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Résumé.

Plusieurs séries de forces d'oscillateur pour des transitions permises dans l'oxygène neutre, calculées dans le cadre du projet international Opacity, sont présentées et comparées à des données tant expérimentales que théoriques obtenues par d'autres auteurs. On montre que les présents résultats sont d'une haute précision.

Summary.

Several series of oscillator strengths for allowed transitions in neutral oxygen, calculated in the framework of the international Opacity Project, are presented and compared with both experimental and theoretical data obtained by other authors. It is shown that the present results are of high accuracy.

1. Introduction.

The international Opacity Project (*OP*), mentioned in several other papers in this volume, aims at reestimating stellar envelope opacities (see the general description of the project by Seaton, 1987). In order to achieve this task, it is essential to calculate a large number of accurate radiative atomic data (term energies, oscillator strengths, photoionisation cross sections) and parameters for pressure broadening of spectral lines. Of course, the atomic data produced by the various participants to the *OP* will also be of use in other fields of astrophysics. Needless to say, it is important to try to assess the accuracy of these new results.

The authors of the present report have already compared their cross sections for the photoionisation of the $^3P^e$, $^1D^e$ and $^1S^e$ states of neutral oxygen with recent theoretical and experimental work (see Butler & Zeippen, 1990*a*, and references therein). The conclusion of this study is that the *OP* cross sections are of very good accuracy and certainly precise enough for opacity calculations. The present paper will be concerned with several series of oscillator strengths for allowed transitions in the same atom. Our choice is justified by the fact that the neutral member of most isoelectronic sequences is among the most difficult, if not the most difficult one to treat accurately, and also by the possibility of comparing *OP* data to other theoretical results and experimental measurements, thus complementing the assessment of Butler & Zeippen (1990*a*). The bulk of the *OP* radiative data for the oxygen isoelectronic sequence will be presented in a paper being prepared for the Atomic Data for Opacity Calculations (*ADOC*) series in *J. Phys. B* (Butler & Zeippen, 1990*b*).

2. Theoretical methods and physical models.

The two most extended calculations to date have been performed independently by Bell & Hibbert (1990, later referred to as *BH*) and by the authors of this paper (later referred to as *BZ*), using the close-coupling approximation (Burke & Seaton, 1971) as implemented in a revised version of the RMATRX program described by Berrington *et al.* (1974, 1978) and new codes based on optimised techniques (see, for example, Seaton, 1985) for the asymptotic region. The new OPACITY set of computer programs is described by Berrington *et*

al. (1987). Let us recall that, in the collisional formalism adopted by *BH* and *BZ*, the total system (here neutral oxygen) is considered as being formed of a target or residual ion (here O^+) plus a scattered electron. The wavefunctions describing the target are of course an essential element of the calculation. This is where the main difference between the *BH* and *BZ* calculations lies.

BZ chose to base their work on the target wavefunctions described by Butler & Zeippen (1990*a*) : only the eight O^+ terms corresponding to the ground complex (configurations $2p^3$, $2s2p^4$, $2p^5$) are considered and the orbitals are built with the help of a version of the code SUPERSTRUCTURE (Eissner *et al.*, 1974) due to Nussbaumer & Storey (1978). On the other hand, *BH* decided to use the wavefunctions built by Bell *et al.* (1989) : eleven O^+ terms are included (thus incorporating some n=3 terms) and the orbitals are produced by the codes CIV3 (Hibbert, 1975) and CIVPOL (Le Dourneuf, 1990). A complete discussion of the target problem can be found in Butler & Zeippen (1990*a*) who show that their eight-term target is adequate for photoionisation calculations. A comparison between the findings of *BH* and *BZ* concerning oscillator strengths will provide a further test of the importance of the n=3 target terms.

The most complete previous elaborate calculations are by Pradhan & Saraph (1977, later referred to as *PS*) who also used the close-coupling approximation, but as implemented in the University College London (*UCL*) chain of computer programs (Eissner, 1972; Crees *et al.*, 1978; Saraph, 1976), and with a seven-term O^+ target constructed by Pradhan (1976) with the help of SUPERSTRUCTURE (Eissner *et al.*, 1974). Other published theoretical values were obtained by Zeippen *et al.* (1977), using SUPERSTRUCTURE, by Ganas (1980), using an analytic atomic independent-particle model potential, and by Froese Fischer (1987), using the multi-configuration Hartree-Fock method with Breit-Pauli relativistic corrections (*MCHF* + *BP*).

Finally, it should be noted that *BH* used the CIV3 code (Hibbert, 1975) to perform configuration-interaction (*CI*) calculations of oscillator strengths for a few of the transitions they treated collisionally. The corresponding results are listed in the present tables with a *BH*2 label, while the values they obtained with the OPACITY package are marked *BH*1.

3. Comparison between the various sets of results.

BH discuss in some detail their oscillator strengths as compared to previous work. They mention the existence of the *OP* data but note that those are as yet unpublished. In the present report, we will complete the tables given in *BH* by adding our *OP* results and extending the comparison. *BH* list the values they obtained both with the length (*L*) and velocity (*V*) formalisms. Considering the fact that the *L* data are generally rated as the most accurate, and also that only the *L* oscillator strengths are used in subsequent *OP* opacity calculations or indeed calculated for all transitions, we will not reproduce any *V* results here. However, since the agreement between the *L* and *V* data is an indication of the quality of a given calculation, mention will be made in the text of this aspect for some transitions.

a. The $^3P - ^3S^o$ transitions (see Table 1).

The discrepancy between the *BH*1 and *BZ* sets of data is never more than 3 % for all transitions, except for the transitions $2p^4 - 2p^3ns$, with n=4 to 10, for which the difference goes up to 12 %. In these cases, the *OP* values of *BZ* are closer to the findings of *PS* and Zeippen *et al.* (1977). Also, *BZ* agree better with the recent experimental result of Doering *et al.* (1985) and they tend to be in better accord with Ganas (1980). On the other hand, for the $2p^4 - 2p^3ns$ transitions, *BH*1 obtain a better agreement between their *L* and *V* data than *BZ* (typically, a maximum discrepancy of 10 %, as compared to 20 %). Finally, the *BH*2 findings are closer to the *BZ* or *PS* results than the *BH*1 ones. The conclusion must be that the *OP* data calculated by *BZ* are accurate to 10 % or better (much better for most transitions in the table).

b. The $^3S^o - ^3P$ transitions (see Table 2).

The discrepancy between the *BH*1 and *BZ* sets of data is within 5 % for most transitions, and within 10 % for the transitions $4s - 5p, 6p$; $5s - 7p, 8p$; $6s - 8p, 9p, 10p$; $7s - 9p, 10p$. It goes up to 14 % for the transitions $3s - 4p$; $5s - 9p, 10p$. As pointed out by *BH*, it is of course difficult to obtain accurate values for very small oscillator strengths. It should be noted, however, that the agreement between the *OP* *L* and *V* results by *BZ*, for the $3s - np$ and $4s - np$ transitions (and in particular for the transition $3s - 4p$), is markedly better

than the one obtained by $BH1$ (typically, a maximum discrepancy of a few percent, as compared to up to a factor of four). In conclusion, the OP set of data by BZ will be rated as accurate to 10 % (and better for most transitions in the table).

c. The $^3P - ^3D^o$ transitions (see Table 3).

The discrepancy between the $BH1$ and BZ sets of data is within 5 % for most transitions and within 10 % for the others, with the remarkable exception of the $2p^4 - 2p^3 4d$ transition for which the discrepancy goes up to a factor of two! Note that for this latter transition, the BZ result is much closer to the theoretical values of $BH2$, PS and Ganas (1980), as well as to the experimental finding of Doering *et al.* (1985). Also, where available, the V data calculated by BZ agree better with the corresponding L results than is the case for the $BH1$ values (typically, a maximum discrepancy of 11 %, as compared to 22 %). Finally, BZ are closer to Doering *et al.* (1985) for the $2p^4 - 2p^3 3d$ transition, closer to PS for the $2p^4 - 2p^3 5d$ and $3p - 4d$ transitions, and closer to Wiese *et al.* (1966) for the $3p - 4d$ transition than $BH1$. The OP data of BZ can then be considered as accurate to within 10 % (and better for most transitions in the table).

d. The $^3D^o - ^3P$ transitions (see Table 4).

The discrepancy between the $BH1$ and BZ sets of data is not more than 5 % for the $3d - np$; $nd - (n+1)p$ transitions, and not more than 10 % for the others, with the exception of the $4d - 8p, 9p, 10p$ transitions, for which it goes up to 17 %. It should be noted that the latter oscillator strengths are very small and that the agreement between the L and V results of $BH1$ gets worse as n increases in the $4d - np$ series of transitions. The OP results of BZ will be rated as accurate to 10 % or better for all significant transitions.

e. The $^5D^o - ^5P$ transitions (see Table 5).

The discrepancy between the $BH1$ and BZ sets of data is not more than 5 % for the $nd - (n+1)p$ transitions, but goes up to about a factor of two for the $nd - (n+2)p$ transitions. The oscillator strengths are much smaller (and therefore more difficult to get right) for the latter transitions. The agreement between the L and V results of $BH1$ is less good for the $nd - (n+2)p$ cases and also markedly worse than the agreement obtained by BZ for the $3d - 5p$ case (a discrepancy of 55 %, as compared to 7 %). The OP data by BZ should be accurate to within 5 % for the $nd - (n+1)p$ transitions but no solid conclusion can be drawn for the $nd - (n+2)p$ transitions.

f. The $^5S^o - ^5P$ transitions (see Table 6).

The discrepancy between the $BH1$ and BZ sets of data is within 5 % for all $ns - np$ transitions for $ns - (n+1)p$ transitions, with n=4 to 9, and for $ns - (n+2)p$ transitions, with n=7 and 8, and not more than 10 % for the others, with the exception of the $4s - (7 \text{ to } 10)p$ and the $5s - 10p$ transitions, for which it goes up to 26 %. The latter transitions correspond to small oscillator strengths and the agreement between L and V results obtained by BZ is better than the one achieved by BH (typically, a maximum discrepancy of 12 %, as compared to 45 %). In conclusion, the OP data of BZ will rated as accurate to within 10 % for all significant transitions.

g. The $^5P - ^5S^o$ transitions (see Table 7).

The discrepancy between the $BH1$ and BZ sets of data is not more than 3 % for all transitions. The accuracy of the OP data can thus be rated as to within a few percent.

h. The $^5P - ^5D^o$ transitions (see Table 8).

The discrepancy between the $BH1$ and BZ sets of data is not more than 5 % for all transitions, except for the $3p - (6 \text{ to } 10)d$ transitions for which it goes up to 7 %. Note that for all the latter cases the agreement between L and V results is better in BZ than in $BH1$ (typically, a maximum discrepancy of 5 %, as compared to 16 %). Here again, the OP data of BZ can be rated as accurate to better than 10 %.

4. Conclusion.

From the detailed comparison above, it appears that both the *BH*1 and *BZ* sets of data are very accurate, with perhaps a few dubious values in the first set. This might be due to the fact that the target used by *BZ* is a well-balanced description of the ground complex O^+, while by incorporating only some of the n=3 terms in their calculation, *BH* do not obtain a completely coherent model. Their study is useful, however, in showing that the effect of those excited terms is not essential as compared to that of the n=2 terms. To assess completely the importance of the target terms outside the complex, even larger calculations are needed but they would demand large amounts of computer time and human effort, and could require changes in the numerical methods or theoretical formalisms. As it is, confronted by the necessity of performing accurate but manageable calculations for the whole isoelectronic sequence, *BZ* seem to have produced data, which, from the first two tests of their accuracy (Butler & Zeippen, 1990a, and present paper) appear to be more than precise enough (well within the 10 % range for all significant transitions) for opacity calculations and perhaps other astrophysical problems as well. It should also be pointed out that the older calculations by *PS* and Zeippen *et al.* (1977) gave results whose accuracy is quite satisfactory, considering the computing facilities available at the time. On the experimental front, as already noted by *BH*, the measurements are scattered, illustrating the difficulty of obtaining accurate results in this case. Some of the experimental data come, however, close to calculated values, as mentioned in the text or shown in the tables.

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Table 1. Oscillator strengths for ^3P - $^3S^o$ transitions in neutral oxygen.

Transition	BH1	BH2	BZ	PS	Other calculations		Experiment		
$2p^4$-$2p^3$3s	4.96(-2)	5.11(-2)	5.12(-2)	5.37(-2)	4.19(-2)[a]	5.60(-2)[b]	4.8±.3(-2)[c]	5.0±.4(-2)[d]	4.5±1.(-2)[e]
							5.0(-2)[f]	5.3±.6(-2)[g]	
4s	8.17(-3)	1.00(-2)	9.14(-3)	9.24(-3)	8.95(-3)[b]		5.9±1.5(-3)[e]	1.0±.2(-2)[h]	
5s	2.93(-3)		3.30(-3)	3.29(-3)	3.14(-3)[b]		1.5±.5(-3)[e]		
6s	1.40(-3)		1.57(-3)	1.60(-3)	1.48(-3)[b]				
7s	7.73(-4)		8.75(-4)		8.20(-4)[b]	8.74(-4)[i]			
8s	4.74(-4)		5.37(-4)		5.37(-4)[i]				
9s	3.12(-4)		3.54(-4)		3.54(-4)[i]				
10s	2.16(-4)		2.45(-4)		2.45(-4)[i]				
$2p^3$3p-$2p^3$4s	1.89(-1)	2.10(-1)	1.84(-1)	1.87(-1)			1.63(-1)[j]		
5s	1.77(-2)		1.73(-2)	1.68(-2)			1.62(-2)[j]		
6s	5.79(-3)		5.64(-3)	5.58(-3)			4.27(-3)[j]		
7s	2.72(-3)		2.64(-3)						
8s	1.53(-3)		1.48(-3)						
9s	9.49(-4)		9.19(-4)						
10s	6.34(-4)		6.14(-4)						
$2p^3$4p-$2p^3$5s	3.21(-1)		3.17(-1)	3.23(-1)					
6s	2.80(-2)		2.79(-2)	2.86(-2)					
7s	9.12(-3)		9.05(-3)						
8s	4.31(-3)		4.28(-3)						
9s	2.43(-3)		2.42(-3)						
10s	1.54(-3)		1.52(-3)						
$2p^3$5p-$2p^3$6s	4.54(-1)		4.48(-1)						
7s	3.84(-2)		3.83(-2)						
8s	1.24(-2)		1.24(-2)						
9s	5.87(-3)		5.86(-3)						
10s	3.34(-3)		3.33(-3)						
$2p^3$6p-$2p^3$7s	5.84(-1)		5.77(-1)						
8s	4.85(-2)		4.85(-2)						
9s	1.56(-2)		1.56(-2)						
10s	7.37(-3)		7.39(-3)						
$2p^3$7p-$2p^3$8s	7.07(-1)		7.06(-1)						
9s	5.82(-2)		5.86(-2)						
10s	1.86(-2)		1.88(-2)						
$2p^3$8p-$2p^3$9s	8.36(-1)		8.34(-1)						
10s	6.81(-2)		6.87(-2)						
$2p^3$9p-$2p^3$10s	9.64(-1)		9.62(-1)						

Table 2. Oscillator strengths for $^3S^o$ - ^3P transitions in neutral oxygen.

Transition	BH1	BH2	BZ	PS	Experiment			
$2p^3 3s$-$2p^3 3p$	1.03(0)	1.03(0)	1.05(0)	1.06(0)	8.98(-1)[j]	8.92(-1)[k]	8.0(-1)[l]	8.2±.3(-1)[m]
$4p$	8.63(-3)	1.89(-3)	7.73(-3)	9.60(-3)	5.6(-3)[j]	3.2(-2)[l]		
$2p^3 4s$-$2p^3 4p$	1.51(0)	1.36(0)	1.51(0)					
$5p$	2.28(-2)		2.16(-2)					
$6p$	3.15(-3)		2.89(-3)					
$2p^3 5s$-$2p^3 5p$	1.94(0)		1.94(0)					
$6p$	3.71(-2)		3.54(-2)					
$7p$	6.13(-3)		5.72(-3)					
$8p$	1.89(-3)		1.73(-3)					
$9p$	7.92(-4)		7.08(-4)					
$10p$	3.98(-4)		3.50(-4)					
$2p^3 6s$-$2p^3 6p$	2.37(0)		2.36(0)					
$7p$	5.07(-2)		4.87(-2)					
$8p$	9.23(-3)		8.64(-3)					
$9p$	3.07(-3)		2.84(-3)					
$10p$	1.36(-3)		1.24(-3)					
$2p^3 7s$-$2p^3 7p$	2.79(0)		2.79(0)					
$8p$	6.40(-2)		6.17(-2)					
$9p$	1.24(-2)		1.17(-2)					
$10p$	4.29(-3)		4.00(-3)					
$2p^3 8s$-$2p^3 8p$	3.21(0)		3.21(0)					
$9p$	7.72(-2)		7.44(-2)					
$10p$	1.55(-2)		1.47(-2)					
$2p^3 9s$-$2p^3 9p$	3.63(0)		3.62(0)					
$10p$	9.02(-2)		8.70(-2)					
$2p^3 10s$-$2p^3 10p$	4.05(0)		4.04(0)					

Table 3. Oscillator strengths for ^3P - $^3D^o$ transitions in neutral oxygen.

Transition	BH1	BH2	BZ	PS	Other calculations		Experiment	
$2p^4$-$2p^3$3d	2.07(-2)	2.04(-2)	1.90(-2)	2.03(-2)	3.15(-2)[b]		1.9±.1(-2)[h]	1.0(-2)[j]
4d	7.75(-3)	1.27(-2)	1.56(-2)	1.48(-2)	1.62(-2)[b]		1.6±.6(-2)[h]	
5d	6.86(-3)		6.30(-3)	6.45(-3)	8.82(-3)[b]			
6d	3.78(-3)		3.63(-3)	3.74(-3)	5.24(-3)[b]			
7d	2.37(-3)		2.29(-3)		3.35(-3)[b]	2.36(-3)[i]		
8d	1.58(-3)		1.54(-3)		1.59(-3)[i]			
9d	1.11(-3)		1.08(-3)		1.12(-3)[i]			
10d	8.11(-4)		7.91(-4)		8.14(-4)[i]			
$2p^4$-$2p^3$3s'	5.45(-2)	5.35(-2)	5.41(-2)	5.58(-2)	4.96(-2)[a]		5.8±.4(-2)[c]	6.1±.6(-2)[h] 5.0±.3(-2)[n]
$2p^3$3p-$2p^3$3d	9.71(-1)	1.00(0)	9.65(-1)	9.66(-1)			7.5(-1)[j]	
4d	4.32(-2)	1.26(-2)	3.98(-2)	2.75(-2)			3.98(-2)[j]	
5d	8.28(-3)		7.88(-3)					
6d	2.85(-3)		2.67(-3)					
7d	1.29(-3)		1.20(-3)					
8d	6.99(-4)		6.44(-4)					
9d	4.22(-4)		3.87(-4)					
10d	2.76(-4)		2.52(-4)					
$2p^3$4p-$2p^3$4d	1.23(0)		1.22(0)					
5d	9.12(-2)		8.83(-2)					
6d	2.39(-2)		2.28(-2)					
7d	9.74(-3)		9.23(-3)					
8d	4.99(-3)		4.70(-3)					
9d	2.92(-3)		2.75(-3)					
10d	1.87(-3)		1.76(-3)					
$2p^3$5p-$2p^3$5d	1.46(0)		1.46(0)					
6d	1.31(-1)		1.27(-1)					
7d	3.79(-2)		3.65(-2)					
8d	1.65(-2)		1.58(-2)					
9d	8.80(-3)		8.40(-3)					
10d	5.32(-3)		5.07(-3)					
$2p^3$6p-$2p^3$6d	1.68(0)		1.68(0)					
7d	1.65(-1)		1.61(-1)					
8d	5.04(-2)		4.89(-2)					
9d	2.26(-2)		2.19(-2)					
10d	1.24(-2)		1.19(-3)					

Transition	BH1	BZ
$2p^3$7p-$2p^3$7d	1.87(0)	1.89(0)
8d	1.95(-1)	1.92(-1)
9d	6.14(-2)	6.01(-2)
10d	2.82(-2)	2.75(-2)
$2p^3$8p-$2p^3$8d	2.08(0)	2.10(0)
9d	2.24(-1)	2.21(-1)
10d	7.19(-2)	7.06(-2)
$2p^3$9p-$2p^3$9d	2.28(0)	2.30(0)
10d	2.52(-1)	2.49(-1)
$2p^3$10p-$2p^3$10d	2.48(0)	2.50(0)

Table 4. Oscillator strengths for $^3D^o$ - ^3P transitions in neutral oxygen.

Transition	BH1	BH2	BZ
$2p^3 3d$-$2p^3 4p$	1.85(-1)	1.81(-1)	1.82(-1)
5p	3.79(-3)		4.00(-3)
6p	1.02(-3)		1.07(-3)
7p	4.40(-4)		4.61(-4)
8p	2.37(-4)		2.46(-4)
9p	1.44(-4)		1.49(-4)
10p	9.47(-5)		9.76(-5)
$2p^3 4d$-$2p^3 5p$	3.54(-1)		3.53(-1)
6p	6.30(-3)		6.70(-3)
7p	1.63(-3)		1.82(-3)
8p	7.07(-4)		8.17(-4)
9p	3.82(-4)		4.53(-4)
10p	2.34(-4)		2.83(-4)
$2p^3 5d$-$2p^3 6p$	5.23(-1)		5.22(-1)
7p	7.81(-3)		8.49(-3)
8p	2.02(-3)		2.20(-3)
9p	8.89(-4)		9.47(-4)
10p	4.91(-4)		5.33(-4)
$2p^3 6d$-$2p^3 7p$	6.78(-1)		6.83(-1)
8p	8.85(-3)		9.68(-3)
9p	2.20(-3)		2.42(-3)
10p	9.63(-4)		1.06(-3)
$2p^3 7d$-$2p^3 8p$	8.33(-1)		8.41(-1)
9p	9.56(-3)		1.05(-2)
10p	2.29(-3)		2.55(-3)
$2p^3 8d$-$2p^3 9p$	9.87(-1)		9.96(-1)
10p	1.01(-2)		1.12(-2)
$2p^3 9d$-$2p^3 10p$	1.14(0)		1.15(0)

Table 5. Oscillator strengths for $^5D^o$ - ^5P transitions in neutral oxygen.

Transition	BH1	BH2	BZ	PS
$2p^3 3d$-$2p^3 4p$	1.61(-1)	1.59(-1)	1.59(-1)	1.59(-1)
5p	7.77(-4)		9.34(-4)	
$2p^3 4d$-$2p^3 5p$	3.18(-1)		3.14(-1)	
6p	1.10(-3)		1.41(-3)	
$2p^3 5d$-$2p^3 6p$	4.66(-1)		4.62(-1)	
7p	1.10(-3)		1.54(-3)	
$2p^3 6d$-$2p^3 7p$	5.95(-1)		6.06(-1)	
8p	9.72(-4)		1.48(-3)	
$2p^3 7d$-$2p^3 8p$	7.32(-1)		7.47(-1)	
9p	7.96(-4)		1.35(-3)	
$2p^3 8d$-$2p^3 9p$	8.67(-1)		8.86(-1)	
10p	6.17(-4)		1.18(-3)	
$2p^3 9d$-$2p^3 10p$	1.00(0)		1.02(0)	

Table 6. Oscillator strengths for $^5S^o$ - ^5P transitions in neutral oxygen.

Transition	BH1	BH2	BZ	PS	Experiment	
$2p^3 3s$-$2p^3 3p$	9.76(-1)	9.71(-1)	9.78(-1)	9.78(-1)	9.22(-1)[j]	7.0(-1)[l]
4p	2.87(-3)	7.85(-3)	3.19(-3)	3.27(-3)	2.29(-3)[j]	2.9(-3)[l]
$2p^3 4s$-$2p^3 4p$	1.48(0)	1.53(0)	1.46(0)	1.46(0)		
5p	1.50(-2)		1.56(-2)			
6p	1.72(-3)		1.89(-3)			
7p	4.00(-4)		4.67(-4)			
8p	1.35(-4)		1.66(-4)			
9p	5.72(-5)		7.37(-5)			
10p	2.82(-5)		3.80(-5)			
$2p^3 5s$-$2p^3 5p$	1.92(0)		1.90(0)			
6p	2.85(-2)		2.93(-2)			
7p	4.30(-3)		4.60(-3)			
8p	1.28(-3)		1.39(-3)			
9p	5.26(-4)		5.84(-4)			
10p	2.63(-4)		2.97(-4)			
$2p^3 6s$-$2p^3 6p$	2.35(0)		2.33(0)			
7p	4.15(-2)		4.31(-2)			
8p	7.18(-3)		7.61(-3)			
9p	2.33(-3)		2.51(-3)			
10p	1.03(-3)		1.12(-3)			
$2p^3 7s$-$2p^3 7p$	2.75(0)		2.75(0)			
8p	5.48(-2)		5.68(-2)			
9p	1.02(-2)		1.07(-2)			
10p	3.47(-3)		3.70(-3)			
$2p^3 8s$-$2p^3 8p$	3.17(0)		3.17(0)			
9p	6.79(-2)		7.03(-2)			
10p	1.32(-2)		1.38(-2)			
$2p^3 9s$-$2p^3 9p$	3.59(0)		3.59(0)			
10p	8.08(-2)		8.36(-2)			
$2p^3 10s$-$2p^3 10p$	4.00(0)		4.01(0)			

Table 7. Oscillator strengths for ^5P - $^5S^o$ transitions in neutral oxygen.

Transition	BH1	BH2	BZ	PS	Experiment
$2p^3 3p$-$2p^3 4s$	1.65(-1)	1.70(-1)	1.64(-1)	1.64(-1)	1.73(-1)[j]
5s	1.73(-2)		1.69(-2)	1.68(-2)	1.48(-2)[j]
6s	5.78(-3)		5.61(-3)	8.66(-3)	4.50(-3)[j]
7s	2.73(-3)		2.65(-3)		
8s	1.53(-3)		1.48(-3)		
9s	9.49(-4)		9.23(-3)		
10s	6.34(-4)		6.17(-4)		
$2p^3 4p$-$2p^3 5s$	2.97(-1)		2.96(-1)	3.00(-1)	
6s	2.82(-2)		2.80(-2)	2.16(-2)	
7s	9.34(-3)		9.22(-3)		
8s	4.44(-3)		4.38(-3)		
9s	2.51(-3)		2.48(-3)		
10s	1.58(-3)		1.56(-3)		

Table 7. Continued.

Transition	BH1	BZ
$2p^3 5p - 2p^3 6s$	4.27(-1)	4.29(-1)
7s	3.89(-2)	3.86(-2)
8s	1.27(-2)	1.26(-2)
9s	6.05(-3)	6.00(-3)
10s	3.45(-3)	3.42(-3)
$2p^3 6p - 2p^3 7s$	5.56(-1)	5.60(-1)
8s	4.92(-2)	4.89(-2)
9s	1.60(-2)	1.59(-2)
10s	7.60(-3)	7.54(-3)
$2p^3 7p - 2p^3 8s$	6.86(-1)	6.90(-1)
9s	5.93(-2)	5.90(-2)
10s	1.91(-2)	1.90(-2)
$2p^3 8p - 2p^3 9s$	8.15(-1)	8.19(-1)
10s	6.93(-2)	6.89(-2)
$2p^3 9p - 2p^3 10s$	9.44(-1)	9.49(-1)

Table 8. Oscillator strengths for ^5P - $^5D^o$ transitions in neutral oxygen.

Transition	BH1	BH2	BZ	PS	Experiment	
$2p^3 3p - 2p^3 3d$	9.28(-1)	9.50(-1)	9.26(-1)	9.26(-1)	9.0(-1)[j]	
4d	7.50(-2)	8.03(-2)	7.23(-2)	6.34(-2)	6.64(-2)[j]	5.3(-2)[l]
5d	1.99(-2)		1.89(-2)	1.88(-2)	1.40(-2)[j]	1.6(-2)[l]
6d	8.16(-3)		7.67(-3)			
7d	4.19(-3)		3.91(-3)			
8d	2.46(-3)		2.29(-3)			
9d	1.57(-3)		1.47(-3)			
10d	1.07(-3)		1.00(-3)			
$2p^3 4p - 2p^3 4d$	1.11(0)	1.18(0)	1.12(0)	1.13(0)		
5d	1.23(-1)		1.20(-1)	1.19(-1)		
6d	3.78(-2)		3.64(-2)			
7d	1.69(-2)		1.61(-2)			
8d	9.15(-3)		8.71(-3)			
9d	5.56(-3)		5.30(-3)			
10d	3.67(-3)		3.50(-3)			
$2p^3 5p - 2p^3 5d$	1.28(0)		1.30(0)			
6d	1.59(-1)		1.56(-1)			
7d	5.21(-2)		5.06(-2)			
8d	2.42(-2)		2.34(-2)			
9d	1.34(-2)		1.30(-2)			
10d	8.37(-3)		8.06(-3)			
$2p^3 6p - 2p^3 6d$	1.46(0)		1.48(0)			
7d	1.90(-1)		1.88(-1)			
8d	6.43(-2)		6.28(-2)			
9d	3.05(-2)		2.97(-2)			
10d	1.72(-2)		1.68(-2)			
$2p^3 7p - 2p^3 7d$	1.63(0)		1.66(0)			
8d	2.19(-1)		2.17(-1)			
9d	7.53(-2)		7.39(-2)			
10d	3.62(-2)		3.54(-2)			

Table 8. Continued.

Transition	BH1	BZ
$2p^3 8p-2p^3 8d$	1.80(0)	1.83(0)
9d	2.46(-1)	2.44(-1)
10d	8.56(-2)	8.43(-2)
$2p^3 9p-2p^3 9d$	1.97(0)	2.01(0)
10d	2.72(-1)	2.70(-1)
$2p^3 10p-2p^3 10d$	2.14(0)	2.18(0)

Notes.

BH1 = Bell and Hibbert (1990) with OPACITY codes (length values only).

BH2 = Bell and Hibbert (1990) with CIV3 code (length values only).

BZ = Butler and Zeippen (1990) with OPACITY codes (length values only).

PS = Pradhan and Saraph (1977) with UCL codes.

See text for details.

Other calculations.

a = Froese Fischer (1987).

b = Ganas (1980).

i = Zeippen et al. (1977).

Experiment.

c = Smith et al. (1971).

d = Lin et al. (1972).

e = Clyne and Piper (1976).

f = Reader et al. (1980).

g = Jenkins (1985).

h = Doering et al. (1985).

j = Wiese et al. (1966).

k = Kroll et al. (1985).

l = Bromander et al. (1978).

m = Bischel et al. (1981).

n = Kernahan and Simpson (1982).