2 E-2	
		9.0 E 3		8.5 E-2	
		1.0 E 4		7.6 E-2	
Cd	HI76	1.2 E 4		5.4 E-2	
		1.45E 4		4.6 E-2	
In	HI76	1.2 E 4		4.7 E-2	
		1.45E 4		4.0 E-2	
Sn	HI76	1.2 E 4		4.4 E-2	
		1.45E 4		3.9 E-2	
Sb	HI76	1.2 E 4		4.5 E-2	
		1.45E 4		4.0 E-2	
Te	HI76	1.2 E 4		4.4 E-2	
		1.45E 4		3.7 E-2	
Ta	AN76	3.0 E 4		2.7 E-2	
		3.5 E 4		2.5 E-2	
		4.0 E 4		2.3 E-2	
		4.5 E 4		2.3 E-2	
		4.5 E 4		2.2 E-2	
		5.0 E 4		2.2 E-2	
		5.5 E 4		2.1 E-2	
		6.0 E 4		2.1 E-2	
		6.5 E 4		1.98E-2	
		7.0 E 4		1.82E-2	
		7.5 E 4		1.72E-2	
		8.0 E 4		1.60E-2	

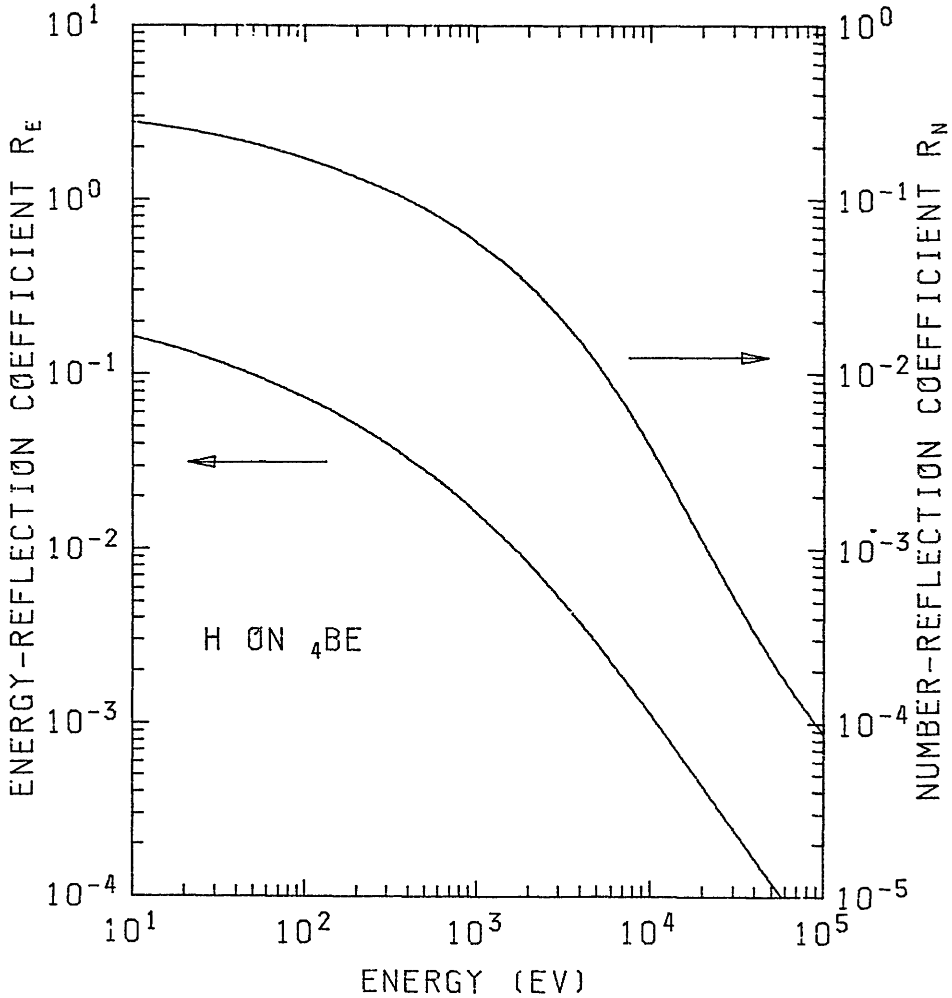
TABLE IV. Experimental Data on R_N, R_E, and r_E of ^{4}He Ions on Ta to Pb
See page 24 for Explanation of Tables

Target & Data Source		Energy (eV)	R_N	R_E	r_E
Ta	~~HI76~~	1.2 E 4		5.3 E-2	
		1.45E 4		4.6 E-2	
W	AM81	1.0 E 2	7.8 E-1		
		1.5 E 2	8.2 E-1		
		2.0 E 2	7.3 E-1		
		3.0 E 2	7.1 E-1		
		3.0 E 2	7.3 E-1		
		5.0 E 2	5.2 E-1		
		7.0 E 2	4.9 E-1		
		7.0 E 2	6.7 E-1		
		1.0 E 3	5.7 E-1		
		1.0 E 3	5.6 E-1		
		1.5 E 3	2.5 E-1		
W	EC79	5.0 E 3	1.82E-1	8.87E-2	4.88E-1
		1.0 E 4	1.59E-1	7.23E-2	4.55E-1
		1.5 E 4	1.37E-1	6.62E-2	4.83E-1
		2.0 E 4	1.25E-1	5.25E-2	4.20E-1
W	HI76	1.2 E 4		5.9 E-2	
		1.45E 4		5.1 E-2	
Pt	HI76	1.2 E 4		5.9 E-2	
		1.45E 4		5.0 E-2	
Au	EC79	5.0 E 3	1.40E-1		
		1.0 E 4	1.35E-1	6.39E-2	4.73E-1
		1.6 E 4	1.17E-1	5.27E-2	4.51E-1
Au	HI76	1.2 E 4		7.5 E-2	
		1.45E 4		6.5 E-2	
Au	KO83	5.0 E 3		1.4 E-1	
Au	SC78	5.0 E 3		1.38E-1	
		6.0 E 3		1.36E-1	
		7.0 E 3		1.26E-1	
		8.0 E 3		1.26E-1	
		9.0 E 3		1.16E-1	
		1.0 E 4		1.03E-1	
Au	VE80	1.0 E 4	1.34E-1		
		1.6 E 4	1.11E-1	4.6 E-2	4.14E-1
Pb	AN76	3.0 E 4		3.3 E-2	
		3.5 E 4		2.9 E-2	
		3.5 E 4		2.7 E-2	

TABLE IV. Experimental Data on R_N, R_E, and r_E of ^4He Ions on Pb
See page 24 for Explanation of Tables

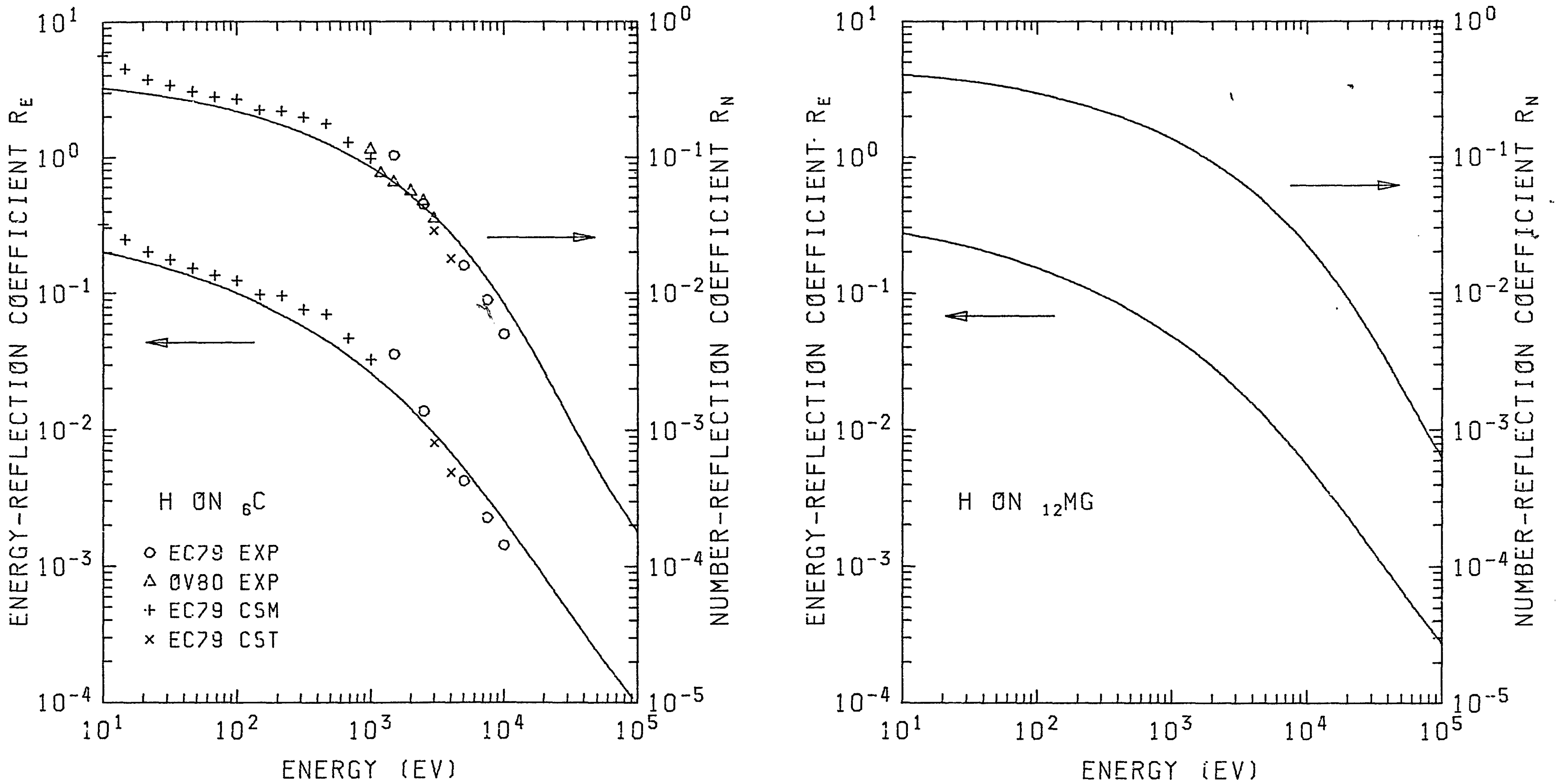
Target & Data Source		Energy (eV)	R_N	R_E	r_E
Pb	AN76	4.0 E 4		2.7 E-2	
		4.0 E 4		3.0 E-2	
		4.5 E 4		2.6 E-2	
		5.0 E 4		2.4 E-2	
		5.5 E 4		2.1 E-2	
		6.0 E 4		2.4 E-2	
		6.5 E 4		1.8 E-2	
Pb	HI76	1.2 E 4		8.1 E-2	
		1.45E 4		7.0 E-2	



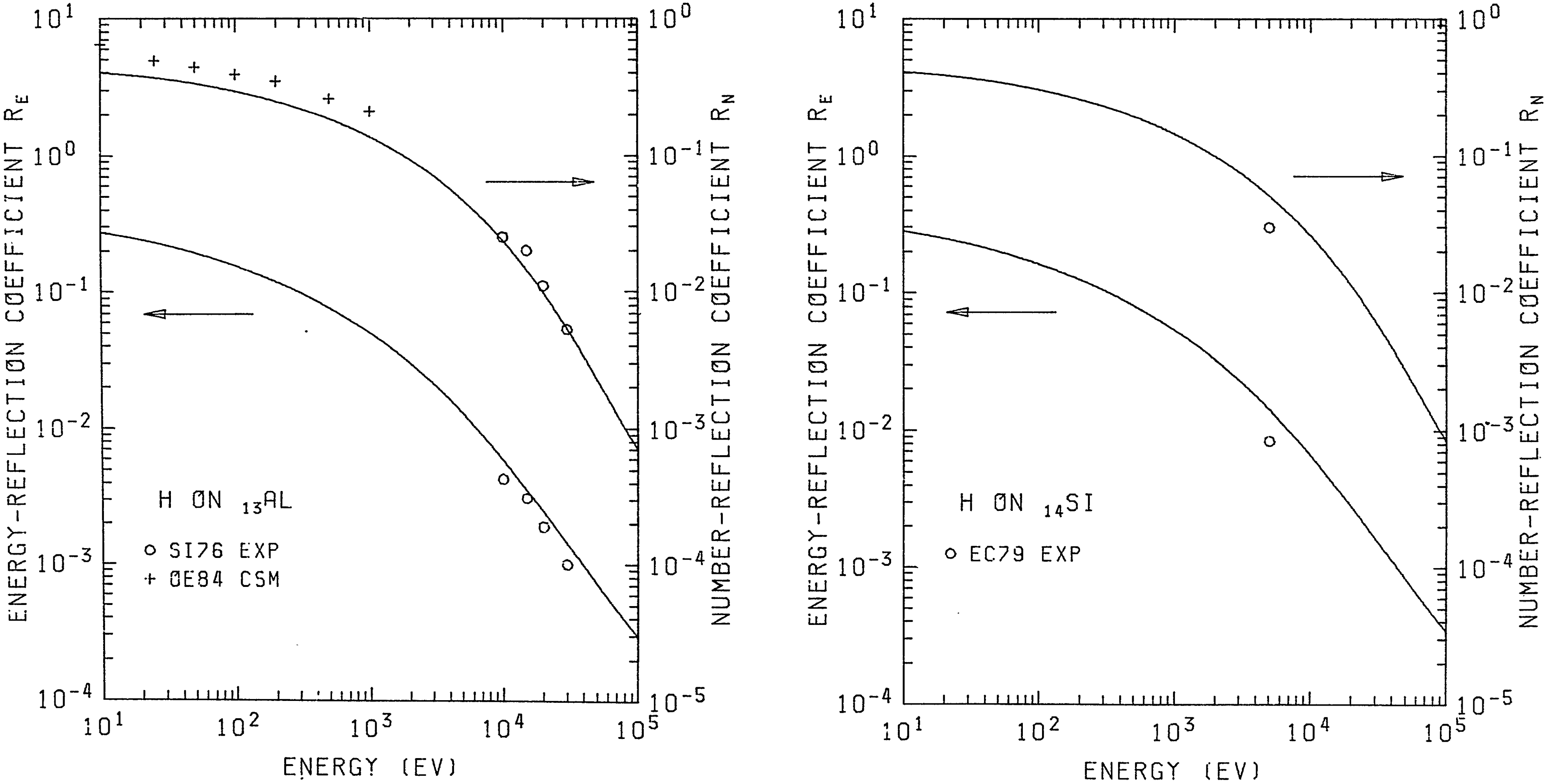


GRAPH I. R_N and R_E vs Energy for H Ions on Li and Be

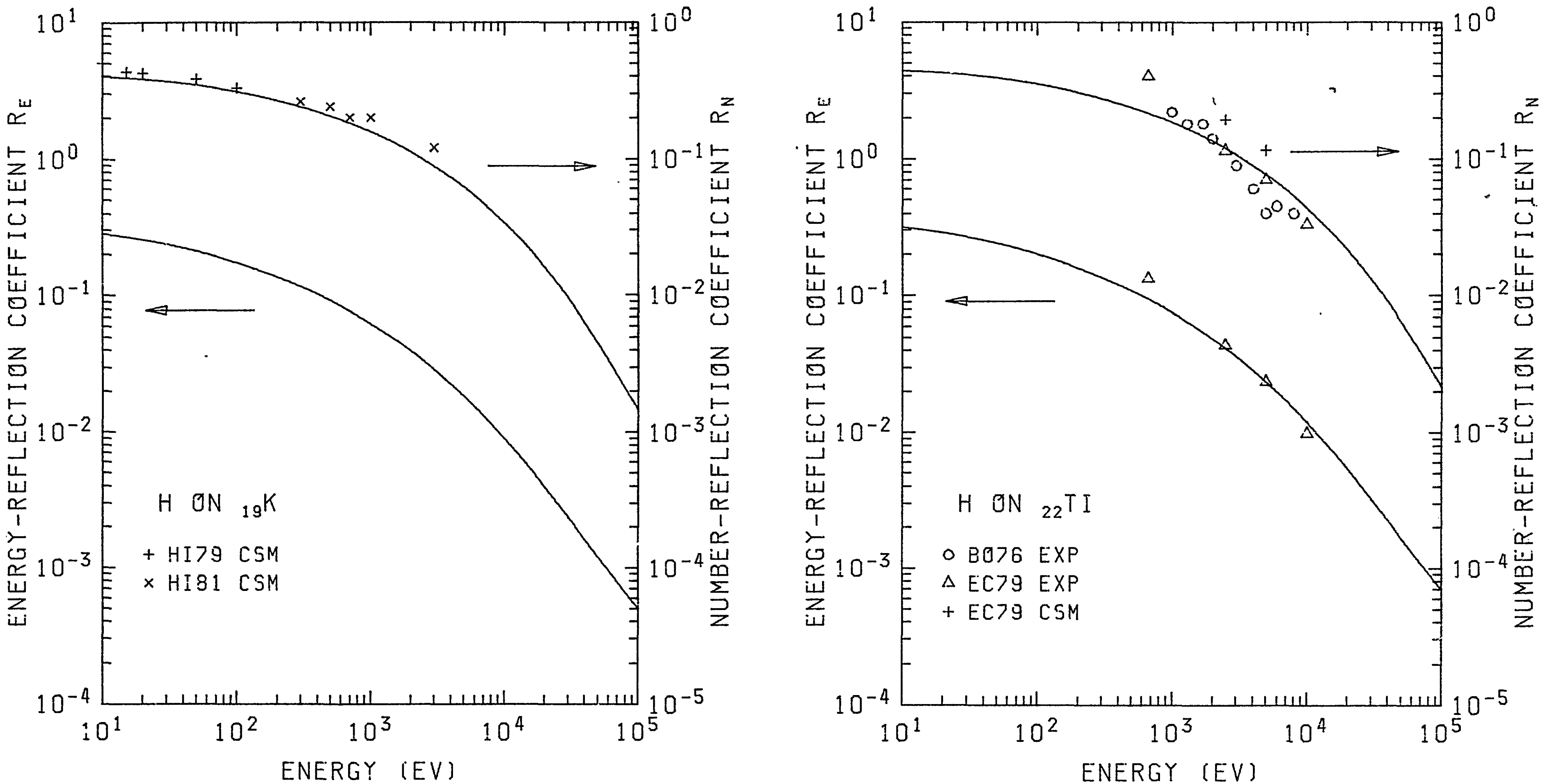
See page 25 for Explanation of Graphs



GRAPH I. R_N and R_E vs Energy for H Ions on C and Mg
See page 25 for Explanation of Graphs

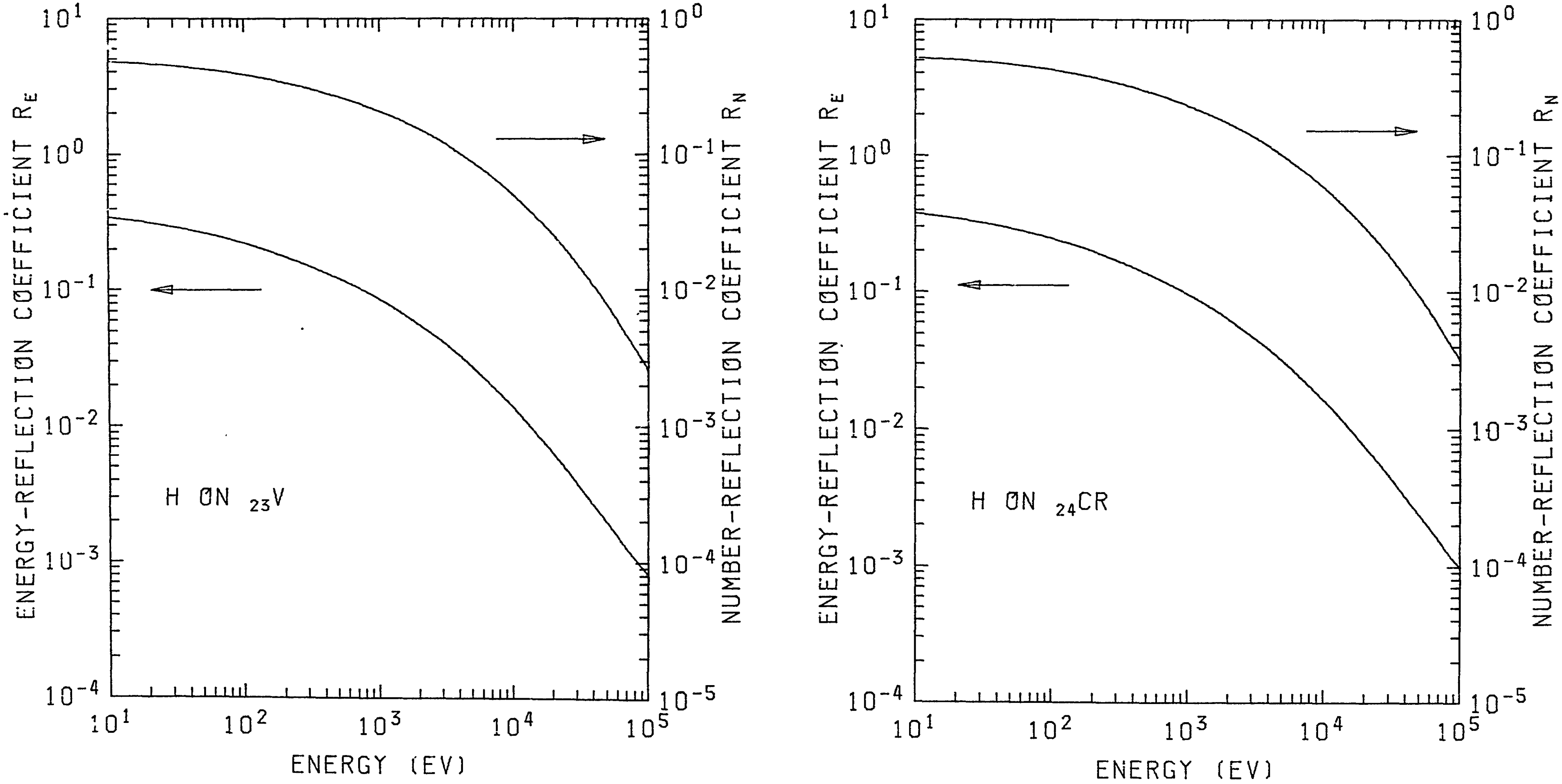


GRAPH I. R_N and R_E vs Energy for H Ions on Al and Si
See page 25 for Explanation of Graphs



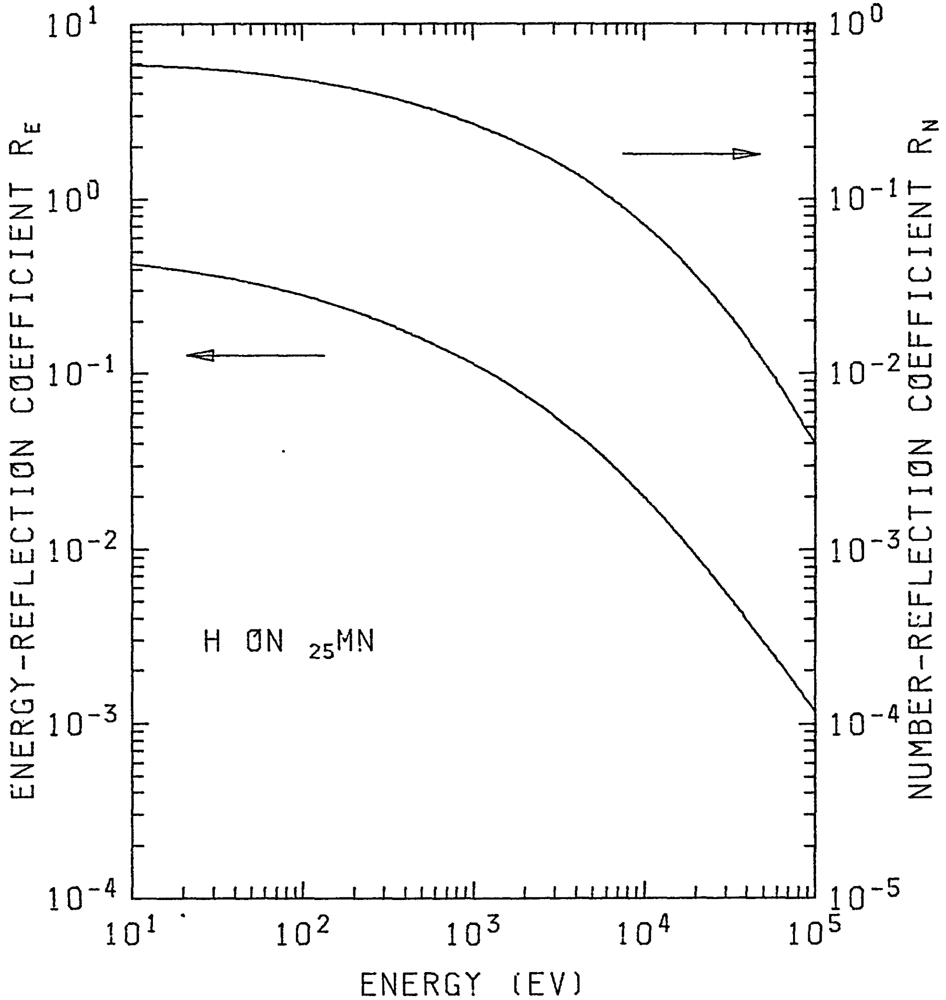
GRAPH I. R_N and R_E vs Energy for H Ions on K and Ti

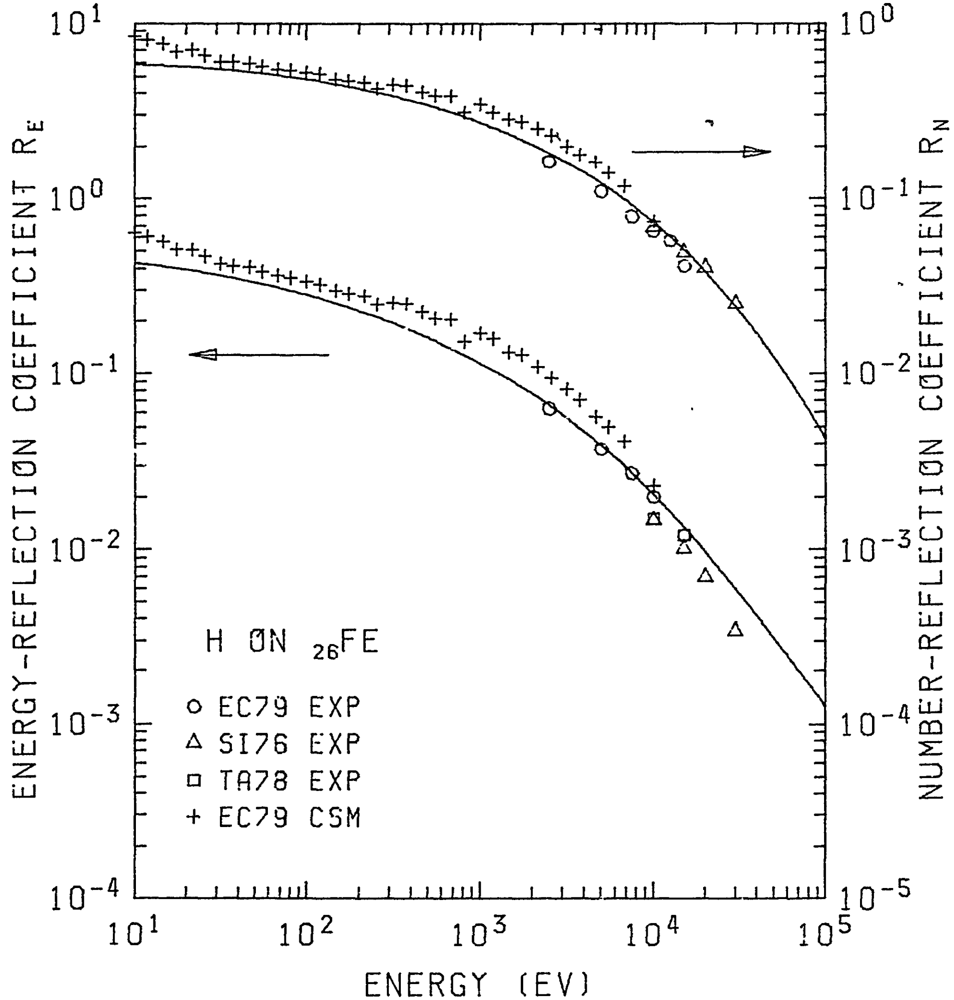
See page 25 for Explanation of Graphs



GRAPH I. R_N and R_E vs Energy for H Ions on V and Cr

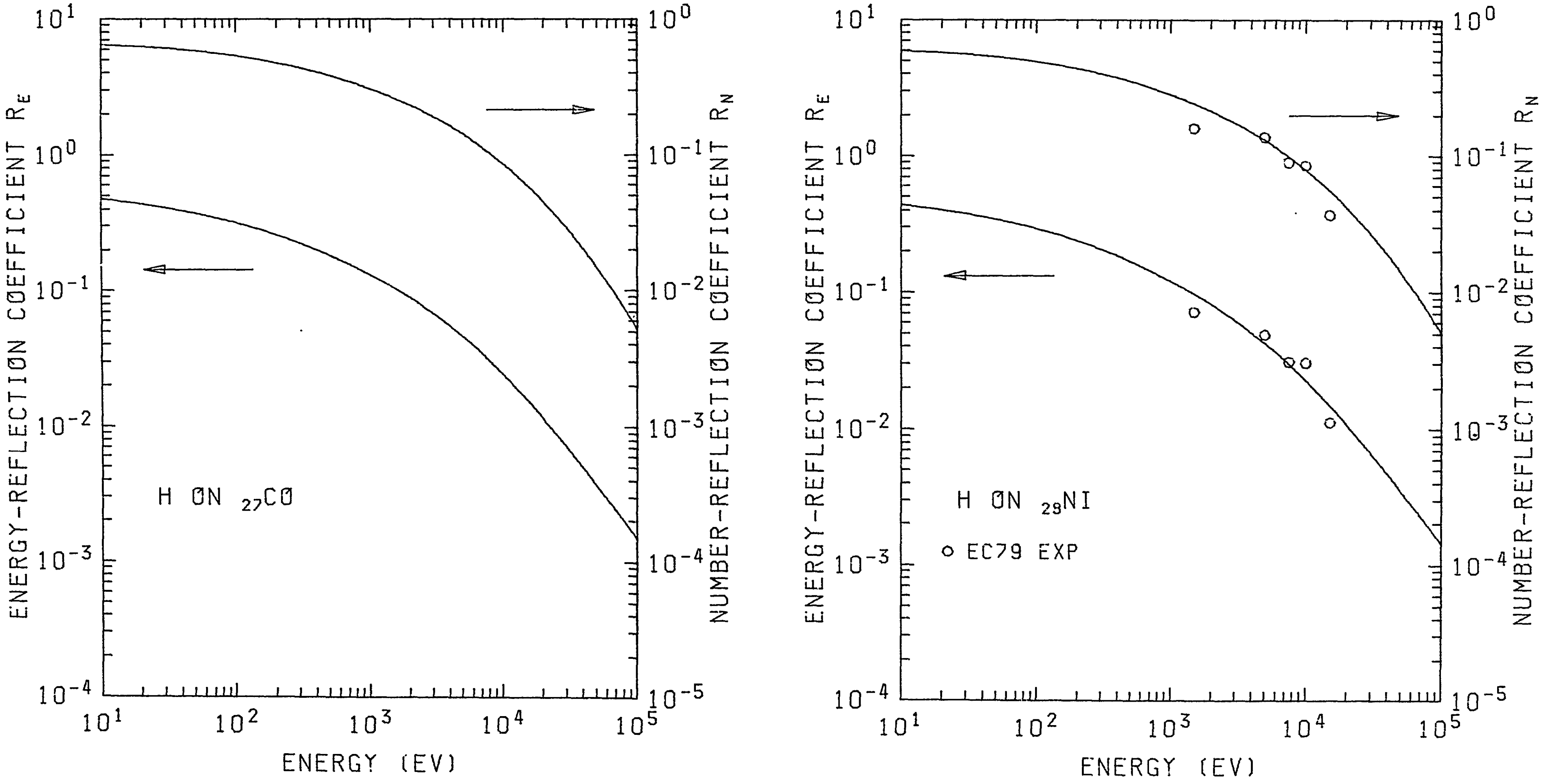
See page 25 for Explanation of Graphs



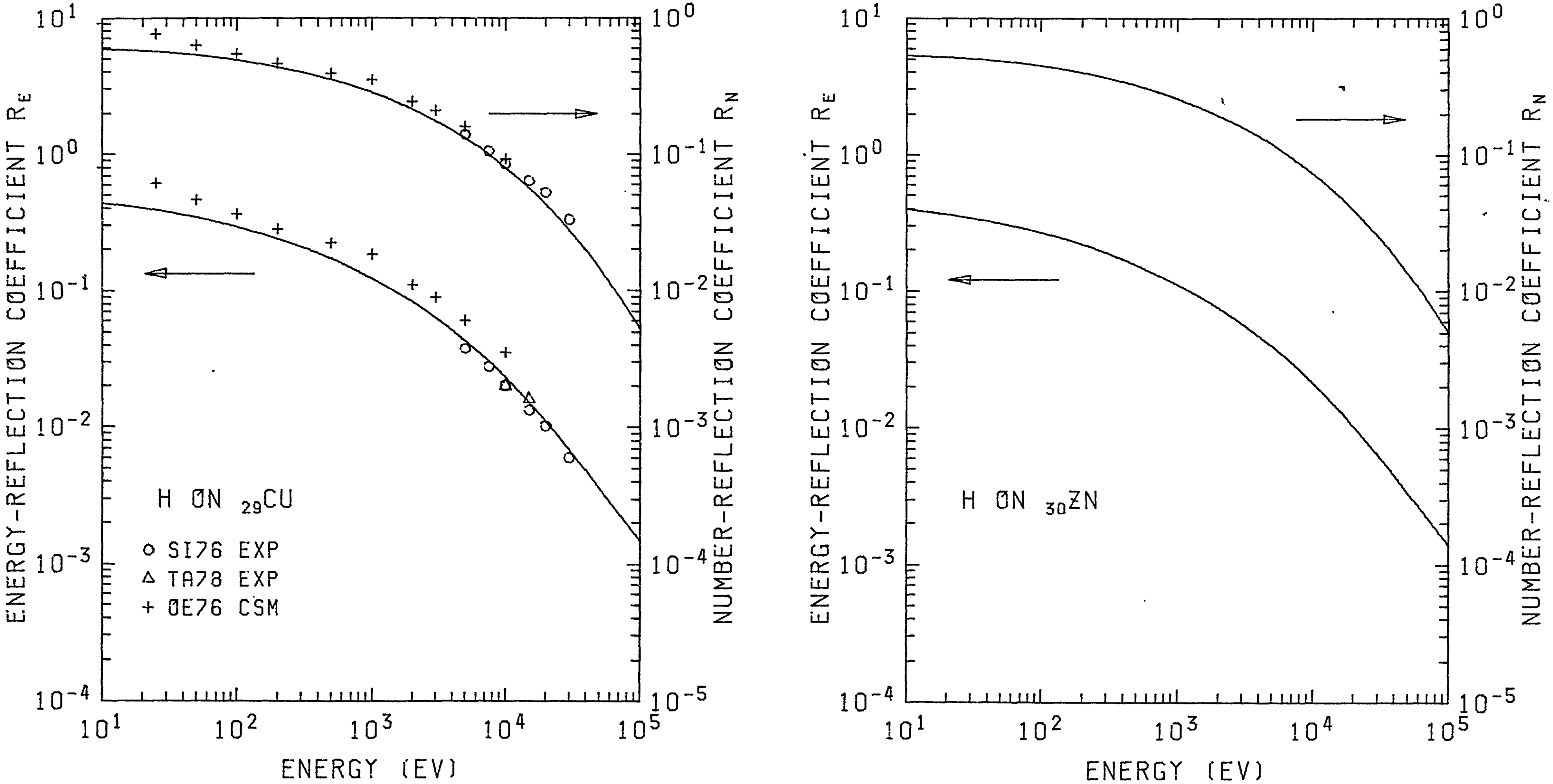


GRAPH I. R_N and R_E vs Energy for H Ions on Mn and Fe

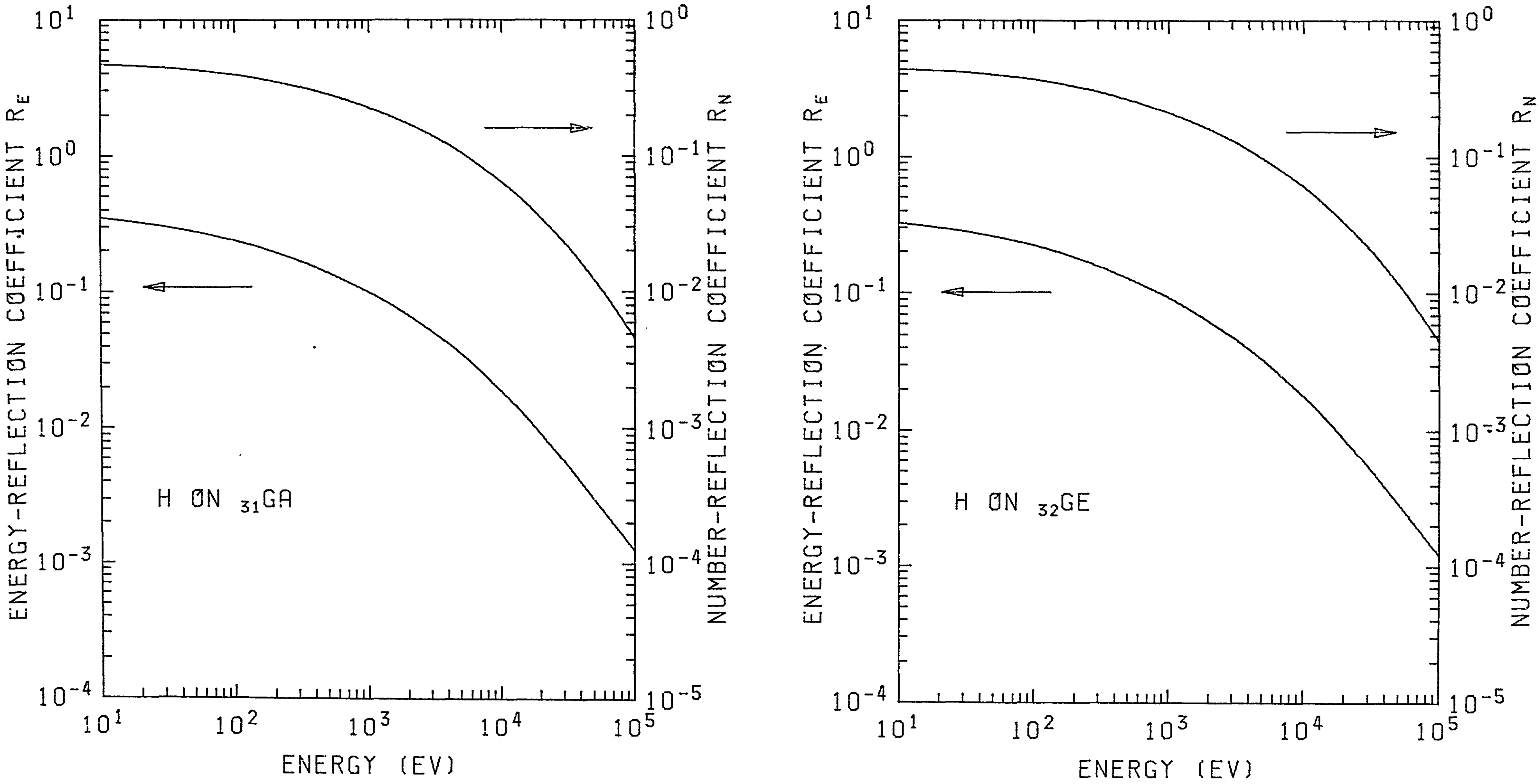
See page 25 for Explanation of Graphs



GRAPH I. R_N and R_E vs Energy for H Ions on Co and Ni
See page 25 for Explanation of Graphs

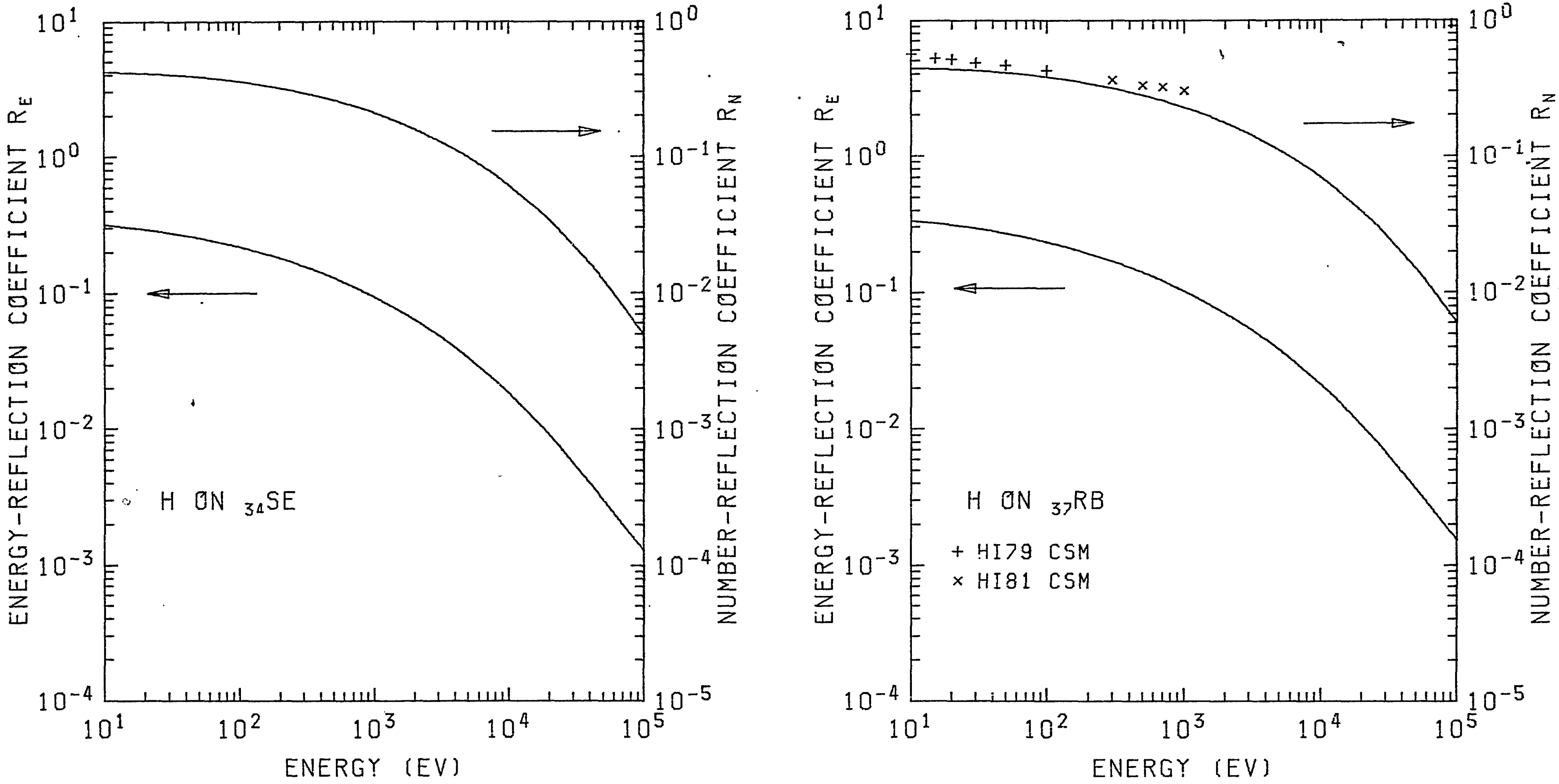


GRAPH I. R_N and R_E vs Energy for H Ions on Cu and Zn
See page 25 for Explanation of Graphs



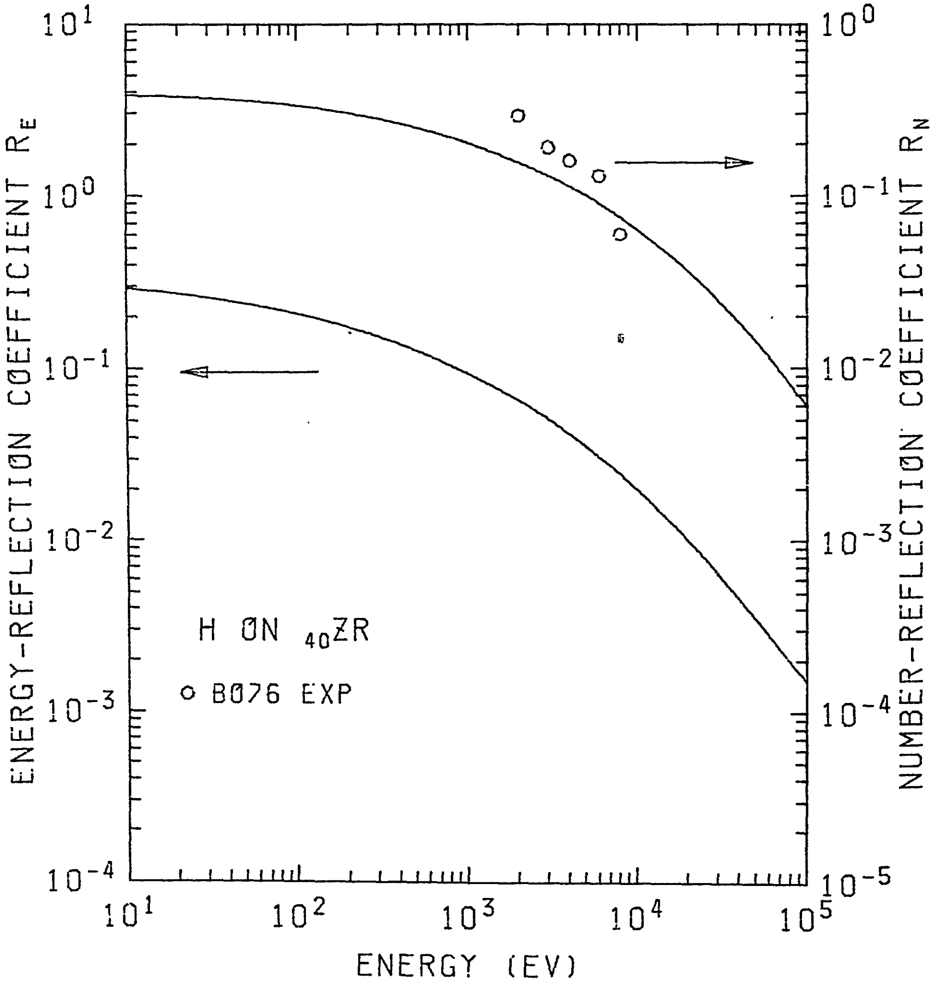
GRAPH I. R_N and R_E vs Energy for H Ions on Ga and Ge

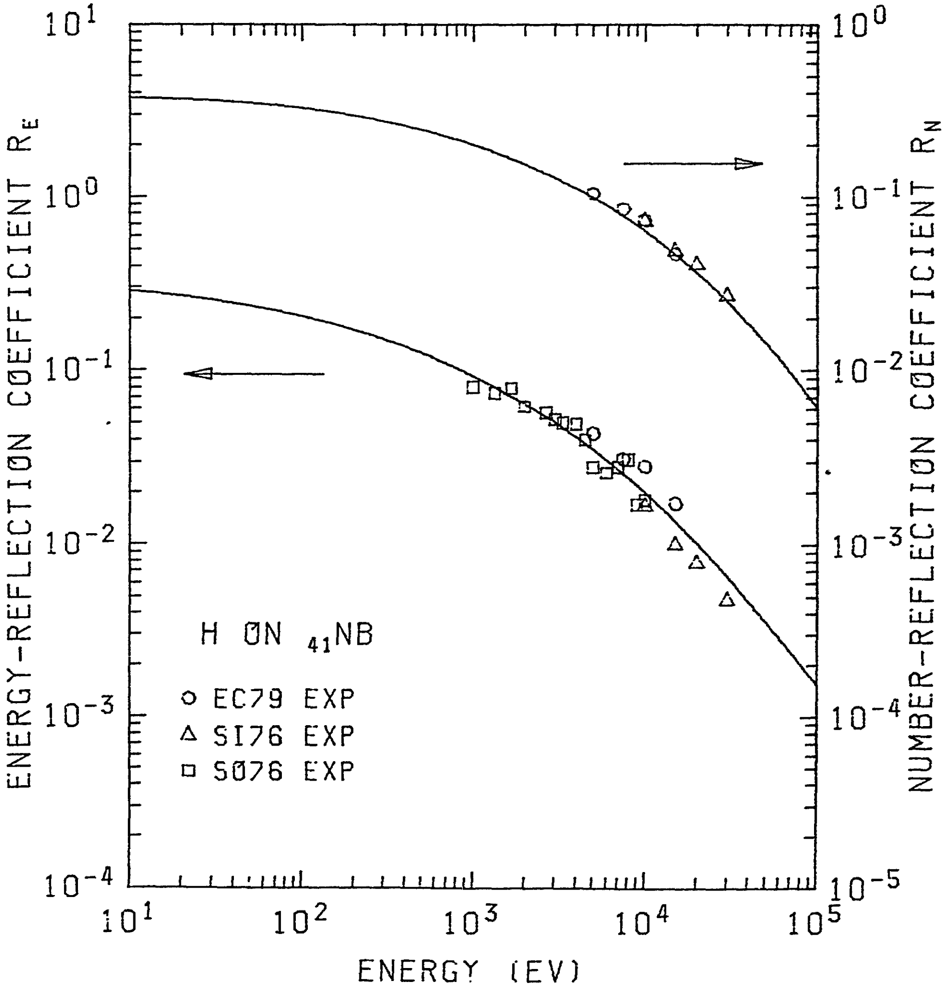
See page 25 for Explanation of Graphs



GRAPH I. R_N **and** R_E **vs Energy for H Ions on Se and Rb**

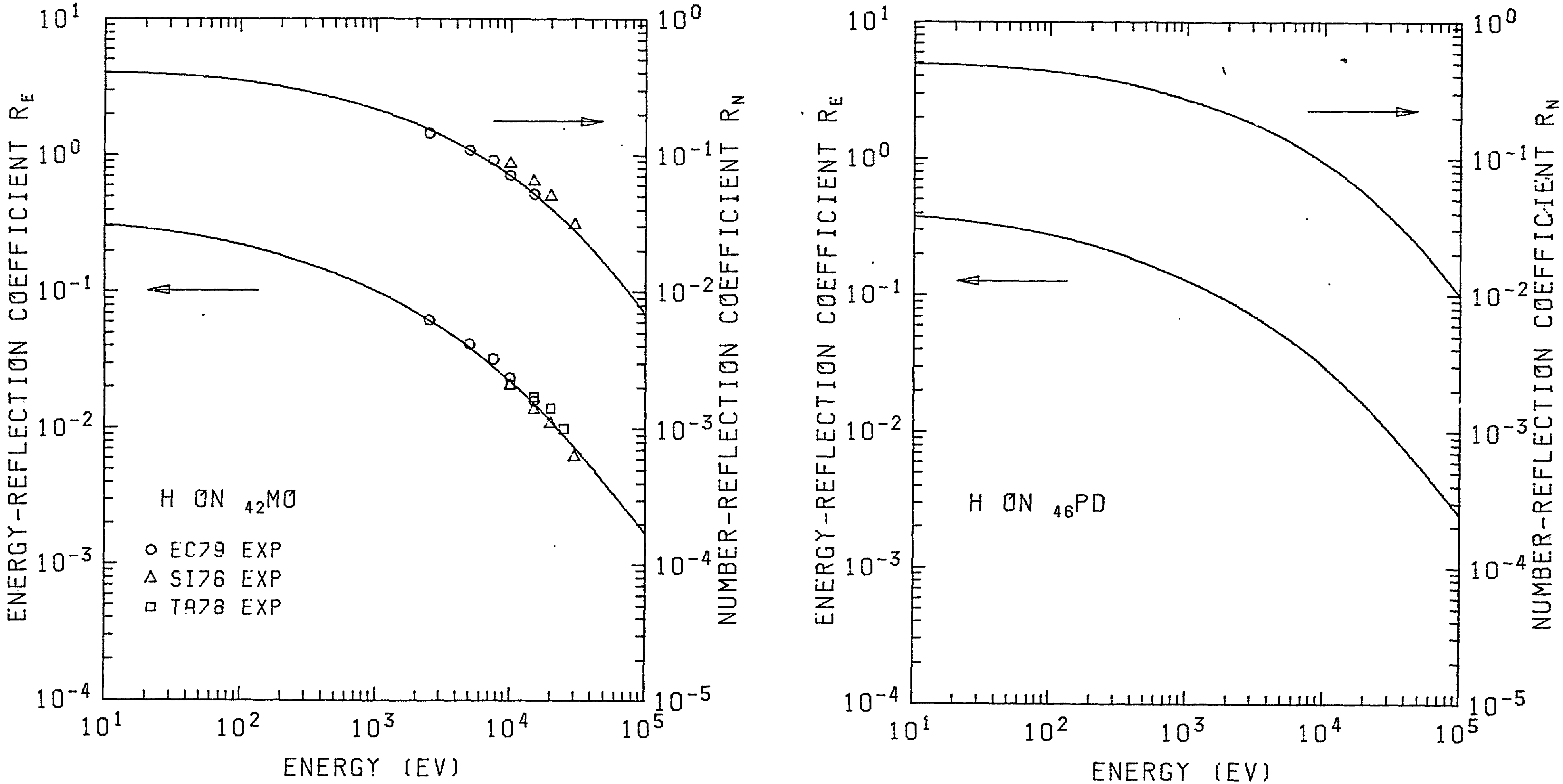
See page 25 for Explanation of Graphs





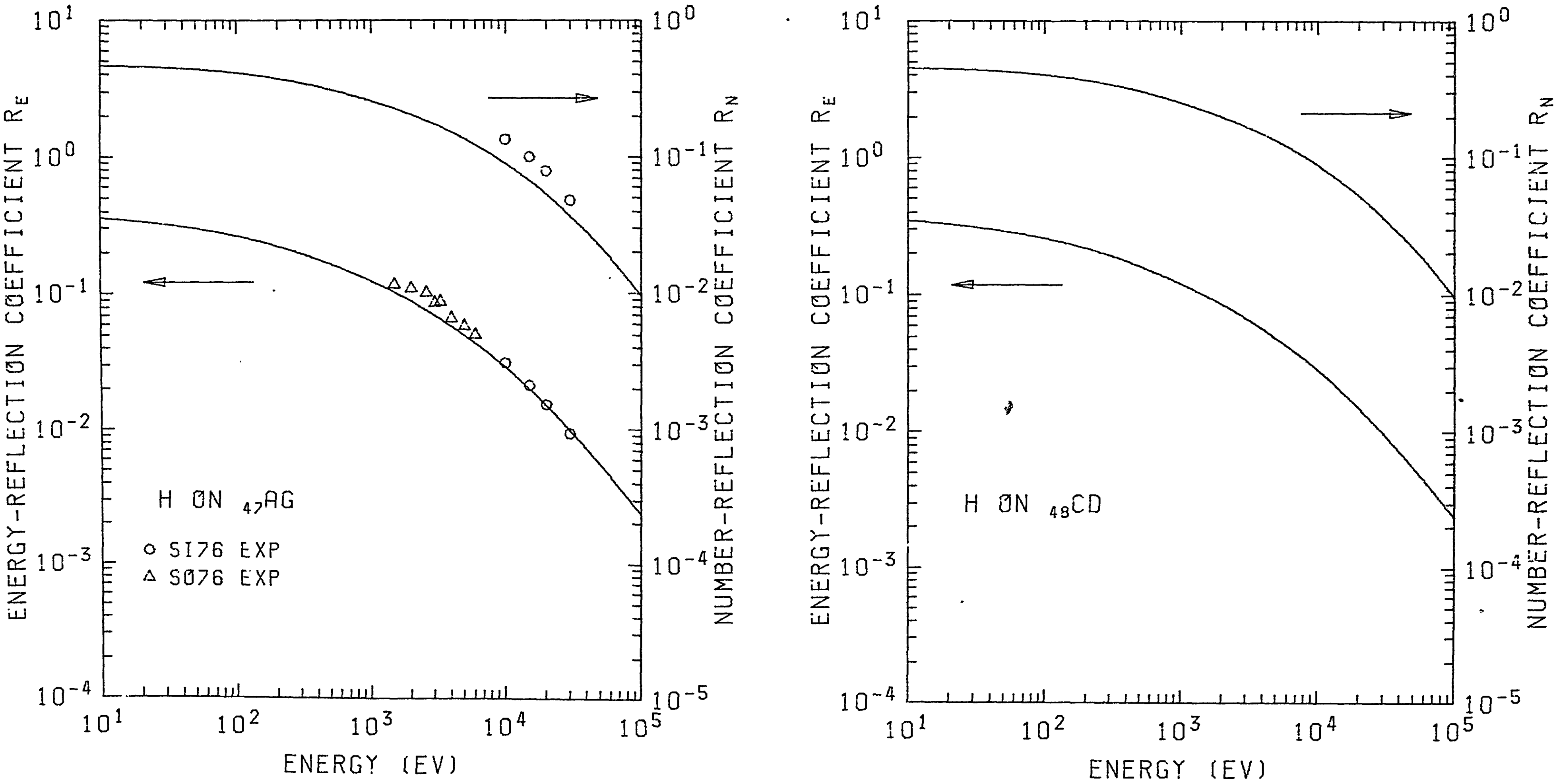
GRAPH I. R_N and R_E vs Energy for H Ions on Zr and Nb

See page 25 for Explanation of Graphs

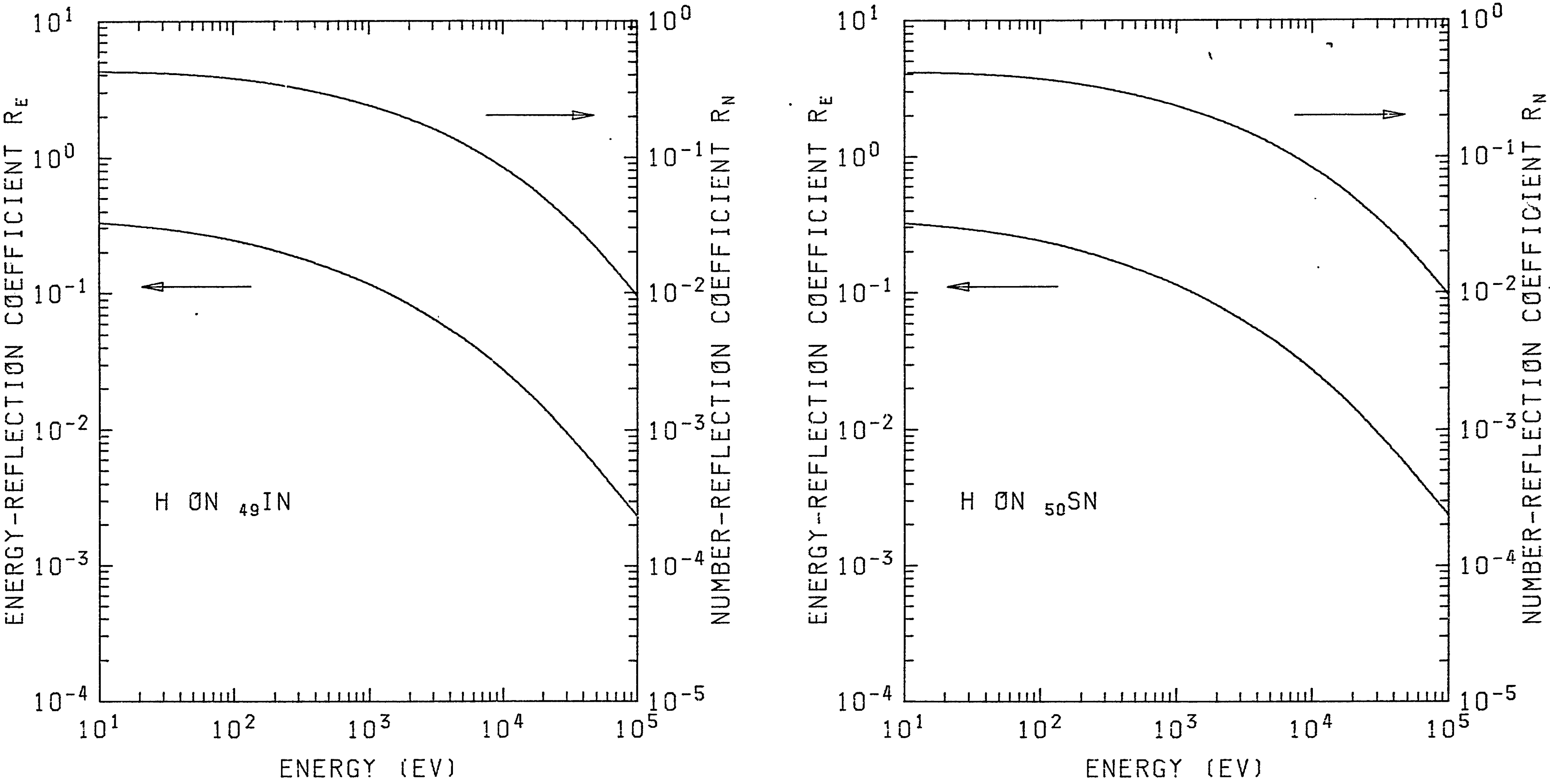


GRAPH I. R_N and R_E vs Energy for H Ions on Mo and Pd

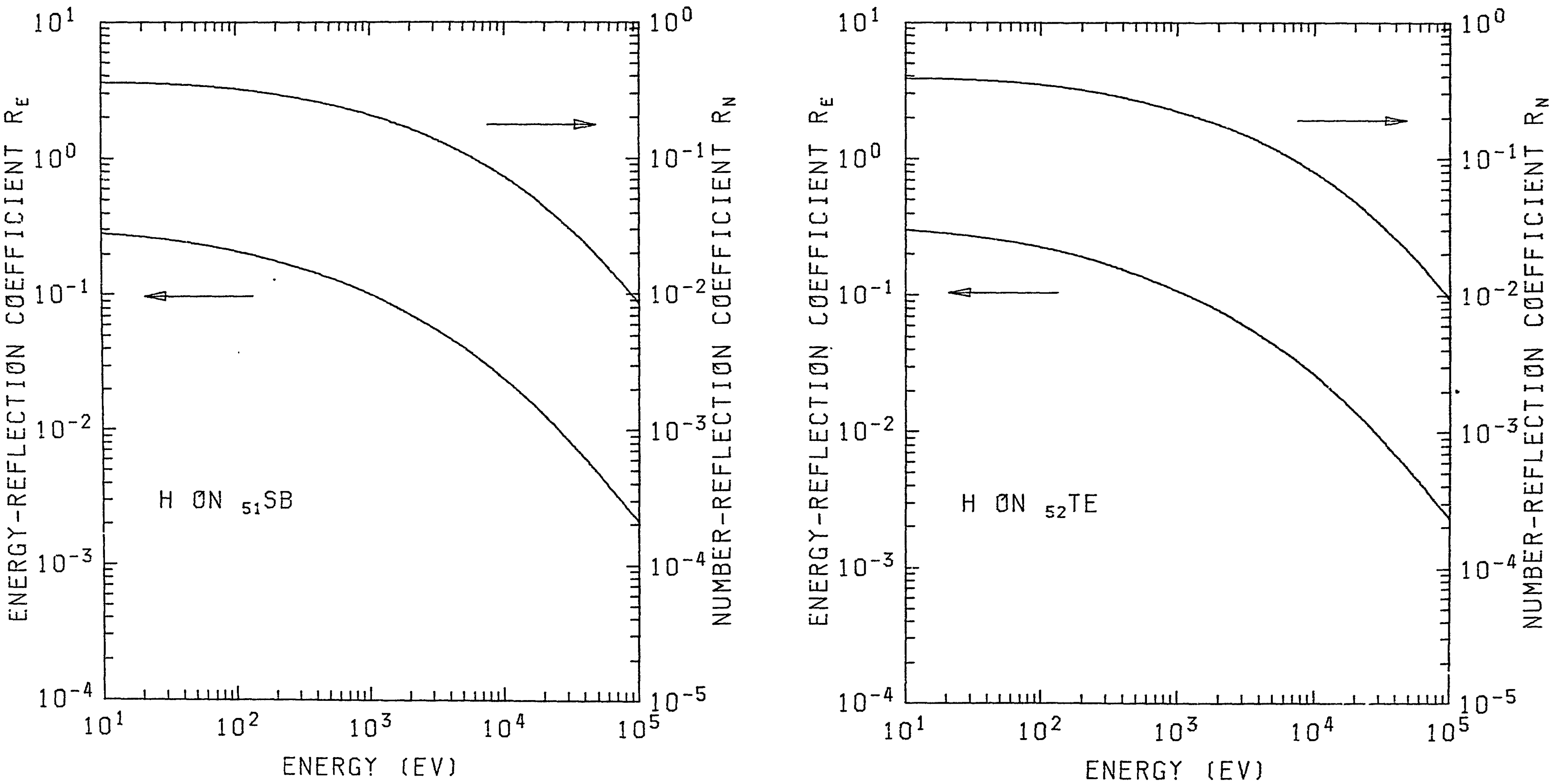
See page 25 for Explanation of Graphs



GRAPH I. R_N and R_E vs Energy for H Ions on Ag and Cd
See page 25 for Explanation of Graphs

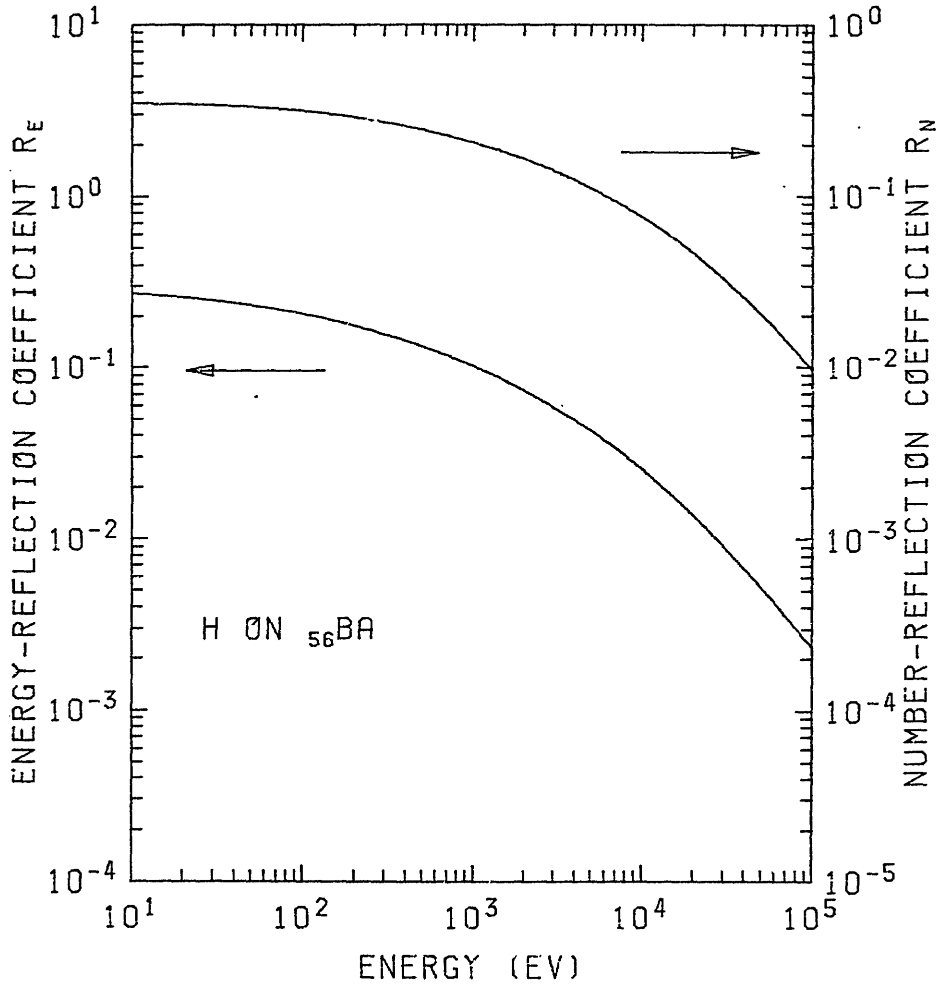


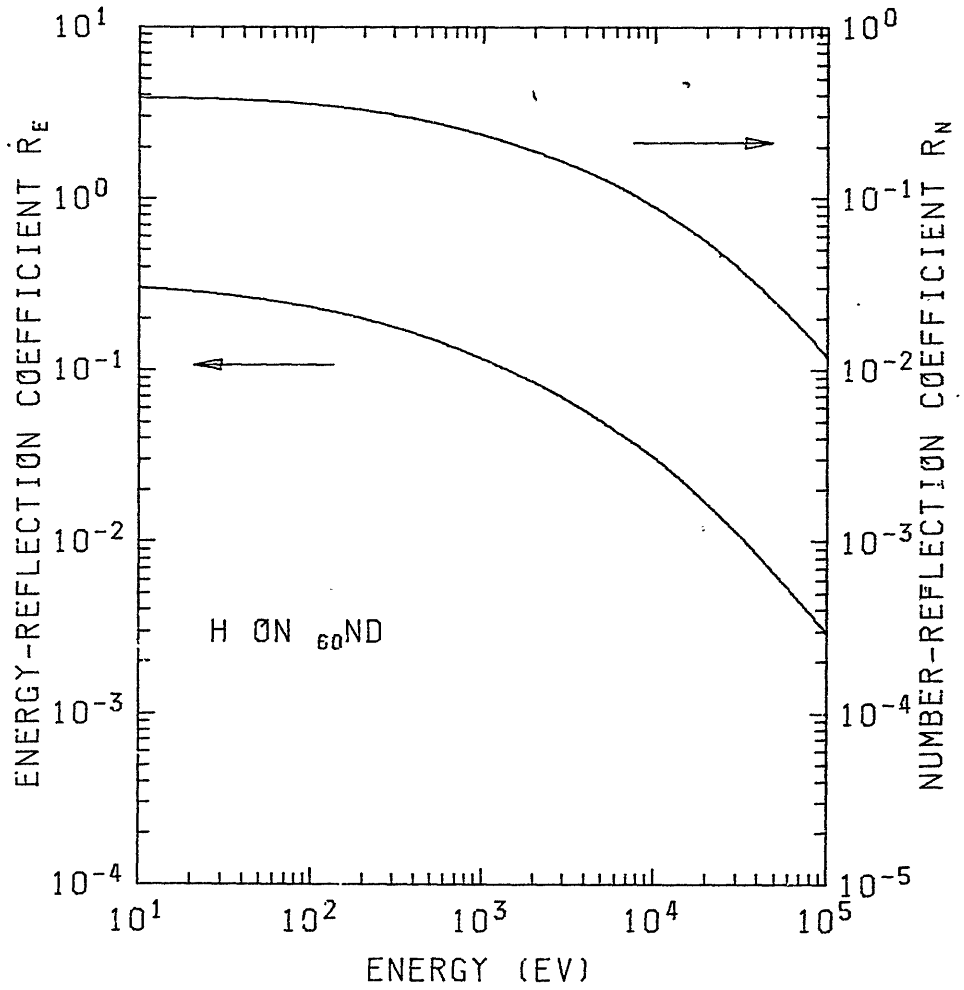
GRAPH I. R_N and R_E vs Energy for H Ions on In and Sn
See page 25 for Explanation of Graphs



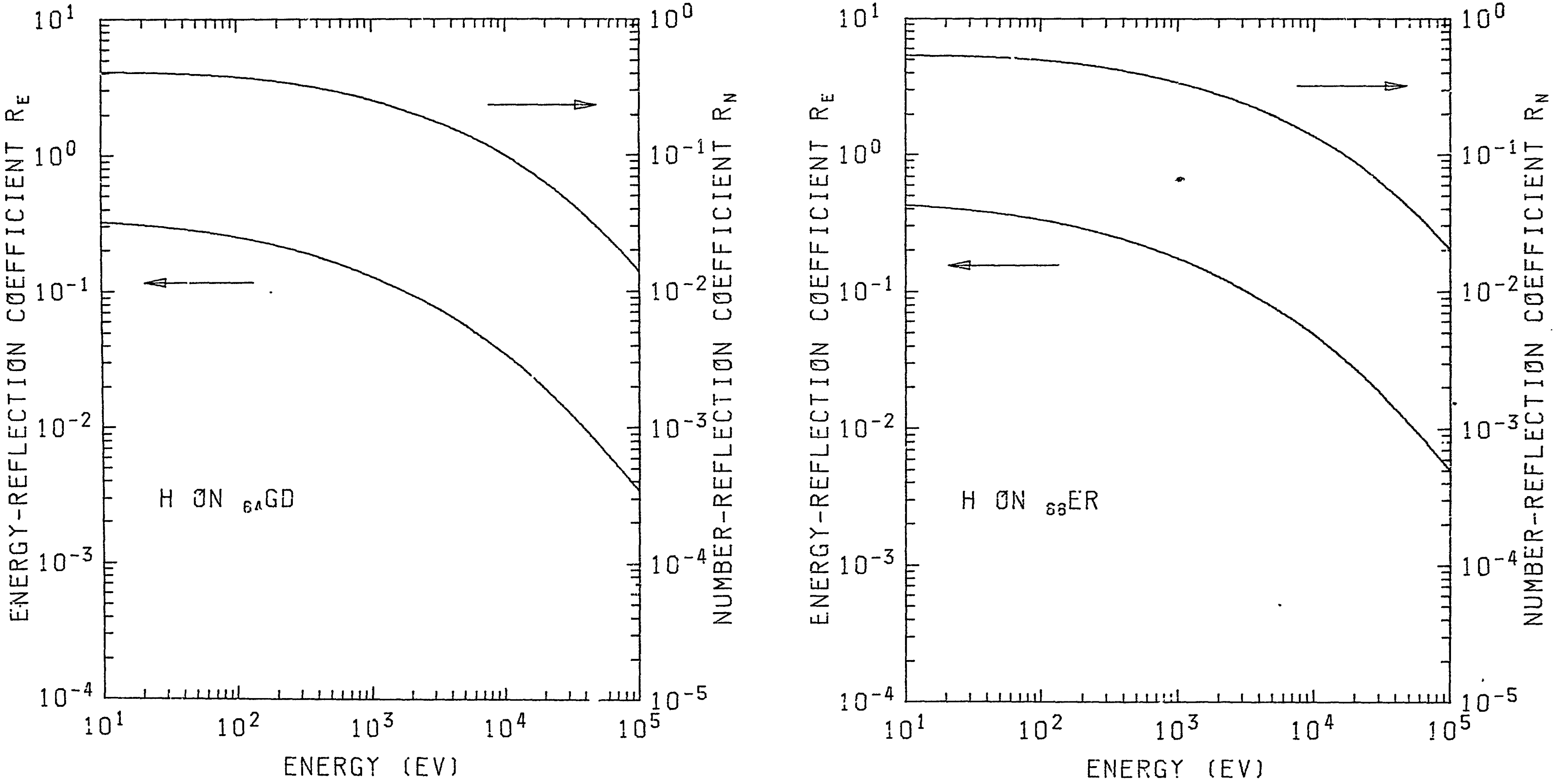
GRAPH I. R_N and R_E vs Energy for H Ions on Sb and Te

See page 25 for Explanation of Graphs

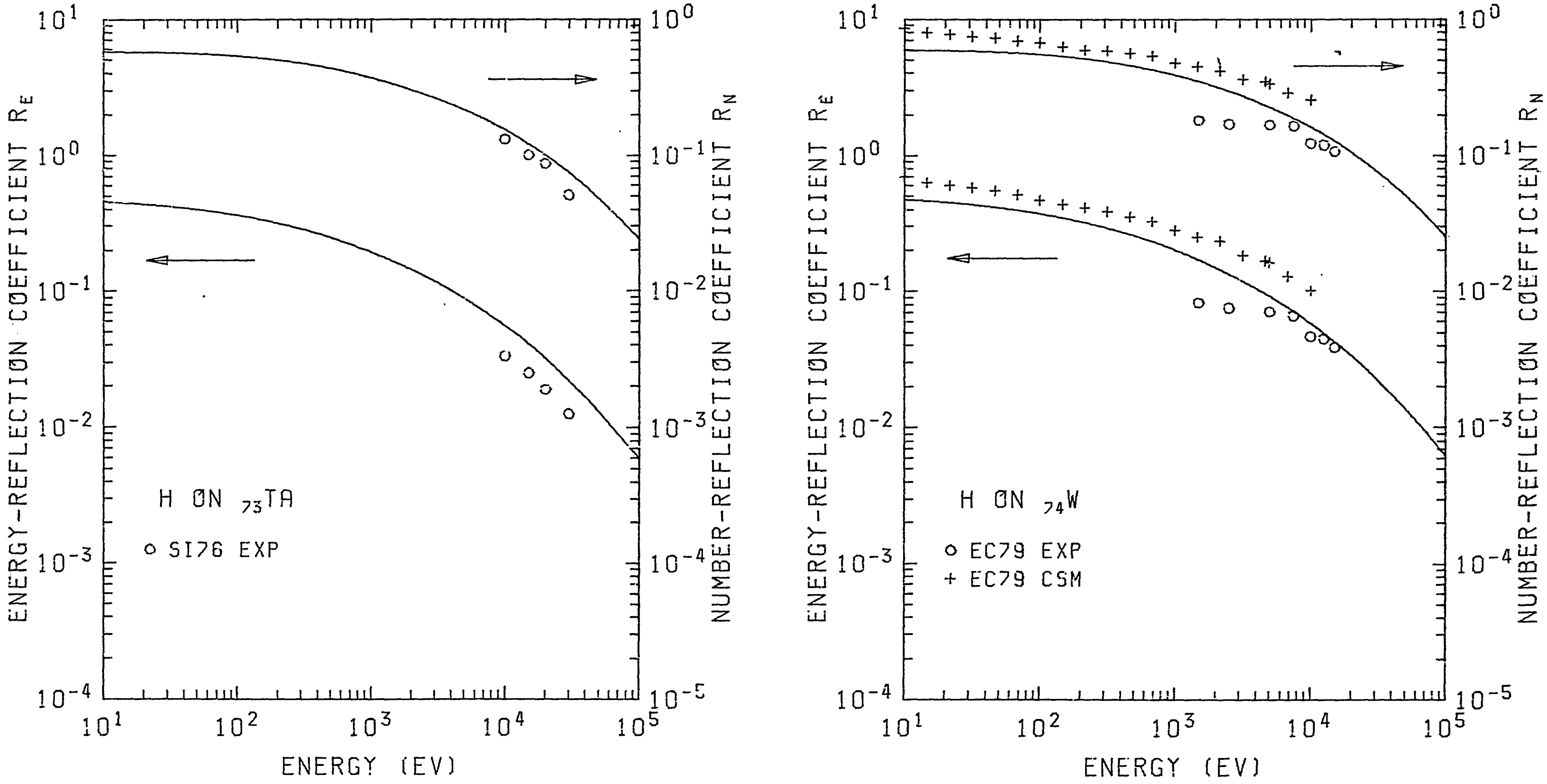




GRAPH I. R_N and R_E vs Energy for H Ions on Ba and Nd
See page 25 for Explanation of Graphs

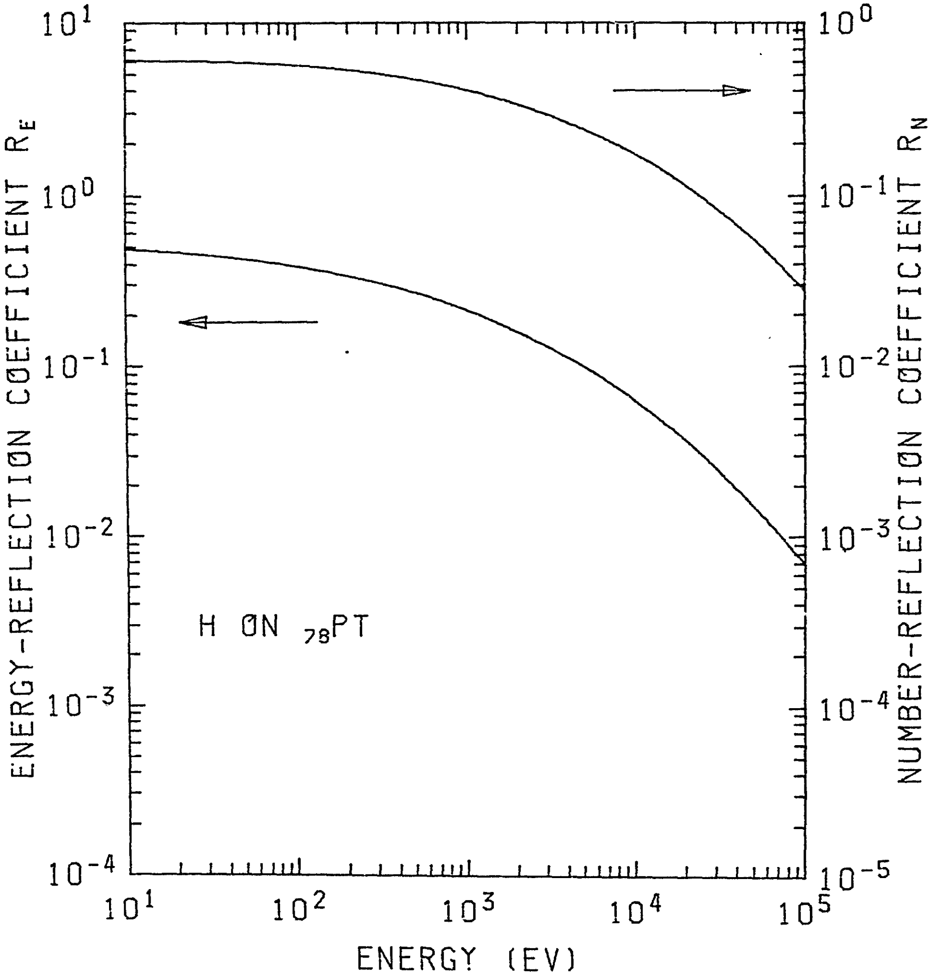


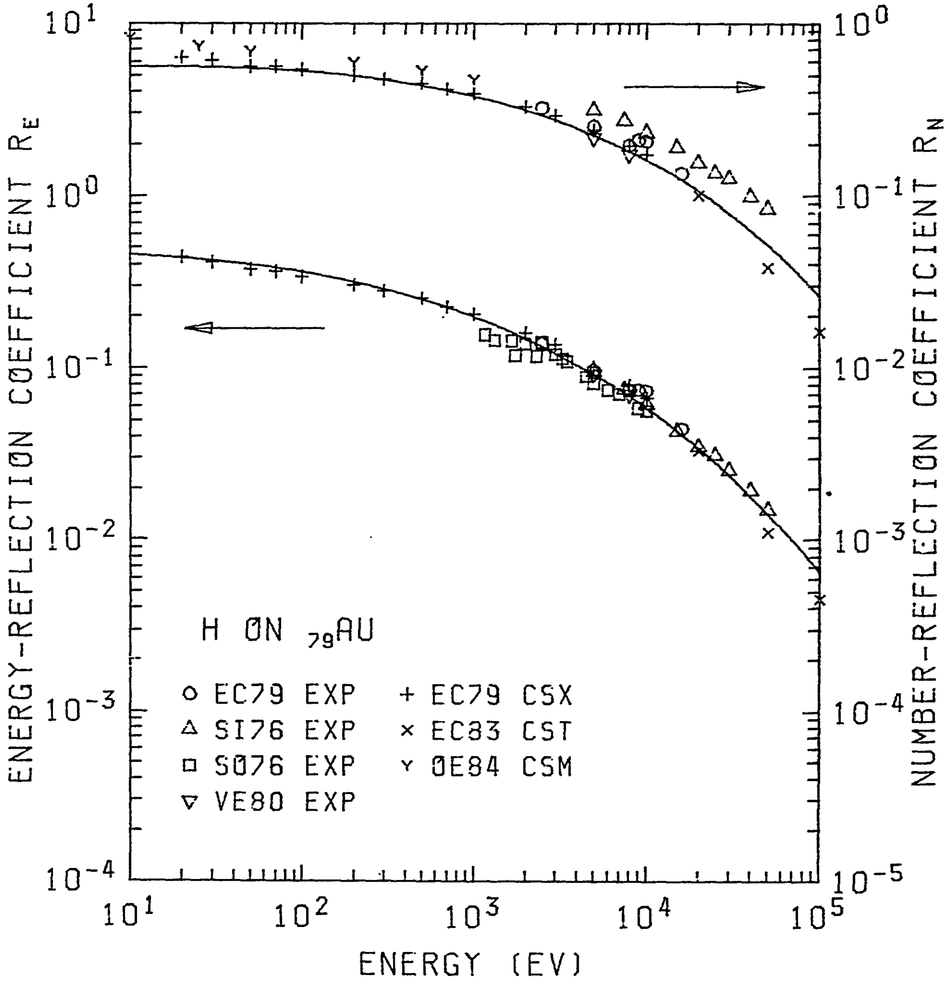
GRAPH I. R_N and R_E vs Energy for H Ions on Gd and Er
See page 25 for Explanation of Graphs



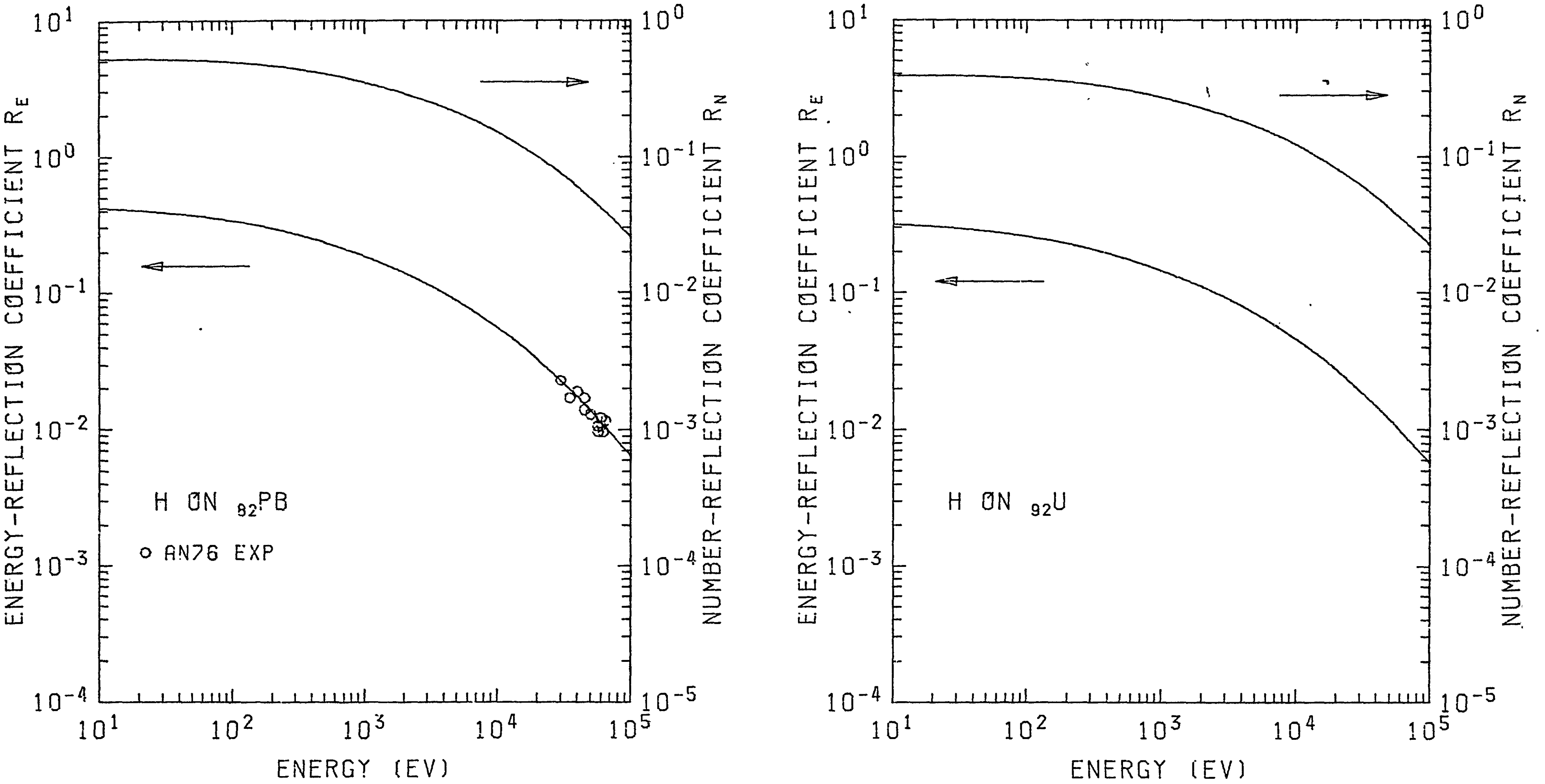
GRAPH I. R_N and R_E vs Energy for H Ions on Ta and W

See page 25 for Explanation of Graphs

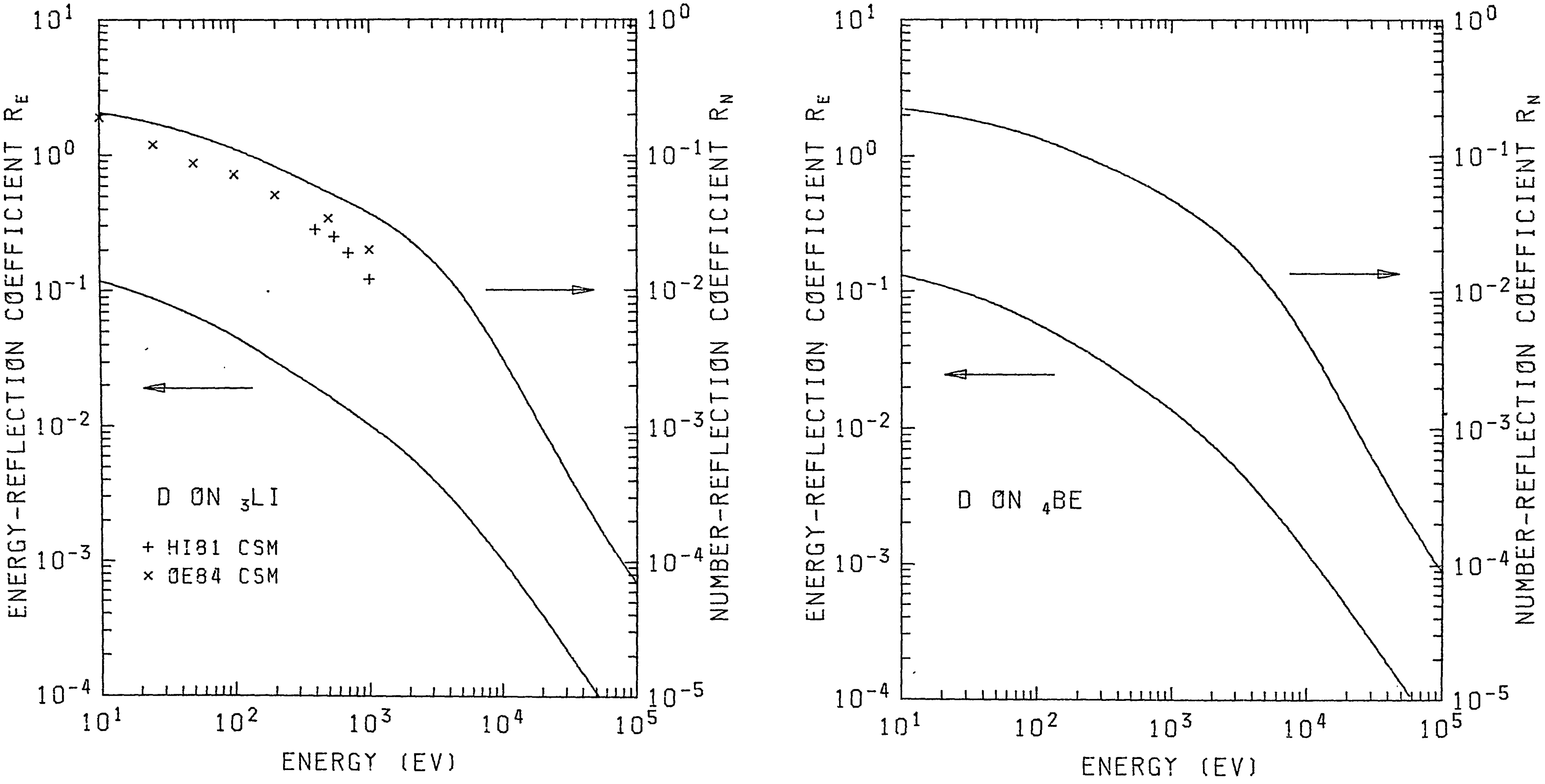




GRAPH I. R_N and R_E vs Energy for H Ions on Pt and Au
See page 25 for Explanation of Graphs

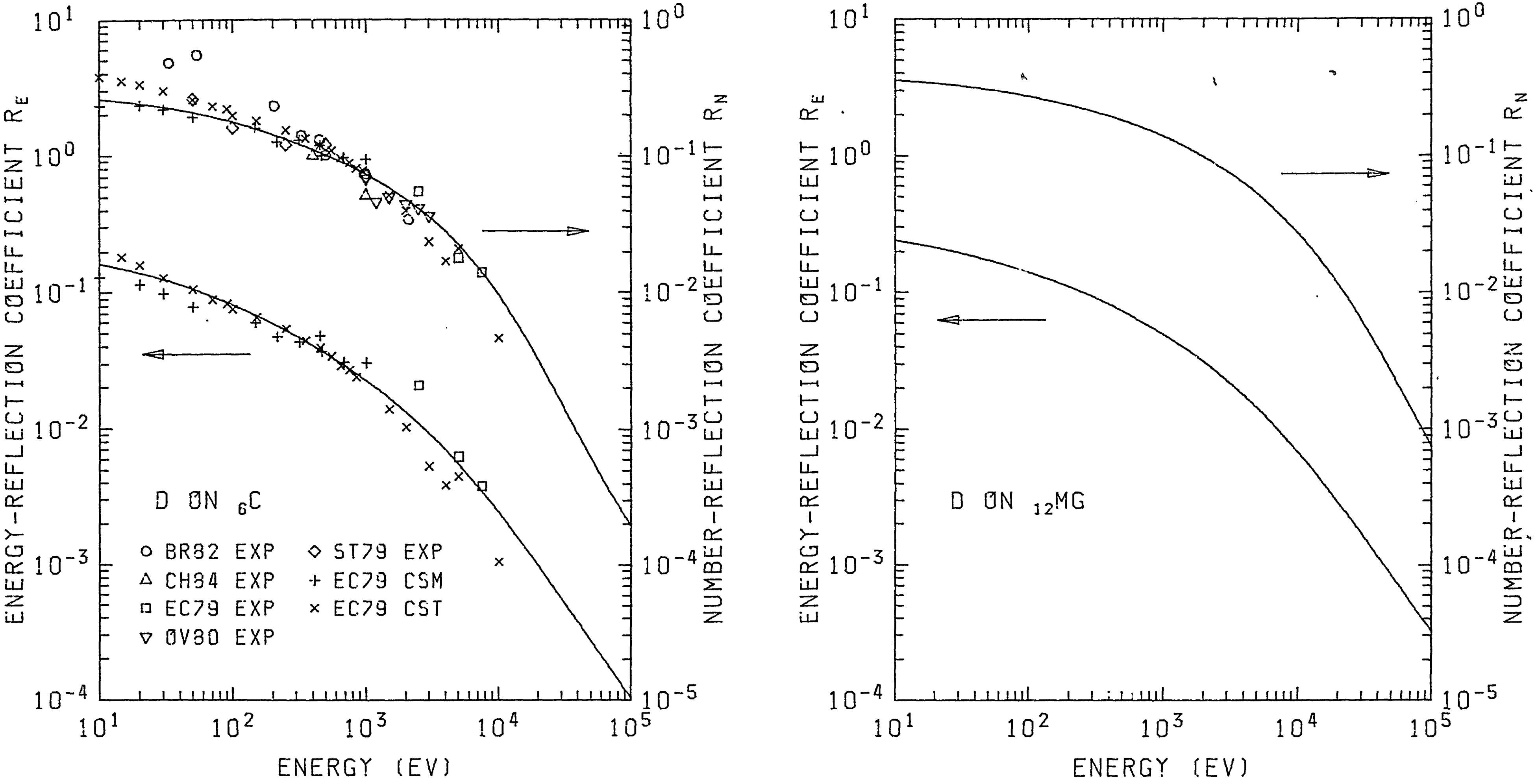


GRAPH I. R_N and R_E vs Energy for H Ions on Pb and U
See page 25 for Explanation of Graphs

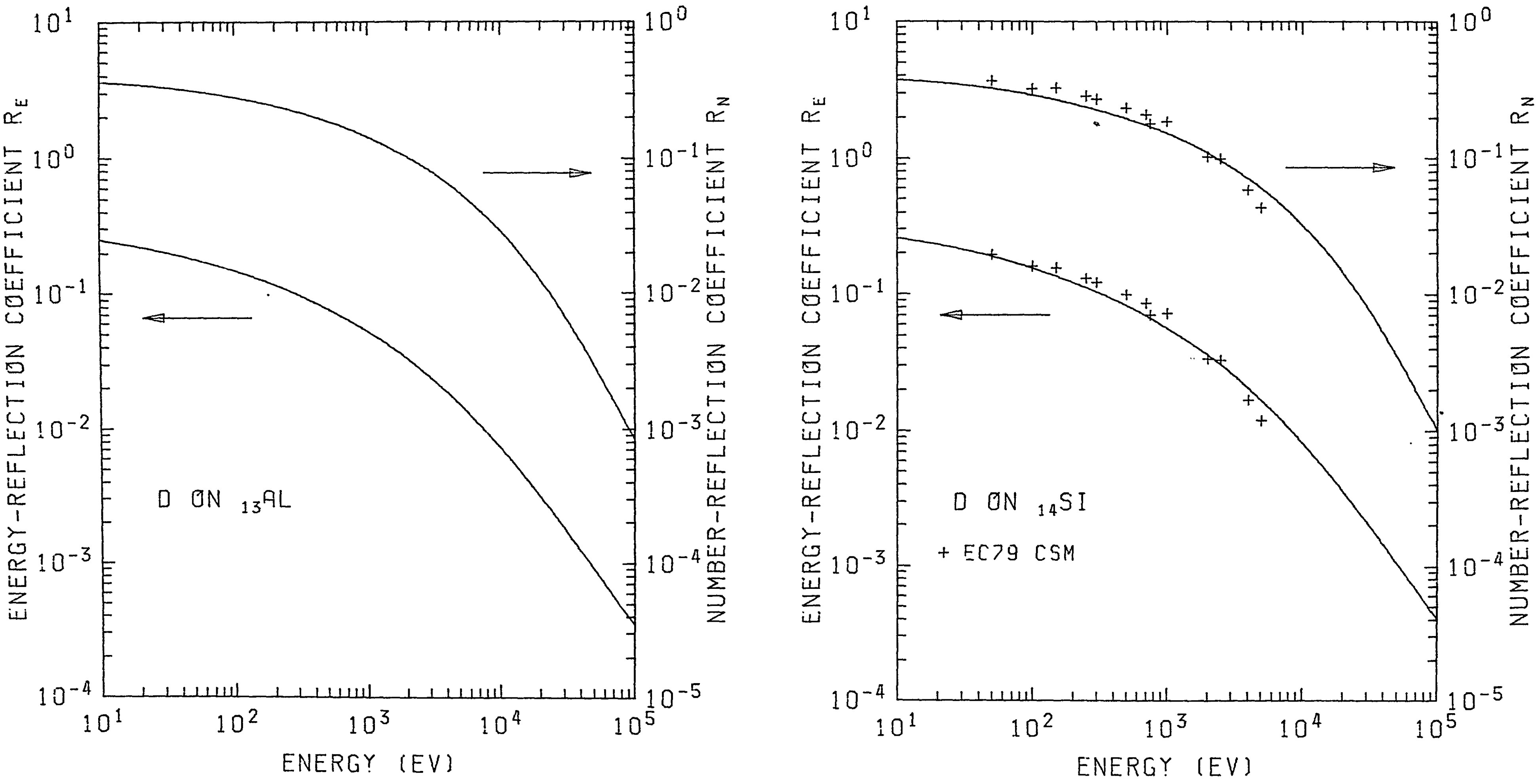


GRAPH II. R_N and R_E vs Energy for D Ions on Li and Be

See page 25 for Explanation of Graphs

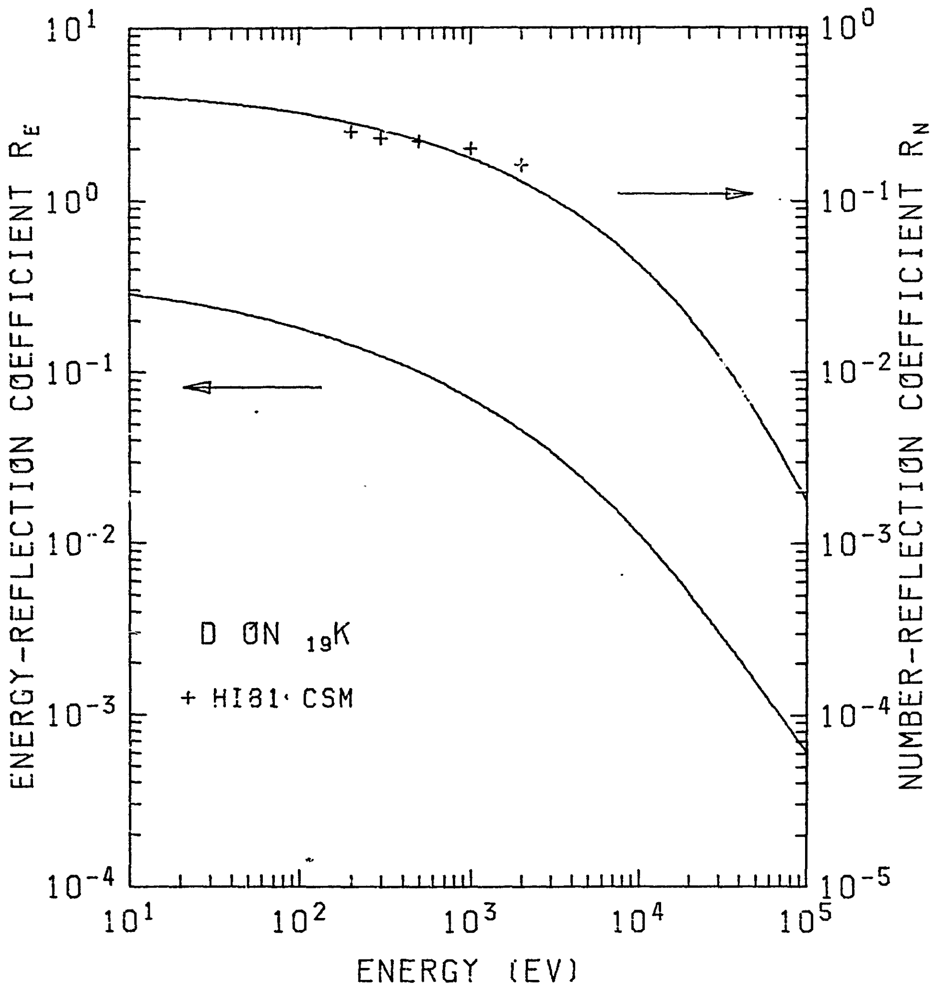


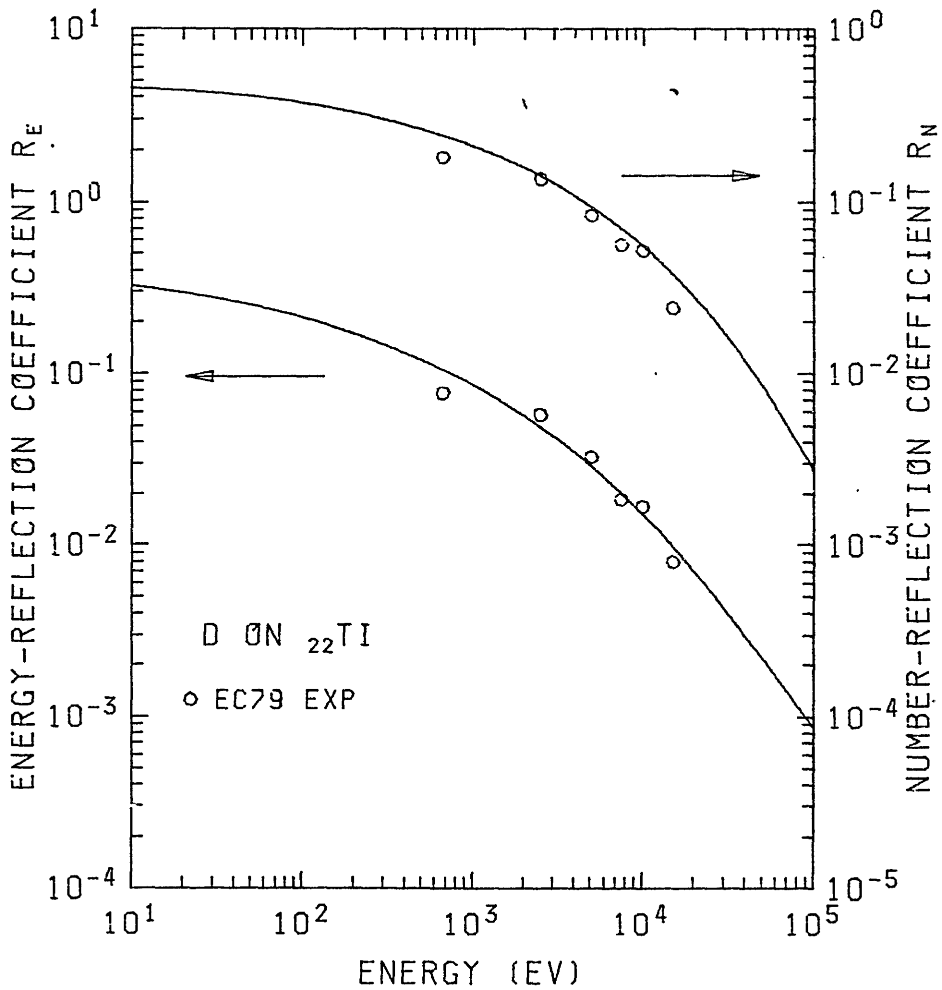
GRAPH II. R_N and R_E vs Energy for D Ions on C and Mg
See page 25 for Explanation of Graphs



GRAPH II. R_N and R_E vs Energy for D Ions on Al and Si

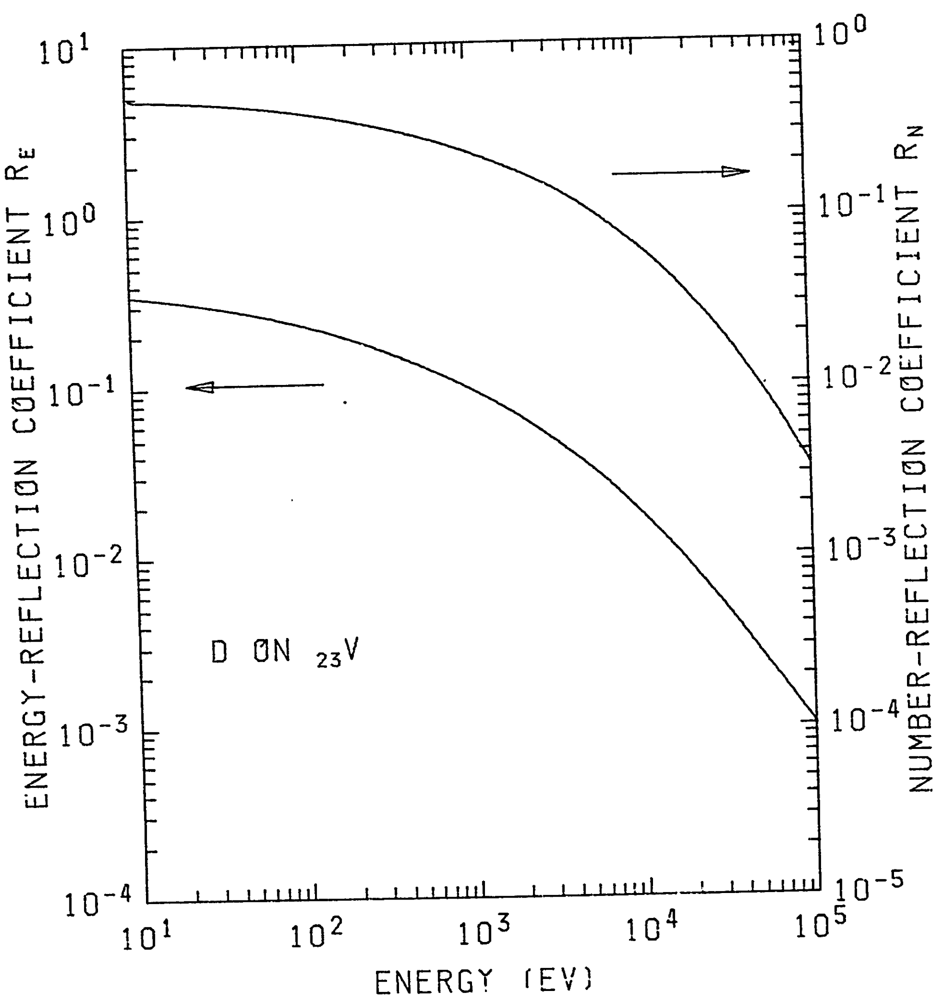
See page 25 for Explanation of Graphs

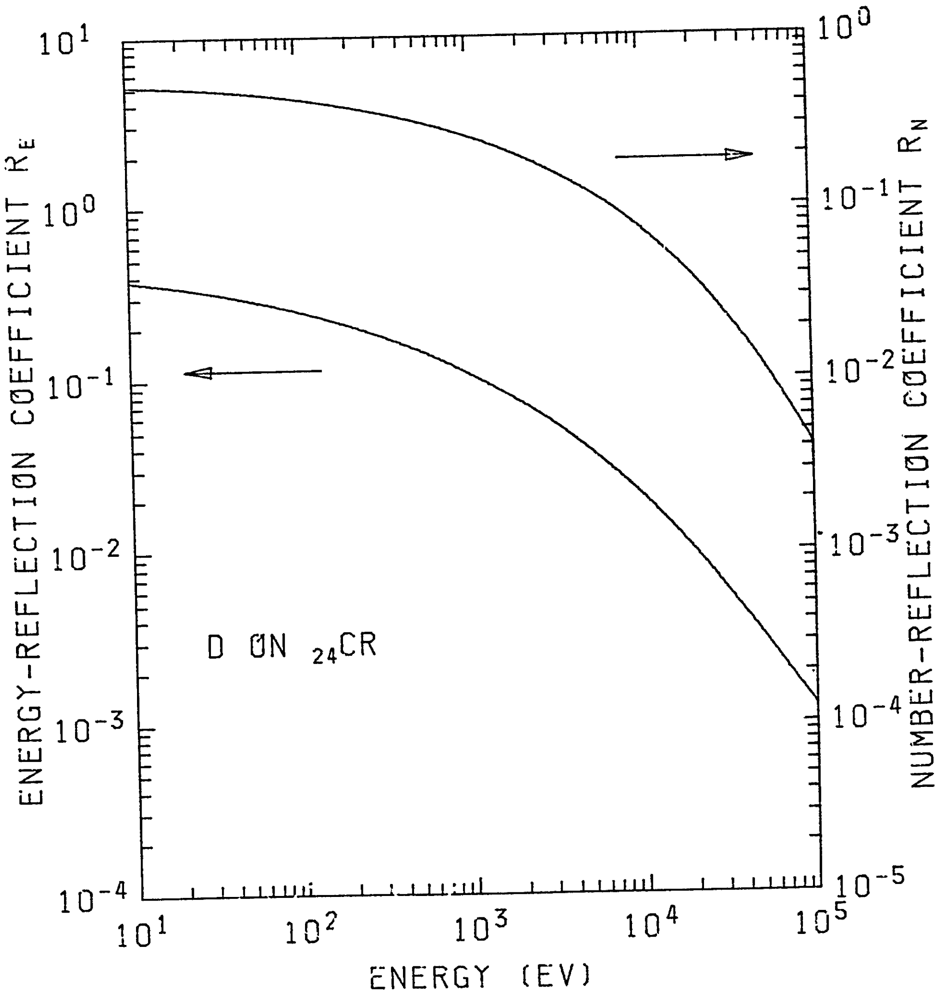




GRAPH II. R_N and R_E vs Energy for D Ions on K and Ti

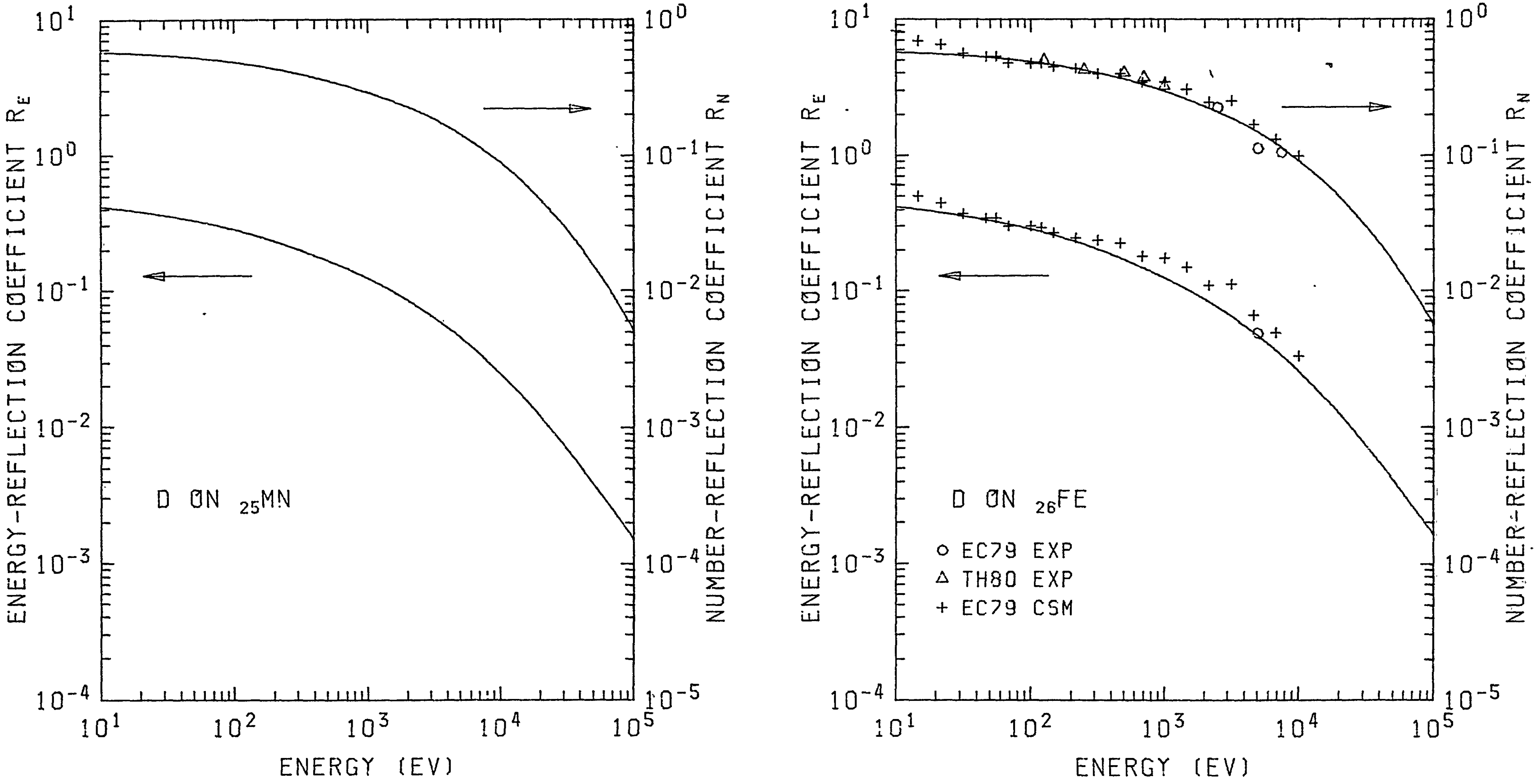
See page 25 for Explanation of Graphs





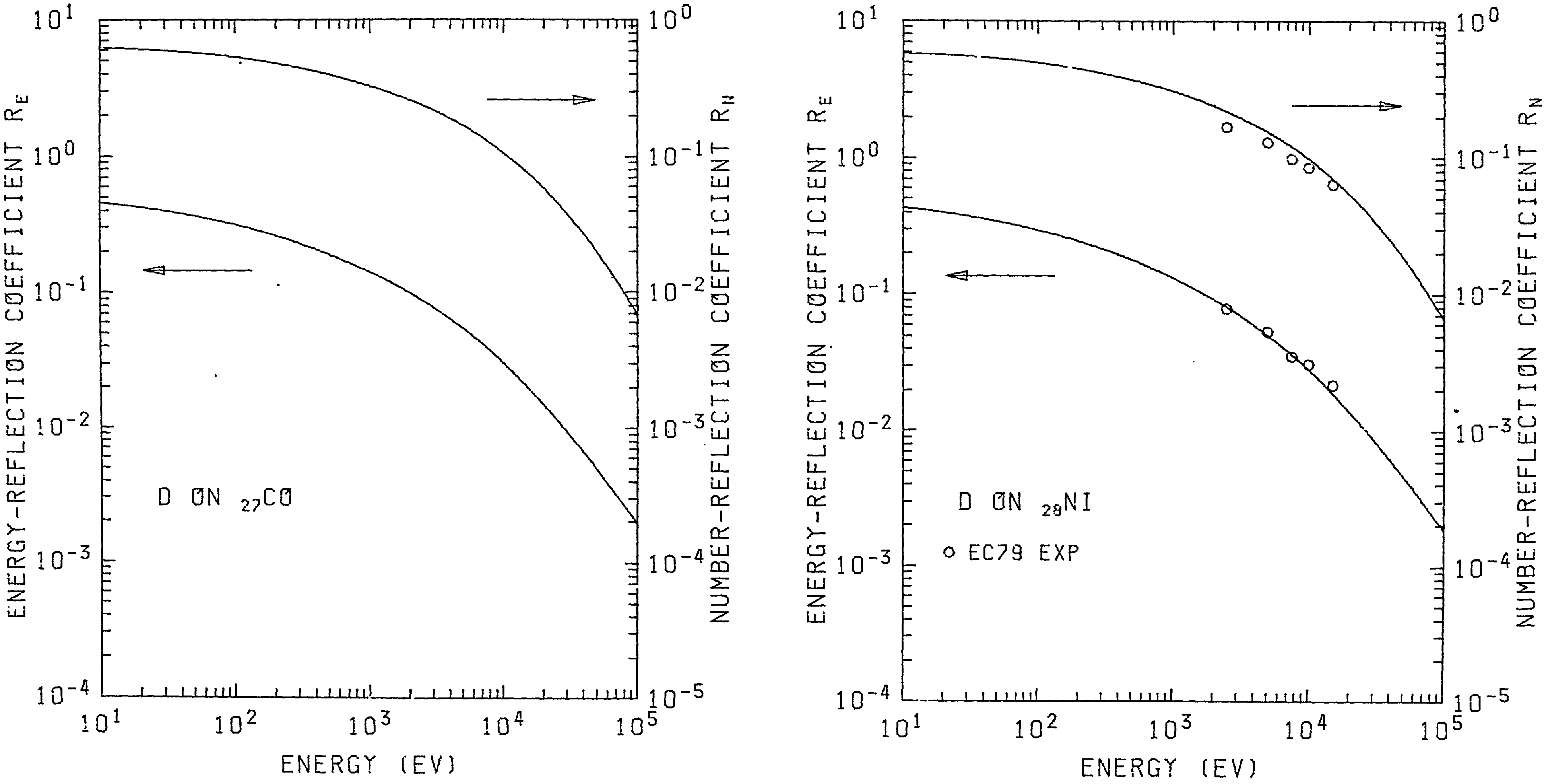
GRAPH II. R_N and R_E vs Energy for D Ions on V and Cr

See page 25 for Explanation of Graphs

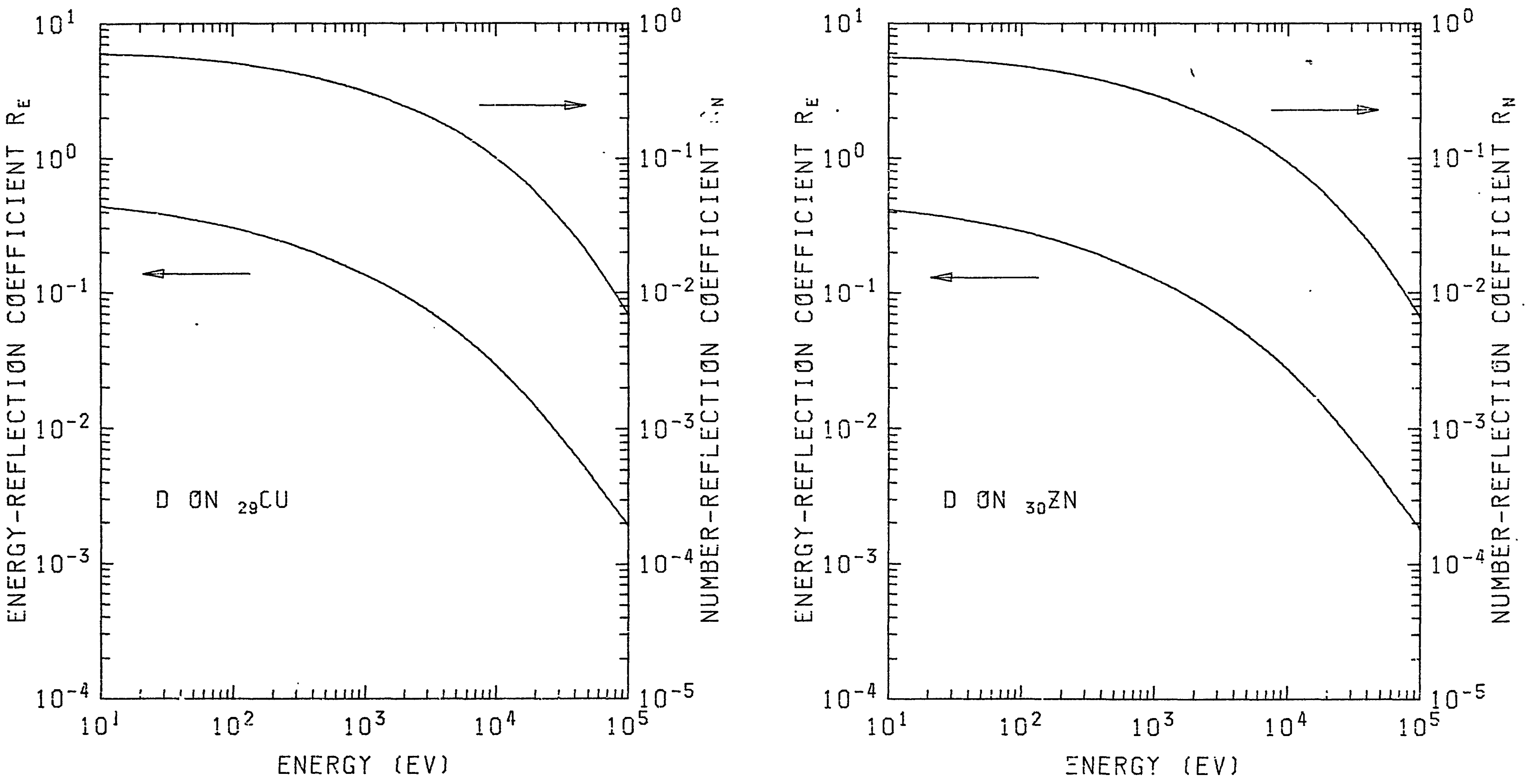


GRAPH II. R_N and R_E vs Energy for D Ions on Mn and Fe

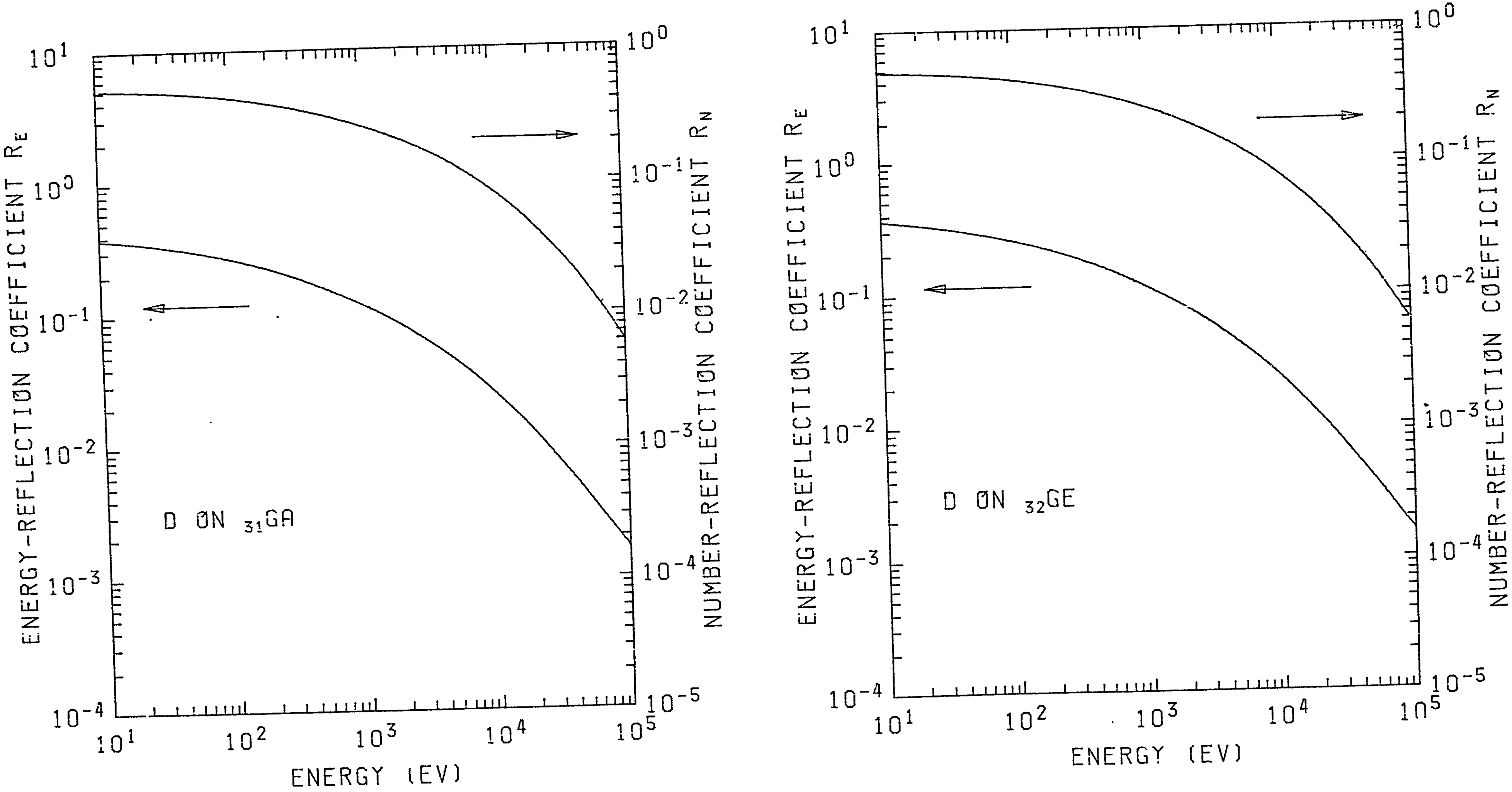
See page 25 for Explanation of Graphs



GRAPH II. R_N and R_E vs Energy for D Ions on Co and Ni
See page 25 for Explanation of Graphs

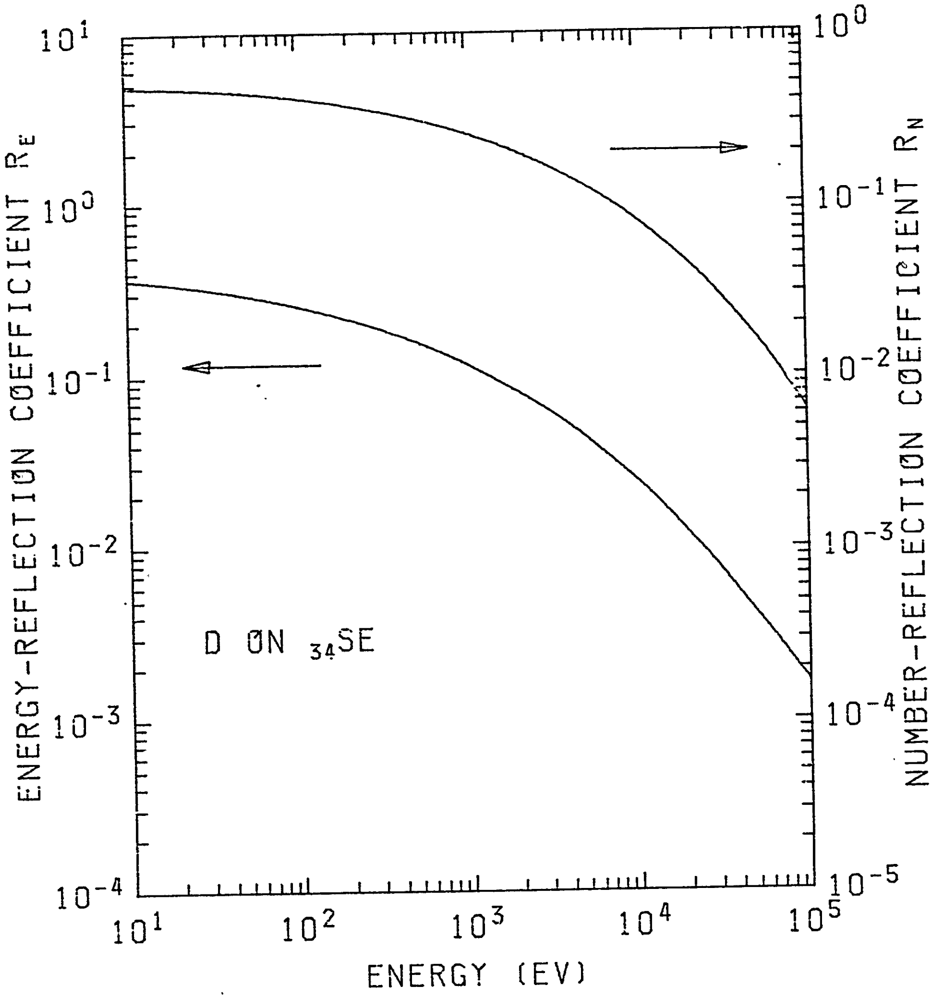


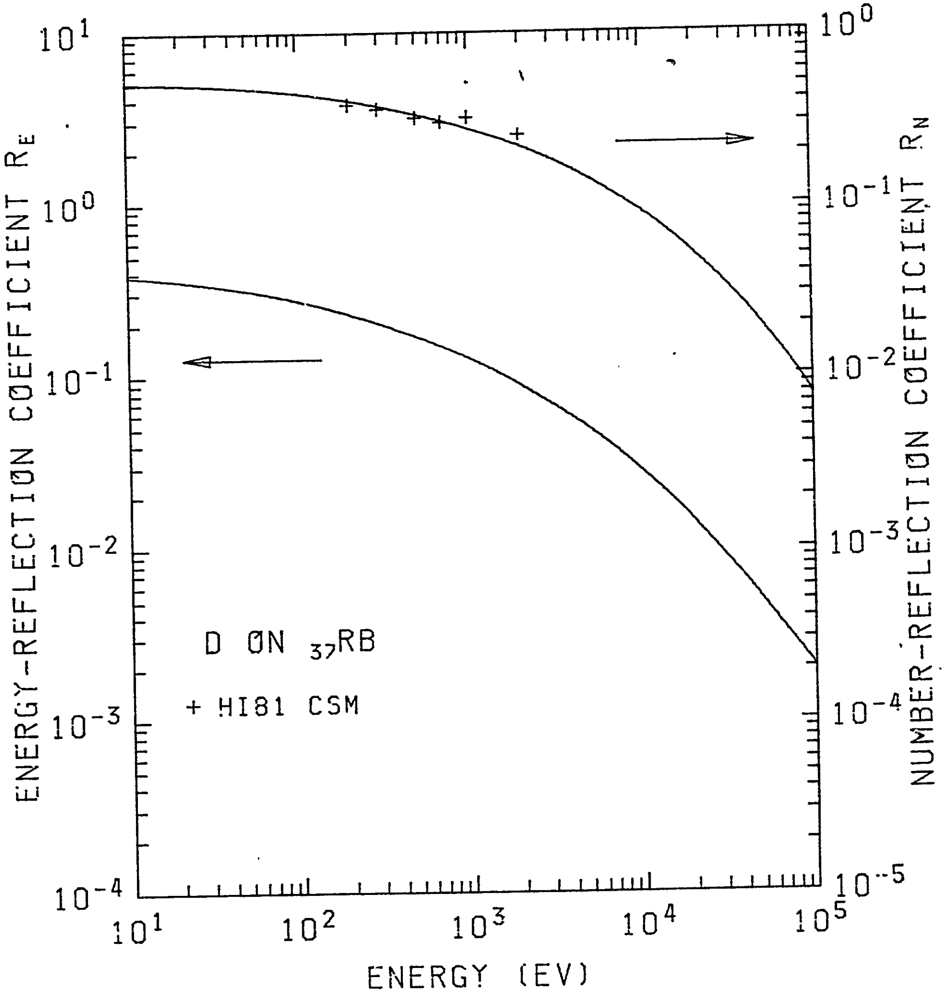
GRAPH II. R_N and R_E vs Energy for D Ions on Cu and Zn
See page 25 for Explanation of Graphs



GRAPH II. R_N and R_E vs Energy for D Ions on Ga and Ge

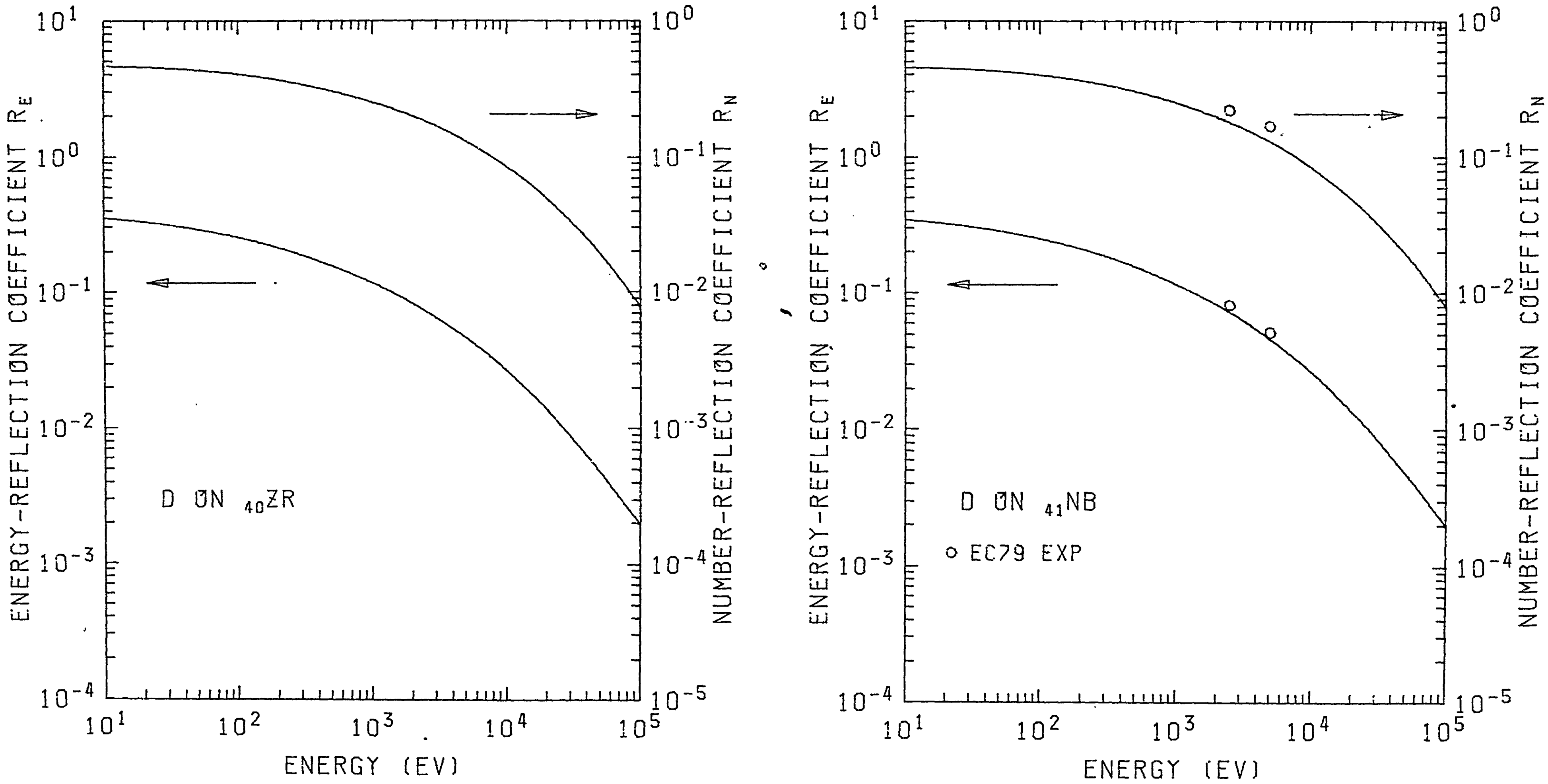
See page 25 for Explanation of Graphs



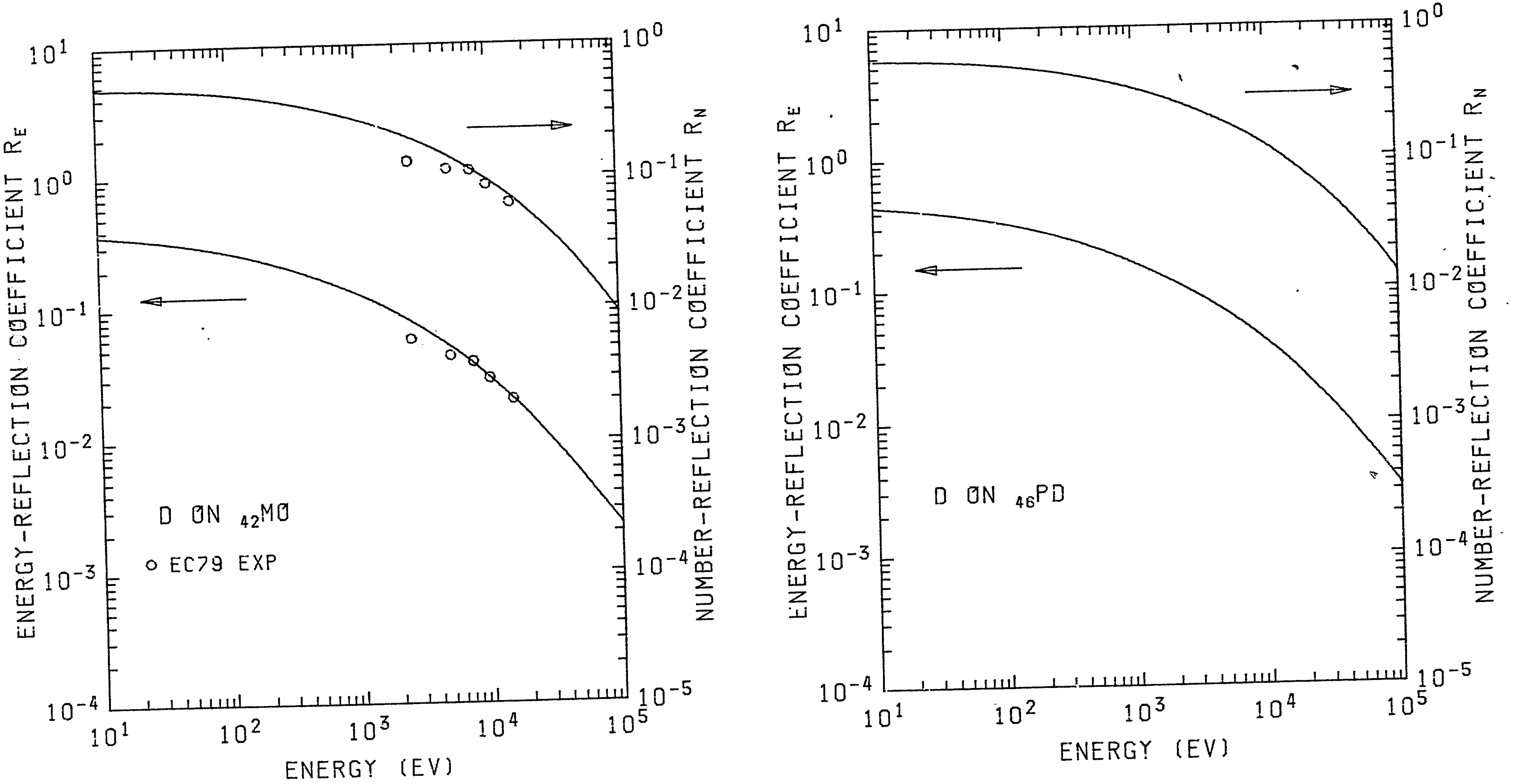


GRAPH II. R_N and R_E vs Energy for D Ions on Se and Rb

See page 23 for Explanation of Graphs

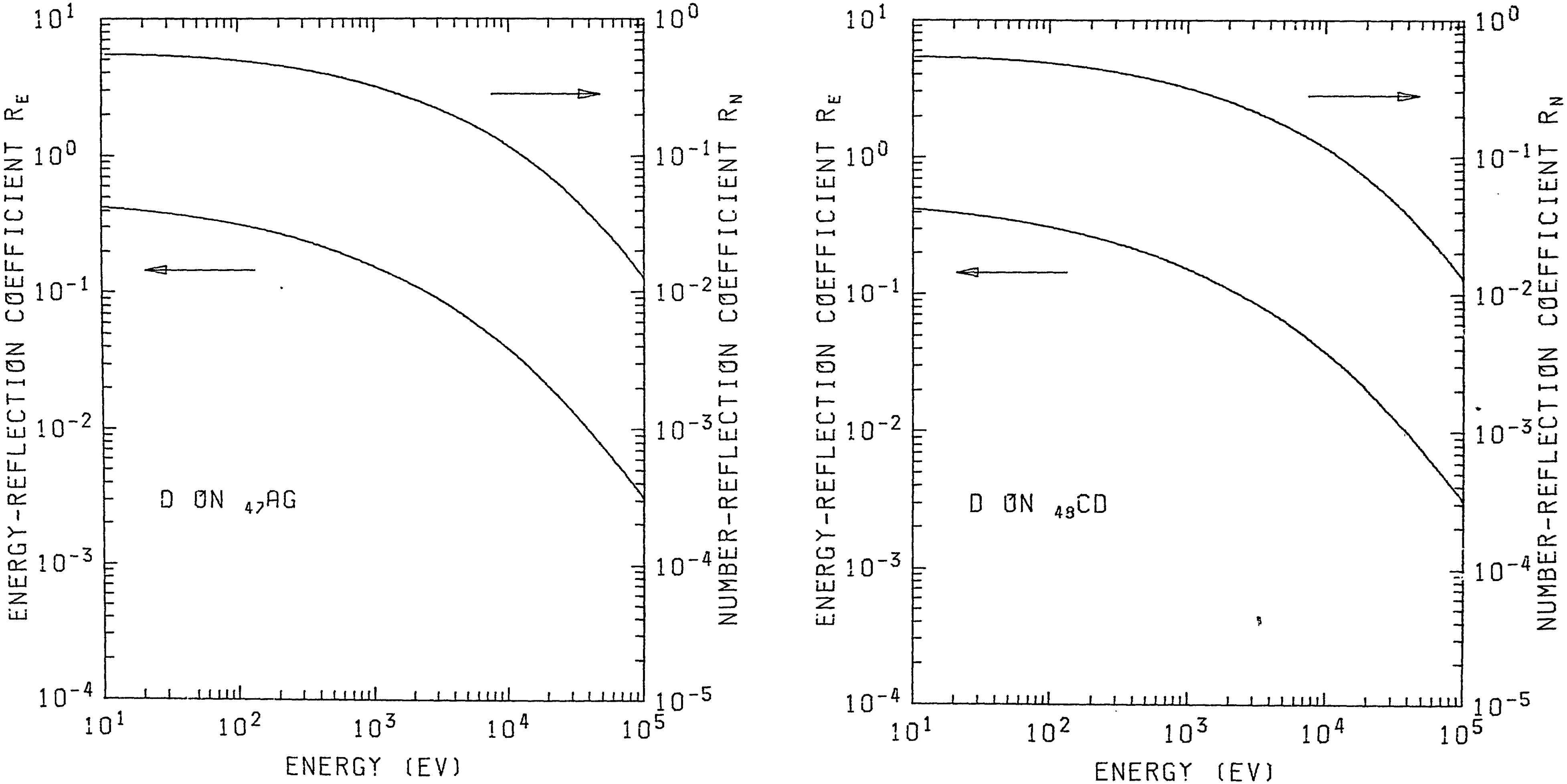


GRAPH II. R_N and R_E vs Energy for D Ions on Zr and Nb
See page 25 for Explanation of Graphs



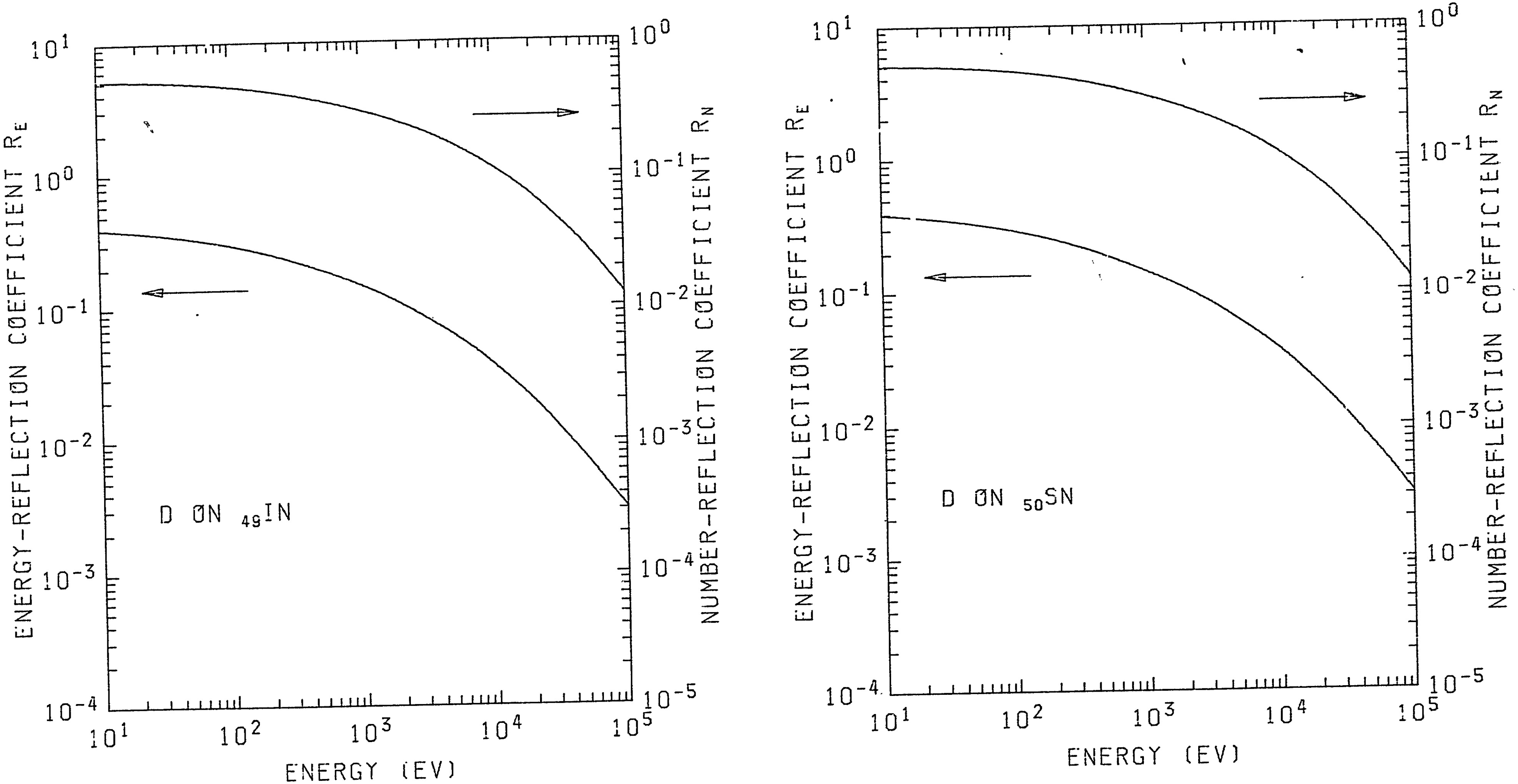
GRAPH II. R_N and R_E vs Energy for D Ions on Mo and Pd

See page 25 for Explanation of Graphs



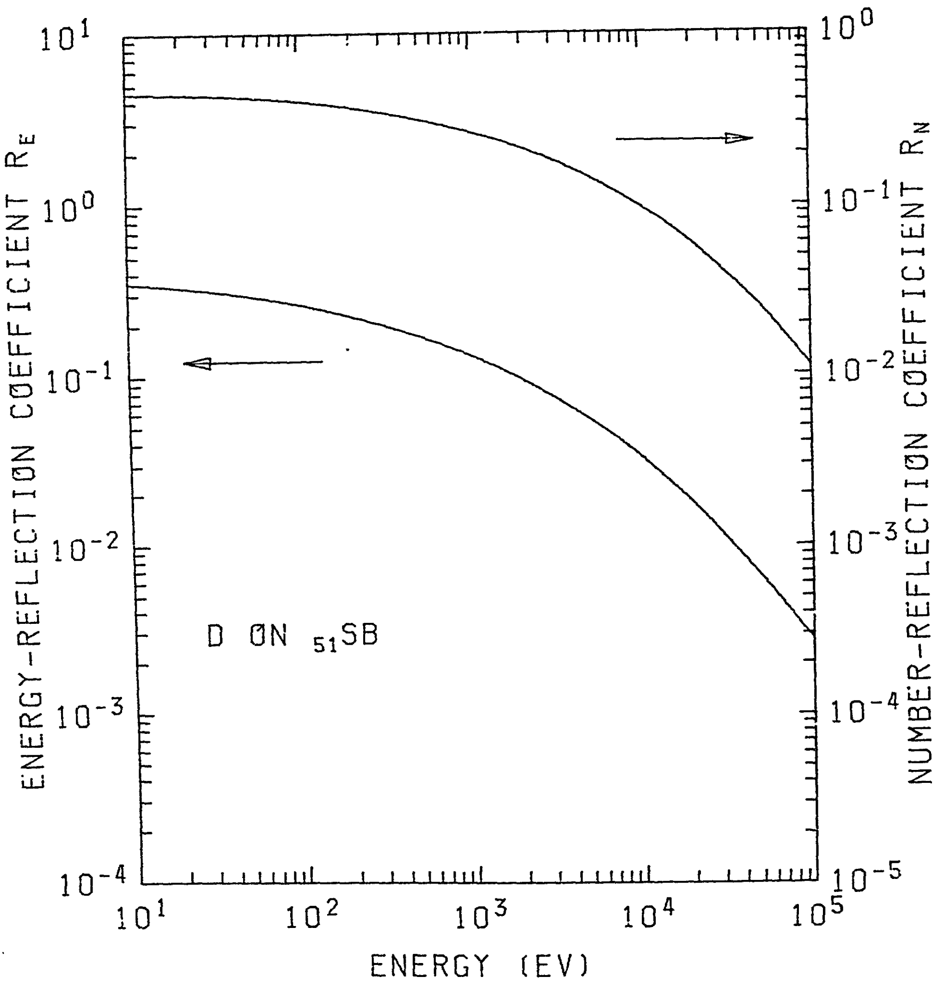
GRAPH II. R_N and R_E vs Energy for D Ions on Ag and Cd

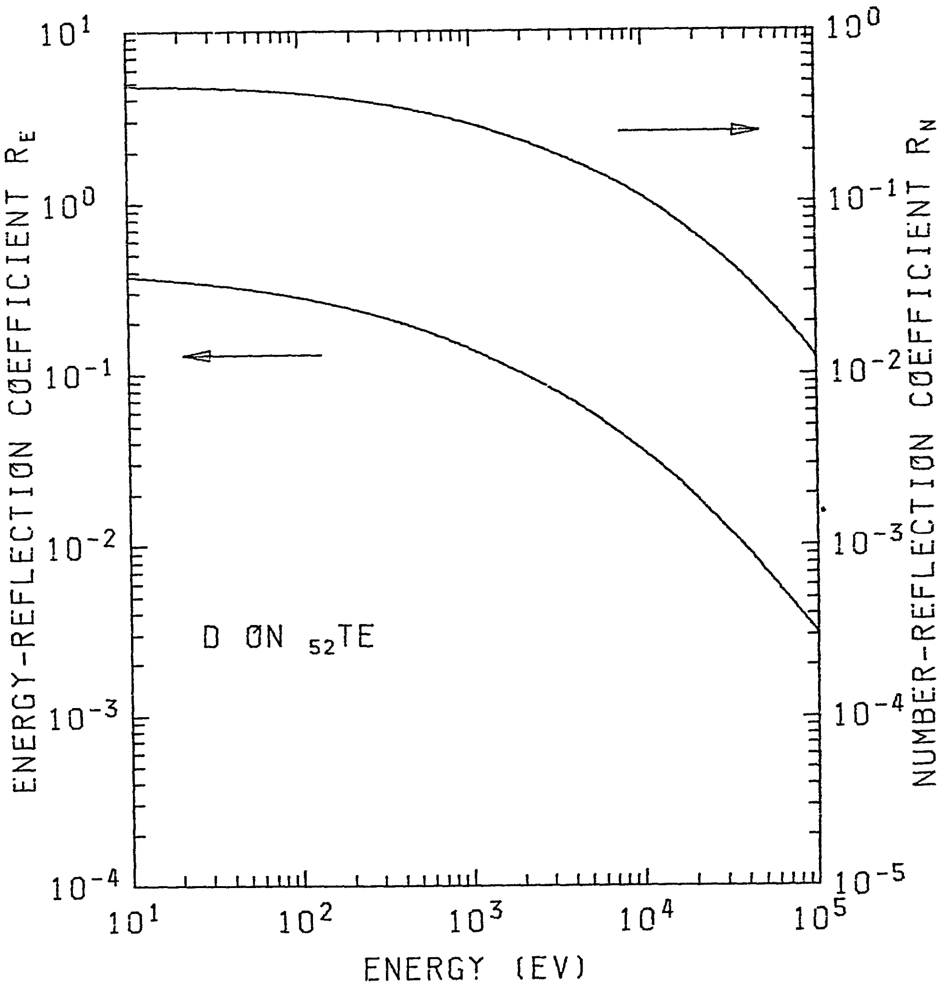
See page 25 for Explanation of Graphs



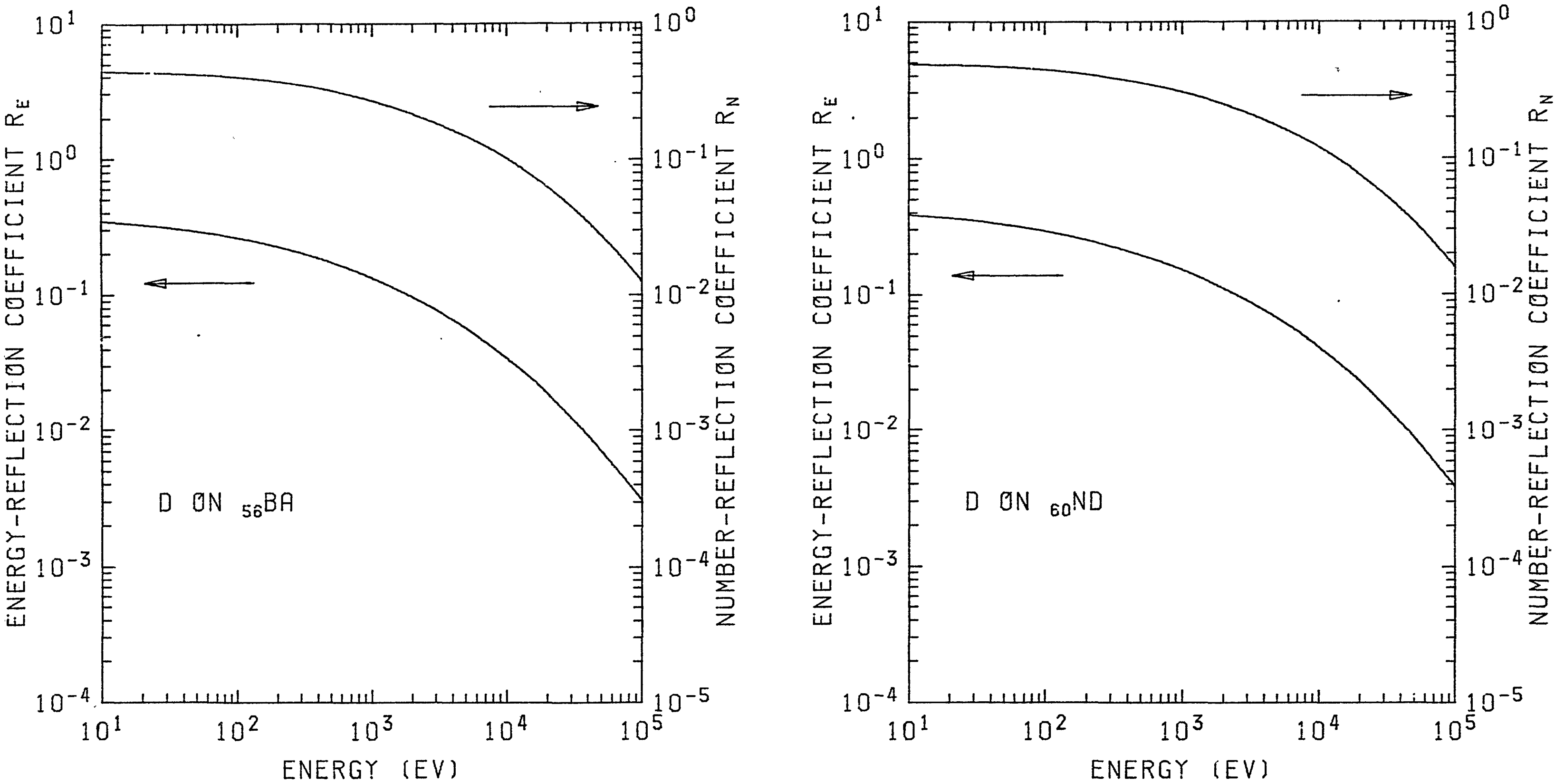
GRAPH II. R_N and R_E vs Energy for D Ions on In and Sn

See page 25 for Explanation of Graphs



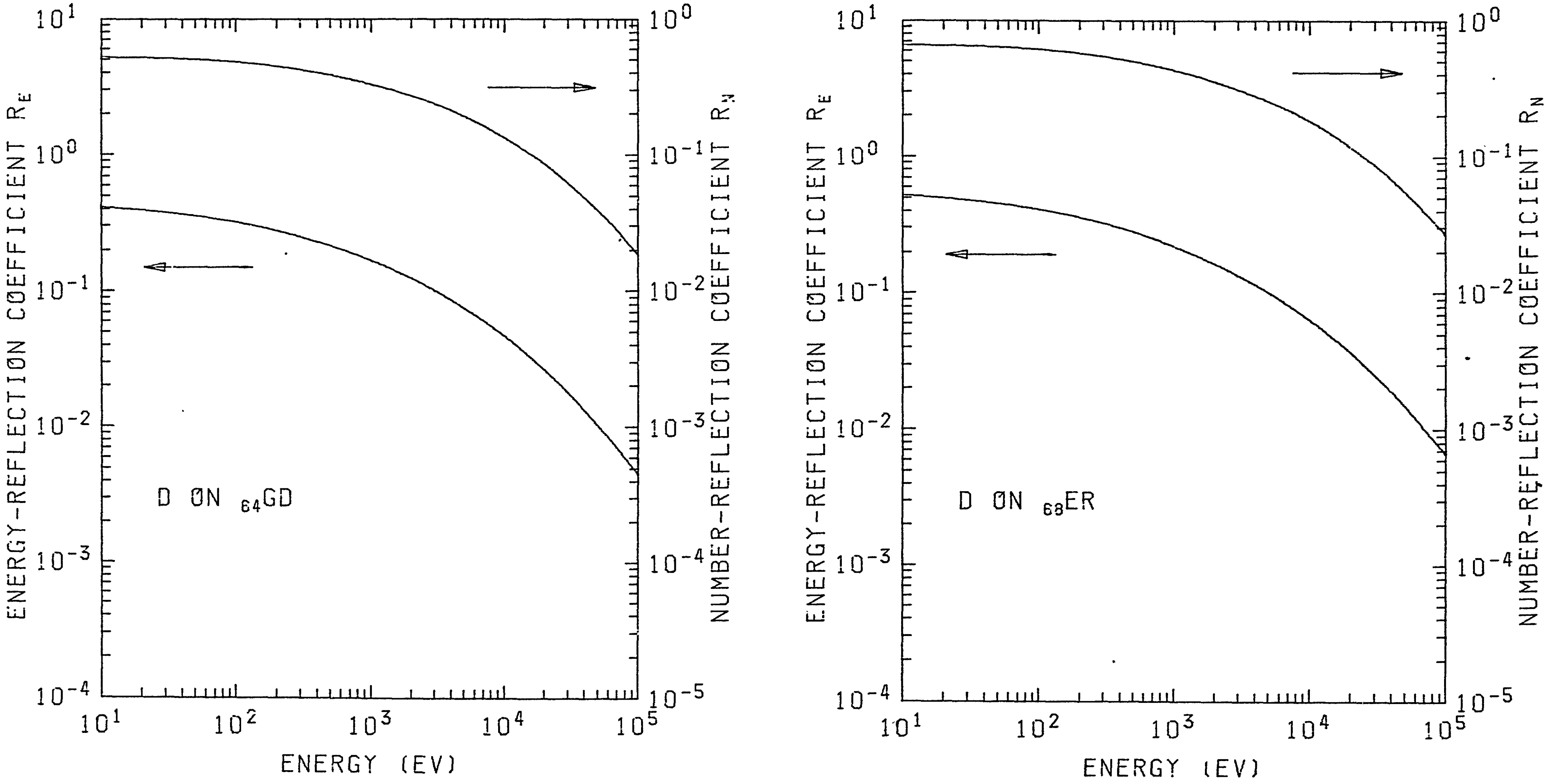


GRAPH II. R_N and R_E vs Energy for D Ions on Sb and Te
See page 25 for Explanation of Graphs

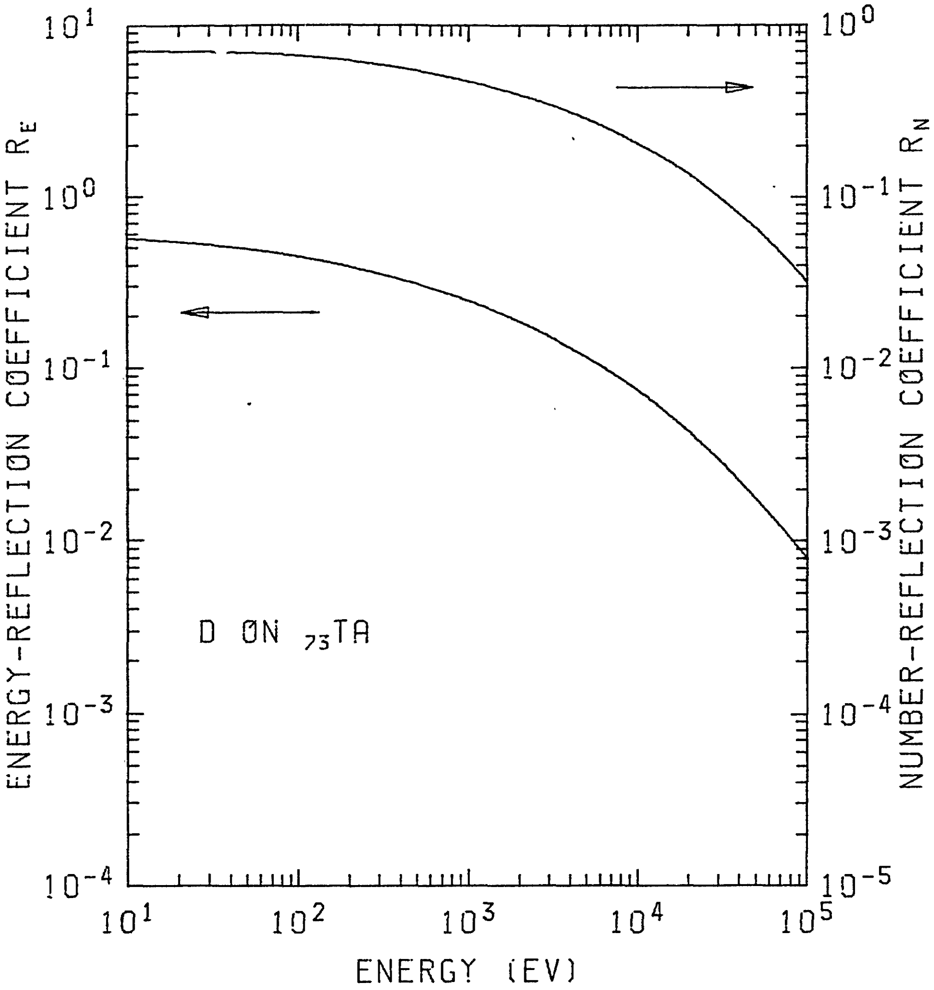


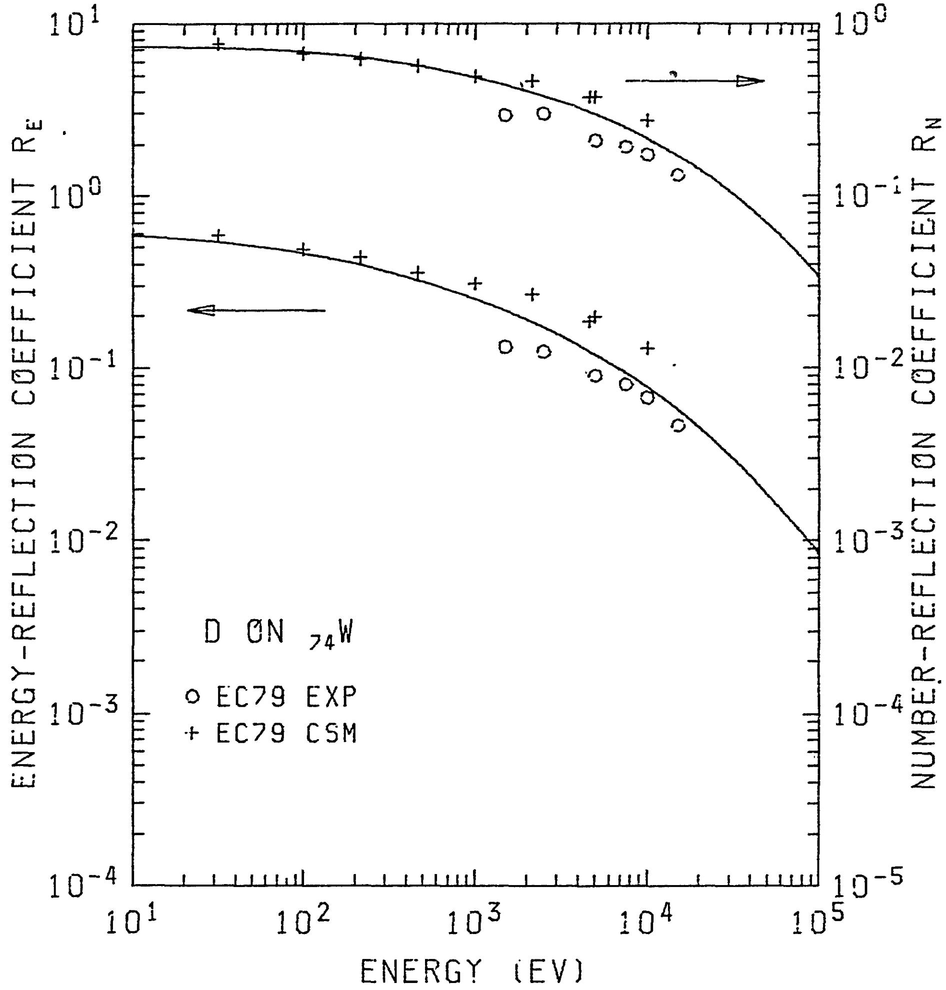
GRAPH II. R_N and R_E vs Energy for D Ions on Ba and Nd

See page 25 for Explanation of Graphs



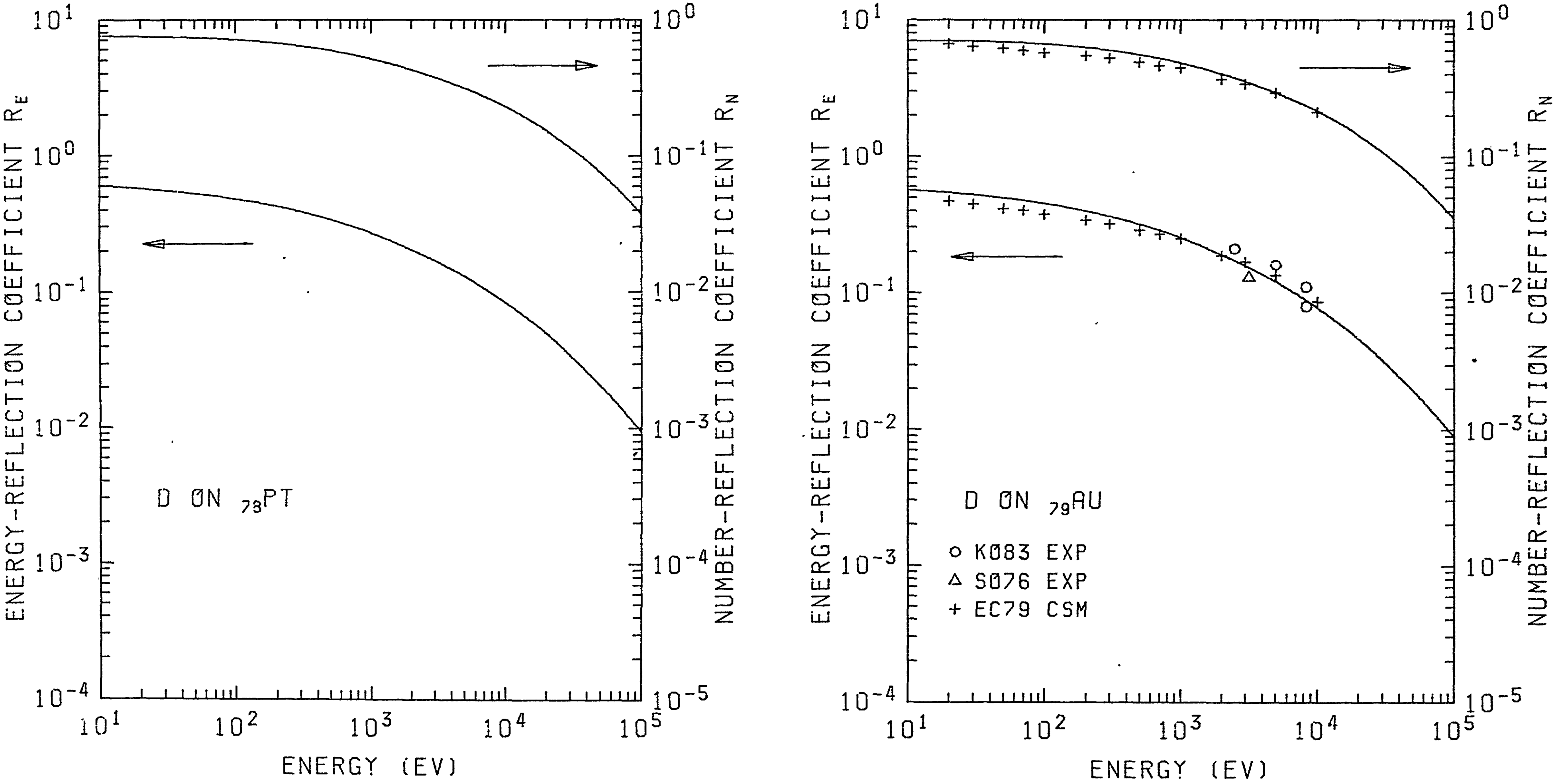
GRAPH II. R_N and R_E vs Energy for D Ions on Gd and Er
See page 25 for Explanation of Graphs





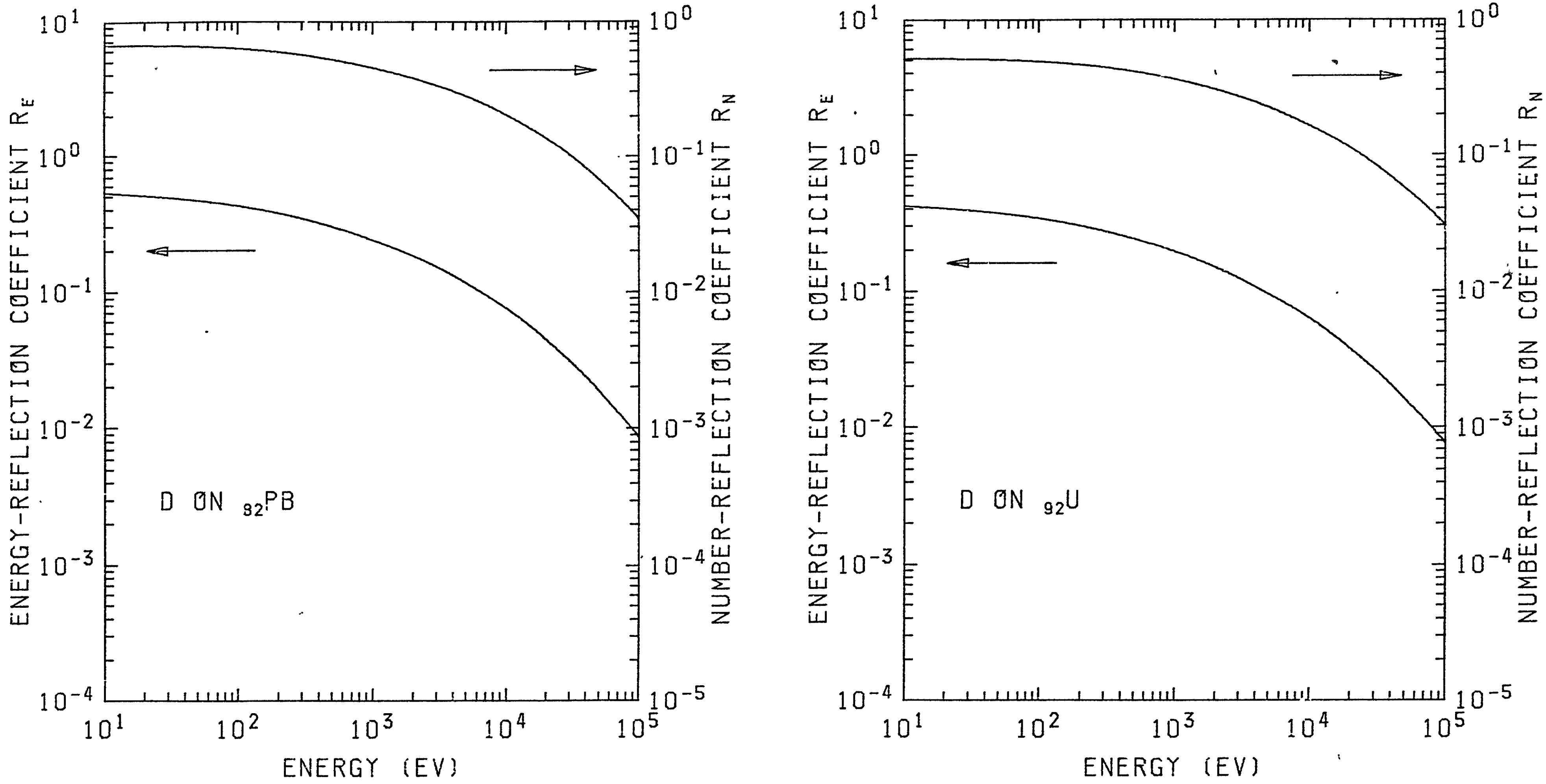
GRAPH II. R_N and R_E vs Energy for D Ions on Ta and W

See page 25 for Explanation of Graphs

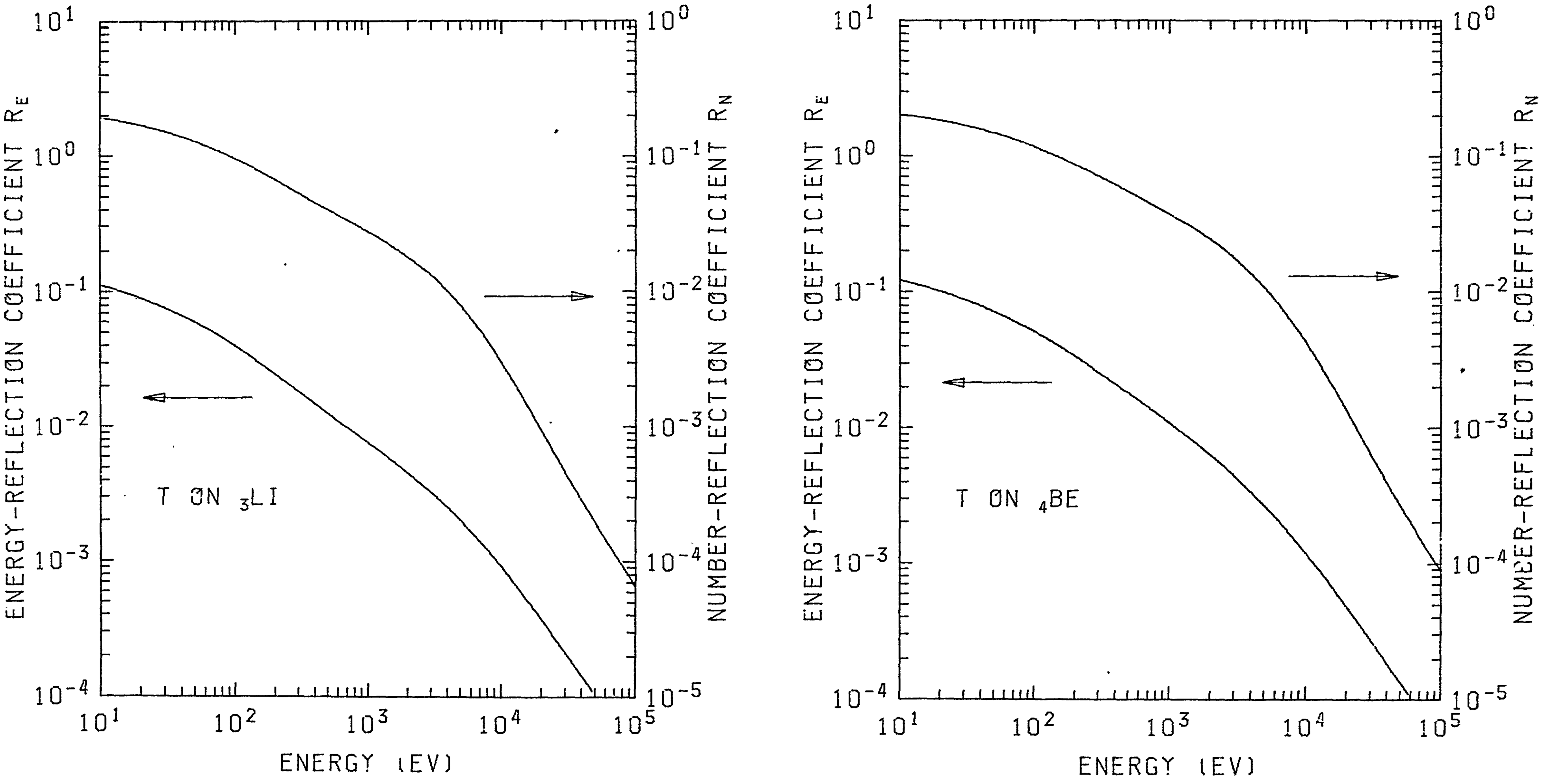


GRAPH II. R_N and R_E vs Energy for D Ions on Pt and Au

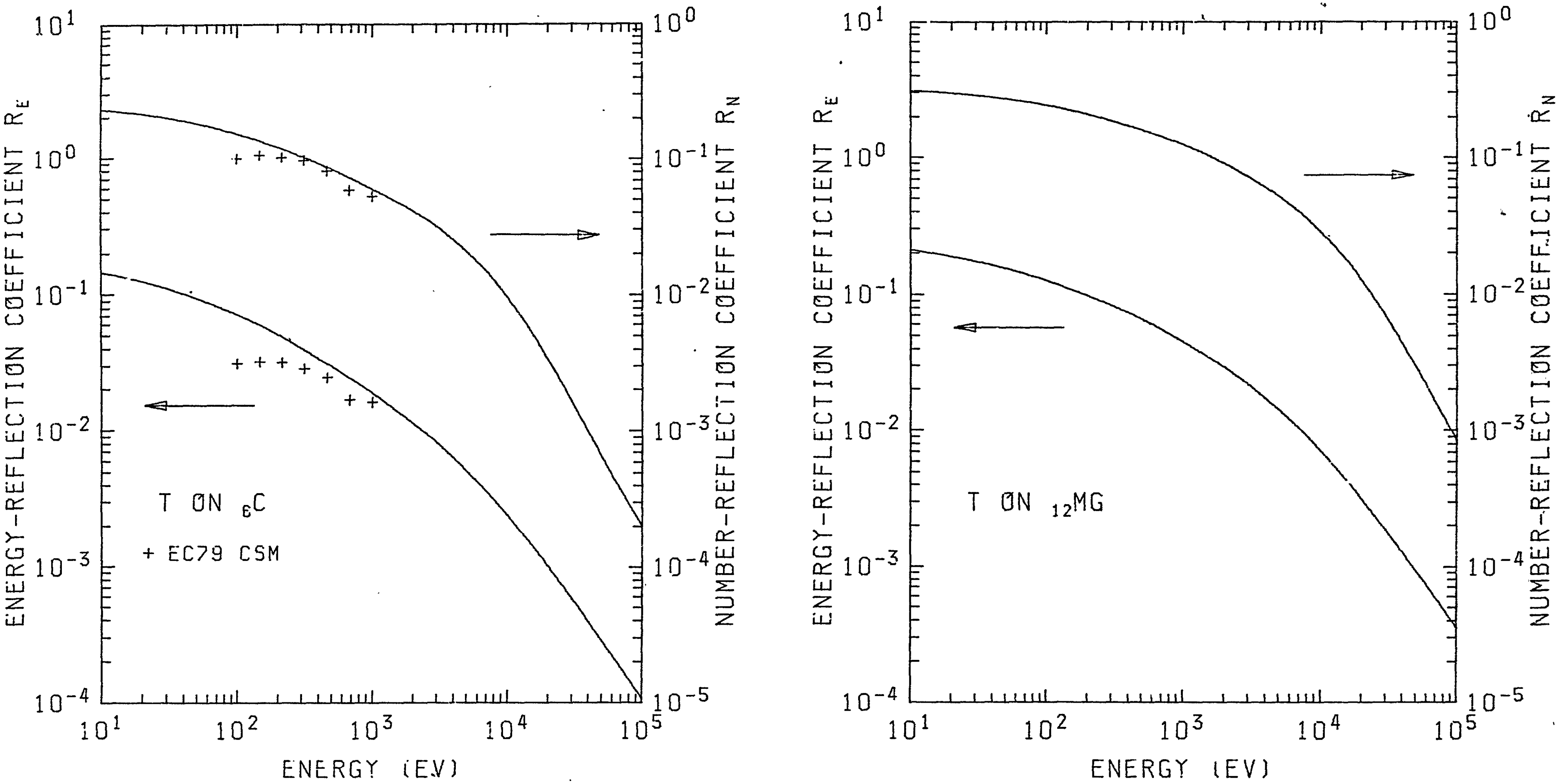
See page 25 for Explanation of Graphs



GRAPH II. R_N and R_E vs Energy for D Ions on Pb and U
See page 25 for Explanation of Graphs

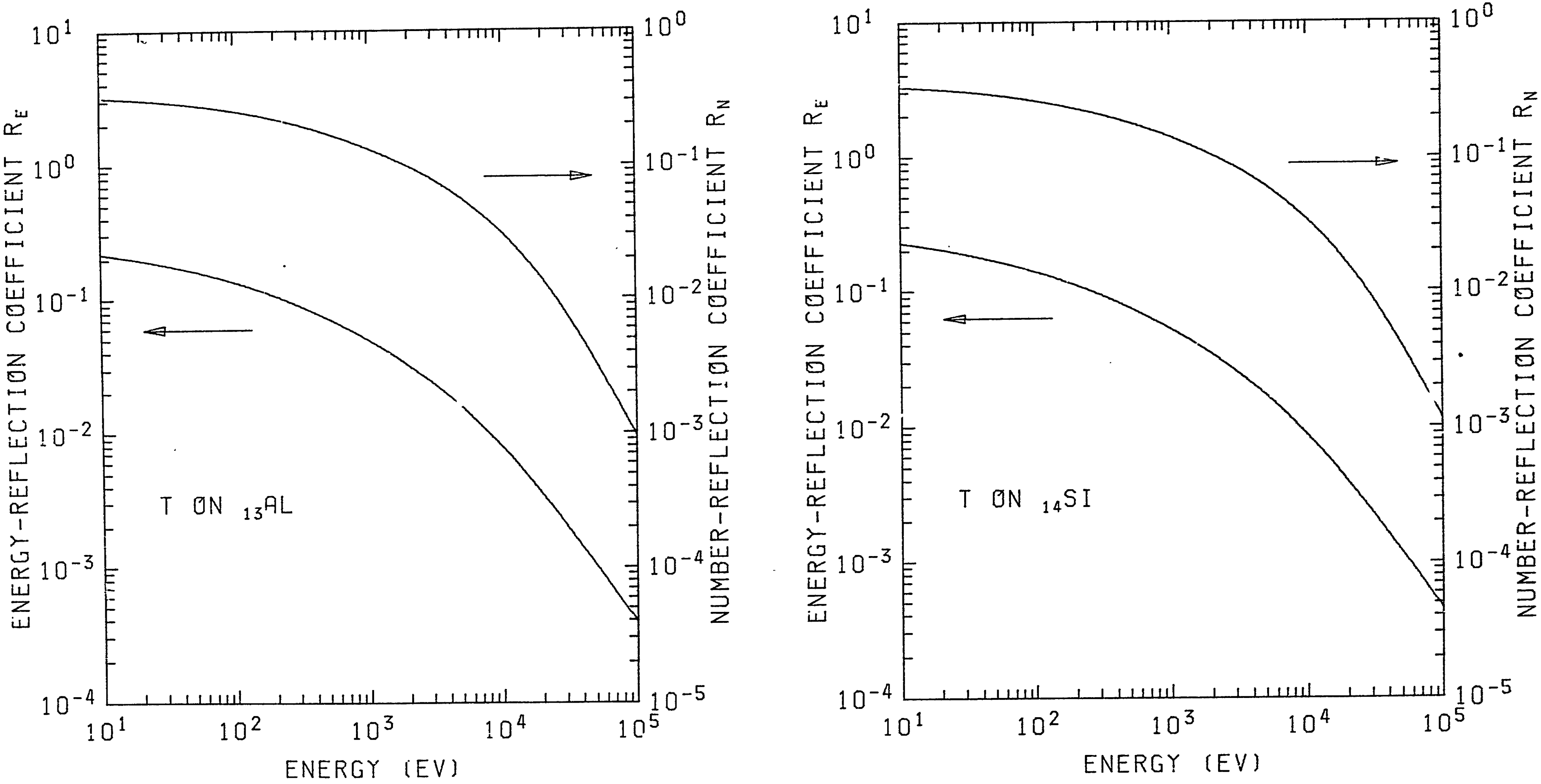


GRAPH III. R_N and R_E vs Energy for T Ions on Li and Be
See page 25 for Explanation of Graphs

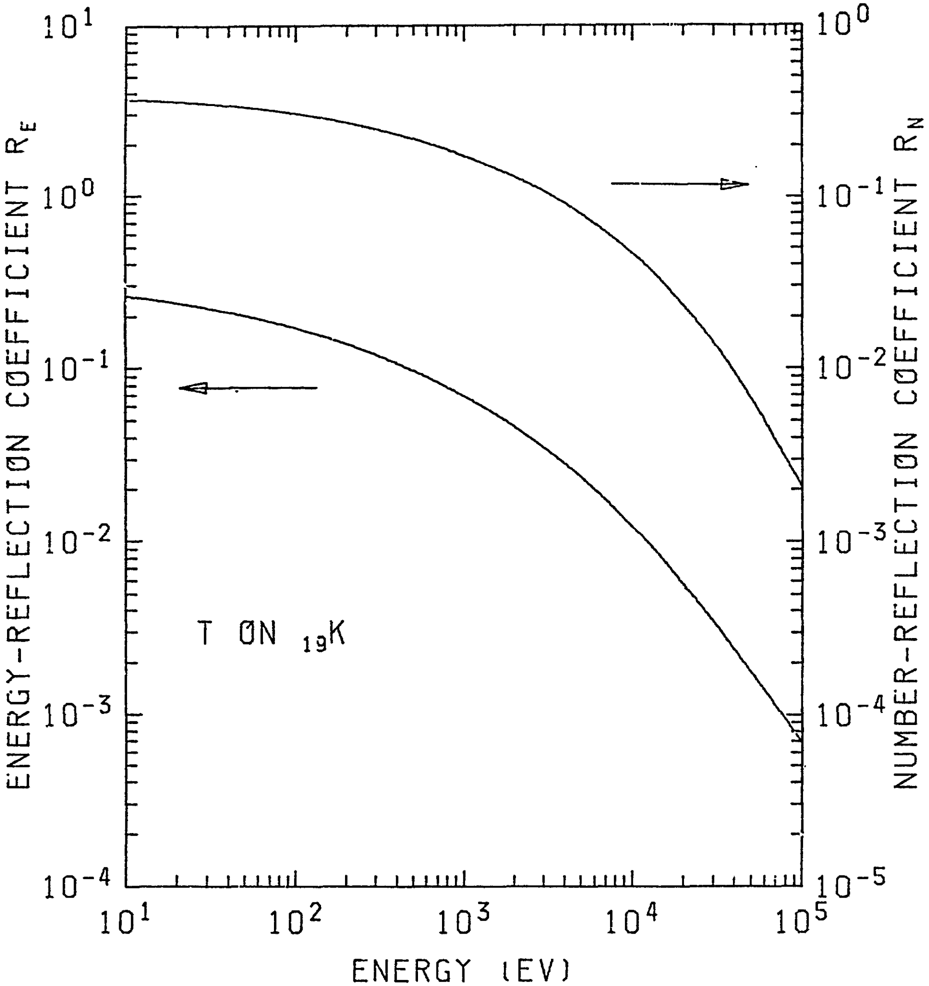


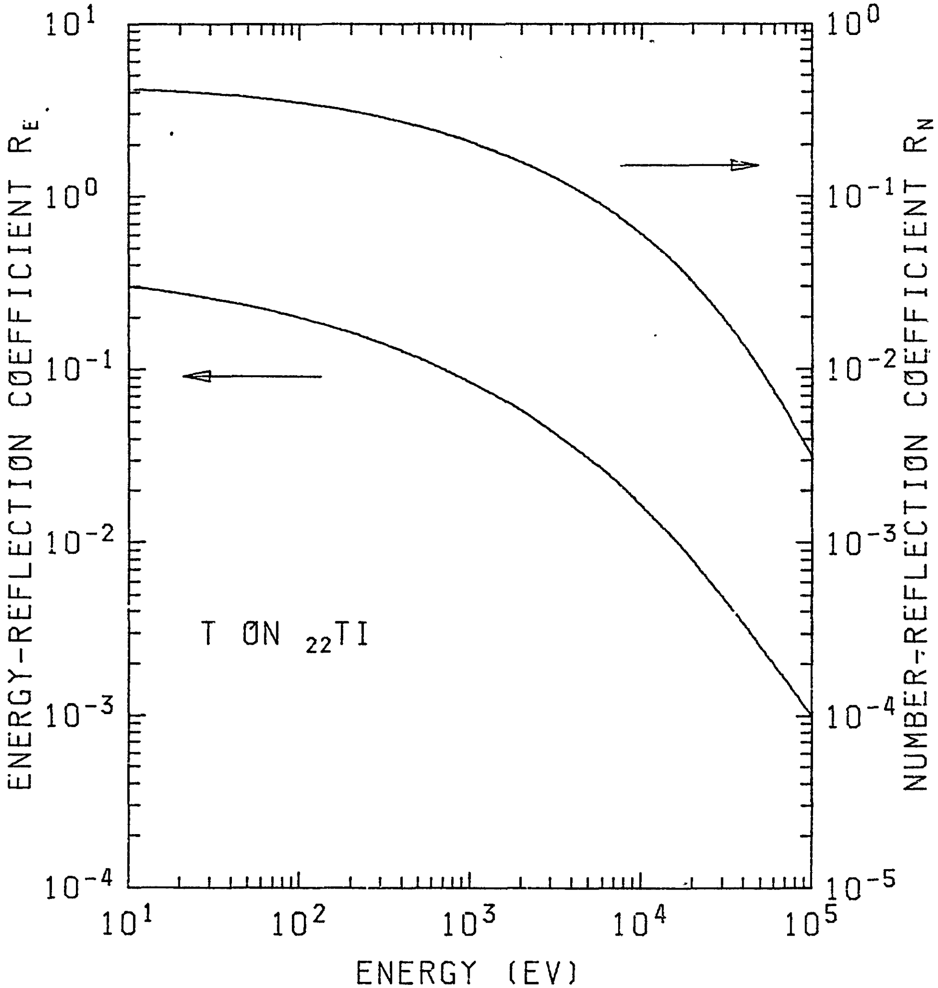
GRAPH III. R_N and R_E vs Energy for T Ions on C and Mg

See page 25 for Explanation of Graphs



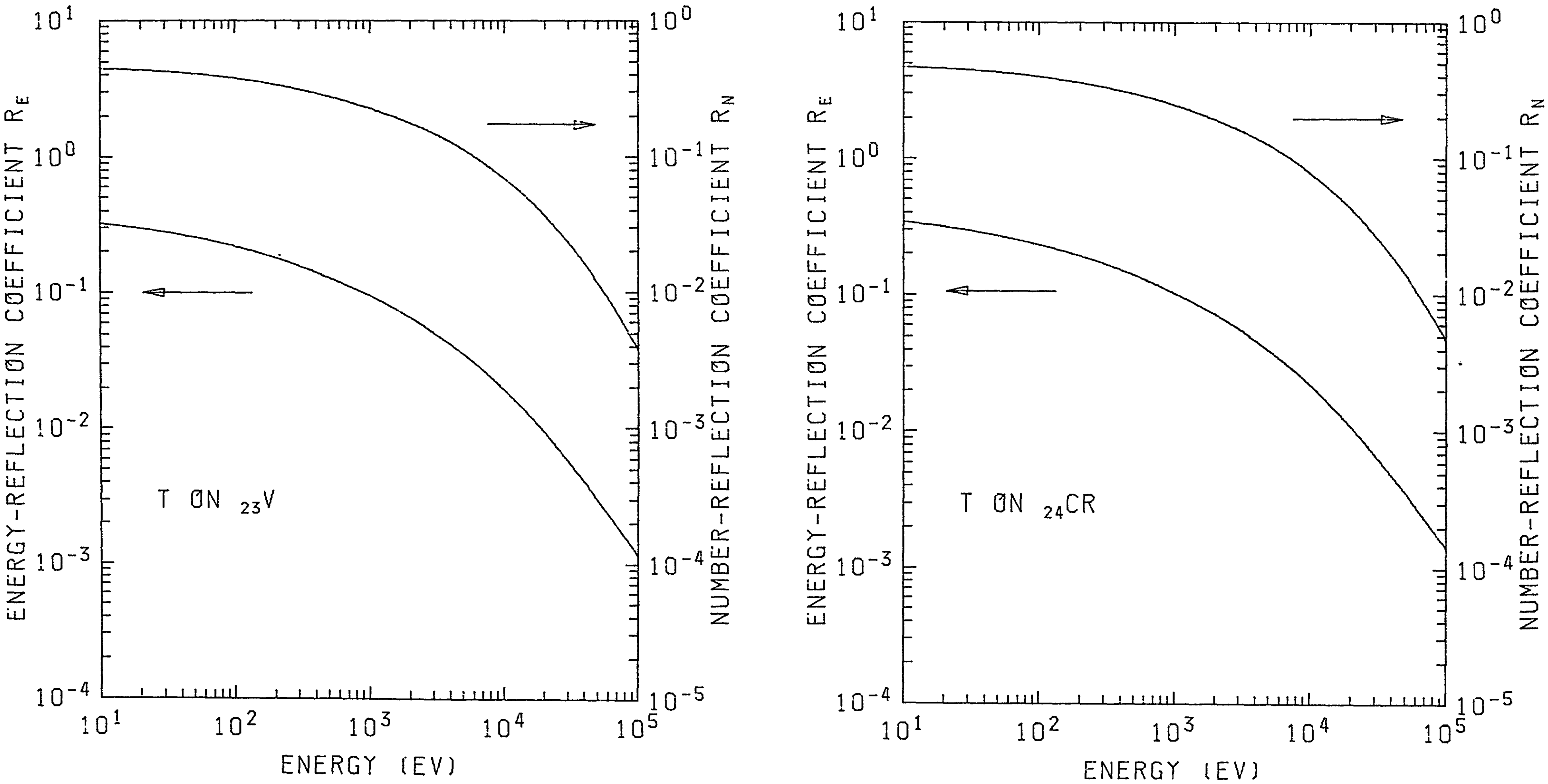
GRAPH III. R_N and R_E vs Energy for T Ions on Al and Si
See page 25 for Explanation of Graphs



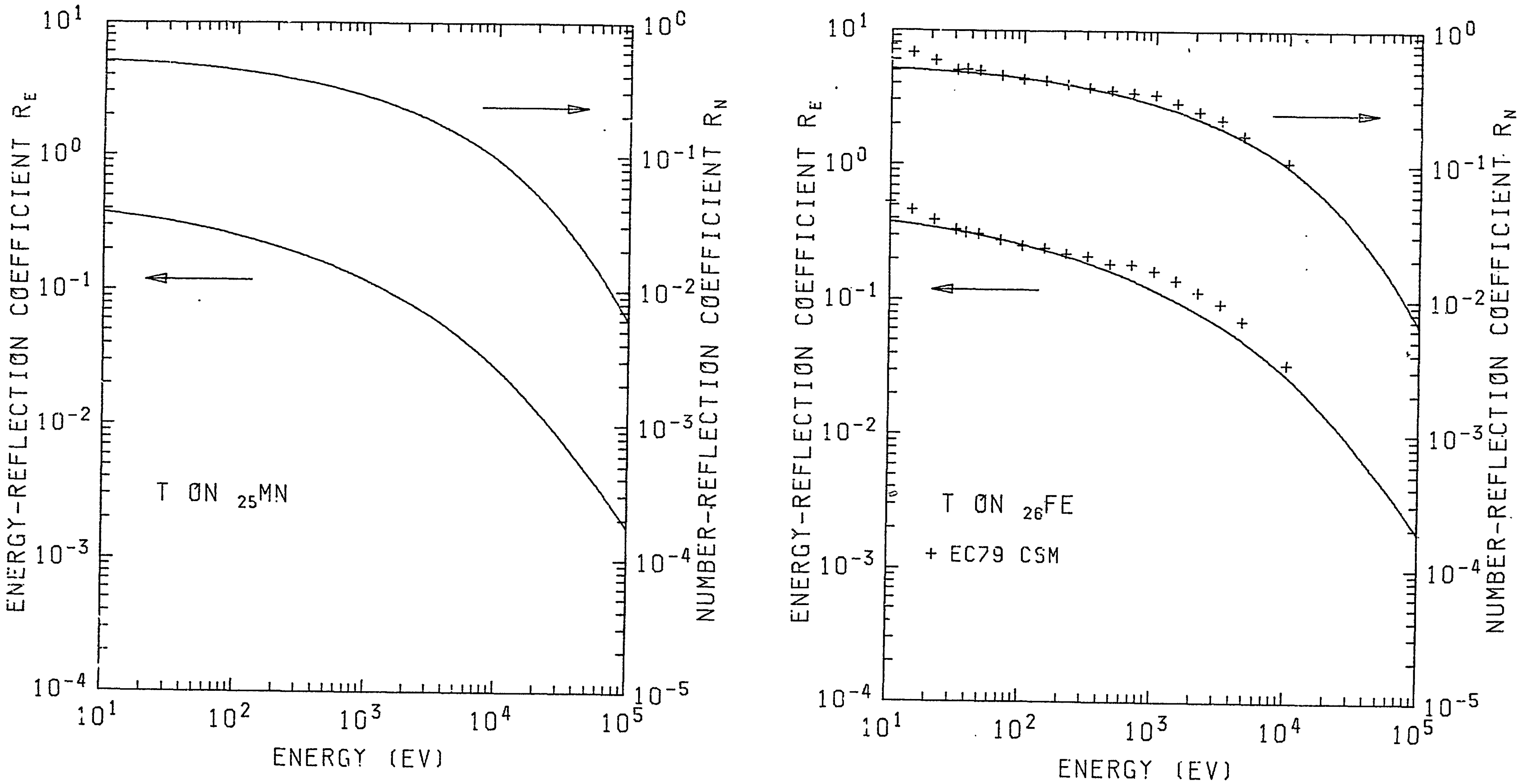


GRAPH III. R_N and R_E vs Energy for T Ions on K and Ti

See page 25 for Explanation of Graphs

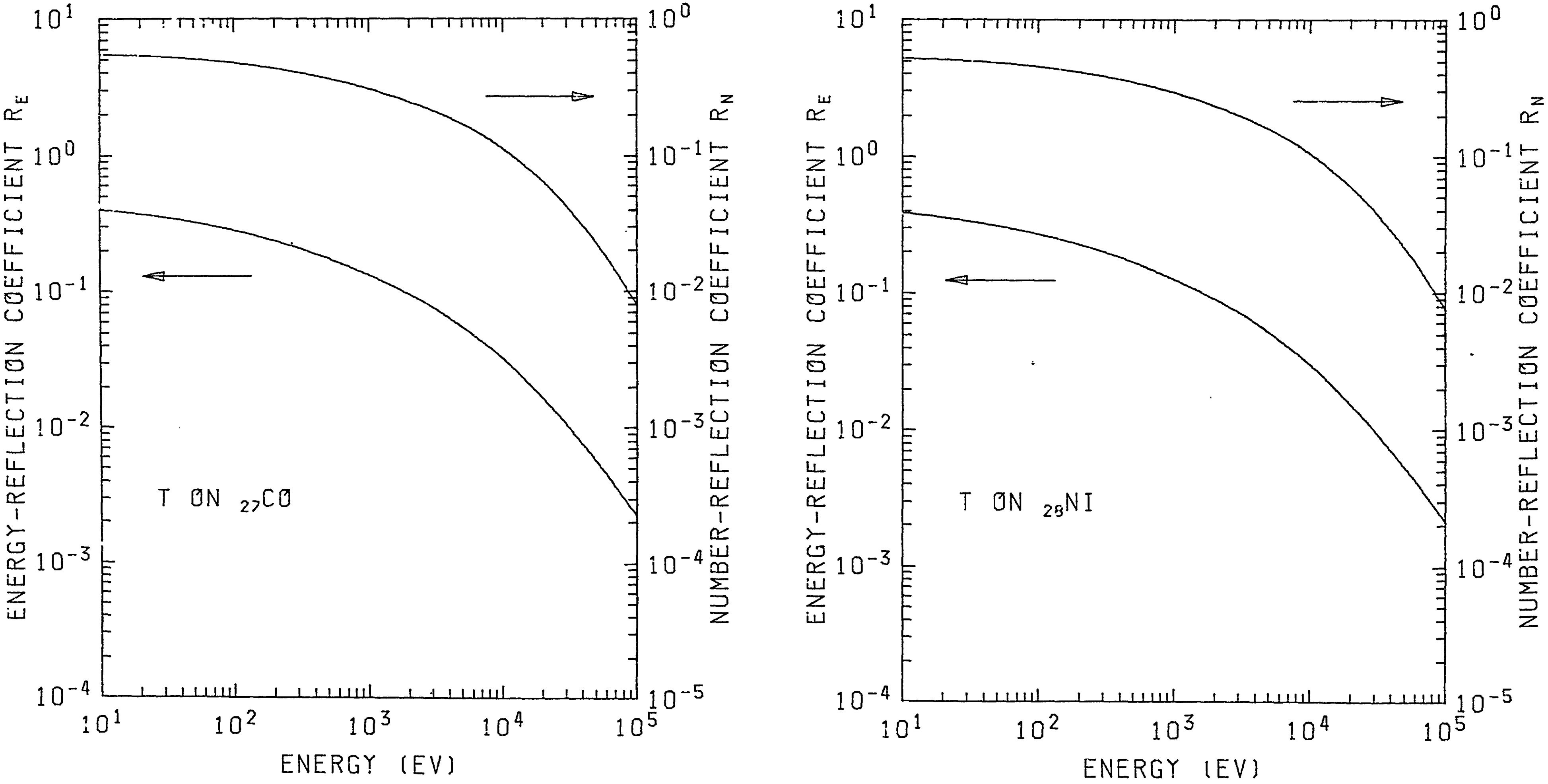


GRAPH III. R_N and R_E vs Energy for T Ions on V and Cr
See page 25 for Explanation of Graphs



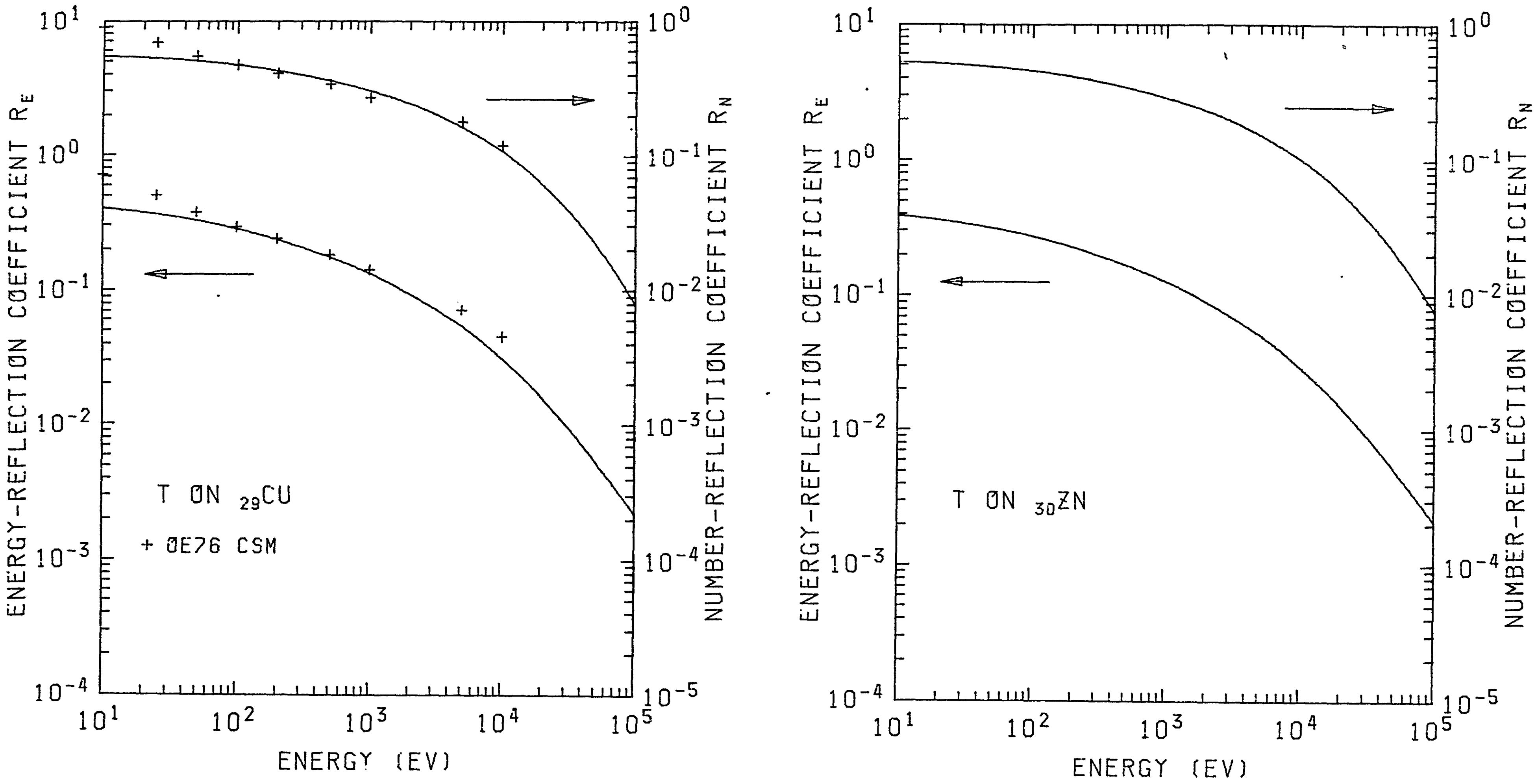
GRAPH III. R_N and R_E vs Energy for T Ions on Mn and Fe

See page 25 for Explanation of Graphs



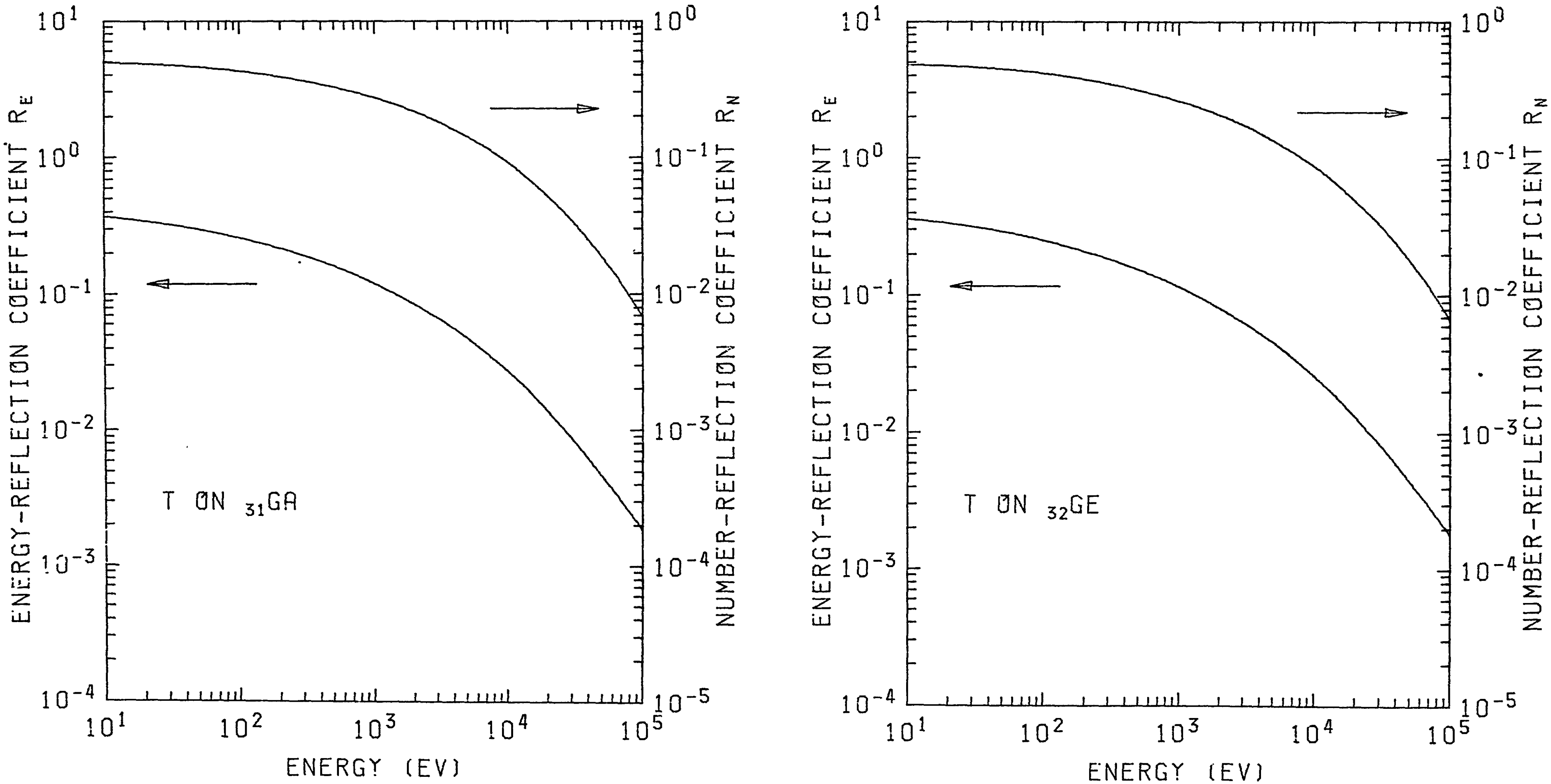
GRAPH III. R_N and R_E vs Energy for T Ions on Co and Ni

See page 25 for Explanation of Graphs



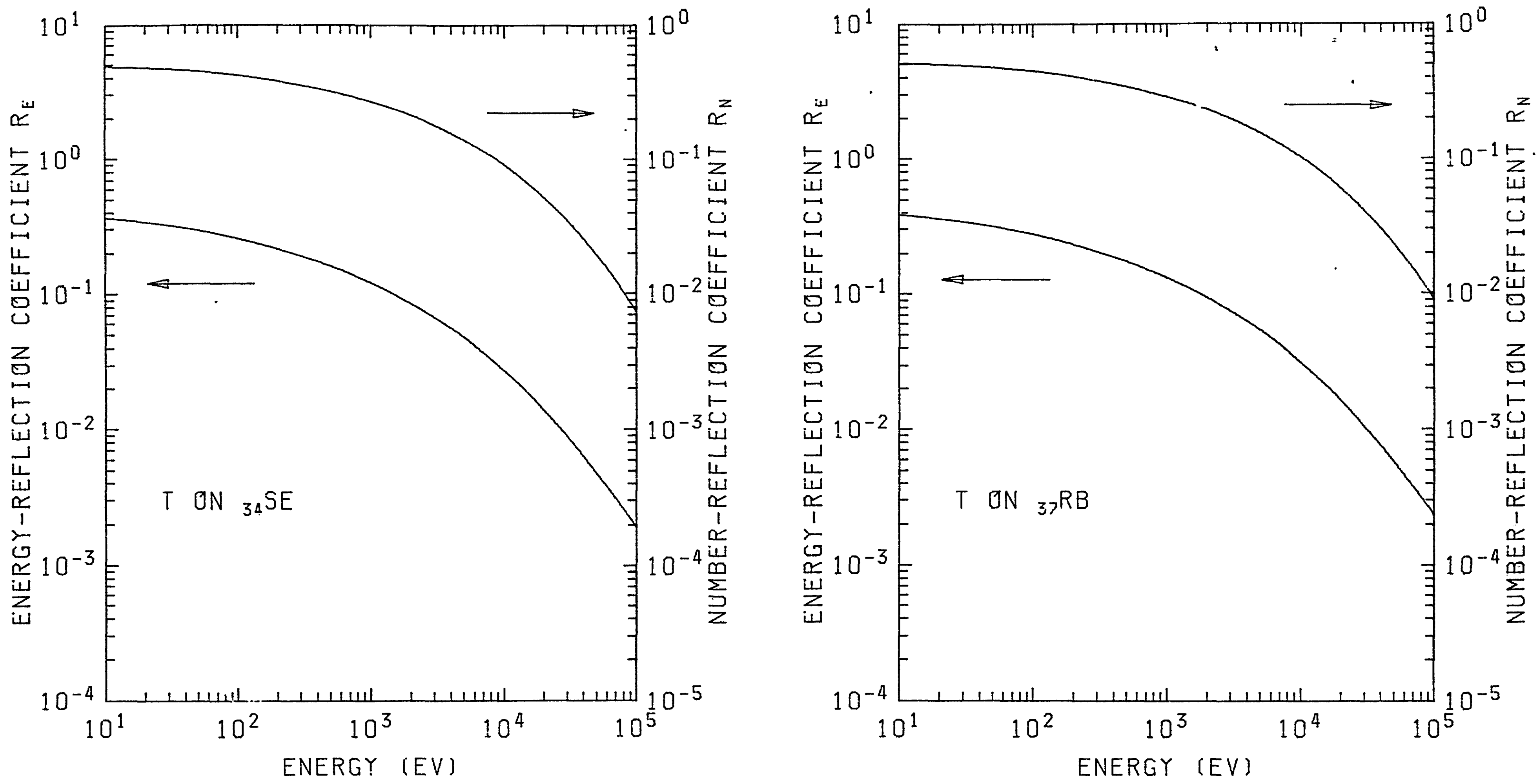
GRAPH III. R_N and R_E vs Energy for T Ions on Cu and Zn

See page 25 for Explanation of Graphs



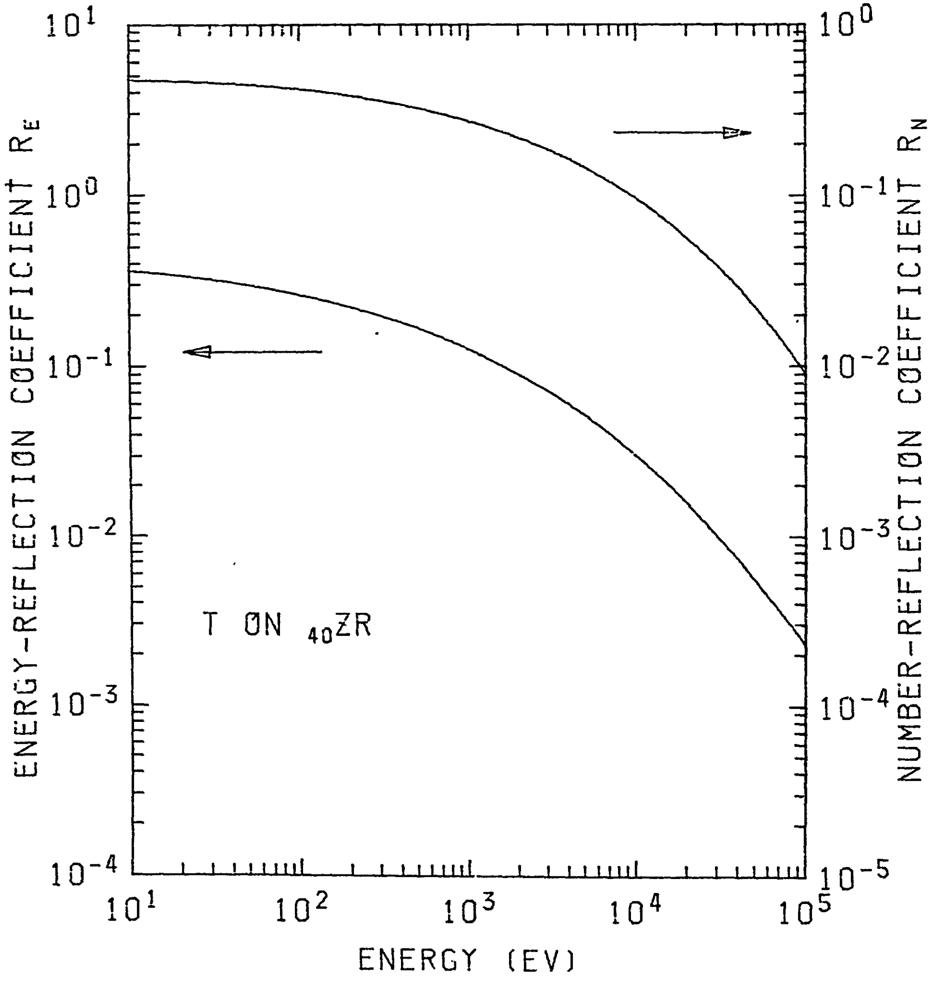
GRAPH III. R_N and R_E vs Energy for T Ions on Ga and Ge

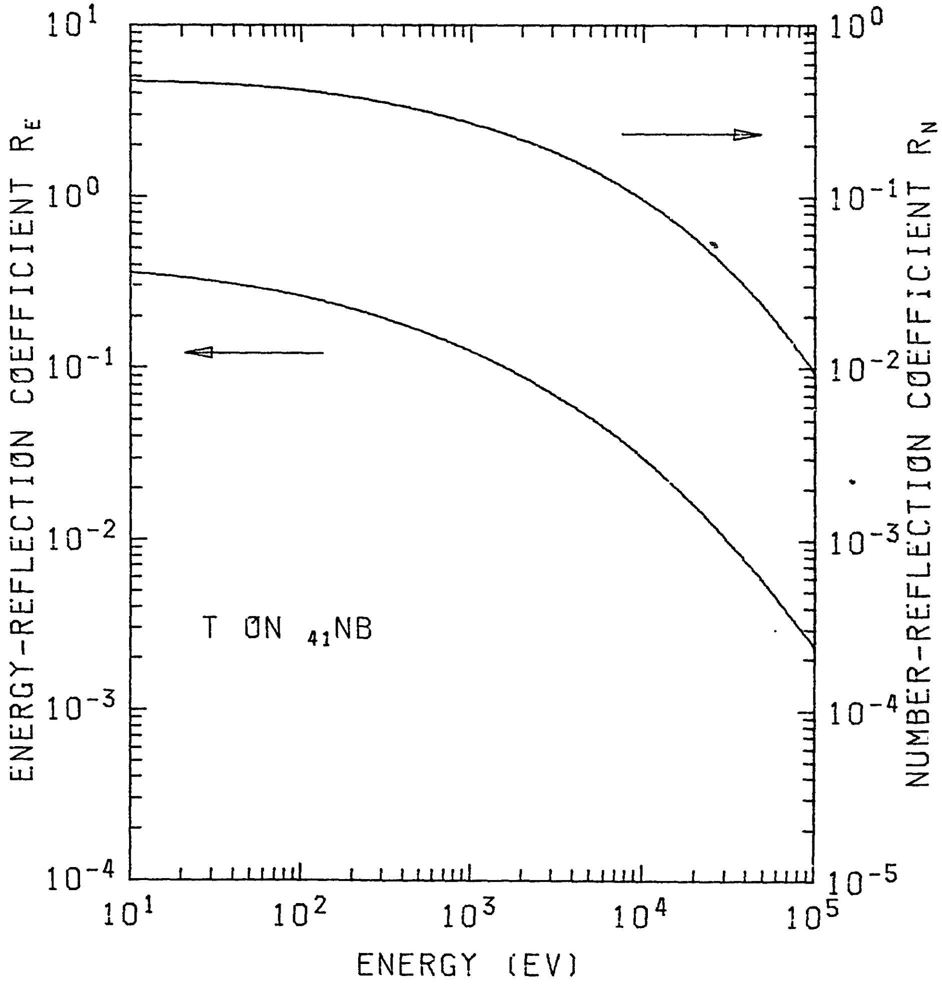
See page 25 for Explanation of Graphs



GRAPH III. R_N and R_E vs Energy for T Ions on Se and Rb

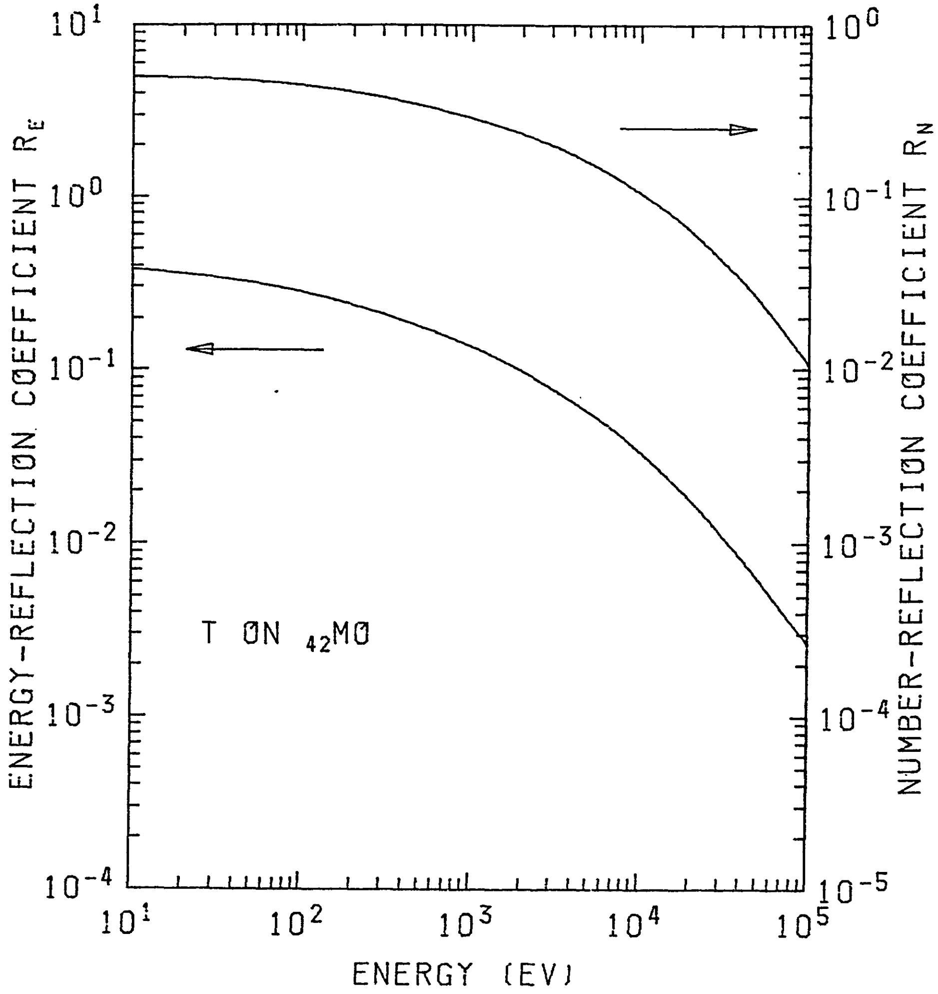
See page 25 for Explanation of Graphs

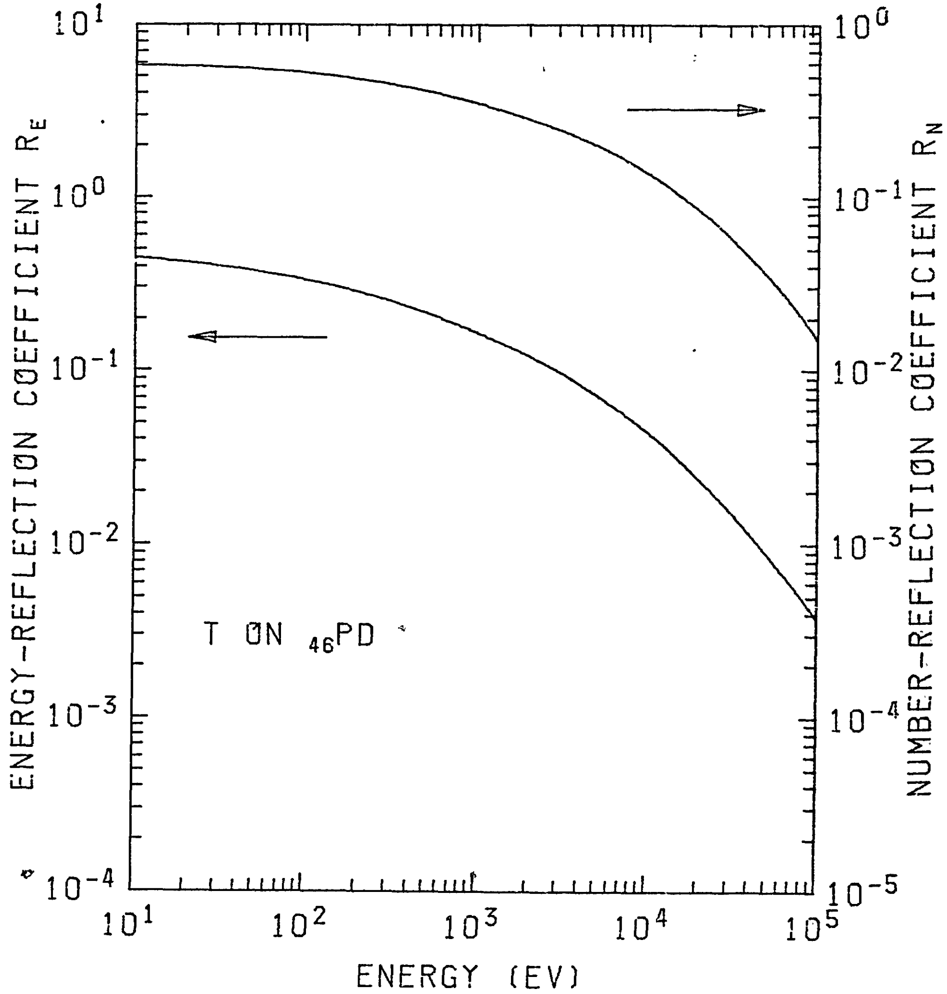




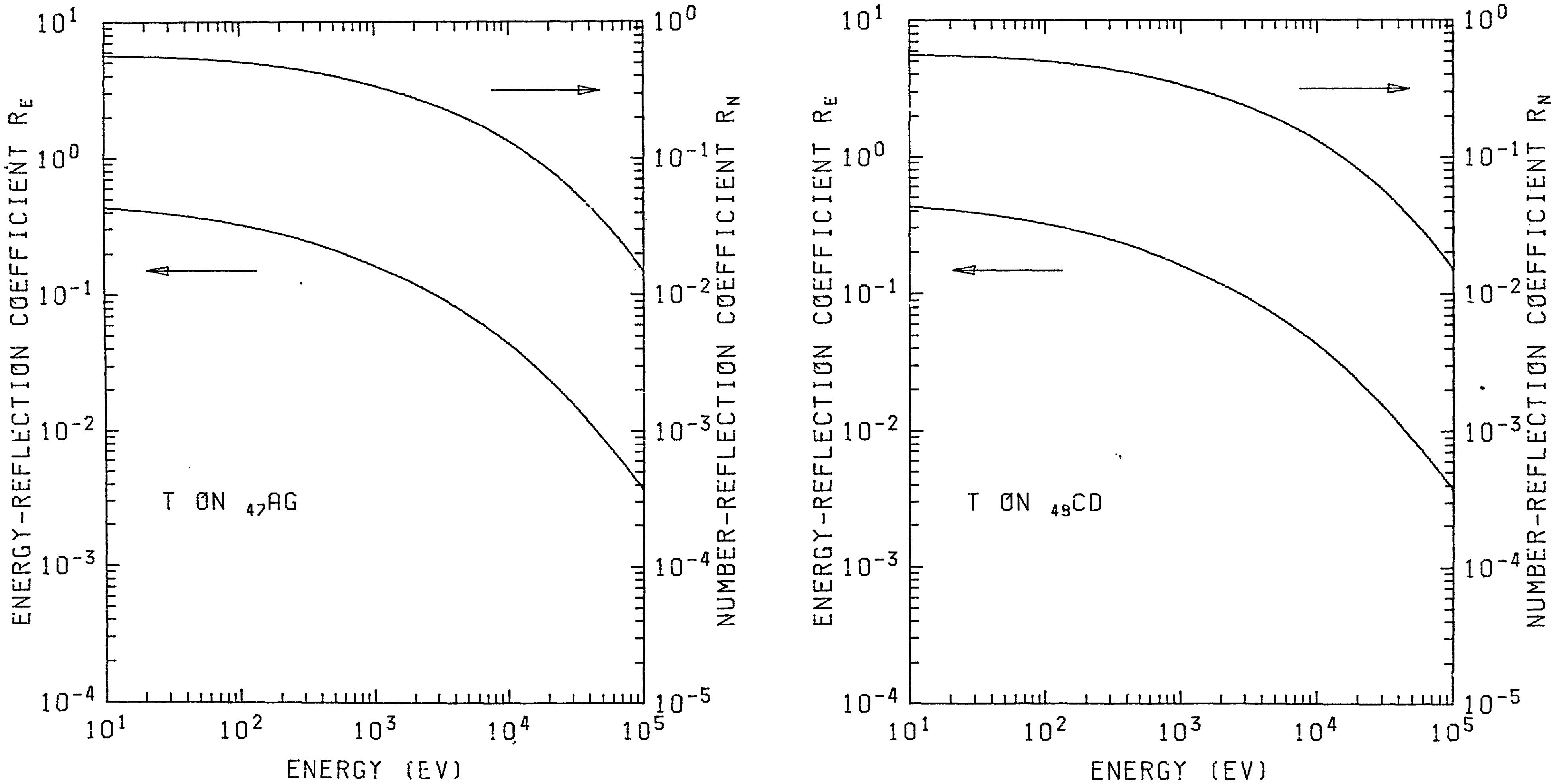
GRAPH III. R_N and R_E vs Energy for T Ions on Zr and Nb

See page 25 for Explanation of Graphs



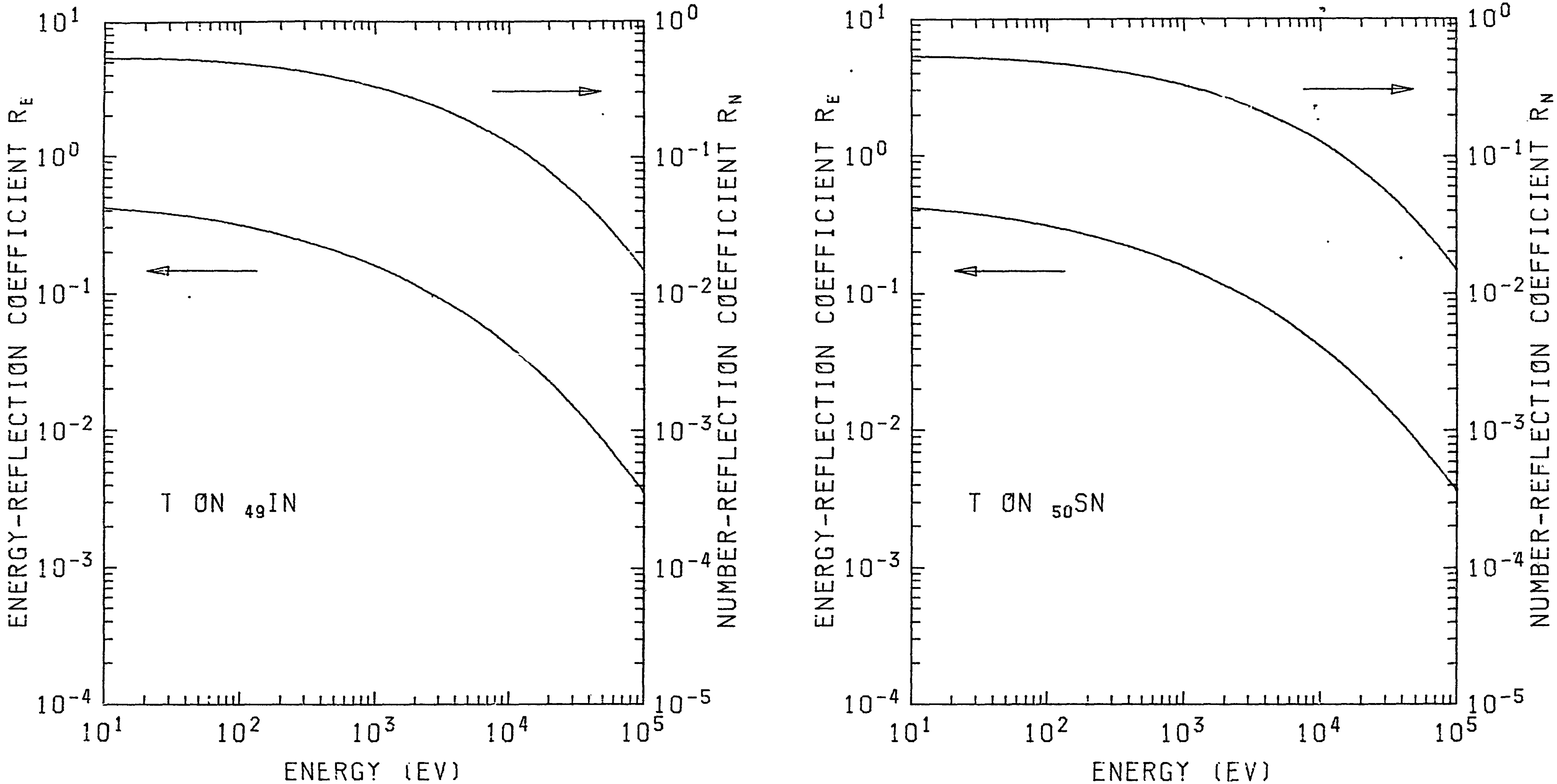


GRAPH III. R_N and R_E vs Energy for T Ions on Mo and Pd
See page 25 for Explanation of Graphs



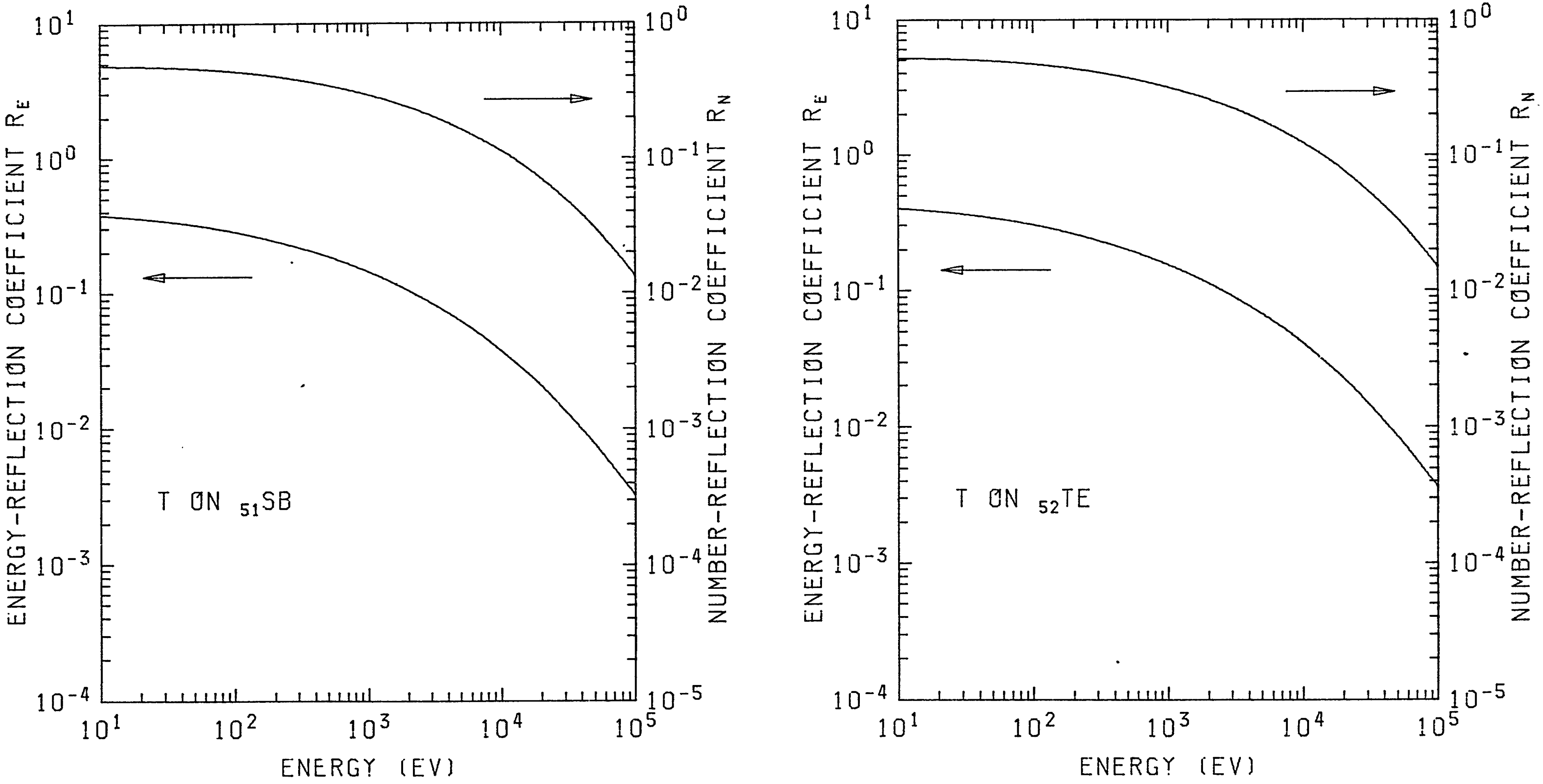
GRAPH III. R_N and R_E vs Energy for T Ions on Ag and Cd

See page 25 for Explanation of Graphs

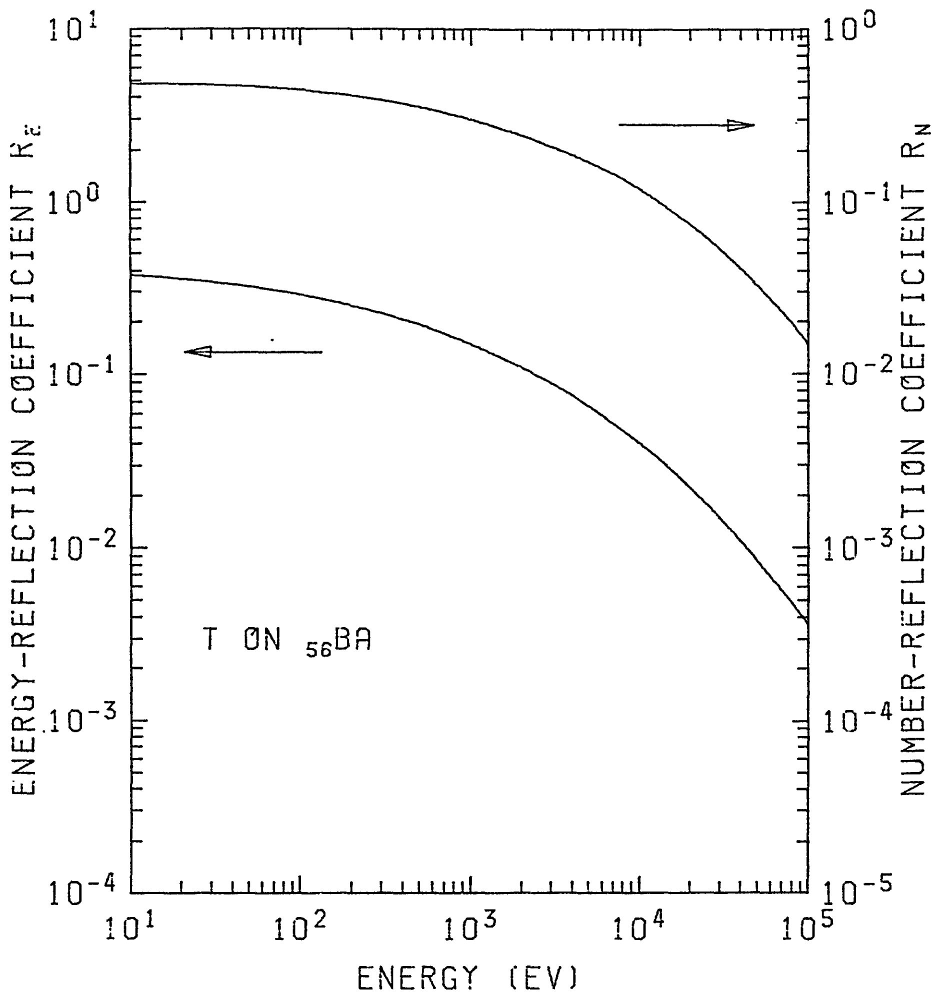


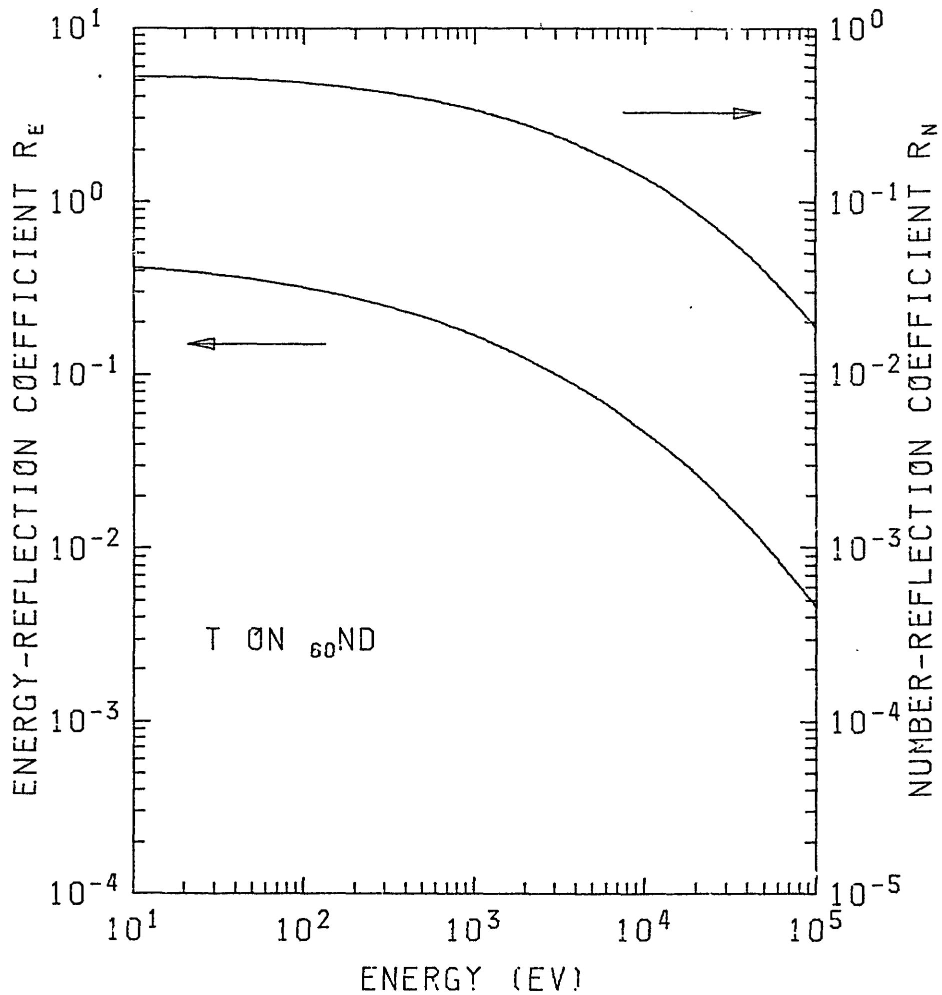
GRAPH III. R_N and R_E vs Energy for T Ions on In and Sn

See page 25 for Explanation of Graphs



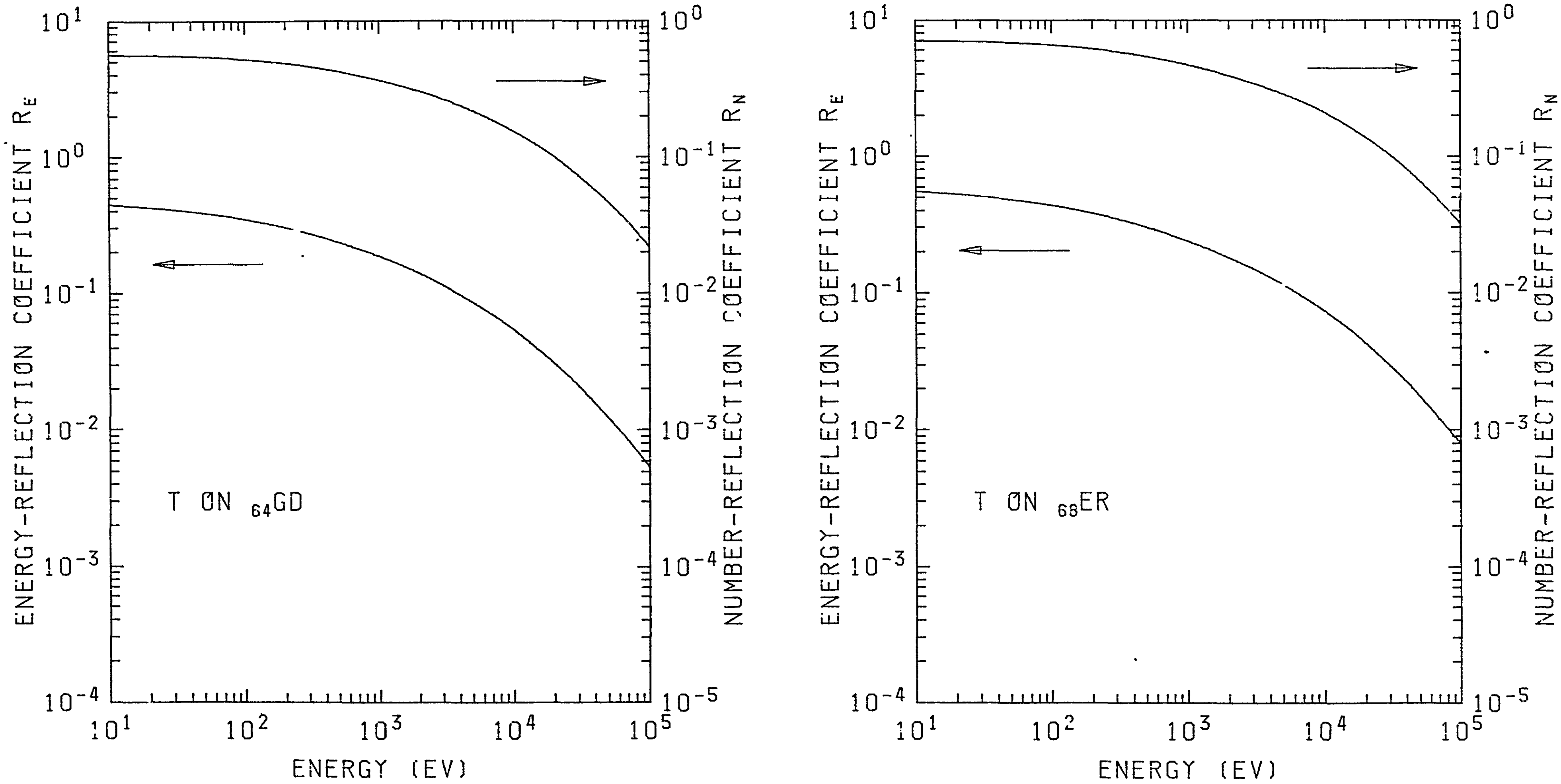
GRAPH III. R_N and R_E vs Energy for T Ions on Sb and Te
See page 25 for Explanation of Graphs





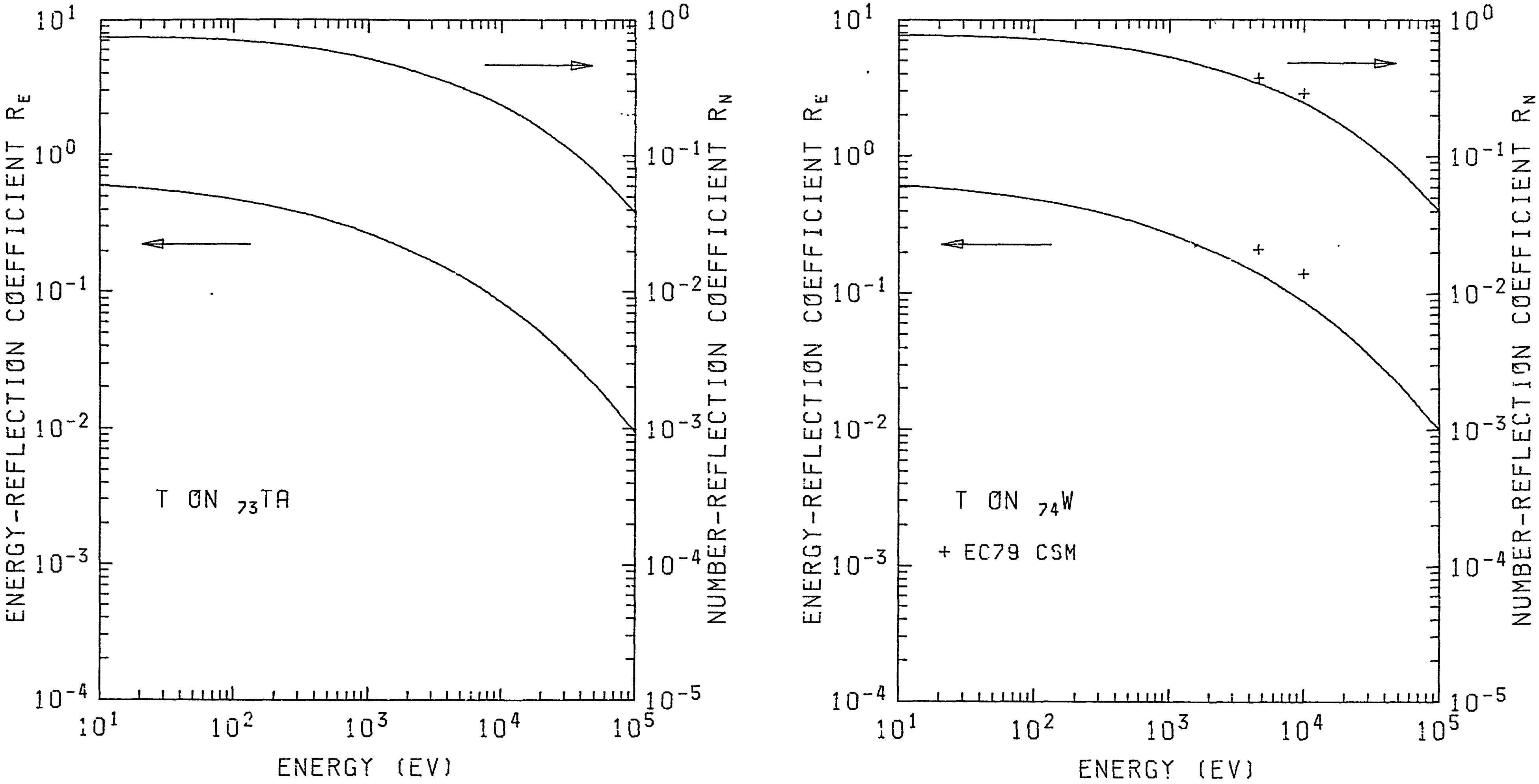
GRAPH III. R_N and R_E vs Energy for T Ions on Ba and Nd

See page 25 for Explanation of Graphs

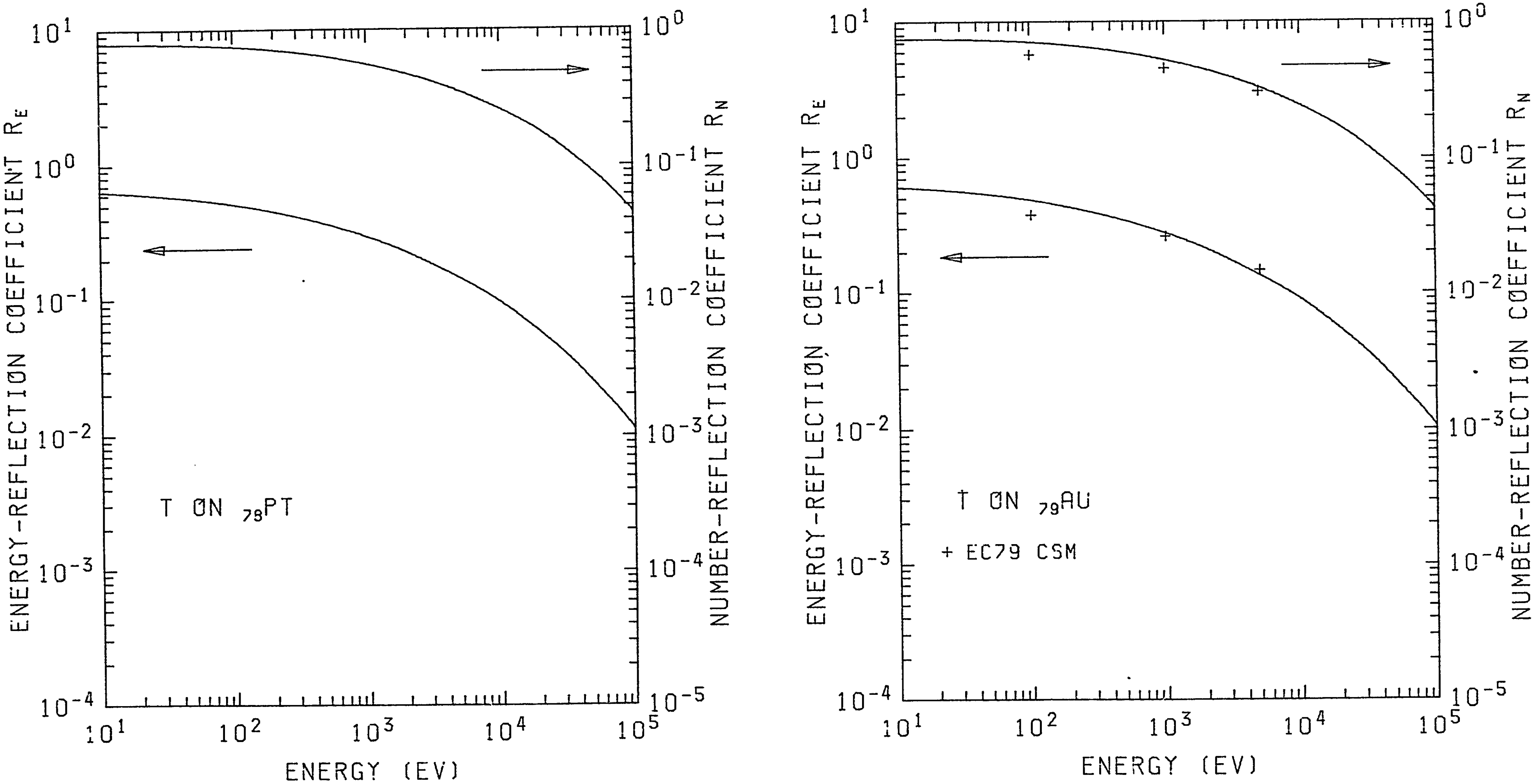


GRAPH III. R_N and R_E vs Energy for T Ions on Gd and Er

See page 25 for Explanation of Graphs

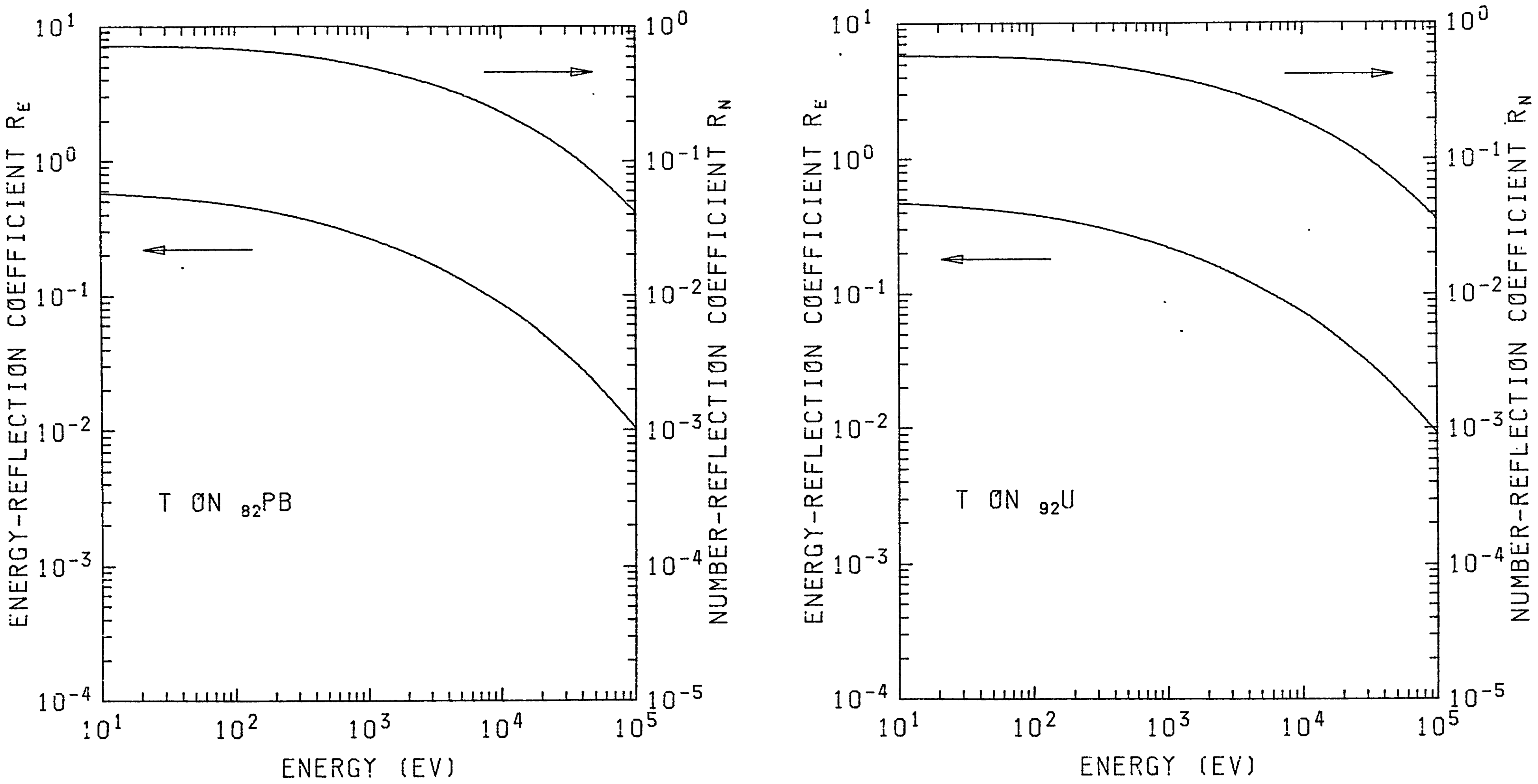


GRAPH III. R_N and R_E vs Energy for T Ions on Ta and W
See page 25 for Explanation of Graphs



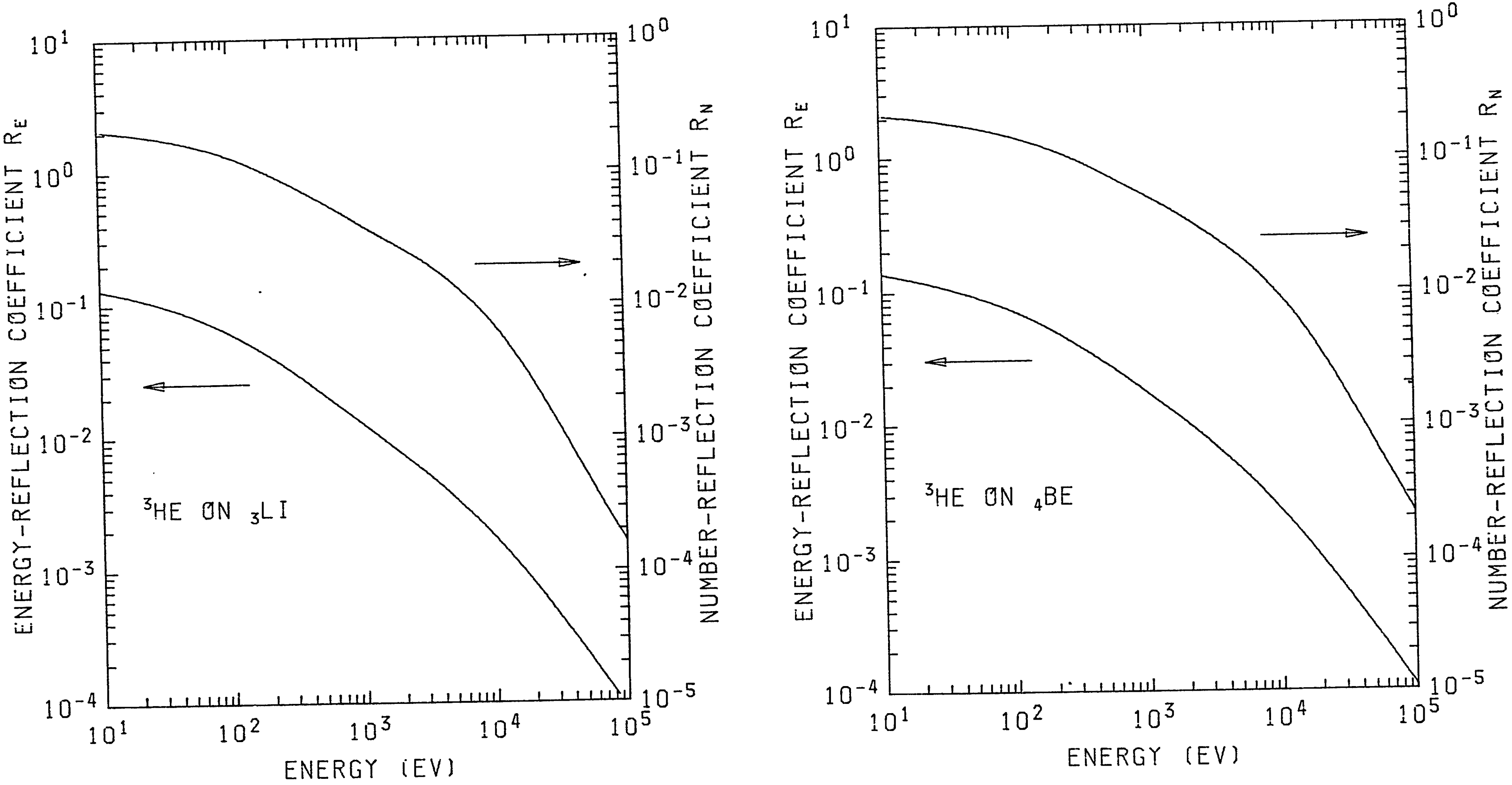
GRAPH III. R_N and R_E vs Energy for T Ions on Pt and Au

See page 25 for Explanation of Graphs



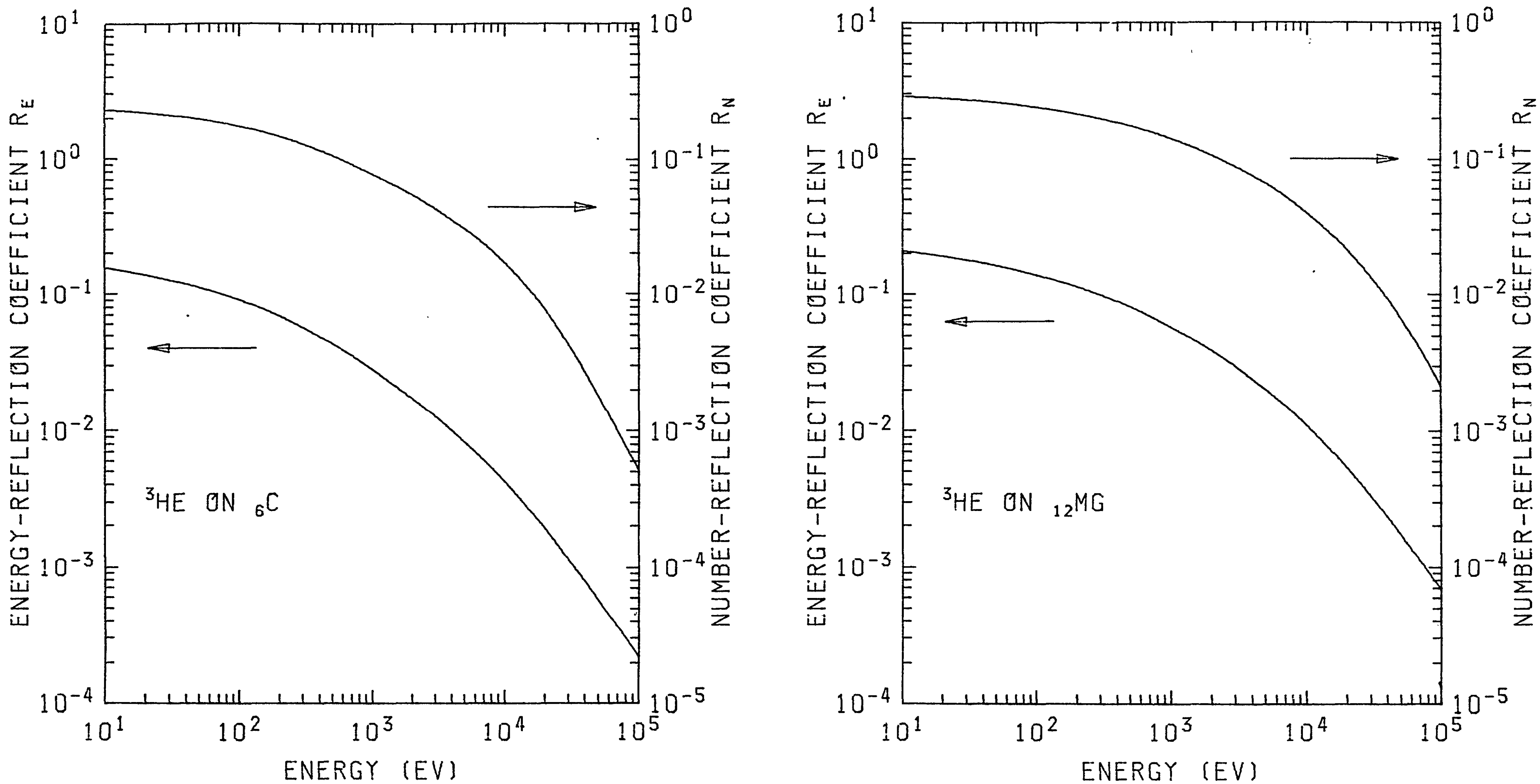
GRAPH III. R_N and R_E vs Energy for T Ions on Pb and U

See page 25 for Explanation of Graphs



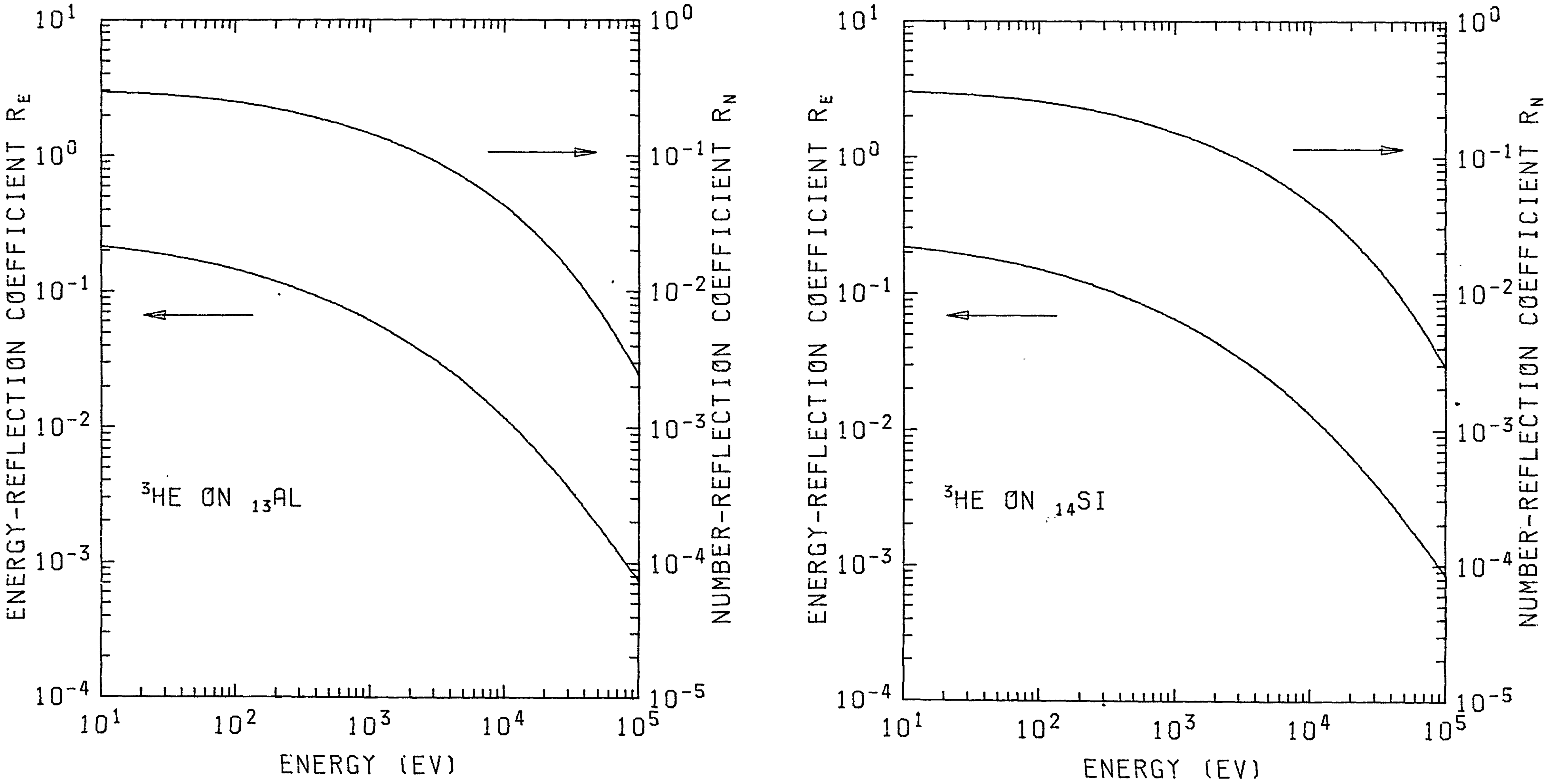
GRAPH IV. R_N and R_E vs Energy for ^{3}He Ions on Li and Be

See page 25 for Explanation of Graphs



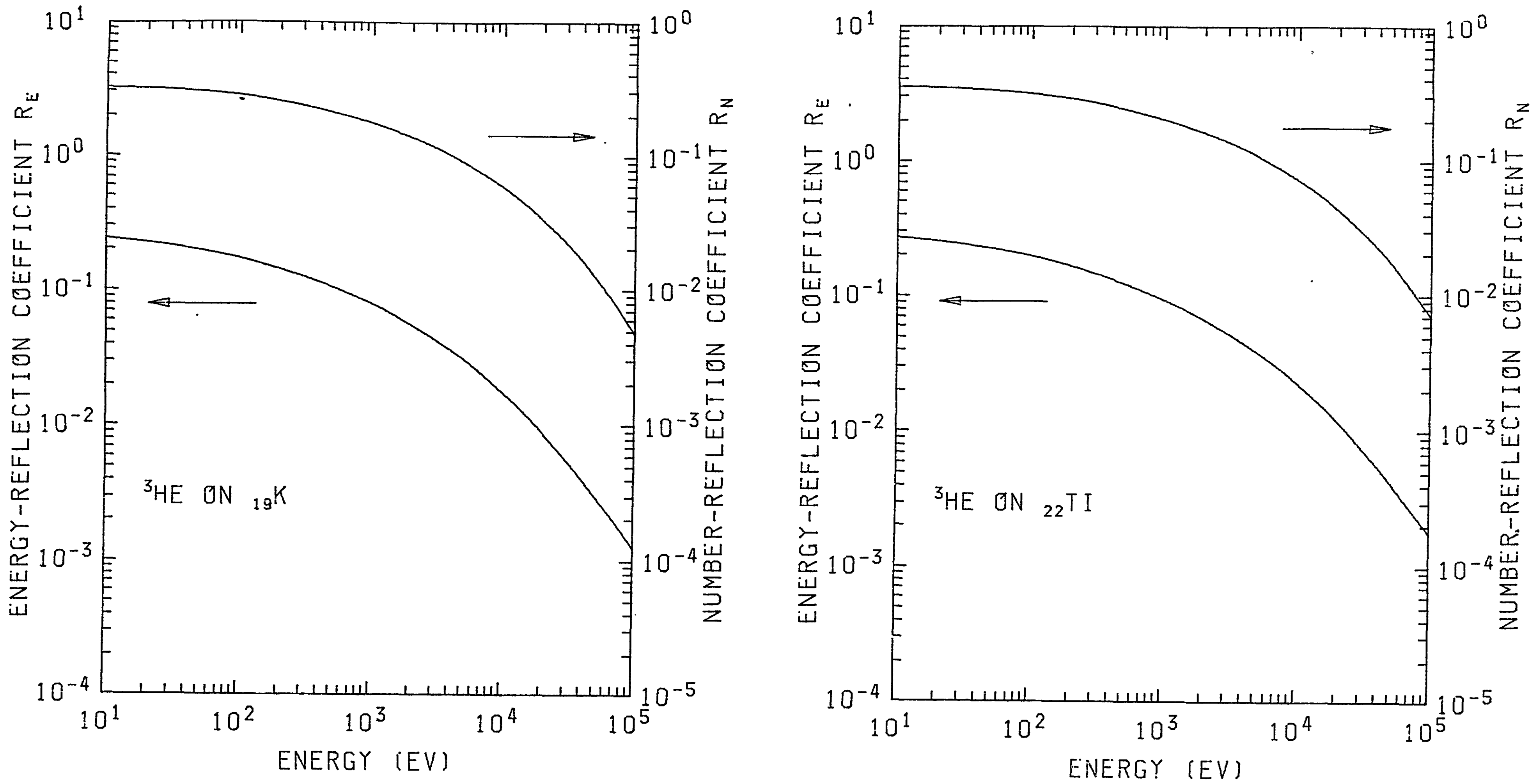
GRAPH IV. R_N and R_E vs Energy for ^{3}He Ions on C and Mg

See page 25 for Explanation of Graphs



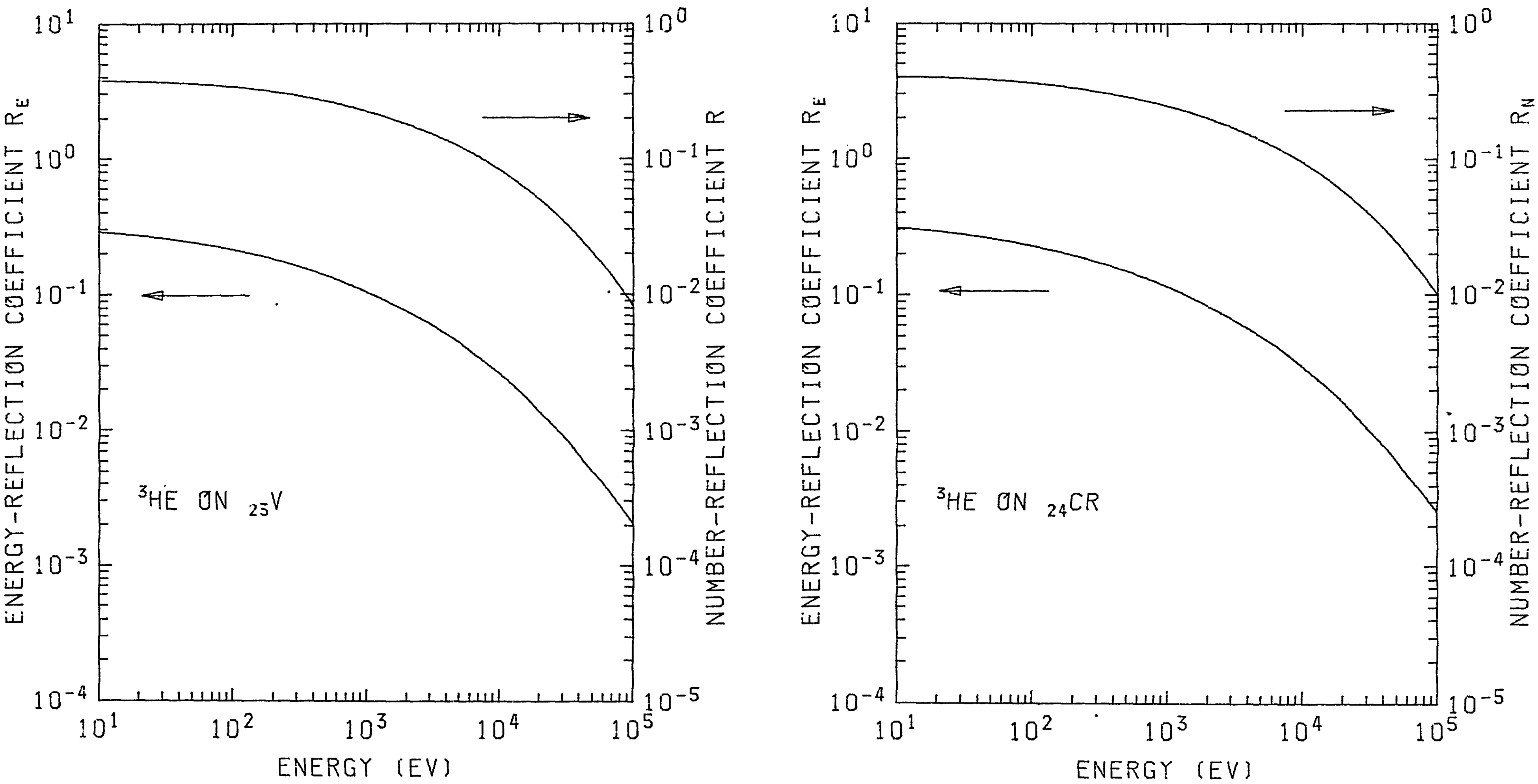
GRAPH IV. R_N and R_E vs Energy for ^{3}He Ions on Al and Si

See page 25 for Explanation of Graphs



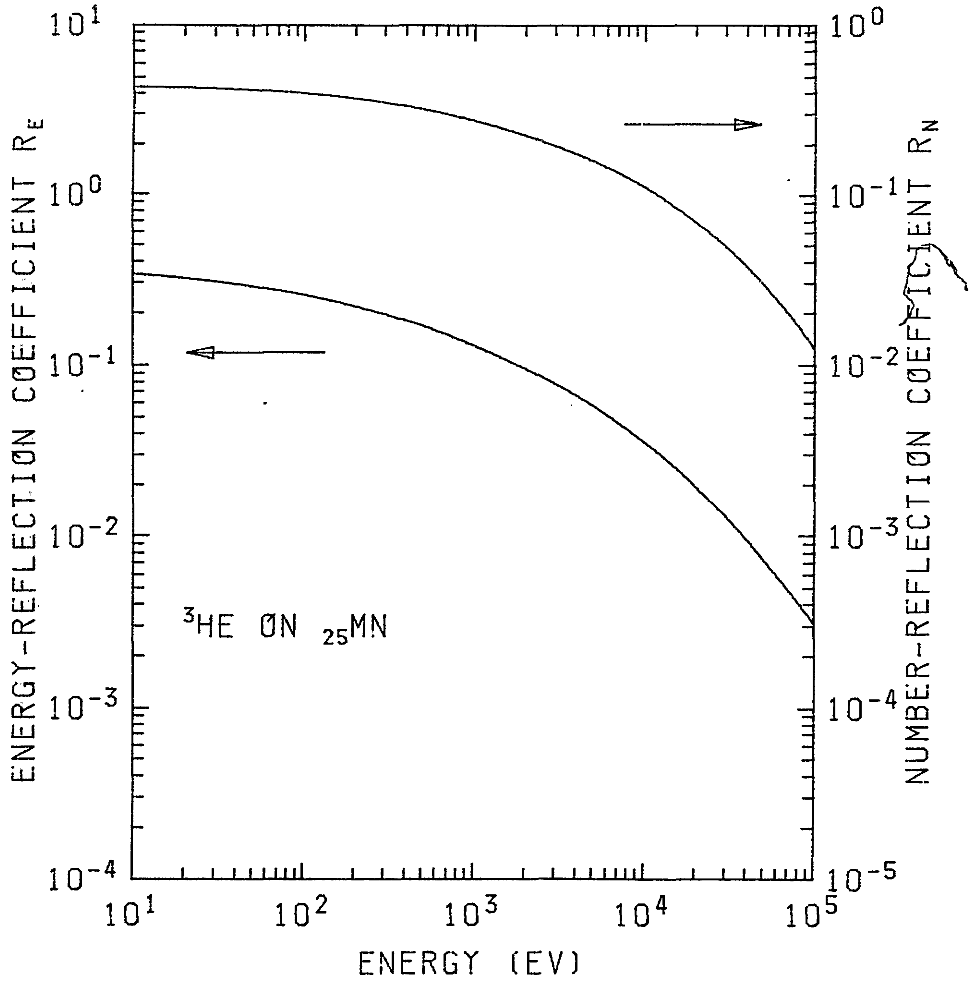
GRAPH IV. R_N and R_E vs Energy for ^{3}He Ions on K and Ti

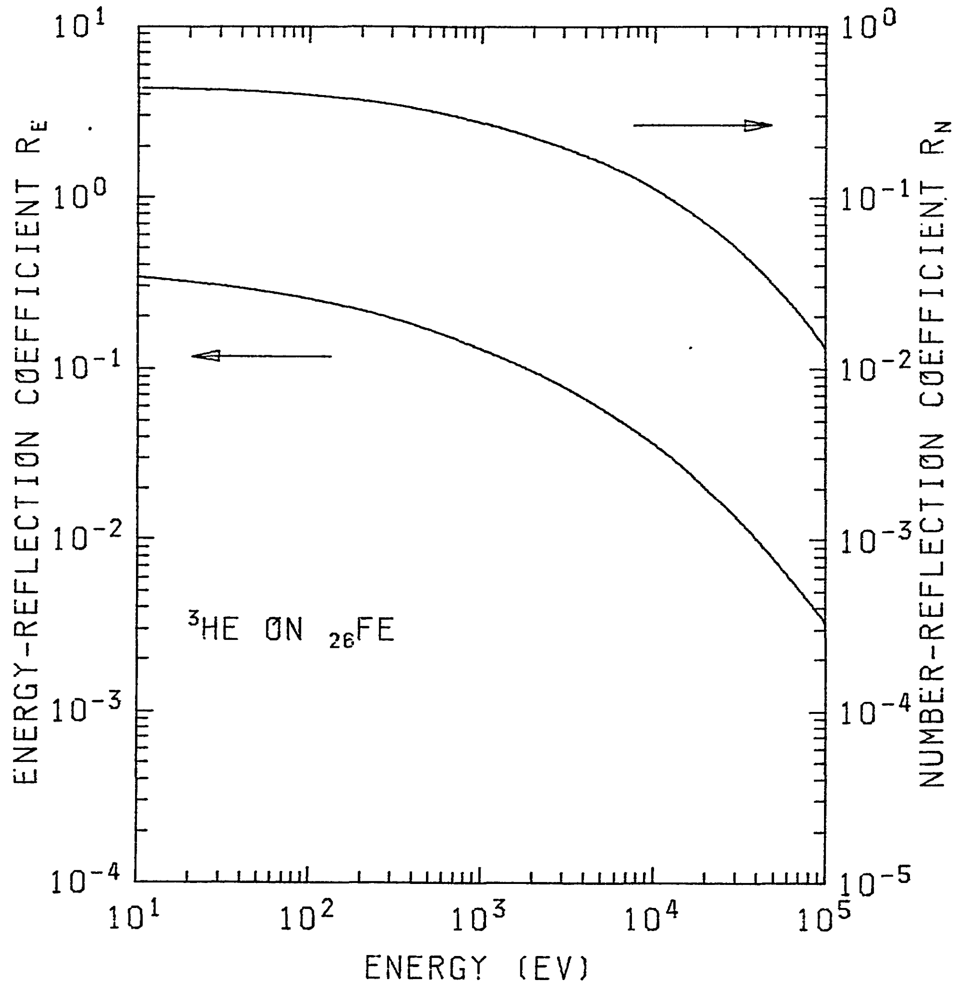
See page 25 for Explanation of Graphs



GRAPH IV. R_N and R_E vs Energy for ^{3}He Ions on V and Cr

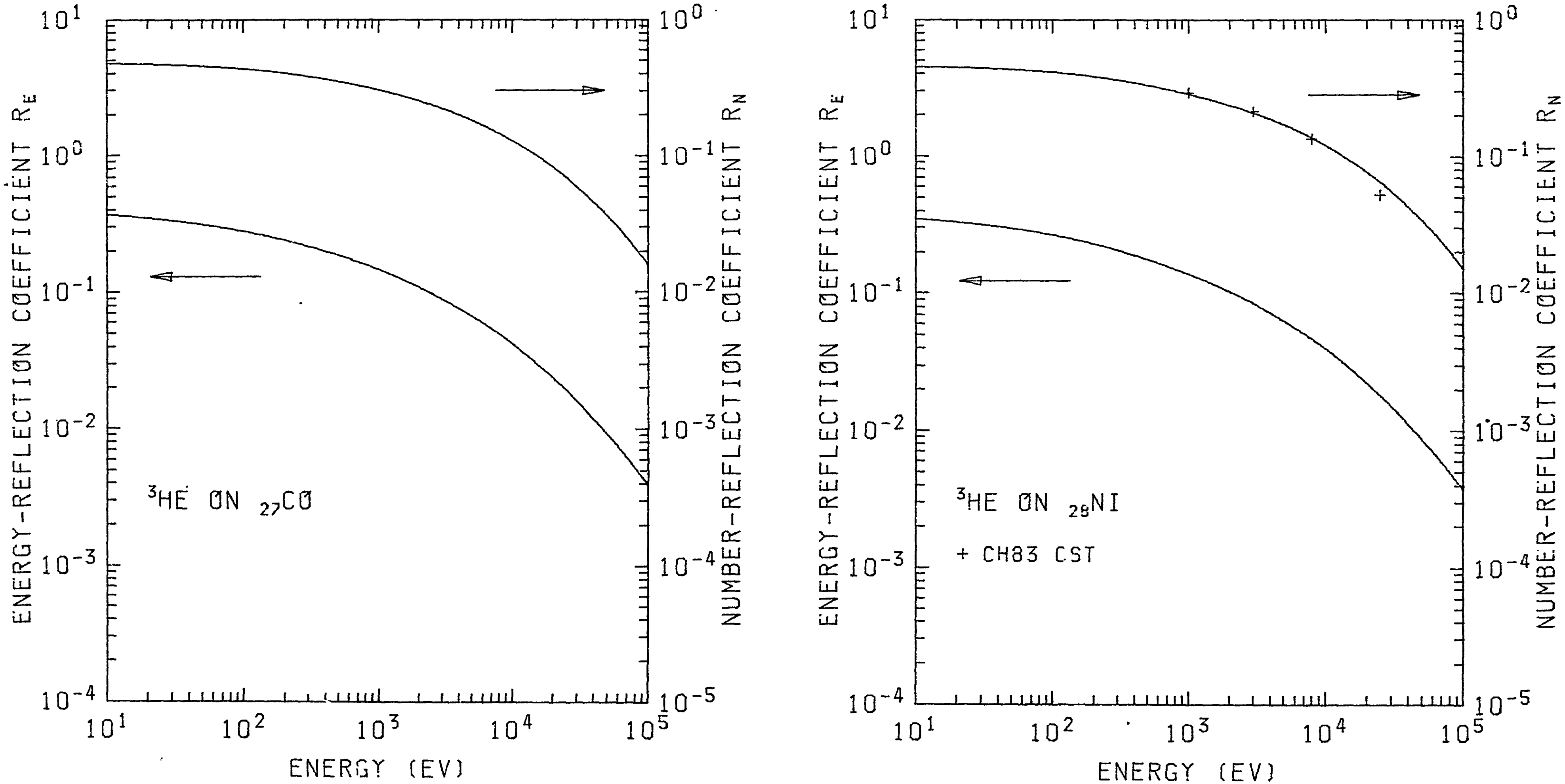
See page 25 for Explanation of Graphs





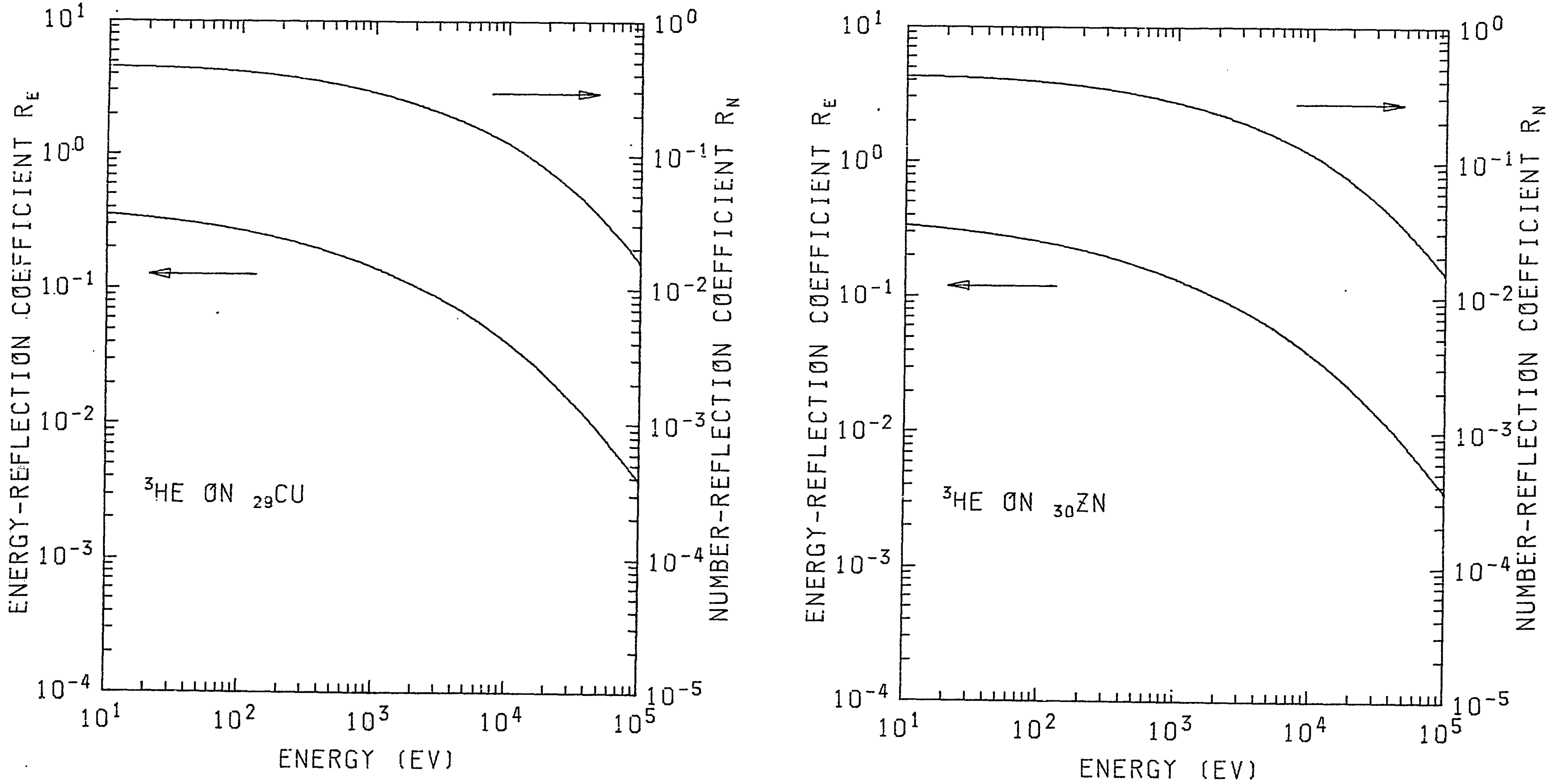
GRAPH IV. R_N and R_E vs Energy for ^{3}He Ions on Mn and Fe

See page 25 for Explanation of Graphs



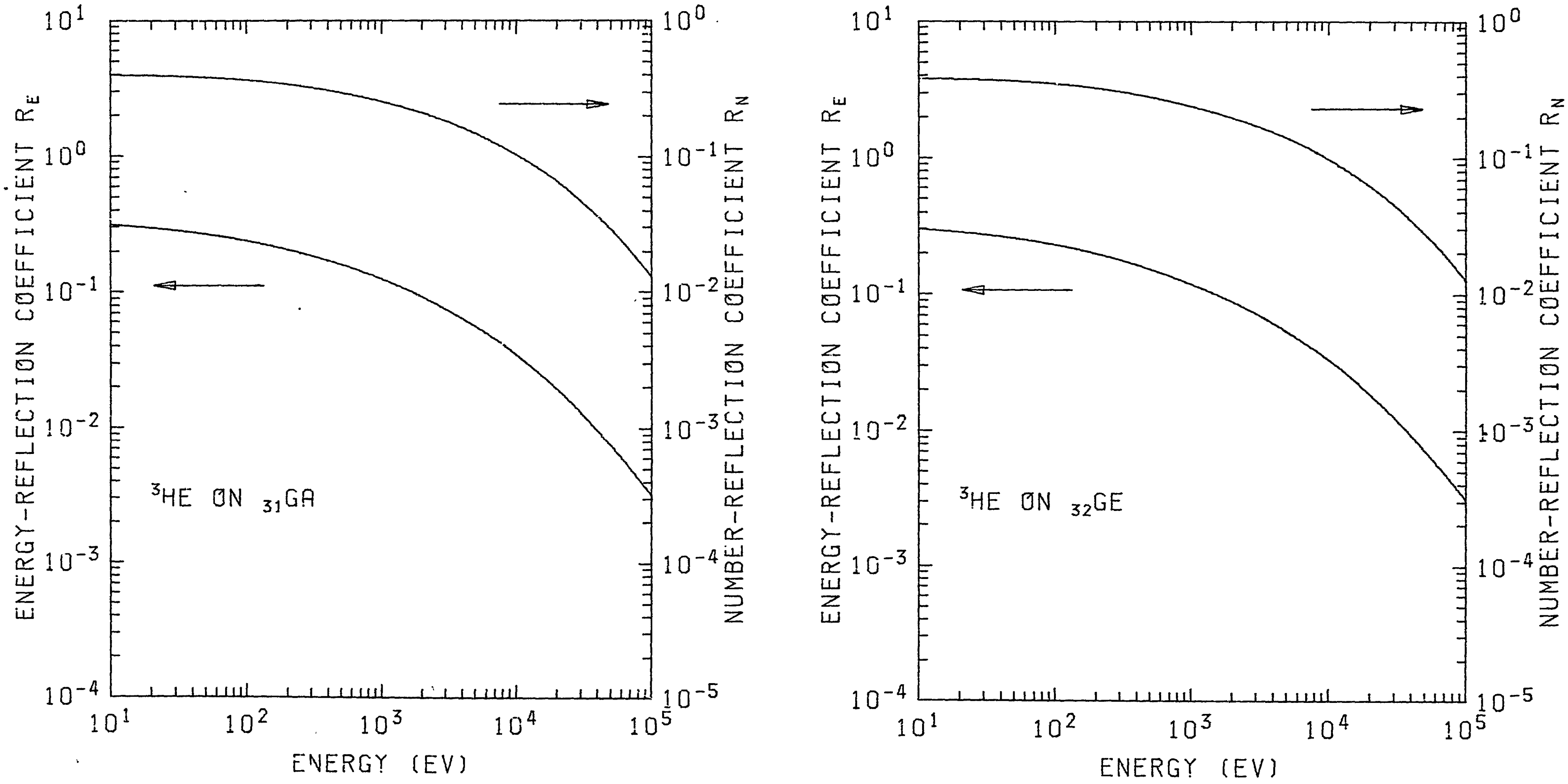
GRAPH IV. R_N and R_E vs Energy for ^{3}He Ions on Co and Ni

See page 25 for Explanation of Graphs

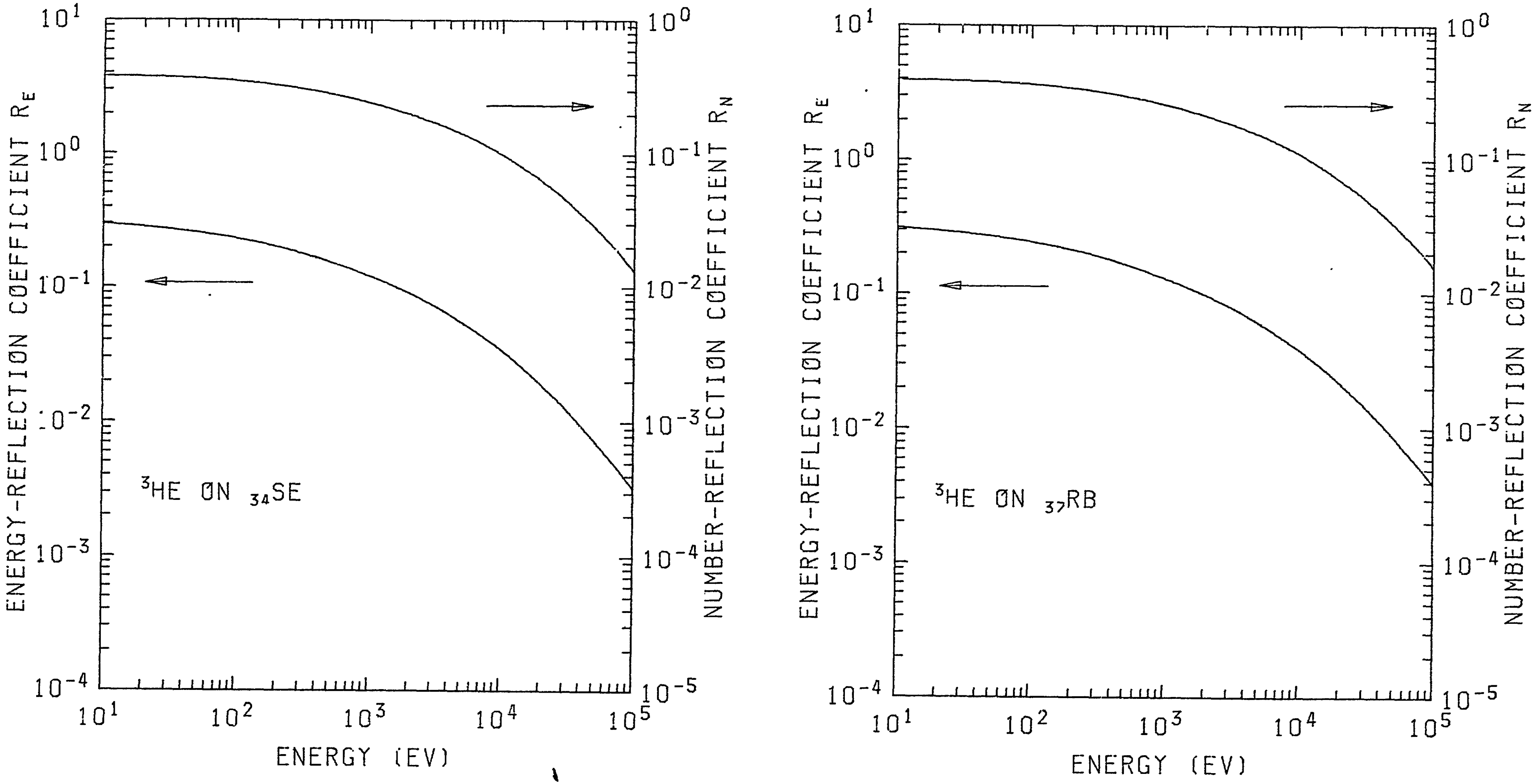


GRAPH IV. R_N and R_E vs Energy for ^{3}He Ions on Cu and Zn

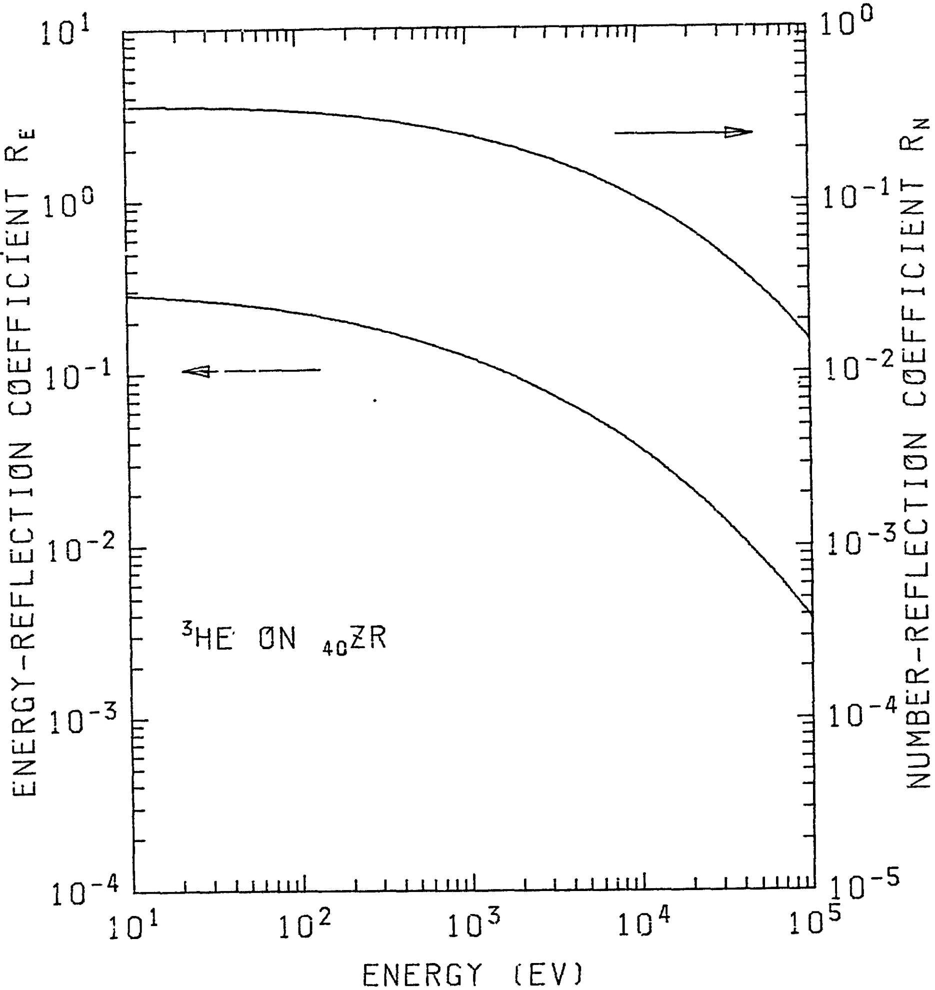
See page 25 for Explanation of Graphs

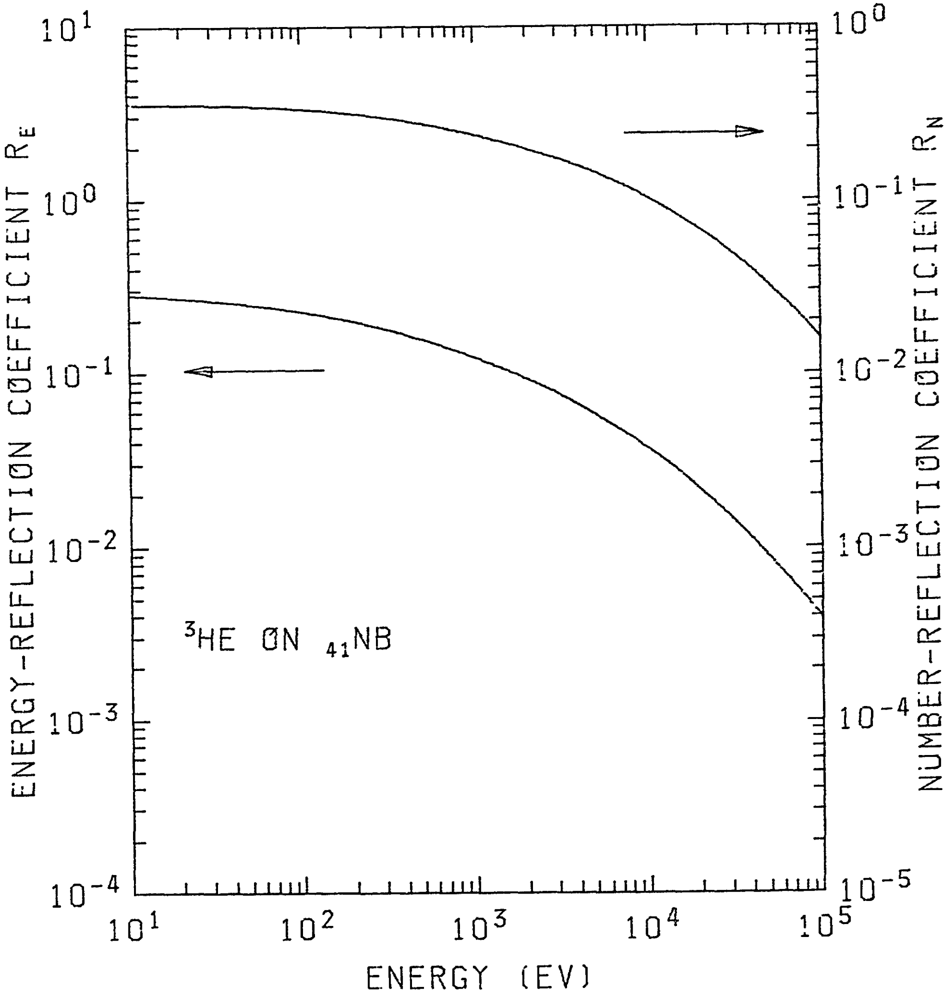


GRAPH IV. R_N and R_E vs Energy for ^{3}He Ions on Ga and Ge
See page 25 for Explanation of Graphs



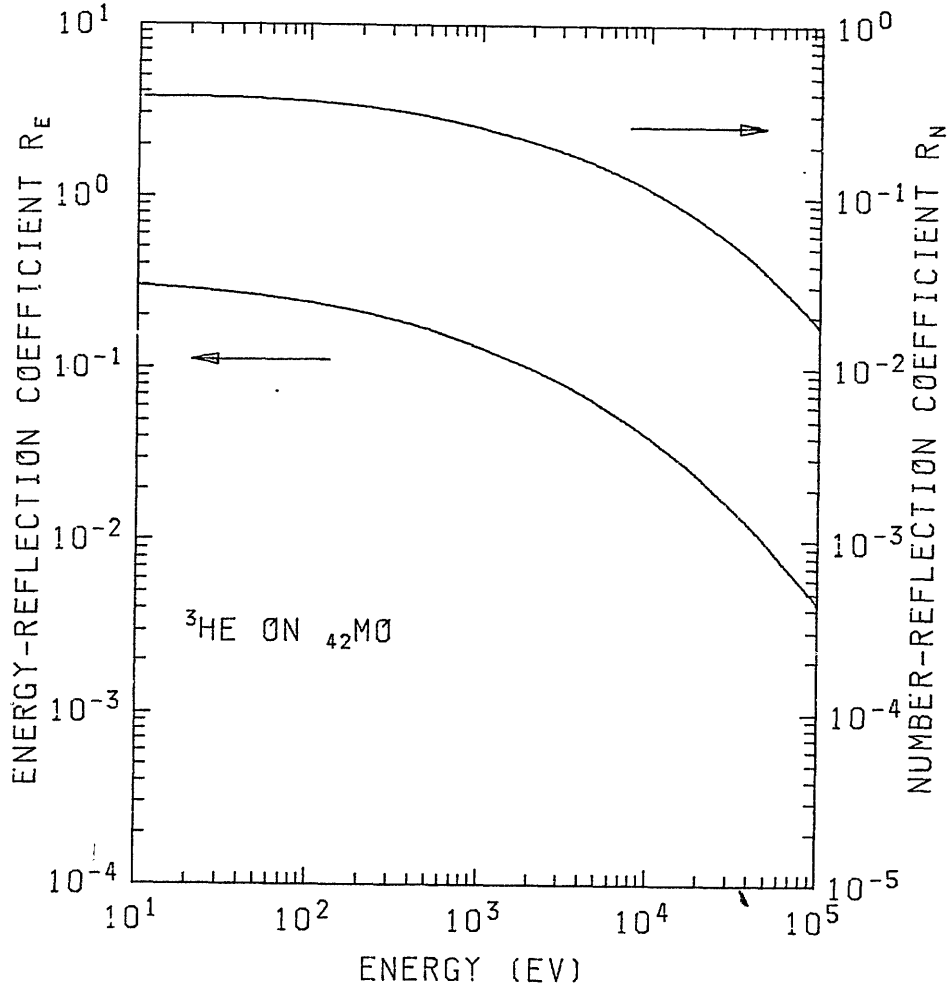
GRAPH IV. R_N and R_E vs Energy for ^{3}He Ions on Se and Rb
See page 25 for Explanation of Graphs

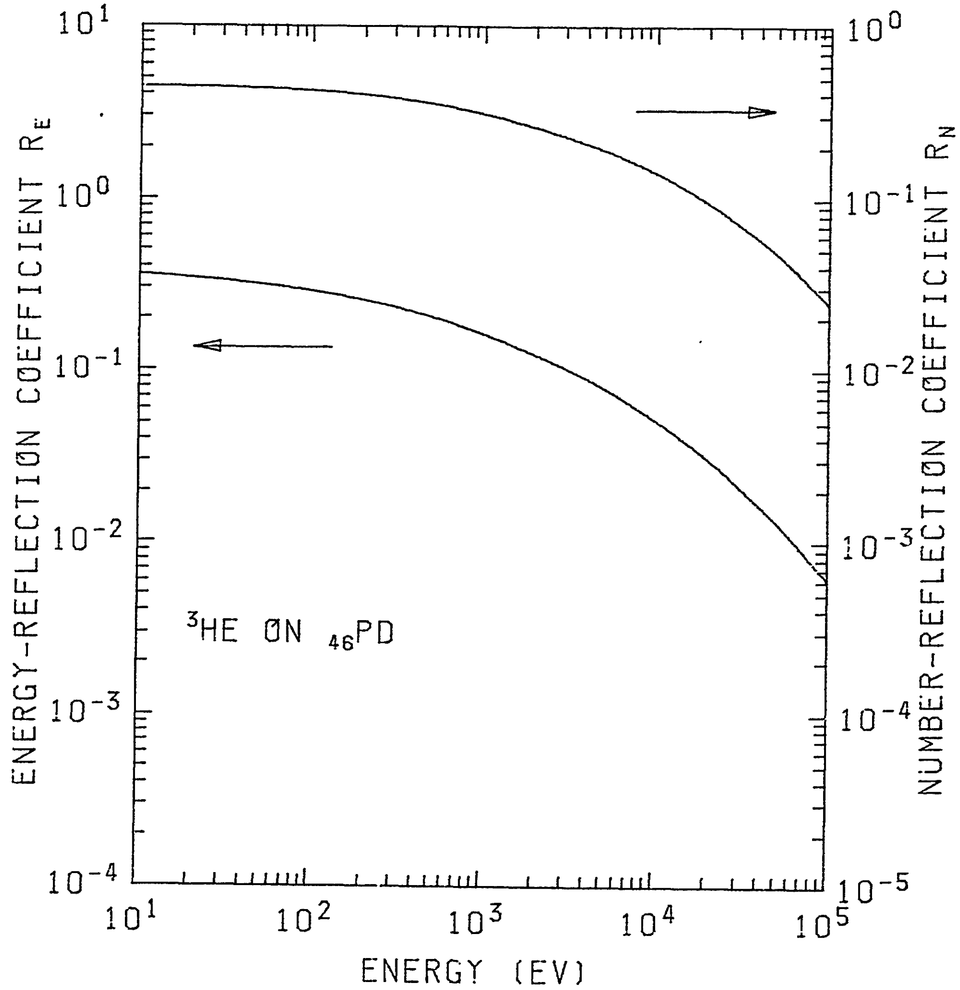




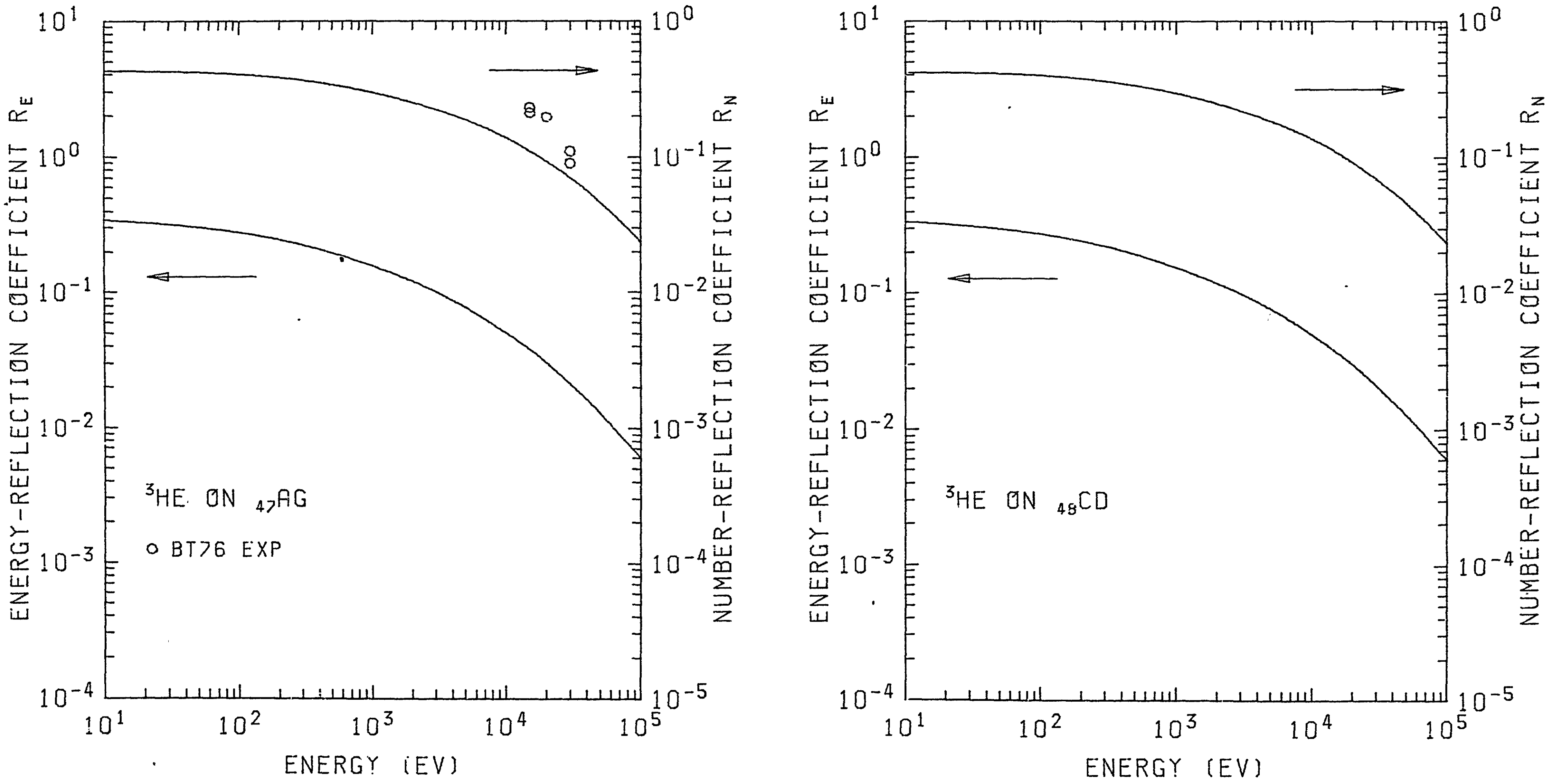
GRAPH IV. R_N and R_E vs Energy for ^3He Ions on Zr and Nb

See page 25 for Explanation of Graphs



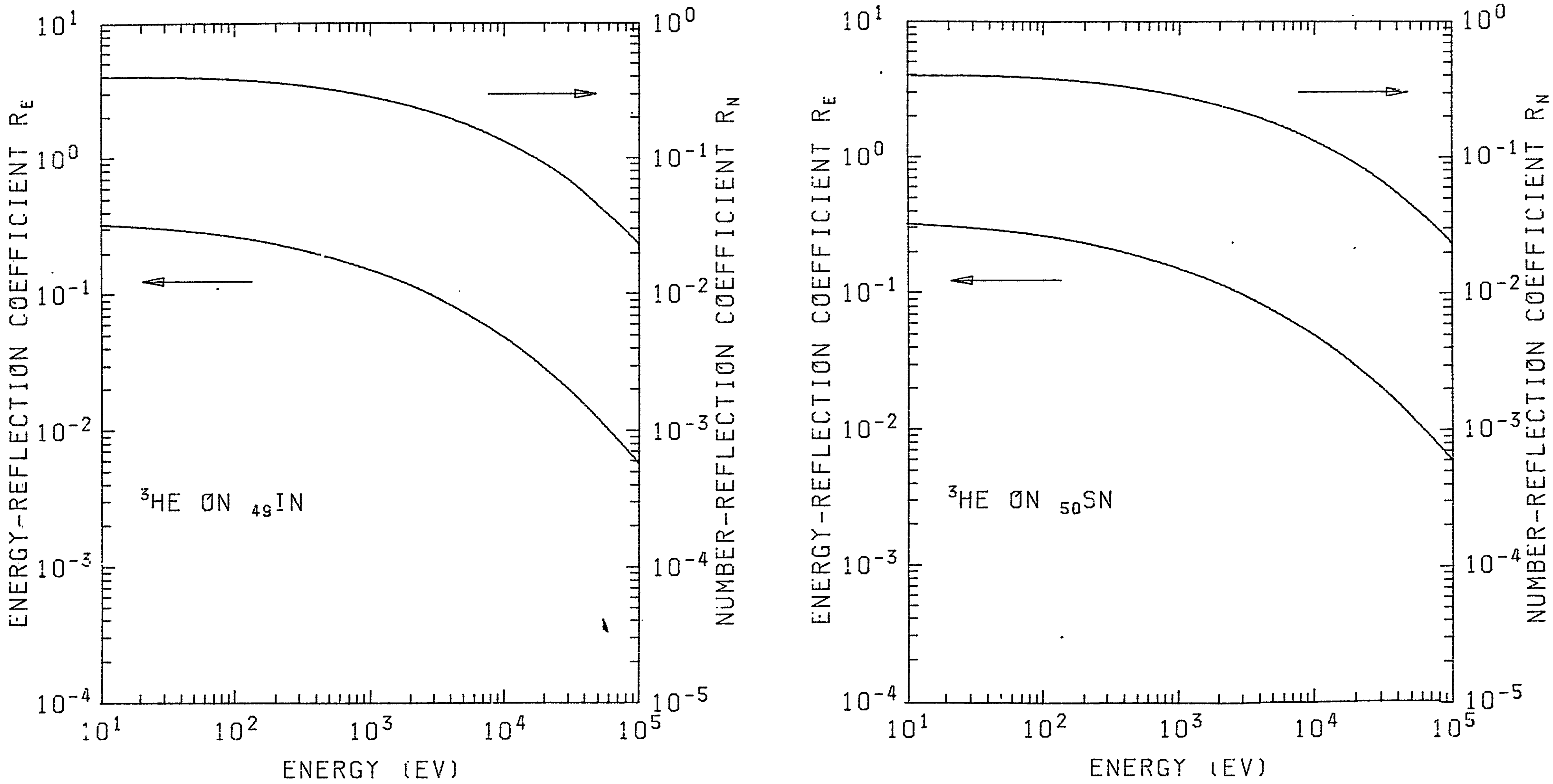


GRAPH IV. R_N and R_E vs Energy for ^{3}He Ions on Mo and Pd
See page 25 for Explanation of Graphs



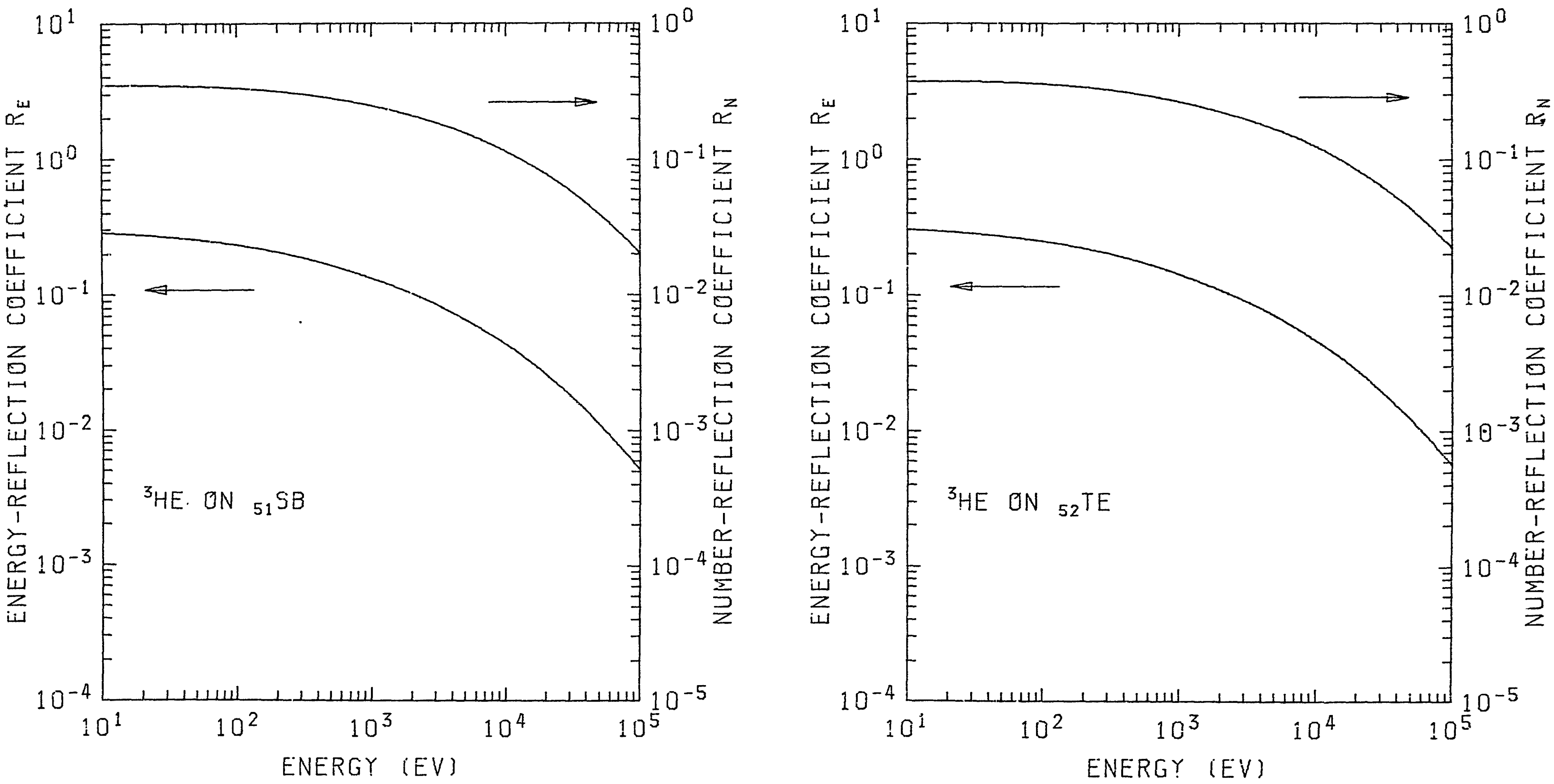
GRAPH IV. R_N and R_E vs Energy for ^{3}He Ions on Ag and Cd

See page 25 for Explanation of Graphs



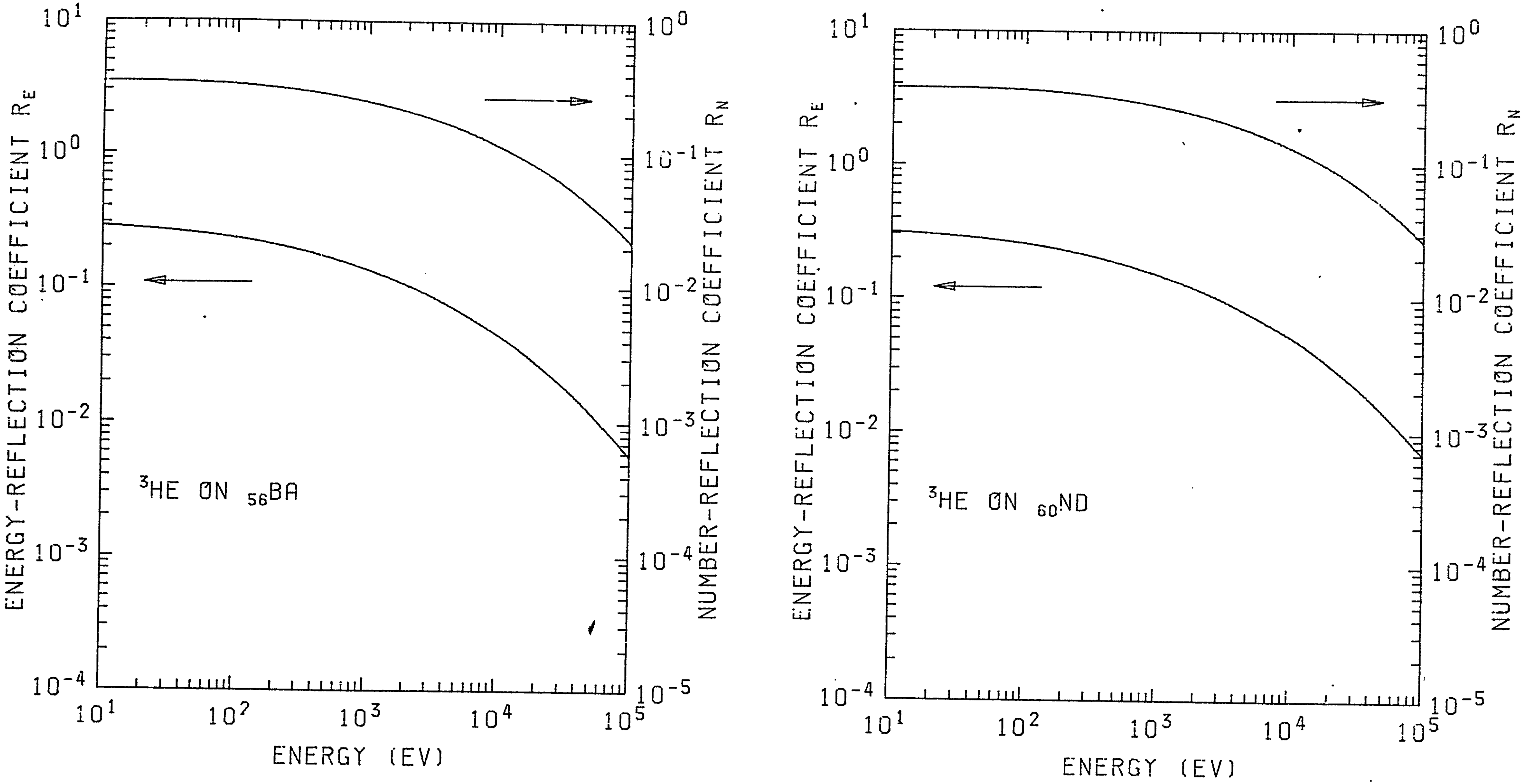
GRAPH IV. R_N and R_E vs Energy for ^{3}He Ions on In and Sn

See page 25 for Explanation of Graphs



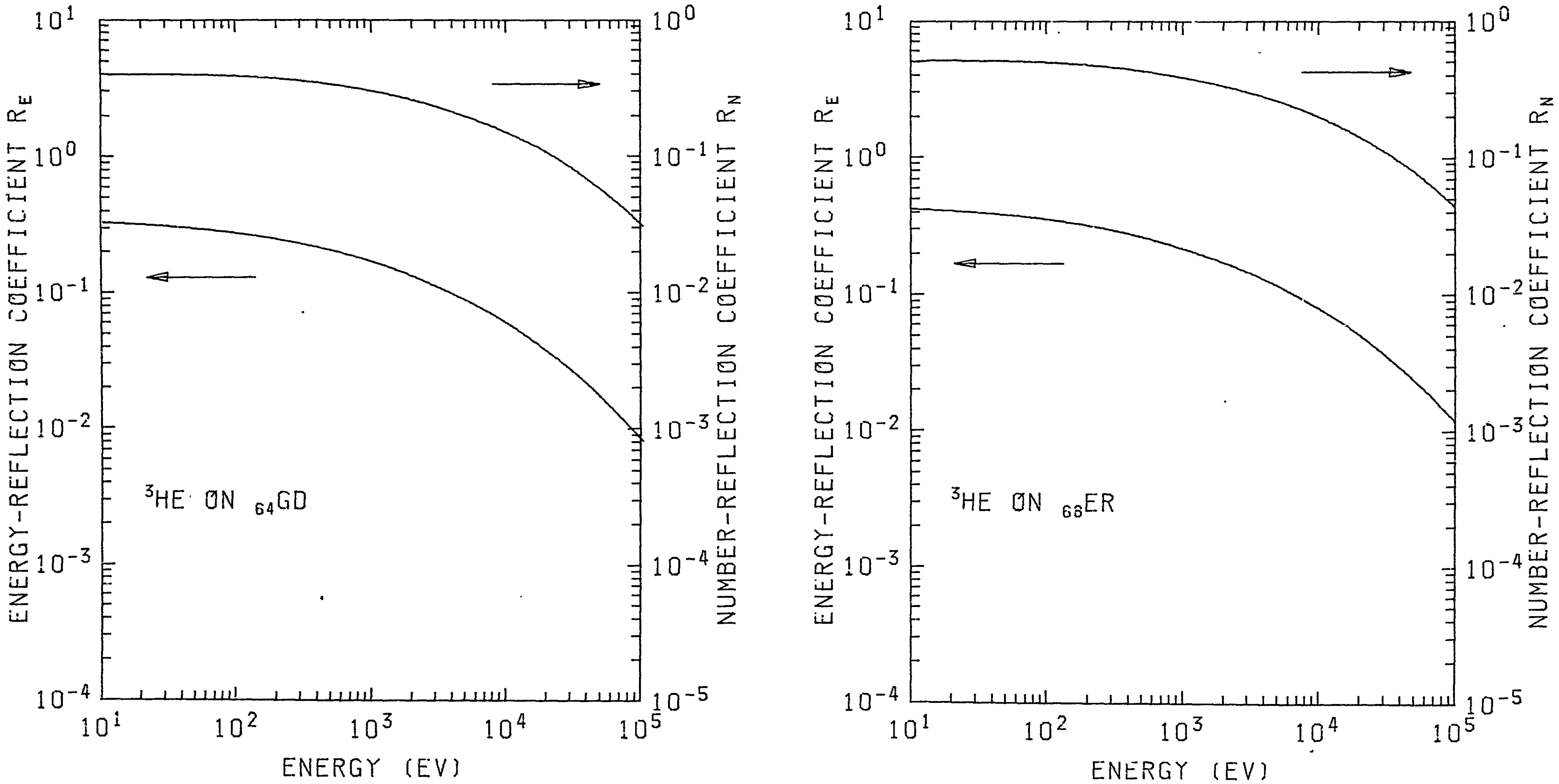
GRAPH IV. R_N and R_E vs Energy for ^{3}He Ions on Sb and Te

See page 25 for Explanation of Graphs



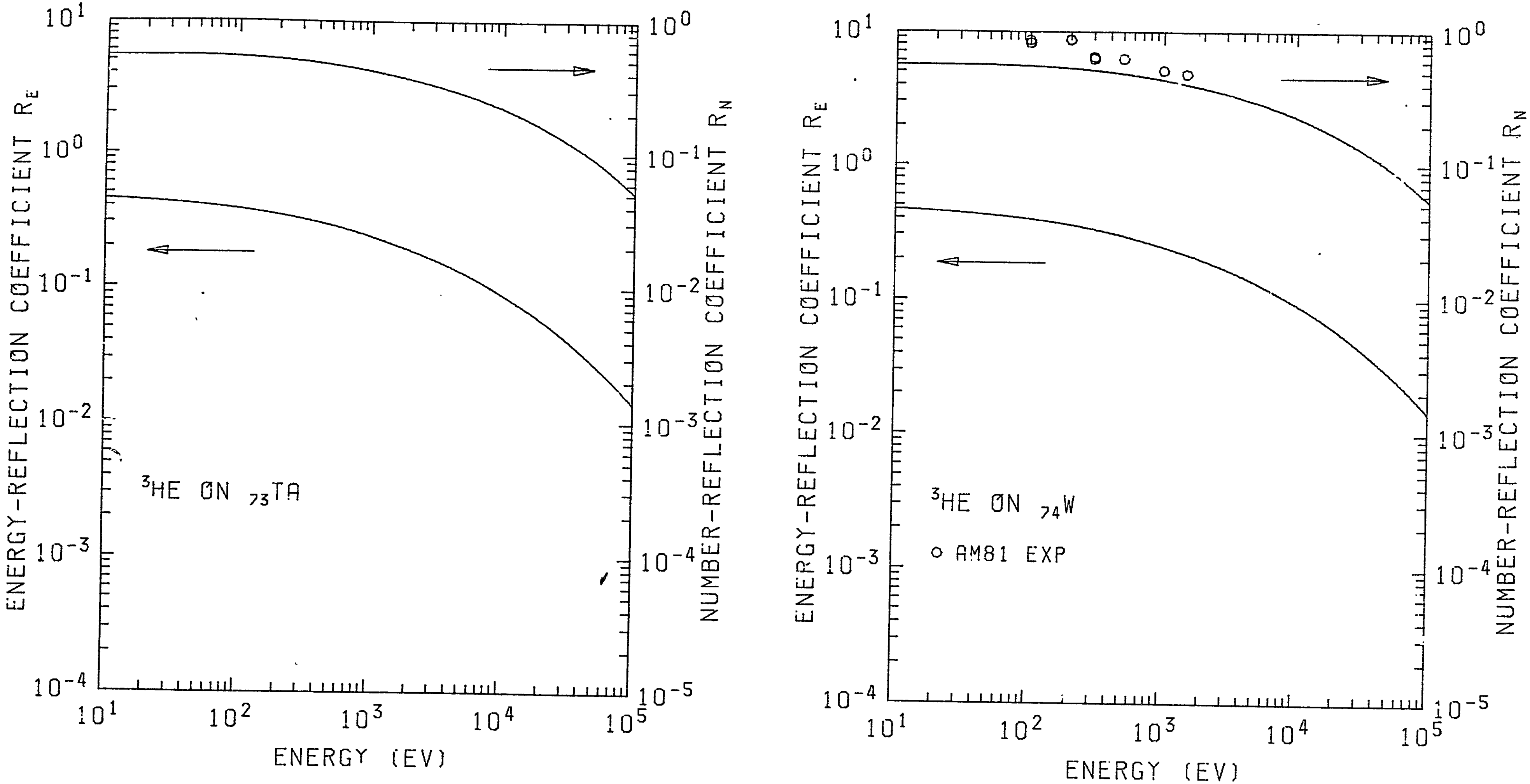
GRAPH IV R_N and R_E vs Energy for ^{3}He Ions on Ba and Nd

See page 25 for Explanation of Graphs



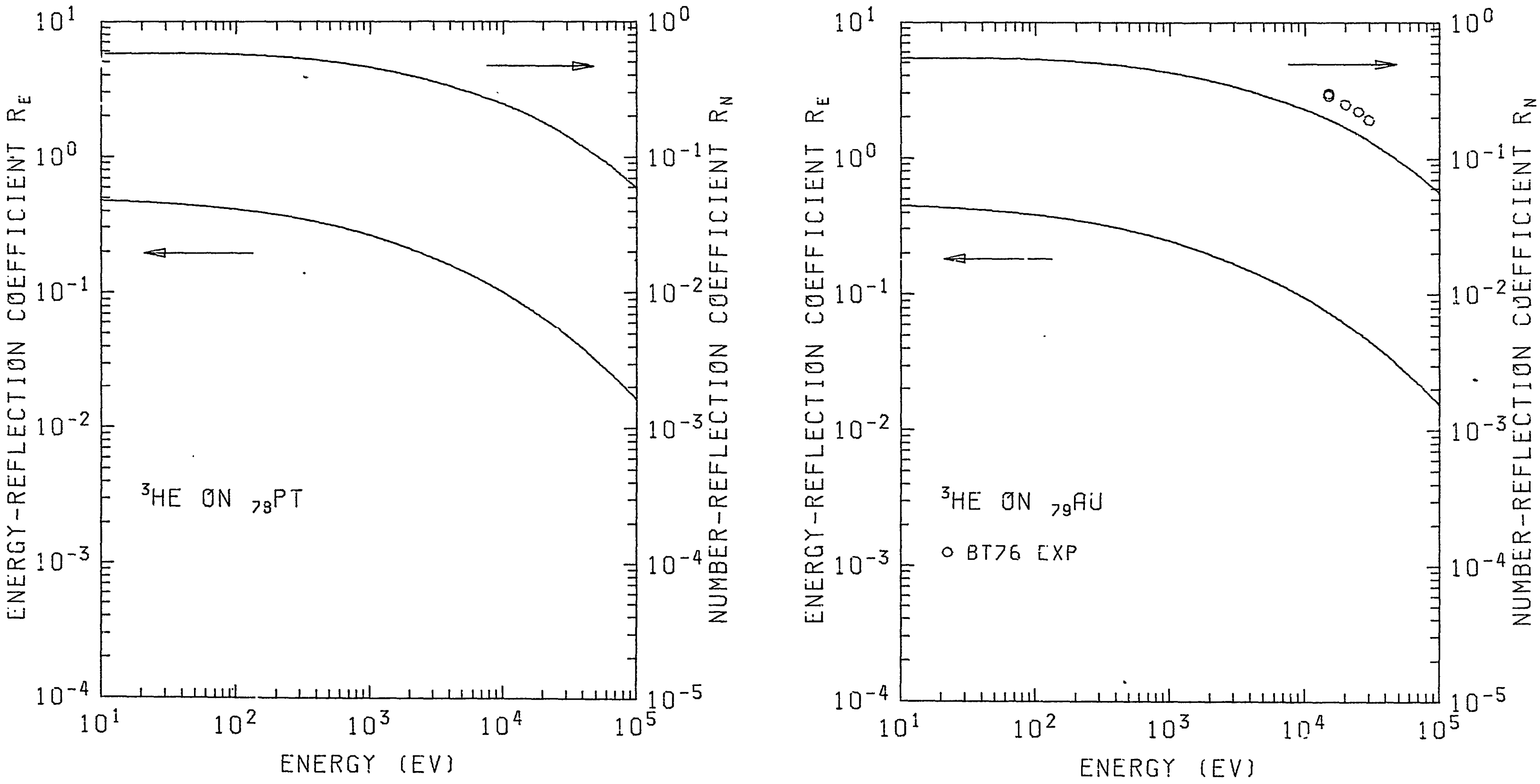
GRAPH IV. R_N and R_E vs Energy for ^{3}He Ions on Gd and Er

See page 25 for Explanation of Graphs



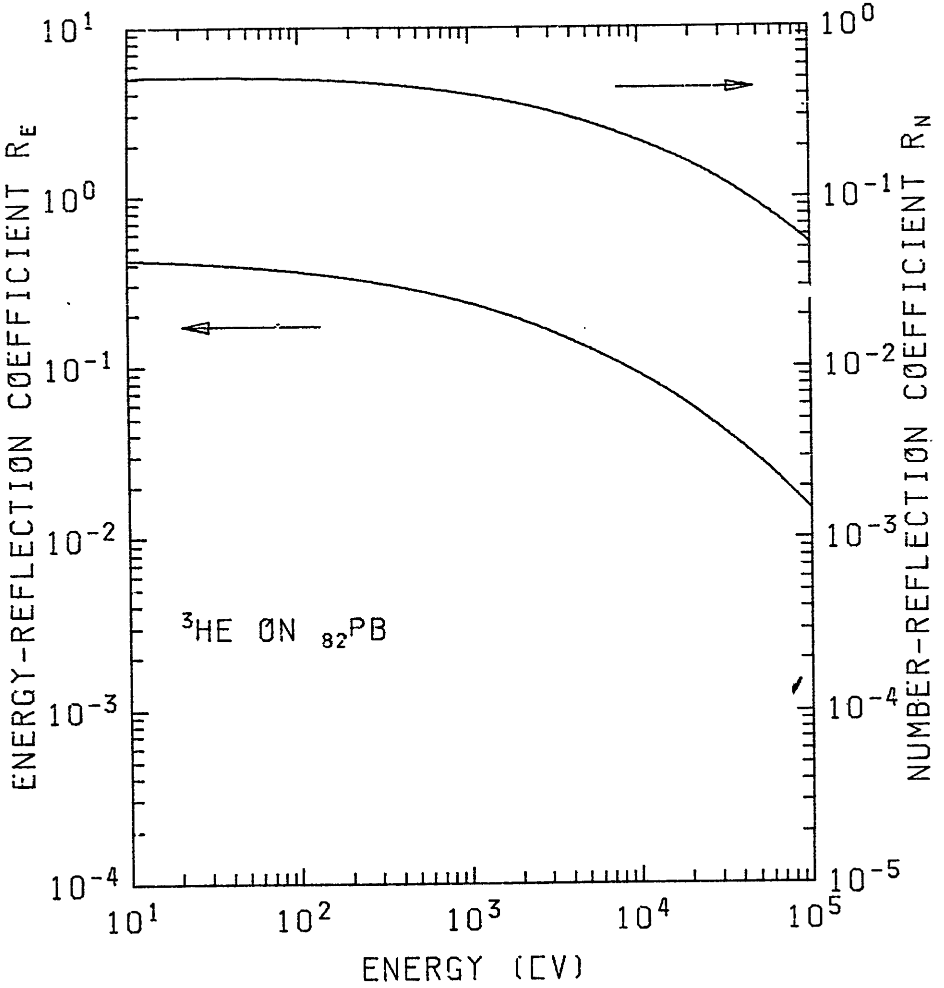
GRAPH IV. R_N and R_E vs Energy for ^{3}He Ions on Ta and W

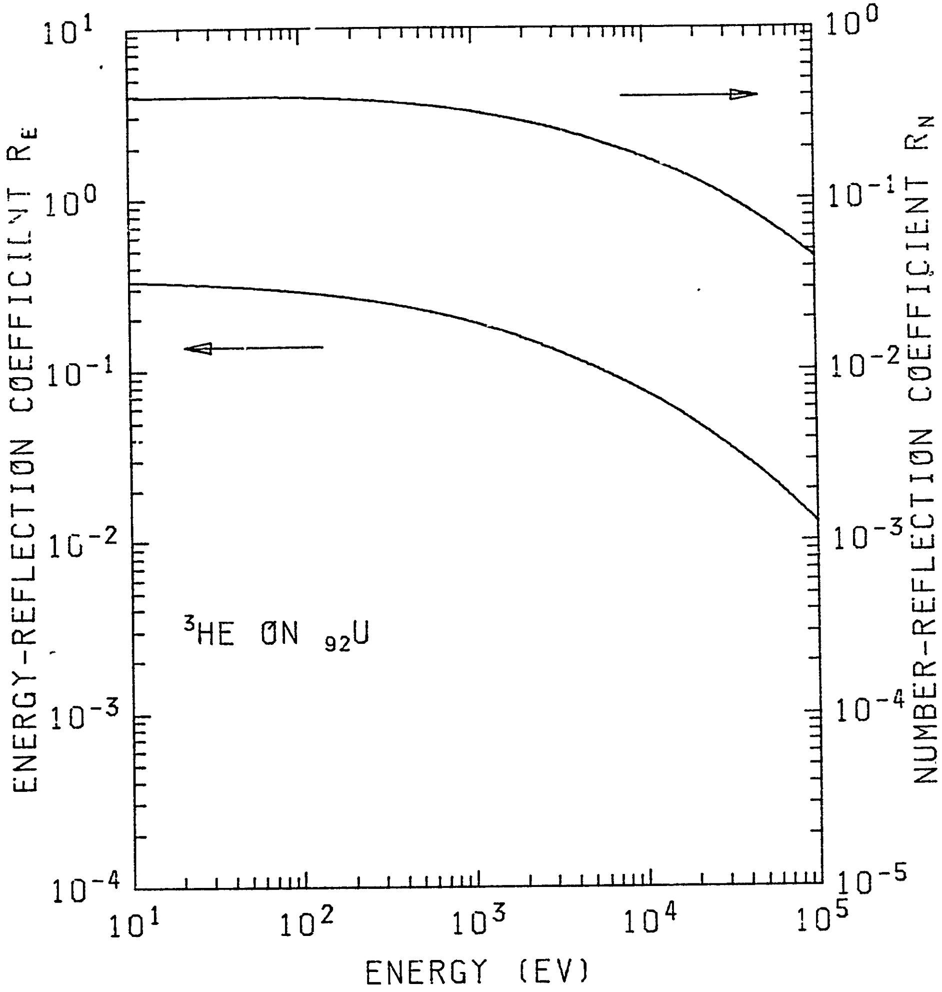
See page 25 for Explanation of Graphs



GRAPH IV. R_N and R_E vs Energy for ^{3}He Ions on Pt and Au

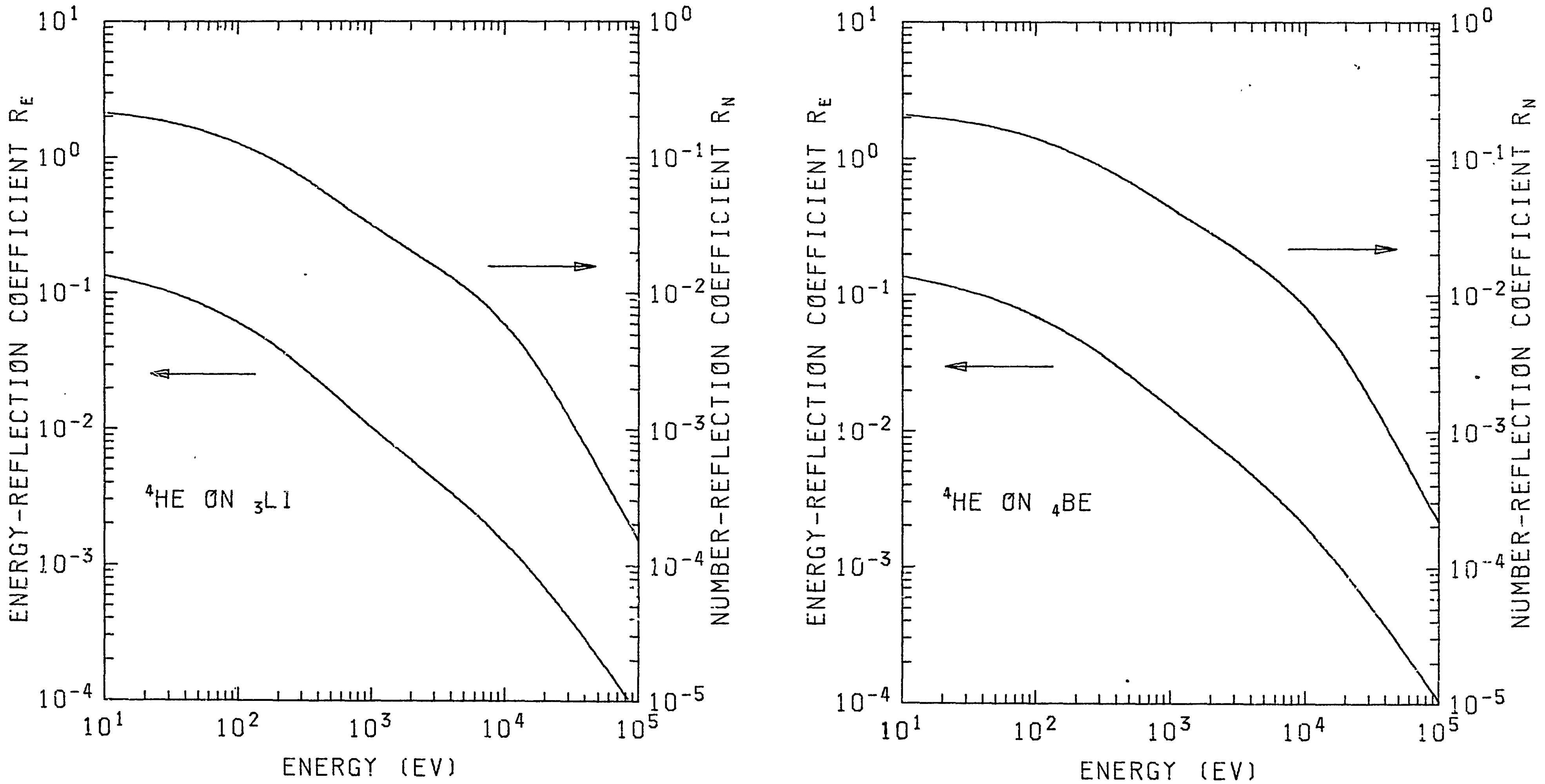
See page 25 for Explanation of Graphs





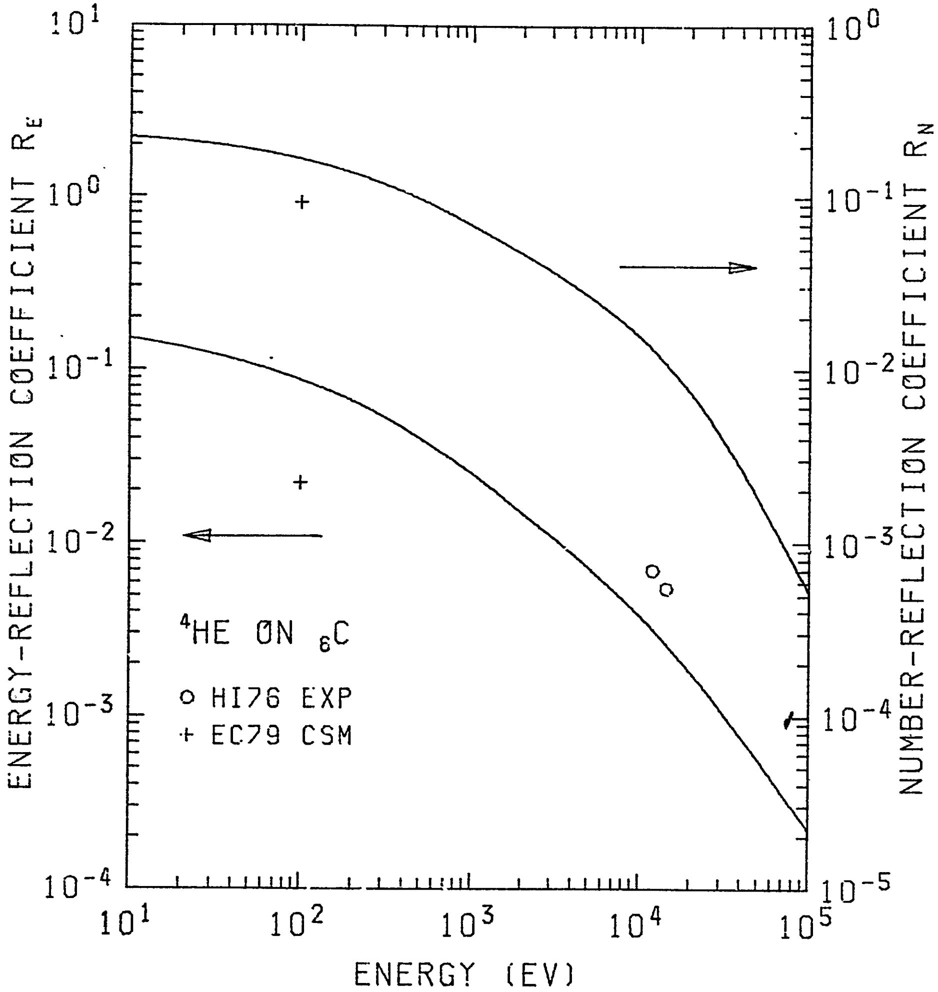
GRAPH IV. R_N and R_E vs Energy for ^{3}He Ions on Pb and U

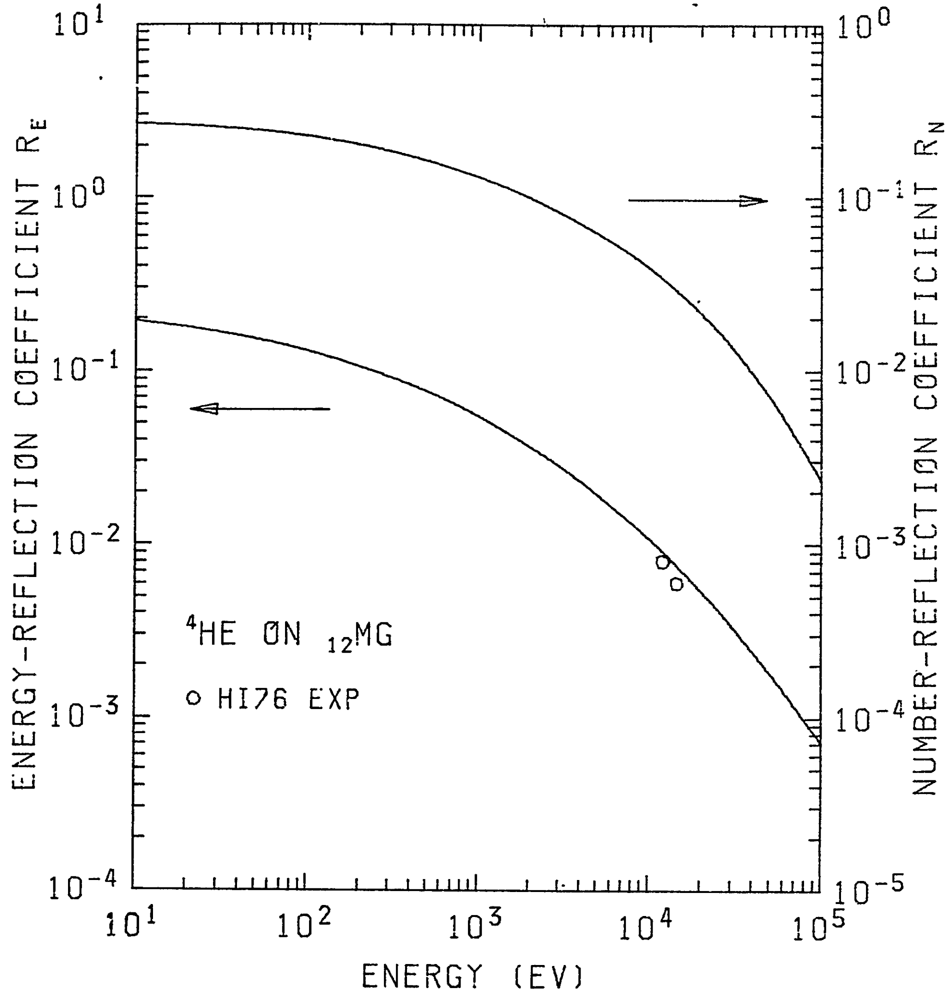
See page 25 for Explanation of Graphs



GRAPH V. R_N and R_E vs Energy for ^{4}He Ions on Li and Be

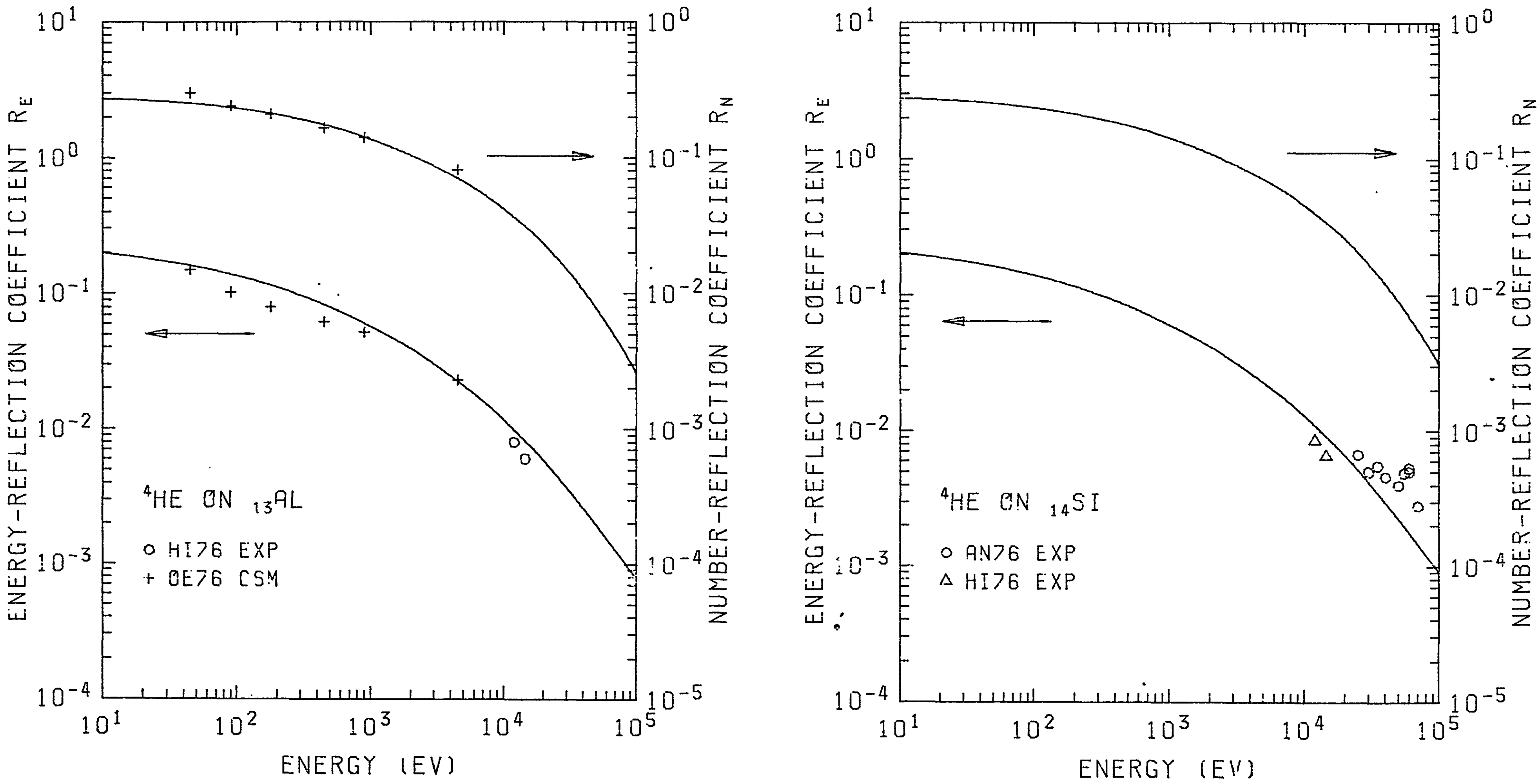
See page 25 for Explanation of Graphs





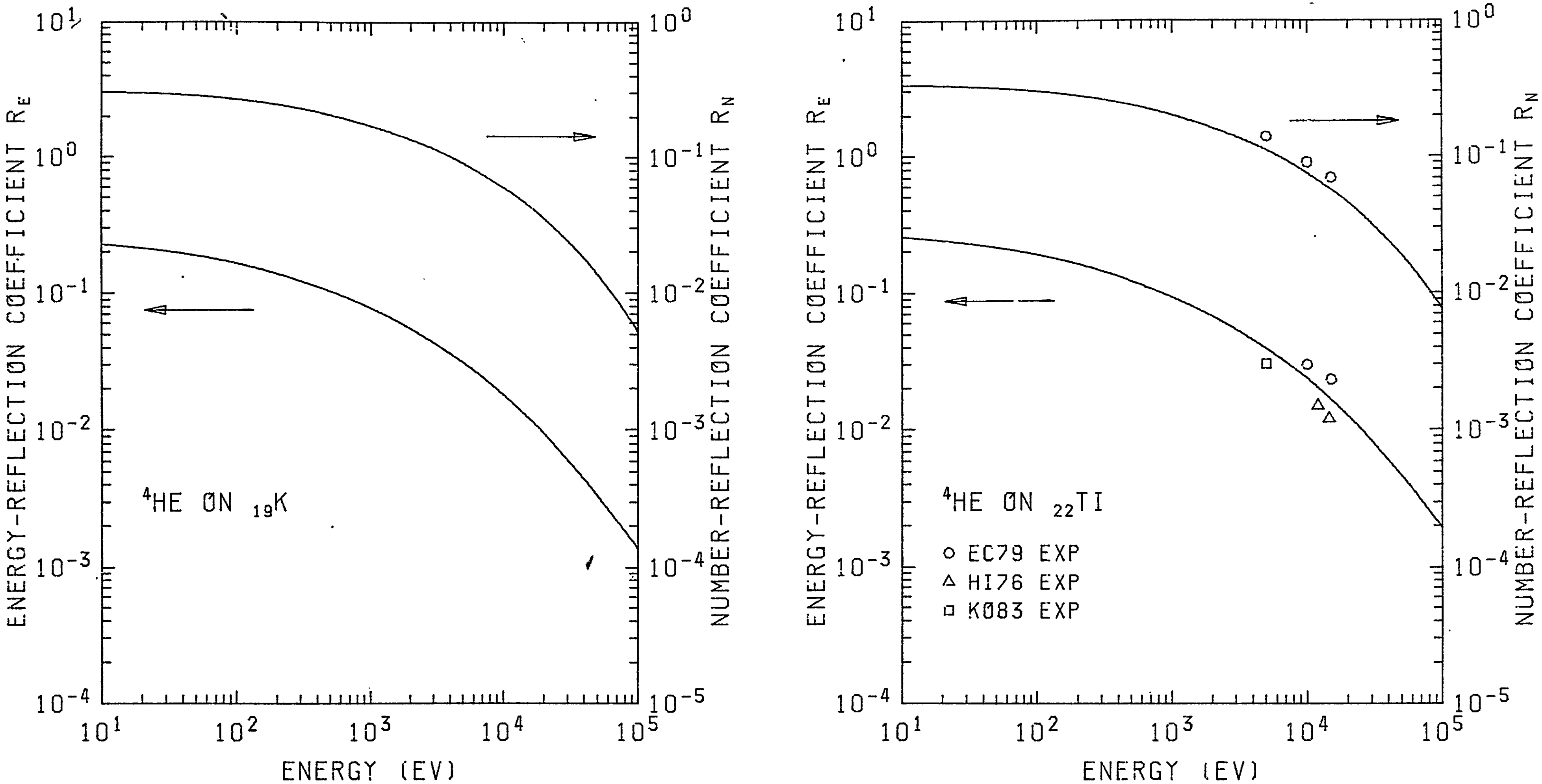
GRAPH V. R_N and R_E vs Energy for ^{4}He Ions on C and Mg

See page 25 for Explanation of Graphs



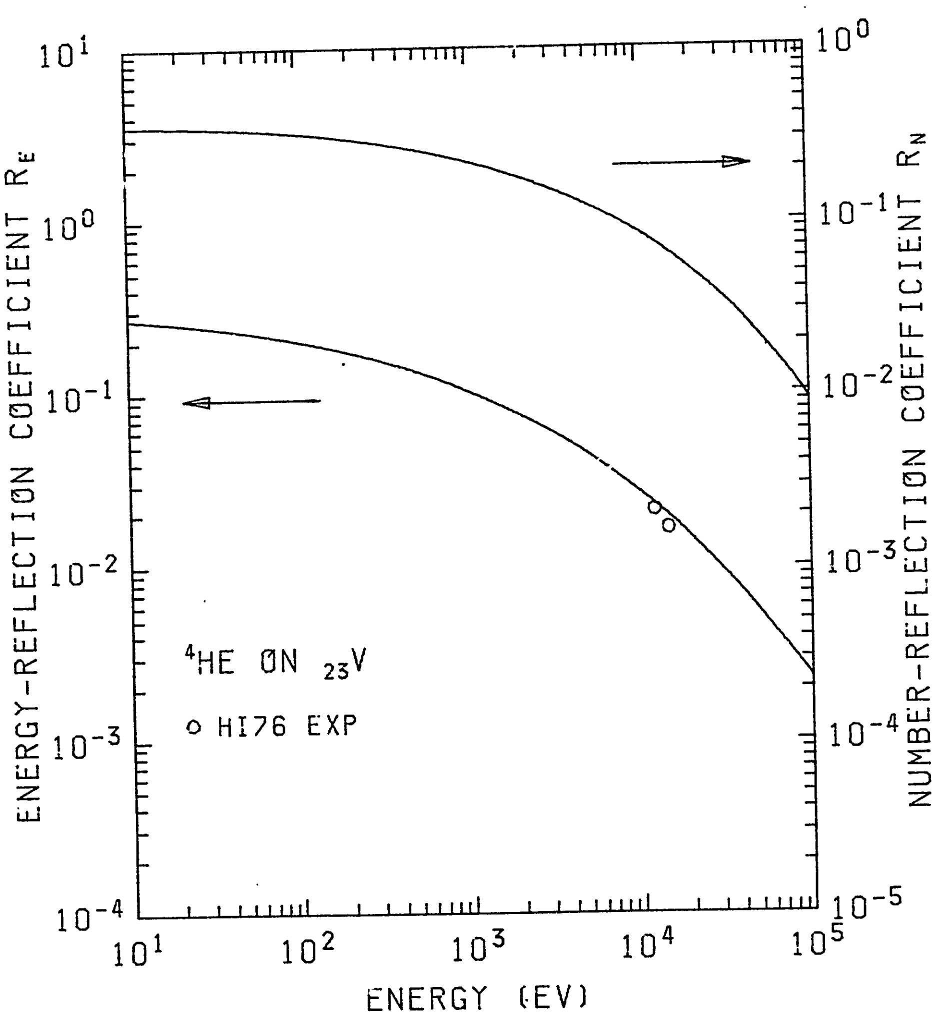
GRAPH V. R_N and R_E vs Energy for ^{4}He Ions on Al and Si

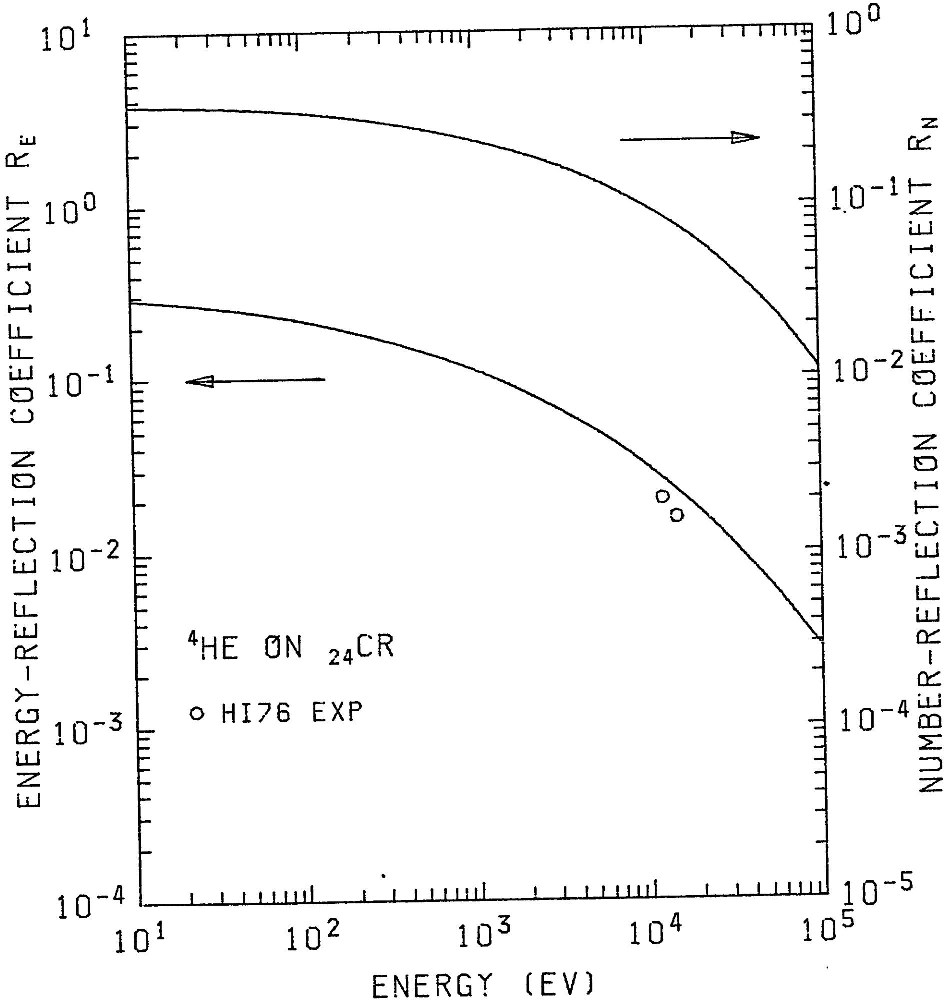
See page 25 for Explanation of Graphs



GRAPH V. R_N and R_E vs Energy for ^{4}He Ions on K and Ti

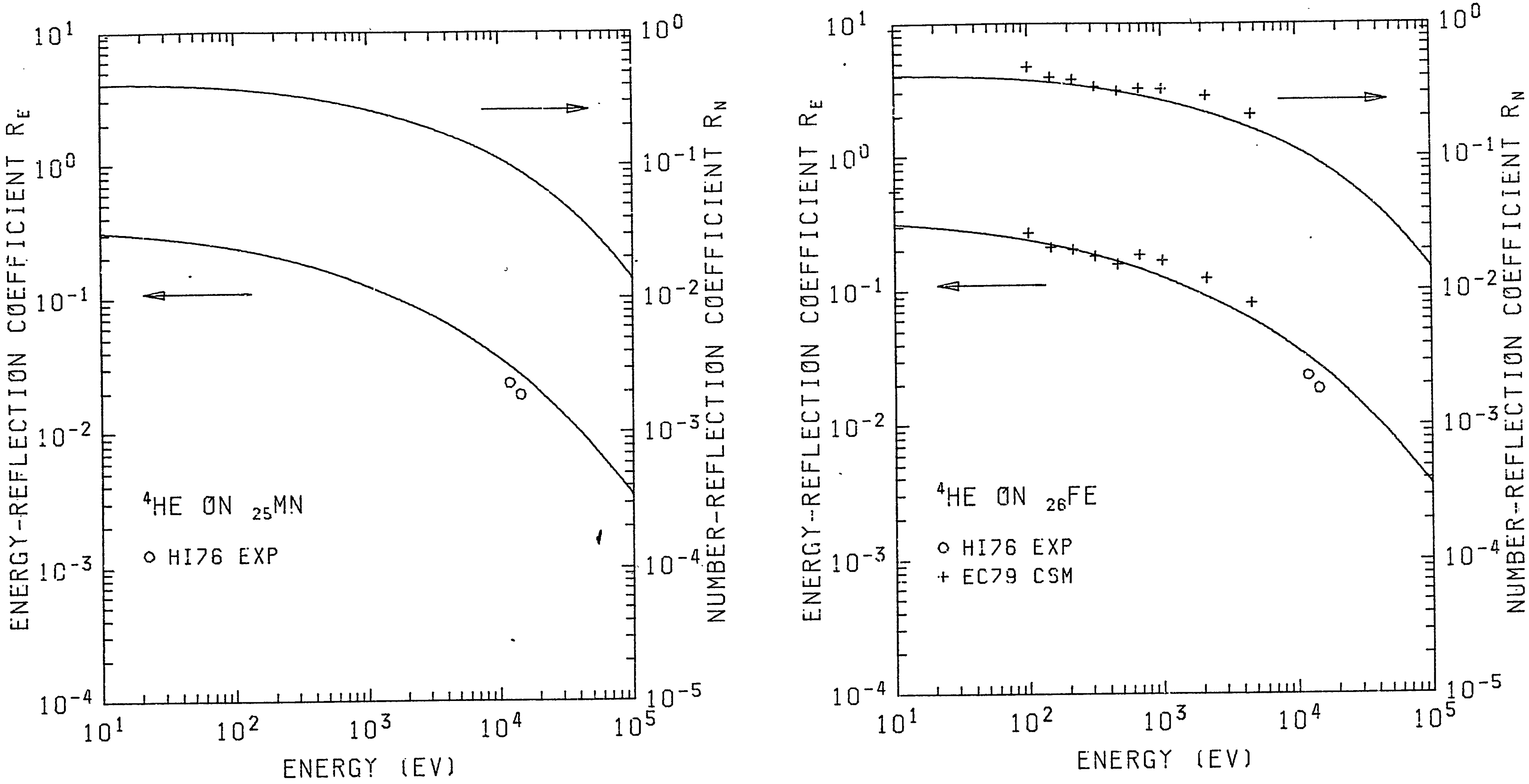
See page 25 for Explanation of Graphs





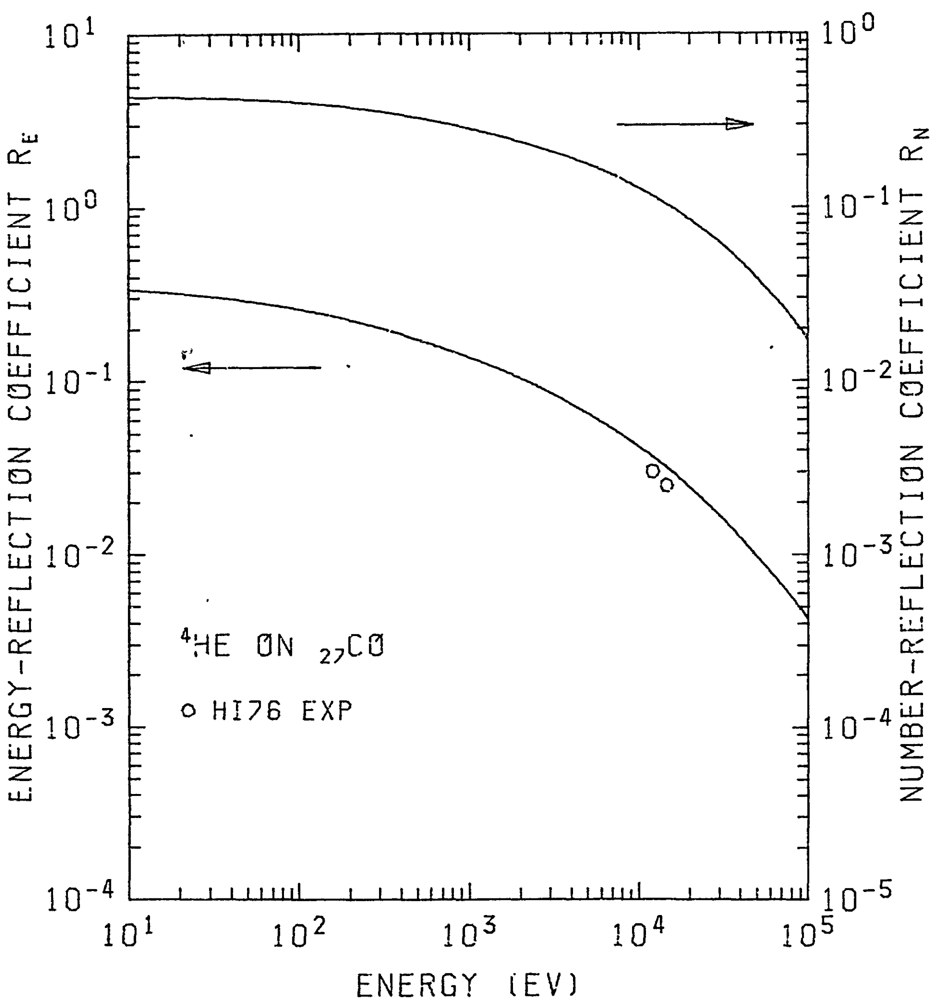
GRAPH V. R_N and R_E vs Energy for ^{4}He Ions on V and Cr

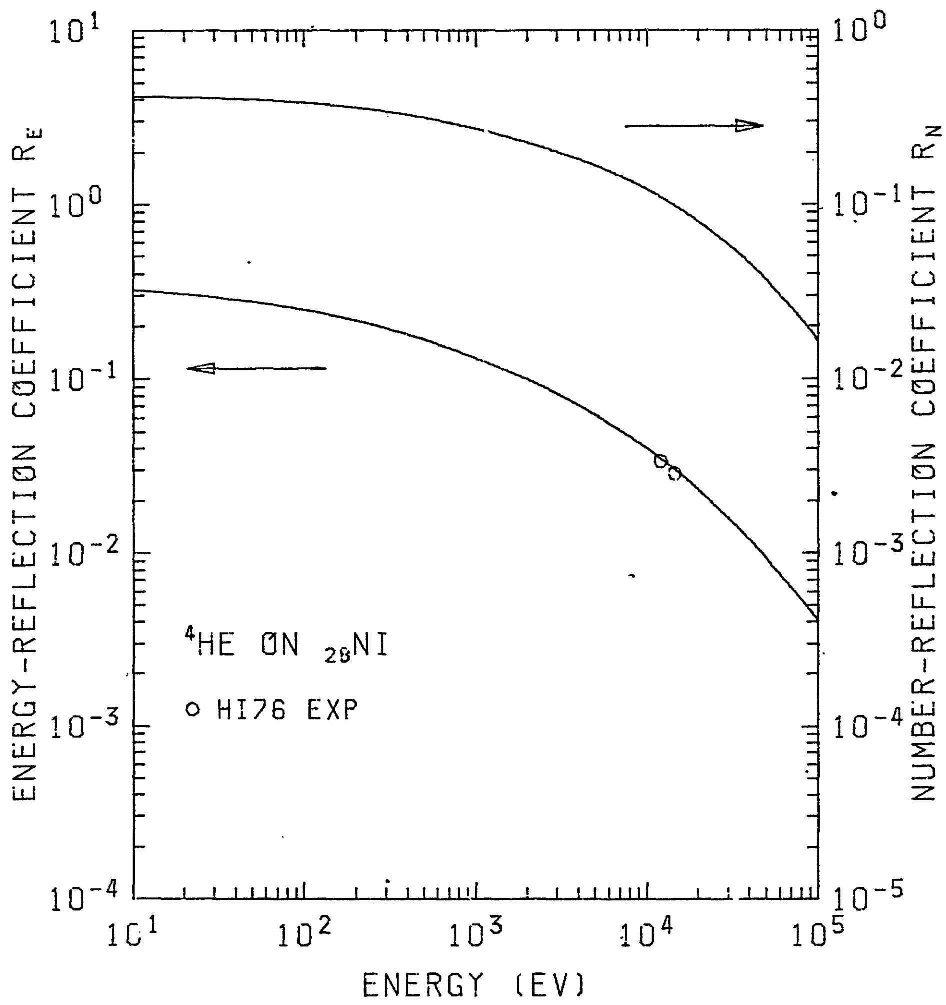
See page 25 for Explanation of Graphs



GRAPH V. R_N and R_E vs Energy for ^{4}He Ions on Mn and Fe

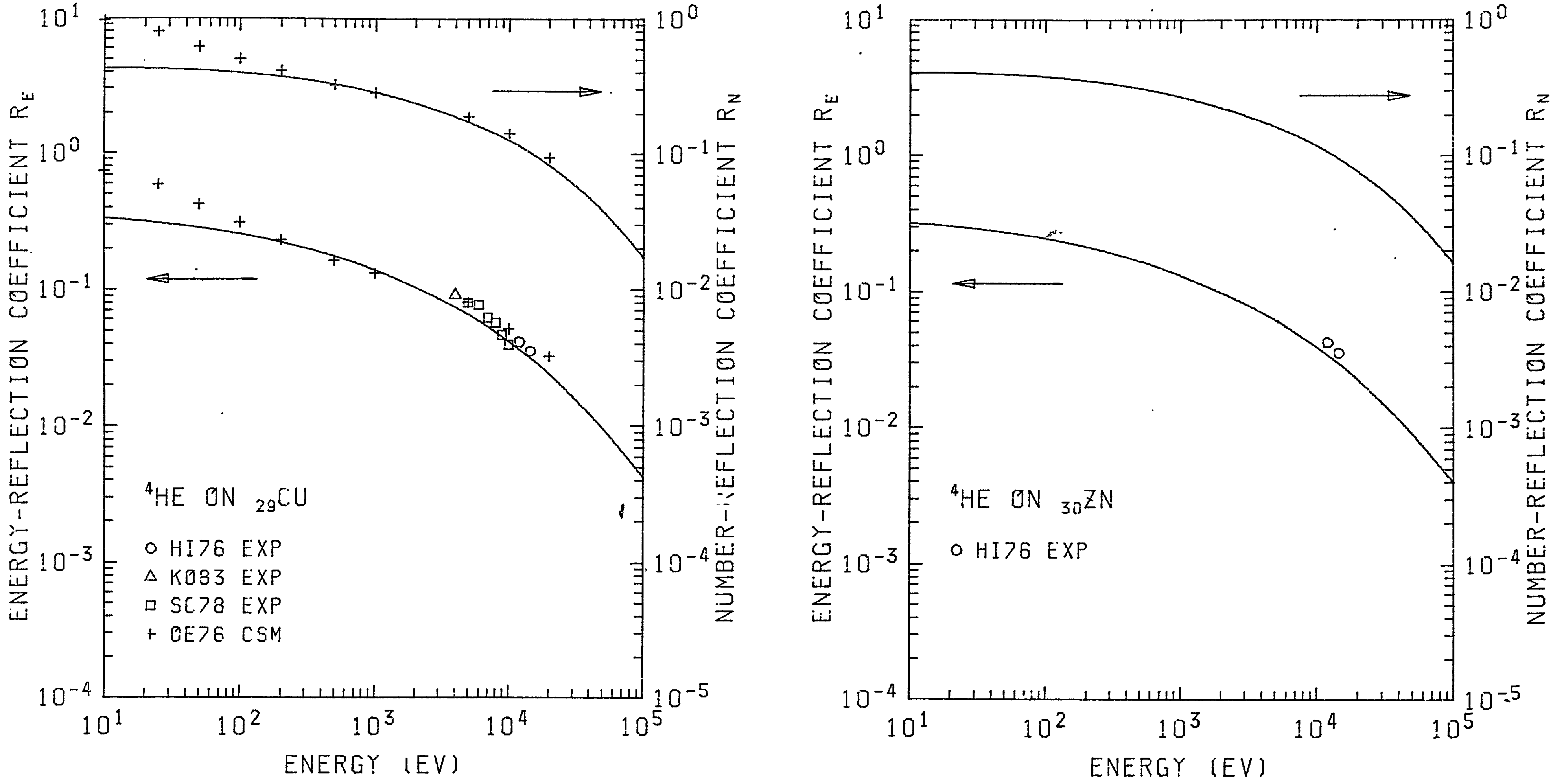
See page 25 for Explanation of Graphs





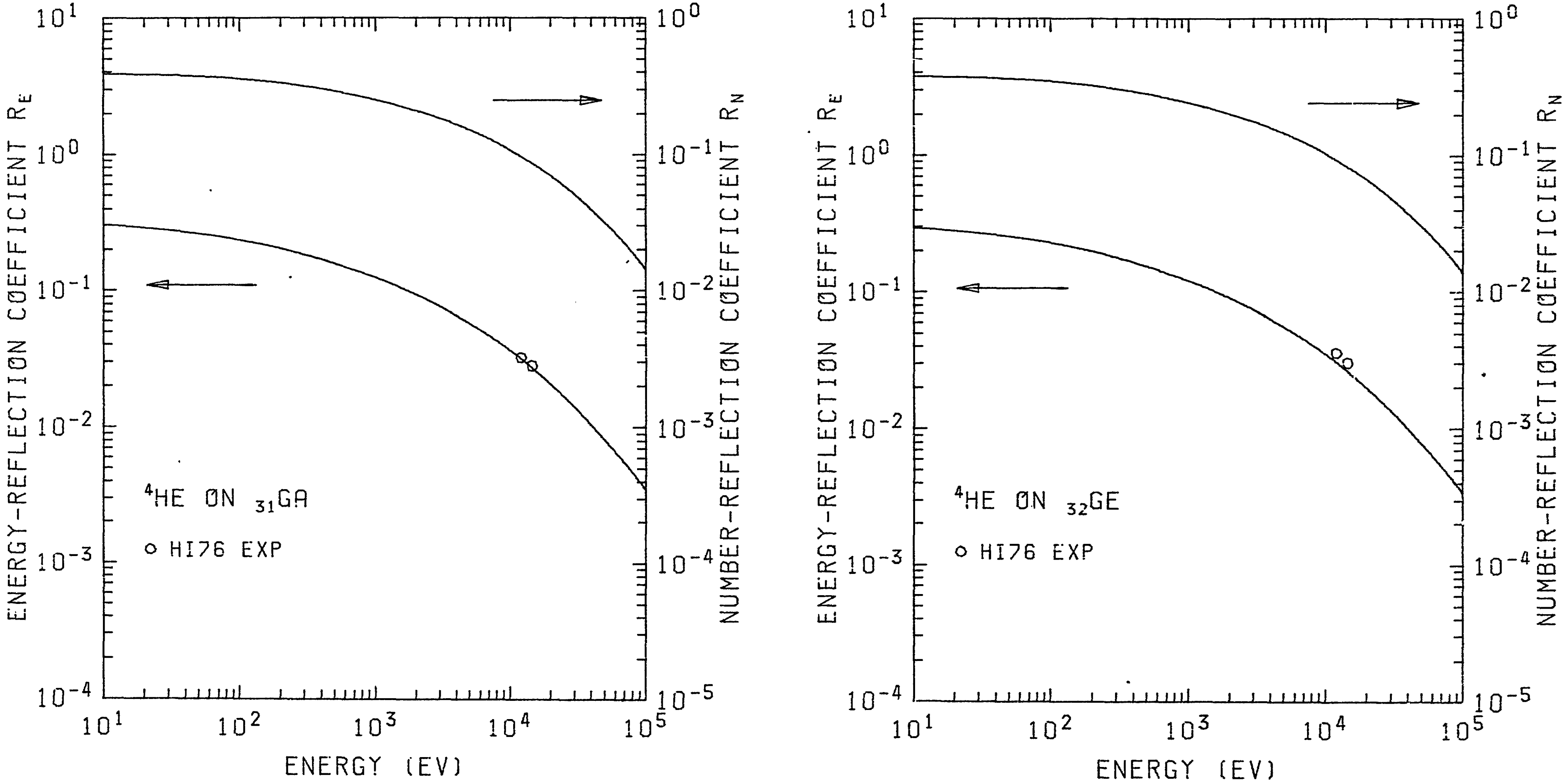
GRAPH V. R_N and R_E vs Energy for ^{4}He Ions on Co and Ni

See page 25 for Explanation of Graphs



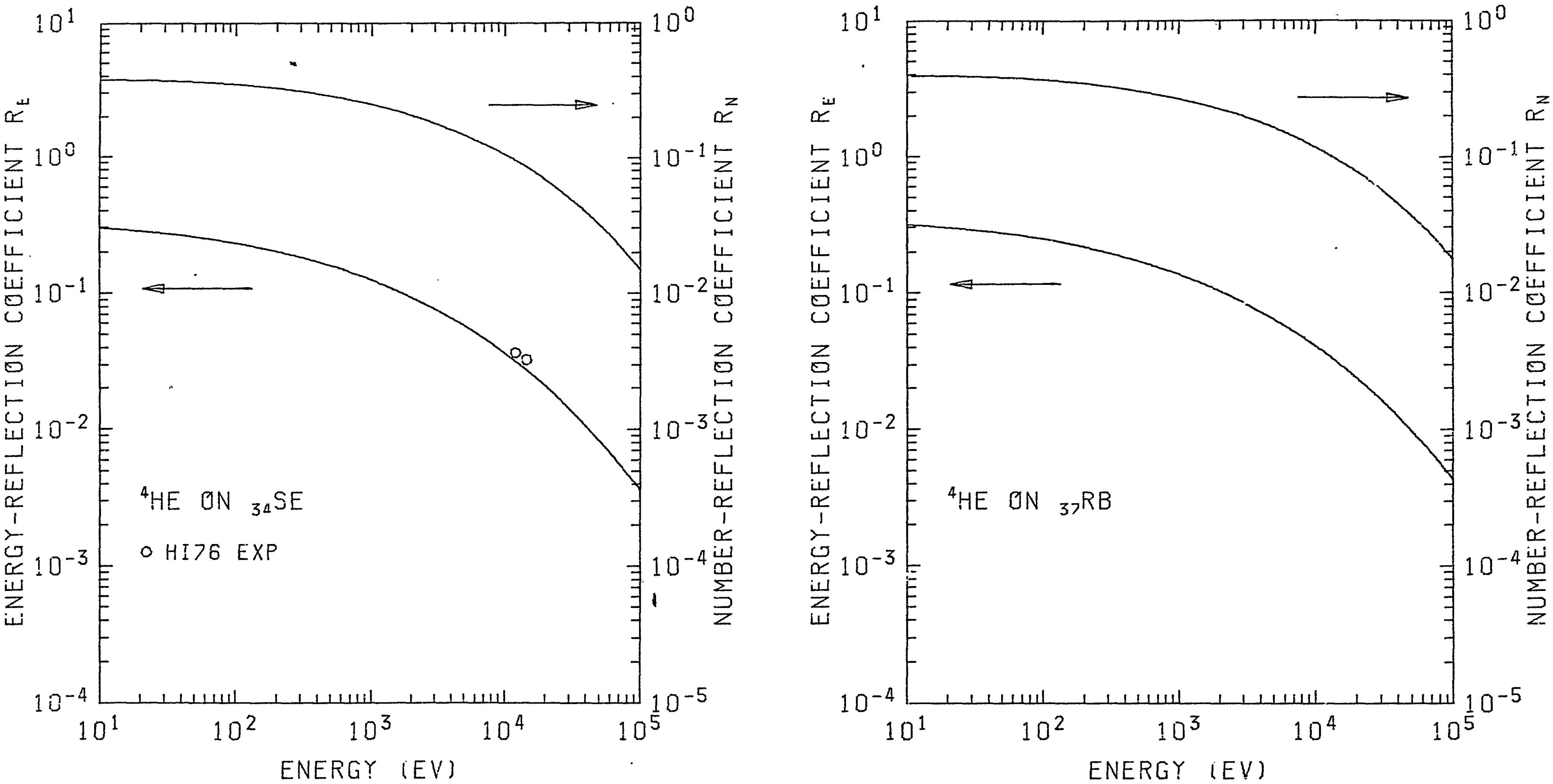
GRAPH V. R_N and R_E vs Energy for ^{4}He Ions on Cu and Zn

See page 25 for Explanation of Graphs



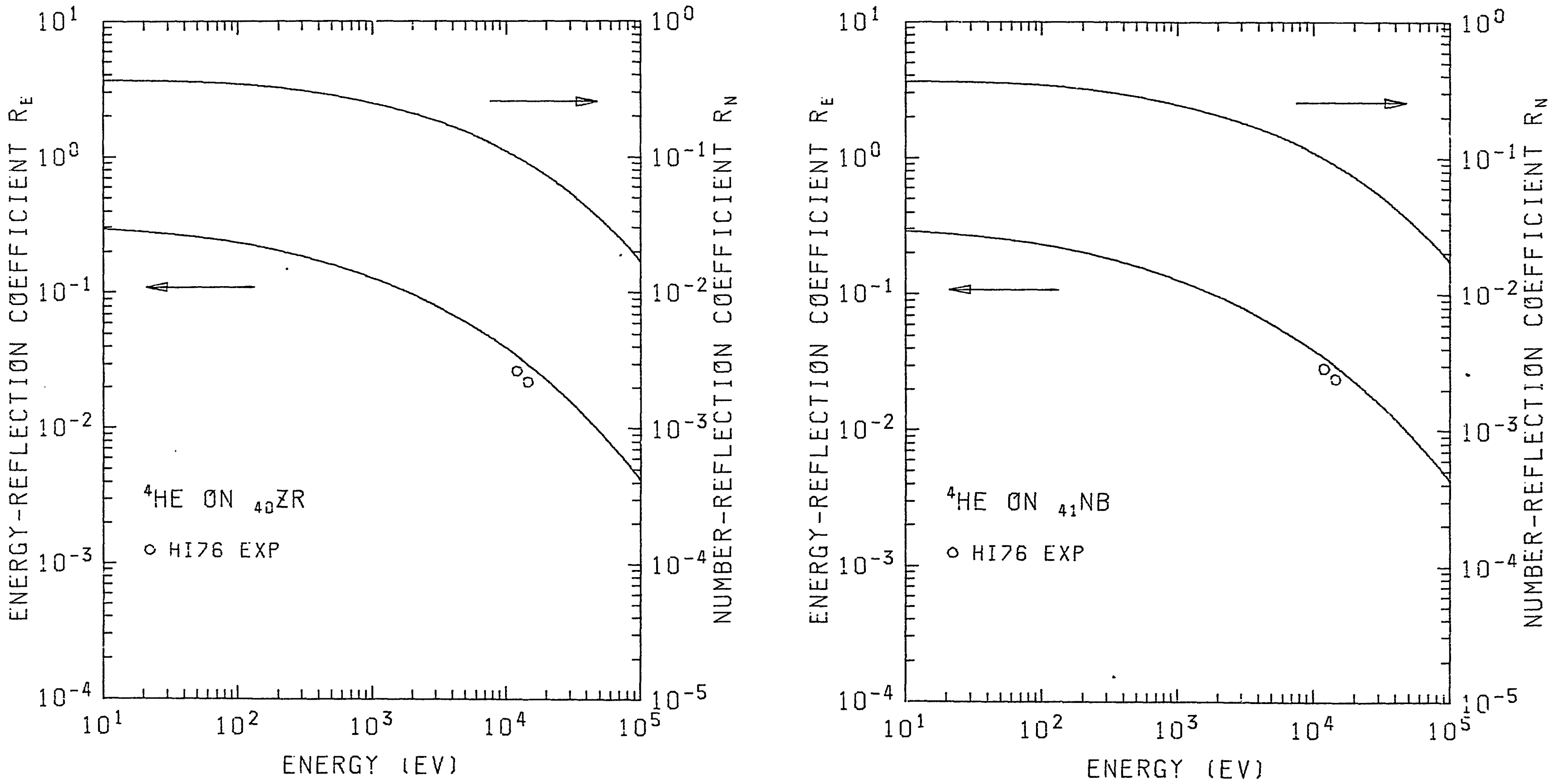
GRAPH V. R_N and R_E vs Energy for ^{4}He Ions on Ga and Ge

See page 25 for Explanation of Graphs



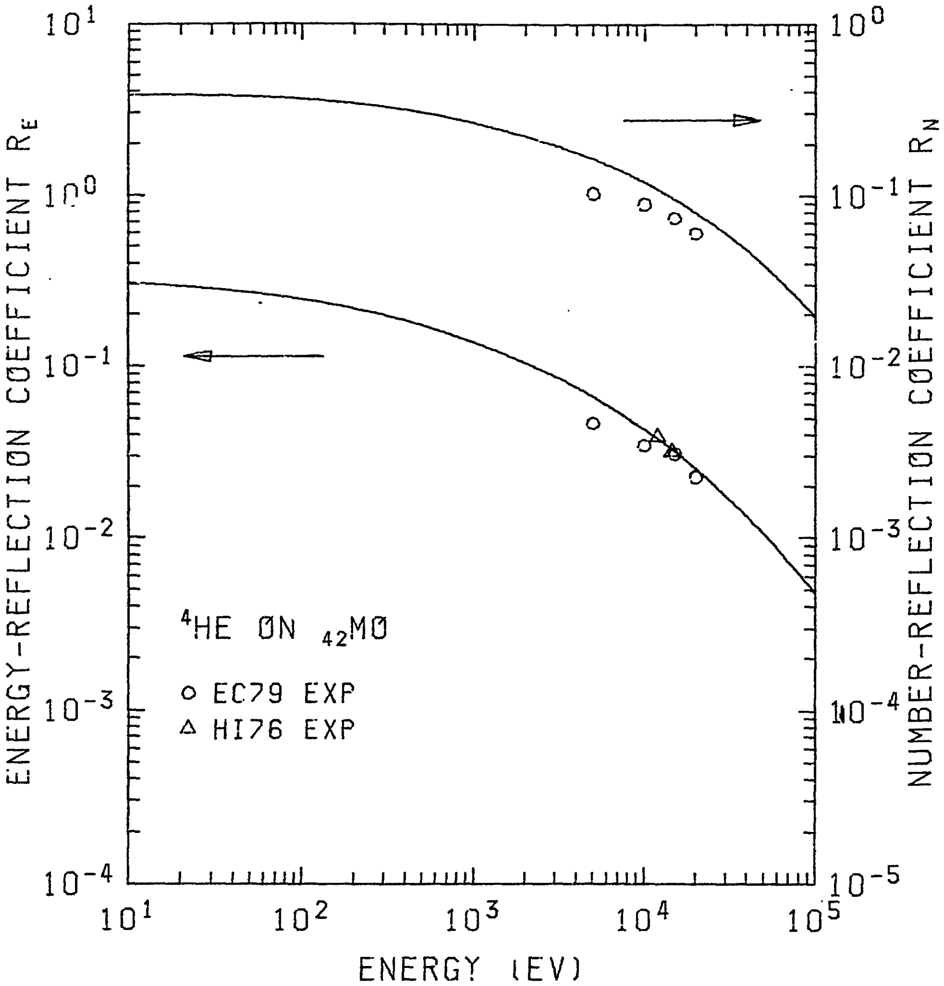
GRAPH V. R_N and R_E vs Energy for ^{4}He Ions on Se and Rb

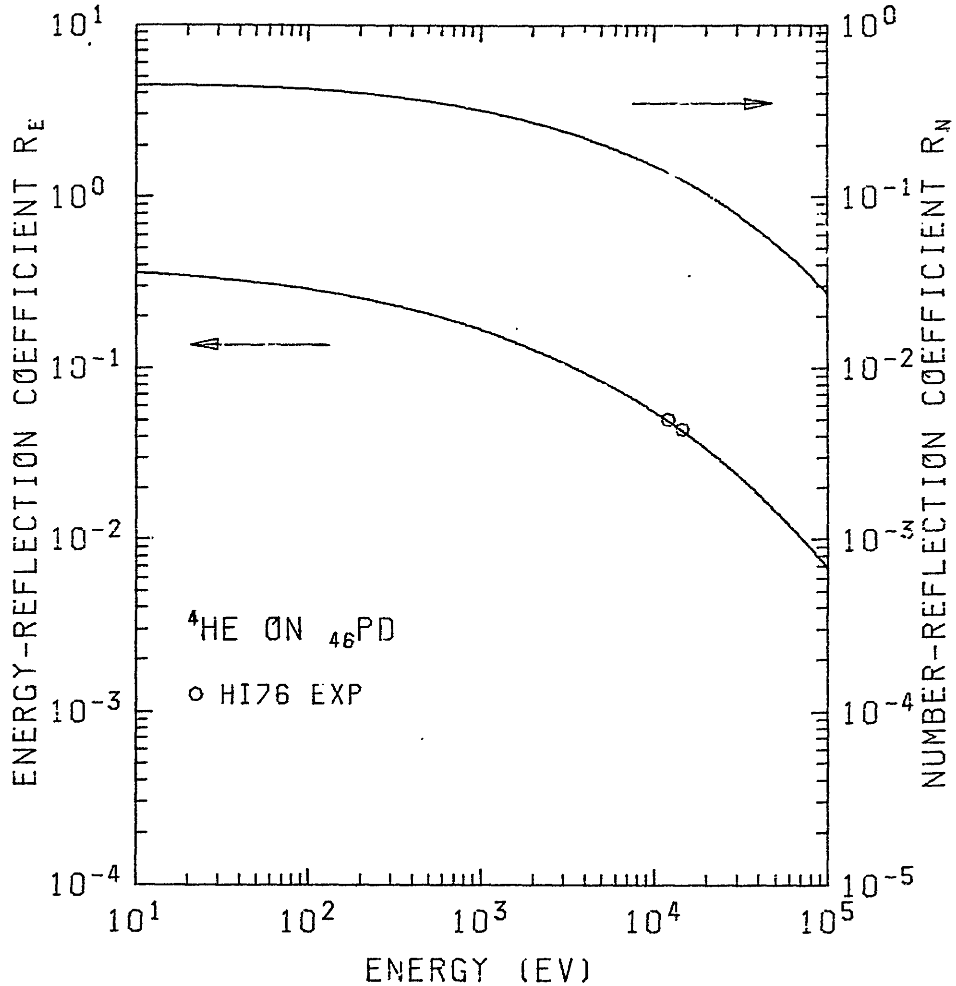
See page 25 for Explanation of Graphs



GRAPH V. R_N and R_E vs Energy for ^{4}He Ions on Zr and Nb

See page 25 for Explanation of Graphs





GRAPH V. R_N and R_E vs Energy for ^{4}He Ions on Mo and Pd

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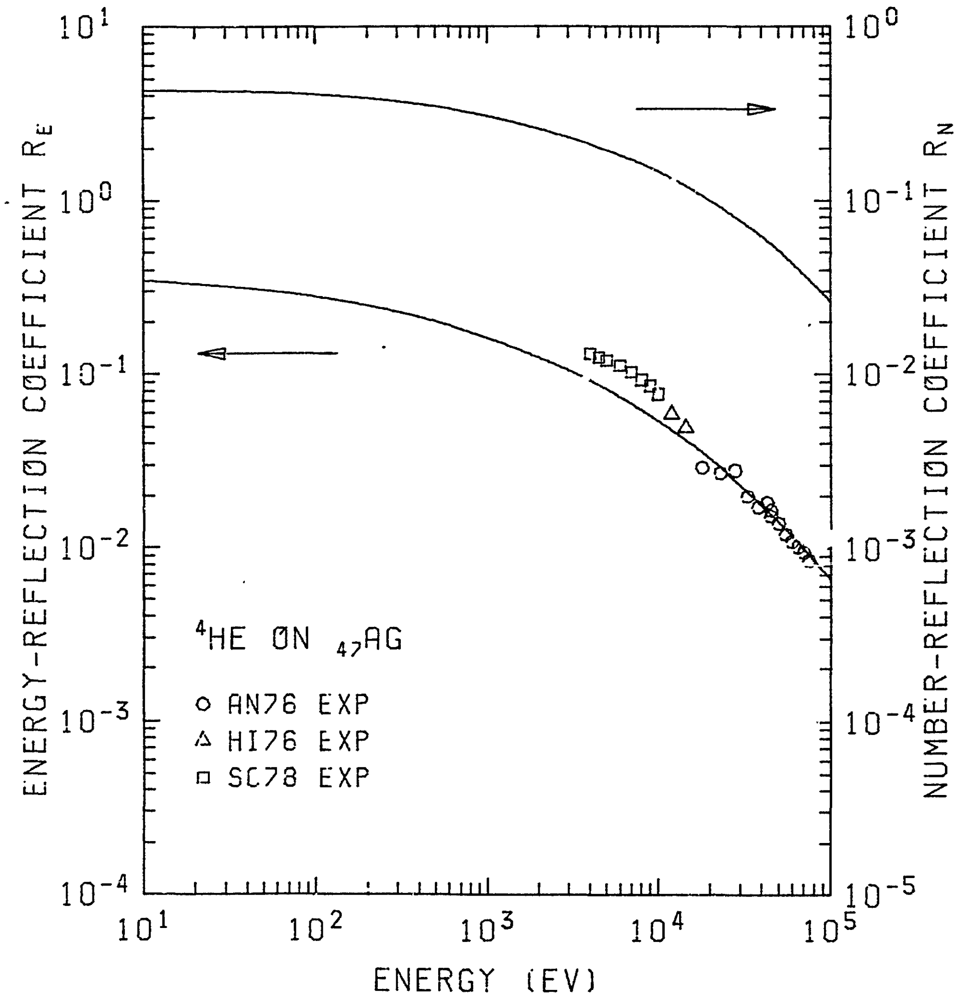

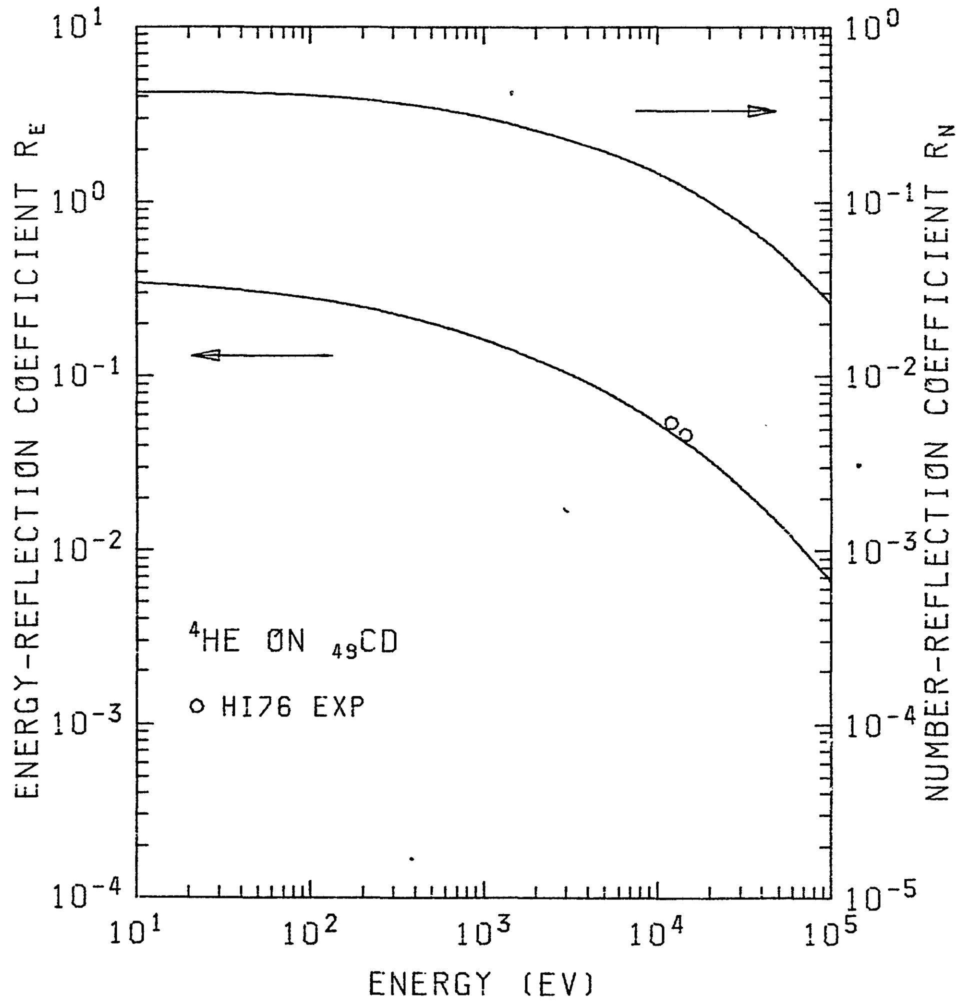

GRAPH V. R_N and R_E vs Energy for ^{4}He Ions on Ag and Cd

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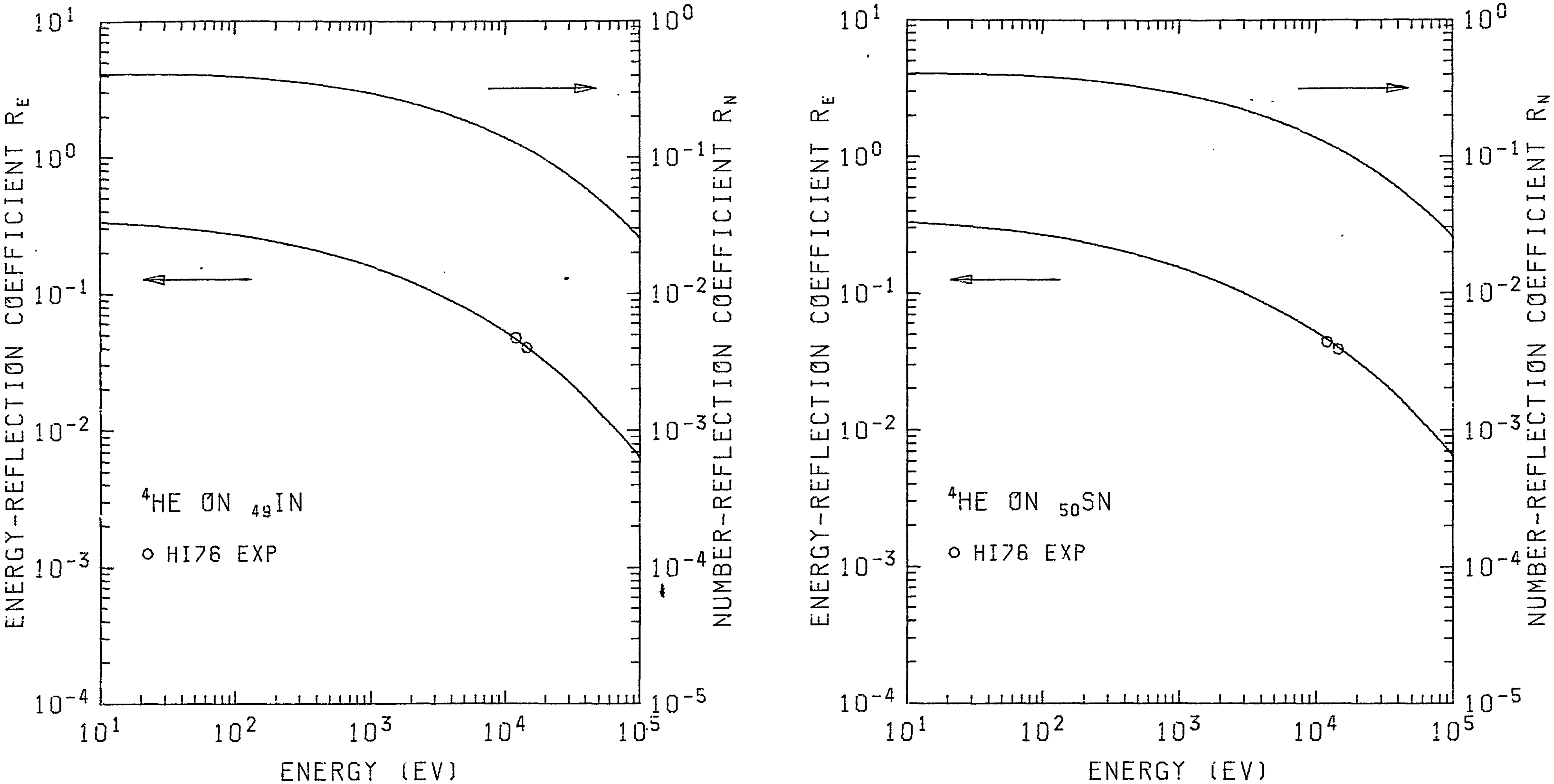

GRAPH V. R_N and R_E vs Energy for ^{4}He Ions on In and Sn

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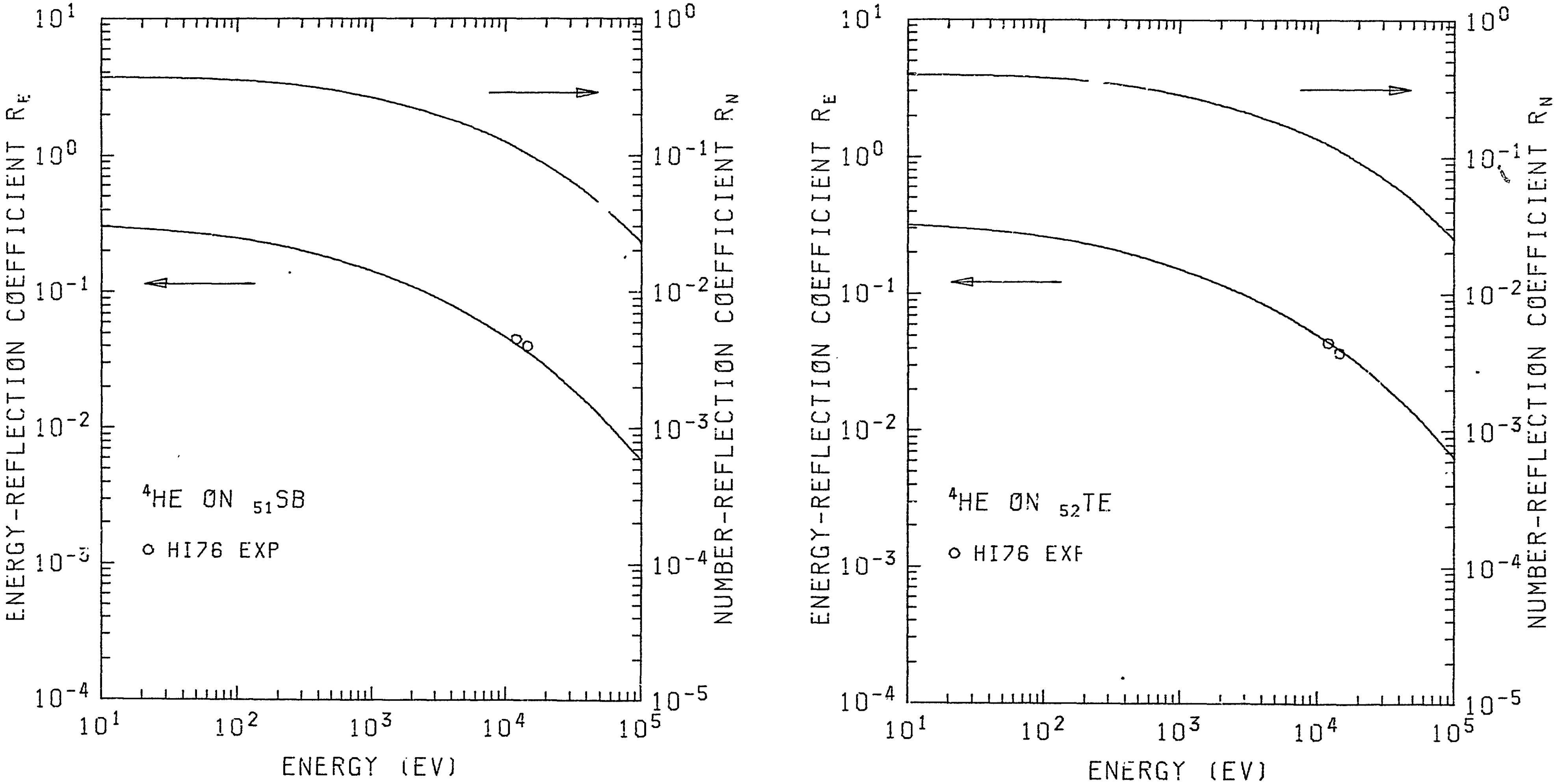

GRAPH V. R_N and R_E vs Energy for ^{4}He Ions on Sb and Te
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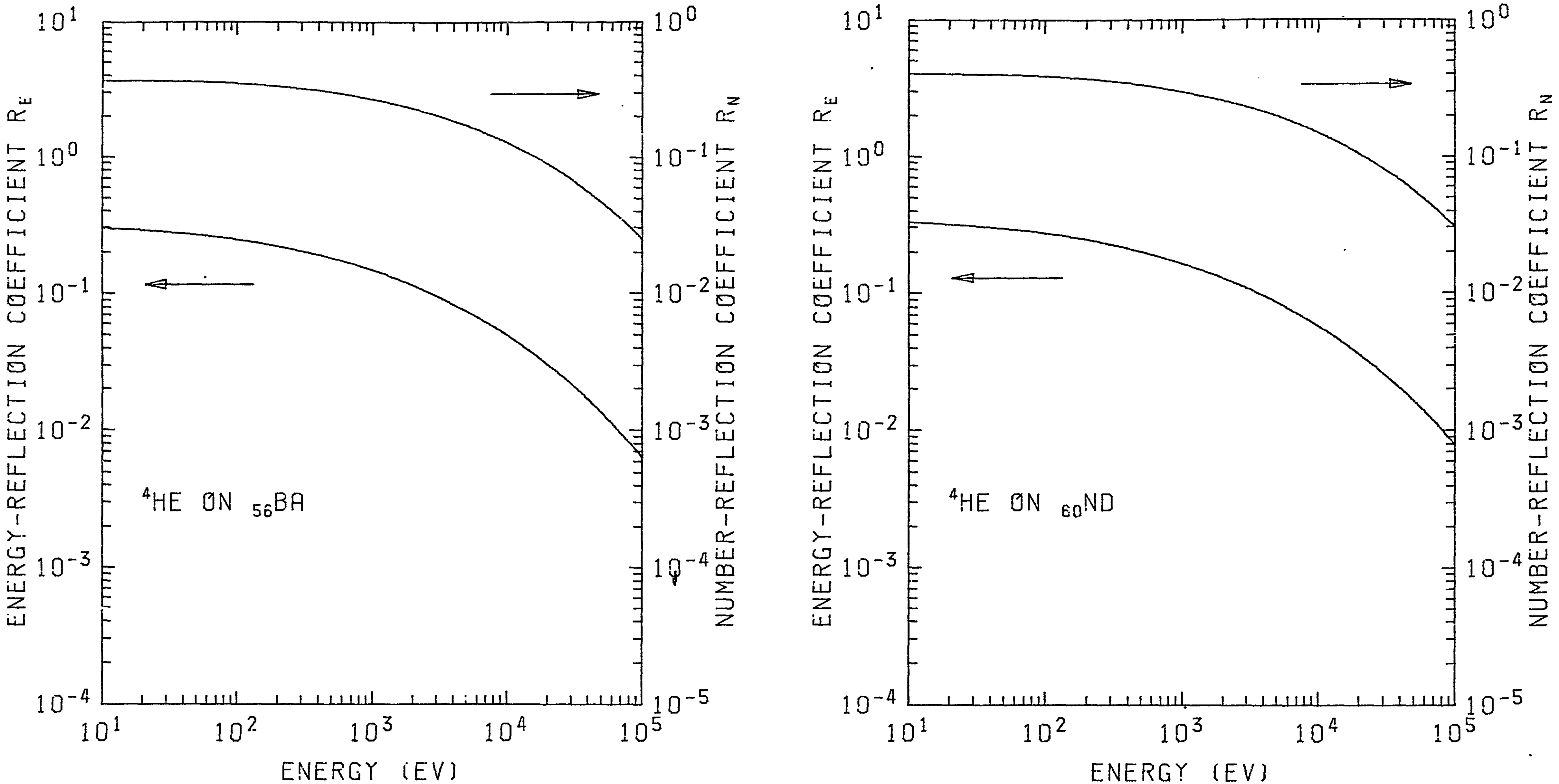

GRAPH V. R_N and R_E vs Energy for ^{4}He Ions on Ba and Nd

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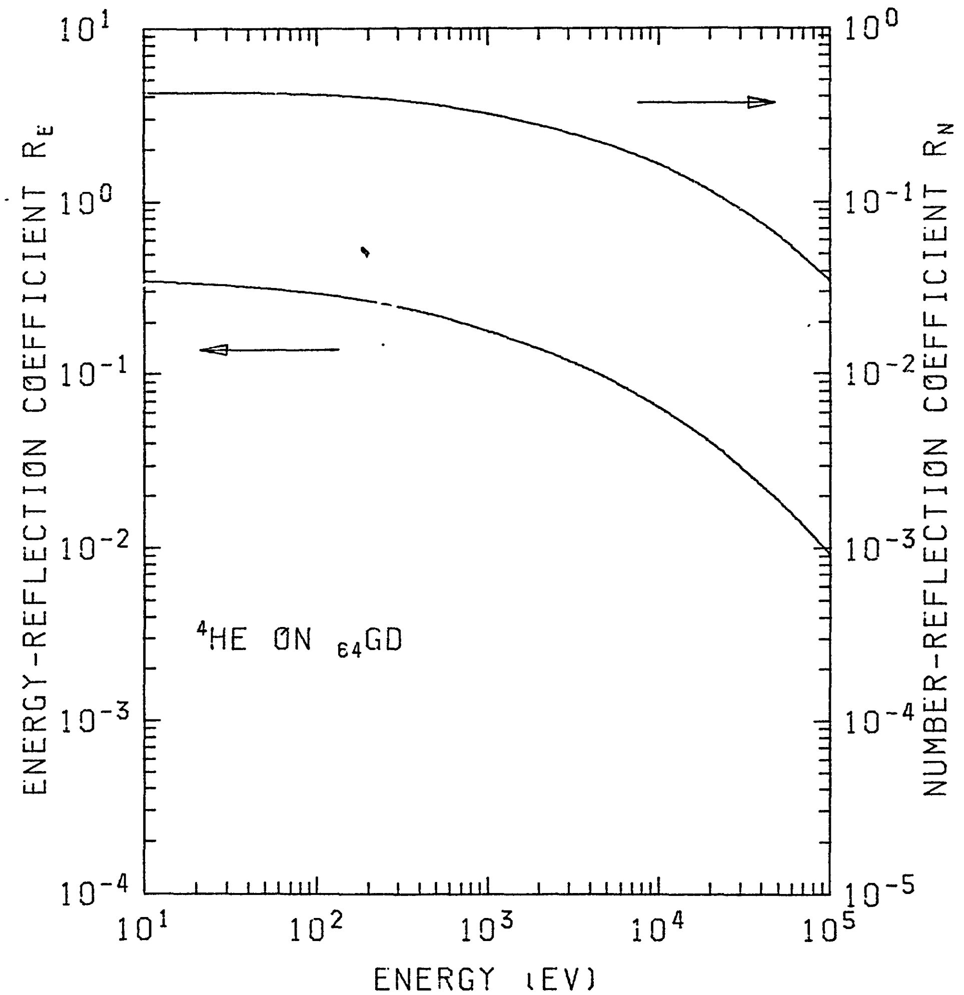

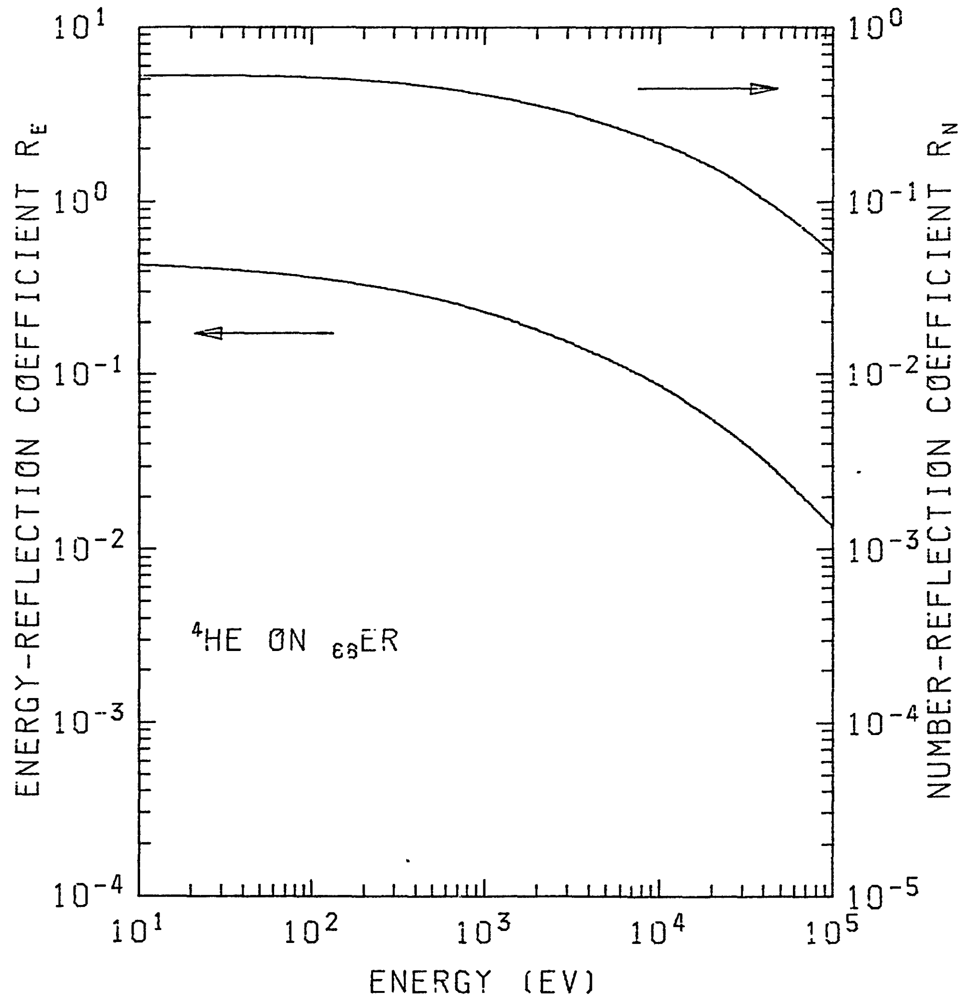

GRAPH V. R_N and R_E vs Energy for ^{4}He Ions on Gd and Er

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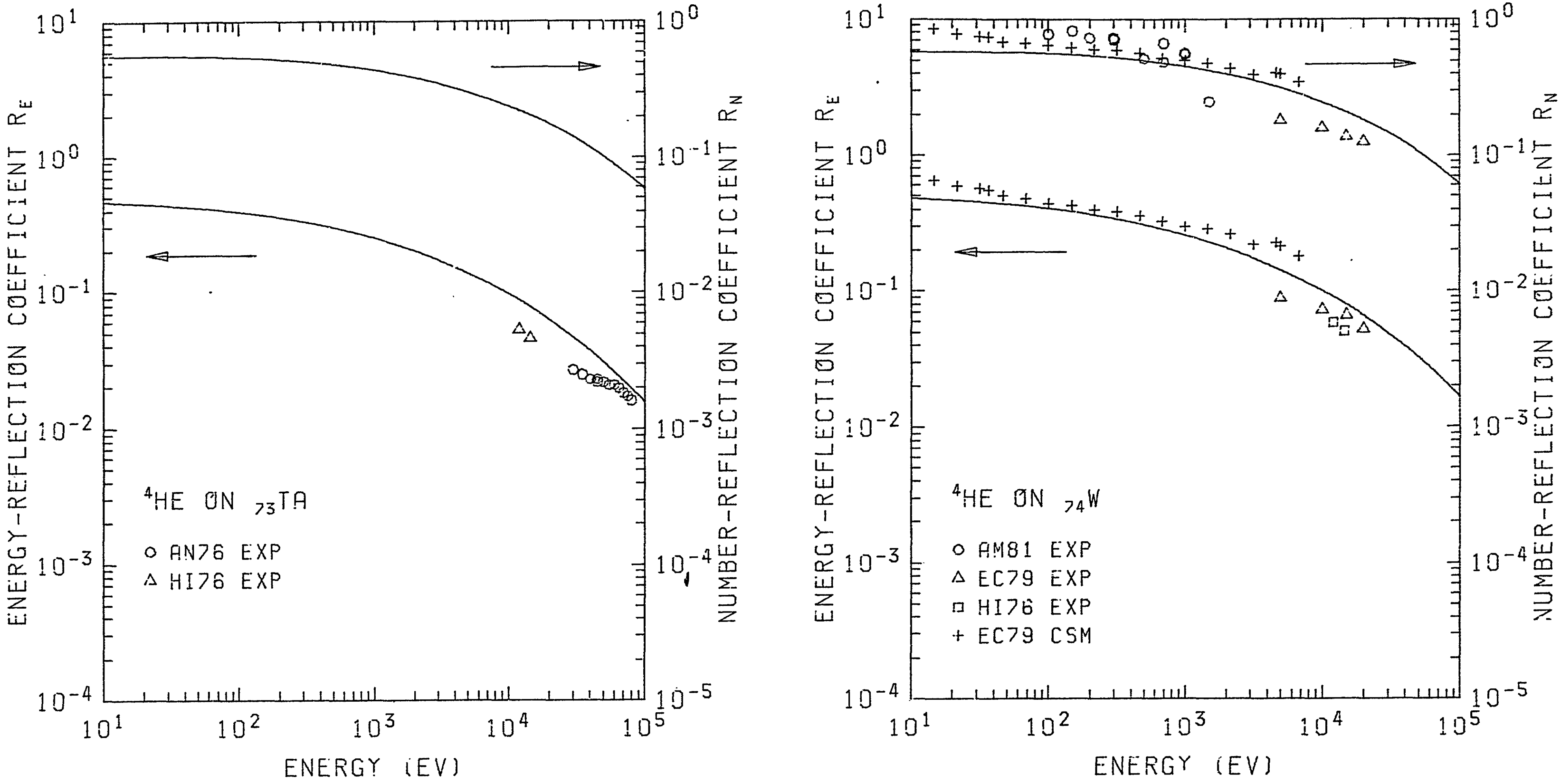

GRAPH V. R_N and R_E vs Energy for ^{4}He Ions on Ta and W

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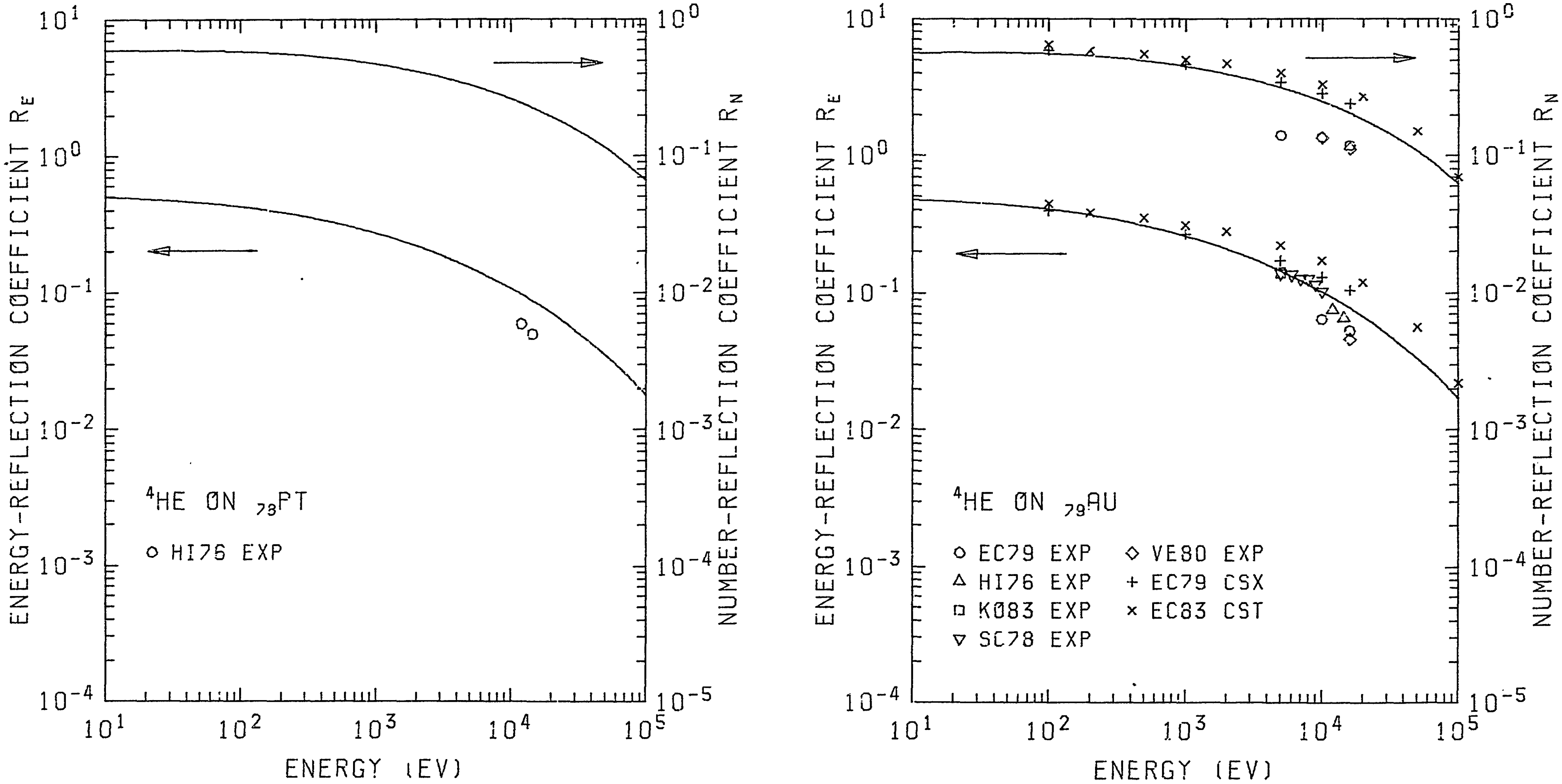

GRAPH V. R_N and R_E vs Energy for ^{4}He Ions on Pt and Au
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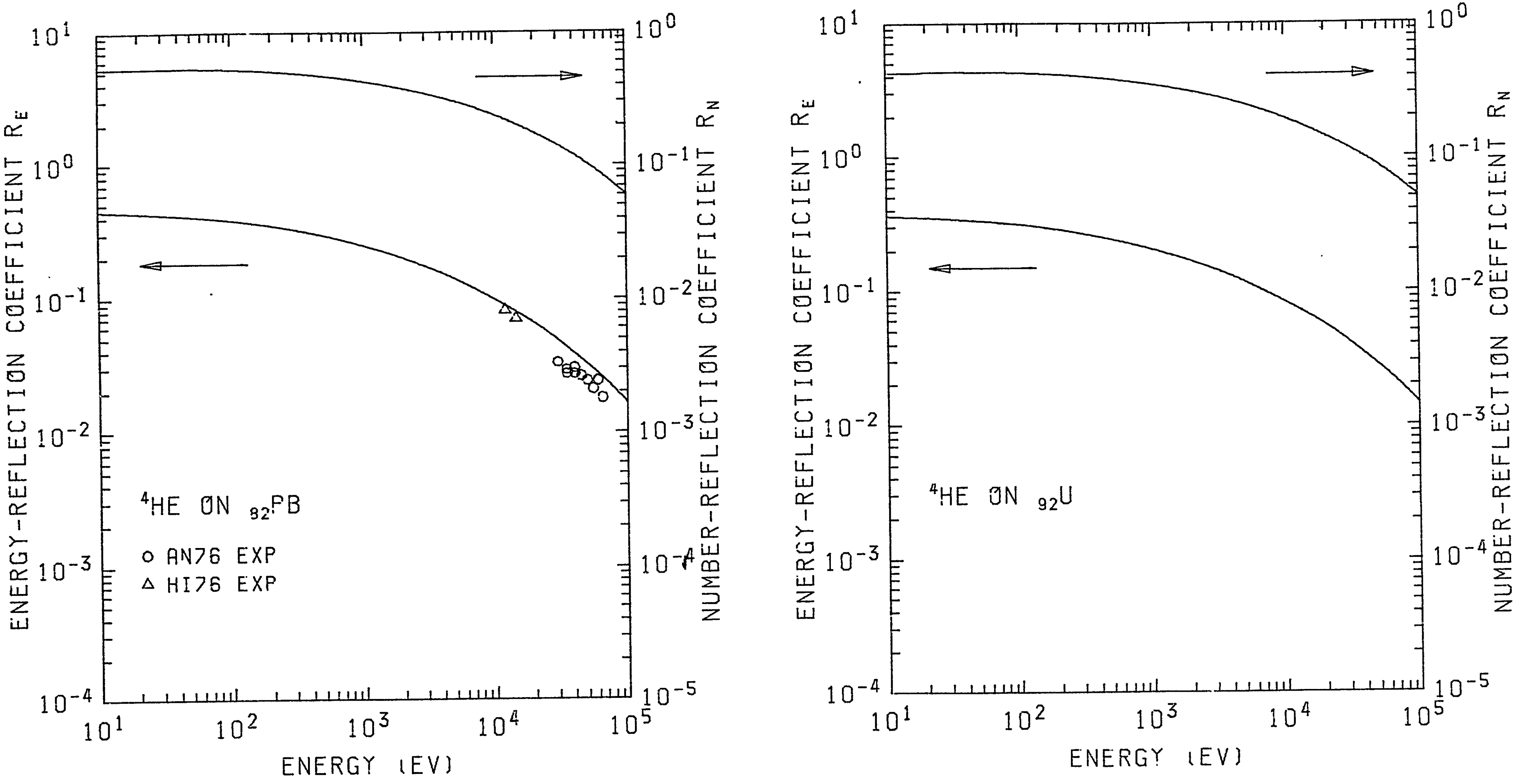

GRAPH V. R_N and R_E vs Energy for ^{4}He Ions on Pb and U

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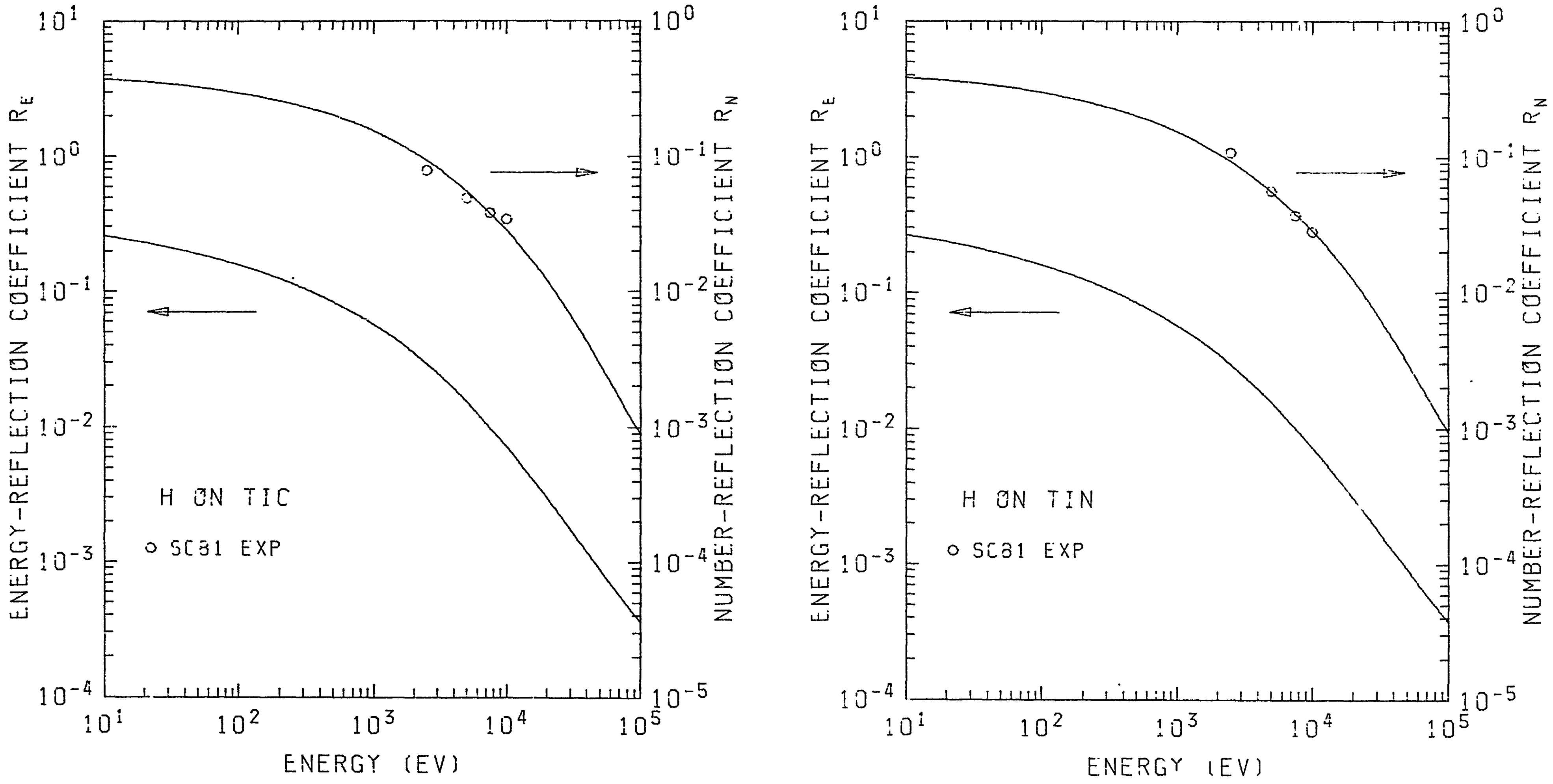

GRAPH VI. R_N and R_E vs Energy for H Ions on TiC and TiN

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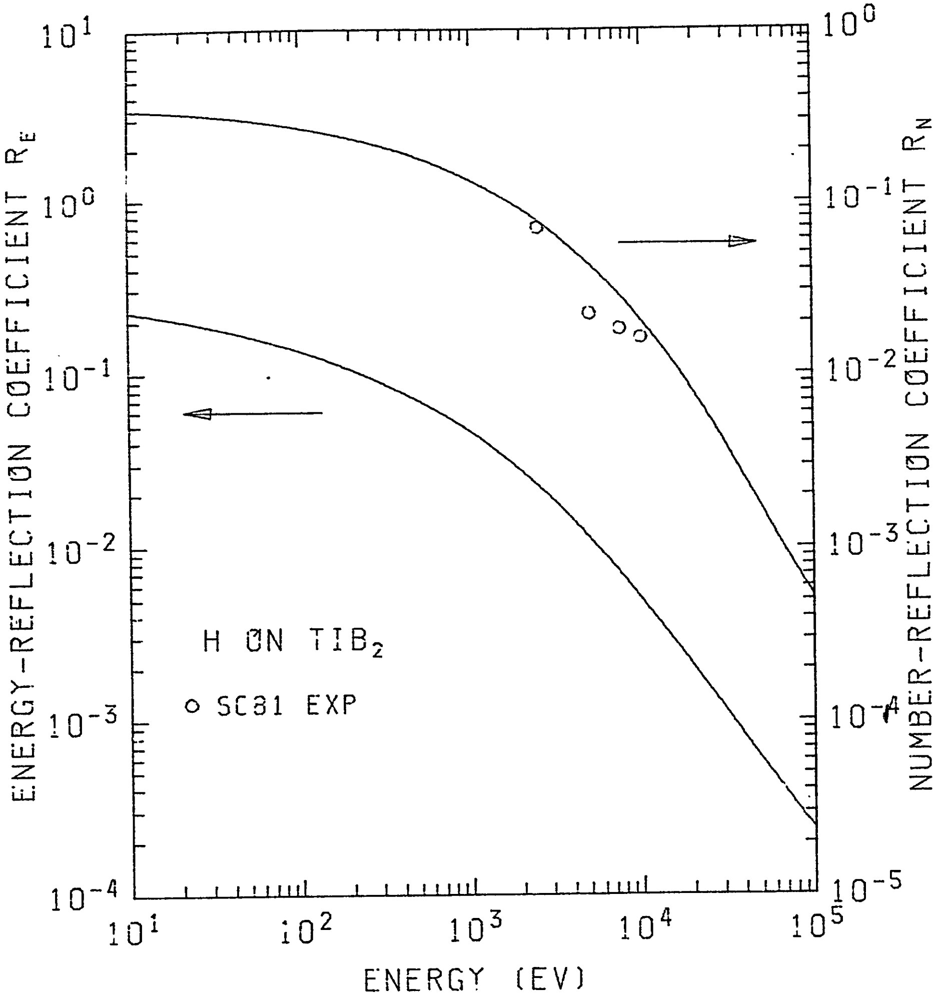

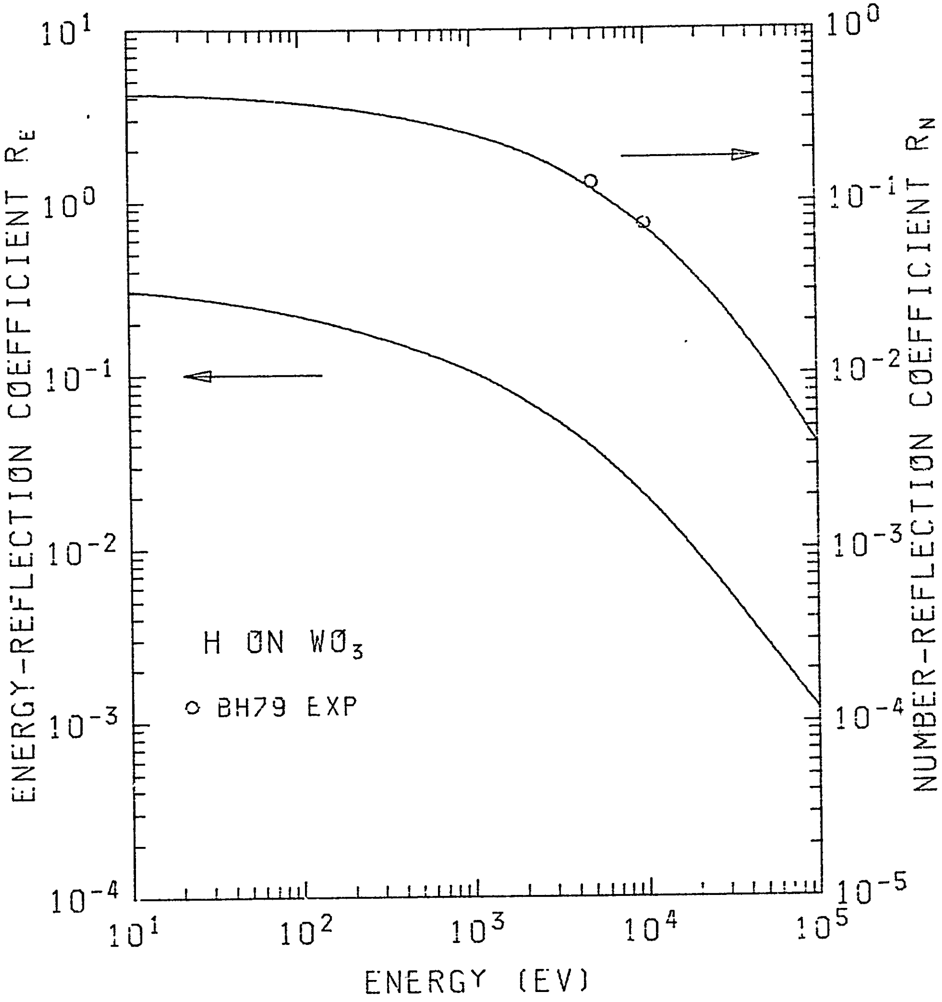

GRAPH VI. R_N and R_E vs Energy for H Ions on TiB_2 and WO_3

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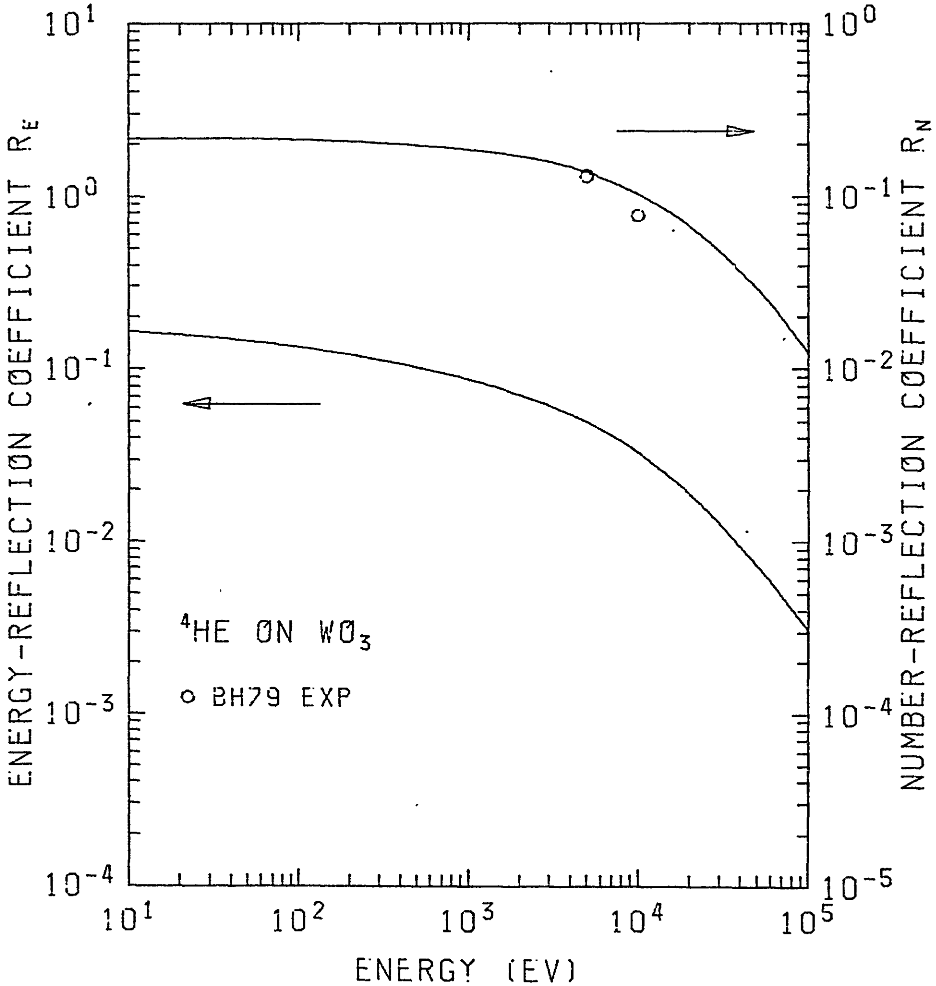

GRAPH VI. R_N and R_E vs Energy for ^4He Ions on WO_3
See page 25 for Explanation of Graphs

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