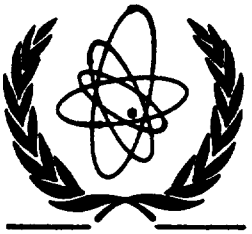

International Atomic Energy Agency

INDC(NDS)-385

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Critically Assessed Electron-Impact Excitation Cross Sections for He (1^1S)

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November 1998

IAEA NUCLEAR DATA SECTION, WAGRAMERSTRASSE 5, A-1400 VIENNA

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ABSTRACT

In this paper we reconsider the previous assessment of collision strengths, now mostly presented as cross sections, for excitation of He (1^1S) to He ($n^{1,3}L$) states (n=2-4, L=0-3). Due to the appearance of additional theoretical results the assessment can now be often given within smaller error limits than before for the singlet levels, as well as for the lower triplet levels (n=2). For the higher excited triplet states more studies are desirable to reduce the possible errors.

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1. INTRODUCTION

In a previous paper [1] we have given an assessment of electron impact cross-section data for excitation of helium from the 1^1S state to $n^{1,3}L$ states (n=2-6), based on the experiment, in the energy range between about 30 and 2000 eV electron impact energy, and on the available theoretical calculations. For the experiment, we used mostly the results from photon emission. For the theory, we used the R-matrix 29-state (Rm 29) close coupling (CC) data with impact energy between the excitation threshold and the ionization energy, averaged over 0.02 Rydbergs, and the first Born approximation at high energies, valid for singlet state excitation. The theory was considered sufficiently accurate (better than 5-10 percent) in the impact energy range used. The experimental data for singlet excitation often showed good accuracy (better than 10 percent), but for the 2^1S state (from differential scattering) and n^1D states we could not guarantee accuracy better than, generally, 20 to 30 percent. In the case of triplet excited states, the accuracy was not better than about 30 percent in the experiment, or even less at relatively high energies.

In the mean time, more theoretical work has been performed, which enables us to reconsider and improve the accuracy in the assessment of the excitation cross-sections. This work includes: the convergent close-coupling (CCC) calculations (CCC69 and CCC75, with inclusion of 69 and 75 states, respectively) of Fursa and Bray [2] over the entire energy range, the more complete Rm 29 CC data of Sawey and Berrington [3], between threshold and 34 eV (but only usable below the ionization threshold), the results for the transitions to n=2 and n=3 levels with the pseudostates R-matrix (RMPS) method by Bartschat et al. [4] (improving the Rm 29 data above the ionization threshold by inclusion of pseudostates for the continuum) between threshold and 80 eV, and the Ochkur and Coulomb-Born with Exchange (CBE) calculations of Shevelko [5]. A review of some of these theoretical results, compared with the experiment, has been given recently by Fursa and Bray [6], that includes both differential and total excitation cross-sections, as well as the electron impact coherence parameters. Generally, in our improved assessment we shall consider Rm 29 CC results up to the ionization threshold (where it is more accurate than RMPS and CCC), RMPS2 for excitation to n=2 levels up to 80 eV, RMPS3 for excitation to n=3 (including n=2) levels up to 40 eV, CCC69 and CCC75 data everywhere, preferring the CCC69 data for excitation of S and P states, and CCC75 data for the excitation of D and F states (according to I. Bray, private communication), and the CBE and Ochkur data at higher energies for triplet excitation. The Rm 29 CC data of Berrington [7], used in our previous

paper, were averaged over 0.02 Rydbergs and are consistent with (but less detailed than) those of Sawey and Berrington [3]. The first Born data for excitation to singlet states, used before at high energies [1], can be retained.

Since the appearance of reference [1], new cross sections have been obtained for different n=2 and n=3 levels by Trajmar and co-workers by using their measured angular differential scattering cross sections for inelastic (energy loss selected) scattering of electrons [8,9] at 30, 50 and 100 eV impact energy, with quoted errors of about 25 percent. Recently, experimental and theoretical data available through the end of 1996 have been compiled and graphically presented by Kato and Itikawa [10].

We further note that the data of [1] have been parametrically presented by Kato and Janev [11] and have been implemented in the ADAS data base [12].

2. DATA ASSESSMENT

2.1. Excitation to Singlet States

We start to reconsider the tables of reference [1] on the recommended choice of experimental (and empirical) and theoretical cross-sections, making new tables and graphs. (The data numbers contain 5 significant figures, more than corresponding to the possible errors.)

Table 1 shows the cross sections for the 1^1S-2^1S transition. In most of the columns, the values of the cross sections (given in units of 10^{-18} cm^2 ≡ [-18] cm^2) and the collision strengths Omega for both the old and the new assessed data are given. The columns indicated by X[1] and Omega[1] contain the previously assessed data, X and Omega represent the newly assessed data, using some of the theoretical results in the other columns. Column X[1] contains Rm 29 Av data, averaged between the excitation and ionization thresholds, and the data derived from inelastic differential scattering experiments at higher energies, which converge to the first Born results given from 1000-2000 eV. In [1] we quoted the possible error in the energy region between 30 and 700 eV to be about 30 percent at 30 eV, decreasing to 10 percent near the Born region. We see that the new theoretical data in the first five cross-section columns are, generally, in much better agreement than the prescribed 30 percent accuracy in [1], and are in agreement with the data of [1], as well. In our new assessment we choose for recommendation a mixture of RMPS2 and CCC69 data between the ionization threshold and 80 eV, X[1] at 100 eV, and the CCC69 data at higher energies, up to the Born values at 1000 eV. The new assessment does not differ much from the previous one and the error is probably mostly within the aimed limit of 10

percent.

For the 1^1S-3^1S transition, we could present experimental data in ref. [1] with small errors (<10 percent) for the energy range between 50 and 2000 eV, and possibly larger errors towards 25 eV. In Table 2 these data are presented in columns X[1] and Omega[1], together with the Rm29Av data between the excitation and ionization thresholds. We see that these data are mostly close to the CCC69 results. Only at 200 eV, there is a relatively large difference. Above the ionization threshold, we choose the CCC69 values up to 50 eV, retaining the previous data at higher energies (see the columns X and Omega). At high energies, the experimental data converge towards the first Born results (see ref. [1]).

For the data for the 1^1S-4^1S transition, presented in Table 3, the considerations are almost the same as for the 1^1S-3^1S transition. Above the ionization threshold, we choose the CCC69 results at 25 and 26.5 eV, and the previous experimental cross section values at higher energies. Again, a relatively large difference exists between the experimental and CCC69 data at 200 eV.

For the excitation to $n(2\text{-}4)^1P$ and $n(3\text{-}4)^1D$ states, we use similar considerations in our re-assessment, which we may not mention everywhere. The data for the 1^1S-$2,3,4^1P$ transitions are presented in Tables 4-6 in a similar way as those for the transitions discussed above. The X[1] data are from optical experiments between 30 and 2000 eV, with errors smaller than 10 percent, and converging well to the Born values near 500 eV (see ref. [1]). Below the ionization threshold, X[1] comes from Rm29Av. Generally, these data are consistent with the theoretical data given in the tables, and our new recommended data in columns X and Omega are almost the same as the previous ones. Only for 4^1P the difference of the CCC results and the experiment is relatively large below 100 eV. (We correct a misprint in Table 3 of ref. [1], at 100 eV, where Omega must be 0.204 instead of 0.104.)

The data for the 1^1S-3^1D transition are given in Table 7. The experimental (empirical) data from Table 1c of [1] were often quoted with an accuracy not better than 20 to 30 percent (there is a misprint, 3^1D 80-100 eV Moustafa adjusted by 1/15, must be adjusted by 1/1.15). The CCC75 values differ from X[1] mostt significantly at 40, 50 and 500 eV, the difference amounting up to a factor of 1.20 at 50 eV. However, it appears that the CCC75 and CCC69 data differ rather significantly from each other below 100 eV as well, the difference being up to a factor of 1.30. As mentioned before, according to I. Bray, the CCC75 results for the D levels should be preferred over those of CCC69 calculations. However, at 40 and 50 eV, the CCC69

data are close to those in X[1]. The RMPS2 values are often relatively low. The previous assessed data X[1] or Omega[1] are consistent with the Rm29 results below the ionization threshold, at many energies they are in agreement with the CCC75 data and converge to the Born values at high energies (see ref. [1]). The new assessed data in columns X and Omega, therefore, do not differ from the previously assessed ones.

The data for the 1^1S-4^1D transition are given in Table 8. The CCC data differ from X[1] most significantly below 50 eV, up to a factor of 1.29 at 30 eV. However, the convergence of CCC75 and CCC69 results is not good in the range of 30 to 80 eV, the disagreement being between a factor of 1.30 and 1.17. In that energy range, the CCC69 data are often closer to the experiment, X[1], whereas above 80 eV the CCC75 results are closer to the experiment than are the CCC69 data. We now recommend the Rm29 values up to 24.3 eV and for the higher energies we recommend the experimental data, X[1]. Similarly as for 3^1D, X for 4^1D is taken to be the same as X[1]. The possible error now can be claimed to be within 10 to 20 percent.

The data for the 1^1S-4^1F transition are given in Table 9. We have not considered this transition in reference [1] and the data may not be very accurate. We may choose the CCC values for X at all energies.

2.2. Excitation to Triplet States

Having brought the assessment of singlet excitation mostly within 10 percent error, we are now going to triplet states excitation. As we have seen in reference [1], the errors in experimental cross sections or collision strengths for the triplet states are much larger than those for the singlet states. This is particularly true at higher energies where the triplet state cross sections become very small due to the strongly decreasing probability for electron exchange. So, in our assessment of the triplet excitation data, we are more dependent on theoretical results than was the case for the singlet states. As we shall first illustrate for the 1^1S-2^3S transition, our considerations are often similar to those used for 1^1S-n^1L transitions, but at higher energies we can only use theoretical data in our assessment. Apart from using data tables, we shall now use also graphs to represent the cross section data.

In Table 10 and Figs. 1a,b we present the 1^1S-2^3S data. The previous data from ref. [1] are again presented in the columns X[1] and Omega[1], including Rm29Av data from threshold up to the ionization threshold, experimental data from differential inelastic scattering at higher energies up to 100 eV, and empirical data above 100 eV (see ref. [1]). Just as for the excitation

to singlet states, we see that the agreement between X[1] and the CCC69 values is very good from 30 to 500 eV except at 200 eV, where the difference is a factor of 1.20. This means that we can quote the data with much smaller errors than before in [1], where they were often given an accuracy not better than 30 percent. At lower energies, Rm29 data, showing resonances [3], are more detailed than the CCC results. We see that between 21 and 26 eV, the CCC69, Rm29 and Rm29Av data (included in X[1]) are consistent with each other. Between 26 and 34 eV, some Rm29 values seem too large, reflecting the well known fact that the Rm CC method does not provide good values for energies above the ionization threshold [4]. Therefore, it is good to consider also the RMPS data: RMPS2 values fit well to Rm29 values near the ionization threshold and are, generally, close to X[1] and CCC69 data above that energy, differing at most by a factor of 1.16 at 80 eV from X[1]. At sufficiently high energies, the CBE data (coinciding with those of the Ochkur approximation [5]) should become valid. We see in Fig. 1 that the CCC and CBE data have the same trend. It is, however, unclear which one of these data sets should be preferred, because what we call "experiment" at higher energies, in fact, are empirical data. However, the new assessed X data, close to X[1], can be claimed to have errors below about 10 percent up to about 100 eV, when we choose the Rm29 data up to the ionization threshold, continuing with the CCC69 results up to 100 eV. Above 100 eV, where the cross section decreases rapidly with increasing the impact energy, we can take either the CCC or CBE data, the uncertainty increasing for the smaller cross sections or omegas. We have taken the CCC69 data as our recommended cross section values above 100 eV. The data of Trajmar [8] are the most recent ones, derived from inelastic differential scattering data with possible errors of 25 percent.

The 1^1S-3^3S transition is shown in Table 11 and Figs. 2a,b. The experimental data from reference [1] in X[1] are in fact empirical, and have been interpolated between results for 2^3S and 4^3S excitation. For this reason, and somewhat analogous to our assessment of the excitation to 2^3S, we choose for excitation to 3^3S (see columns X and Omega): Rm29 up to the ionization threshold and CCC69 at higher energies. Only at 23.45 and 25 eV, the divergence for CCC69 and CCC75 is above 10 percent (about 15 percent). In general, the RMPS3 results are consistent with the CCC69 results. The errors for the 1^1S-3^3S cross sections are estimated to be larger than those for 1^3S-2^3S, but the present assessed values (see columns X and Omega) for 1^1S-3^3S may be more accurate than the empirical values in ref. [1] (see the columns X[1] and Omega[1]), and

are about 30 percent lower. Whereas for energies larger than 70 eV in Table 3d of Ref. [1] the ratio of the excitation cross sections for 2^3S and 3^3S was 3.29, it is now about 4.66 for energies above 100 eV, and 4.06 for the CBE results. When we scale (see ref. [13]) the 3^3S data with respect to $2\,^3S$, taking the cross section as a uniform function proportional to $n^{-3}U_n^{-4}$ as a function of the reduced impact energy E/U_n (U_n is the electron excitation energy), the 3^3S cross sections become even smaller than the present assessed data (not shown). We have also considered the data derived from the angular differential inelastic scattering by Trajmar et al. [8] and Chutjian and Thomas [14], and the optical data obtained with pulsed electron beam and time scanning of radiation of Bogdanova and Yurgenson [15], not considered in ref. [1]. These data are given with a possible error of about 25 percent. Our new assessed data come only close to a part of these experimental data.

The 1^3S-4^3S data are shown in Table 12 and Figs. 3a,b. The agreement between the new CCC results and the experimental data in X[1] is not very good, the difference often being around a factor of about 1.5. Generally, there is a good agreement between the CCC69 and CCC75 data. We choose for the recommended 1^3S-4^3S data, with relatively large uncertainty (see columns X and Omega), the Rm29 data up to 24.5 eV, the CCC69 data at higher energies, reaching no better accuracy than before in ref. [1]. In the energy region above about 100 eV, the ratio between the excitation cross sections of 3^3S and 4^3S is about 2.60 for the presently assessed data, 2.55 for the CBE data and 2.17 for the assessed data of ref. [1]. With scaling we find about 2.9 for this ratio. The large difference of the present assessed CCC69 data and the assessed experimental data of ref. [1] can be found back in the different cross section ratios, being relatively small in ref. [1] both for the 2/3 and 3/4 levels. The experimental data of [1], largely based on optical experiments, as discussed by Heddle and Gallagher [16], also need further consideration.

Next we consider the 1^1S-n^3P series of transitions, and we start with n=2, see Table 13 and Figs. 4a,b. For this state the relevant experimental values of ref. [1] have an empirical character over a large impact energy range. The difference of CCC69 data with respect to the experiment varies with a factor between 1.09 and 1.5, and that of RMPS2 with respect to the experiment varies with a factor between 1.02 and 1.21. We choose in X and Omega the Rm29 values in the energy range up to the ionization threshold, continuing with the CCC69 data at higher impact energies. The CBE and Ochkur data have the same trend, but are no more exactly coinciding as in the case of excitation to n^3S; the CCC69 and Ochkur values are close to each

other above about 50 eV. The experimental and theoretical differential scattering data at 30 eV by Roeder et al. [17] lead to confidence in the CCC theory, so that our present assessment may be fairly accurate at energies smaller than 80 eV (at 80 eV the CCC69 and CCC75 results differ by about 12 percent). For the 1^1S-3^3P transition, the data are given in Table 14 and Figs. 5a,b. CCC69 differs by a factor between 1.19 and 1.37 from the experimental data X[1] and Omega[1] and does not converge within ten percent at 22.6 and 80 eV. The RMPS3 results are consistent with the CCC results. For the recommended cross sections we choose the Rm29 data up to the ionization threshold and the CCC69 data at higher energies, converging to the Ochkur values. For the 1^3S-4^3P transition in Table 15 and Figs. 6a,b there are no good experiments. We choose the data according to the scheme used for 1^3S-3^3P. The error in both data sets may be larger than for 1^3S-2^3P. More optical experiments are desired to confirm the assessment here.

Just as in the case of 1^1S-n^3S, some extra considerations are given below for 1^1S-n^3P. The cross section ratios between 3^3P and 2^3P were 3.5 at energies above 100 eV in ref. [1]. We now get about 3.22 for the assessed data (CCC), 3.35 for CBE, 3.31 for Ochkur and roughly 5.8 from the scaling. The assessed 3^3P cross sections, when compared to new experimental data, as for 3^3S, are closest to Chutjian and Thomas [14] at 30 and 40 eV, and to Trajmar et al. [8] and Bogdanova and Yurgenson [15] at 100 eV. At 50 eV, the disagreement of the assessed cross section with the two latter groups is rather large. For 3^3P and 4^3P the ratio of the assessed data is about 2.35 (with an irregularity at 900 eV), 2.41 for CBE, 2.40 for Ochkur and about 2.7 for the scaling. In general, all theories have about the same ratio; from the scaling we get too large ratios. For the singlet levels, these ratios come closer to the experiment and the theory, except for n^1D.

Now we consider the 1^3S-n^3D (n=3,4) transitions, the data for which are given in Tables 16 and 17, and Figs. 7a,b and 8a,b. For excitation to 3^3D, the experimental data are empirical and are derived from experimental data on excitation to 4^3D, which are not very accurate (see ref. [1]). For 1^3S-3^3D, we choose the Rm29 data up to the ionization threshold and the CCC75 data at higher energies, the latter converging to the CBE data. At most energies up to 100 eV, the CCC75 and CCC69 results differ from each other more than 10 percent (up to 33 percent at 40 eV). The RMPS3 results are in good agreement with those of the CCC75 calculations at most energies. For the 1^3S-4^3D transition, the experimental data are not very accurate [1]. Again, the CCC75 and CCC69 results show differences larger than 10 percent at most energies up to 80 eV.

In the assessment we followed the Rm29 data up to the ionization threshold and the CCC75 values at higher energies. These relatively small cross sections may not be too accurate, both for 3^3D and 4^3D, particularly at higher energies, but they are, generally, better than the data given in Ref. [1]. For the cross section ratios of 3^3D and 4^3D we get 1.67 for the assessed data, 1.77 for CBE data, 1.76 for the Ochkur approximation data and 2.7 from the scaling, where scaling does not work well both for the singlet and triplet D levels. For 3^3D, the data of Bogdanova and Yurgenson [15] are much different from the assessed data at 50 eV and 100 eV, but the authors do not claim high accuracy of their data, see Table 16.

The data for the 1^1S-4^3F transition are given in Table 18 and figures 9a,b. This transition was not considered in reference [1] and the data are not very accurate. We may recommend the Rm29 data up to the ionization threshold and the CCC75 data at higher energies.

3. CONCLUSION

In conclusion, we can say that the reconsideration and some modification of the data assessment in reference [1], with taking account of new theoretical data of CCC[2], Rm29 [3], RMPS [4], CBE and Ochkur approximation [5], leads to the possibility to attribute smaller errors to the cross sections for many transitions. In the case of 1^1S-n^1L (n=2-4) transitions, we, generally, reach the aimed accuracy, i.e. an error smaller than 10 percent; for the 1^1S-n^3L transitions this accuracy is present for the n=2 levels at not too high energies, but may decrease with the increase of n and L (when the excitation probability becomes relatively small). In the excitation to triplet states, it appears that the existing data from optical experiments are often not reliable or just missing. Notwithstanding the achieved progress in the data accuracy, it is still questionable whether the CCC results are more reliable than exp[1] data, for instance for the 4^3S and 3^3P levels. More work is needed in this case, but a good experiment is very difficult, as argued, for instance, by Heddle and Gallagher [16]. In some cases the convergence of the CCC results has also to be improved.

ACKNOWLEDGMENT

We wish to thank Drs. I. Bray, K. Bartschat, M.P. Scott and V.P. Shevelko for providing theoretical data for improvement of our assessment in the case of He 1^1S excitation and to Prof. Dr. R.K. Janev for stimulating this effort. We are also thankful to Prof. Dr. Bartschat in particular and to Dr. M. Inokuti for critical remarks on the manuscript. Thanks to Dr. W.E. van

der Kaay for help with the computer management of data and to Drs. T. Kato and Y. Itikawa for compilation of the data. The work is part of the research program of the Stichting voor Fundamenteel Onderzoek der Materie (FOM) which is financially supported by de Stichting voor Nederlands Wetenschappelijk Onderzoek.

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DATA TABLES FOR $1^1S \rightarrow n^{1,3}L$ TRANSITIONS

($n=2\text{-}4,\ 0 \leq L \leq n\text{-}1$)

Table 1: $1^1S \rightarrow 2^1S$ transition

	energy eV	RMPS2	RMPS3	CCC75	CCC69	Rm29	X[1]	X	Omega[1]	Omega
0	20.600	1.2760		2.2011	2.4712					
1	20.800	2.2210				1.4377	1.2824		0.022299	
2	21.000	2.1980		2.4984	2.2231	2.5633	2.3354		0.040999	
3	21.300	2.2400				2.2351	2.2800		0.040599	
4	22.500	2.2600				2.4987	2.2701		0.042700	
5	22.600	2.2620	1.8810	2.3362	2.5442	2.1171	2.3977		0.045300	
6	23.000	2.2650				2.0283	2.1843		0.041999	
7	23.450	2.2700	2.5100	2.4648	2.2622	2.0404	2.1424		0.041999	
8	24.500	2.2770				2.1922	2.0750		0.042499	
9	25.000	2.2790	2.5360	2.2999	2.3076	2.1388		2.3076		0.048228
10	26.500	2.2770	2.5200	2.3628	2.3377	2.4375		2.3377		0.051788
11	30.000	2.2470	2.4540	2.2064	2.0634	2.9586	2.4003	2.2470	0.060199	0.056353
12	33.882	2.1790				25.317		2.1790		0.061720
13	35.000		2.2576							
14	35.160	2.1520		1.9700	2.1106			2.1520		0.063254
15	40.000	2.0650	2.1397	1.8597	1.8580		2.1083	2.0650	0.070499	0.069052
16	45.000	1.9510						1.9510		0.073395
17	50.000	1.8490		1.6692	1.6658		1.9378	1.8490	0.080999	0.077286
18	60.000	1.6950					1.7684	1.6950	0.088699	0.085019
19	80.000	1.4170		1.3676	1.2700		1.4952	1.4170	0.099999	0.094767
20	100.00			1.1509	1.1249		1.3038	1.3038	0.10900	0.10900
21	150.00						1.0287		0.12900	
22	200.00			0.79706	0.79356		0.83733	0.79356	0.14000	0.13268
23	250.00									
24	300.00						0.63398		0.15900	
25	350.00									
26	400.00						0.49044		0.16400	
27	500.00			0.38896	0.37982		0.42345	0.37982	0.17700	0.15876
28	600.00						0.32297		0.16200	
29	800.00						0.26765		0.17900	
30	900.00			0.23946	0.23821			0.23821		0.17923
31	1000.0						0.21530		0.18000	
32	1500.0						0.14400		0.18100	
33	2000.0						0.10820		0.18100	

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Table 2: $1^1S \rightarrow 3^1S$ transition

	energy eV	CCC75	CCC69	RMPS3	Rm29	X[1]	X	Omega[1]	Omega
0	22.600	0.29590	0.38591						
1	23.100				0.44015	0.48106		0.0092898	
2	23.450	0.46343	0.39152	0.37300	0.34177	0.41318		0.0080999	
3	24.000				0.45196	0.40820		0.0081899	
4	24.400				0.35395	0.36327		0.0074100	
5	25.000	0.39354	0.36403	0.45260	0.39235	0.28995	0.36403	0.0060599	0.0076081
6	26.500	0.41197	0.40492	0.45800	0.74479		0.40492		0.0089704
7	28.800				0.83899				
8	30.000	0.44460	0.43701	0.47392	0.80144	0.39075	0.43701	0.0097999	0.010960
9	33.882				0.62842				
10	35.000			0.45680		0.41012		0.012000	
11	35.160	0.39105	0.41255				0.41255		0.012126
12	39.700								
13	40.000	0.36537	0.37790	0.42487		0.39474	0.37790	0.013200	0.012637
14	45.000								
15	50.000	0.33054	0.33616			0.33732	0.33732	0.014100	0.014100
16	60.000								
17	80.000	0.28882	0.25472			0.26017	0.26017	0.017400	0.017400
18	100.00	0.23574	0.23141			0.23326	0.23326	0.019500	0.019500
19	150.00					0.17225	0.17225	0.021600	0.021600
20	200.00	0.16884	0.16867			0.14593	0.14593	0.024400	0.024400
21	250.00					0.13110	0.13110	0.027400	0.027400
22	300.00					0.11882	0.11882	0.029800	0.029800
23	350.00					0.10287	0.10287	0.030100	0.030100
24	400.00					0.091508	0.091508	0.030600	0.030600
25	500.00	0.087180	0.84969			0.084451	0.084451	0.035300	0.035300
26	600.00					0.067584	0.067584	0.033900	0.033900
27	800.00					0.057118	0.057118	0.038199	0.038199
28	900.00	0.053809	0.53527						
29	1000.0					0.046292	0.046292	0.038699	0.038699
30	1500.0					0.031420	0.031420	0.039399	0.039399
31	2000.0					0.024462	0.024462	0.040899	0.040899

Table 3: $1^1S \rightarrow 4^1S$ transition

	energy eV	CCC75	CCC69	X[-18]exp	Rm29	X[1]	X	Omega[1]	Omega
0	23.450	0.074803	0.11858						
1	24.000			0.10021	0.12246	0.10021		0.0020106	
2	24.400			0.092710	0.093145	0.092710		0.0018911	
3	25.000	0.13473	0.12943	0.10914	0.18474	0.10914	0.12943	0.0022809	0.0027050
4	26.500	0.13178	0.11351		0.42882		0.11351		0.0025146
5	28.800				0.40371				
6	30.000	0.16529	0.16449	0.16195	0.37720	0.16195	0.16195	0.0040616	0.0040616
7	33.882				0.27456				
8	35.000			0.16514		0.16514	0.16514	0.0048319	0.0048319
9	35.160	0.14990	0.14488						
10	40.000	0.14148	0.14749	0.15198		0.15198	0.15198	0.0050820	0.0050820
11	45.000			0.14307		0.14307	0.14307	0.0053822	0.0053822
12	50.000	0.13118	0.13110	0.13307		0.13307	0.13307	0.0055622	0.0055622
13	60.000			0.11289		0.11289	0.11289	0.0056623	0.0056623
14	80.000	0.11610	0.096917	0.095136		0.095136	0.095136	0.0063625	0.0063625
15	100.00	0.096439	0.091948	0.090589		0.090589	0.090589	0.0075730	0.0075730
16	150.00			0.069886		0.069886	0.069886	0.0087635	0.0087635
17	200.00	0.066729	0.067096	0.059176		0.059176	0.059176	0.0098940	0.0098940
18	250.00			0.052175		0.052175	0.052175	0.010904	0.010904
19	300.00			0.045075		0.045075	0.045075	0.011305	0.011305
20	350.00			0.040345		0.040345	0.040345	0.011805	0.011805
21	400.00			0.036200		0.036200	0.036200	0.012105	0.012105
22	500.00	0.035228	0.034357	0.032550		0.032550	0.032550	0.013605	0.013605
23	600.00			0.026327		0.026327	0.026327	0.013205	0.013205
24	800.00			0.022587		0.022587	0.022587	0.015106	0.015106
25	900.00	0.021694	0.021245						
26	1000.0			0.017591		0.017591	0.017591	0.014706	0.014706
27	1500.0			0.011807		0.011807	0.011807	0.014806	0.014806
28	2000.0			0.0090349		0.0090349	0.0090349	0.015106	0.015106

Table 4: $1^1S \rightarrow 2^1P$ transition

	energy eV	RMPS2	RMPS3	CCC75	CCC69	Rm29	X[1]	X	Omega[1]	Omega
0	20.600			0.34623	0.28148					
1	21.000			0.62105	0.67861					
2	21.300	0.36273				0.19656				
3	22.500	0.92253				1.4673	1.3982		0.026300	
4	22.600	0.97278	1.0725	1.5417	1.5134	1.1644	1.3232		0.025000	
5	23.000	1.0727				1.3262	1.3002		0.025000	
6	23.450	1.2701	1.2100	1.5906	1.6035	1.7241	1.3263		0.026000	
7	24.500	1.6551				1.8407	1.7381		0.035600	
8	25.000	1.8428	1.8846	2.2276	2.1148	1.8804		2.1148		0.044198
9	26.500	2.3432	2.2200	2.7419	2.6404	2.2569		2.6404		0.058494
10	28.800	2.9893				3.9457				
11	30.000	3.3980	3.1334	3.8867	3.7775	4.8645	3.7480	3.7480	0.093999	0.093999
12	33.882	4.5233				6.6831				
13	35.000		4.5254							
14	35.160	4.8666		5.3979	5.4464		5.4094	5.4094	0.15900	0.15900
15	40.000	5.8082	5.5770	6.6498	6.5835		6.4295	6.4295	0.21500	0.21500
16	45.000	6.8719					7.7087	7.7087	0.29000	0.29000
17	50.000	7.7371		8.1924	8.3633		8.2058	8.2058	0.34300	0.34300
18	60.000	8.8357					9.5097	9.5097	0.47699	0.47699
19	80.000	10.045		10.600	10.980		10.138	10.138	0.67799	0.67799
20	100.00			10.865	11.199		10.096	10.096	0.84399	0.84399
21	150.00						9.1707	9.1707	1.1500	1.1500
22	200.00			9.0461	8.9707		8.3135	8.3135	1.3900	1.3900
23	250.00						7.6077	7.6077	1.5900	1.5900
24	300.00						6.9379	6.9379	1.7400	1.7400
25	350.00						6.3910	6.3910	1.8700	1.8700
26	400.00						5.9510	5.9510	1.9900	1.9900
27	500.00			5.5368	5.5361		5.6699	5.6699	2.3700	2.3700
28	600.00						5.0240	5.0240	2.5200	2.5200
29	800.00						3.7530	3.7530	2.5100	2.5100
30	900.00			3.6965	3.6960					
31	1000.0						3.1340	3.1340	2.6200	2.6200
32	1500.0						2.3365	2.3365	2.9300	2.9300
33	2000.0						1.8481	1.8481	3.0900	3.0900

Table 5: $1^1S \rightarrow 3^1P$ transition

	energy eV	CCC75	CCC69	RMPS3	Rm29	X[1]	X	Omega[1]	Omega
0	22.600	0.097724	0.086286						
1	23.200				0.055169	0.051600		0.0010008	
2	23.450	0.23744	0.23182	0.12800	0.10967				
3	23.600				0.15307	0.12266		0.0024200	
4	23.800				0.20405	0.17490		0.0034799	
5	24.000				0.24083	0.21781		0.0043700	
6	24.300				0.24022	0.23973		0.0048700	
7	25.000	0.39821	0.37652	0.39709	0.25948		0.37652		0.0078691
8	26.500	0.47246	0.45360	0.45700	0.69965		0.45360		0.010049
9	28.800				1.4122				
10	30.000	0.74797	0.73259	0.64833	1.6268	0.73765	0.73765	0.018500	0.018500
11	33.882				2.1659				
12	35.000					1.1107	1.1107	0.032500	0.032500
13	35.160	1.0891	1.0803	1.0459					
14	40.000	1.4030	1.3579	1.0342		1.3786	1.3786	0.046099	0.046099
15	45.000					1.6587	1.6587	0.062399	0.062399
16	50.000	1.8809	1.8933			1.8397	1.8397	0.076899	0.076899
17	60.000					2.1531	2.1531	0.10800	0.10800
18	80.000	2.4619	2.5424			2.4223	2.4223	0.16200	0.16200
19	100.00	2.4619	2.6686			2.4402	2.4402	0.20400	0.20400
20	150.00					2.2568	2.2568	0.28300	0.28300
21	200.00	2.2314	2.2103			2.0814	2.0814	0.34800	0.34800
22	250.00					1.8804	1.8804	0.39299	0.39299
23	300.00					1.7704	1.7704	0.44399	0.44399
24	350.00					1.6302	1.6302	0.47699	0.47699
25	400.00					1.5102	1.5102	0.50499	0.50499
26	500.00	1.3717	1.3714			1.2895	1.2895	0.53899	0.53899
27	600.00					1.1085	1.1085	0.55599	0.55599
28	800.00					0.91508	0.91508	0.61199	0.61199
29	900.00	0.91683	0.91691						
30	1000.0					0.79307	0.79307	0.66299	0.66299
31	1500.0					0.58772	0.58772	0.73699	0.73699
32	2000.0					0.46800	0.46800	0.78248	0.78248

Table 6: $1^1S \rightarrow 4^1P$ transition

	energy eV	CCC75	CCC69	Rm29	X[1]	X	Omega[1]	Omega
0	23.450	0.056300	0.10466					
1	23.900			0.024524	0.020076		0.00040112	
2	24.100			0.034744	0.033149		0.00066786	
3	24.300			0.053164	0.062425		0.0012681	
4	25.000	0.16455	0.17018	0.13397		0.17018		0.0035567
5	26.500	0.21408	0.20146	0.43333		0.20146		0.0044630
6	28.800			0.79746				
7	30.000	0.25918	0.23938	0.90112	0.30981	0.30981	0.0077699	0.0077699
8	33.882			1.1326				
9	35.160	0.38698	0.37454					
10	40.000	0.51637	0.49339		0.58613	0.58613	0.019600	0.019600
11	45.000							
12	50.000	0.72562	0.71805		0.83254	0.83254	0.034800	0.034800
13	60.000				0.94299	0.94299	0.047299	0.047299
14	80.000	0.95890	0.98817		1.1498	1.1498	0.076899	0.076899
15	100.00	1.1732	1.1241		1.0694	1.0694	0.089399	0.089399
16	150.00				1.0207	1.0207	0.12800	0.12800
17	200.00	0.89407	0.94840		0.89116	0.89116	0.14900	0.14900
18	250.00							
19	300.00				721.70	721.70	181.00	181.00
20	350.00							
21	400.00				0.61304	0.61304	0.20500	0.20500
22	500.00	0.54833	0.58653		0.52871	0.52871	0.22100	0.22100
23	600.00				0.47648	0.47648	0.23900	0.23900
24	800.00				0.37829	0.37829	0.25300	0.25300
25	900.00	0.36740	0.36498					
26	1000.0				0.31938	0.31938	0.26700	0.26700
27	1500.0				0.23206	0.23206	0.29100	0.29100
28	2000.0				0.19019	0.19019	0.31800	0.31800

Table 7: $1^1S \rightarrow 3^1D$ transition

	energy eV	CCC75	CCC69	RMPS3	Rm29	X[1]	X	Omega[1]	Omega
0	22.600	0.22393	0.22599		0.0000				
1	23.200				0.26043	0.26399		0.0051200	
2	23.450	0.18562	0.15375	0.23700	0.18874				
3	23.600				0.28622	0.29246		0.0057700	
4	23.800				0.21109	0.21662		0.0043099	
5	24.000				0.26675	0.20634		0.0041399	
6	24.300				0.17721	0.18164		0.0036899	
7	25.000	0.17378	0.15939	0.18114	0.17991	0.19187	0.19187	0.0040099	0.0040099
8	26.500	0.17974	0.16862	0.13000	0.35208				
9	28.800				0.43611				
10	30.000	0.20893	0.22540	0.18192	0.44658	0.22807	0.22807	0.0057199	0.0057199
11	33.882				0.38764				
12	35.000			0.18174		0.24778	0.24778	0.0072499	0.0072499
13	35.160	0.22090	0.26854						
14	40.000	0.22701	0.28213	0.18703		0.25897	0.25897	0.0086599	0.0086599
15	45.000					0.26396	0.26396	0.0099299	0.0099299
16	50.000	0.21711	0.26428			0.26077	0.26077	0.010900	0.010900
17	60.000					0.22727	0.22727	0.011400	0.011400
18	80.000	0.17280	0.19832			0.18541	0.18541	0.012400	0.012400
19	100.00	0.14404	0.15477			0.14354	0.14354	0.012000	0.012000
20	150.00					0.093302	0.093302	0.011700	0.011700
21	200.00	0.075596	0.075568			0.070575	0.070575	0.011800	0.011800
22	250.00					0.057895	0.057895	0.012100	0.012100
23	300.00					0.044658	0.044658	0.011200	0.011200
24	350.00								
25	400.00					0.031998	0.031998	0.010700	0.010700
26	500.00	0.027169	0.027099			0.024163	0.024163	0.010100	0.010100
27	600.00					0.019936	0.019936	0.0099999	0.0099999
28	800.00					0.015550	0.015550	0.010400	0.010400
29	900.00	0.014353	0.014473						
30	1000.0					0.012440	0.012440	0.010400	0.010400
31	1500.0					0.0077991	0.0077991	0.0097799	0.0097799
32	2000.0					0.0058194	0.0058194	0.0097299	0.0097299

Table 8: $1^1S \rightarrow 4^1D$ transition

	energy eV	CCC75	CCC69	Rm29	X[1]	X	Omega[1]	Omega
0	23.450	0.13508	0.12260					
1	23.600							
2	23.800							
3	24.000			0.10656	0.084232		0.0016900	
4	24.300			0.064978	0.065471		0.0013300	
5	25.000	0.086674	0.090976	0.17225	0.10479	0.10479	0.0021900	0.0021900
6	26.500	0.094287	0.10001	0.34757				
7	28.800			0.34058				
8	30.000	0.098350	0.12733	0.32536	0.12201	0.12201	0.0030600	0.0030600
9	33.882			0.24748				
10	35.000				0.13336	0.13336	0.0039199	0.0039199
11	35.160	0.12198	0.15267					
12	40.000	0.12820	0.15827		0.13906	0.13906	0.0046499	0.0046499
13	45.000				0.13902	0.13902	0.0052299	0.0052299
14	50.000	0.12282	0.15234		0.13804	0.13804	0.0057699	0.0057699
15	60.000				0.12002	0.12002	0.0060199	0.0060199
16	80.000	0.095420	0.11102		0.098386	0.098386	0.0065799	0.0065799
17	100.00	0.080076	0.084926		0.079068	0.079068	0.0066099	0.0066099
18	150.00				0.051436	0.051436	0.0064499	0.0064499
19	200.00	0.039228	0.038634		0.038756	0.038756	0.0064799	0.0064799
20	250.00				0.031771	0.031771	0.0066399	0.0066399
21	300.00				0.024602	0.024602	0.0061699	0.0061699
22	350.00							
23	400.00				0.017584	0.017584	0.0058799	0.0058799
24	500.00	0.014297	0.015602		0.013302	0.013302	0.0055599	0.0055599
25	600.00				0.010985	0.010985	0.0055099	0.0055099
26	800.00				0.0085527	0.0085527	0.0057199	0.0057199
27	900.00	0.0075718	0.0076441					
28	1000.0				0.0068541	0.0068541	0.0057299	0.0057299
29	1500.0				0.0042903	0.0042903	0.0053799	0.0053799
30	2000.0				0.0032028	0.0032028	0.0053549	0.0053549

Table 9: $1^1S \rightarrow 4^1F$ transition

	energy eV	CCC75	Rm29	X	Omega
0	23.200				
1	23.450	0.015805		0.015805	0.00030984
2	23.600				
3	23.800				
4	24.000		0.038565		
5	24.300		0.020686		
6	25.000	0.016322	0.048481	0.016322	0.00034112
7	26.500	0.015812	0.035196	0.015812	0.00035029
8	28.800		0.024060		
9	30.000	0.010502	0.023621	0.010502	0.00026338
10	33.882		0.018466		
11	35.000				
12	35.160	0.0088943		0.0088943	0.00026143
13	40.000	0.0073990		0.0073990	0.00024742
14	45.000				
15	50.000	0.0051287		0.0051287	0.00021437
16	60.000				
17	80.000	0.0020619		0.0020619	0.00013790
18	100.00	0.0013557		0.0013557	0.00011333
19	150.00				
20	200.00	0.00036849		0.00036849	6.1610e-05
21	250.00				
22	300.00				
23	350.00				
24	400.00				
25	500.00	0.00010500		0.00010500	4.3890e-05
26	600.00				
27	800.00				
28	900.00	5.6413e-05		5.6413e-05	4.2444e-05
29	1000.0				
30	1500.0				
31	2000.0				

Table 10: $1^1S \rightarrow 2^3S$ transition

	energy eV	RMPS2	RMPS3	CCC75	CCC69	Rm29	CBE	X[1]	X	Omega[1]	Omega	Trajmar
0	20.000	4.6014		4.5554	4.2755	3.8422		3.7500		0.062699		
1	20.300	5.2365				5.7706		5.6981		0.096699		
2	20.600	3.1312		3.4370	3.3566	4.2761		4.5292		0.077998		
3	20.800	4.4006				3.9060	1.5118	4.3132		0.075000		
4	21.000	3.4087		3.4411	3.4973	4.7357		4.1809		0.073398		
5	21.400	3.1068				3.3985	2.0416	3.6333		0.065000		
6	22.400	2.9031				2.3737	2.6048	3.2254		0.060399		
7	22.600	2.8806	3.6036	3.2222	2.9389	3.8225		3.5355		0.066797		
8	23.450	2.7483	2.8200	3.0247	3.1147	3.2254		2.9484		0.057800		
9	24.500	2.5819				2.7747	3.0096	2.8562		0.058499		
10	25.000	2.5029	2.4839	2.7238	2.6384	2.6263		2.3000	2.6384	0.048069	0.055141	
11	26.500	2.2987	2.3500	2.4862	2.3544	2.7760			2.3544	0.052158	0.052158	
12	28.800	2.0491				3.1898	2.8512					
13	30.000	1.8994	1.9763	1.9133	1.9635	3.1499	2.0000	1.9000	1.9635	0.047651	0.049243	2.4400
14	33.882	1.5199				1.8154						
15	35.000	1.4134	1.4575					1.4500		0.042426		
16	35.160			1.4771	1.5198				1.5198	0.044672	0.044672	
17	37.300						1.9712					
18	40.000	1.1428	1.1978	1.1468	1.1247			1.1800	1.1247	0.039458	0.037609	
19	45.000	0.87214						0.93000		0.034986		
20	50.000	0.67540		0.73075	0.75386			0.74000	0.75386	0.030931	0.031511	0.86500
21	54.300						0.87648					
22	55.000											
23	60.000	0.44722						0.49000		0.024578		
24	70.000							0.35000		0.020482		
25	80.000	0.22592		0.25637	0.24502			0.26000	0.24502	0.017388	0.016387	
26	88.300						0.24816					
27	90.000							0.18000		0.013543		
28	100.00			0.14835	0.15004			0.14000	0.15004	0.011704	0.012543	0.12600
29	150.00							0.047000		0.0058937		
30	156.00						0.049630					
31	200.00			0.027932	0.028731			0.024000	0.028731	0.0040127	0.0048037	
32	250.00							0.014000		0.0029259		
33	292.00						0.0079000					

Table 10: $1^1S \rightarrow 2^3S$ transition (contd.)

	energy eV	RMPS2	RMPS3	CCC75	CCC69	Rm29	CBE	X[1]	X	Omega[1]	Omega	Trajmar
34	300.00							0.0091000		0.0022822		
35	400.00							0.0046000		0.0015382		
36	500.00			0.0026219	0.0023996			0.0025000	0.0023996	0.0010450	0.0010030	
37	564.00						0.0011200					
38	900.00			0.00050050	0.00049416				0.00049416	0.00037180	0.00037180	
39	1110.0						0.00015000					
40	2200.0						2.0000e-05					

Table 11: $1^1S \rightarrow 3^3S$ transition

	energy eV	CCC75	CCC69	RMPS3	Rm29	CBE	X[1]	X	Omega[1]	Omega	Trajmar	Chutjian	Bogdanova
0	23.000				0.56324		0.89453		0.017200				
1	23.200				0.90229		0.86104		0.016700				
2	23.450	0.87058	0.73190	0.73500	0.66313								
3	23.600				0.67412		0.77549		0.015300				
4	23.800				0.78405		0.71871		0.014300				
5	23.900				0.71070	0.50512							
6	24.100				0.68495		72962		1470.0				
7	24.300				0.65470		65962		1340.0				
8	24.500				0.62836								
9	24.900				0.68696	0.59312							
10	25.000	0.75740	0.66148	0.67188	0.70814		0.70000	0.70814	0.014630	0.014800			
11	26.500	0.67076	0.67658	0.65100	1.0788			0.67658		0.014989			
12	27.100				1.1344	0.68816							
13	28.800				1.0799								
14	29.200											0.38000	
15	30.000	0.54909	0.57053	0.57070	0.93701		0.68000	0.57053	0.017054	0.014309	0.58000		
16	31.300				0.72611	0.66000							
17	35.000						0.60000		0.017556				
18	35.160	0.41293	0.41351	0.42679				0.41351		0.012154			
19	39.700											0.24000	
20	39.800					0.46112							
21	40.000	0.31994	0.30285	0.34139			0.49000	0.30285	0.016385	0.010127			
22	45.000						0.33000		0.012414				
23	50.000	0.18499	0.19421				0.26000	0.19421	0.010868	0.0081177	0.21500		0.22200
24	55.000												
25	56.800					0.20944							
26	60.000						0.16000		0.0080254				
27	70.000						0.11000		0.0064371				
28	80.000	0.057562	0.055299				0.079000	0.055299	0.0052834	0.0036983			
29	90.000						0.055000		0.0041381				
30	90.800					0.060540							
31	100.00	0.032026	0.032549				0.042000	0.032549	0.0035111	0.0027210	0.025000		0.045000
32	150.00						0.014000		0.0017556				
33	159.00					0.012230							

Table 11: $1^1S \rightarrow 3^3S$ transition (contd.)

	energy eV	CCC75	CCC69	RMPS3	Rm29	CBE	X[1]	X	Omega[1]	Omega	Trajmar	Chutjian	Bogdanova
34	200.00	0.0059716	0.0061505				0.0072000	0.0061505	0.0012038	0.0010283			
35	250.00						0.0042000		0.00087778				
36	295.00					0.0019700							
37	300.00						0.0027000		0.00067714				
38	400.00						0.0014000		0.00046815				
39	500.00	0.00055800	0.00051038				0.00075000	0.00051038	0.00031349	0.00021333			
40	567.00					0.00028000							
41	900.00	0.00010660	0.00010664					0.00010664		8.0235e-05			
42	1110.0					4.0000e-05							

Table 12: $1^1S \rightarrow 4^3S$ transition

	energy eV	CCC75	CCC69	Rm29	CBE	X[1]	X	Omega[1]	Omega
0	23.450	0.28673	0.16671						
1	23.700			0.39116		0.31444		0.0062299	
2	24.000			0.25558		0.25220		0.0050600	
3	24.200			0.19327	0.16421				
4	24.300			0.21118		0.19690		0.0039999	
5	24.500			0.27854					
6	24.700			0.38743	0.20416				
7	25.000	0.27878	0.22405	0.43551		0.31600	0.22405	0.0066042	0.0046826
8	25.800			0.55636	0.22528				
9	26.500	0.24996	0.25893	0.58184			0.25893		0.0057363
10	27.900			0.49777	0.26224				
11	30.000	0.21715	0.22441	0.36595		0.30600	0.22441	0.0076743	0.0056280
12	32.100			0.20943	0.25344				
13	35.000					0.25400		0.0074319	
14	35.160	0.16855	0.15632				0.15632		0.0045946
15	40.000	0.12793	0.12103			0.19900	0.12103	0.0066544	0.0040470
16	40.600				0.17778				
17	45.000					0.15300		0.0057557	
18	50.000	0.075706	0.078056			0.11800	0.078056	0.0049323	0.0032627
19	57.600				0.081140				
20	60.000					0.074300		0.0037268	
21	70.000					0.050000		0.0029259	
22	80.000	0.022798	0.021182			0.036400	0.021182	0.0024344	0.0014166
23	90.000					0.025000		0.0018810	
24	91.600				0.023580				
25	100.00	0.012536	0.012553			0.018800	0.012553	0.0015716	0.0010494
26	150.00					0.0065500		0.00082135	
27	160.00				0.0047900				
28	200.00	0.0022807	0.0023490			0.0033800	0.0023490	0.00056512	0.00039274
29	250.00					0.0019500		0.00040754	
30	296.00				0.00077000				
31	300.00					0.0012700		0.00031851	
32	400.00					0.00065000		0.00021735	
33	500.00	0.00021266	0.00019499			0.00034800	0.00019499	0.00014546	8.1504e-05

Table 12: $1^1S \rightarrow 4^3S$ transition (contd.)

	energy eV	CCC75	CCC69	Rm29	CBE	X[1]	X	Omega[1]	Omega
34	568.00				0.00011000				
35	900.00	4.4512e-05	3.8874e-05				3.8874e-05		2.9248e-05
36	1110.0				1.0000e-05				

Table 13: $1^1S \rightarrow 2^3P$ transition

	energy eV	RMPS2	RMPS3	CCC75	CCC69	Rm29	CBE	Ochkur	X[1]	X	Omega[1]	Omega	Trajmar
0	20.600			1.1507	1.1007								
1	21.000	0.68191		1.4133	1.1462	0.17088							
2	21.100					0.55557			0.51178		0.0090274		
3	21.400	1.1992				1.0620			1.0404		0.018613		
4	21.500					1.1461	4.0480	2.9920					
5	21.700					1.3009			1.2564		0.022792		
6	21.900					1.4857			1.4624		0.026774		
7	22.000					1.5659	5.0688	3.8898					
8	22.200					1.7512			1.7054		0.031650		
9	22.600	1.8110	2.2223	2.1770	2.2074	2.3818			2.0229		0.038219		
10	22.800					1.9831			1.9321		0.036827		
11	23.100					1.9677		4.6816	2.0255		0.039115		
12	23.400					2.0448			1.9283		0.037721		
13	23.450	2.0781	1.9300	2.2044	2.2691	2.4230	5.8432						
14	23.800					2.0607			2.1060		0.041902		
15	24.000					2.0993			2.0885		0.041903		
16	24.200					2.2737			2.1942	..	0.044390		
17	24.500	2.3075				2.3289			2.2645		0.046380		
18	25.000	2.3800	2.2655	2.4026	2.2635	2.1531				2.2635		0.047307	
19	25.200					2.0886	5.7904	4.8752					
20	26.500	2.4771	2.2800	2.4102	2.2950	2.3021				2.2950		0.050841	
21	29.500					3.5277	4.8224	3.9952					
22	30.000	2.4502	2.2390	2.2302	2.1895	3.5487			2.6000	2.1895	0.065206	0.054913	3.2000
23	33.862	2.2631				2.4095							
24	35.160	2.1747	1.9600	2.0092	1.9575					1.9575		0.057535	
25	38.000						3.3088	2.3056					
26	40.000	1.8693	1.7622	1.8904	1.6258				1.9000	1.6258	0.063535	0.054367	
27	45.000	1.4648											
28	50.000	1.1587		1.0641	1.1059				1.4000	1.1059	0.058519	0.046226	1.7500
29	54.300												
30	55.000						1.4238	0.88000					
31	60.000	0.81790							1.0300		0.051664		
32	70.000								0.70000		0.040963		
33	80.000	0.41337		0.32844	0.36998				0.49000	0.36998	0.032770	0.024744	

Table 13: $1^1S \rightarrow 2^3P$ transition (contd.)

	energy eV	RMPS2	RMPS3	CCC75	CCC69	Rm29	CBE	Ochkur	X[1]	X	Omega[1]	Omega	Trajmar
34	89.000						0.50688	0.22528					
35	90.000								0.35000		0.026333		
36	100.00			0.17605	0.19363				0.28000	0.19363	0.023407	0.016187	0.18900
37	157.00						0.075330	0.042940					
38	200.00			0.026269	0.024420				0.036000	0.024420	0.0060191	0.0040829	
39	250.00								0.020000		0.0041799		
40	293.00						0.010670	0.0067600					
41	300.00								0.011000		0.0027587		
42	400.00								0.0044000		0.0014713		
43	500.00			0.0014468	0.0014544				0.0019000	0.0014544	0.00079418	0.00060792	
44	565.00						0.0011300	0.00095000					
45	900.00			0.00023077	0.00023130					0.00023130		0.00017403	
46	1110.0						0.00014000	0.00013000					
47	2200.0						2.0000e-05	2.0000e-05					

Table 14: $1^1S \rightarrow 3^3P$ transition

	energy eV	CCC75	CCC69	RMPS3	Rm29	CBE	Ochkur	X[1]	X	Omega[1]	Omega	Trajmar	Chutjian	Bogdanova
0	22.600	0.26395	0.31891											
1	23.100				0.26927			0.29672		0.0057300				
2	23.450	0.43250	0.43569	0.38900	0.27545									
3	23.500				0.31050	1.2813	0.80784	0.33544		0.0065899				
4	23.700				0.37763			0.38258		0.0075800				
5	24.000				0.43950			0.40471		0.0081199				
6	24.100				0.42685	1.5805	1.0542							
7	24.300				0.41300			0.41743		0.0084798				
8	24.500				0.39254									
9	24.900				0.38629									
10	25.000	0.47032	0.46249	0.51187	0.39378			0.62800	0.46249	0.013125	0.0096658			
11	25.100				0.40032	1.7406	1.2742							
12	26.500	0.49946	0.47702	0.51600	0.72222				0.47702		0.010568			
13	27.200				0.90154	1.6139	1.3394							
14	28.000				1.0552									
15	28.800				1.1214									
16	29.200												0.47000	
17	30.000	0.51551	0.54123	0.51689	1.1041			0.73800	0.54123	0.018509	0.013574	0.72000		
18	31.500				0.94935	1.2549	1.1141							
19	33.882				0.56028									
20	35.000							0.62800		0.018375				
21	35.160	0.51385	0.49492	0.52248					0.49492		0.014547			
22	39.700												0.41000	
23	40.000	0.45707	0.42637	0.49065		0.87120	0.65848	0.53000	0.42637	0.017723	0.014257			
24	50.000	0.31228	0.31841					0.38300	0.31841	0.016009	0.013309	0.48400		0.21100
25	55.000													
26	57.000					0.50512	0.25520							
27	60.000							0.26700		0.013392				
28	70.000							0.19300		0.011294				
29	80.000	0.099812	0.11223					0.14200	0.11223	0.0094967	0.0075056			
30	90.000							0.10600		0.0079753				
31	91.000					0.14590	0.066350							
32	100.00	0.054941	0.060274					0.081500	0.060274	0.0068132	0.0050388	0.058000		0.048000
33	150.00							0.022000		0.0027587				

Table 14: $1^1S \rightarrow 3^3P$ transition (contd.)

	energy eV	CCC75	CCC69	RMPS3	Rm29	CBE	Ochkur	X[1]	X	Omega[1]	Omega	Trajmar	Chutjian	Bogdanova
34	159.00					0.022350	0.012760							
35	200.00	0.0082322	0.0075693					0.010200	0.0075693	0.0017054	0.0012656			
36	250.00							0.0057000		0.0011913				
37	295.00					0.0032000	0.0020200							
38	300.00							0.0032000		0.00080254				
39	400.00							0.0012500		0.00041799				
40	500.00	0.00044993	0.00045964					0.00053000	0.00045964	0.00022153	0.00019213			
41	567.00					0.00034000	0.00029000							
42	900.00	7.0871e-05	7.3252e-05						7.3252e-05		5.5114e-05			
43	1110.0					4.0000e-05	4.0000e-05							

Table 15: $1^1S \rightarrow 4^3P$ transition

	energy eV	CCC75	CCC69	Rm29	CBE	Ochkur	X[1]	X	Omega[1]	Omega
0	23.450	0.089500	0.097114							
1	23.800			0.12565			0.11308		0.0022499	
2	24.000			0.10806			0.10666		0.0021400	
3	24.200				0.54208	0.32736				
4	24.300			0.11868			0.11863		0.0024099	
5	24.500			0.14432						
6	24.800				0.66528	0.42768				
7	25.000	0.20557	0.16845	0.23196				0.16845		0.0035204
8	25.800			0.31898	0.71808	0.51744				
9	26.500	0.23282	0.22464	0.40174				0.22464		0.0049764
10	27.900			0.57880	0.65648	0.54560				
11	30.000	0.19548	0.20600	0.54386				0.20600		0.0051663
12	32.200			0.38634	0.50336	0.45584				
13	33.882			0.25190						
14	35.160	0.20414	0.19181					0.19181		0.0056380
15	40.000	0.18205	0.17036					0.17036		0.0056967
16	40.700				0.34320	0.27104				
17	50.000	0.12610	0.13038					0.13038		0.0054496
18	57.700				0.20592	0.10560				
19	80.000	0.042860	0.047322					0.047322		0.0031648
20	91.700				0.060540	0.027630				
21	100.00	0.026693	0.026726					0.026726		0.0022343
22	160.00				0.0093500	0.0053300				
23	200.00	0.0034797	0.0033458					0.0033458		0.00055940
24	296.00				0.0013400	0.00085000				
25	500.00	0.00019134	0.00020314					0.00020314		8.4911e-05
26	568.00				0.00014000	0.00012000				
27	900.00	3.0526e-05	3.0253e-05					3.0253e-05		2.2762e-05
28	1110.0				2.0000e-05	2.0000e-05				

Table 16: $1^1S \rightarrow 3^3D$ transition

	energy eV	CCC75	CCC69	RMPS3	Rm29	CBE	Ochkur	X[1]	X	Omega[1]	Omega	Bogdanova
0	22.600	0.14306	0.14456									
1	23.000											
2	23.200				0.063882			0.074761		0.0014500		
3	23.450	0.13155	0.15702	0.22200	0.21934							
4	23.600				0.12165	0.050510	0.024290	0.20781		0.0040999		
5	23.800				0.087452			0.10655		0.0021200		
6	24.000				0.086075			0.10018		0.0020100		
7	24.100				0.089341	0.074980	0.031330					
8	24.300				0.085653			0.088606		0.0018000		
9	24.500				0.078606							
10	24.900				0.096559							
11	25.000	0.12409	0.11524	0.11937	0.10378				0.12409		0.0025934	
12	25.200				0.11867	0.10965	0.037310					
13	26.500	0.11189	0.094239	0.11300	0.15528				0.11189		0.0024787	
14	27.300				0.14898	0.14731	0.038010					
15	28.000				0.13927			0.11800		0.0027621		
16	28.800				0.12460							
17	30.000	0.11195	0.12438	0.11379	0.12680			0.17000	0.11195	0.0042635	0.0028075	
18	31.600				0.15142	0.15330	0.030100					
19	33.882				0.19082							
20	35.000			0.084771				0.13600		0.0039793		
21	35.160	0.085988	0.10211						0.085988		0.0025275	
22	40.000	0.060251	0.080434	0.070370				0.098000	0.060251	0.0032770	0.0020147	
23	40.100					0.096800	0.016830					
24	50.000	0.036473	0.043879					0.051000	0.036473	0.0021318	0.0015245	0.052000
25	57.100					0.035730	0.0062500					
26	60.000							0.031000		0.0015549		
27	70.000							0.022000		0.0012874		
28	80.000	0.0077822	0.0098125					0.015200	0.0077822	0.0010166	0.00052046	
29	90.000							0.012400		0.00093295		
30	91.100					0.0060700	0.0015900					
31	100.00	0.0035475	0.0040249					0.0100000	0.0035475	0.00083598	0.00029656	0.0100000
32	150.00							0.0034000		0.00042635		
33	159.00					0.00063000	0.00030000					

Table 16: $1^1S \rightarrow 3^3D$ transition (contd.)

	energy eV	CCC75	CCC69	RMPS3	Rm29	CBE	Ochkur	X[1]	X	Omega[1]	Omega	Bogdanova
34	200.00	0.00032529	0.00033006					0.0016000	0.00032529	0.00026751	5.4387e-05	
35	250.00							0.00090000		0.00018810		
36	295.00					7.0000e-05	5.0000e-05					
37	400.00							0.00050000		0.00016720		
38	500.00	1.3232e-05	1.3461e-05						1.3232e-05		5.5308e-06	
39	567.00					1.0000e-05	1.0000e-05					
40	600.00							0.00040000		0.00020064		
41	900.00	1.9788e-06	2.0130e-06						1.9788e-06		1.4888e-06	
42	1000.0							0.00024000		0.00020064		

Table 17: $1^1S \rightarrow 4^3D$ transition

	energy eV	CCC75	CCC69	Rm29	CBE	Ochkur	X[1]	X	Omega[1]	Omega
0	23.450	0.098369	0.061278							
1	23.900			0.051651			0.049299		0.00098499	
2	24.000			0.051585						
3	24.100						0.033702		0.00067900	
4	24.300			0.031111	0.027456	0.013429	0.031160		0.00063299	
5	24.500			0.040036						
6	24.800			0.072350	0.040656	0.017354				
7	25.000	0.078223	0.094451	0.096365				0.078223		0.0016348
8	25.900			0.15703	0.058784	0.020592				
9	26.500	0.061388	0.076883	0.14715				0.061388		0.0013600
10	28.000			0.10407	0.079024	0.021120	0.050000		0.0011704	
11	30.000	0.058356	0.077735	0.089634			0.085000	0.058356	0.0021318	0.0014635
12	32.200			0.10327	0.082720	0.016826				
13	33.882			0.11661						
14	35.000						0.068000		0.0019896	
15	35.160	0.048726	0.064737					0.048726		0.0014322
16	40.000	0.037302	0.049707				0.049000	0.037302	0.0016385	0.0012474
17	40.700				0.052272	0.0094340				
18	50.000	0.021847	0.026585				0.025400	0.021847	0.0010617	0.00091318
19	57.700				0.019888	0.0035200				
20	60.000						0.015500		0.00077746	
21	70.000						0.011000		0.00064371	
22	80.000	0.0046087	0.0060000				0.0076000	0.0046087	0.00050828	0.00030823
23	90.000						0.0062000		0.00046648	
24	91.700				0.0034320	0.00089900				
25	100.00	0.0022677	0.0023454				0.0050000	0.0022677	0.00041799	0.00018958
26	150.00						0.0017000		0.00021318	
27	160.00				0.00035900	0.00017200				
28	200.00	0.00019144	0.0019404				0.00078000	0.00019144	0.00013041	3.2008e-05
29	250.00						0.00044000		9.1958e-05	
30	296.00				4.2000e-05	2.7000e-05				
31	400.00						0.00027000		9.0286e-05	
32	500.00	7.5586e-06	8.6028e-06					7.5586e-06		3.1594e-06
33	568.00				4.0000e-06	4.0000e-06				

Table 17: $1^1S \rightarrow 4^3D$ transition (contd.)

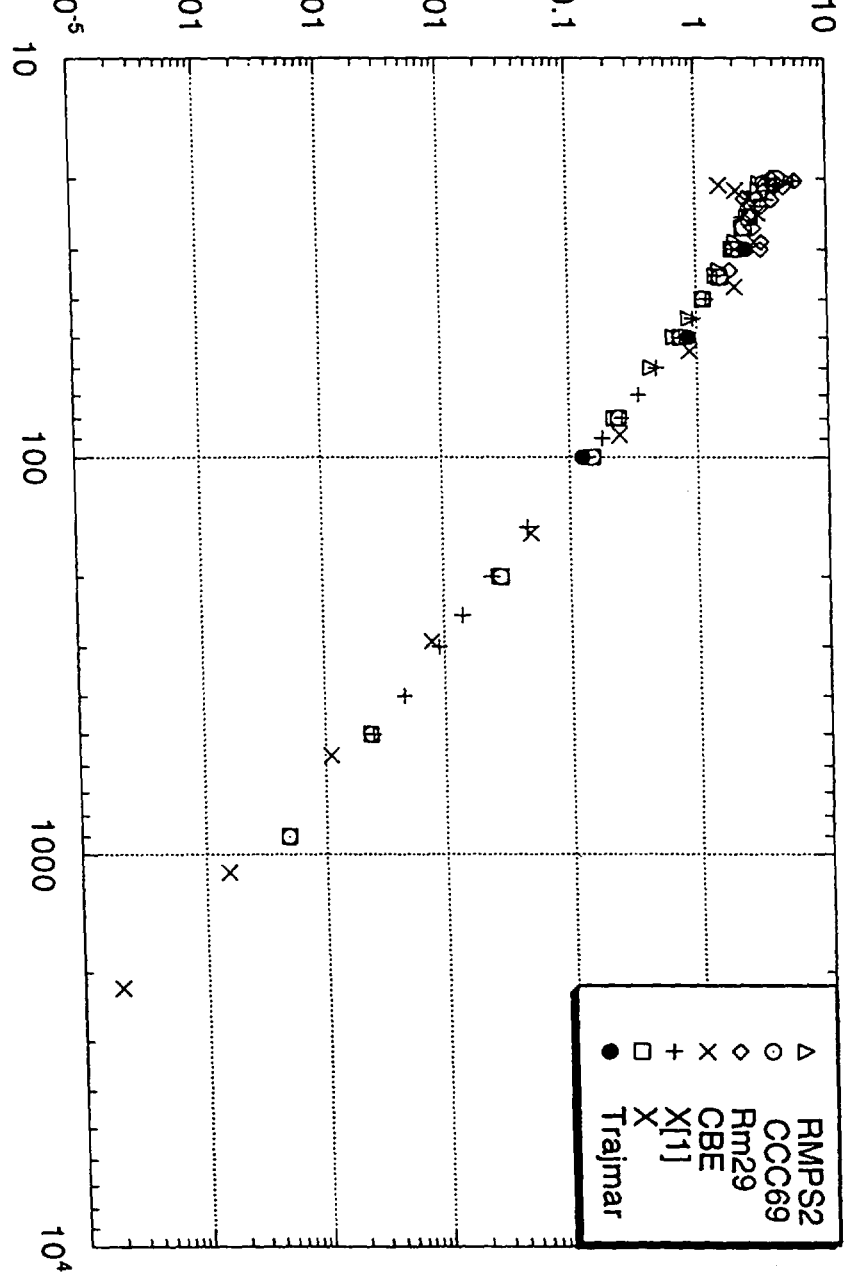
	energy eV	CCC75	CCC69	Rm29	CBE	Ochkur	X[1]	X	Omega[1]	Omega
34	600.00						0.00019000		9.5302e-05	
35	900.00	1.1464e-06	1.1540e-06					1.1464e-06		8.6255e-07
36	1000.0	.					0.00012000		0.00010032	
37	1110.0				1.0000e-06	1.0000e-06				

Table 18: $1^1S \rightarrow 4^3F$ transition

	energy eV	CCC75	CCC69	Rm29	CBE	Ochkur	X	Omega
0	23.450	0.019405						
1	23.900			0.030255				
2	24.000			0.039364				
3	24.300			0.012459	0.057200	0.014330		
4	24.500			0.021482				
5	24.800				0.11176	0.018128		
6	25.000	0.0088433		0.031484			0.0088433	0.00018482
7	25.900			0.028173	0.20592	0.021296		
8	26.500	0.010437		0.025729			0.010437	0.00023122
9	28.000			0.020322	0.30976	0.021296		
10	30.000	0.0074581		0.016751			0.0074581	0.00018704
11	32.200			0.0090271	0.30800	0.016438		
12	33.882			0.0055852				
13	35.160	0.0036755					0.0036755	0.00010803
14	40.000	0.0021925					0.0021925	7.3314e-05
15	40.700				0.15893	0.0089410		
16	50.000	0.0010079					0.0010079	4.2130e-05
17	57.700				0.036432	0.0032560		
18	80.000	0.00013661					0.00013661	9.1366e-06
19	91.700				0.0040480	0.00082700		
20	100.00	3.8944e-05					3.8944e-05	3.2556e-06
21	160.00				0.00031900	0.00015800		
22	200.00	1.9677e-06					1.9677e-06	3.2899e-07
23	296.00				3.0000e-05	2.5000e-05		
24	500.00	7.1653e-08					7.1653e-08	2.9950e-08
25	688.00				4.0000e-06	4.0000e-06		
26	900.00	1.1707e-08					1.1707e-08	8.8081e-09

FIGURES FOR $1^1S \rightarrow n^3L$ TRANSITIONS

($n=2-4, 0 \leq L \leq n-1$)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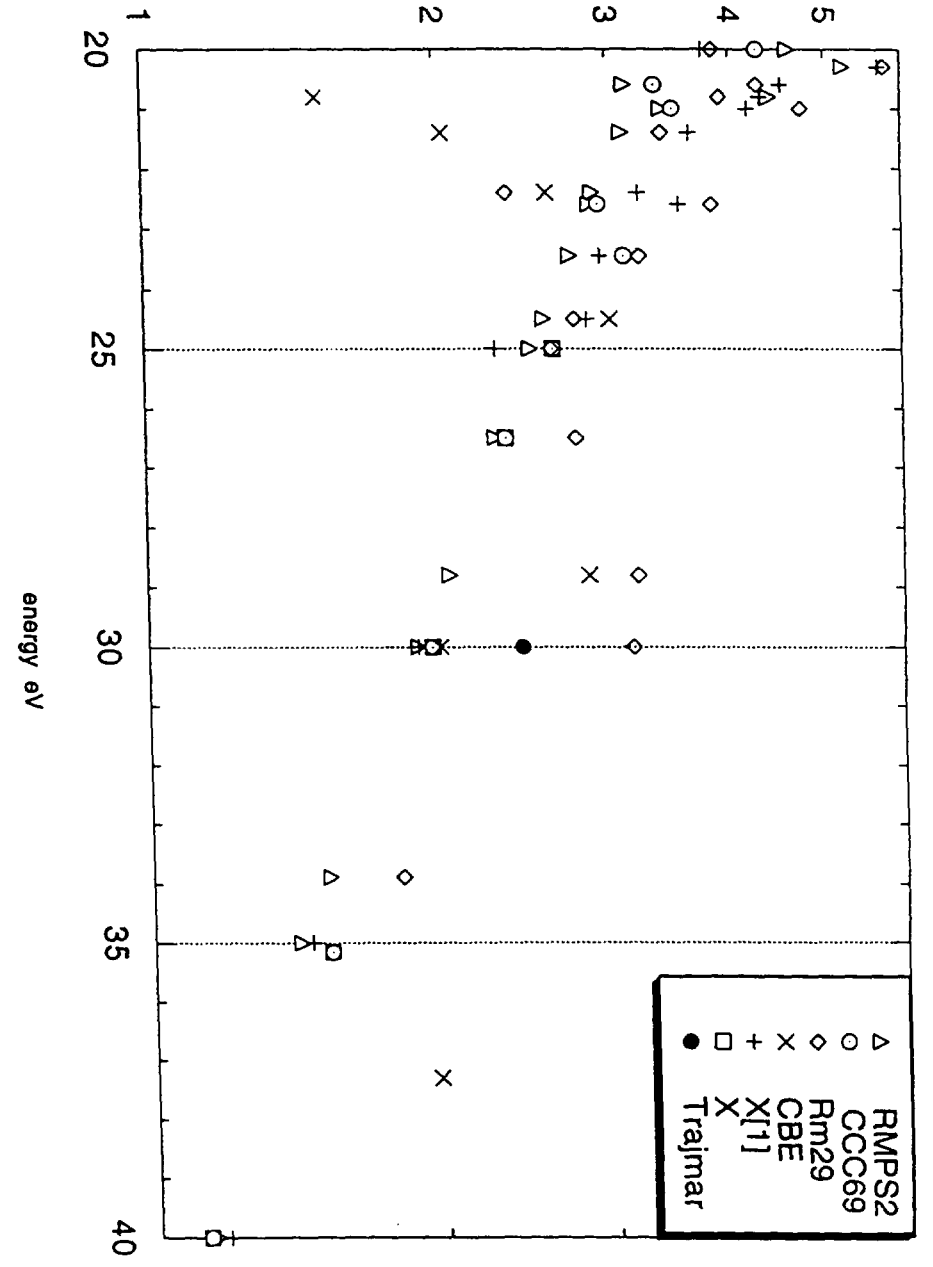
RMPS2
CCC69
Rm29
CBE
X[1]
X
Trajmar
10
1
0.1
0.01
0.001
0.0001
10^{-5}
10
100
1000
10^4
energy eV

Fig. 1a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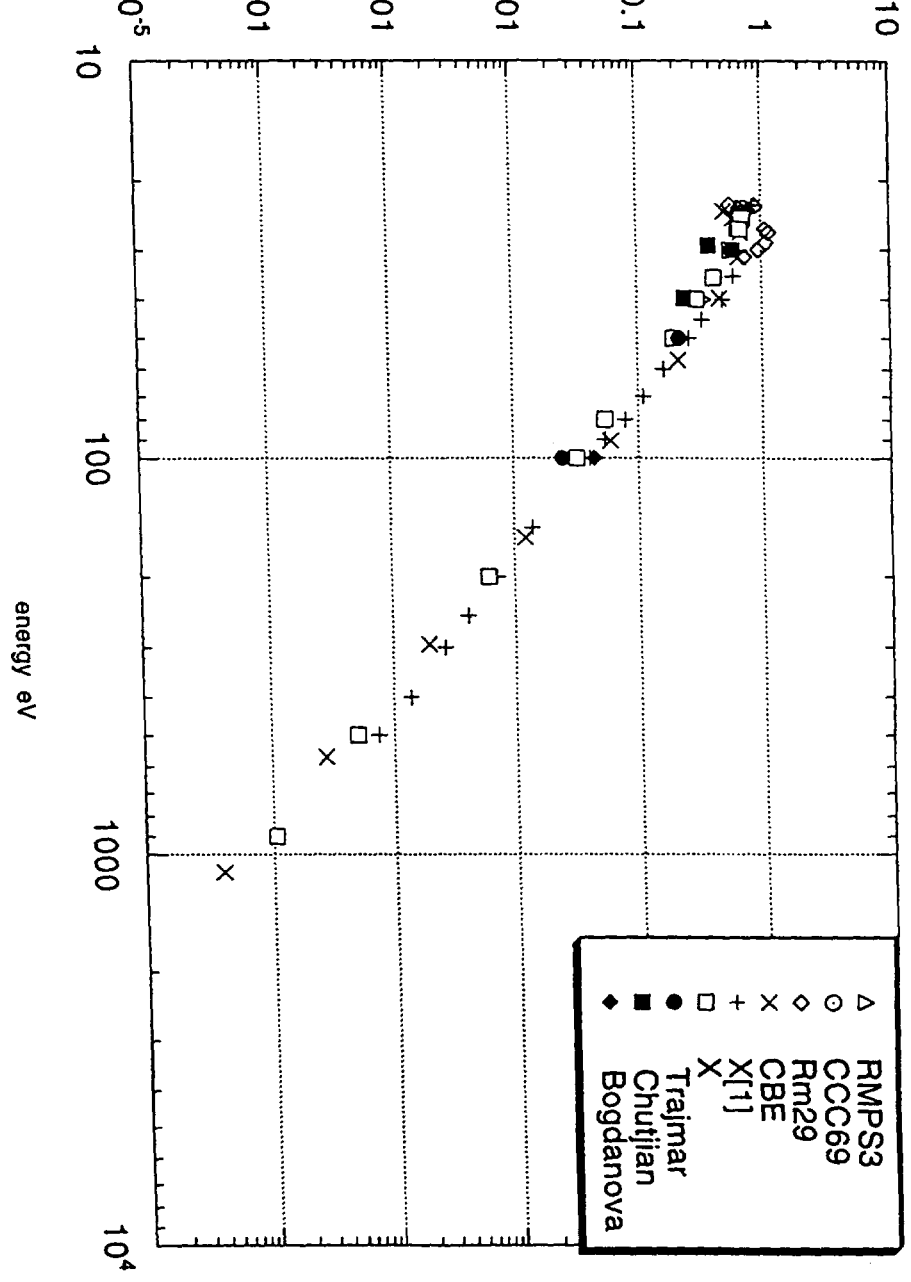
energy eV
1
2
3
4
5
20
25
30
35
40
RMPS2
CCC69
Rm29
CBE
X[1]
X
Trajmar

Fig. 1b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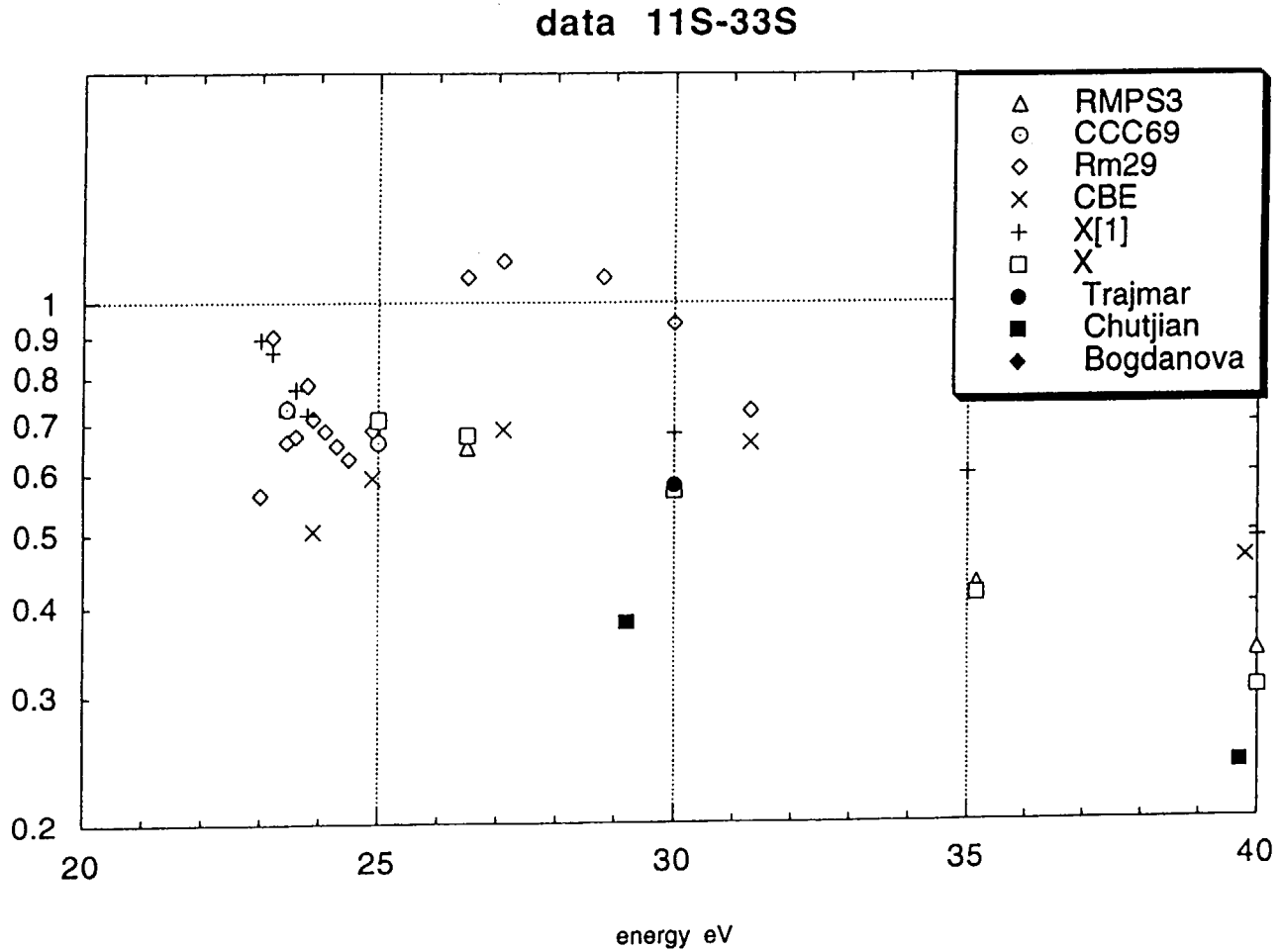
CCC69
Rm29
CBE
X[1]
X
Trajmar
Chutjian
Bogdanova
10
1
0.1
0.01
0.001
0.0001
10^{-5}
10
100
1000
10^{4}
energy eV

Fig. 2a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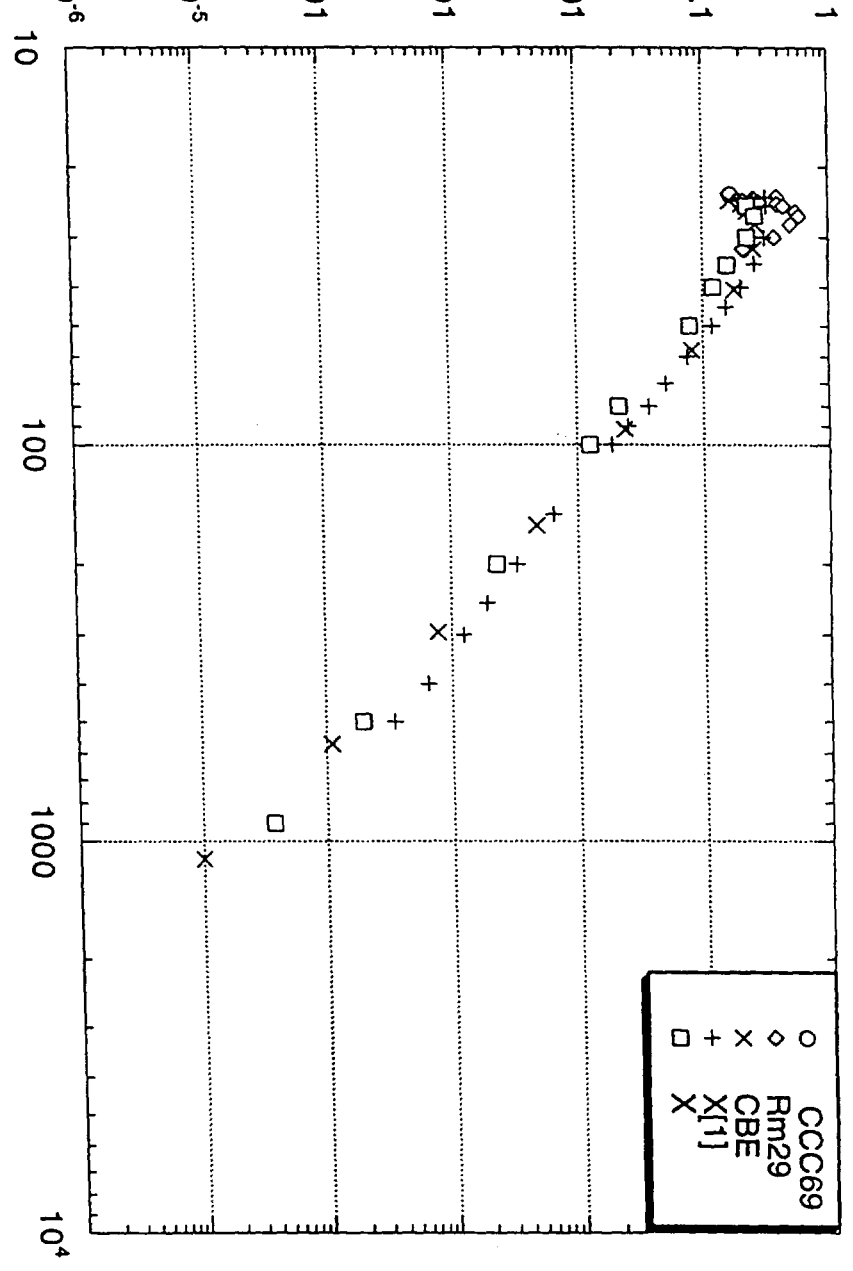
RMPS3
CCC69
Rm29
CBE
X[1]
X
Trajmar
Chutjian
Bogdanova
X[-18]
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
20
25
30
35
40
energy eV

Fig. 2b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CCC69
Rm29
CBE
X[1]
X
1
0.1
0.01
0.001
0.0001
10^{-5}
10^{-6}
10
100
1000
10^{4}
energy eV

Fig. 3a

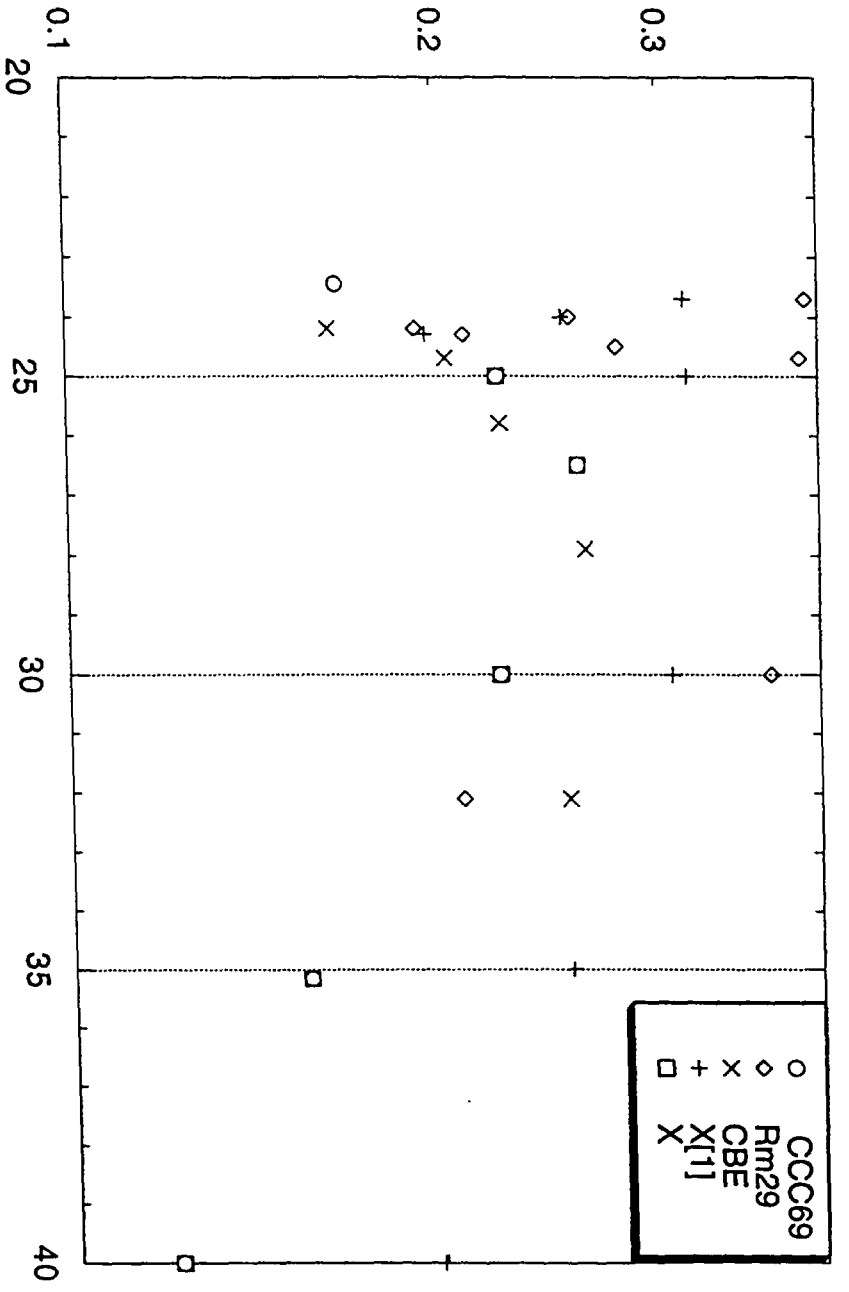
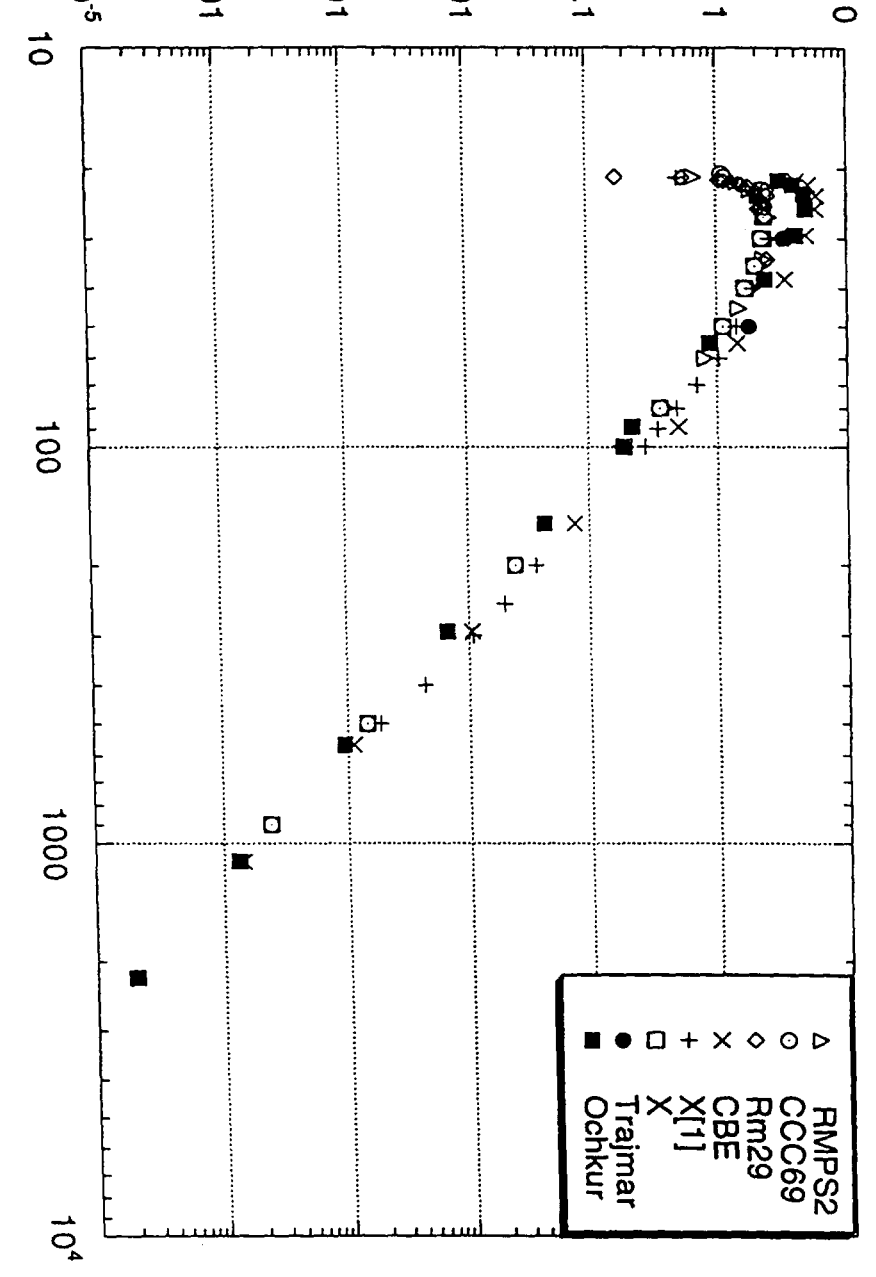


Fig. 3b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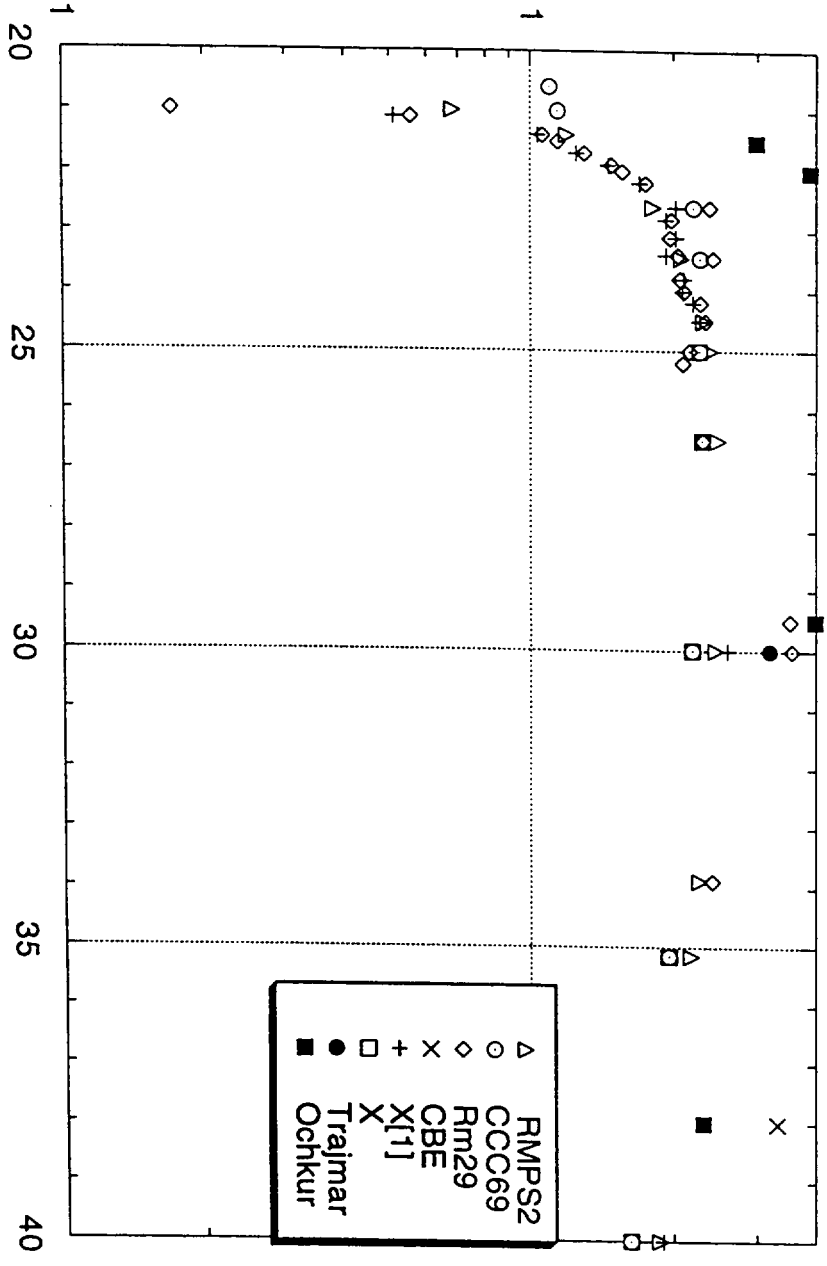
RMPS2
CCC69
Rm29
CBE
X[1]
X
Trajmar
Ochkur
10
1
0.1
0.01
0.001
0.0001
10^{-5}
10
100
1000
10^4

Fig. 4a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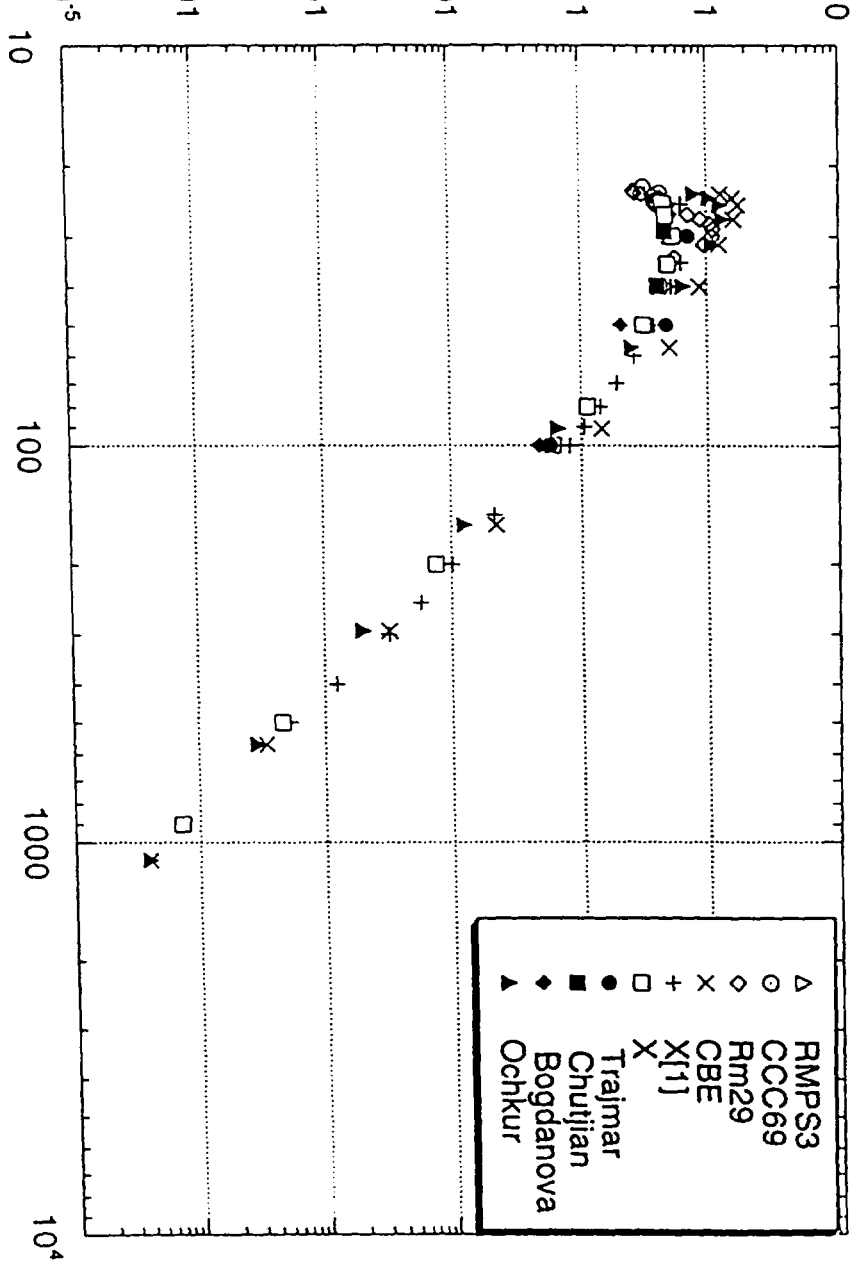
RMPS2
CCC69
Rm29
CBE
X[1]
X
Trajmar
Ochkur
energy eV
0.1
1
20
25
30
35
40

Fig. 4b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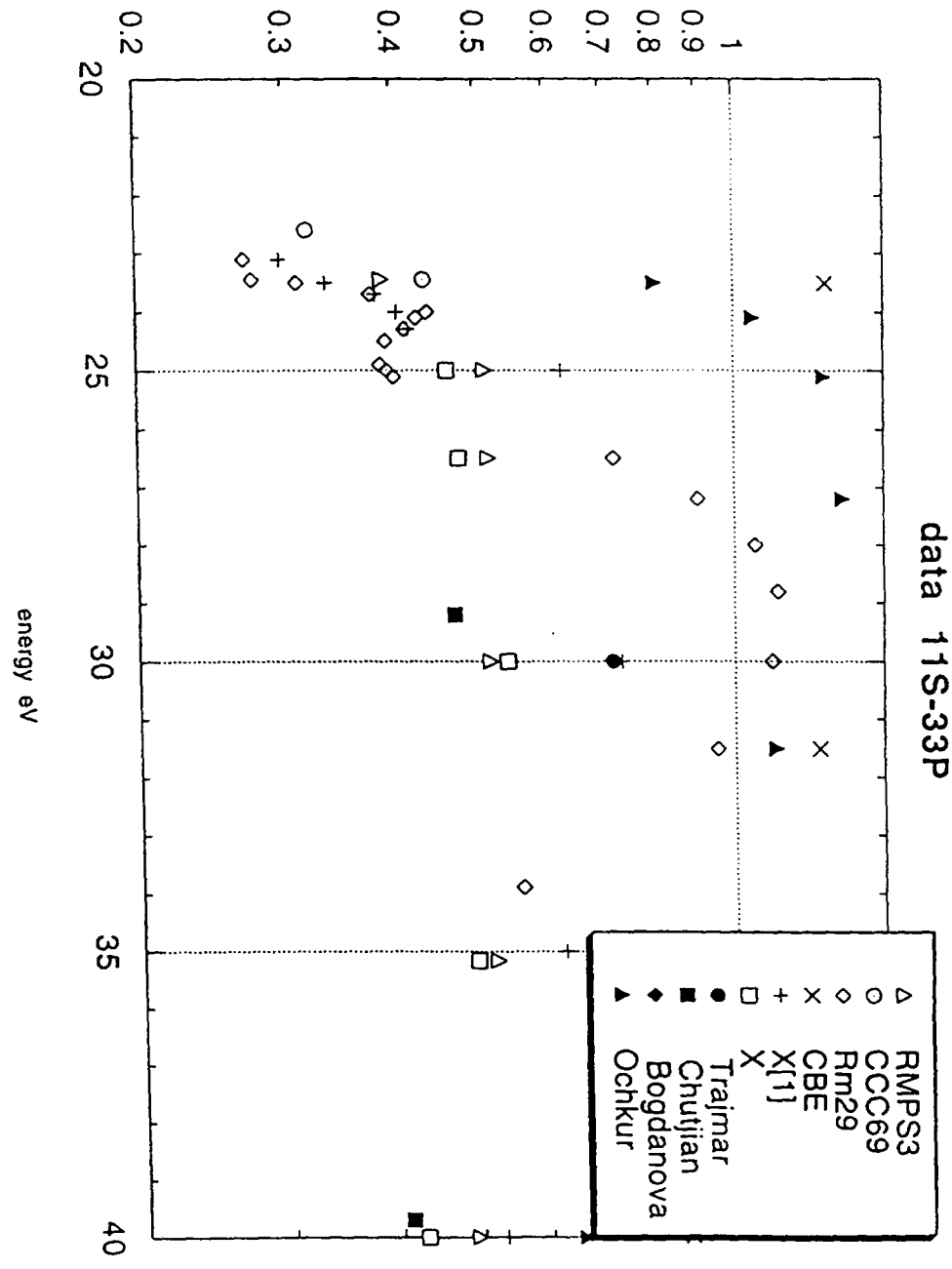
RMPS3
CCC69
Rm29
CBE
X[1]
X
Trajmar
Chutjian
Bogdanova
Ochkur
10
1
0.1
0.01
0.001
0.0001
10^{-5}
10
100
1000
10^4
energy eV

Fig. 5a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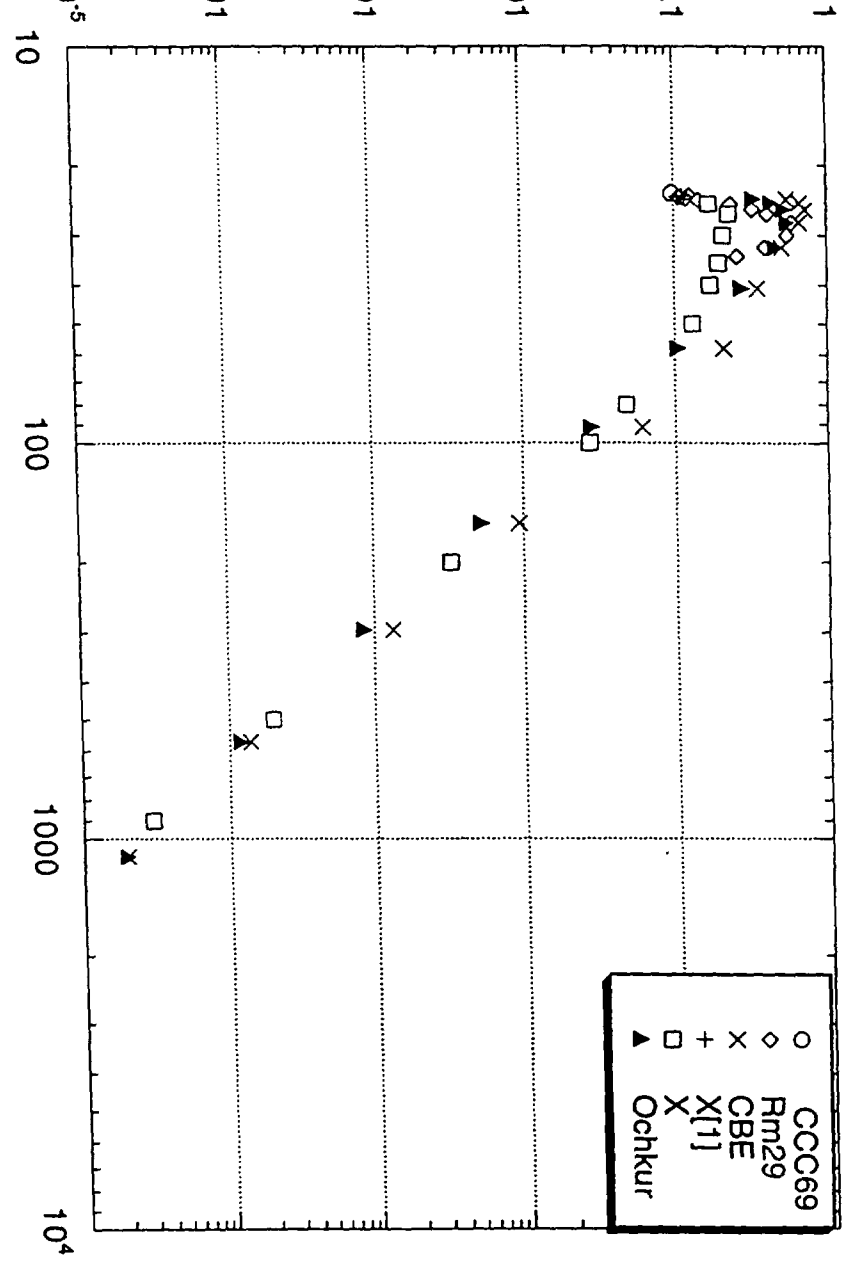
CCC69
Rm29
CBE
X[1]
X
Trajmar
Chutjian
Bogdanova
Ochkur
energy eV
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
20
25
30
35
40

Fig. 5b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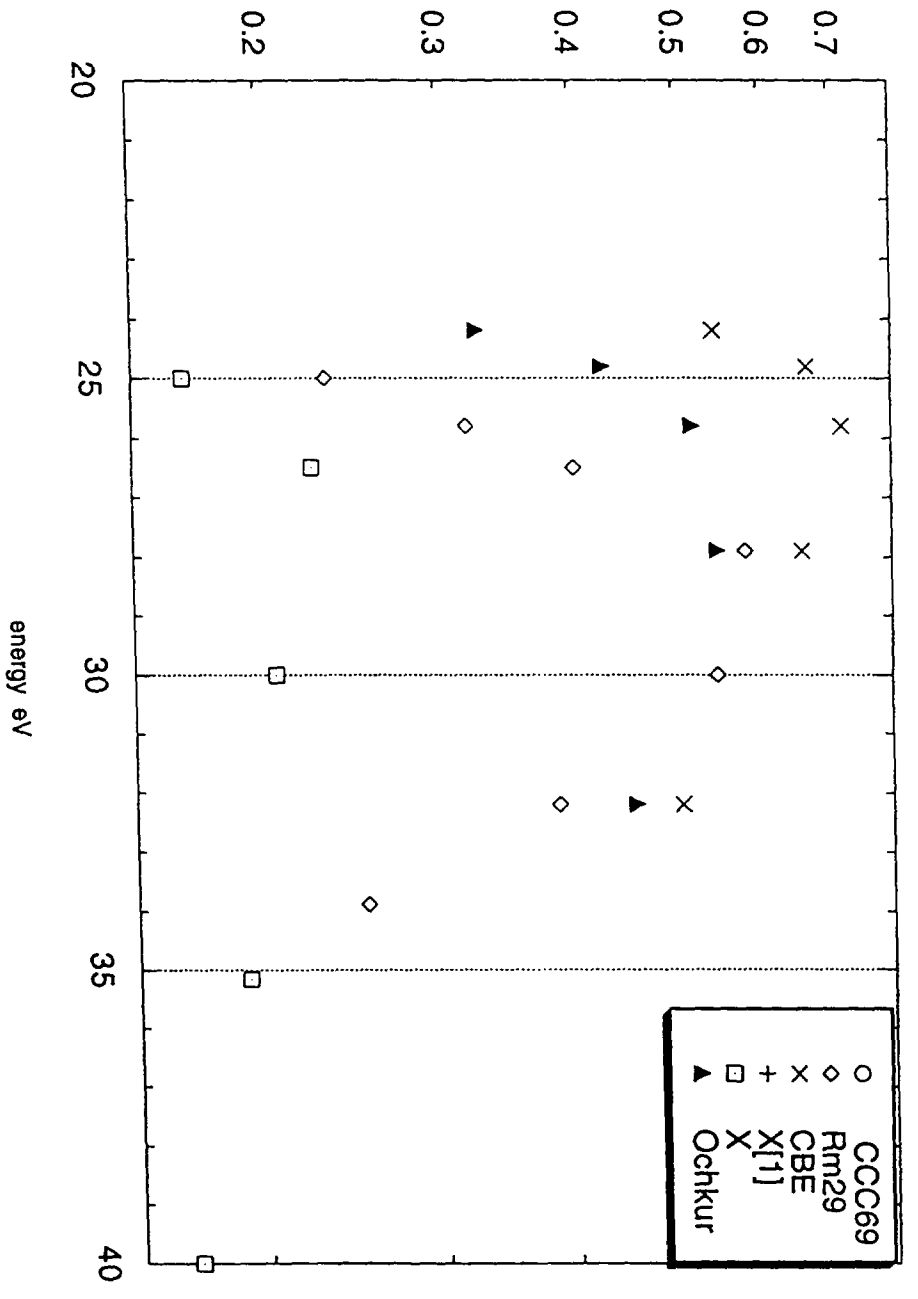
CCC69
Rm29
CBE
X[1]
X
Ochkur
1
0.1
0.01
0.001
0.0001
10^{-5}
10
100
1000
10^{4}
energy eV

Fig. 6a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CCC69
Rm29
CBE
X[1]
X
Ochkur
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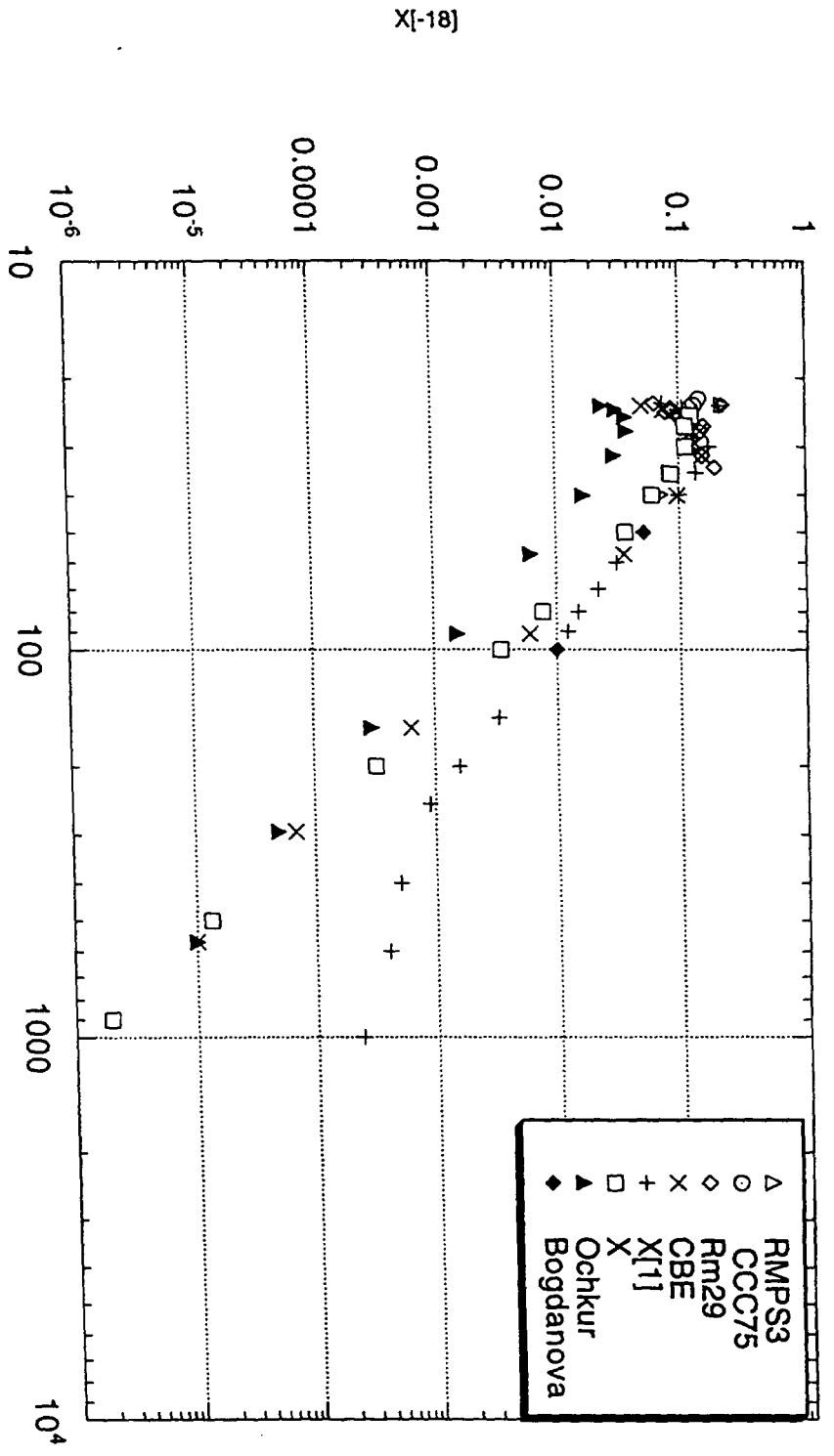
0.6
0.5
0.4
0.3
0.2
20
25
30
35
40
energy eV

Fig. 6b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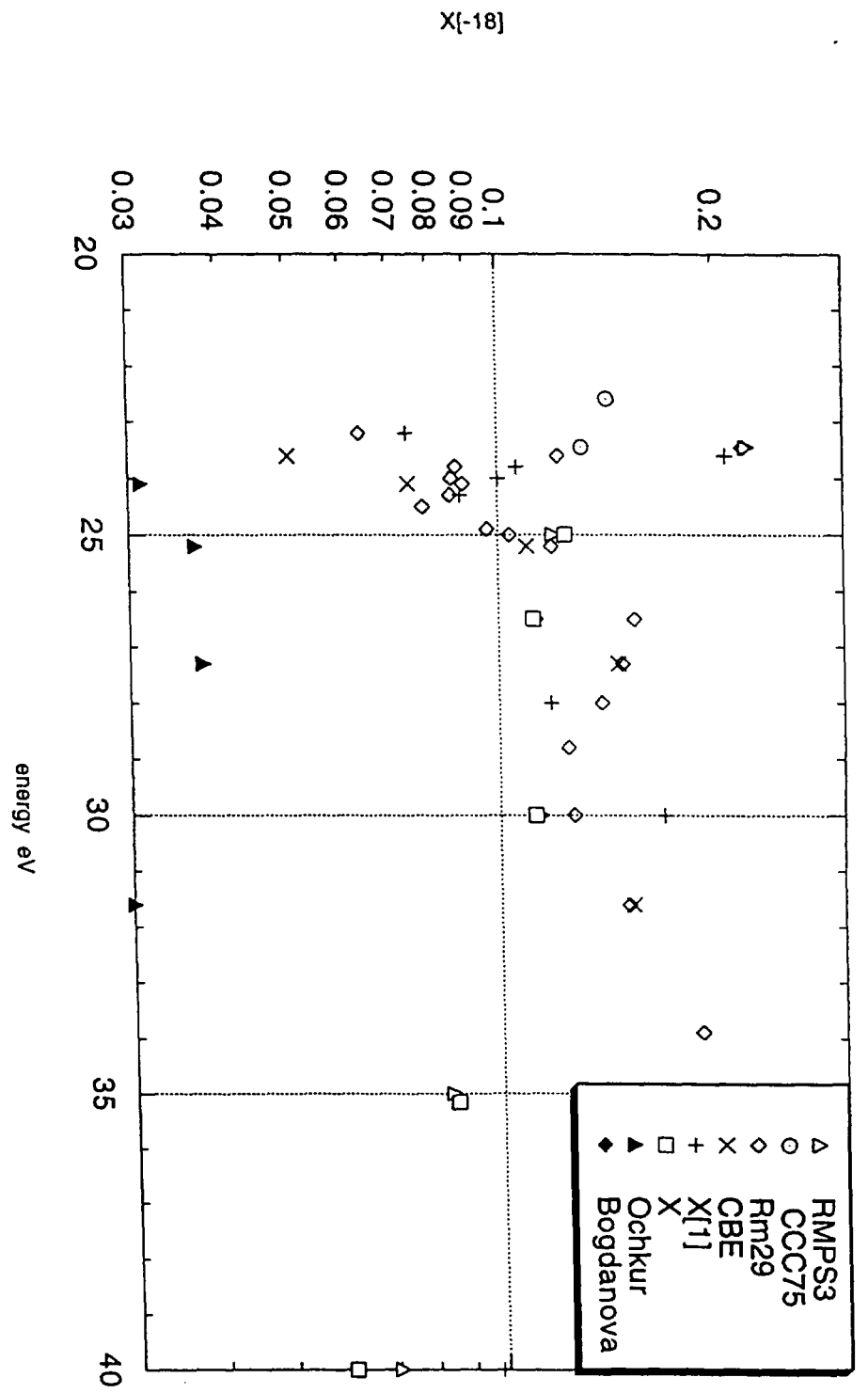
RMPS3
CCC75
Rm29
CBE
X[1]
X
Ochkur
Bogdanova
1
0.1
0.01
0.001
0.0001
10^{-5}
10^{-6}
10
100
1000
10^4
energy eV

Fig. 7a


X[-18]
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RMPS3
CCC75
Rm29
CBE
X[1]
X
Ochkur
Bogdanova
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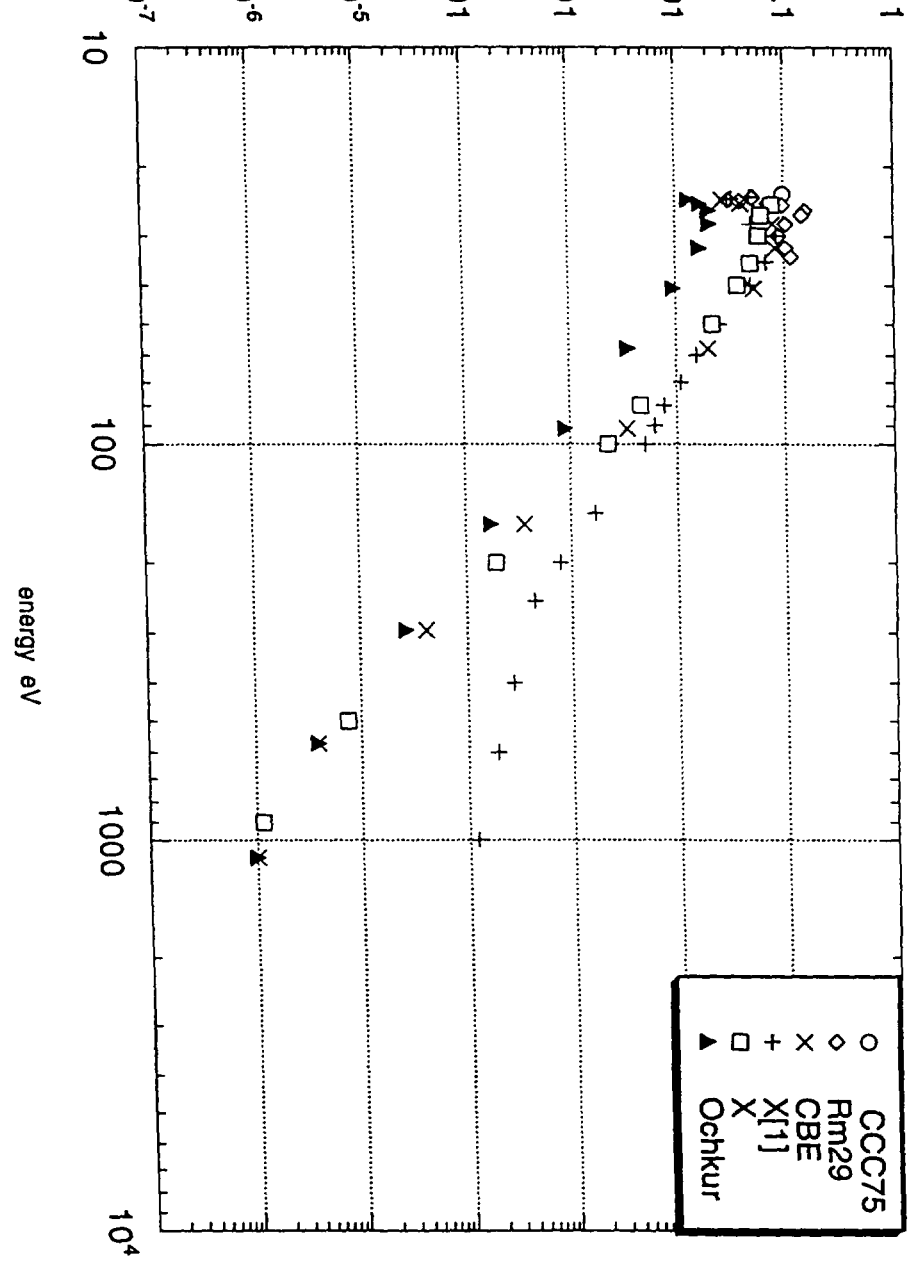
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
20
25
30
35
40
energy eV

Fig. 7b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CCC75
Rm29
CBE
X[1]
X
Ochkur
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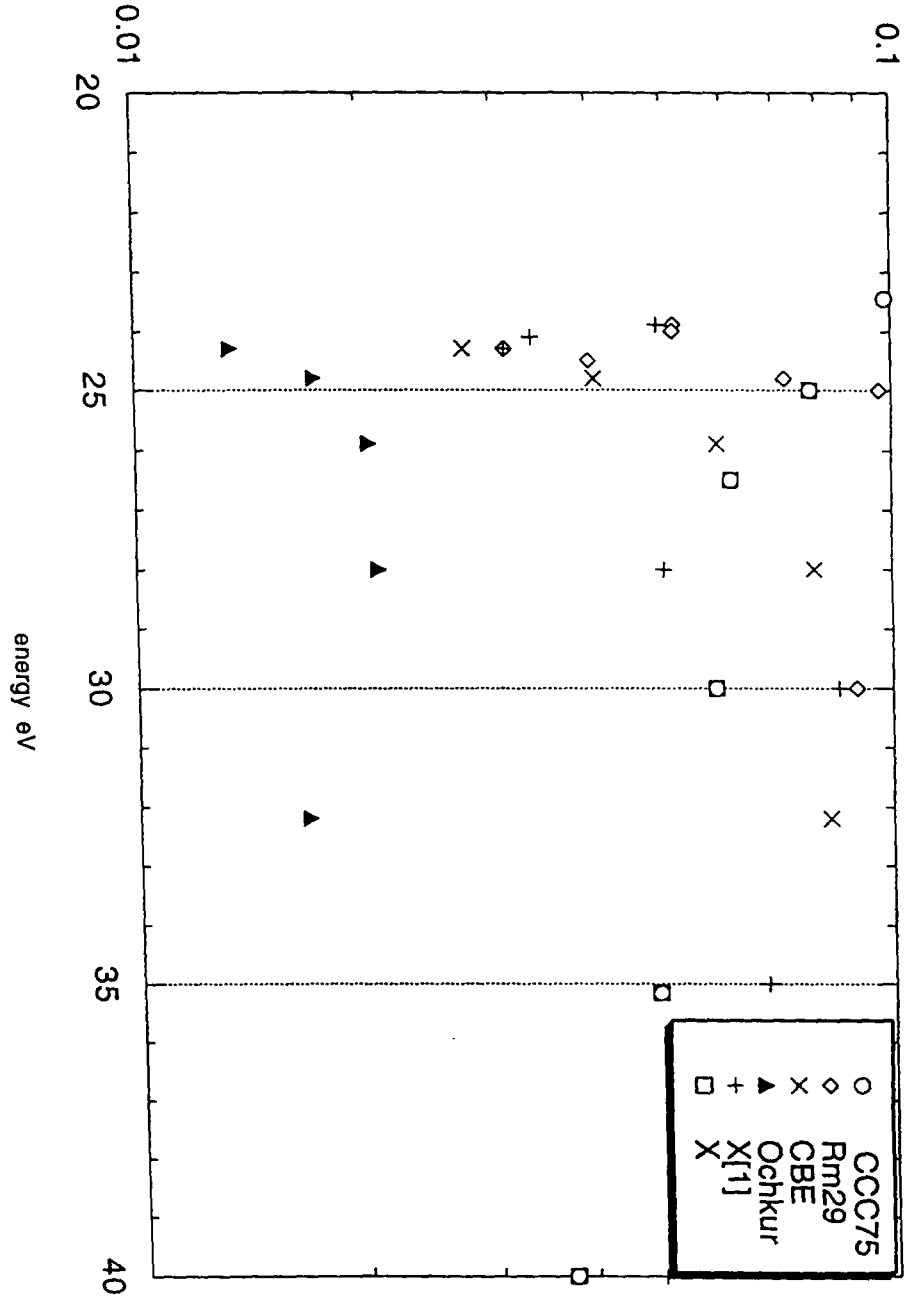
0.01
0.001
0.0001
10^{-5}
10^{-6}
10^{-7}
10
100
1000
10^4
energy eV

Fig. 8a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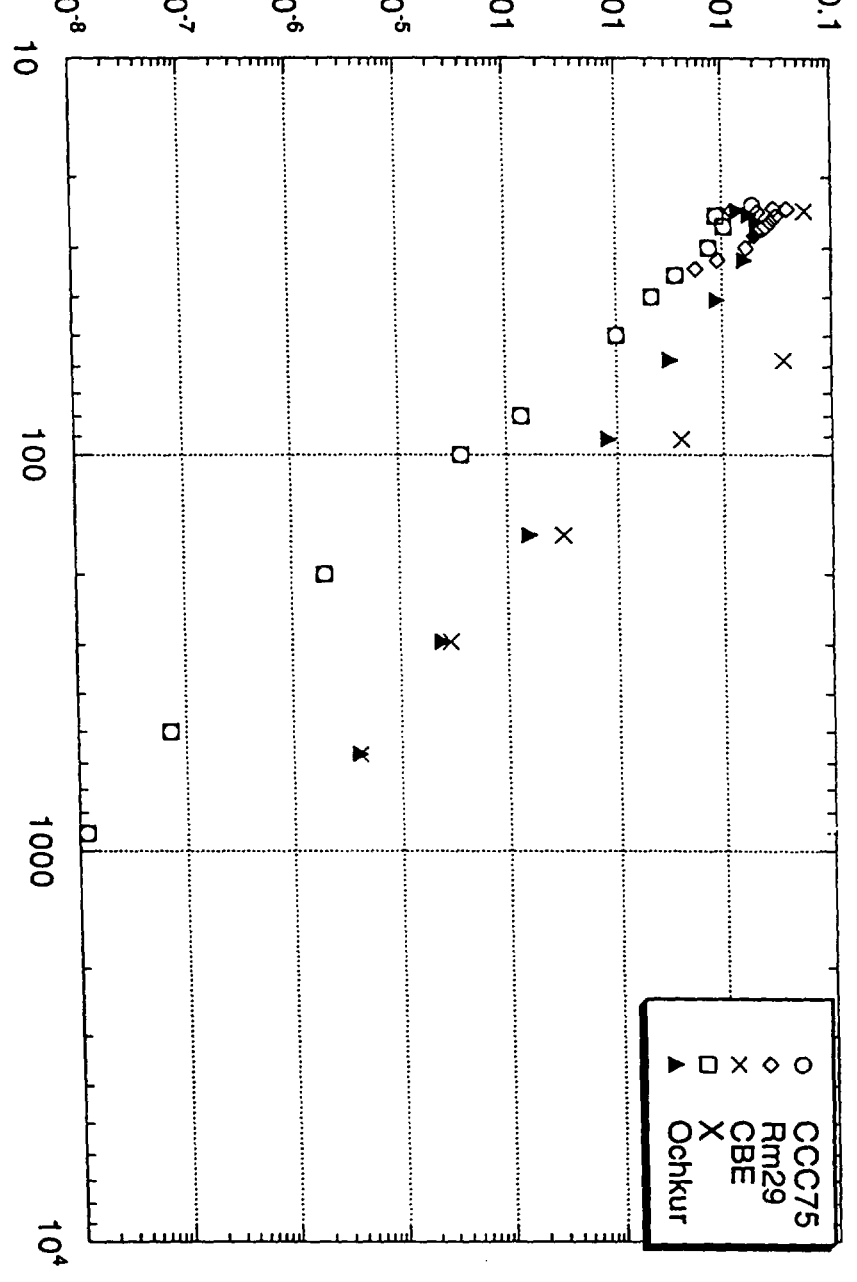
0.01
20
25
30
35
40
energy eV
CCC75
Rm29
CBE
Ochkur
X[1]
X

Fig. 8b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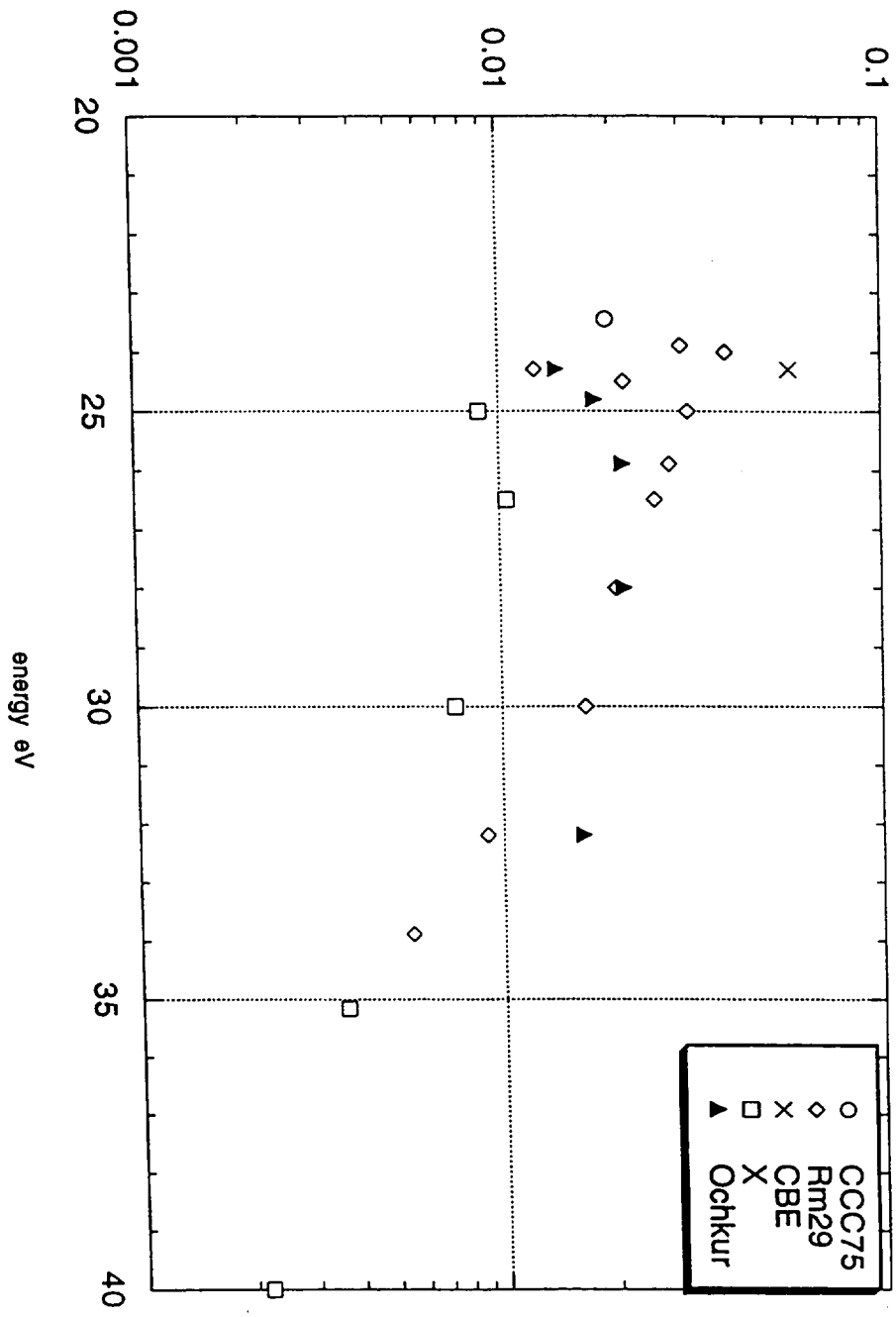
Rm29
CBE
Ochkur
0.1
0.01
0.001
0.0001
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10
100
1000
10^4
energy eV

Fig. 9a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0.1
0.01
0.001
20
25
30
35
40
energy eV
CCC75
Rm29
CBE
X
Ochkur

Fig. 9b