

# Oxygen (O<sub>2</sub>)

## 1. Recommended electron collision cross section

### (1) Elastic momentum transfer cross section (Q<sub>m</sub>)

Energy(eV)	Cross section(Å <sup>2</sup> )	Energy(eV)	Cross section(Å <sup>2</sup> )
0.0000	0.35000	2.5000	6.90000
0.0010	0.35000	3.0000	6.30000
0.0020	0.35000	3.6000	5.80000
0.0030	0.40000	4.0000	5.55000
0.0050	0.50000	5.0000	5.20000
0.0070	0.59000	5.5000	5.08000
0.0100	0.70000	5.8000	5.02000
0.0120	0.77000	6.0000	5.00000
0.0150	0.87000	6.2000	5.01000
0.0200	1.01000	6.5000	5.04000
0.0250	1.15000	6.8000	5.06000
0.0300	1.27000	7.0000	5.08000
0.0400	1.49000	8.0000	5.20000
0.0500	1.70000	9.0000	5.50000
0.0600	1.88000	9.6000	5.80000
0.0800	2.30000	10.0000	6.00000
0.0900	2.50000	11.0000	6.50000
0.1000	2.68000	11.6000	7.00000
0.1200	3.00000	12.0000	7.10000
0.1500	3.36000	12.6000	7.08000
0.2000	3.90000	13.0000	7.02000
0.2500	4.40000	15.0000	6.70000
0.3000	4.90000	20.0000	6.10000
0.3300	5.15000	25.0000	5.60000
0.3700	5.46000	30.0000	5.10000
0.4000	5.62000	40.0000	4.30000
0.5000	6.06000	50.0000	3.70000
0.5400	6.18000	60.0000	3.10000
0.5700	6.26000	80.0000	2.26800
0.6000	6.34000	100.0000	1.75000
0.7100	6.56000	120.0000	1.46000
0.8000	6.68000	150.0000	1.20000
0.9000	6.80000	200.0000	0.94700
1.0000	6.92000	250.0000	0.76900
1.2000	7.08000	300.0000	0.62700
1.4000	7.20000	400.0000	0.43100
1.5000	7.26000	500.0000	0.31300
1.7000	7.38000	600.0000	0.24600
1.9000	7.46000	800.0000	0.16300
2.0000	7.46500	1000.0000	0.11500
2.1000	7.40000	1500.0000	0.05960
2.2000	7.30000	2000.0000	0.03740

### (2) Rotational excitation cross section (Q<sub>r</sub>) Threshold = 0.070eV, Energy loss = 0.020eV

Energy(eV)	Cross section(Å <sup>2</sup> )	Energy(eV)	Cross section(Å <sup>2</sup> )
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0.0700	0.00000	0.9300	0.00000
0.0800	0.00540	1.0200	0.00000
0.1000	0.00000	1.0300	0.06120
0.2000	0.00000	1.0500	0.00000
0.2100	0.03240	1.1300	0.00000
0.2200	0.00000	1.1400	0.03978
0.3200	0.00000	1.1600	0.00000
0.3300	0.05760	1.2300	0.00000
0.3500	0.00000	1.2400	0.05100
0.4400	0.00000	1.2600	0.00000
0.4500	0.04590	1.3400	0.00000
0.4700	0.00000	1.3500	0.03060
0.5600	0.00000	1.3700	0.00000
0.5700	0.05712	1.4400	0.00000
0.5900	0.00000	1.4500	0.02040
0.6800	0.00000	1.4700	0.00000
0.6900	0.06834	1.5400	0.00000
0.7100	0.00000	1.5500	0.01020
0.7900	0.00000	1.5700	0.00000
0.8000	0.07956	1.6400	0.00000
0.8100	0.00000	1.6500	0.00408
0.9000	0.00000	1.6700	0.00000
0.9100	0.07140	100.0000	0.00000

(3) **Attachment cross section ( $Q_{att}(\times 1000)$ )** Threshold = 0.058eV, Energy loss = 0.058eV

Energy(eV)	Cross section( $\text{\AA}^2$ )	Energy(eV)	Cross section( $\text{\AA}^2$ )
0.0580	0.00000	0.9300	0.00000
0.0730	0.05600	1.0200	0.00000
0.0830	0.18000	1.0300	0.00420
0.0890	0.04200	1.0500	0.00000
0.0950	0.08400	4.7000	0.00000
0.1030	0.18000	5.0000	0.90000
0.1090	0.00000	5.5000	4.00000
0.2000	0.00000	5.7800	6.00000
0.2100	0.03560	6.0000	8.00000
0.2300	0.00000	6.2000	11.00000
0.3200	0.00000	6.5000	14.80000
0.3300	0.02300	6.7000	17.45000
0.3500	0.00000	6.7200	17.40000
0.4400	0.00000	6.8500	15.50000
0.4500	0.01450	7.0000	14.20000
0.4700	0.00000	7.3500	6.00000
0.5600	0.00000	7.7000	3.00000
0.5700	0.01100	8.4800	1.70000
0.5900	0.00000	9.6300	0.80000
0.6800	0.00000	9.8800	0.78000
0.6900	0.00800	10.0000	0.76000
0.7100	0.00000	10.5400	0.74000
0.7900	0.00000	11.0800	0.72000
0.8000	0.00700	11.5400	0.70000
0.8200	0.00000	12.0000	0.68000
0.9000	0.00000	100.0000	0.00000
0.9100	0.00550		

(4) **Vibrational excitation cross section ( $Q_{v1}$ )** Threshold = 0.190eV, Energy loss = 0.190eV

Energy(eV)	Cross section( $\text{\AA}^2$ )	Energy(eV)	Cross section( $\text{\AA}^2$ )
0.1900	0.00000	1.2600	0.00000
0.2000	0.00150	1.3400	0.00000
0.2100	0.00150	1.3500	0.02105
0.2300	0.00000	1.3700	0.00000
0.3200	0.00000	1.4400	0.00000
0.3300	0.62250	1.4500	0.00702
0.3500	0.00000	1.4700	0.00000
0.4400	0.00000	1.5400	0.00000
0.4500	1.49175	1.5500	0.00255
0.4700	0.00000	1.5700	0.00000
0.5600	0.00000	1.6300	0.00000
0.5700	1.57250	1.6500	0.00090
0.5900	0.00000	1.6700	0.00000
0.6800	0.00000	3.5000	0.00000
0.6900	1.40250	4.2500	0.04000
0.7100	0.00000	5.0000	0.12000
0.7900	0.00000	6.0000	0.23000
0.8000	1.27500	7.0000	0.35000
0.8200	0.00000	8.0000	0.42500
0.9000	0.00000	9.0000	0.40000
0.9100	0.76500	10.0000	0.30000
0.9300	0.00000	11.0000	0.20000
1.0200	0.00000	12.0000	0.14300
1.0300	0.36338	13.0000	0.10200
1.0500	0.00000	14.0000	0.07100
1.1300	0.00000	15.0000	0.02500
1.1400	0.14345	20.0000	0.01000
1.1600	0.00000	45.0000	0.00000
1.2300	0.00000	100.0000	0.00000
1.2400	0.06057		

(5) **Vibrational excitation cross section ( $Q_{v2}$ )** Threshold = 0.560eV, Energy loss = 0.380eV

Energy(eV)	Cross section( $\text{\AA}^2$ )	Energy(eV)	Cross section( $\text{\AA}^2$ )
0.5600	0.00000	1.1600	0.00000
0.5700	0.11900	1.2300	0.00000
0.5900	0.00000	1.2400	0.08075
0.6800	0.00000	1.2600	0.00000
0.6900	0.35275	1.3400	0.00000
0.7100	0.00000	1.3500	0.05100
0.7900	0.00000	1.3700	0.00000
0.8000	0.45475	1.4400	0.00000
0.8200	0.00000	1.4500	0.02360
0.9000	0.00000	1.4700	0.00000
0.9100	0.39525	1.5400	0.00000
0.9300	0.00000	1.5500	0.01085
1.0200	0.00000	1.5700	0.00000
1.0300	0.26775	1.6300	0.00000
1.0500	0.00000	1.6500	0.00434
1.1300	0.00000	1.6700	0.00000
1.1400	0.17000	3.5000	0.00000

4.0000	0.00000	12.0000	0.07300
5.0000	0.02800	13.0000	0.05100
6.0000	0.04000	14.0000	0.02800
7.0000	0.07300	15.0000	0.01300
8.0000	0.09400	20.0000	0.00500
9.0000	0.11000	45.0000	0.00000
10.0000	0.10900	100.0000	0.00000
11.0000	0.09300		

**(6) Vibrational excitation cross section ( $Q_{v3}$ )** Threshold = 0.680eV, Energy loss = 0.570eV

Energy(eV)	Cross section( $\text{\AA}^2$ )	Energy(eV)	Cross section( $\text{\AA}^2$ )
0.6800	0.00000	1.4700	0.00000
0.6900	0.00315	1.5400	0.00000
0.7100	0.00000	1.5500	0.02105
0.7900	0.00000	1.5700	0.00000
0.8000	0.01828	1.6300	0.00000
0.8200	0.00000	1.6500	0.01020
0.9000	0.00000	1.6700	0.00000
0.9100	0.07650	3.5000	0.00000
0.9300	0.00000	4.0000	0.00000
1.0200	0.00000	5.0000	0.00000
1.0300	0.10200	6.0000	0.01250
1.0500	0.00000	7.0000	0.03630
1.1300	0.00000	8.0000	0.05880
1.1400	0.09775	9.0000	0.07500
1.1600	0.00000	10.0000	0.06750
1.2300	0.00000	11.0000	0.05630
1.2400	0.08075	12.0000	0.04750
1.2600	0.00000	13.0000	0.03000
1.3400	0.00000	14.0000	0.01750
1.3500	0.07013	15.0000	0.00880
1.3700	0.00000	20.0000	0.00000
1.4400	0.00000	45.0000	0.00000
1.4500	0.03825	100.0000	0.00000

**(7) Vibrational excitation cross section ( $Q_{v4}$ )** Threshold = 0.790eV, Energy loss = 0.750eV

Energy(eV)	Cross section( $\text{\AA}^2$ )	Energy(eV)	Cross section( $\text{\AA}^2$ )
0.7900	0.00000	1.3500	0.04272
0.8000	0.00128	1.3700	0.00000
0.8200	0.00000	1.4400	0.00000
0.9000	0.00000	1.4500	0.03635
0.9100	0.00468	1.4700	0.00000
0.9300	0.00000	1.5400	0.00000
1.0200	0.00000	1.5500	0.02742
1.0300	0.00034	1.5700	0.00000
1.0500	0.00000	1.6300	0.00000
1.1300	0.00000	1.6500	0.02105
1.1400	0.01403	1.6700	0.00000
1.1600	0.00000	6.0000	0.00000
1.2300	0.00000	7.0000	0.02750
1.2400	0.02678	8.0000	0.03500
1.2600	0.00000	9.0000	0.04130
1.3400	0.00000	10.0000	0.04630

11.0000	0.03130	14.0000	0.00880
12.0000	0.02500	15.0000	0.00000
13.0000	0.01750	100.0000	0.00000

(8) **Electronic excitation cross section ( $a^1\Delta_g$ )** Threshold = 0.977eV, Energy loss = 0.977eV

Energy(eV)	Cross section( $\text{\AA}^2$ )	Energy(eV)	Cross section( $\text{\AA}^2$ )
0.9770	0.00000	10.040	0.07500
1.5000	0.00580	13.000	0.05500
2.0000	0.01530	15.100	0.04550
3.0000	0.04000	17.500	0.03870
3.5000	0.05500	20.500	0.03240
4.0000	0.07000	24.900	0.02560
5.0000	0.09500	30.900	0.01960
6.0000	0.11500	41.000	0.01370
7.0000	0.11000	45.000	0.01200
8.0000	0.09500	100.000	0.00000
9.0000	0.08500		

(9) **Electronic excitation cross section ( $b^1\Sigma_g^+$ )** Threshold = 1.627eV, Energy loss = 1.627eV

Energy(eV)	Cross section( $\text{\AA}^2$ )	Energy(eV)	Cross section( $\text{\AA}^2$ )
1.6270	0.00000	11.0000	0.01950
2.0000	0.00260	12.0000	0.01670
3.0000	0.01070	13.0000	0.01500
3.5000	0.01130	14.9000	0.01400
4.0000	0.01390	17.0000	0.01300
5.0000	0.01520	19.4000	0.01250
5.6900	0.01840	20.7000	0.01250
6.5400	0.02200	22.5000	0.01100
7.1000	0.02600	24.0000	0.01000
7.6000	0.02850	28.0000	0.00800
8.4100	0.02780	35.1000	0.00630
9.2600	0.02600	41.9000	0.00180
10.0000	0.02300	45.1000	0.00000

(10) **Excitation cross section ( $Q_{ex}$  of 6 eV)** Threshold = 6.000eV, Energy loss = 6.000eV

Energy(eV)	Cross section( $\text{\AA}^2$ )	Energy(eV)	Cross section( $\text{\AA}^2$ )
6.0000	0.00000	12.0000	0.16500
7.1500	0.01000	15.0000	0.10500
7.1600	0.23000	17.0000	0.06500
7.9000	0.24000	20.0000	0.04750
8.5000	0.23500	45.0000	0.01900
9.0000	0.23000	100.0000	0.00000
10.0000	0.21000		

(11) **Excitation cross section ( $Q_{ex}$  of Schumann-Runge)** Threshold = 8.400eV, Energy loss = 8.400eV

Energy(eV)	Cross section( $\text{\AA}^2$ )	Energy(eV)	Cross section( $\text{\AA}^2$ )
8.4000	0.00000	11.0000	0.40000
9.0000	0.09000	12.0000	0.69000
10.0000	0.22000	13.0000	0.90000

14.0000	1.20000	70.0000	1.50000
15.0000	1.25000	80.0000	1.10000
16.0000	1.35000	100.0000	0.70000
18.0000	1.42000	120.0000	0.50000
19.0000	1.44000	150.0000	0.30000
20.0000	1.50000	200.0000	0.24000
22.0000	1.65000	250.0000	0.15000
25.0000	2.30000	300.0000	0.10400
30.0000	2.70000	400.0000	0.07600
35.0000	2.90000	500.0000	0.06000
40.0000	2.95000	600.0000	0.05000
45.0000	2.90000	800.0000	0.04000
50.0000	2.80000	1000.0000	0.03000
60.0000	2.10000		

(12) **Excitation cross section ( $Q_{ex}$  of Longest band)** Threshold = 9.970eV, Energy loss = 9.970eV

Energy(eV)	Cross section( $\text{\AA}^2$ )	Energy(eV)	Cross section( $\text{\AA}^2$ )
9.9700	0.00000	50.0000	0.05600
11.0000	0.01300	60.0000	0.04600
12.0000	0.02400	70.0000	0.04100
13.0000	0.03300	80.0000	0.03500
14.0000	0.04200	100.0000	0.02800
15.0000	0.05000	120.0000	0.02300
16.0000	0.05700	150.0000	0.01760
18.0000	0.06800	200.0000	0.01320
20.0000	0.07400	250.0000	0.00990
22.0000	0.07700	300.0000	0.00810
25.0000	0.07900	400.0000	0.00570
30.0000	0.07700	500.0000	0.00440
35.0000	0.07000	600.0000	0.00350
40.0000	0.06500	800.0000	0.00240
45.0000	0.06100	1000.0000	0.00180

(13) **Excitation cross section ( $Q_{ex}$  of Second band)** Threshold = 10.29eV, Energy loss = 10.29eV

Energy(eV)	Cross section( $\text{\AA}^2$ )	Energy(eV)	Cross section( $\text{\AA}^2$ )
10.2900	0.00000	50.0000	0.00750
11.0000	0.00120	60.0000	0.00640
12.0000	0.00280	70.0000	0.00560
13.0000	0.00430	80.0000	0.00480
14.0000	0.00560	100.0000	0.00380
15.0000	0.00680	120.0000	0.00310
16.0000	0.00770	150.0000	0.00240
18.0000	0.00920	200.0000	0.00180
20.0000	0.01000	250.0000	0.00140
22.0000	0.01060	300.0000	0.00110
25.0000	0.01080	400.0000	0.00080
30.0000	0.01040	500.0000	0.00060
35.0000	0.00960	600.0000	0.00050
40.0000	0.00890	800.0000	0.00030
45.0000	0.00830	1000.0000	0.00020

(14) **Total ionization cross section ( $Q_i$ )** Threshold = 12.06eV, Energy loss = 12.06eV

Energy(eV)	Cross section( $\text{\AA}^2$ )	Energy(eV)	Cross section( $\text{\AA}^2$ )
12.0600	0.00000	150.0000	2.54000
15.0000	0.06000	200.0000	2.39000
20.0000	0.27000	250.0000	2.20000
25.0000	0.54000	300.0000	2.01000
30.0000	0.83000	400.0000	1.72000
40.0000	1.37000	500.0000	1.51000
50.0000	1.79000	600.0000	1.34000
60.0000	2.09000	800.0000	1.10000
70.0000	2.31000	1000.0000	0.94000
80.0000	2.43000	1200.0000	0.82000
100.0000	2.57000	1500.0000	0.70000
120.0000	2.58000	2000.0000	0.55000

(15) **Excitation cross section ( $Q_{ex}$ )** Threshold = 13.30eV, Energy loss = 13.30eV

Energy(eV)	Cross section( $\text{\AA}^2$ )	Energy(eV)	Cross section( $\text{\AA}^2$ )
13.3000	0.00000	70.0000	0.02070
14.0000	0.00080	80.0000	0.02080
15.0000	0.00200	100.0000	0.02040
16.0000	0.00350	120.0000	0.01980
18.0000	0.00650	150.0000	0.01860
20.0000	0.00920	200.0000	0.01670
22.0000	0.01110	250.0000	0.01530
25.0000	0.01310	300.0000	0.01390
30.0000	0.01540	400.0000	0.01160
35.0000	0.01710	500.0000	0.01020
40.0000	0.01820	600.0000	0.00920
45.0000	0.01920	800.0000	0.00750
50.0000	0.01970	1000.0000	0.00650
60.0000	0.02040		

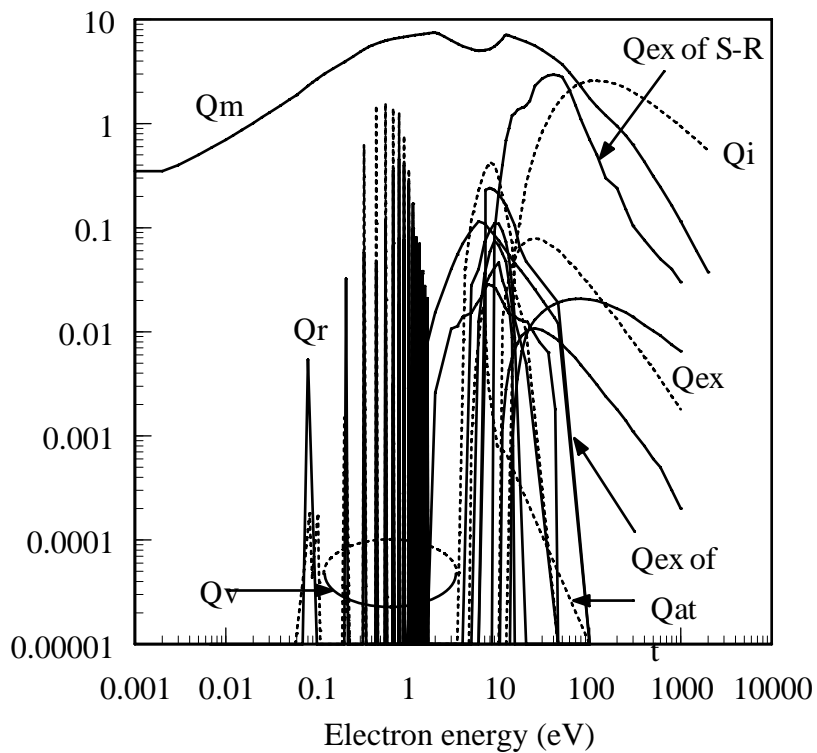


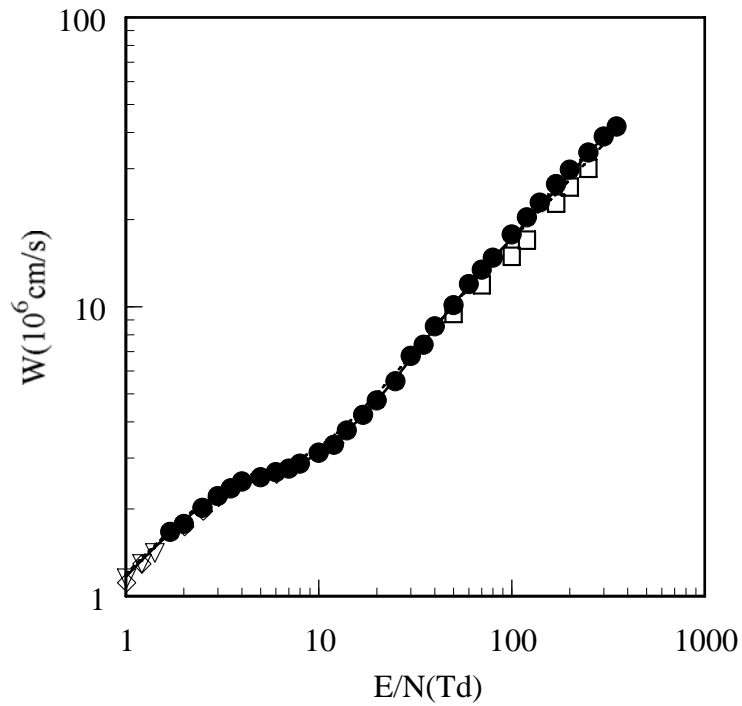
Fig.1 Recommended electron collision cross sections for O<sub>2</sub>.

## 2. Related electron swarm data

### (1) Electron drift velocity, W, in pure O<sub>2</sub>

E/N(Td)	W(10 <sup>6</sup> cm/s)	E/N(Td)	W(10 <sup>6</sup> cm/s)
1.7	1.6669	30.0	6.7602
2.0	1.7751	35.0	7.3894
2.5	2.0187	40.0	8.5537
3.0	2.2161	50.0	10.1223
3.5	2.3568	60.0	11.9701
4.0	2.4875	70.0	13.4186
5.0	2.5747	80.0	14.7751
6.0	2.6799	100.0	17.7568
7.0	2.7565	120.0	20.3519
8.0	2.8656	140.0	22.9056
10.0	3.1293	170.0	26.5241
12.0	3.3304	200.0	29.7691
14.0	3.736	250.0	34.1091
17.0	4.2291	300.0	38.7066
20.0	4.7396	350.0	41.9314
25.0	5.5285		

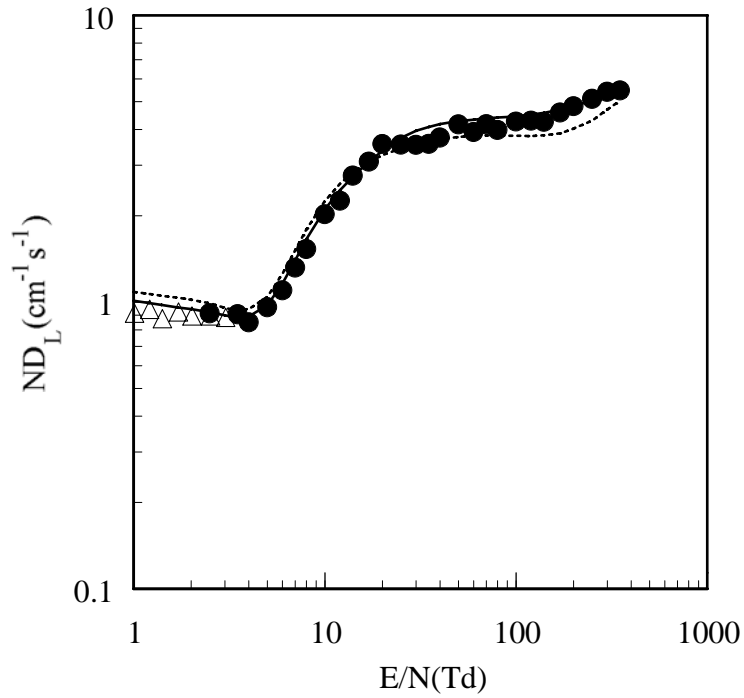




**Fig.2 Electron drift velocity in pure O<sub>2</sub>. Solid curve, using the recommended cross section data; dotted curve, Phelps; (◇), Crompton; (▽), Reid; (□), Roznerski; (●), present result**

**(2) Product of longitudinal diffusion coefficient and gas number density, ND<sub>L</sub> in pure O<sub>2</sub>**

E/N(Td)	ND <sub>L</sub> (10 <sup>20</sup> cm <sup>-1</sup> s <sup>-1</sup> )	E/N(Td)	ND <sub>L</sub> (10 <sup>20</sup> cm <sup>-1</sup> s <sup>-1</sup> )
2.5	0.91361	35.0	3.56003
3.5	0.9069	40.0	3.74778
4.0	0.84943	50.0	4.16531
5.0	0.95897	60.0	3.91821
6.0	1.09827	70.0	4.16766
7.0	1.31839	80.0	3.98101
8.0	1.52981	100.0	4.25984
10.0	2.02441	120.0	4.28829
12.0	2.25671	140.0	4.25116
14.0	2.7596	170.0	4.58324
17.0	3.08714	200.0	4.82039
20.0	3.5573	250.0	5.11266
25.0	3.53922	300.0	5.41174
30.0	3.53338	350.0	5.46957



**Fig.3**  $ND_L$  in pure  $O_2$ . Solid curve, using the recommended cross section data; dotted curve, Phelps; ( $\triangle$ ), Nelson et. al.; ( $\bullet$ ), present result

**(3) Electron drift velocity,  $W$ , in  $O_2$ -Ar mixtures**

**1.01%  $O_2$ -Ar mixture**

E/N(Td)	$W(10^6 \text{ cm/s})$	E/N(Td)	$W(10^6 \text{ cm/s})$
0.035	0.689	0.25	0.679
0.04	0.726	0.3	0.629
0.05	0.786	0.35	0.588
0.06	0.814	0.4	0.56
0.07	0.836	0.5	0.528
0.08	0.845	0.6	0.511
0.1	0.858	1.0	0.491
0.12	0.847	1.2	0.507
0.14	0.832	1.4	0.518
0.17	0.798	1.7	0.536
0.2	0.754	2.0	0.562

**4.994%  $O_2$ -Ar mixture**

E/N(Td)	$W(10^6 \text{ cm/s})$	E/N(Td)	$W(10^6 \text{ cm/s})$
0.12	1.2253	0.5	1.3919
0.14	1.3049	0.6	1.288
0.17	1.3642	0.7	1.2172
0.2	1.462	0.8	1.1407
0.25	1.5216	1.0	1.0561
0.3	1.5099	1.2	1.0065
0.35	1.4975	1.4	0.961
0.4	1.485	1.7	0.957

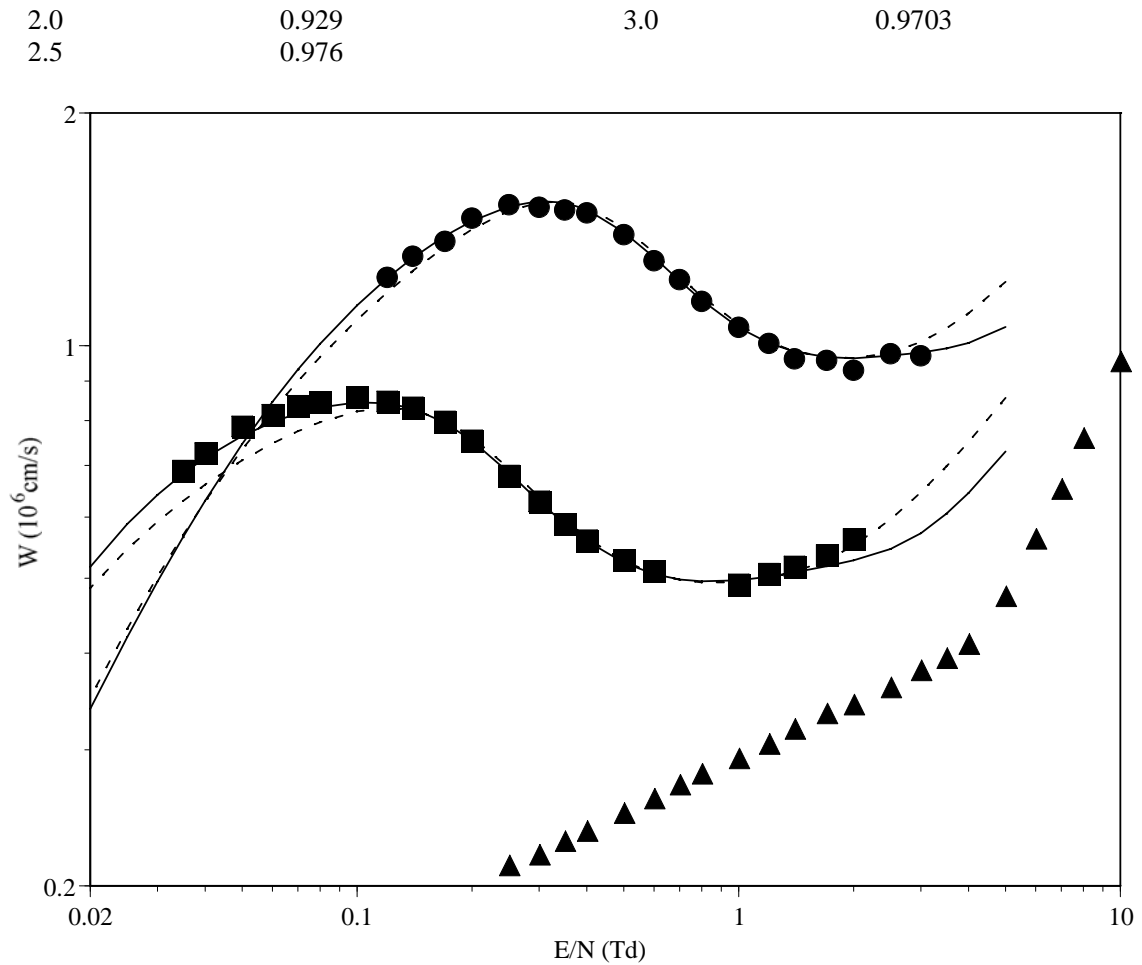


Fig.4 Electron drift velocity in O<sub>2</sub>-Ar mixtures. Solid curve, using the recommended cross section data; (●),(■), present results

(4) Product of longitudinal diffusion coefficient and gas number density, ND<sub>L</sub> in O<sub>2</sub>-Ar mixtures

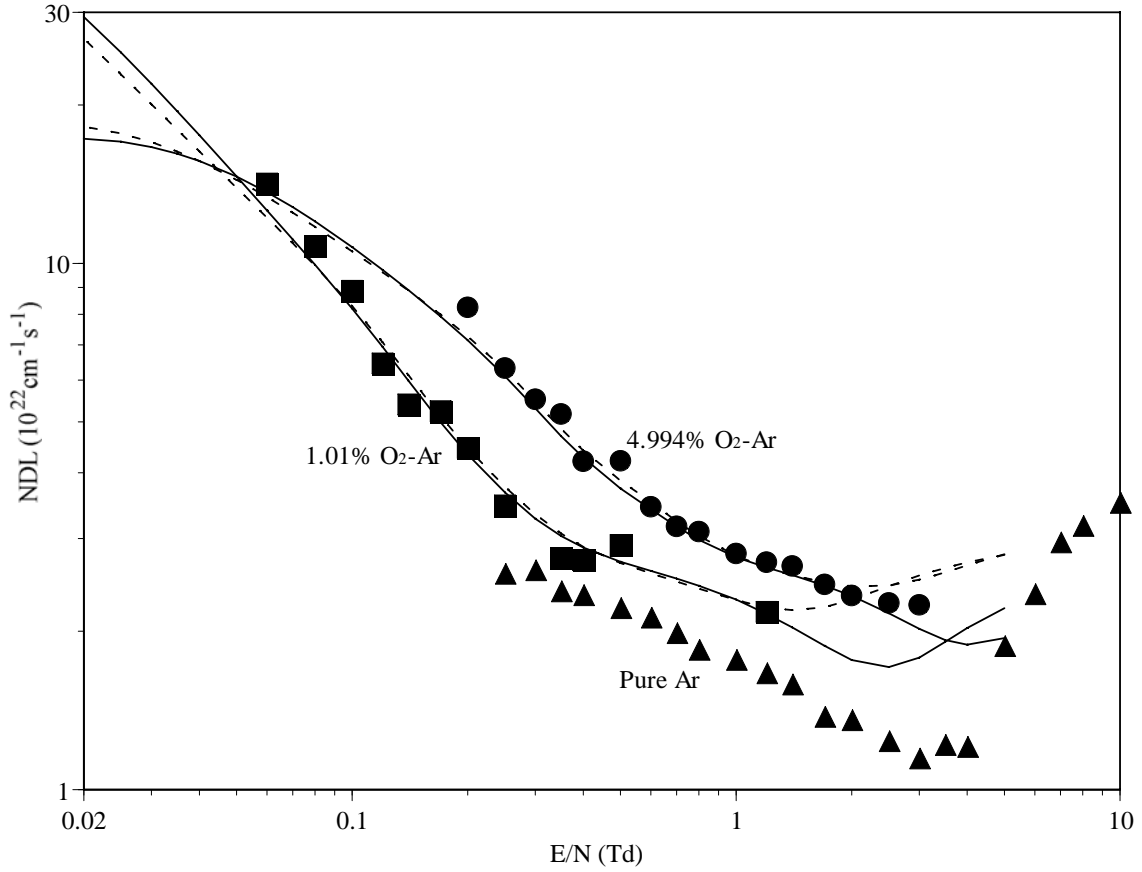
**1.01% O<sub>2</sub>-Ar mixture**

E/N(Td)	ND <sub>L</sub> (10 <sup>20</sup> cm <sup>-1</sup> s <sup>-1</sup> )	E/N(Td)	ND <sub>L</sub> (10 <sup>20</sup> cm <sup>-1</sup> s <sup>-1</sup> )
0.06	14.1863	0.2	4.462
0.08	10.7874	0.25	3.4688
0.1	8.874	0.35	2.7558
0.12	6.456	0.4	2.7289
0.14	5.3953	0.5	2.9166
0.17	5.2379	1.2	2.1776

**4.994% O<sub>2</sub>-Ar mixture**

E/N(Td)	ND <sub>L</sub> (10 <sup>20</sup> cm <sup>-1</sup> s <sup>-1</sup> )	E/N(Td)	ND <sub>L</sub> (10 <sup>20</sup> cm <sup>-1</sup> s <sup>-1</sup> )
0.2	8.25	0.5	4.2155
0.25	6.32591	0.6	3.44764
0.3	5.51713	0.7	3.1647
0.35	5.17294	0.8	3.09312
0.4	4.20595	1.0	2.81

1.2	2.70543	2.0	2.33799
1.4	2.66053	2.5	2.26287
1.7	2.45456	3.0	2.24395



**Fig.5**  $ND_L$  in O<sub>2</sub>-Ar mixtures. Solid curve, using the recommended cross section data; (●),(■), present results