# Infrared Emission Spectrum of KF

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The high-resolution infrared emission spectrum of potassium monofluoride has been recorded with a Fourier transform spectrometer. Over 900 vibration-rotation transitions, from the  $v = 1 \rightarrow 0$  to the  $v = 8 \rightarrow 7$  vibrational bands, have been assigned. Improved spectroscopic constants have been obtained for the KF ground electronic state by combining the infrared measurements with the existing microwave data. (© 1996 Academic Press, Inc.

### INTRODUCTION

The KF molecule has been extensively studied by many different spectroscopic methods. Early high resolution studies include molecular beam electric resonance experiments (1-4), and millimeter-wave molecular beam spectroscopy (5). The low resolution infrared absorption measurements of KF vapor (6, 7) and matrix isolation spectra of the monomer and dimer were published (8, 9). Improved vibrational constants were obtained in an infrared diode laser study (10) of the  $v = 2 \leftarrow 0, 3 \leftarrow 1$  and  $4 \leftarrow 2$  overtones. By combining a small number of infrared measurements with the existing microwave data, Maki and Lovas (10) obtained a reliable set of Dunham constants. Recent experimental measurements on KF include a measurement of the spontaneous vibrational decay rates (11), electron diffraction (12), and a more extensive measurement of the hyperfine structure (13).

The KF molecule has also been the target of several *ab initio* calculations of molecular properties such as the dissociation energy (14). More recently, Modisette *et al.* (15), reported a calculation of the electronic structure using the increasingly popular density functional approach, while Garcia–Cuesta *et al.* (16) used large basis sets and extensive electron correlation. Dyall and Partridge (17) explored the effects of relativistic corrections to the properties of alkali fluorides.

In the work reported here we have made the first high resolution measurements of the fundamental ( $v = 1 \rightarrow 0$ ) vibration-rotation band and related hot bands by infrared emission spectroscopy with a Fourier transform spectrometer. High resolution Fourier transform data are now available for the entire nonradioactive alkali fluoride family, LiF (18), NaF (19), KF (this work), RbF (20), and CsF (20).

### EXPERIMENTAL DETAILS

The high resolution infrared emission spectrum of KF has been recorded with a Bruker IFS 120 HR Fourier transform spectrometer. The technique used has been described previously in, for example, our paper on NaF (19). The KF spectrum was recorded at 900°C with a resolution of 0.01 cm<sup>-1</sup> over the range 350–750 cm<sup>-1</sup> with a 3.5- $\mu$ m-thick Mylar beamsplitter. The final recording consisted of 50 coadded scans. A portion of the spectrum is displayed in Fig. 1.

### **RESULTS AND DISCUSSION**

Although potassium has three natural isotopes, <sup>39</sup>K (93.26%), <sup>40</sup>K (0.01%), and <sup>41</sup>K (6.73%), only the main isotope was observed in this experiment. Over 900 transitions were observed and analyzed. The assignment of the rotational lines was based on the previous constants found in the literature (*10*). The position of the lines was calibrated in accordance with the strong pure rotational HF lines (*21*, *22*) that appeared in the spectrum. Eight vibrational bands



**FIG. 1.** A portion of the *R* branch of the vibration–rotation spectrum of KF. The lines of the 1-0 band are marked with their J'' values.

## TABLE 1

# Observed Rovibrational Line Positions of the $X^{1}\Sigma^{+}$ State of KF in cm<sup>-1</sup> (Observed—Calculated Values in Units of 10<sup>-3</sup> cm<sup>-1</sup> Are Shown in the Column Labeled $\Delta$ )

j. J.   J.   J.   Description   A.   J.   J.   Description   A.   J.   J.   Description     50   98   3825847   042   21   14   201717   02   20   24   2412175     50   33325847   012   3812673   018   44   3822647   018   14   2821470   018   12   24   247578   007   21   24   242578   018   24   242578   018   14   281747   018   14   281747   018   40   24   344264   017   16   1401782   15   34   2441402   018   25   24   242587   018   24   2442887   017   16   301325   11   34   344448   34   34   3444489   38   3444489   38   3444489   38   3444489   38   3444489   38   3444489   38   3444489   34   3444489   34		1	-0 band			2	-1 band			3	-2 band			1	-0 band				2-1 band			3-2	band	
55   56   58<	J	J	Observed	Δ	J _	J	Observed	Δ	Ĵ	Ĵ	Observed	Δ	J	J	Observed	۵	J	J	Observed	Δ	J.	<u>í</u> c	Dbserved	Δ
59   57   322.58/1   0   5   40   327.48   6.8   42   42   423.578   50   323.527   70   50   333.527   70   50   333.527   70   50   333.527   70   50   32   22   427.578   60   22   42   42.578   50   50   32   22   427.578   60   70 <	57	58	381.7618 (	0.46	52	53	381.2055 -	0.17	46	47	381.2909	-3.62	12	11	427.7177 -0	0.21	20	19	426.6514 -0.	03 2	3 22	2 4	23.1407	0.14
55   56   38.1572   177   00   51   38.2574   073   1   13   48.7757   071   22   24.27879   0.07   22   42.47879   0.07   22   42.47879   0.07   22   42.47879   0.07   22   42.47879   0.07   22   42.47879   0.07   22   42.47879   0.07   22   42.47879   0.07   22   42.47871   0.07   22   42.47871   0.07   22   42.47871   0.07   22   42.47871   0.07   22   42.47871   0.07   22   42.47871   0.07   22   42.47871   0.07   22   42.47871   0.07   22   42.47871   0.07   22   42.47871   0.07   22   42.47471   0.07   22   42.47471   0.07   22   42.47471   0.07   23   24.47471   0.07   23   24.47471   0.07   23   24.47471   0.07   23   24.47471   0.07   23.47471   0.07   24.47471	56	57	382.5647 (	0.52	51	52	381.9823	0.01	45	46	382.0413	0.13	13	12	428.2142 -0	0.02	21	20	427.1051 0.	08 2	4 23	34	23.5756	0.02
64   65   88   150   38   12   24   247	55	56	383.3612 -1	1.77	50	51	382.7548 -	0.18	44	45	382.7844	0.73	14	13	428.7057 -(	0.01	22	21	427.5538 0.	03 2	5 24	4 4	24.0063	0.59
55   54   55<	54	55	384.1579 (	0.03	49	50	383.5227	-1	43	44	383.5227	0.58	15	14	429.1938	1.39	23	22	427.9975 -0.	07 2	5 25	54	24.4311	0.09
22   53   385   747   0.08   40   47   385.898   177   17   16   40   177   17   16   40   120   20   22	53	54	384.9471 -	1.65	47	48	385.0486 -	0.35	42	43	384.2564	-0.08	16	15	429.6726 -	1.64	24	23	428.4362 -0.	36 2	7 26	54	24.8511	-0.38
51   52   388   388   51   51   38   384   51   388   51   52   38   384   51   38   38   34   38   34   38   34   38   34   38   34   38	52	53	385.7347 -0	0.89	46	47	385.8068	1.29	41	42	384.9876	0.77	17	16	430.1525	1.22	25	24	428.8707 0.	06 2	8 2	/ 4 	25.2647	-2.32
15   15   39   40   43   386   10	51	52	386.5179 -(	0.47	45	46	386.5578 -	0.26	40	41	385.7131	0.04	18	17	430.6235 -	0.06	26	25	429.2998 0	.U5 2	9 20	54	25.6/89	1.28
a   a	50	51	387.3011	3.92	43	44	388.0510	0.15	39	40 20	380.4308	1.59	19	10	431.0910	0.15	27	20	429.7230 -0.	23 3 Q1 3	U Z: 1 3.	n 2	26 4839	-0.10
Pr   Pr<	49	10	388 8426	1.34	42	43	389 5284	1 21	37	38	387 8674	0.13	20	20	432 0108 -	0.03	29	28	430.5595 1	.74 3	2 3	1 4	26.8799	-0.03
ef   30   300	40	49	389.6101	0.8	40	42	390 2600	0.75	36	37	388 5773	0.46	22	21	432.4636	-0.1	30	29	430,9673 0	.05 3	3 3	2 4	27.2710	0.21
es   es<	46	47	390 3720	0.16	39	40	390,9874	0.32	35	36	389,2811	-1.25	23	22	432.9114 -	0.11	31	30	431.3714 -0	.29 3	4 3	3 4	27.6566	-0.02
44   43   927   83   924298   0.01   34   300.6769   1.2   52   24   333.822   0.25   33   34   242195   0.5   34   323.820   0.55   0.5   35   35   34   333.822   0.07   38   342.8356   0.15   34   323.8320   0.05   34   323.8320   0.05   34   323.8320   0.05   34   323.8320   0.05   34   323.8320   0.05   34   323.8320   0.05   34   323.8320   0.05   34   323.8320   0.05   34   323.8320   0.05   34   323.8320   0.05   34   333.8340   0.07   40   33   343.8320   0.05   34   333.8347   0.06   33   343.83300   0.01   34   333.24   347.118   0.01   34   333.24   347.118   0.01   34   343.3470   0.02   34   333.24   347.118   34   343.3470   0.02   343.3480   34	45	46	391.1304	0.12	38	39	391.7109	0.03	34	35	389.9848	1.01	24	23	433.3544 -	0.06	32	31	431.7711 -0	.06 3	5 3	4 4	28.0376	0.02
43   43   322551   0.56   37   383   3825551   0.15   37   384   2827643     41   42   303000   56   53   334562   0.15   35   34425259   0.05   35   34425259   0.05   35   34425259   0.05   35   34425259   0.05   35   34425259   0.05   35   34425259   0.05   35   34425259   0.05   35   34425259   0.05   36   3433192   0.07   36   3434767   0.05   31   345366   0.14   43   342547     39   397047   0.12   23   396567   0.07   37   34   344770   0.04   43   347116   0.14   43   3431477   0.02   43   44   431264   44   4314477   0.04   43   437147   0.04   43   437147   0.04   43   4371476   0.04   4314476   0.04   431447   43425416   44   44425416<	44	45	391.8847	0.06	37	38	392.4298 -	0.61	33	34	390.6799	-1.2	25	24	433.7923 -	0.15	33	32	432.1652 -0	.54 3	63	5 4	28.4144	0.87
42   43   393.300 - 0.5   35   34   323.800 - 0.5   34   43.9398 0.0   34   34.9398 0.0   35   34   429.1964     41   394.821 - 0.05   31   34   35.2657 0.51   28   30   33.427 0.22   30   24   35.0665 0.43   35   35   35.655 0.68   28   29   43.066 0.01   38   34.43278 0.02   44   43.0583     38   396.925.04   21   23   35.6550 0.08   27   28   34.7512 0.08   43.7512 0.01   40   45.188   44   44   43.05053     39   397.705   0.14   29   39.7470 0.02   22   39.87470 0.02   24   43.06768 0.01   34.3222.0.34   42   45.8548 0.24   44   43.18.023     31   399.001   0.23   27   28.98710 0.02   22   39.8740 0.02   0.24   42   45.8548 0.24   44   43.1808     31   399.001   0.23   27   40.0670 0.067   22   40.06769 0.07 <td< td=""><td>43</td><td>44</td><td>392.6352</td><td>0.36</td><td>36</td><td>37</td><td>393.1462</td><td>0.34</td><td>32</td><td>33</td><td>391.3750</td><td>0.84</td><td>26</td><td>25</td><td>434.2258</td><td>0.23</td><td>34</td><td>33</td><td>432.5551 -0</td><td>.15 3</td><td>73</td><td>64</td><td>28.7843</td><td>-0.17</td></td<>	43	44	392.6352	0.36	36	37	393.1462	0.34	32	33	391.3750	0.84	26	25	434.2258	0.23	34	33	432.5551 -0	.15 3	73	64	28.7843	-0.17
1   1   2   34   2   34   34   34   34   35	42	43	393.3800 -	0.95	35	36	393.8566 -	-0.49	31	32	392.0627	-0.33	27	26	434.6536 -	0.15	35	34	432.9398 0	.03 3	83	7 4	129.1504	-0.01
40   41   394,8616   0.78   33   34   352,275   0.51   29   30   332,275   0.51   29   30   335,965   1.7   34   434,052   0.05   34   34   352,955   0.05   28   394,103   0.08   23   1   345,216   0.1   38   34   344,276   0.04   44   430,2194     38   397,775   0.14   29   30   392,046   1.22   25   26   396,178   0.41   34   34   347,512   0.04   45   44   44   43   432,447   44   44   435,471   333   437,771   0.14   44   435,471   333   439,376   1.4   44   435,471   44   435,271   44   435,471   33   439,337   0.14   44   435,471   334   439,337   0.1   44   435,271   44   435,271   44   435,271   44   435,271   44   435,271	41	42	394.1229 -	80.0	34	35	394.5643	0.14	30	31	392.7474	-0.26	28	27	435.0765 -	0.44	36	35	433.3192 -0	.07 3	93	8 4	29.5120	0.64
39   40   395   594   1   30   436   36   37   434   628   -0.00   7   28   394   403   21   335   7   30   434   21   435   200   74   39   34   444   700   0.2   44   44   44   44   44   45   45   30   457   30   457   30   457   30   445   44   45   44   44   454   44   454   457   30   457   44   45   457   44   45   457   44   45   457   44   45   457   44   457   44   457   44   457   44   457   44   457   44   457   44   457   44   457   44   457   44   457   44   457   44   457   44   457   44   44   457   44   457   444   4	40	41	394.8616	0.78	33	34	395.2675	0.51	29	30	393.4279	-0.22	30	29	435.9066	-1.7	37	36	433.6940 0	.17 4	0 3	94	29.8670	-0.23
38   39   3963.238   .00   31   32   3964.523   .03   32   344.72   .04   42   41   430   333   344.427   .00   42   41   430   333   444.427   .00   24   44   430   430   333   444.475   .00   24   44   43   431   430   437.1125   0.4   40   435.138   -2.4   44   431   431   430     34   3999.070   0.52   27   20   398.1710   0.01   35   433.2826.00   0.14   44   435.1730   12   433.242   437.472   44   438.282.01   43   42   435.848   0.28   44   433.242   433.242   433.442   44   433.442   44   443.445   443   443.445   443   443.445   443   441.450   433.444   443.445   443.445   443.445   443.445   443.445   443.445   444.445   444.445   444.445   444.445 <td>39</td> <td>40</td> <td>395.5934 -</td> <td>1.04</td> <td>32</td> <td>33</td> <td>395.9655 -</td> <td>-0.08</td> <td>28</td> <td>29</td> <td>394.1034</td> <td>-0.89</td> <td>31</td> <td>30</td> <td>436.3166 -</td> <td>0.01</td> <td>38</td> <td>37</td> <td>434.0632 -0</td> <td>.05 4</td> <td>1 4</td> <td>04</td> <td>30.2194</td> <td>1.38</td>	39	40	395.5934 -	1.04	32	33	395.9655 -	-0.08	28	29	394.1034	-0.89	31	30	436.3166 -	0.01	38	37	434.0632 -0	.05 4	1 4	04	30.2194	1.38
37   38   397   0487   0.487   0.49   30   34   310   300   34   340   300   340   300   340   300   340   300   340   300   340   300   340	38	39	396.3238 -	0.09	31	32	396.6592	-0.8	27	28	394.7766	0.38	32	31	436.7206	0.74	39	38	434.4276 -0	.04 4	24	14	130,5653	1.45
39   30   33   39   34   39   39   30<	37	38	397.0487 -	0.49	30	31	397.3497 -	-0.48	26	27	395.4450	1.04	33	32	437.1185	0.43	40	39	434./8/0 0	.02 4 วง ง	3 4	24	130.9045	0
33   35   36   36   37   36   37   36   37   37   37   37   37   37   37   38   38   399   0778   37   38   38   399   0778   37   36   438   638   0.22   10   47   45   413   42   435   399   078   13   36   438   039   016   43   42   435   424   435   433   14   43   42   435   436   130	36	37	397.7705	0.14	29	30	398.0348 -	0.10	25	20 25	390.1078	0.41	34 25	33	437.3112 -	0.05	41	40	435.1300 -	∠.4 4 33 ∆	4 4 5 1	5 4 4 4	131.2404	-0.2
3   3	30	35	390.4077	0.52	20	29	399.3953	0.15	24	24	397 4207	-0.65	36	35	438 2823 -	-0.34	43	42	435 8348 0	28 4	64	54	131 8963	0.12
32 33 400.0129 0.4 25 26 400.7371 0.14 21 22 338.7179 0.23 38 67 438.0337 0.01 45 44 436.079 0.62 48 47 432.5116   31 32 401.019 0.52 20 21 399.308 0.76 39 343.97845 0 44 44 44.	34	34	399 9078 -	0.23	26	27	400.0679 -	-0.23	22	23	398.0721	0.19	37	36	438.6605 -	-0.16	44	43	436.1733 -0	.12 4	74	64	32.2162	-0.25
31 32 4013729 0.39 24 25 4014019 0.52 20 21 339.3608 0.76 39 339.7605 0.4 74 64 537.765 0.01 49 48 422.816   30 402.0063 018 23 24 402.0677 0.15 19 400.2626 1.17 41 444.01249 0.04 48 437.7452 0.16 52 51 433.4464   28 400.664 0.6 21 440.650 0.34 16 17 418.442 444.474 0.04 48 437.7452 0.16 55 54 434.030   26 406.47476 0.34 19 20 406.590 0.7 15 16 407.150 0.25 14.33.4000 0.5 55 438.000 0.75 55 438.000 0.75 55 438.000 0.75 56 434.602 22 406.7569 0.75 16 407.150 0.02 14 14.42.402.11.33 0.35 15 438.003 0.07 56 54 434.802 <td>32</td> <td>33</td> <td>400.6129</td> <td>0.34</td> <td>25</td> <td>26</td> <td>400.7371</td> <td>0.14</td> <td>21</td> <td>22</td> <td>398.7179</td> <td>-0.23</td> <td>38</td> <td>37</td> <td>439.0337</td> <td>0.01</td> <td>45</td> <td>44</td> <td>436.5079 0</td> <td>.62 4</td> <td>8 4</td> <td>7 4</td> <td>132.5316</td> <td>-0.08</td>	32	33	400.6129	0.34	25	26	400.7371	0.14	21	22	398.7179	-0.23	38	37	439.0337	0.01	45	44	436.5079 0	.62 4	8 4	7 4	132.5316	-0.08
0   1   402.008.0   0.18   23   24   402.017   0.18   19   20   399.975   0.07   40   39.9745   0.0   47   46   477.4762   0.14   51   50   433.4644     29   400.3365   0.67   21   22   403.3652   0.34   17   18   401.620   0.14   44   440.4749   0.04   49   48   477.475   0.16   52   433.7411     27   404.0684   0.05   20   21   404.0156   0.34   16   17   401.8842   0.1   43   44   441.650   0.04   55   54   434.3143     25   405.4221   0.05   18   19   405.2690   13   14   403.313   33   47   442.4837   12   433.862   10.11   433.462   433.462   433.462   13.4   433.462   13.4   433.462   14.7   442.4837   12   443.862   10.1   433.462   433	31	32	401.3129	0.39	24	25	401.4019	0.52	20	21	399.3608	0.76	39	38	439.3995 -	2.15	46	45	436.8360 0	.01 4	9 4	8 4	432.8418	-0.03
9   0   402   02   22   402,1167   0.63   18   19   400,6261   0.7   41   40   401,222   0.01   48   47   477,475   0.14   55   52   433,441     28   404,0694   -0.08   20   24   404,0156   0.34   16   17   401,8842   0.1   43   42   440,8220   0.01   55   54   434,4334     26   27   404,776   0.34   19   202   900,903   11   14   403,7317   0.64   44   411,650   0.33   52   439,520   0.07   55   54   439,520   0.07   55   54   439,520   0.07   55   54   439,520   0.07   55   54   439,520   0.07   55   54   439,520   0.07   55   54   439,520   0.07   55   54   439,520   0.07   55   54   439,520   0.07   56   54,349,440	30	31	402.0083	0.18	23	24	402.0617	0.16	19	20	399.9975	-0.07	40	39	439.7645	0	47	46	437.1602 0	.54 5	0 4	9 4	433.1468	0.1
28 29 403.3858.087 21 22 403.3622.034 17 18 401.201 0.47 42 41 440.4740 0.04 49 48 477.715 0.16 52 51 433.711   27 404.7476 0.34 19 20 404.6522 0.57 15 16 402.5049 0.76 44 43 441.5019 0.04 52 51 438.4033 0.97 54 53 434.553   23 406.7569 0.47 16 17 405.507 11 12 404.3383 0.35 47 46 441.8109 0.01 55 54 439.2799 0.11 55 54 439.2799 0.11 55 54 439.2799 0.11 55 54 439.2799 0.11 55 54 439.2799 0.11 55 54 439.2799 0.11 55 54 439.2799 0.11 55 54 439.2799 0.11 55 54 439.2799 0.11 55 54 439.2799 0.11 54.55 55	29	30	402.7000	0.49	22	23	402.7167	-0.63	18	19	400.6296	-1.17	41	40	440.1222 -	-0.01	48	47	437.4782 0	.14 5	1 5	0 4	433.4464	-0.09
27 28 404.0694.06 20 21 404.0156.0.34 16 17 401.8842 0.1 43 42 440.222 0.12 50 49 433.0966 0.18 51 53 52 434.0302   26 27 407.476 0.38 18 19 405.2869 0.09 14 15 40.1195 0.28 14 441.8340 0.38 51 52 433.8998 0.07 55 54 434.8532   24 25 406.0913 0.58 16 17 18 405.2967 0.11 11 403.7317 0.64 46 44 441.8340 0.25 54 433.9282 0.07 55 54 438.928 0.07 55 54 438.9562 0.27 743.5362 0.23 444.24.837 1.2 55 54 439.5627 0.20 75 440.375 0.02 55 54 438.9686 0.01 55 54 436.375 0.05 55 54 443.4163 0.03 55 54 443.4163 0.03 55<	28	29	403.3858 -	-0.87	21	22	403.3692	0.34	17	18	401.2601	0.47	42	41	440.4749	0.04	49	48	437.7915 0	.16 5	2 5	1 4	\$33.7411	-0.04
26 27 404.7476 0.34 19 20 404.652 0.57 15 16 402.5049 0.76 44 44 15019 0.04 55 54 434.5932   24 25 406.0613 0.58 17 18 405.3209 0.07 16 17 406.5607 0.14 12 13 404.3383 0.35 47 46 421.1608 0.02 54 438.9226 0.07 56 55 434.8652   22 406.7569 0.47 16 17 406.5607 0.14 12 13 404.3383 0.35 47 46 442.1608 0.02 54 53.8621 0.22 57 56 439.8621 0.22 57 56 439.8621 0.22 57 43.38362 0.01 50 443.1103 0.03 57 54.40.3756 0.06 59 58 439.8621 0.22 57 440.376 0.06 59 58 439.8606 1.1 40.062 59 58 443.1613 0.01 56 54 443.1613 </td <td>27</td> <td>28</td> <td>404.0694 -</td> <td>-0.06</td> <td>20</td> <td>21</td> <td>404.0156</td> <td>-0.34</td> <td>16</td> <td>17</td> <td>401.8842</td> <td>0.1</td> <td>43</td> <td>42</td> <td>440.8222 -</td> <td>-0.12</td> <td>50</td> <td>49</td> <td>438.0996 0</td> <td>.18 5</td> <td>3 5</td> <td>2</td> <td>434.0302</td> <td>-0.35</td>	27	28	404.0694 -	-0.06	20	21	404.0156	-0.34	16	17	401.8842	0.1	43	42	440.8222 -	-0.12	50	49	438.0996 0	.18 5	3 5	2	434.0302	-0.35
25 26 405.4221 0.05 18 19 405.299 0.03 14 15 403.7137 0.4 46 441.5019 0.04 52 51 438.000 0 55 54 438.926 007 55 54 434.8655   23 24 406.7569 0.04 16 17 406.6607 0.14 12 13 404.333 0.35 47 46 442.1608 0.02 54 53 439.826 0.07 55 54 439.866 201 55 54 439.866 201 55 54 439.846 201 55 54 439.846 201 55 54 439.846 201 55 54 440.059 0.02 56 439.846 201 55 54 440.376 0.06 59 430.857 0.06 59 430.875 0.06 59 440.0375 0.06 59 440.0375 0.06 59 440.4352 0.01 56 440.8322 0.01 62 61 436.858 61 60 59	26	27	404.7476 -	0.34	19	20	404.6592	0.57	15	16	402.5049	0.76	44	43	441.1650	0.38	51	50	438.4033 0	.97 5	4 5	3 '	434.3148	0
24 25 406.0913 10.58 17 18 405.937 10.94 46 54 441.840 0.13 53 52 438.932 0.01 56 53 434.8562   22 23 407.4185 0.06 15 16 407.1857 0.02 11 12 13 404.3383 0.03 54 7 442.4837 1.2 55 54 393.8406 2.01 58 54 393.8406 2.01 58 54 393.8406 2.01 58 57 440.378 0.07 58 47 452.457 100 18 400.7307 0.8 8 9 406.7302 0.03 51 440.3171 0.02 55 54 440.6375 0.06 61 60 59 440.3932 0.01 62 61 436.808 16 17 11 12 406.421 0.03 6 7 407.8831 -2.39 53 52 444.032 0.06 59 440.8323 0.01 63 64 63 441.8409 0.03 64	25	26	405.4221	0.05	18	19	405.2969	-0.09	14	15	403.1195	-0.28	45	44	441.5019	0.04	52	51	438.7000	0 5	5 5	4 ·	434.5938	0
23 24 440.799 0.47 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 11 12 14 404.900 0.02 14 12 15 16 439.5621 0.22 57 56 54 39.800 0.21 55 54 49.9800 0.21 0.25 75 56 439.5621 0.22 57 56 440.099-0.29 59 58 435.3960   20 21 408.775 0.06 13 14 408.423 0.01 58 57 440.375 0.06 60 59 440.6375 0.06 60 59 440.6375 0.06 60 59 440.8375 0.06 60 59 440.8376 0.06 59 440.8376 0.06 59 440.8376 0.06 59 440.8376 0.06 59 440.8376 0.06 59 440.8368 0.06 60 59 440.8368 0.06 59 440.8368 0.06 59 440.8368	24	25	406.0913 -	-0.58	1/	18	405.9307	0.14	13	14	403.7317	0.04	46	45	441.8340	0.13	53	52	438.9926	1.07 C	10 D	5 5	434.8053	-2.39
12 22 23 407 412 407 442 747 442 798 70 547 549 56 55 <td>23</td> <td>24</td> <td>406./569 -</td> <td>-0.47</td> <td>10</td> <td>16</td> <td>400.0007</td> <td>-0.02</td> <td>12</td> <td>12</td> <td>404.3363</td> <td>0.35</td> <td>47</td> <td>40</td> <td>442.1608</td> <td>1.2</td> <td>54 55</td> <td>53 54</td> <td>439.2799 0</td> <td>1.11 5</td> <td>00 0 7 5</td> <td>6</td> <td>434.0090</td> <td>2.09</td>	23	24	406./569 -	-0.47	10	16	400.0007	-0.02	12	12	404.3363	0.35	47	40	442.1608	1.2	54 55	53 54	439.2799 0	1.11 5	00 0 7 5	6	434.0090	2.09
1 21 408,7276 0.06 13 14 408,423 0.82 9 10 406,732 0.08 57 56 440,1099 0.29 55 58 435,657   19 20 409,3754 0.03 12 13 409,6327 0.08 51 50 443,1103 0.01 55 54 440,0376 0.08 61 60 59 440,0376 0.08 61 60 59 440,0375 0.06 61 60 54 54 444,0120 0.60 59 440,6375 0.06 61 64 63 464,6000   16 17 411,2344 1.64 9 10 410,8431 0.09 5 54 444,032 0.08 61 60 441,1440 0.38 63 62 436,6362   13 14 412,6271 0.66 7 8 412,0271 0.56 55 54 444,43,032 0.08 63 64 432,032 0.8 65 64 433,056 64 432,032 0.01	22	23	407.4103	0.00	14	15	407 8071	0.64	10	11	405 5385	0.23	40	47	442.4037	_0.05	56	55	439 8406 2	01 9	8 5	7	435 3980	-16
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	20	21	408 7276	0.06	13	14	408.4235	0.82	9	10	406.1316	-0.18	50	49	443 1103	0.03	57	56	440.1099 -0	.29 5	59 5	8	435.6579	0.1
18 19 410.0191 0.17 11 12 409.6421 0.2 7 8 407.3062 0.84 52 51 443.7172 0.02 59 58 440.6375 0.06 61 60 436.1586   17 118 410.6582 0.16 10 11 410.2448 0.03 6 7 407.8831 -2.39 53 52 444.0128 0 60 59 440.8932 0.01 62 61 436.4006   16 17 11.12944 1.64 9 10 410.8431 -0.09 5 54 444.45850 -2.2 61 441.1420 0.38 64 63 441.6293 0.8 65 64 437.095 65 54 445.6156 -0.0 64 63 441.6293 0.8 65 647.737.616 64 437.3451 10.03 58 57 54 445.6156 -0.17 66 647.537.166 647.537.427 10.3 65 64 437.437.427 10.2 70 64 437.427 10.1 11<	19	20	409.3754 -	-0.03	12	13	409.0337	-0.8	8	9	406.7202	-0.63	51	50	443.4163	0.01	58	57	440.3756 -0	.87 6	50 5	9	435.9109	0.29
17 18 410.6582 0.16 10 11 410.2448 -0.03 6 7 407.8831 -2.39 53 52 444.0128 0 60 59 440.8332 0.01 62 61 436.4002   16 17 411.9235 0.46 8 9 10 410.8431 -0.09 5 6 444.5032 0.08 61 60 441.1440 0.38 63 62 436.637   14 15 412.5479 0.86 7 8 412.0271 0.56 3 4 409.5975 -1.08 56 55 444.8681 0.04 63 62 441.6293 0.8 65 437.3165   12 13 413.7669 -0.5 6 443.4350 -1.41 59 58 445.6756 0.17 66 64 42.307 0.8 67 442.867 0.14 71 70 437.442 1.2 71 74 43.442.993 0.01 67 64 442.367 0.8 68 437.3737 73 74	18	19	410.0191	0.17	11	12	409.6421	0.2	7	8	407.3062	0.84	52	51	443.7172	0.02	59	58	440.6375 0	0. <b>06</b> 6	61 6	0	436.1586	0.33
16 17 411.2944 1.64 9 10 410.8431 -0.09 5 6 408.4615 0.46 53 444.3032 0.08 61 60 441.1440 0.38 63 62 436.637   15 16 411.9235 0.46 8 9 411.4370 0.14 4 5 50 55 54 444.5050 -3.2 62 61 411.3288 0.03 64 63 62 441.6293 0.8 65 64 437.0951   13 14 13.1671 -3.04 6 7 412.6110 0.43 2 1 412.9019 -0.03 58 57 445.4125 1.03 65 64 442.0937 1.68 64 437.0951   11 12 141.50087 1.54 3 2 113.4909 -0.64 65 442.7474 0.12 70 69 483.1472   10 11 415.0087 1.52 414.6490 -3.4 63 646.1877 0.12 68 67 442.7474 0.12 </td <td>17</td> <td>18</td> <td>410.6582</td> <td>0.16</td> <td>10</td> <td>11</td> <td>410.2448</td> <td>-0.03</td> <td>6</td> <td>7</td> <td>407.8831</td> <td>-2.39</td> <td>53</td> <td>52</td> <td>444.0128</td> <td>0</td> <td>60</td> <td>59</td> <td>440.8932</td> <td>).01 e</td> <td>62 6</td> <td>51</td> <td>436.4006</td> <td>0</td>	17	18	410.6582	0.16	10	11	410.2448	-0.03	6	7	407.8831	-2.39	53	52	444.0128	0	60	59	440.8932	).01 e	62 6	51	436.4006	0
15 16 411.9235 0.46 8 9 411.4370 -0.14 4 5 409.0377 1.69 55 54 444.8681 0.04 63 62 61 441.3888 0.03 64 63 436.6684   14 15 412.6779 0.86 7 8 412.0271 0.56 3 4 409.5975 -1.08 56 55 444.8681 0.04 63 62 441.6293 0.8 65 64 437.0956   12 13 413.7669 -0.02 5 6 413.1871 0.07 2 1 412.9019 -0.03 58 57 445.4125 1.03 65 64 442.0937 1.63 67 64 437.3457   10 11 415.6102 0.19 2 414.3490 -0.49 5 411.44909 -0.6 61 60 446.1877 0.12 68 67 422.747 0.12 70 69 438.1477 0.13 72 71 438.642   10 145.6102 0.20 </td <td>16</td> <td>17</td> <td>411.2944</td> <td>1.64</td> <td>9</td> <td>10</td> <td>410.8431</td> <td>-0.09</td> <td>5</td> <td>6</td> <td>408.4615</td> <td>0.46</td> <td>54</td> <td>53</td> <td>444.3032</td> <td>80.0</td> <td>61</td> <td>60</td> <td>441.1440 0</td> <td>).38 6</td> <td>63 E</td> <td>2</td> <td>436.6373</td> <td>-0.26</td>	16	17	411.2944	1.64	9	10	410.8431	-0.09	5	6	408.4615	0.46	54	53	444.3032	80.0	61	60	441.1440 0	).38 6	63 E	2	436.6373	-0.26
14 15 412,5479 - 0.86 7 8 412,0271 0.56 3 44,8681 0.04 63 62 441,6293 0.8 65 64 437,0951   13 14 413,1671 - 3.04 6 7 412,6110 - 0.43 2 3 410,1631 2.56 57 56 445,1425 0.09 64 63 441,8292 0.11 66 65 437,3161   11 12 414,3984 -0.9 4 5 413,7660 -1.54 3 2 413,4350 -1.41 59 58 57 56 445,6756 -0.17 66 54 442,0937 0.86 67 437,7421   10 11 415,0087 1.58 3 414,9049 -0.6 61 60 446,1877 0.12 68 67 442,9474 0.12 71 70 438,350   6 7 416,2090 -0.22 1 2 416,3097 0.43 64 63 446,9155 0.17 71 70 443,1570 0.13 72	15	16	411.9235	0.46	8	9	411.4370	-0.14	4	5	409.0337	1.69	55	54	444.5850	-3.2	62	61	441.3888 0	0.03 <del>(</del>	64 6	3	436.8688	-0.51
13 14 413.1671 - 3.04 6 7 412.6110 - 0.43 2 3 410.1631 2.56 57 56 445.1425 - 0.09 64 63 441.8629 - 0.11 66 65 437.315   12 13 413.7869 - 0.02 5 6 413.1918 0.07 2 1 412.9019 - 0.03 58 57 445.4128 1.03 66 64 442.037 1.68 66 64 437.532'   11 12 413.3984 - 0.9 4 5 413.7660 - 1.54 3 2 413.4983 0.1 59 58 445.6756 - 0.17 66 64 422.541 - 0.18 68 67 437.542'   9 10 415.6102 - 0.19 2 3 414.9049 - 0.49 5 4 414.4909 -0.6 61 60 446.1877 0.12 68 67 422.747 0.12 70 69 438.412'   8 9 416.2090 - 0.22 1 2 415.4689 1.32 6 5 415.087' 0.17 70 443.537' 0.17 71 438.538' 0.13 74	14	15	412.5479	-0.86	7	8	412.0271	0.56	3	4	409.5975	-1.08	56	55	444.8681	0.04	63	62	441.6293	0.8 6	65 6	64	437.0959	0.12
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	13	14	413.16/1	-3.04	6		412.6110	-0.43	2	3	410.1631	2.56	57	56	445.1425	-0.09	64	63	441.8629 -0	).11 (	56 6	5	437.3165	-0.38
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	12	13	413./009 -	0.02	c A	5	413.1910	1.54	2	ו כ	412,9019	-0.03	58	57	445.4128	1.03	60	64	442.0937	1.03 0	57 C	27	437.3323	-0.1
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	10	11	414.3904	1.58	4 2	4	413.7000	-0.86		2	413.4350	-1.41	59	50	440.0/00	-0.17	67	66	442.3107	).04 ( )13 f	50 C	57 58	437.1429	-0.14
8 9 416.209 -0.22 1 2 415.4689 1.32 6 5 415.007 -3.42 62 61 446.4352 -0.33 69 68 442.9547 -0.14 71 70 438.3421   7 8 416.7998 -3.65 3 2 418.2085 -0.39 7 6 415.5280 -0.09 63 62 446.6782 0.08 70 69 443.1570 -0.13 72 71 438.3421   5 6 417.9784 0.01 5 4 419.2728 -0.13 9 8 416.6465 0.58 65 64 447.1472 0.04 72 71 443.5451 -0.19 74 73 438.8924   4 5 418.5588 0.18 6 5 417.9778 -0.21 71 70 443.9117 -0.08 74 439.0561   3 4 19.1361 1.14 7 6 420.373 0.04 73 72 443.9117 -0.08 74 439.0561 74	9	10	415.6102	-0.19	2	3	414.9049	-0.49	5	4	414,4909	-0.6	61	60	445.5545	0.01	68	67	442 7474 (	).12	70 e	,0 59	438.1475	-0.26
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	8	9	416.2090	-0.22	1	2	415.4689	1.32	6	5	415.0087	-3.42	62	61	446 4352	-0.33	69	68	442.9547	0.14	71 7	70	438.3420	-0.06
6 7 417.3930 -0.16 4 3 418.7436 0.38 8 7 416.0397 0.43 64 63 446.9155 0.17 71 70 443.3537 -0.2 73 72 438.714'   5 6 417.9784 0.01 5 4 419.2728 -0.13 9 8 416.5465 0.58 65 64 447.1472 0.04 72 71 443.5451 -0.19 74 73 438.8924   4 5 418.5588 0.18 6 5 419.778 -0.26 10 9 417.0474 -0.37 66 65 447.5948 0.13 74 73 443.9177 -0.08 76 75 74 444.0866 -0.26 78 74 39.35492   0 1 420.8340 -1.27 10 9 421.8527 0.39 69 68 448.0207 0.12 76 75 444.205 0.07 78 439.95492   0 1 420.8340 -1.27 10 9 421.8557	7	8	416.7998	-3.65	3	2	418.2085	-0.39	7	6	415.5280	-0.09	63	62	446.6782	80.0	70	69	443.1570 -0	0.13	72 7	71	438.5308	-0.21
5 6 417.9784 0.01 5 4 419.2728 -0.13 9 8 416.5465 0.58 65 64 447.1472 0.04 72 71 443.5451 -0.19 74 73 438.8924   4 5 418.5588 -0.18 6 5 419.7978 -0.26 10 9 417.0474 -0.37 66 65 447.3737 0.04 73 72 443.7313 0.01 75 74 439.0657   3 4 419.1361 1.14 7 6 420.8140 -0.01 12 11 417.5451 0.05 67 66 647.5948 0.13 74 73 443.9117 -0.08 76 75 444.40866 -0.26 78 74 39.35493   0 1 420.8340 -1.27 10 9 421.8513 0.12 13 12 418.5257 0.39 69 68 448.0207 0.12 76 74 444.4205 0.07 83.9301 39.861   2 23.0355 0.	6	7	417.3930	-0.16	4	3	418.7436	0.38	8	7	416.0397	0.43	64	63	446.9155	0.17	71	70	443.3537	-0.2	73 7	2	438.7147	0.19
4 5 418.5588 - 0.18 6 5 419.7978 - 0.26 10 9 417.0474 - 0.37 66 65 447.3737 0.04 73 72 443.7313 0.01 75 74 439.0651   3 4 419.1361 1.14 7 6 420.3181 - 0.23 11 10 417.5451 0.05 67 66 447.5948 0.13 74 73 443.9117 - 0.08 76 75 443.9147 -0.08 76 74 439.0551   2 3 419.7059 - 0.42 8 7 420.8340 - 0.01 12 11 418.5257 0.39 69 68 448.0207 0.12 76 74 444.266 - 0.26 78 74 39.5491   0 1 420.8340 - 1.27 10 9 421.85513 0.12 13 12 418.5257 0.39 69 68 448.0207 0.12 76 74 444.4205 0.07 80 79 78 439.9561   3 22.3556 0.86 12 11 422.3494 0.03	5	6	417.9784	0.01	5	4	419.2728	-0.13	9	8	416.5465	0.58	65	64	447.1472	0.04	72	71	443.5451 -0	0.19	74 7	73	438.8926	-0.08
3 4 419.1361 1.14 7 6 420.3181 - 0.23 11 10 417.5451 0.05 67 66 447.5948 0.13 74 73 443.9117 - 0.08 76 75 439.232:   2 3 419.7059 - 0.42 8 7 420.8340 - 0.01 12 11 418.0342 -3.3 68 67 447.8103 0 75 74 444.0866 - 0.26 78 77 439.549   0 1 420.8340 - 1.27 10 9 421.8513 0.12 13 12 418.5257 0.39 69 68 448.0207 0.12 76 74 444.0866 - 0.26 78 74 439.701   3 2 423.0385 0.92 11 10 422.5256 - 0.08 14 13 419.0083 -0.02 70 69 448.2220 -3.3 77 76 444.4205 - 0.07 80 79 439.806 439.866 439.866 449.47321 - 0.29 81 80 439.986 439.486 424.1103 - 0.77 13 12 423.8756 16	4	5	418.5588	-0.18	6	5	419.7978	-0.26	10	9	417.0474	-0.37	66	65	447.3737	0.04	73	72	443.7313 (	0.01	75 7	74	439.0650	-0.32
2 3 419.7059 0.42 8 7 420.8340 -0.01 12 11 418.0342 -3.3 68 67 447.8103 0 75 74 444.0866 -0.26 78 77 439.549   0 1 420.8340 -1.27 10 9 421.8513 0.12 13 12 418.5257 0.39 69 68 448.0207 0.12 76 75 444.2561 -0.36 79 78 439.5701   3 2 423.0355 0.92 11 10 422.5252 -0.08 14 13 419.0083 -0.02 70 69 448.2220 -3.3 77 76 444.4205 -0.07 80 79 439.8400   4 3 423.5756 0.86 12 11 422.8494 -0.03 15 14 419.4901 3.47 71 70 448.249 0.2 79 78 444.7321 -0.29 81 80 439.866 50 65 424.6397 -0.51 14 423.8766 0.82	3	4	419.1361	1.14	7	6	420.3181	-0.23	11	10	417.5451	0.05	67	66	447.5948	0.13	74	73	443.9117 -0	0.08	76 7	75	439.2324	-0.16
0 1 420.8340 -1.27 10 9 421.8513 0.12 13 12 418.2557 0.39 69 68 448.0207 0.12 76 75 444.2561 -0.36 79 78 439.701   3 2 423.0385 0.92 11 10 422.3526 -0.08 14 13 419.0083 -0.02 70 69 448.2220 -3.3 77 76 444.4205 -0.07 80 79 439.840   4 3 423.5756 0.86 12 11 422.32494 -0.03 15 14 419.4901 3.47 71 70 448.4249 0.2 79 78 444.7321 -0.29 81 80 439.9860   5 4 424.1103 -0.37 13 12 423.8293 0.56 17 16 420.4297 0.82 73 72 448.6185 -0.06 80 79 444.5184 -0.25 84 83 440.255 7 76 444.5184 -0.27 82 81 440.	2	3	419.7059	-0.42	8	7	420.8340	-0.01	12	11	418.0342	-3.3	68	67	447.8103	0	75	74	444.0866 -0	0.26	78	77	439.5499	-0.81
3 2 423.0005 0.92 11 10 422.002 -0.00 14 13 419.0003 -0.02 70 69 448.2220 -3.3 77 76 444.4205 -0.07 80 79 439.840   4 3 423.5756 -0.86 12 11 422.8494 -0.03 15 14 419.4901 3.47 71 70 448.4249 0.2 79 78 444.7321 -0.29 81 80 439.986   5 4 424.1103 0.37 13 12 423.8415 0.05 16 15 419.9602 0.08 72 71 448.6185 -0.06 80 79 448.802 0.27 82 81 440.255   6 5 424.6397 -0.51 14 13 420.8297 0.82 73 72 448.6185 -0.06 80 79 74 448.6185 -0.17 83 82 440.250   7 6 425.1641 -0.88 15 14 420.8292 0.82 73	0	1	420.8340	-1.27	10	9	421.8513	0.12	13	12	418.5257	0.39	69	68	448.0207	0.12	76	75	444.2561 -	J.36	/9 :	/8 70	439.7015	-0.09
+ 5 +22.0730 0.00 12 11 +22.0750 0.00 12 11 +22.0750 0.00 13 14 +19.4901 3.47 71 70 448.64249 0.2 79 70 444.7321 -0.29 81 60 439.960   5 4 424.1103 -0.37 13 12 423.3415 0.05 16 15 419.9602 0.08 72 71 448.6185 -0.06 80 79 444.820 0.27 82 81 440.122   6 5 424.6397 -0.51 14 13 423.8293 0.56 17 16 420.4297 0.82 73 72 448.8069 -0.1 81 80 445.0216 -0.47 83 82 440.250   7 6 425.1641 -0.88 15 14 424.3110 -0.17 18 17 420.8932 0.47 73 448.9900 0.07 82 81 445.1584 -0.25 84 83 440.375   7 6 425.1641 -0.88 15 424.7891 0.22 19 18<	3	2	423.0385	0.92	11	10	422.3526	-0.08	14	13	419.0083	-0.02	70	69	448.2220	-3.3	70	76	444.4205 -	1.07	0U . 81 4	79 80	439.0406	-0.4 0.16
6 5 424.6397 0.51 14 13 423.8293 0.56 17 16 420.4297 0.82 73 72 448.8069 -0.1 81 80 45.0216 -0.47 83 82 440.2500   7 6 425.6789 -0.58 15 14 424.3110 -0.17 18 17 420.8932 0.47 73 74 488.9900 0.07 82 81 445.1584 -0.25 84 83 440.3750   8 7 425.6789 6.19 16 15 424.7891 0.22 19 18 421.3494 -2.56 75 74 449.1676 0.26 83 82 445.2892 -0.49 85 84 440.491   8 74 74 74 74 449.1676 0.26 83 82 445.2892 -0.49 85 84 440.491   8 74 74 74 74 74 74 74 74 74 73 74 74 74 74 74 7	4	د ۸	423.3/30	-0.00	12	12	422.0494	-0.03	10 16	14	419.4901	3.47 0.09	/1 70	/U 74	440.4249	U.2	19	70	444./321 -1 444.8802 -1	0.23	82 I	50 81	440 1000	-0.10 A A
7   6   425.1641   0.08   15   14   424.3110   0.17   18   17   420.8932   0.4   74   73   448.9900   0.07   82   81   445.1584   0.25   84   83   440.375     8   7   425.6789   6.19   16   122.47891   0.22   19   18   421.3494   -2.56   75   74   449.1676   0.26   83   82   445.2892   0.49   85   84   440.491     0   445.15264   0.17   18   471.3494   -2.56   75   74   449.1676   0.26   83   82   445.2892   0.49   85   84   440.491   93   445.4128   93   445.4128   93   445.4128   93   445.4128   93   445.4128   93   445.4128   93   445.4128   93   445.4128   93   445.4128   93   445.4128   93   445.4128   93   445.4128   93   445.4128   93   44	5 6	5	424 6397	-0.51	14	13	423 8293	0.56	17	16	420 4297	0.82	72	72	448 8069	-0.00	81	80	445.0216 -	0.47	83 8	82	440,2502	-0.1
8 7 425.6789 -6.19 16 15 424.7891 0.22 19 18 421.3494 -2.56 75 74 449.1676 0.26 83 82 445.2892 -0.49 85 84 440.491	7	6	425,1641	-0,88	15	14	424.3110	-0.17	18	17	420.8932	0.4	74	73	448.9900	0.07	82	81	445.1584	0.25	84	B3	440.3756	1.92
	8	7	425.6789	-6.19	16	15	424.7891	0.22	19	18	421.3494	-2.56	75	74	449.1676	0.26	83	82	445.2892 -	0.49	85	84	440.4914	-0.14
9 0 420,1900 -4,34 17 10 420,2047 2.32 20 19 421,0000 0.2 76 75 449,3395 0.14 84 83 440,4120 -2.31 86 85 440,004	9	8	426.1955	-4.94	17	16	425.2647	2.92	20	19	421.8066	0.2	76	75	449.3395	0.14	84	83	445.4128 -	2.31	86	85	440.6042	0.4
10 9 426.7109 -0.12 18 17 425.7299 0.05 21 20 422.2559 -0.01 77 76 449.5059 0.1 85 84 445.5344 -0.7 87 86 440.710	10	9	426.7109	-0.12	18	17	425.7299	0.05	21	20	422.2559	-0.01	77	76	449.5059	0.1	85	84	445.5344	-0.7	87	86	440.7106	0.04
11 10 427.2166 -0.25 19 18 426.1955 2.41 22 21 422.7005 -0.11 78 77 449.6667 -0.01 86 85 445.6484 -0.96 88 87 440.810	11	10	427.2166	-0.25	19	18	426.1955	2.41	22	21	422.7005	-0.11	78	77	449.6667	-0.01	86	85	445.6484 -	0.96	88	87	440.8108	-1

TABLE 1—Continued

	1-0 band			2-1 band			3-2 band				4-3 band			5-4 band			6-5 band
	Observed A	,		Observed A	,	r	Observed			r	Observed A			Observed A		ť	Observed A
79 78	449 8220 -0.05	87	86	445 7575 -0.63	89	88	440 9080	0.59	8	7	411 2944 -6.01	43	42	421 2156 -0.09	38	37	414 7536 0.53
80 79	449.9719 0.02	88	87	445.8606 -0.71	90	89	440,9969	-0.55	9	8	411.8036 0.96	44	43	421.5462 1.5	39	38	415.1032 -0.55
81 80	450.1163 0.12	89	88	445.9582 -0.59	91	90	441.0816	-0.26	10	9	412.3003 0.04	45	44	421.8687 -0.07	40	39	415,4493 -0.17
82 81	450.2551 0.23	90	89	446.0506 -0.15	92	91	441.1590	-1.72	11	10	412.7928 -0.45	46	45	422.1879 0.07	41	40	415.7901 -0.16
83 82	450.3880 -0.01	91	90	446.1368 -0.19	93	92	441.2346	0.67	12	11	413.2816 0.18	47	46	422.5015 -0.25	42	41	416.1260 -0.1
84 83	450.5154 -0.2	92	91	446.2174 -0.18	94	93	441.3009	-0.59	13	12	413.7660 0.97	48	47	422.8131 2.45	43	42	416.4571 0.17
85 84	450.6377 0.14	93	92	446.2928 0.2	95	94	441.3632	-0.15	14	13	414.2443 0.46	49	48	423.1138 -0.71	44	43	416.7827 -0.1
86 85	450.7539 0.06	94	93	446.3623 0.35	96	95	441.4198	0.19	15	14	414.7184 0.38	50	49	423.4135 0.23	45	44	417.1038 0.21
87 86	450.8646 0.01	95	94	446.4239 -1.62	97	96	441.4710	0.7	16	15	415.1880 0.66	51	50	423.7071 0.17	46	45	417.4197 0.25
88 87	450.9696 -0.04	96	95	446.4837 0.19	98	97	441.5166	1.43	17	16	415.6522 0.19	52	51	423.9949 -0.58	47	46	417.7300 -0.38
89 88	451.0693 0.2	97	96	446.5365 0.73	9 <b>9</b>	98	441.5548	0.33	18	17	416.1121 0.14	53	52	424.2788 -0.09	48	47	418.0342 -1.94
90 89	451.1629 0.1	98	97	446.5834 1.03	100	99	441.5869	-1.09	19	18	416.5657 -1.33	54	53	424.5571 -0.2	49	48	418.3386 1.66
91 90	451.2509 -0.01	99	98	446.6244 1.23	101	100	441.6133	-2.53	20	19	417.0183 0.9	55	54	424.8307 0.29	50	49	418.6325 -0.16
92 91	451.3334 -0.01	100	99	446.6593 1	109	108	441.6293	-2.6	21	20	417.4639 0.91	56	55	425.0997 1.23	51	50	418.9230 -0.33
93 92	451.4100 -0.05	101	100	446.6895 1.88	103	102	441.6543	-0.12	22	21	417.9035 -0.32	57	56	425.3629 1.53	52	51	419.2089 0.02
94 93	451.4809 -0.18	102	101	446.7115 0.31	105	104	441.6683	-1.69	23	22	418.3386 -1.18	58	57	425.6195 0.44	53	52	419.4901 0.67
95 94	451.5467 0.29	103	102	446.7289 -0.13					24	23	418.7716 0.66	59	58	425.8716 -0.03	54	53	419.7650 0.25
96 95	451.6065 0.52	104	103	446.7440 2.9					25	24	419.1970 -0.23	60	59	426.1198 0.9	55	54	420.0352 0.08
97, 96	451.6601 0.22								26	25	419.6186 -0.12	61	60	426.3628 1.74	56	55	420.3014 1.1
98 97	451.7077 -0.24								27	26	420.0352 -0.1	62	61	426.5976 -0.42	57	56	420.5616 1.26
99 98	451.7501 -0.16								28 20	27	420.4472 0.17	63	62	426.8294 -0.26	58	57	420.8153 0.02
100 99	451.7876 0.71								29	28	420.8538 -0.09	64	63	427.0565 0.33	59	58	421.0646 -0.47
101 100	451.8180 0.3								30	29	421.2559 0.01	60	04	427.2773 -0.03	60	59	421.3096 -0.09
102 101	451.8409 -1.8								22	21	421.0531 0.19	67	60	427.4925 -0.78	61	60	421.5462 -2.9
103 102	451.004/ 2.00								32	32	422.0434 0.27	68	67	427.7037 -0.27	62	62	421.7035 0.05
104 103	431.0014 0.17								34	22	422.4322 -0.13	60	68	427.9094 -0.02	64	62	422.0130 1.00
									35	34	423 1922 0 23	70	69	428 3043 -0.02	65	64	422.2373 1.10
	4-3 hand			5-4 hand			6-5 band		36	35	423 5640 -0.37	71	70	428 4939 -0.06	66	65	422.6689 0.47
									37	36	423 9340 21	72	71	428 6777 -0.45	67	66	422 8767 0.01
40 41	381 2243 2.9	7	6	406 1171 2 06	27	28	381 2512	1 91	38	37	424 2945 0 24	73	72	428 8563 -0.68	68	67	423 0795 -0.17
39 40	381,9397 1.91	, 8	7	406.6180 0.37	26	27	381.9030	2.06	39	38	424.6520 0.22	74	73	429.0308 0.24	69	68	423 2778 0.41
38 39	382.6438 -6.28	9	8	407.1126 -3.05	25	26	382.5495	1.05	40	39	425.0043 0.02	76	75	429,3624 0.88	70	69	423.4697 -0.1
37 38	383.3612 2.98	10	9	407.6084 -0.55	23	24	383.8307	-0.16	41	40	425.3514 -0.26	78	77	429.6726 1.64	71	70	423.6573 0.31
36 37	384.0622 -0.13	11	10	408.0977 0.04	19	20	386.3440	-0.99	42	41	425.6937 -0.42	79	78	429.8169 -0.76	73	72	424.0188 3.39
35 36	384.7612 -1.1	12	11	408.5815 -0.16	16	17	388.1837	-2.2	43	42	426.0322 0.72	80	79	429.9557 -3.18	74	73	424.1872 0.52
34 35	385.4601 1.96	13	12	409.0615 0.41	15	16	388.7908	-0.05	44	43	426.3628 -1.04	81	80	430.0949 0.14	75	74	424.3524 -0.24
33 34	386.1486 -1.24	14	13	409.5359 0.17	13	14	389.9848	-3.16	45	44	426.6898 -1.28	82	81	430.2194 -5.74	76	75	424.5134 0.06
32 33	386.8381 0.71	15	14	410.0050 -0.75	12	13	390.5844	4.37	46	45	427.0133 -0.05	83	82	430.3492 -0.96	77	76	424.6685 -0.05
31 32	387.5214 0.67	16	15	410.4703 -0.77	10	11	391.7518	0.74	47	46	427.3305 0.06	84	83	430.4695 -0.11	78	77	424.8187 0.18
30 31	388.2006 0.73	17	16	410.9317 0.04	9	10	392.3268	-3.27	48	47	427.6423 -0.21	85	84	430.5832 -0.53	79	78	424.9646 1.5
29 30	388.8760 1.15	18	17	411.3882 0.69	7	8	393.4635	-11	49	48	427.9495 0.03	86	85	430.6916 -0.69	81	80	425.2364 0.24
28 29	389.5454 -0.26	19	18	411.8388 0.15	3	4	395.7068	-4.66	50	49	428.2515 0.25	87	86	430.7955 0.14	83	82	425.4880 0.39
27 28	390.2112 -0.99	20	19	412.2856 0.64	11	10	403.4564	-1.62	51	50	428.5481 0.09	88	87	430.8920 -1.07	84	83	425.6055 0.32
26 27	390.8742 -0.36	21	20	412.7263 -0.29	15	14	405.3489	-0.66	52	51	428.8397 0.1	89	88	430.9853 0.16	85	84	425.7161 -1.3
25 26	391.5328 0.14	22	21	413.1671 3.6	17	16	406.2605	-6.83	53	52	429.1263 0.35	90	89	431.0724 0.66	86	85	425.8248 0.64
24 25	392.1862 -0.27	23	22	413.5950 -0.49	18	17	406.7202	1.03	54	53	429.4070 -0.2	92	91	431.2301 1.72	87	86	425.9258 0.32
23 24	392.8374 1.32	24	23	414.0226 -0.19	19	18	407.1647	-1.6	55	54	429.6835 0.22	93	92	431.2969 -1.54	88	87	426.0273 5.95
22 23	393.4822 0.85	25	24	414.4452 -0.07	20	19	407.6084	-0.35	56	55	429.9557 1.48	95	94	431.4207 -1.04	89	88	426.1141 2.38
21 22	394.1229 0.52	20	25	414.8631 0.17	21	20	408.0470	0.59	5/	56	430.2194 -0.55	97	96	431.5241 1.23	90	89	426.1955 -1.21
20 21	394.7500 -0.42	21	20	415.2756 0.01	22	21	408.4797	0.28	58	57	430.4805 0.02	99	98	431.6014 -0.06	92	91	426.3628 12.74
19 20	395.3922 0.77	20	2/	410.0039 0.12	23	22	408.9078	0.21	59	58	430.7357 -0.09	100	400	431.6322 -0.23	93	92	426.4203 1.83
17 19	390.0207 1.12	29	20	410.0071 0.15	24	23	409.3305	-0.62	60	59	430.9853 -0.56	101	100	431.6586 0.92	94	93	426:4839 2.5
16 17	390.0434 0.14	21	29	410.4031 -0.00	20	24	409./46/	-1.1	60	61	431.2301 -0.59	103	102	431.6912 -0.23	95	94	426.5397 0.92
15 16	397.2034 0.73	30	21	410.0700 -0.03	20	25	410.1031	1 1 9	62	67	431.4710 0.7				96	95	426.59/6 6.91
14 15	398 4877 -0.62	22	30	417 6505 -0.27	21	20	410.0760	-0.84	64	62	431 9341 0 20				31	90 07	426.6769 0.00
13 14	399 0937 -0.02	24	22	418 0342 4 66	20	28	411 3766	0.04	65	64	432 1573 -0.25				90 00	08 31	426.0700 -0.92
12 13	399.6963 -0.24	35	34	418.4037 0.36	30	29	411 7698	-1 33	66	65	432 3758 -0.27				33	50	-20.7108 -2
11 12	400.2889 -5.07	36	35	418.7716 -0.71	31	30	412 1603	-0.61	67	66	432 5890 -0.26						
9 10	401.4758 0.11	37	36	419,1361 -0.14	32	31	412,5479	2.02	68	67	432,7972 0.04						
3 2	408.7276 7.99	38	37	419.4901 -5.17	33	32	412.9262	0.25	69	68	432.9996 -0.05						
4 3	409.2434 -1.58	39	38	419.8491 -0.21	34	33	413.3008	-0.42	70	69	433.1971 0.12						
54	409.7654 -0.4	40	39	420.1985 0.19	35	34	413.6713	-0.18	71	70	433.3884 -0.46						
65	410.2826 0.62	41	40	420.5425 0.08	36	35	414.0365	-0.45	72	71	433.5753 -0.02						
76	410.7941 0.63	42	41	420.8818 0.21	37	36	414.3984	0.9	73	72	433.7567 0.13						

### INFRARED EMISSION OF KF

### **TABLE 1**—Continued

4-3 band					5-4 band		6-5 band				7-6 band						8-7 band	-			
J	J	Observed <b>D</b>	ſ	J	Observed	۵	L	J.	Observed	Δ	J	J	Observed	۵	L	J	Observed Δ	L	J.	Observed	Δ
74	73	433.9318 -0.54									40	39	410.7553	-1.15	58	57	411.3766 -2.15				
75	74	434.1030 0.24									41	40	411.0935	-0.51	60	59	411.8615 -1.01				
76	75	434.2675 -0.22									42	41	411.4257	-0.85	61	60	412.0968 0.15				
77	76	434.4276 0.29									43	42	411.7535	-0.77	62	61	412.3264 0.59				
78	77	434.5811 -0.43									44	43	412.0759	-1.03	63	62	412.5479 -1.9				
79	78	434.7298 -0.46									45	44	412.3944	-0.3	64	63	412.7697 0.98				
80	79	434.8698 -3.77									46	45	412.7072	-0.22	65	64	412.9824 -0.05				
81	80	435.0111 -0.24									47	46	413.0152	-0.03	66	65	413.1918 0.76				
82	81	435.1388 -4.92									48	47	413.3169	-1.14	67	66	413.3942 -0.26				
83	82	435.2704 -0.21									49	48	413.6165	0.66	68	67	413.5950 2.28				
84	83	435.3980 5.97									50	49	413.9079	-0.69	69	68	413.7869 1.05				
85	84	435.5077 -0.27									51	50	414.1966	0.32	70	69	413.9693 -4.47				
86	85	435.6181 -0.31									52	51	414.4781	-0.84	71	70	414.1577 1.23				
87	86	435.7239 0.54									54	53	415.0296	0.39	72	71	414.3379 3.91				
88	87	435.8219 -0.82									55	54	415.2971	0.46	73	72	414.5063 0.02				
89	88	435.9109 -5.59									56	55	415.5603	1.22							
90	89	436.0042 -0.62									57	56	415.8162	-0.19							
91	90	436.0882 0.66									58	57	416.0688	0.15							
92	91	436.1586 -6.08									59	58	416.3154	-0.39							
93	92	436.2358 -0.43									60	59	416.5657	8.03							
94	93	436.3016 -0.62									61	60	416.7998	5.29							
95	94	436.3626 0.03									62	61	417.0183	-7.91							
96	95	436.4163 -1.06									63	62	417.2523	-0.51							
98	97	436.5079 -2									64	63	417.4639	-10							
											65	64	417.6910	0.68							
											66	65	417.9035	2.16							
		7-6 band			8-7 band						67	66	418.1073	0.22							
											68	67	418.3083	0.59							
26	25	405.5181 -1.19	34	33	404.0156 1	.42					69	68	418.5044	1.36							
28	27	406.3243 -1.1	38	37	405.4363 -2	2.18					70	69	418.6947	1.55							
30	29	407.1126 0.3	40	39	406.1171 -	-4.4					71	70	418.8781	0.03							
31	30	407.4984 -0.11	41	40	406.4537 -2	2.03					72	71	419.0574	-0.29							
32	31	407.8831 3.13	43	42	407.1126 3	8.21					73	72	419.2330	0.96							
33	32	408.2548 -1.77	48	47	408.6563 -0	0.89					75	74	419.5670	2.15							
34	33	408.6275 -0.81	50	49	409.2434 1	.74					76	75	419.7236	0.22							
35	34	408.9958 0.61	51	50	409.5252 -1	.13					77	76	419.8825	5.91							
36	35	409.3572 0.01	52	51	409.8061 0	0.03					78	77	420.0229	-1.51							
37	36	409.7139 -0.45	53	52	410.0787 -2	2.04					79	78	420.1669	-0.12							
38	37	410.0659 -0.7	54	53	410.3508	0.3					81	80	420.4297	-6.4							
39	38	410.4142 0.24	57	56	411.1310 1	1.73					85	84	420.9107	0.9							

TABLE 2 Dunham  $Y_{\mu}$  Coefficients for the  $X^{1}\Sigma^{+}$  Ground State of KF

TABLE 3 Spectroscopic Constants for the  $X^{1}\Sigma^{+}$ Ground State of KF (in cm<sup>-1</sup>)

Dunham $Y_{ij}$ Coeffic	cients for the $X^{-1}\Sigma^{+}$ Gro	ound State of KF	v	T <sub>v</sub>	B <sub>v</sub>	10 <sup>7</sup> D <sub>v</sub>
Dunham coefficients	Value (cm <sup>-1</sup> )	Previous work <sup>a</sup>	0	0	0.278771826(43)	4.84025(74)
Y <sub>10</sub> Y <sub>20</sub>	426.261872(98) -2.449801(44)	426.26119(84) -2.449513(400)	1	421.392834(50)	0.276450649(48)	4.83832(71)
$10^3 Y_{30}$	9.4357(79)	9.3447(564)	2	837.970760(65)	0.274143387(56)	4.83549(69)
$10^5 Y_{40}$	-1.048(53)	-				
$Y_{01}$	0.279937682(52)	0.279937548(64)	3	1249.789858(88)	0.271850416(73)	4.83222(67)
$10^3 Y_{11}$ $10^6 Y_{21}$	-2.335154(42) 6.933(10)	-2.335296(97) 7.057(25)	4	1656.90571(11)	0.269571722(92)	4.82813(65)
$10^{8} Y_{31}$ $10^{7} Y_{02}$	1.873(89) -4.84117(78)	-4.8320(50)	5	2059.37425(13)	0.26730728(11)	4.82306(64)
10 <sup>10</sup> Y <sub>12</sub>	1.254(59)	[0.633771] <sup>b</sup>	6	2457.25102(20)	0.26505730(14)	4.81735(63)
10 <sup>11</sup> Y <sub>22</sub>	3.720(77)	3.72(25)				
<sup>a</sup> Ref. 10.	<u></u>		7	2850.58980(55)	0.26282242(32)	4.81143(73)
<sup>b</sup> The value of $Y_{12}$ , and als	o the values of $Y_{03}$ and $Y_{13}$ , y	were fixed at the values	8	3239.4513(24)	0.2605997(14)	4.8017(19)

 $^{\rm b}$  The value of  $Y_{12},$  and also the values of  $Y_{03}$  and  $Y_{13},$  were fixed at the values calculated from the Dunham a<sub>i</sub> potential parameters.

from  $v = 1 \rightarrow 0$  to  $v = 8 \rightarrow 7$  were observed; the line positions are reported in Table 1. In order to obtain improved spectroscopic constants for KF that can describe both the infrared and microwave data, all of the lines reported in Table 1 were fitted, together with the hyperfine-corrected microwave (1, 4) and millimeter-wave transitions (5) belonging to the first three vibrational levels. Dunham  $Y_{ij}$  coefficients, listed in Table 2, were obtained by fitting the data set to the energy level expression (23)

$$E(v, J) = \sum_{i,j} Y_{ij} \left( v + \frac{1}{2} \right)^{i} [J(J+1)]^{j}.$$

The customary spectroscopic constants for the  $X^{1}\Sigma^{+}$  ground state of KF are given in Table 3. From the  $Y_{01}$  equilibrium constant, the equilibrium internuclear separation  $r_{\rm e} = 2.1714558(2)$  Å was calculated.

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