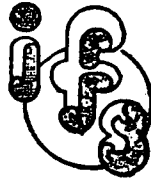


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INSTITUTE OF FUNDAMENTAL STUDIES

KANDY SCHOOL OF SCIENCE

NATIONAL INSTRUMENTATION WORKSHOP

ON

**SPECTROSCOPY**

**13-21 January 1991**

at the IFS Auditorium, Kandy

The Institute of Fundamental Studies  
Hantana Road  
Kandy

122

0122

Tel. 08-32002

A 0 1 2 2

## LIST OF PARTICIPANTS

Name	Organization
S.M.S. Samarakoon	Soil and Foliar Analytical Lab, Galle. Tel: 09-22324
M.A. Wijedasa	Soil and Foliar Analytical Lab, Galle: Tel: 09-22324
G.K.R. Senadeera	Dept. of Physics, University of Peradeniya. Tel: 08-88693
K.P.N. Jinadasa	Dept. of Geology, University of Peradeniya. Tel: 08-88301
V. Pahawattaarachchi	National Aquatic Resources Agency, Colombo.

### List of IFS participants

J.M.S. Bandara	Photo chemistry
D. Withana	Ecology
U.S. Ketapearachchi	Solar Energy
V. Manoharan	Iron Toxicity
S. Ramanayake	Biotechnology
R.A.P. Rupasinghe	Gems
M.J.S.J. Suriyajeewan	Superconductivity
M.F. Mohamed	Winged Bean
B. Nadaraja	Pesticides
D. Subasinghe	Phosphate

**Participants: - Waiting List**

C.T.K. Tilakaratna	Photochemistry
K.A. Sri Krishnaraj	Malaria
S.J.K. Gamage	Gems
W.C.B. Kiridena	Photochemistry
D.P.J. Mendis	Photochemistry

**IFS Observers**

(This includes the five members on the waiting list)

N. Karunasinghe  
R.B. Marasinghe  
D. Palliyaguru  
A. Pathirana  
P. Katulanda  
M. Ratnayake  
A. Priyadarshana  
N. Kangaharan  
K. Ravichandran  
S. Subanesan  
T. Krishnakumar  
P.A. Liyanarachchi  
W. Batukumara  
B.G.S. Samarawickrema

**Institute of Fundamental Studies  
Kandy School of Science  
Workshop on Spectroscopy**

**Jan 15-Jan 19, 1991**

**by**

**Professor Raj K Khanna**

**Office 332**

**Tel : 241**

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**Workshop Venue** : To be announced on each day.

**Instructor** : Professor Raj K. Khanna  
Department of Chemistry  
College Park  
University of Maryland, MD  
U.S.A.

Tel: Office: 301 454 2611  
Residence: 301 384 8798

Tlx: 650 251 8992 MCIUW  
Fax: 301 405 9357

**Office** : Room 332; Tel: Ext. 241

**Residence** : Room 105

**Office hours** : 1300 h. – 1400 h. (By appointment)

**Workshop Secretariat** : Ms. Anne George; Tel: Ext. 328

**Laboratories** : Lab. No. 120 – FTIR spectrometer  
Lab. No. 330 – UV-vis spectrometer  
Lab. No. 328 – Spectrofluorescence spectrometer

**Pre-requisites** : Undergraduate physical chemistry  
Molecular orbital theory  
Basic concepts of group theory  
Basic understanding of quantum chemistry

**Course outline** : Refer to scientific program

**Quiz** : All problem should reflect an individual effort and will be graded accordingly. While working with problems you may consult course notes and textbooks. Please do not confer each other.

**Problem Sets** : 3 problem sets

**Grading** : 60% problem sets; 40% quiz

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**Kandy School of Science - Video Unit**

**15 Jan 1991**

**0900 hr      Cosmos - A. C. Clarke**

**0920 hr      Documentary**

**Inauguration of IFS  
Laboratories**

**0930 hr      End**

**Ven: Auditorium**

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Kandy School of Science  
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### Meals

**Breakfast/ Lunch/ Dinner : Rs 16/=**

**(make reservations at the registration desk)**

### Accommodation

**Single room Rs 75/= per day**

### Important telephone numbers

Reception	0
Check-in point	333
KSS office	337
Instructor	241

Institute of Fundamental Studies  
Kandy School of Science  
**Workshop on Spectroscopy**

Jan 15-Jan 19, 1991

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**Participants 15**

**Scope**

The scope of the workshop is to provide introduction to instrumentation and experimental techniques in the investigations of the electronic, vibrational, and rotational spectra of molecules in the gaseous, liquid and solid phases.

A set of laboratory experiments will be carried out to illustrate the nature of the results, their comparisons with theoretical predictions, and possible applications in qualitative and quantitative analysis.

It is anticipated that the mornings will be reserved for lecture material followed by experimental work and data analysis in the afternoons.

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**Experiment #1: UV-vis absorption spectra of some  
conjugated chains**

**The wavelengths of the absorption maxima will be related to  
the chain lengths. The results will be analysed in the  
of simple quantum model calculations.**

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**Experiment#2 : Absorption spectrum of iodine gas**

The analysis of the band systems in the absorption will be carried out to yield the dissociation energy of the molecules. Similar results from the fluorescence spectrum will also be analysed.

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**Experiment #3: Determination of molecular structure from spectroscopic data**

**Infra red absorption spectra of CO, CO<sub>2</sub> CH<sub>4</sub> and other gases will be investigated. From the rotational structures the bond lengths will be calculated.**

**The accuracy of these results will be discussed.**

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**Experiment#4: Determination of thermodynamic quantities  
from spectroscopic data**

**Vibrational and rotational spectroscopic data on several systems will be utilised to evaluate the thermodynamic functions for the chemical species. Calculations for the equilibrium constants for some reactions will be attempted.**

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**Experiment# 5: Quantitative analysis of a mixture**

Absorption spectra of dilute solutions of o-, m- and p-cresols and their mixtures will be investigated. The extinction constants for each species will be determined. A mixture of unknown composition will be analysed for the concentration of each of the species.

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**Experiment #6: Atomic absorption spectra of H and Na**

Whereas Bohr's theory predicts the emission wavelengths for H atoms rather accurately, the quantum numbers for Na and other similar atoms are found to be non-integers.

The concept of Quantum Defect will be examined in the light of spectroscopic data on some univalent atoms.

Bohr's Theory:

$$W_n = - \frac{2\pi^2 \mu e^4}{n^2 h^2}$$

$$\tilde{\nu}_{m \rightarrow n} \text{ (cm}^{-1}\text{)} = \frac{W_m - W_n}{hc} = \frac{2\pi^2 \mu e^4}{h^3 c} \left( \frac{1}{n^2} - \frac{1}{m^2} \right) = \frac{1}{\lambda_{mn}}$$

$n, m$  are integers.  $R_H = \frac{2\pi^2 \mu e^4}{h^3 c}$ ,  $\mu = \frac{m_e m_p}{m_e + m_p}$

$h =$  Planck's Constant =  $6.626 \times 10^{-27}$  erg sec.

$e =$  electronic charge =  $4.803 \times 10^{-10}$  esu

$m_e =$  electronic mass =  $9.109 \times 10^{-28}$  g.

$m_p =$  Proton mass =  $1.6726 \times 10^{-24}$  g.

$c =$  Speed of light =  $2.998 \times 10^{10}$  cm sec<sup>-1</sup>.

$R_H = 109655.51$ .

$R_\infty = 109755.23$ .

$m = 1, \quad n = 2, 3, 4, \dots$

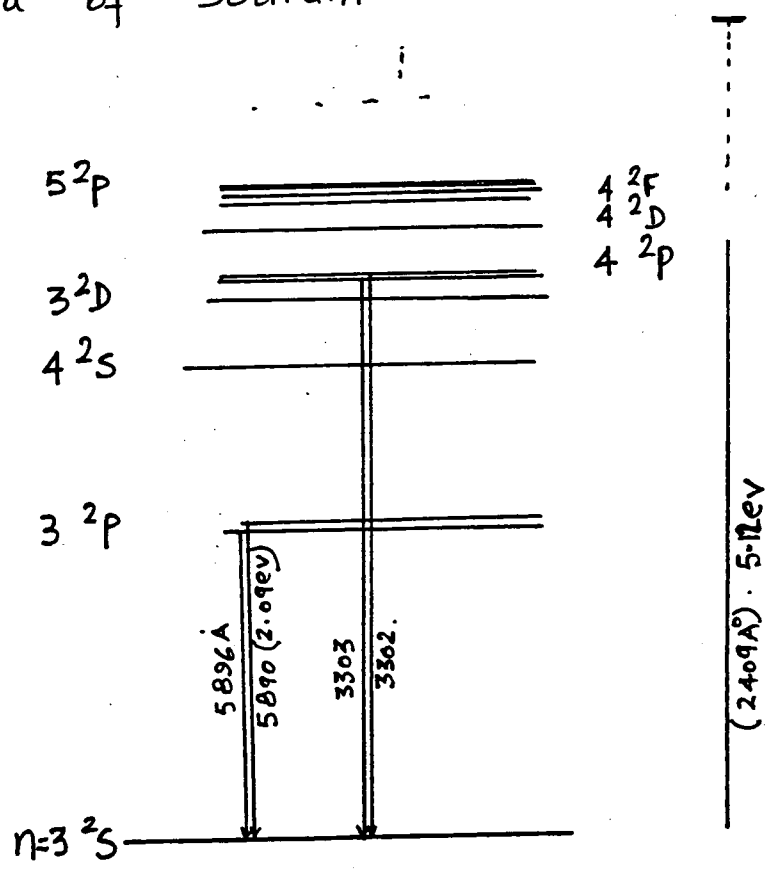
$\lambda_{12}$ (calculated)	1215.93 Å <sup>o</sup>	(Observed) 1215.
$\lambda_{13}$	1025.94	1025.
$\lambda_{14}$	972.74	972.
⋮		
$\lambda_{1\infty}$	911.95	911.

Ionization Potential =  $\frac{hc}{\lambda} = 13.61$  volts.  $\rightarrow 13.595$

$m=2$ ,  $n=3, 4, 5, \dots$

$\lambda_{23}$ (cal):	6566 A	$\lambda_{23}$ (obs)	6563 A
$\lambda_{24}$	4864 "		4861 "
$\lambda_{25}$	4343 "		4341 "
$\lambda_{26}$	4104 "		4102 "
$\lambda_{27}$	3972. "		3970. "

Spectra of Sodium.



Sodium Atom. Quantum Defect.

$$\tilde{\nu} \text{ (cm}^{-1}\text{)} = R \left[ \frac{1}{(n_1 + \mu_1)^2} - \frac{1}{(n_2 + \mu_2)^2} \right]$$

$$R = 109734 \text{ cm}^{-1}$$

Calculate  $\mu$ 's for various s, p, d, levels.

Example:

Ionization Potential 5.12 eV  $\rightarrow 2410 \text{ \AA}^0 \rightarrow 41,494 \text{ cm}^{-1}$   
 corresponds to  $n_1 = 3 [3^2S]$  to  $n_2 = \infty$

$$41,494 \text{ cm}^{-1} = 109734 \text{ cm}^{-1} \left[ \frac{1}{(3 + \mu_{3s})^2} \right]$$

Calculation for  $\mu_{3s}$  gives :

$$3 + \mu_{3s} = 1.626 \text{ or } \mu_{3s} = -1.374$$

Now take a transition  $3S \rightarrow 4P$ .  $\lambda = 3302.5 \text{ \AA}^0$

$$30,280 = 109734 \left[ \frac{1}{(1.626)^2} - \frac{1}{(n_2 + \mu_{4p})^2} \right], n_2 = 4 \Rightarrow 30,7280 \text{ cm}^{-1}$$

$$\text{This gives } 4 + \mu_{4p} = 3.127, \mu_{4p} = 0.873$$

From the data (spectral) calculate  $\mu$ 's for s, p, d, ... series  
 & tabulate. Any conclusions?

H-Table A.  $(n)_i - (n)_k$  Transitions (Average Values)

Transition	$\lambda(\text{\AA})$	$E_i(\text{cm}^{-1})$	$E_k(\text{cm}^{-1})$	$g_i$	$g_k$	$A_k(\text{sec}^{-1})$	$f_{ik}$	$S(\text{a.t.u.})$	$\log gf$	Accu- racy	Source
$n_2 - n_1$											
1-2 ( $L_\alpha$ )	1215.67	0	82259	2	8	$4.699 \times 10^8$	0.4162	3.330	-0.0797	AA	1
1-3 ( $L_\beta$ )	1025.72	0	97492	2	18	$5.575 \times 10^7$	$7.910 \times 10^{-2}$	0.5339	-0.8008	AA	1
1-4 ( $L_\gamma$ )	792.537	0	102824	2	32	$1.278 \times 10^7$	$2.899 \times 10^{-2}$	0.1855	-1.2367	AA	1
1-5 ( $L_\delta$ )	949.743	0	105292	2	50	$4.125 \times 10^6$	$1.394 \times 10^{-2}$	$8.711 \times 10^{-2}$	-1.5548	AA	1
1-6 ( $L_\epsilon$ )	937.803	0	106632	2	72	$1.644 \times 10^6$	$7.799 \times 10^{-3}$	$4.813 \times 10^{-2}$	-1.8069	AA	1
1-7	930.748	0	107440	2	98	$7.568 \times 10^5$	$4.814 \times 10^{-3}$	$2.948 \times 10^{-2}$	-2.0165	AA	1
1-8	926.226	0	107965	2	128	$3.869 \times 10^5$	$3.183 \times 10^{-3}$	$1.940 \times 10^{-2}$	-2.1961	AA	1
1-9	923.150	0	108325	2	162	$2.143 \times 10^5$	$2.216 \times 10^{-3}$	$1.346 \times 10^{-2}$	-2.3534	AA	1
1-10	920.963	0	108582	2	200	$1.263 \times 10^5$	$1.605 \times 10^{-3}$	$9.729 \times 10^{-3}$	-2.4934	AA	1
1-11	919.352	0	108772	2	242	$7.834 \times 10^4$	$1.201 \times 10^{-3}$	$7.263 \times 10^{-3}$	-2.6196	AA	1
1-12	918.129	0	108917	2	288	$5.066 \times 10^4$	$9.214 \times 10^{-4}$	$5.567 \times 10^{-3}$	-2.7345	AA	1
1-13	917.181	0	109030	2	338	$3.393 \times 10^4$	$7.227 \times 10^{-4}$	$4.362 \times 10^{-3}$	-2.8400	AA	1
1-14	916.429	0	109119	2	392	$2.341 \times 10^4$	$5.774 \times 10^{-4}$	$3.482 \times 10^{-3}$	-2.9375	AA	1
1-15	915.824	0	109191	2	450	$1.657 \times 10^4$	$4.686 \times 10^{-4}$	$2.824 \times 10^{-3}$	-3.0281	AA	1
1-16	915.329	0	109250	2	512	$1.200 \times 10^4$	$3.856 \times 10^{-4}$	$2.323 \times 10^{-3}$	-3.1129	AA	1
1-17	914.919	0	109299	2	578	8858	$3.211 \times 10^{-4}$	$1.933 \times 10^{-3}$	-3.1924	AA	1
1-18	914.576	0	109340	2	648	6654	$2.702 \times 10^{-4}$	$1.626 \times 10^{-3}$	-3.2673	AA	1
1-19	914.286	0	109375	2	722	5077	$2.296 \times 10^{-4}$	$1.381 \times 10^{-3}$	-3.3381	AA	1
1-20	914.039	0	109405	2	800	3928	$1.967 \times 10^{-4}$	$1.183 \times 10^{-3}$	-3.4052	AA	1
1-21	913.826	0	109430	2	882	3077	$1.698 \times 10^{-4}$	$1.021 \times 10^{-3}$	-3.4691	AA	1
1-22	913.641	0	109452	2	968	2438	$1.476 \times 10^{-4}$	$8.874 \times 10^{-4}$	-3.5299	AA	1
1-23	913.480	0	109471	2	1058	1952	$1.291 \times 10^{-4}$	$7.761 \times 10^{-4}$	-3.5880	AA	1
1-24	913.339	0	109488	2	1152	1578	$1.136 \times 10^{-4}$	$6.827 \times 10^{-4}$	-3.6436	AA	1
1-25	913.215	0	109503	2	1250	1286	$1.005 \times 10^{-4}$	$6.037 \times 10^{-4}$	-3.6970	AA	1
1-26	913.104	0	109517	2	1352	1057	$8.928 \times 10^{-5}$	$5.364 \times 10^{-4}$	-3.7482	AA	1
1-27	913.006	0	109528	2	1458	875.3	$7.970 \times 10^{-5}$	$4.788 \times 10^{-4}$	-3.7975	AA	1
1-28	912.918	0	109539	2	1568	729.7	$7.144 \times 10^{-5}$	$4.292 \times 10^{-4}$	-3.8450	AA	1
1-29	912.839	0	109548	2	1682	612.2	$6.429 \times 10^{-5}$	$3.862 \times 10^{-4}$	-3.8908	AA	1
1-30	912.768	0	109557	2	1800	516.7	$5.806 \times 10^{-5}$	$3.487 \times 10^{-4}$	-3.9351	AA	1
1-31	912.703	0	109565	2	1922	438.6	$5.261 \times 10^{-5}$	$3.160 \times 10^{-4}$	-3.9779	AA	1
1-32	912.645	0	109572	2	2048	374.2	$4.782 \times 10^{-5}$	$2.872 \times 10^{-4}$	-4.0193	AA	1
1-33	912.592	0	109578	2	2178	320.8	$4.360 \times 10^{-5}$	$2.618 \times 10^{-4}$	-4.0595	AA	1
1-34	912.543	0	109584	2	2312	276.3	$3.986 \times 10^{-5}$	$2.394 \times 10^{-4}$	-4.0985	AA	1
1-35	912.499	0	109589	2	2450	239.0	$3.653 \times 10^{-5}$	$2.194 \times 10^{-4}$	-4.1363	AA	1
1-36	912.458	0	109594	2	2592	207.6	$3.357 \times 10^{-5}$	$2.016 \times 10^{-4}$	-4.1730	AA	1
1-37	912.420	0	109599	2	2738	181.0	$3.092 \times 10^{-5}$	$1.856 \times 10^{-4}$	-4.2088	AA	1
1-38	912.385	0	109603	2	2888	158.4	$2.854 \times 10^{-5}$	$1.713 \times 10^{-4}$	-4.2436	AA	1
1-39	912.353	0	109607	2	3042	139.1	$2.640 \times 10^{-5}$	$1.585 \times 10^{-4}$	-4.2774	AA	1
1-40	912.324	0	109610	2	3200	122.6	$2.446 \times 10^{-5}$	$1.469 \times 10^{-4}$	-4.3105	AA	1
2-3 ( $H_\alpha$ )	6562.80	82259	97492	8	18	$4.410 \times 10^7$	0.6407	110.7	0.7098	AA	1
2-4 ( $H_\beta$ )	4861.32	82259	102824	8	32	$8.419 \times 10^6$	0.1193	15.27	-0.0202	AA	1
2-5 ( $H_\gamma$ )	4340.46	82259	105292	8	50	$2.530 \times 10^6$	$4.467 \times 10^{-2}$	5.105	-0.4469	AA	1
2-6 ( $H_\delta$ )	4101.73	82259	106632	8	72	$9.732 \times 10^5$	$2.209 \times 10^{-2}$	2.386	-0.7527	AA	1
2-7 ( $H_\epsilon$ )	3970.07	82259	107440	8	98	$4.389 \times 10^5$	$1.270 \times 10^{-2}$	1.328	-0.9929	AA	1
2-8	3889.05	82259	107965	8	128	$2.215 \times 10^5$	$8.036 \times 10^{-3}$	0.8228	-1.1919	AA	1
2-9	3835.38	82259	108325	8	162	$1.216 \times 10^5$	$5.429 \times 10^{-3}$	0.5482	-1.3622	AA	1
2-10	3797.90	82259	108582	8	200	$7.122 \times 10^4$	$3.851 \times 10^{-3}$	0.3851	-1.5114	AA	1
2-11	3770.63	82259	108772	8	242	$4.397 \times 10^4$	$2.835 \times 10^{-3}$	0.2815	-1.6443	AA	1
2-12	3750.15	82259	108917	8	288	$2.834 \times 10^4$	$2.151 \times 10^{-3}$	0.2124	-1.7643	AA	1
2-13	3734.37	82259	109030	8	338	$1.893 \times 10^4$	$1.672 \times 10^{-3}$	0.1644	-1.8737	AA	1
2-14	3721.94	82259	109119	8	392	$1.303 \times 10^4$	$1.326 \times 10^{-3}$	0.1300	-1.9743	AA	1
2-15	3711.97	82259	109191	8	450	9210	$1.070 \times 10^{-3}$	0.1046	-2.0674	AA	1
2-16	3703.85	82259	109250	8	512	6658	$8.764 \times 10^{-4}$	$8.547 \times 10^{-2}$	-2.1542	AA	1
2-17	3697.15	82259	109299	8	578	4910	$7.270 \times 10^{-4}$	$7.077 \times 10^{-2}$	-2.2354	AA	1

Numerous determinations of the oscillator strengths for the famous *D*-lines of the  $3s-3p$  doublet are available. It is surprising to find that even among the fairly recent values, differences of up to 30 percent exist (e.g., compare the multiplet oscillator strength value of 1.24 obtained from an anomalous dispersion method by Kwater [1] with a value of 0.96 obtained from a lifetime measurement by Kibble, et. al. [2]). The adopted value for the doublet is the average of the supposedly most refined versions of precise experimental and theoretical methods. Specifically it includes the results of a self-consistent field calculation including polarization effects by Biermann and Lübeck [3], a central field approximation by Prokof'ev [4], a magnetic rotation experiment by Stephenson [5], lifetime determinations with the phase-shift technique by Cunningham and Link [6], with the delayed coincidence method of Kibble, et. al. [2], and with the Hanle-effect method by Baylis [8]. An uncertainty of less than 3 percent for the averaged value is indicated by the good agreement among the various selected results.

Values for the  $3s-4p$ ,  $3s-5p$ ,  $3s-6p$ ,  $3p-4s$  and  $4s-4p$  transitions are taken solely from the calculations of Prokof'ev [4], which are considered more advanced than any of the other available approaches. (It should be noted that differences between the various methods are usually only of the order of a few percent.) For the transitions  $3s-np$ , where  $n$  runs from 7 to 18, the semi-empirical calculations of Anderson and Zilitis [9], and the *relative* anomalous dispersion measurements of Filippov and Prokof'ev [10] are available. When multiplied by a factor of 0.0134, the values of Filippov and Prokof'ev are found to agree with those of Anderson and Zilitis to within 15 percent; therefore, an average of the normalized values of Filippov and Prokof'ev and the results of Anderson and Zilitis is taken for the above transitions. The lifetime measurement of the  $4d$  level by Karstensen and Schramm [7] has been applied to the transitions  $3p-4d$  and  $4p-4d$ , together with the above-quoted calculations by Prokof'ev [4] and Anderson and Zilitis [9]. Experiment and theory (i.e., the sum of the calculated transition probabilities) agree within 6 percent. The branching ratios are based solely on the calculated results.

For all other transitions, the only available sources are the Coulomb approximation and the semi-empirical calculations of Anderson and Zilitis. Agreement between the two methods is good in general; however, the semi-empirical method of Anderson and Zilitis is considered more refined and their values are used in all cases. For the  $3p-6s$ ,  $3p-4d$  and  $3p-5d$  transitions, additional results are available from self-consistent field calculations by Chapman, et. al. [11]. These agree within a few percent with the adopted values.

### References

- [1] Kwater, G. S., Vestnik Leningrad Univ. Ser. Fiz. i Khim. No. 2, 135-141 (1947). (Translated in "Optical Transition Probabilities," Office of Technical Services, U.S. Dept. of Commerce, Washington, D.C.)
- [2] Kibble, B. P., Copley, C., and Krause, L., Phys. Rev. **153**, 9-12 (1967).
- [3] Biermann, L. and Lübeck, K., Z. Astrophys. **25**, 325-339 (1948).
- [4] Prokof'ev, V. K., Z. Physik **58**, 255-267 (1929).
- [5] Stephenson, G., Proc. Phys. Soc. London **A64**, 453-464 (1951).
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- [7] Karstensen, F., and Schramm, J., Z. Physik **195**, 370-379 (1966).
- [8] Baylis, W., Thesis Munich (1967) and to be published.
- [9] Anderson, E. M., and Zilitis, V. A., Optics and Spectroscopy (U.S.S.R.) **16**, 99-101 (1964).
- [10] Filippov, A., and Prokof'ev, V. K., Z. Physik **56**, 458-476 (1929).
- [11] Chapman, R. D., Clarke, W. H., and Aller, L. H., Astrophys. J. **144**, 376-380 (1966).

### Na I. Allowed Transitions

No.	Transition Array	Multiplet	$\lambda(\text{\AA})$	$E_i(\text{cm}^{-1})$	$E_k(\text{cm}^{-1})$	$g_i$	$g_k$	$f_{ki}(10^8 \text{ sec}^{-1})$	$f_{ik}$	S(at.u.)	log $gf$	Accuracy	Source
1	$3s-3p$	$^2S-^2P^{\circ}$ (1)	5891.8	0	16968	2	6	0.629	0.982	38.1	0.293	A	2, 3, 4, 5, 6, 8.
			5889.95	0	16973	2	4	0.630	0.655	25.4	0.117	A	ls
			5895.92	0	16956	2	2	0.628	0.327	12.7	-0.184	A	ls
2	$3s-4p$	$^2S-^2P^{\circ}$ (2)	3302.61	0	30271	2	6	0.0292	0.0142	0.311	-1.55	C+	4
			3302.37	0	30273	2	4	0.0290	0.0094	0.207	-1.73	C+	ls
			3302.98	0	30267	2	2	0.0293	0.00477	0.104	-2.021	C+	ls

Na I. Allowed Transitions—Continued



No.	Transition Array	Multiplet	$\lambda(\text{\AA})$	$E_i(\text{cm}^{-1})$	$E_k(\text{cm}^{-1})$	$g_i$	$g_k$	$A_{ki}(10^6 \text{ sec}^{-1})$	$f_{ik}$	$S(\text{at.u.})$	$\log gf$	Accuracy	Source
3	3s-5p	$^2S-^2P^o$ (1 uv)	2852.8	0	35042	2	6	0.0060	0.00221	0.0415	-2.355	C+	4
			2852.81	0	35043	2	4	0.0060	0.00147	0.0276	-2.53	C+	ls
			2853.01	0	35040	2	2	0.0060	$7.4 \times 10^{-4}$	0.0138	-2.83	C+	ls
4	3s-6p	$^2S-^2P^o$ (2 uv)	2680.4	0	37297	2	6	0.00226	$7.3 \times 10^{-4}$	0.0129	-2.84	C+	4
5	3s-7p	$^2S-^2P^o$ (3 uv)	2593.9	0	38541	2	6	0.00120	$3.61 \times 10^{-4}$	0.0062	-3.140	C+	9, 10n
6	3s-8p	$^2S-^2P^o$ (4 uv)	2543.8	0	39299	2	6	$6.6 \times 10^{-4}$	$1.92 \times 10^{-4}$	0.00322	-3.416	C+	9, 10n
7	3s-9p	$^2S-^2P^o$ (5 uv)	2512.1	0	39795	2	6	$4.05 \times 10^{-4}$	$1.15 \times 10^{-4}$	0.00190	-3.64	C+	9, 10n
8	3s-10p	$^2S-^2P^o$ (6 uv)	2490.70	0	40137	2	6	$2.76 \times 10^{-4}$	$7.7 \times 10^{-5}$	0.00126	-3.81	C+	9, 10n
9	3s-11p	$^2S-^2P^o$	[2475.5]	0	40383	2	6	$1.94 \times 10^{-4}$	$5.3 \times 10^{-5}$	$8.7 \times 10^{-4}$	-3.97	C+	9, 10n
10	3s-12p	$^2S-^2P^o$	[2464.4]	0	40566	2	6	$1.44 \times 10^{-4}$	$3.92 \times 10^{-5}$	$6.4 \times 10^{-4}$	-4.105	C+	9, 10n
11	3s-13p	$^2S-^2P^o$	[2455.9]	0	40705	2	6	$1.12 \times 10^{-4}$	$3.03 \times 10^{-5}$	$4.90 \times 10^{-4}$	-4.218	C+	9, 10n
12	3s-14p	$^2S-^2P^o$	[2449.4]	0	40814	2	6	$8.6 \times 10^{-5}$	$2.31 \times 10^{-5}$	$3.73 \times 10^{-4}$	-4.335	C+	9, 10n
13	3s-15p	$^2S-^2P^o$	[2444.2]	0	40901	2	6	$6.8 \times 10^{-5}$	$1.84 \times 10^{-5}$	$2.96 \times 10^{-4}$	-4.434	C+	9, 10n
14	3s-16p	$^2S-^2P^o$	[2440.0]	0	40971	2	6	$5.6 \times 10^{-5}$	$1.50 \times 10^{-5}$	$2.41 \times 10^{-4}$	-4.52	C+	9, 10n
15	3s-17p	$^2S-^2P^o$	[2436.6]	0	41028	2	6	$4.64 \times 10^{-5}$	$1.24 \times 10^{-5}$	$1.99 \times 10^{-4}$	-4.61	C+	9, 10n
16	3s-18p	$^2S-^2P^o$	[2433.8]	0	41076	2	6	$3.87 \times 10^{-5}$	$1.03 \times 10^{-5}$	$1.65 \times 10^{-4}$	-4.69	C+	9, 10n
17	3p-4s	$^2P^o-^2S$ (3)	11397	16968	25740	6	2	0.251	0.163	36.7	-0.010	C	4
			11403.8	16973	25740	4	2	0.167	0.163	24.5	-0.186	C	ls
			11381.5	16956	25740	2	2	0.084	0.163	12.2	-0.487	C	ls
18	3p-5s	$^2P^o-^2S$ (5)	6158.6	16968	33201	6	2	0.072	0.0137	1.67	-1.085	C	9
			6160.75	16973	33201	4	2	0.0482	0.0137	1.11	-1.261	C	ls
			6154.23	16956	33201	2	2	0.0241	0.0137	0.56	-1.56	C	ls
19	3p-6s	$^2P^o-^2S$ (8)	5151.9	16968	36373	6	2	0.0330	0.00437	0.445	-1.58	C	9
			5153.40	16973	36373	4	2	0.0220	0.00437	0.297	-1.76	C	ls
			5148.84	16956	36373	2	2	0.0110	0.00437	0.148	-2.058	C	ls
20	3p-7s	$^2P^o-^2S$ (11)	4750.6	16968	38012	6	2	0.0178	0.00201	0.189	-1.92	C	9
			4751.82	16973	38012	4	2	0.0119	0.00201	0.126	-2.095	C	ls
			4747.94	16956	38012	2	2	0.0059	0.00201	0.063	-2.396	C	ls
21	3p-8s	$^2P^o-^2S$ (14)	4544.2	16968	38969	6	2	0.0108	0.00111	0.100	-2.177	C	9
			4545.19	16973	38969	4	2	0.0072	0.00111	0.066	-2.353	C	ls
			4541.63	16956	38969	2	2	0.00359	0.00111	0.0332	-2.65	C	ls
22	3p-9s	$^2P^o-^2S$ (16)	4422.2	16968	39575	6	2	0.0070	$6.8 \times 10^{-4}$	0.060	-2.387	C	9
			4423.25	16973	39575	4	2	0.00466	$6.8 \times 10^{-4}$	0.0398	-2.56	C	ls
			4419.89	16956	39575	2	2	0.00233	$6.8 \times 10^{-4}$	0.0199	-2.86	C	ls

Na I. Allowed Transitions—Continued

No.	Transition Array	Multiplet	$\lambda(\text{\AA})$	$E_i(\text{cm}^{-1})$	$E_k(\text{cm}^{-1})$	$g_i$	$g_k$	$A_{ki}(10^8 \text{sec}^{-1})$	$f_{ik}$	S(at.u.)	log $gf$	Accuracy	Source
23	3p-10s	$^2P^{\circ}-^2S$	4343.8	16968	39983	6	2	0.00480	$4.53 \times 10^{-4}$	0.0389	-2.57	C	9
			4344.74	16973	39983	4	2	0.00320	$4.53 \times 10^{-4}$	0.0259	-2.74	C	ls
			4341.49	16956	39983	2	2	0.00160	$4.53 \times 10^{-4}$	0.0129	-3.043	C	ls
24	3p-11s	$^2P^{\circ}-^2S$	4289.5	16968	40271	6	2	0.00357	$3.28 \times 10^{-4}$	0.0278	-2.71	C	9
			4291.01	16973	40271	4	2	0.00238	$3.28 \times 10^{-4}$	0.0185	-2.88	C	ls
			4287.84	16956	40271	2	2	0.00119	$3.28 \times 10^{-4}$	0.0093	-3.183	C	ls
25	3p-12s	$^2P^{\circ}-^2S$	4251.4	16968	40482	6	2	0.00260	$2.35 \times 10^{-4}$	0.0197	-2.85	C	9
			4252.52	16973	40482	4	2	0.00173	$2.35 \times 10^{-4}$	0.0132	-3.027	C	ls
			4249.41	16956	40482	2	2	$8.7 \times 10^{-4}$	$2.35 \times 10^{-4}$	0.0066	-3.328	C	ls
26	3p-13s	$^2P^{\circ}-^2S$	4222.3	16968	40644	6	2	0.00212	$1.89 \times 10^{-4}$	0.0158	-2.95	C	9
			[4223.2]	16973	40644	4	2	0.00141	$1.89 \times 10^{-4}$	0.0105	-3.122	C	ls
			[4220.2]	16956	40644	2	2	$7.1 \times 10^{-4}$	$1.89 \times 10^{-4}$	0.0053	-3.423	C	ls
27	3p-14s	$^2P^{\circ}-^2S$	4200.1	16968	40769	6	2	0.00177	$1.56 \times 10^{-4}$	0.0129	-3.029	C	9
			[4201.0]	16973	40769	4	2	0.00118	$1.56 \times 10^{-4}$	0.0086	-3.205	C	ls
			[4198.0]	16956	40769	2	2	$5.9 \times 10^{-4}$	$1.56 \times 10^{-4}$	0.00431	-3.51	C	ls
28	3p-3d	$^2P^{\circ}-^2D$ (4)	8191.1	16968	29173	6	10	0.495	0.83	135	0.70	C	4
			8194.82	16973	29173	4	6	0.495	0.75	81	0.477	C	ls
			8183.26	16956	29173	2	4	0.413	0.83	44.7	0.220	C	ls
			8194.79	16973	29173	4	4	0.082	0.083	9.0	-0.479	C	ls
29	3p-4d	$^2P^{\circ}-^2D$ (6)	5686.4	16968	34549	6	10	0.131	0.106	11.9	-0.197	C+	4, 7
			5688.21	16973	34549	4	6	0.131	0.095	7.1	-0.420	C+	ls
			5682.63	16956	34549	2	4	0.109	0.106	3.97	-0.67	C+	ls
			5688.19	16973	34549	4	4	0.0219	0.0106	0.79	-1.373	C+	ls
30	3p-5d	$^2P^{\circ}-^2D$ (9)	4981.4	16968	37037	6	10	0.050	0.0311	3.06	-0.73	C	9
			4982.81	16973	37037	4	6	0.050	0.0280	1.84	-0.95	C	ls
			4978.54	16956	37037	2	4	0.0418	0.0311	1.02	-1.206	C	ls
			[4982.8]	16973	37037	4	4	0.0084	0.00311	0.204	-1.91	C	ls
31	3p-6d	$^2P^{\circ}-^2D$ (12)	4667.5	16968	38387	6	10	0.0257	0.0140	1.29	-1.076	C	9
			4668.56	16973	38387	4	6	0.0257	0.0126	0.77	-1.298	C	ls
			4664.81	16956	38387	2	4	0.0214	0.0140	0.430	-1.55	C	ls
			[4668.6]	16973	38387	4	4	0.00428	0.00140	0.086	-2.252	C	ls
32	3p-7d	$^2P^{\circ}-^2D$ (15)	4496.6	16968	39201	6	10	0.0151	0.0076	0.68	-1.341	C	9
			4497.66	16973	39201	4	6	0.0151	0.0069	0.406	-1.56	C	ls
			4491.18	16956	39201	2	4	0.0126	0.0076	0.225	-1.82	C	ls
			[4497.7]	16973	39201	4	4	0.00251	$7.6 \times 10^{-4}$	0.0451	-2.52	C	ls
33	3p-8d	$^2P^{\circ}-^2D$ (17)	4392.3	16968	39729	6	10	0.0097	0.00466	0.404	-1.55	C	9
			4393.34	16973	39729	4	6	0.0097	0.00419	0.242	-1.78	C	ls
			4390.03	16956	39729	2	4	0.0081	0.00466	0.135	-2.031	C	ls
			[4393.3]	16973	39729	4	4	0.00161	$4.66 \times 10^{-4}$	0.0270	-2.73	C	ls
34	3p-9d	$^2P^{\circ}-^2D$	4323.5	16968	40090	6	10	0.0066	0.00307	0.262	-1.73	C	9
			4324.62	16973	40090	4	6	0.0066	0.00276	0.157	-1.96	C	ls
			4321.40	16956	40090	2	4	0.0055	0.00307	0.087	-2.212	C	ls
			[4324.6]	16973	40090	4	4	0.00109	$3.07 \times 10^{-4}$	0.0175	-2.91	C	ls

Na I. Allowed Transitions—Continued



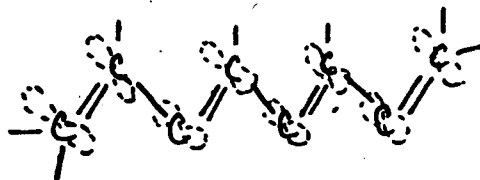
No.	Transition Array	Multiplet	$\lambda(\text{\AA})$	$E_i(\text{cm}^{-1})$	$E_k(\text{cm}^{-1})$	$g_i$	$g_k$	$A_{ki}(10^8 \text{ sec}^{-1})$	$f_{ik}$	$S(\text{at.u.})$	$\log gf$	Accu- racy	Source
35	3p-10d	$^2P^\circ - ^2D$	4275.8	16968	40349	6	10	0.00468	0.00214	0.181	-1.89	C	9
			4276.79	16973	40349	4	6	0.00469	0.00193	0.109	-2.112	C	ls
			4273.64	16956	40349	2	4	0.00391	0.00214	0.060	-2.369	C	ls
			[4276.8]	16973	40349	4	4	$7.8 \times 10^{-4}$	$2.14 \times 10^{-4}$	0.0121	-3.068	C	ls
36	3p-11d	$^2P^\circ - ^2D$	4241.1	16968	40540	6	10	0.00347	0.00156	0.131	-2.029	C	9
			4242.08	16973	40540	4	6	0.00346	0.00140	0.078	-2.252	C	ls
			4238.99	16956	40540	2	4	0.00290	0.00156	0.0435	-2.51	C	ls
			[4242.1]	16973	40540	4	4	$5.8 \times 10^{-4}$	$1.56 \times 10^{-4}$	0.0087	-3.205	C	ls
37	3p-12d	$^2P^\circ - ^2D$	4215.0	16968	40685	6	10	0.00264	0.00117	0.097	-2.154	C	9
			[4215.9]	16973	40685	4	6	0.00263	0.00105	0.058	-2.377	C	ls
			[4212.9]	16956	40685	2	4	0.00220	0.00117	0.0325	-2.63	C	ls
			[4215.9]	16973	40685	4	4	$4.39 \times 10^{-4}$	$1.17 \times 10^{-4}$	0.0065	-3.330	C	ls
38	3p-13d	$^2P^\circ - ^2D$	4195.0	16968	40798	6	10	0.00204	$9.0 \times 10^{-4}$	0.074	-2.269	C	9
			[4195.9]	16973	40798	4	6	0.00204	$8.1 \times 10^{-4}$	0.0446	-2.491	C	ls
			[4192.9]	16956	40798	2	4	0.00170	$9.0 \times 10^{-4}$	0.0248	-2.75	C	ls
			[4195.9]	16973	40798	4	4	$3.40 \times 10^{-4}$	$9.0 \times 10^{-5}$	0.00496	-3.445	C	ls
39	3d-4p	$^2D - ^2P^\circ$	91050	29173	30271	10	6	0.00157	0.117	351	0.068	C	9
			[90880]	29173	30273	6	4	0.00142	0.117	211	-0.154	C	ls
			[91380]	29173	30267	4	2	0.00156	0.098	118	-0.407	C	ls
			[90880]	29173	30273	4	4	$1.57 \times 10^{-4}$	0.0195	23.3	-1.108	C	ls
40	3d-4f	$^2D - ^2F^\circ$	18465.3	29173	34587	10	14	0.140	1.00	610	0.99	C	9
41	3d-5f	$^2D - ^2F^\circ$ (21)	12679.2	29173	37058	10	14	0.0471	0.159	66	0.201	C	9
42	3d-6f	$^2D - ^2F^\circ$ (22)	10834.9	29173	38400	10	14	0.0224	0.055	19.7	-0.257	C	9
43	3d-7f	$^2D - ^2F^\circ$ (23)	9961.28	29173	39209	10	14	0.0127	0.0264	8.7	-0.58	C	9
44	3d-8f	$^2D - ^2F^\circ$ (24)	9465.94	29173	39734	10	14	0.0079	0.0149	4.64	-0.83	C	9
45	3d-9f	$^2D - ^2F^\circ$ (25)	9153.88	29173	40094	10	14	0.0053	0.0093	2.79	-1.033	C	9
46	3d-10f	$^2D - ^2F^\circ$ (26)	8942.96	29173	40352	10	14	0.00371	0.0062	1.83	-1.206	C	9
47	3d-11f	$^2D - ^2F^\circ$ (27)	8796	29173	40539	10	14	0.00245	0.00414	1.22	-1.383	C	9
48	4s-4p	$^2S - ^2P^\circ$	22070	25740	30271	2	6	0.062	1.35	197	0.431	C	4
			22056.4	25740	30273	2	4	0.062	0.90	131	0.255	C	ls
			22083.7	25740	30267	2	2	0.062	0.450	66	-0.046	C	ls
49	4s-5p	$^2S - ^2P^\circ$ (18)	10747	25740	35042	2	6	0.0074	0.0385	2.72	-1.114	C	9
			10746.4	25740	35043	2	4	0.0074	0.0257	1.82	-1.289	C	ls
			10749.3	25740	35040	2	2	0.0074	0.0128	0.91	-1.59	C	ls
50	4s-6p	$^2S - ^2P^\circ$ (19)	8650.3	25740	37297	2	6	0.00231	0.0078	0.444	-1.81	C	9
51	4s-7p	$^2S - ^2P^\circ$ (20)	7810.0	25740	38541	2	6	0.00104	0.00284	0.146	-2.246	C	9

Na I. Allowed Transitions—Continued

No.	Transition Array	Multiplet	$\lambda(\text{\AA})$	$E_i(\text{cm}^{-1})$	$E_k(\text{cm}^{-1})$	$g_i$	$g_k$	$A_{ki}(10^8 \text{ sec}^{-1})$	$f_{ik}$	$S(\text{at.u.})$	$\log gf$	Accuracy	Source
52	4s-8p	$^2S-^2P^o$	7373.3	25740	39299	2	6	$5.6 \times 10^{-4}$	0.00136	0.066	-2.57	C	9
53	4s-9p	$^2S-^2P^o$	[7113.0]	25740	39795	2	6	$3.36 \times 10^{-4}$	$7.6 \times 10^{-4}$	0.0358	-2.82	C	9
54	4s-10p	$^2S-^2P^o$	[6944.0]	25740	40137	2	6	$2.23 \times 10^{-4}$	$4.84 \times 10^{-4}$	0.0221	-3.014	C	9
55	4s-11p	$^2S-^2P^o$	[6827.3]	25740	40383	2	6	$1.53 \times 10^{-4}$	$3.20 \times 10^{-4}$	0.0144	-3.194	C	9
56	4s-12p	$^2S-^2P^o$	[6743.1]	25740	40566	2	6	$1.11 \times 10^{-4}$	$2.27 \times 10^{-4}$	0.0101	-3.343	C	9
57	4s-13p	$^2S-^2P^o$	[6680.0]	25740	40705	2	6	$8.5 \times 10^{-5}$	$1.71 \times 10^{-4}$	0.0075	-3.466	C	9
58	4s-14p	$^2S-^2P^o$	[6632.1]	25740	40814	2	6	$6.3 \times 10^{-5}$	$1.25 \times 10^{-4}$	0.0055	-3.60	C	9
59	4p-6s	$^2P^o-^2S$	16384	30271	36373	6	2	0.0173	0.0232	7.5	-0.86	C	9
			16388.9	30273	36373	4	2	0.0115	0.0232	5.0	-1.033	C	ls
			16373.9	30267	36373	2	2	0.0058	0.0232	2.50	-1.334	C	ls
60	4p-7s	$^2P^o-^2S$	12915	30271	38012	6	2	0.0088	0.0073	1.86	-1.359	C	9
			12917.3	30273	38012	4	2	0.0058	0.0073	1.24	-1.53	C	ls
			12907.9	30267	38012	2	2	0.00292	0.0073	0.62	-1.84	C	ls
61	4p-8s	$^2P^o-^2S$	11495	30271	38968	6	2	0.0051	0.00340	0.77	-1.69	C	9
			[11498]	30273	38968	4	2	0.00343	0.00340	0.51	-1.87	C	ls
			[11490]	30267	38968	2	2	0.00172	0.00340	0.257	-2.168	C	ls
62	4p-9s	$^2P^o-^2S$	10745	30271	39575	6	2	0.00329	0.00190	0.403	-1.94	C	9
			[10747]	30273	39575	4	2	0.00219	0.00190	0.269	-2.119	C	ls
			[10741]	30267	39575	2	2	0.00110	0.00190	0.134	-2.420	C	ls
63	4p-10s	$^2P^o-^2S$	10294	30271	39983	6	2	0.00225	0.00119	0.242	-2.146	C	9
			[10296]	30273	39983	4	2	0.00150	0.00119	0.161	-2.322	C	ls
			[10290]	30267	39983	2	2	$7.5 \times 10^{-4}$	0.00119	0.081	-2.62	C	ls
64	4p-11s	$^2P^o-^2S$	9994.3	30271	40271	6	2	0.00167	$8.3 \times 10^{-4}$	0.164	-2.301	C	9
			[9996.3]	30273	40271	4	2	0.00111	$8.3 \times 10^{-4}$	0.110	-2.477	C	ls
			[9990.3]	30267	40271	2	2	$5.6 \times 10^{-4}$	$8.3 \times 10^{-4}$	0.055	-2.78	C	ls
65	4p-12s	$^2P^o-^2S$	9789.7	30271	40482	6	2	0.00120	$5.8 \times 10^{-4}$	0.112	-2.461	C	9
			[9791.6]	30273	40482	4	2	$8.0 \times 10^{-4}$	$5.8 \times 10^{-4}$	0.074	-2.64	C	ls
			[9785.9]	30267	40482	2	2	$4.02 \times 10^{-4}$	$5.8 \times 10^{-4}$	0.0372	-2.94	C	ls
66	4p-13s	$^2P^o-^2S$	9636.8	30271	40644	6	2	0.00100	$4.63 \times 10^{-4}$	0.088	-2.56	C	9
			[9638.7]	30273	40644	4	2	$6.6 \times 10^{-4}$	$4.63 \times 10^{-4}$	0.059	-2.73	C	ls
			[9633.1]	30267	40644	2	2	$3.33 \times 10^{-4}$	$4.63 \times 10^{-4}$	0.0294	-3.033	C	ls
67	4p-14s	$^2P^o-^2S$	9522.1	30271	40769	6	2	$8.5 \times 10^{-4}$	$3.87 \times 10^{-4}$	0.073	-2.63	C	9
			[9523.9]	30273	40769	4	2	$5.7 \times 10^{-4}$	$3.87 \times 10^{-4}$	0.0485	-2.81	C	ls
			[9518.5]	30267	40769	2	2	$2.85 \times 10^{-4}$	$3.87 \times 10^{-4}$	0.0243	-3.111	C	ls
68	4p-4d	$^2P^o-^2D$	23370	30271	34549	6	10	0.067	0.91	420	0.74	C+	7, 9
			23379.1	30273	34549	4	6	0.067	0.82	252	0.52	C+	ls
			23348.4	30267	34549	2	4	0.056	0.91	140	0.260	C+	ls
			[23379]	30273	34549	4	4	0.0111	0.091	28.0	-0.439	C+	ls

# Absorption Spectra of Conjugated chain Molecules.

Example :

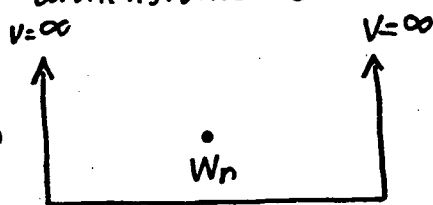


$\pi$ -electrons can be considered to be moving along the entire chain.

Model : Particle in a one-dimensional box

Assumptions: (1) chain is a st. line

(2) no interaction between electrons



Result:

$$W_n = \frac{h^2 n^2}{8mL^2}, \quad n = 1, 2, 3, \dots$$

$m$  = mass of the particle,  $L$  = chain length,  $3 \updownarrow$

$2 \updownarrow$

Consider  $N$  carbon atoms in the chain,  $L \approx Na_0$   $n=1 \updownarrow$

$$a_0 \approx \frac{d_{C-C} + d_{C=C}}{2}$$

$$\lambda_{n \rightarrow n+1} \approx \frac{W_{n+1} - W_n}{hc} = \frac{h(2n+1)}{8mN^2 a_0^2 c}$$

The  $n$  occupied levels are filled with  $2N$  electrons

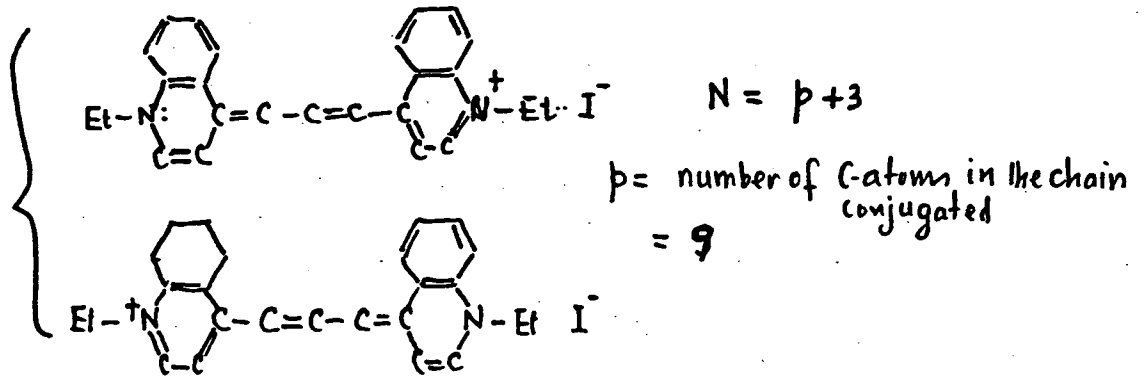
$$\lambda_{n \rightarrow n+1} \approx \frac{h(N+1)}{8mN^2 a_0^2 c}, \quad a_0 \approx 0.139 \text{ nm}$$

$$\text{or } \lambda = \frac{8mN^2 a_0^2 c}{h(N+1)} \Rightarrow 63.7 \frac{(N+1)}{N^2} \text{ in nm}$$

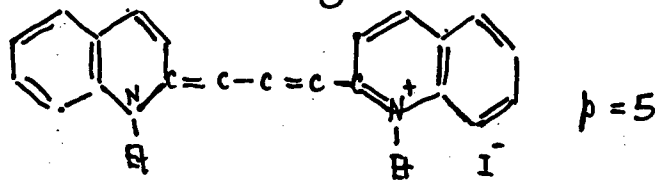
Examples.

	N	$\lambda$ (Å)
Ethylene	2	1625
Butadiene	4	2170
Hexatriene	6	2510
Octatetraene	8	3040
$\alpha$ -Carotene	20	4450
$\beta$ - "	22	4510
$\gamma$ - "	22	4600

1,1', 4,4' -dieth Carbocyanine Iodide .



1,1', 2,2' - dieth. Carbocyanine Iodide



$$\lambda = 637 \cdot \frac{(p+3+\alpha)^2}{p+4}$$

calculate  $\alpha$  for the two dyes.

$$E = \frac{A \times 10^{-2}}{m \times d}$$

~~$$E = \frac{2.800 \times 10^{-2}}{0.1 \times 1.0}$$~~

~~$$m \times d = 3.16$$~~

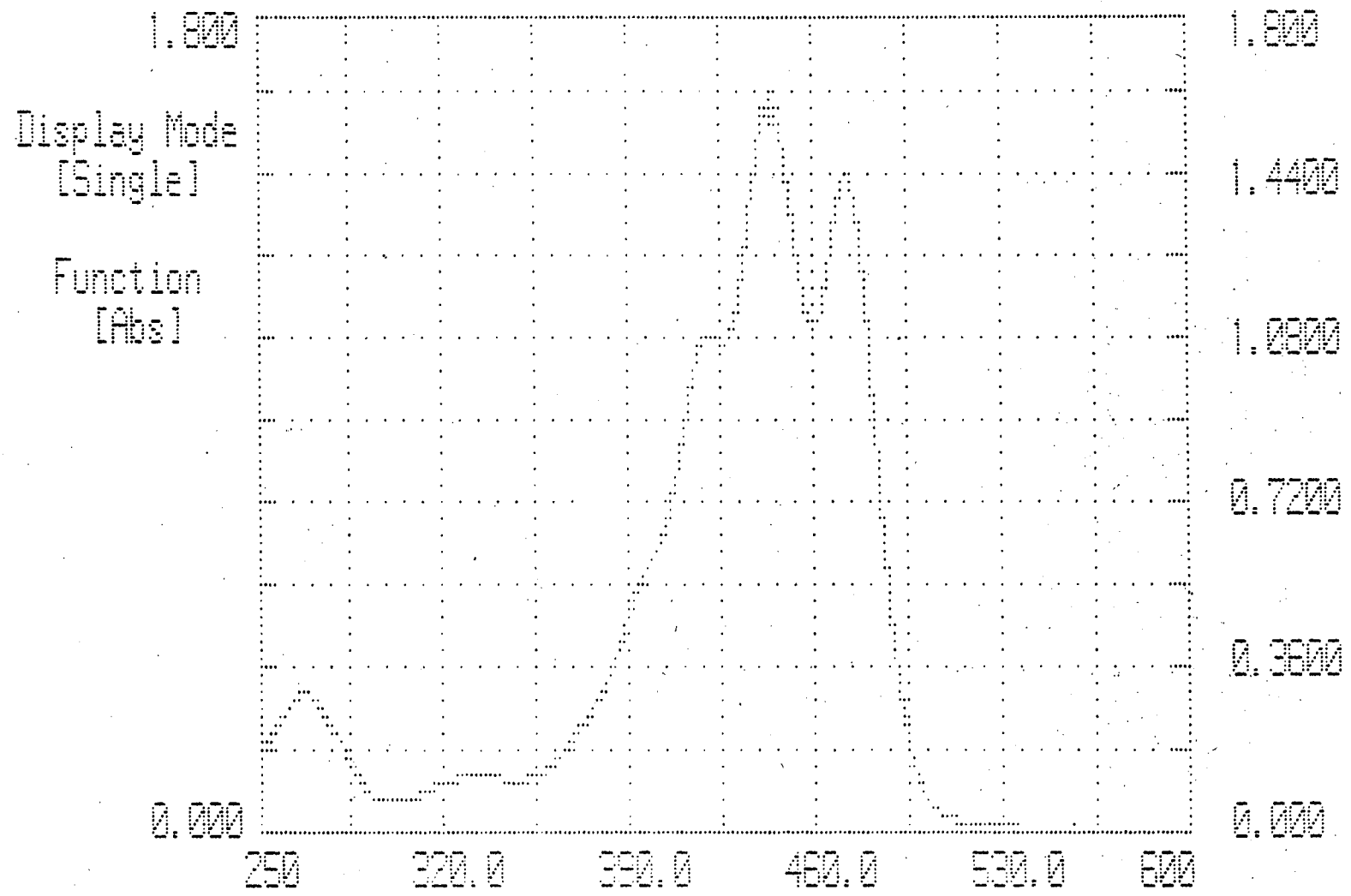
$$E = \frac{1.5997 \times 20 \times 10^{-2}}{m \times d}$$

$$= 2800$$

$$m \times d = 0.114$$

$n = 1.47$   
Solvent: Pet. ether  
Cell: 1 cm.  
Solvent: 20 mL

Scan # 01.05



600 nm/min

TRACE

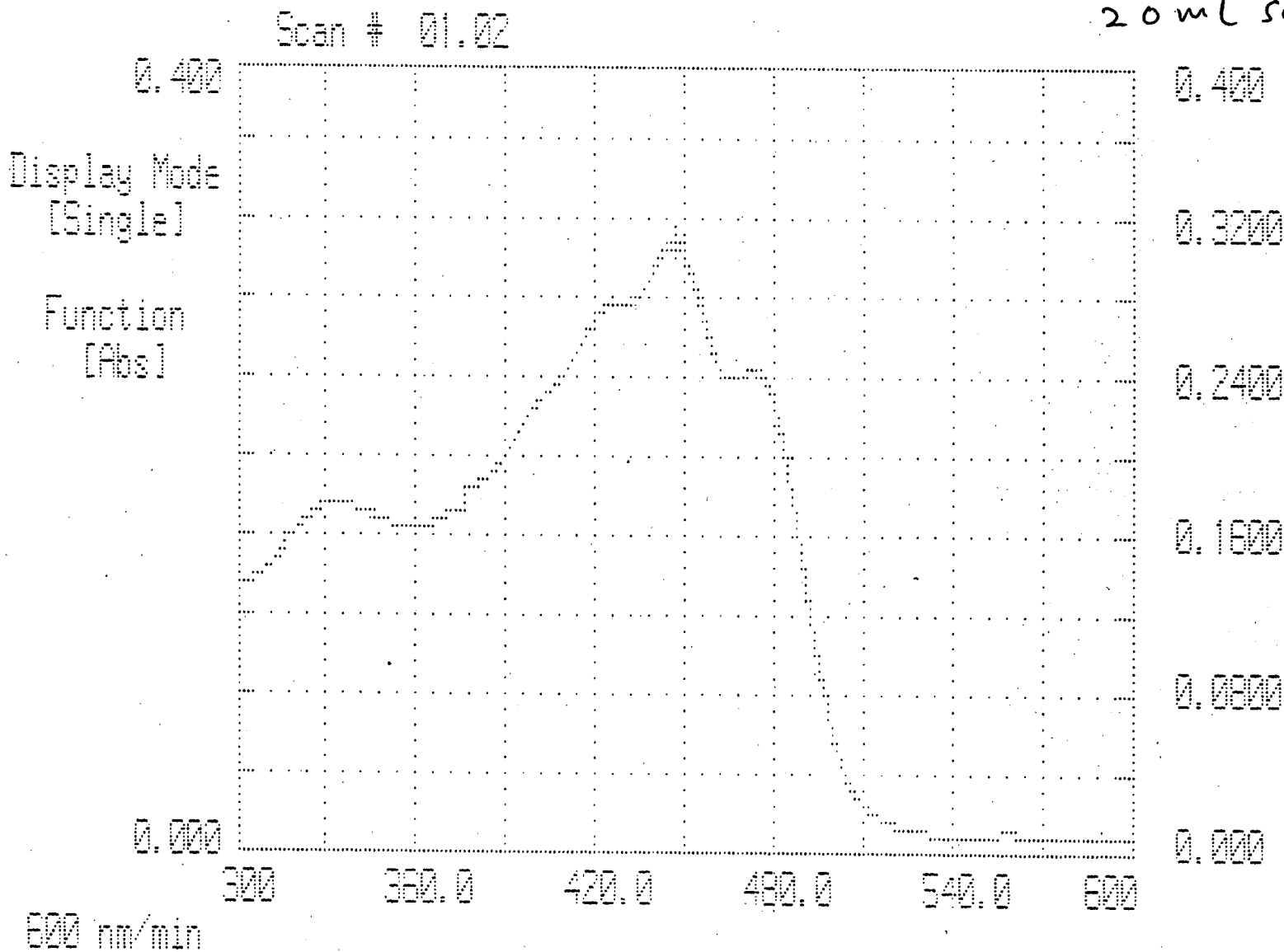
$\lambda$	ABS	SOURCE	MODE	$\lambda$	ABS
600.0	0.0074	Vis/UV	Scan	443.0	1.5997 ✓

$$E = 2592 \checkmark$$

$$= \frac{0.3087 \times 20 \times 10}{mg}$$

$$mg = \frac{0.023}{20 mL} PE$$

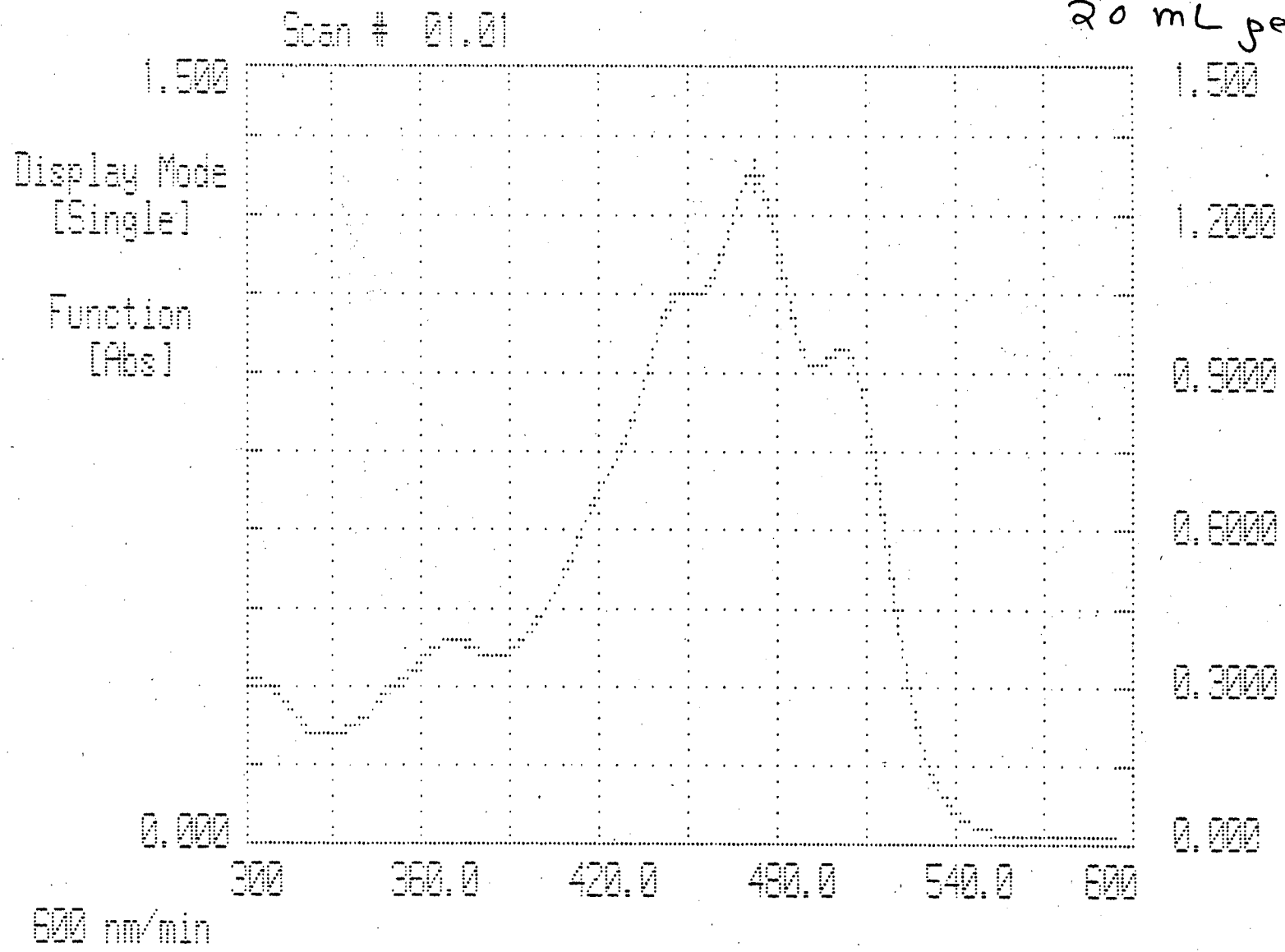
β-carotene  
 Solvent: Petroleum ether  
 Cell: 1 cm,  
 20 mL solvent



TRACE			
λ	ABS	SOURCE	MODE
600.0	0.0084	Vis/UV	Scan
445.5	0.3087 ✓		

$$E = 2891 = \frac{1.2820 \times 20 \times 10}{mg} \quad mg = 0.09$$

C45-B-carotene  
 In petroleum  
 ether  
 1cm cell,  
 20 mL pet.  
 ether

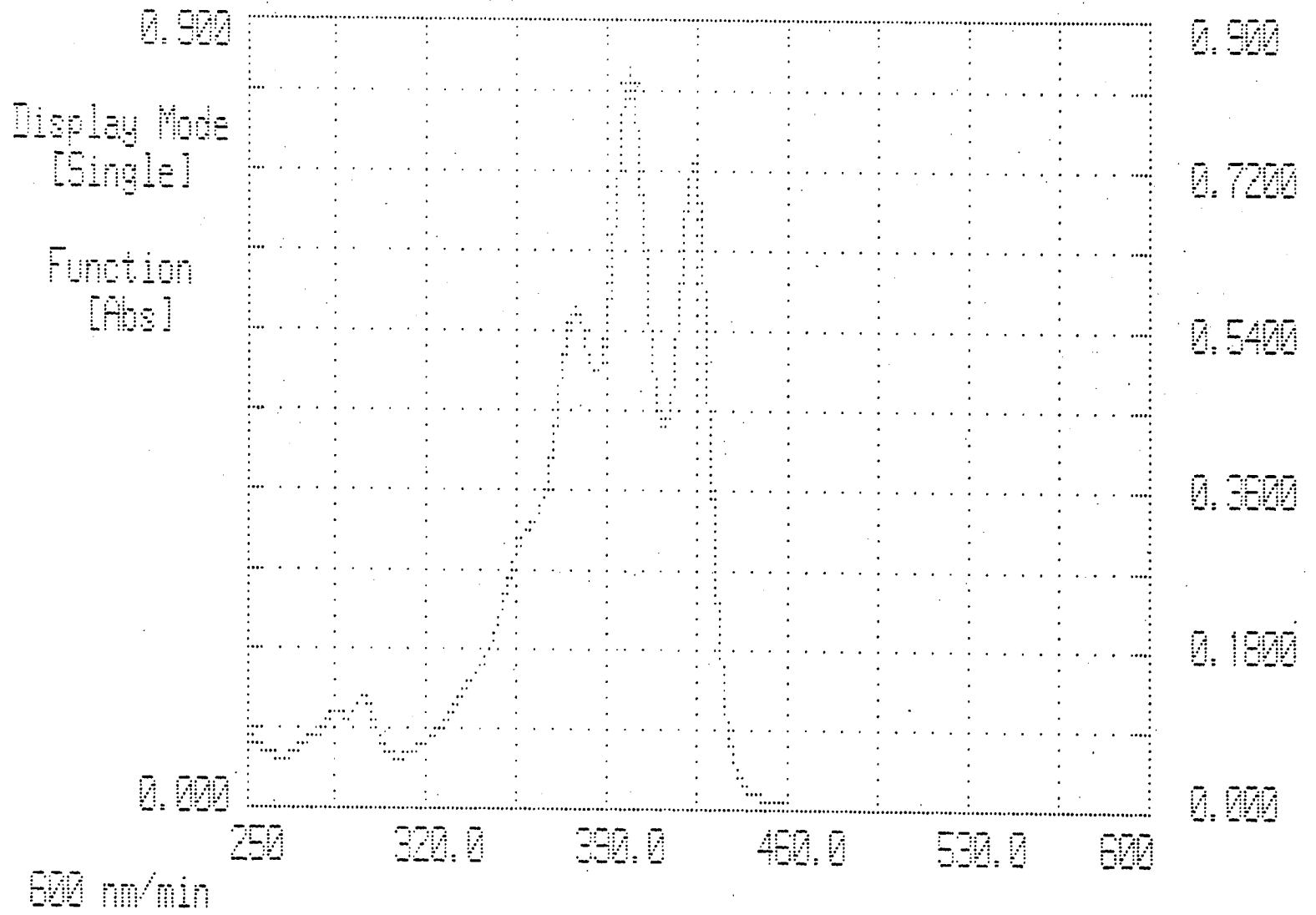


TRACE			
λ	ABS	SOURCE	MODE
600.0	0.0000	Vis/UV	Scan
471.5	1.2820		

Zeta Carotene  
In Petroleum  
ether: 2 mL.  
Cell: 1 cm.

ew

Scan # 01.01



500 nm/min

TRACE			
λ	ABS	SOURCE	MODE
600.0	-0.0001	Vis/UV	Scan
397.5	0.8254		









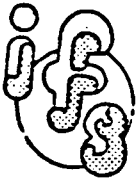








Please return this form duly filled at the reception desk.



## EVALUATION BY LECTURERS/PARTICIPANTS

Each participant is asked to grade the various aspects of this meeting as detailed below. The lowest grade is (1) and the highest grade is (10). You should kindly write your grading in the righthand column.

- |    |  | your<br>grading                                |
|----|--|--|
| 1. | The activity material was:<br>unsatisfactory (1)                 | very satisfactory (10) ..... 10                |
| 2. | The activity facilities were:<br>unsatisfactory (1)              | very satisfactory (10) ..... 3                 |
| 3. | The organization of the activity was:<br>deficient (1)           | excellent (10) ..... 6                         |
| 4. | The activity content was:<br>(a) too difficult (1)               | too low-level (10) ..... 7                     |
|    | (b) not useful (1)   | very useful (10) ..... 10                      |
| 5. | The activity leaders:<br>(a) were poorly organized (1)           | were well organized (10) ..... 10              |
|    | (b) made poor presentation (1)                                   | made excellent presentation (10) ..... 10      |
|    | (c) lectured at a very elementary level (1)                      | lectured at a too advanced level (10) ..... 10 |
| 6. | The activity co-ordinator was:<br>(a) of little help (1)         | of good help (10) ..... 6                      |
|    | (b) unable to cope with problems (1)                             | able to cope with problems (10) ..... 10       |
| 7. | The time allocated for this activity was:<br>inadequate (1)      | more than adequate (10) ..... 3                |
| 8. | I feel overall that the activity was:<br>(a) a waste of time (1) | very useful (10) ..... 7                       |
|    | (b) should not be organized again (1)                            | should be organized again (10) ..... 10        |
| 9. | Other comments about the activity:                               |  |

Please return this form duly filled at the reception desk.



## EVALUATION BY LECTURERS/PARTICIPANTS

Each participant is asked to grade the various aspects of this meeting as detailed below. The lowest grade is (1) and the highest grade is (10). You should kindly write your grading in the righthand column.

		your grading
1.	The activity material was: unsatisfactory (1)	very satisfactory (10) ..... 10
2.	The activity facilities were: unsatisfactory (1)	very satisfactory (10) ..... 10
3.	The organization of the activity was: deficient (1)	excellent (10) ..... 8
4.	The activity content was: (a) too difficult (1)	too low-level (10) ..... 5
	(b) not useful (1)	very useful (10) ..... 10
5.	The activity leaders: (a) were poorly organized (1)	were well organized (10) ..... 10
	(b) made poor presentation (1)	made excellent presentation (10) ..... 10
	(c) lectured at a very elementary level (1)	lectured at a too advanced level (10) ..... 7
6.	The activity co-ordinator was: (a) of little help (1)	of good help (10) ..... 10
	(b) unable to cope with problems (1)	able to cope with problems (10) ..... 10
7.	The time allocated for this activity was: inadequate (1)	more than adequate (10) ..... 5
8.	I feel overall that the activity was: (a) a waste of time (1)	very useful (10) ..... 10
	(b) should not be organized again (1)	should be organized again (10) ..... 10
9.	Other comments about the activity:	

