THE APPARENT ACIDIC DISSOCIATION CONSTANTS OF SOME 5-ARYLTETRAZOLES

Thesis for the Degree of M. S.

MICHIGAN STATE COLLEGE

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1955

THE APPARENT ACIDIC DISSOCIATION CONSTANTS OF SOME 5-ARYLTETRAZOLES

By

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A THESIS

Submitted to the School of Graduate Studies of Michigan State College of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Department of Chemistry

1955

ACKNOWLEDGMENT

The author wishes to express his appreciation to Doctor Robert M. Herbst for his helpful guidance and assistance throughout the performance of this work.

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ABSTRACT

The purpose of this study is to determine the apparent dissociation constants of a number of 5-aryltetrazoles with systematic variation of the position and nature of a substituent in the phenyl group.

The 5-aryltetrazoles were prepared by heating the appropriately substituted benzonitrile with a solution of acetic acid and sodium azide in n-butyl alcohol. The 5-aryltetrazoles prepared in this work were the 5-o, m and p-chlorophenyl, 5-o, m and p-bromophenyl, 5-o and p-methoxyphenyl and 5-phenyl.

Apparent dissociation constants were determined by potentiometric titration of the 5-aryltetrazole in aqueous methanolic solution with standard base. The 5-phenyltetrazoles with *para* or *meta* substituents were stronger acids than the correspondingly substituted benzoic acids, while the *ortho* substituted 5-phenyltetrazoles were slightly weaker acids than the correspondingly substituted benzoic acids. For the 5-aryltetrazoles with a substituent on the benzene ring the observed order of decreasing apparent dissociation constants is *meta* > *para* > *ortho*, but in the substituted benzoic acids the order of decreasing apparent dissociation constants is *ortho* > *meta* > *para*.

Ultraviolet absorption spectra of the 5-aryltetrazoles in 95% ethanol were determined and found to exhibit a single strong absorption band which appears in the range 240-250 mμ with the *meta* and *para* substituted compounds and at somewhat shorter wave length with the *ortho* substituted compounds.

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INTRODUCTION

Tetrazole derivatives in which the hydrogen atom attached to the ring nitrogens has not been replaced generally behave as acidic substances (1, 2, 3). The apparent acidic dissociation of the compounds may be strongly influenced by the nature of the substituent on the carbon atom in the 5-position of the ring. A large variety of 5-substituted tetrazoles have been prepared and the effects of the substituent on the apparent acidic dissociation noted.

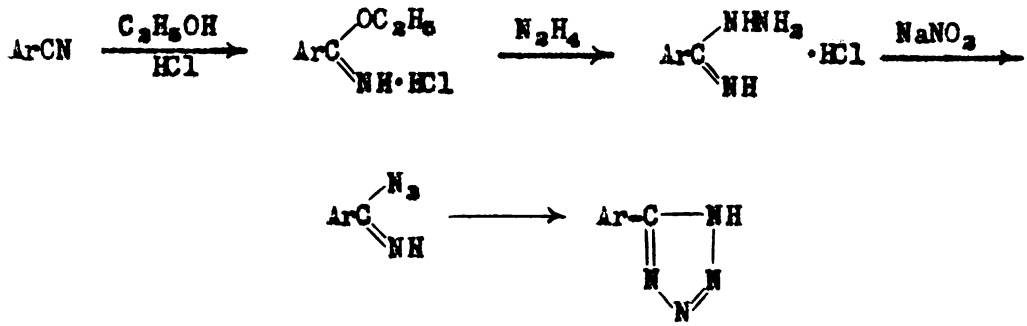
In the 5-alkyltetrazoles ($R\text{-}CN_4H$) the apparent acidic dissociation has been found to be about one-fifth to one-tenth as large as that of the corresponding aliphatic carboxylic acids (R-COOH). It has also been found that the variations in apparent acidic dissociation with the structure of the alkyl groups are generally parallel in the tetrazoles and carboxylic acids (1).

In the 5-aryltetrazoles the apparent acidic dissociation of only 5-phenyltetrazole and the 5-tolyltetrazoles had been reported (1). 5-Phenyltetrazole was shown to be a stronger acid than benzoic acid and the 5-tolyltetrazoles were stronger acids than the corresponding toluic acids. Furthermore, the apparent dissociation constants of the 5-tolyltetrazoles increased in the order ortho < para < meta while the apparent dissociation constants of the toluic acids increased in the order para < meta < ortho. These observations suggested that a study of the apparent acidity of other 5-aryltetrazoles might help to explain this behavior.

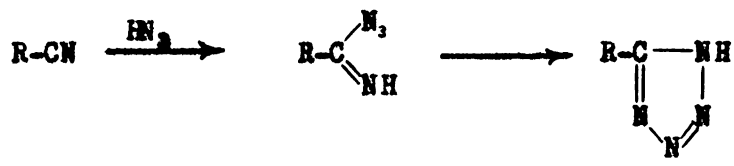
The purpose of this study is to investigate improvements in the method of synthesizing 5-aryltetrazoles, to prepare a number of 5-aryltetrazoles with systematic variation of the position and nature of a substituent in the phenyl group, and to determine the apparent dissociation constants of the new compounds. 5-Chlorophenyltetrazoles, 5-bromophenyltetrazoles and 5-methoxyphenyltetrazoles are described in this work.

DISCUSSION

Tetrazoles with a substituent in the 5 position have been synthesized from nitriles by two general procedures. Pinner (4) developed a series of reactions that have been applied extensively to aryl cyanides which involved stepwise conversion of these compounds into the imino ethers, amidrazones, imide azides and tetrazoles as illustrated schematically below.



Recently it was shown that 5-substituted tetrazoles could be prepared in a single step by heating alkyl or aryl cyanides in sealed tubes with hydrazoic acid in benzene solution (1). It was also reported that a similar reaction took place when the nitrile was heated under similar conditions in isopropyl alcohol solution with equivalent amounts of sodium azide and acetic acid.



Although the interaction of nitriles and hydrazoic acid had always been carried out in sealed tubes at 150° C (1), it was of interest to attempt a simplification of this procedure. It was felt that the reaction might proceed successfully at a somewhat lower temperature, in an open system. Further simplification could be achieved if hydrazoic acid could be liberated from sodium azide in the reaction mixture. The problem was essentially that of finding a solvent of sufficiently high boiling point in which sodium azide and a weak acid such as acetic acid would react with liberation of hydrazoic acid. Earlier work (1) had shown that alcohols might be suitable for this purpose.

In order to determine the best conditions for the reaction a study was undertaken of the preparation of 5-phenyltetrazole from benzonitrile, sodium azide and acetic acid in a series of alcohols of progressively higher boiling point. Using isopropyl alcohol, secondary butyl alcohol and n-butyl alcohol and keeping other conditions the same, it was found that the yield of 5-phenyltetrazole was 64%, 84% and 91%, respectively. Furthermore, it was noted that the crude product obtained when n-butyl alcohol was used as the solvent was less colored and of higher melting point than when other alcohols were used as solvents. Apparently the main factor influencing the yield of 5-phenyltetrazole was the boiling point of the reaction mixture when various solvents were used, as the best results were obtained at the higher temperatures.

Since this method offered the advantage of eliminating the use of sealed tubes and thus made possible the use of larger quantities of reactants, it was adapted to the synthesis of all 5-aryltetrazoles

prepared in this study. Equivalent amounts of the aryl cyanide, sodium azide and acetic acid in n-butyl alcohol were heated under reflux for six days. To compensate for possible loss of hydrazoic acid small amounts of sodium azide and acetic acid were added after four days at reflux temperature. The 5-aryltetrazoles prepared in this manner are listed in Table I. Of this group 5-phenyltetrazole, 5-o-chlorophenyltetrazole and 5-p-methoxyphenyltetrazole have been previously described. The first had been prepared by several procedures (1, 4, 5, 6); 5-o-chlorophenyltetrazole had been prepared by the deamination of 1-amino-5-o-chlorophenyltetrazole (7); 5-p-methoxyphenyltetrazole had been prepared from p-methoxybenzonitrile (8) by the series of reactions developed by Pinner. In addition to these Lossen had described a 5-bromophenyltetrazole which resulted from treatment of 5-phenyltetrazole with bromine water at elevated temperature (9), but the position of bromine substitution had not been established. Lossen's compound appears to be identical with the 5-p-bromophenyltetrazole prepared from p-bromobenzonitrile in this study.

All of the tetrazoles listed in Table I are colorless, acidic substances. The melting points follow the same general order found in substituted benzoic acids, where the <u>para</u> isomer melts considerably higher than the <u>ortho</u> isomer which in turn melts higher than the <u>meta</u> isomer. All the compounds in Table I are soluble in aqueous alkalies, alkali carbonates and bicarbonates and aqueous ammonia. 5-Phenyltetrazole and the <u>ortho</u> and <u>meta</u> substituted compounds were insoluble in cold water, slightly soluble in hot water, ether and benzene and soluble

TABLE I

5-ARYLTETRAZOLES

Substituent	M. P. °C (corr.)	Equivalent Weight	
		Calc.	Found
Phenyl	217-218	146.2	146.8
p-Chlorophenyl	262-263	180.6	180.9
m-Chlorophenyl	139-139.5	180.6	181.2
o-Chlorophenyl	179-180	180.6	181.3
p-Bromophenyl	278-279 dec.	225.1	225.2
m-Bromophenyl	154.5-155	225.1	225.6
o-Bromophenyl	183-183.5	225.1	224.8
p-Methoxyphenyl	238-238.5	176.2	176.8
o-Methoxyphenyl	158.5-159.5	176.2	176.8

in alcohols, acetone and dioxane. The para isomers were generally less soluble than the other isomers; they were only moderately soluble in alcohols and acetone and practically insoluble in dioxane.

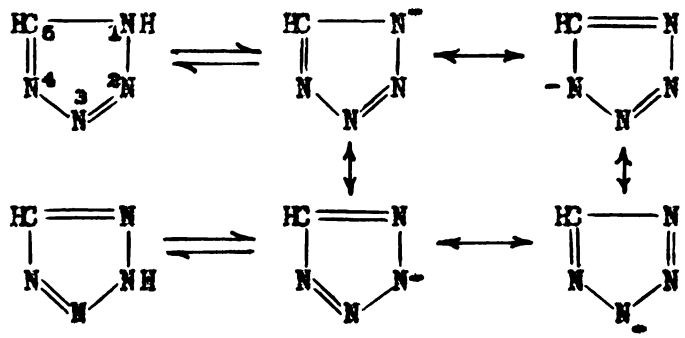
The nitriles used as intermediates for the tetrazole syntheses which were not commercially available were prepared from the acids by way of the acid chlorides and amides. Dehydration of the amides to the nitriles was accomplished smoothly and in very good yields by treatment with phosphorus oxychloride in the presence of sodium metabisulfite (10).

All of the 5-aryltetrazoles form silver salts when silver nitrate in aqueous alcohol is added to a hot solution of the tetrazole in aqueous alcohol. The salts are not light sensitive but decompose with a flash when heated on a spatula. A method of analysis of the silver salts of 5-alkylaminotetrazoles has been reported (11) in which the salts are dissolved by digesting in hot concentrated nitric acid, diluted with water and the silver ion titrated by the Volhard method. An attempt was made to apply this method to 5-aryltetrazoles, however the silver salts could not be dissolved by digesting in nitric acid.

Attempts were made to prepare characteristic crystalline salts with benzylamine, ethylenediamine, 2-aminopyridine, piperidine and n-hexylamine. The salts were formed by addition of an alcoholic solution of the amine to an ether-alcohol solution of the 5-aryltetrazole. However, the salts did not lend themselves to characterization of the tetrazoles since well defined crystals could not be obtained and the compounds did not possess sharp melting points.

Apparent acidic dissociation constants (Table II) and neutralization equivalents (Table I) of all the 5-aryltetrazoles were determined potentiometrically in 50% or 75% aqueous methanol. All the titration curves were typical of a weak acid titrated with a strong base. The phenyl group causes an increase in the acid strength of 5-phenyltetrazole as compared with tetrazole, while with benzoic acid a decrease as compared with formic acid is observed. The 5-phenyltetrazoles with <u>para</u> and <u>meta</u> substituents were stronger acids than the correspondingly substituted benzoic acids while the <u>ortho</u> substituted 5-aryltetrazoles were slightly weaker acids than the correspondingly substituted benzoic acids.

The acidity of tetrazole itself may be explained on the basis of resonance stabilization of the anion by virtue of the increased symmetry and number of the forms contributing to the resonance hybrid of the anion as compared with the unionized molecule.



(I)

It has been suggested that tetrazole and its 5-substituted derivatives R-CN_4H may be considered comparable to the carboxylic acids R-COOH (1). In such derivatives the tetrazole anion offers a greater

TABLE II

APPARENT DISSOCIATION CONSTANTS OF 5-ARYLTETRAZOLES AND THE CORRESPONDING CARBOXYLIC ACIDS[a]

R	R-CN_4H K x 10^6	R-COOH K x 10^6
C_6H_5	29 13[d]	8.0
o-$CH_3C_6H_4$	15.2[b]	9.33[b]
m-$CH_3C_6H_4$	20.0[b]	4.27[b]
p-$CH_3C_6H_4$	15.2[b]	3.55[b]
o-ClC_6H_4	57 25[d]	70.8[c]
m-ClC_6H_4	87	14.5[c]
p-ClC_6H_4	32[d]	10.0[c]
o-BrC_6H_4	60	70.8[c]
m-BrC_6H_4	92 42[d]	13.5[c]
p-BrC_6H_4	30[d]	9.33[c]
o-$CH_3OC_6H_4$	1.2	6.5
p-$CH_3OC_6H_4$	14	2.8

a) Determined in 50% (vol.) methanol at 25°C unless otherwise noted.
b) Reference 13.
c) Determined at 18-22°C, Reference 14.
d) Determined in 75% (vol.) methanol.

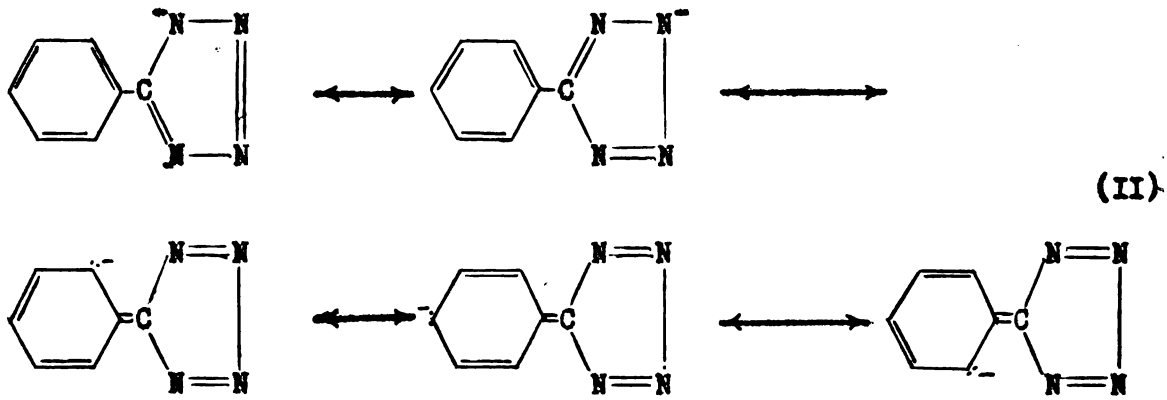
number of resonance forms than the carboxylate ion. If resonance alone is considered this might cause one to predict a greater stability for the tetrazole anion as compared with the carboxylate anion, which would suggest that the tetrazoles should be stronger acids than the carboxylic acids. However, since tetrazole and its 5-alkyl derivatives are generally weaker acids than the carboxylic acids some factor other than resonance considerations must exert a determining influence. It is likely that the greater electronegativity of oxygen as compared with nitrogen is the controlling factor in determining the relative acidity of the two types of acids.

Similar substituents attached to the tetrazole group or the carboxyl group should have similar effects on the acidic dissociation of these groups. Any group that increases the proton affinity of the tetrazole group or the carboxyl group should cause a similar decrease in the acidity of both types of compounds as compared with the parent substances, tetrazole and formic acid. Conversely, groups that decrease the proton affinity should cause an increase in acid strength of the tetrazole or carboxylic acid.

It has been observed in the case of 5-alkyltetrazoles that the apparent acidic dissociation constant is smaller than that of the unsubstituted ring system (1). The decrease in acidity is generally parallel to the decrease in acidity of the alkyl carboxylic acids as compared to formic acid. In these cases the alkyl groups, through the operation of an inductive effect which causes an increase in the proton affinity

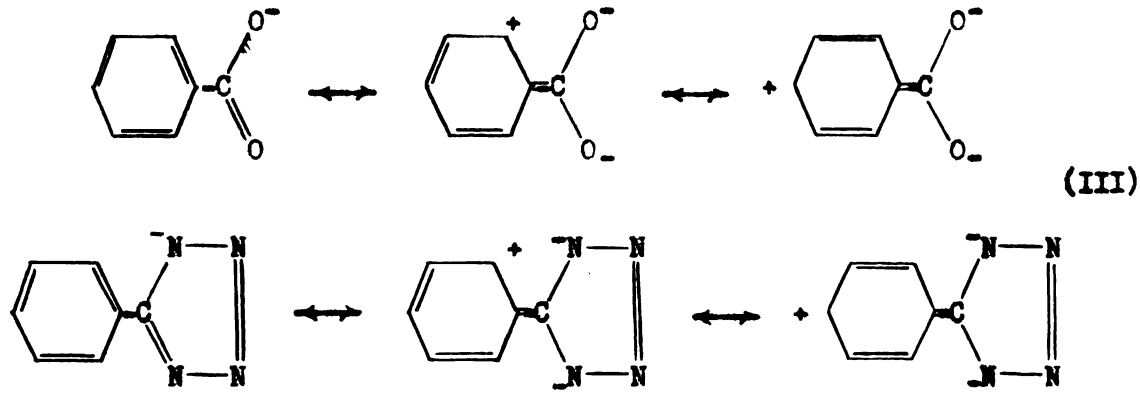
of the tetrazole ring or carboxyl group, cause a significant decrease in the apparent acidity as compared with the unsubstituted compounds.

In the case of the 5-aryltetrazoles the resonance of the tetrazole anion may be supplemented by the resonance contribution of the benzene ring. In addition to the forms indicated before (I) for the parent substance, resonance forms of the following types may also contribute to the hybrid of the 5-phenyltetrazole anion.



(II)

The increase in the number of resonance forms contributing to the hybrid and the resulting lessening of the proton affinity of the tetrazole nucleus would be reflected in a higher degree of acidity. For benzoic acid no resonance forms such as (II) can be drawn. Resonance forms of the benzoate ion involving interaction of the benzene ring and the carboxylate group require a charge separation (III). Similar resonance forms with charge separation may also be written for the 5-phenyltetrazole anion.



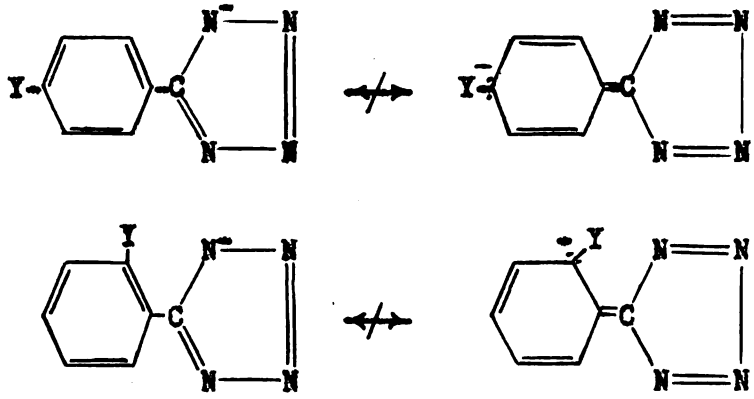
(III)

Since the resonance isomers in (III) involve a charge separation it is not likely that such forms will contribute significantly to the stabilization of the anions. The inability of the phenyl group to supplement the resonance of the benzoate ion in the same way in which it supplements the resonance of the 5-phenyltetrazole anion may be responsible for the observed difference in apparent acid strength of the two types of compounds.

The introduction of substituents onto the benzene ring of 5-phenyltetrazole produces a change in the apparent acidic dissociation constants as noted in Table II. The electronegative bromo and chloro groups increase the apparent dissociation as compared to the parent compound and the electropositive methyl group decreases the apparent dissociation. This is what one would expect from a consideration of the inductive or field effects produced by these substituent groups. However, from this point of view the decrease in apparent dissociation of the methoxyl substituted compounds is not compatible with the slight electronegative character of the group.

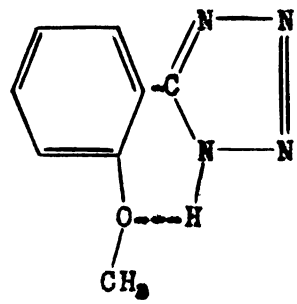
The position of the group on the benzene ring should influence the magnitude of the inductive effect so that the group nearest to the tetrazole ring should exert the strongest influence on the apparent dissociation. This should produce an order of apparent acidic dissociation of ortho > meta > para with electronegative substituents and the opposite order with electropositive substituents. In the 5-aryltetrazoles the observed order of increasing apparent dissociation is meta > para > ortho. This observed order indicates that factors other than the inductive or field effect are also influencing the apparent dissociation of the 5-aryltetrazoles. From a consideration of the resonance forms indicated in II the presence of a substituent in the ortho or para positions may influence the contribution of such forms. The electropositive methyl group would oppose the formation of an unshared pair of electrons on the carbon atom to which the group is attached. Although electronegative, the chloro, bromo and methoxyl group would also oppose the development of an unshared pair of electrons on the carbon atom to which the group is attached due to the repulsion of the electron pair by the outer electrons of the substituent group. This would result in a decrease in apparent acidic dissociation or ortho and para isomers due to the lessening of the contribution of such forms to the resonance hybrid. Another factor which may influence the apparent dissociation of the ortho substituted 5-aryltetrazoles is the bulk of the group or the repulsive force of the group which may oppose the attainment of a coplanar configuration of the benzene and tetrazole

rings. Since a coplanar configuration is necessary for resonance contributions as in II the apparent dissociation would be decreased.



(IV)

The inductive effect and field effect of the methoxyl group in the ortho or para positions would be opposed by the decrease in resonance contribution as indicated in IV. Although the over-all decrease in the apparent dissociation constants of the methoxyphenyltetrazoles may be explained in this way, the large difference between the ortho and para methoxy derivatives must be due to some other factor. The small dissociation constant of 5-o-methoxyphenyltetrazole as compared to that of the para isomer may be due to hydrogen bonding between the methoxyl oxygen and the acidic hydrogen of the tetrazole ring (V).



(V)

In the undissociated forms of the 5-substituted tetrazoles the acidic hydrogen is held at a relatively fixed angle in positions 1 or 2 due to the rigidity of the tetrazole ring structure. When the acidic hydrogen is located at the 1 position the rigidity of the ring would hold the hydrogen in a position favorable for hydrogen bonding with a substituent in the ortho position of a phenyl group at the 5-position of the tetrazole ring. Such hydrogen bonding, as shown in V, would increase the stability of the undissociated molecule and thus decrease the apparent dissociation constant of the compound.

The ultraviolet absorption spectra of the 5-aryltetrazoles do not show the same absorption peaks as either of the parent compounds benzene or tetrazole, as seen from Table III or Figures 1 to 10, The interaction of the phenyl group with the tetrazole ring produces a new chromophore that shows a single absorption band with a maximum at 241 mμ. The absorption spectrum for 5-phenyltetrazole obtained here is identical with that reported by Elpern and Nachod (12).

A bromo or chloro group introduced in the para position of 5-phenyltetrazole produces a shift of the absorption band to longer wave lengths and an increase in the extinction coefficient while the same groups in the meta position produce a slight shift of the absorption band to longer wave lengths but a decrease in the extinction coefficient. When a chloro group is in the ortho position the absorption band is shifted to shorter wave lengths and the absorption coefficient is decreased; a bromo group in the ortho position shifts the absorption peak to still shorter wave lengths, below 220 mμ. This hypsochromic shift produced

TABLE III

WAVE LENGTHS OF MAXIMA AND EXTINCTION COEFFICIENTS
OF TETRAZOLE AND 5-ARYLTETRAZOLES

Compound	Maxima (mμ)	Extinction Coefficient
Tetrazole	257 228	14,000 21,700
5-Phenyltetrazole	241	15,900
5-p-Chlorophenyltetrazole	247	20,400
5-m-Chlorophenyltetrazole	242	14,000
5-o-Chlorophenyltetrazole	234	9,600
5-p-Bromophenyltetrazole	251	21,200
5-m-Bromophenyltetrazole	243	13,300
5-o-Bromophenyltetrazole	220	----
5-p-Methoxyphenyltetrazole	259	16,900
5-o-Methoxyphenyltetrazole	294 246	4,900 11,600

by the ortho halogens may be due to interference with the ease with which the two rings attain coplanarity and the resulting disturbance of the resonance interaction of the phenyl and tetrazole rings. The shift in absorption peak in the ortho bromo compound of more than 21 mμ while the chloro compound produces a shift of only 7 mμ may be due to the difference in size of the two groups.

The methoxyl group in the para position produces a large shift of the absorption band to longer wave lengths and a small increase in extinction coefficient. In the case of the ortho methoxy isomer a second absorption band appears with a maxima at 294 mμ and an extinction coefficient of 4,900. The strong band at 246 mμ probably corresponds to the main band observed in the other compounds. The appearance of the second absorption band at 294 mμ may indicate hydrogen bonding as shown in V.

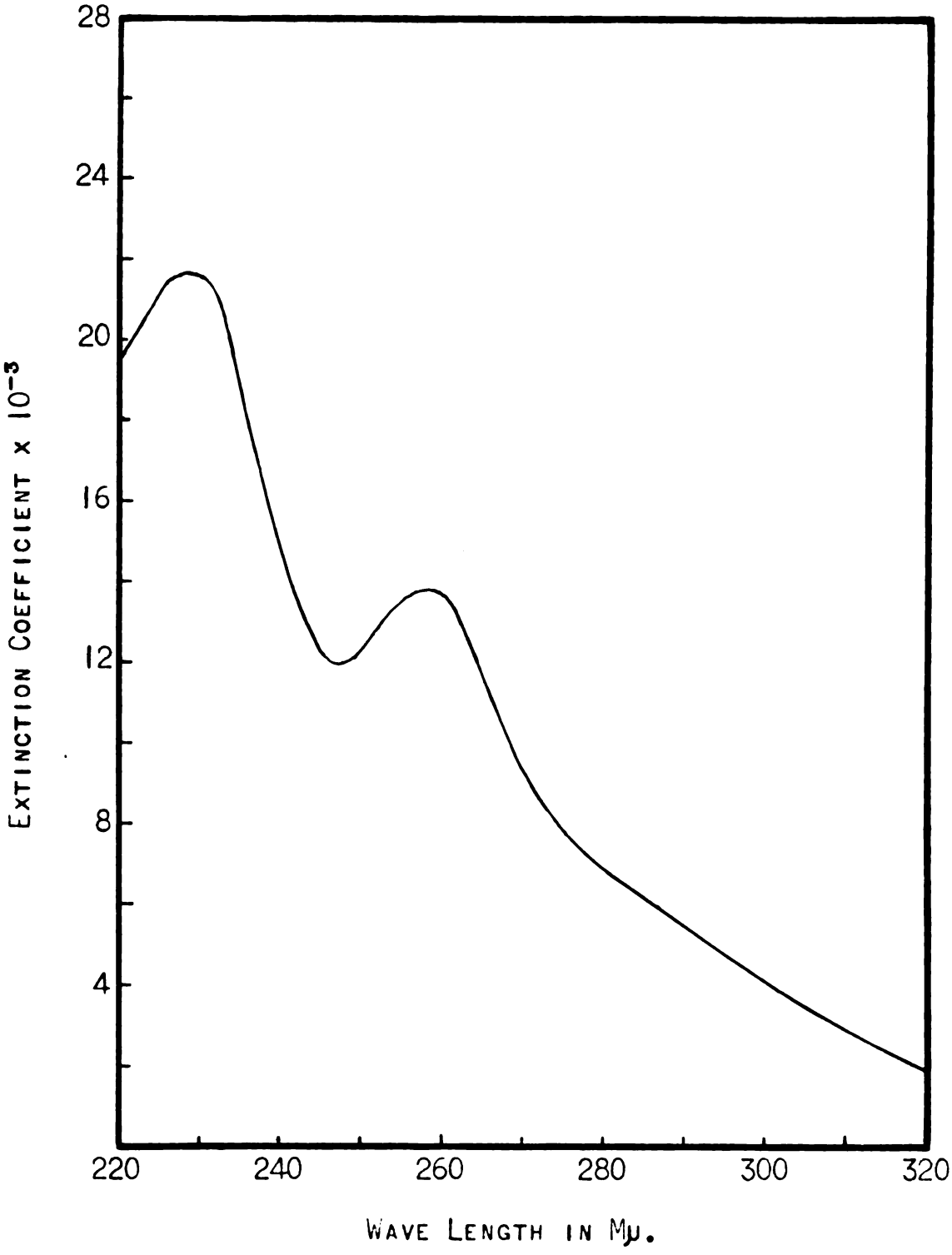


FIGURE 1. ULTRAVIOLET ABSORPTION SPECTRUM OF TETRAZOLE

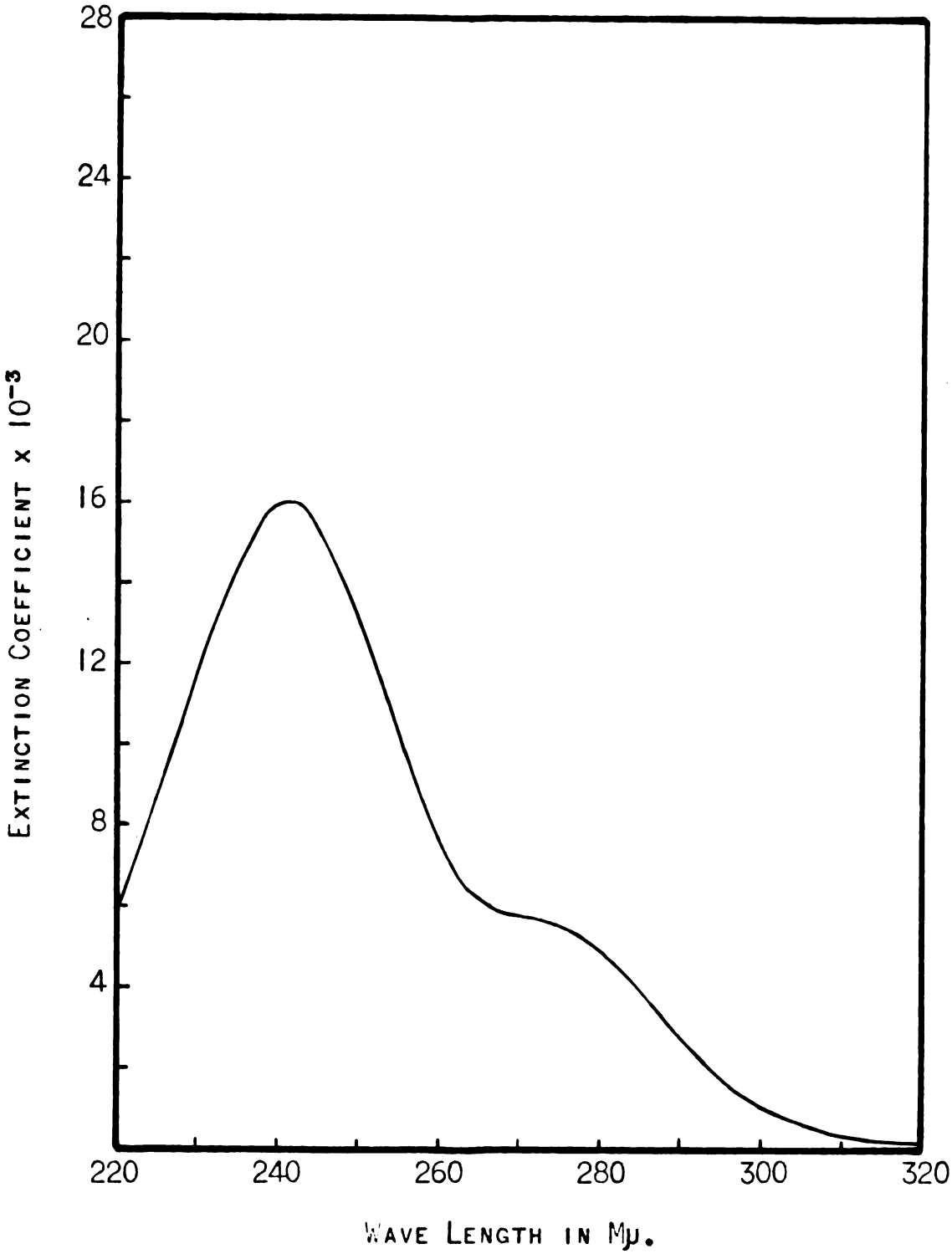


FIGURE 2. ULTRAVIOLET ABSORPTION SPECTRUM OF 5-PHENYLTETRAZOLE

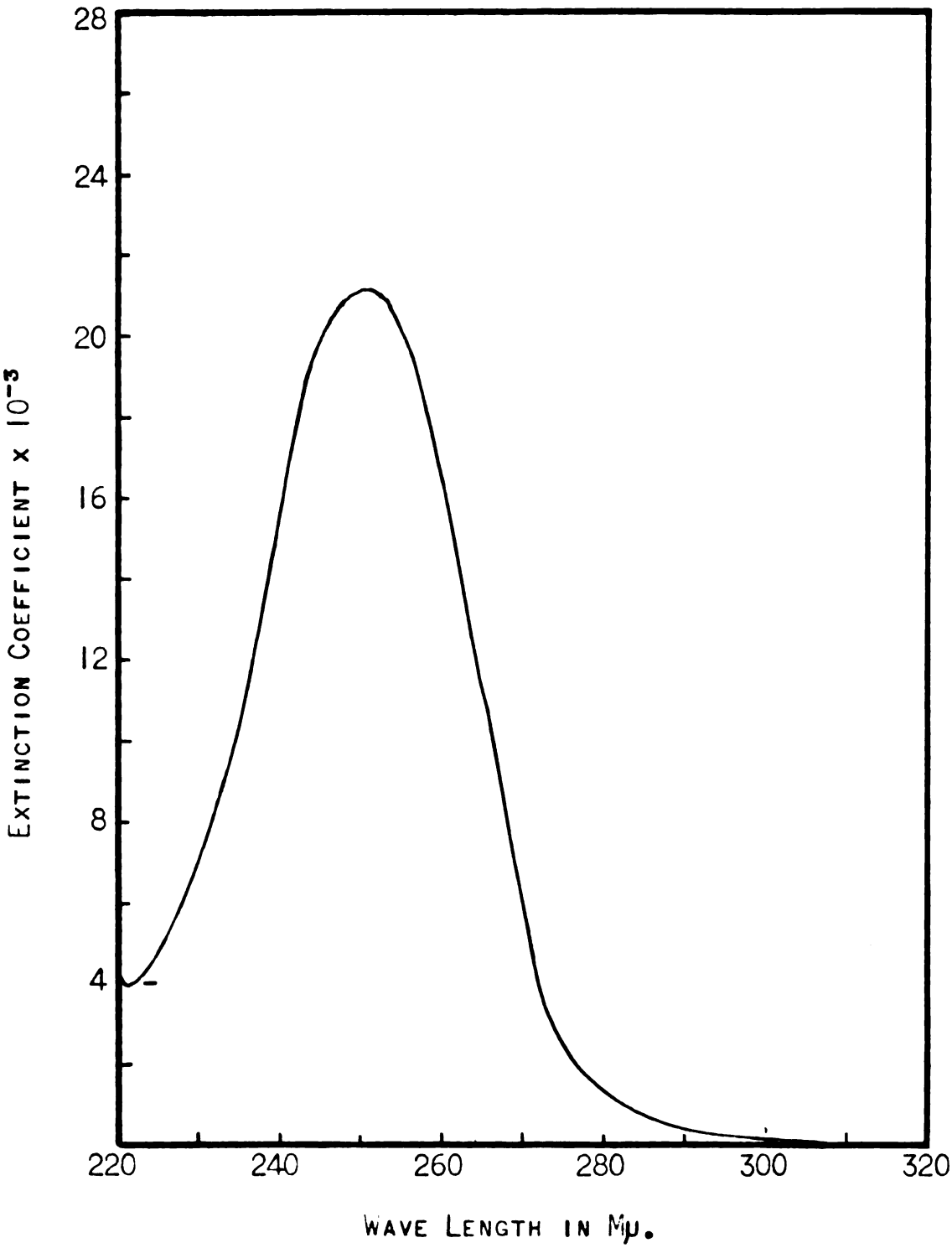


FIGURE 3. ULTRAVIOLET ABSORPTION SPECTRUM OF 5-P-BROMOPHENYLTETRAZOLE

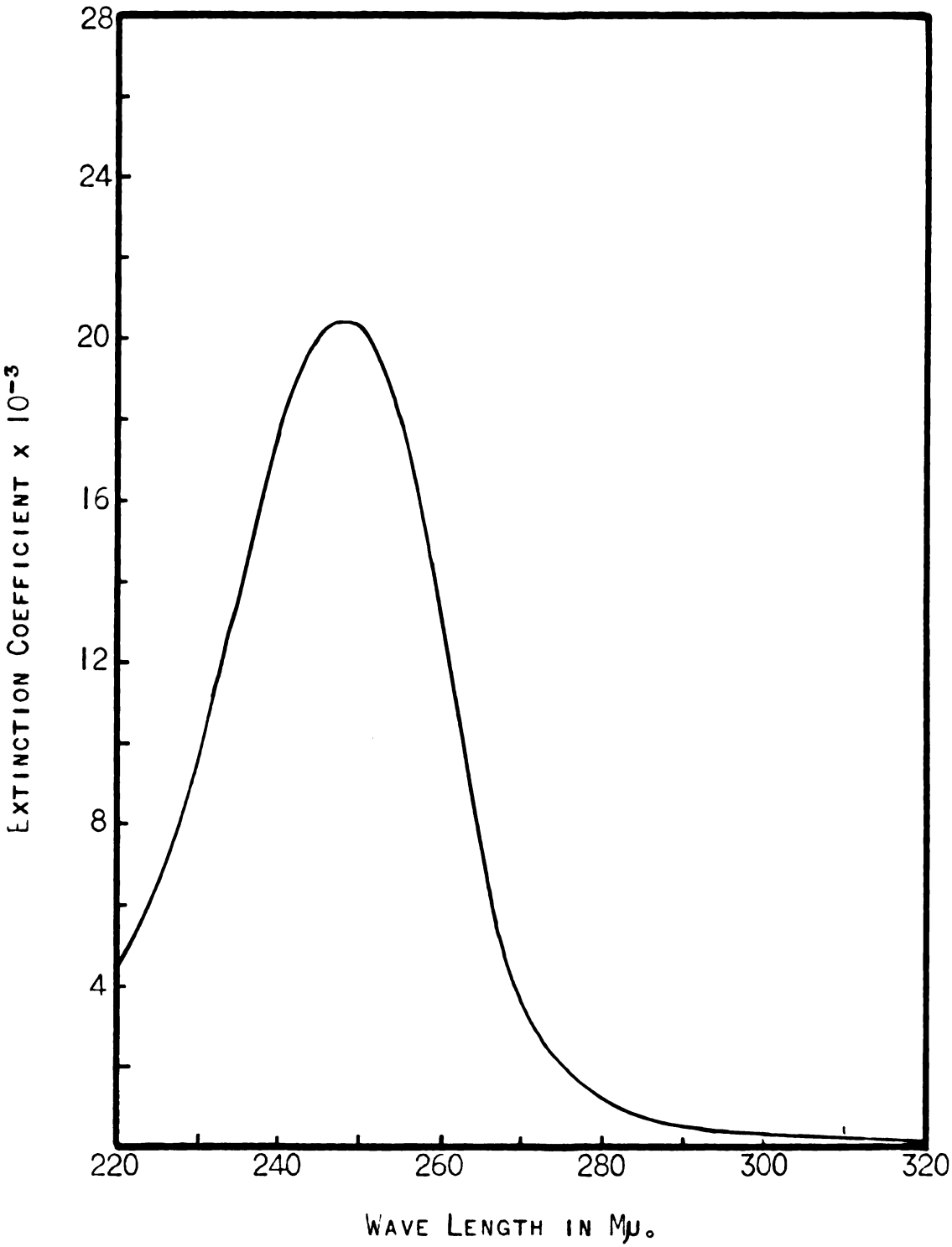


FIGURE 4. ULTRAVIOLET ABSORPTION SPECTRUM OF 5-P-CHLOROPHENYLTETRAZOLE

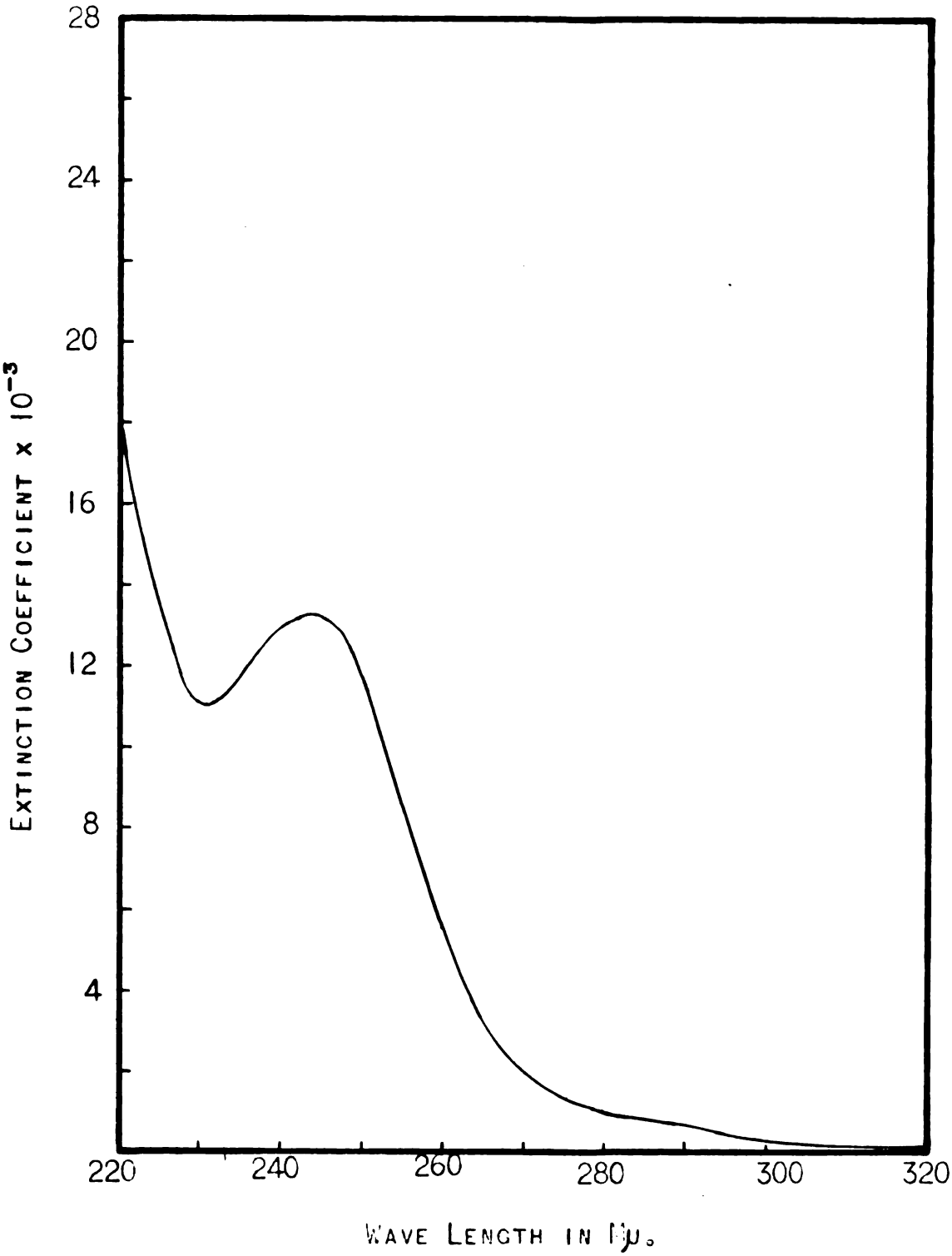


FIGURE 5. ULTRAVIOLET ABSORPTION SPECTRUM OF 5-m-BROMOPHENYLTETRAZOLE

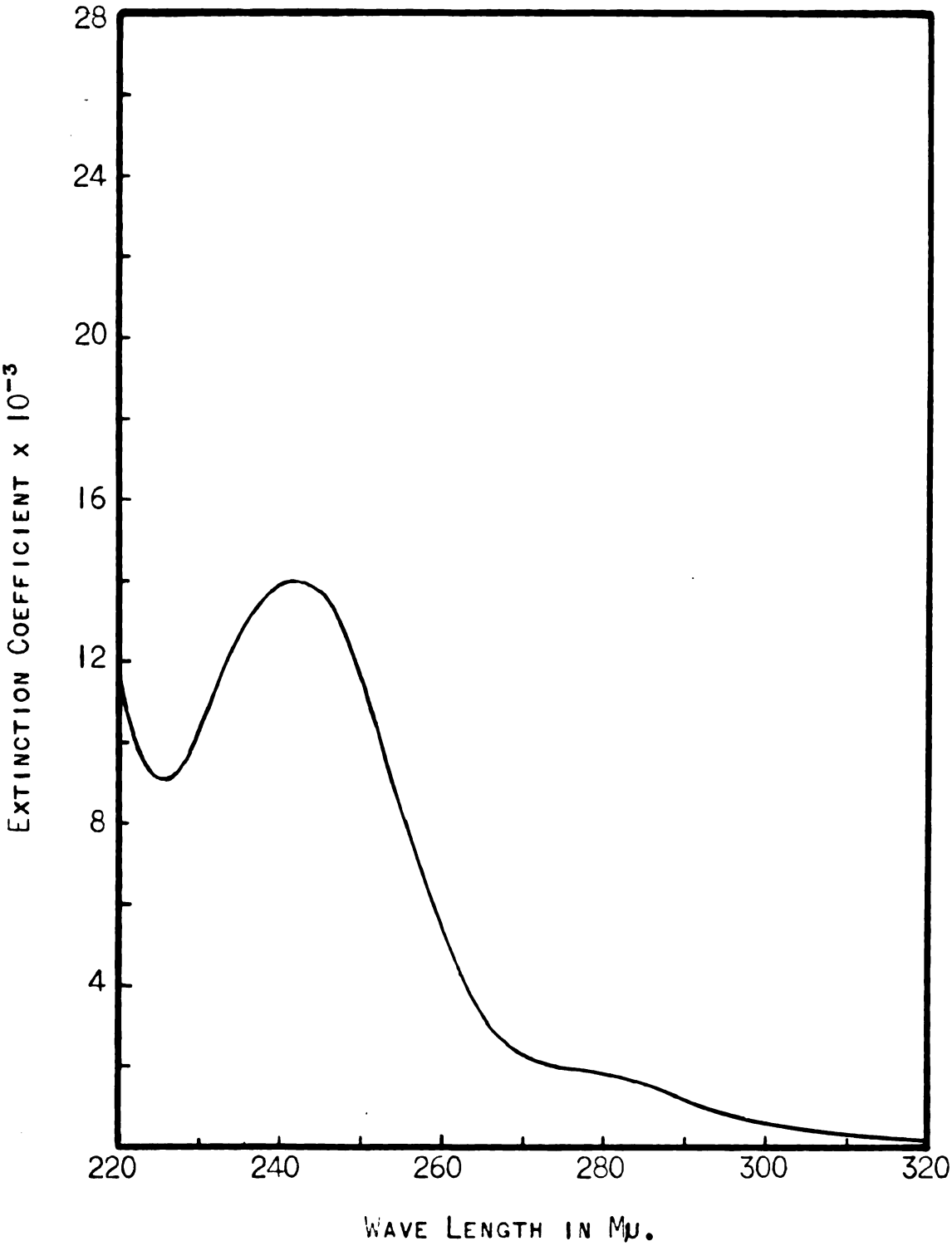


FIGURE 6. ULTRAVIOLET ABSORPTION SPECTRUM OF 5-M-CHLOROPHENYLTETRAZOLE

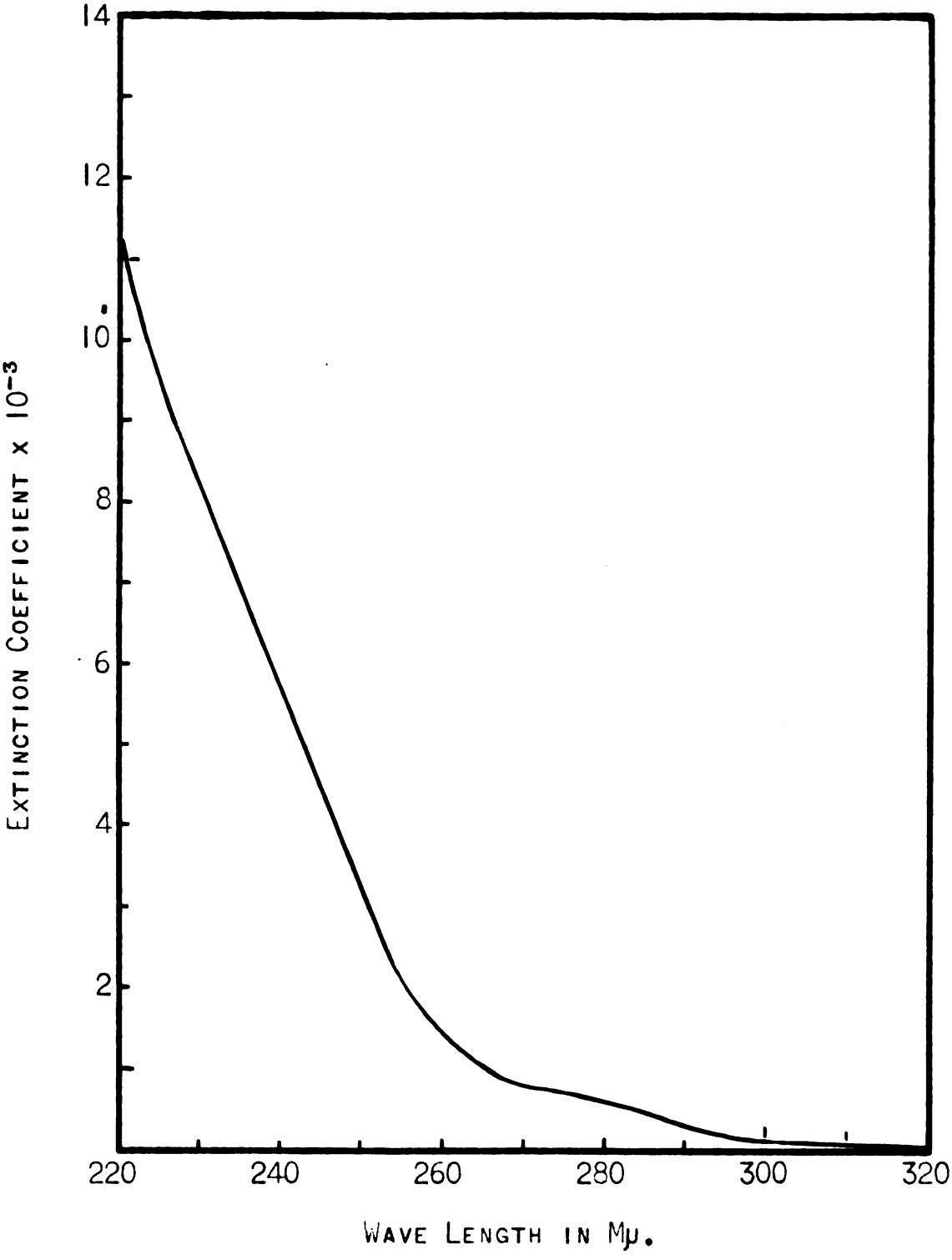


FIGURE 7. ULTRAVIOLET ABSORPTION SPECTRUM OF 5-o-BROMOPHENYLTETRAZOLE

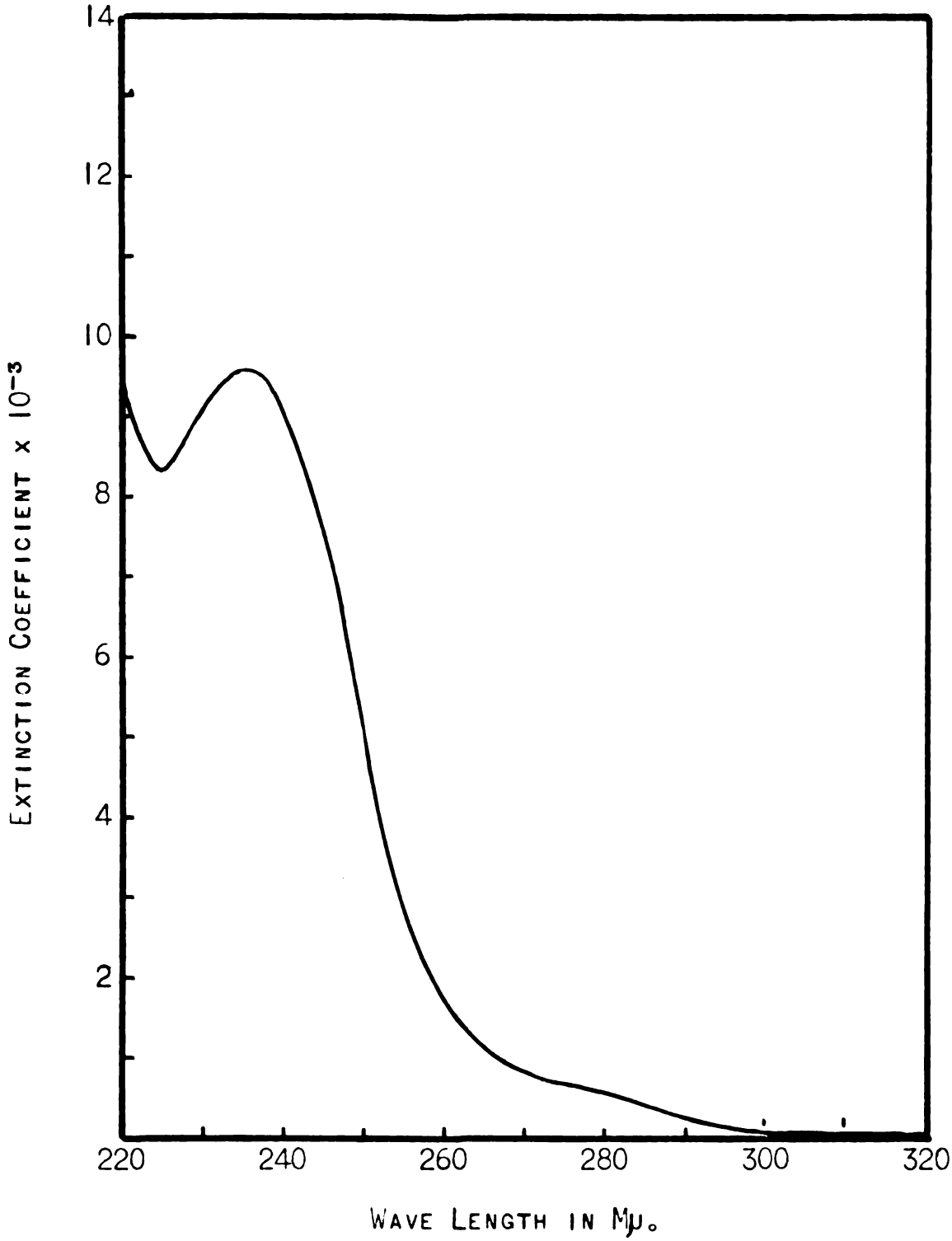


FIGURE 8. ULTRAVIOLET ABSORPTION SPECTRUM OF 5-o-CHLOROPHENYLTETRAZOLE

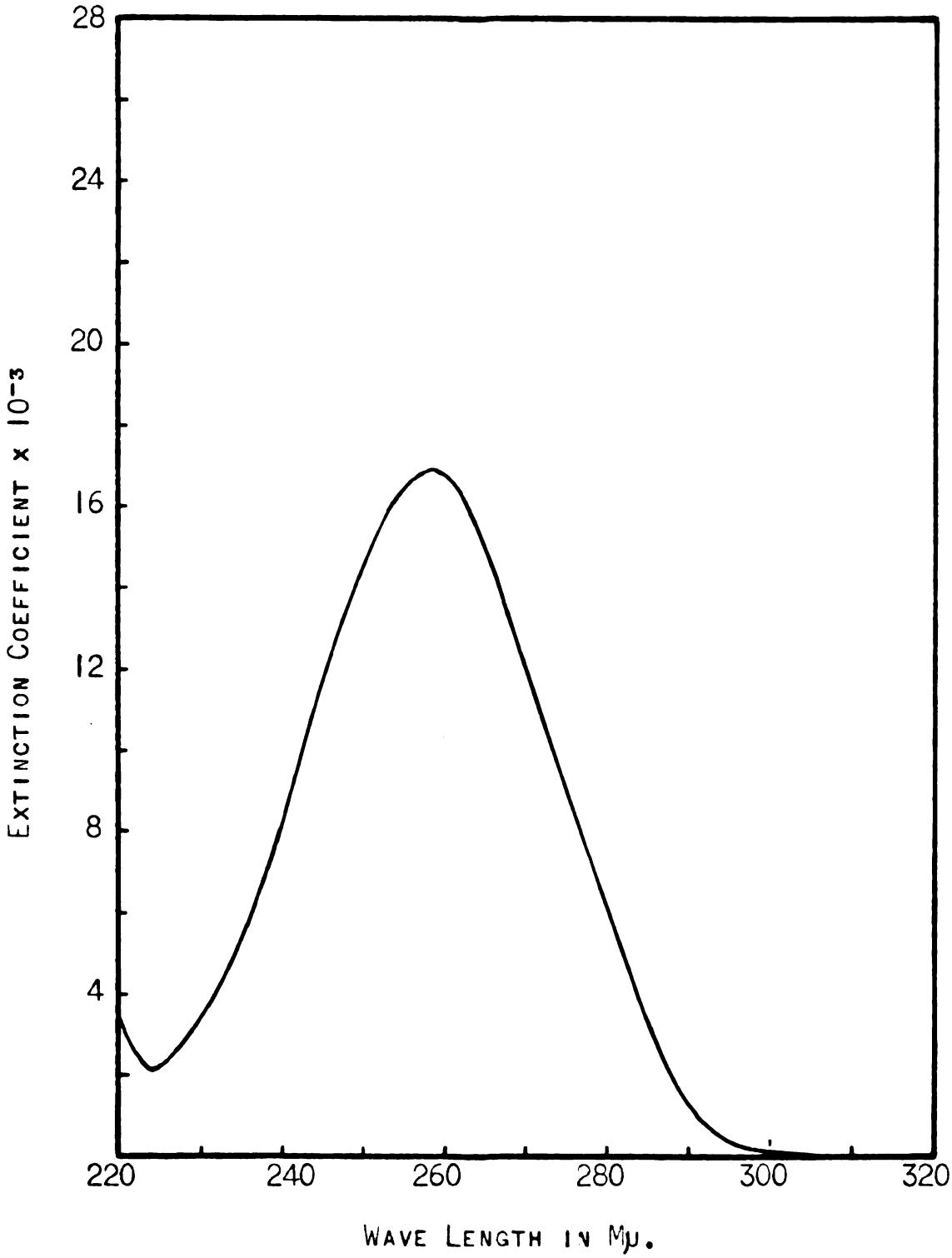


FIGURE 9. ULTRAVIOLET ABSORPTION SPECTRUM OF 5-P-METHOXYPHENYLTETRAZOLE

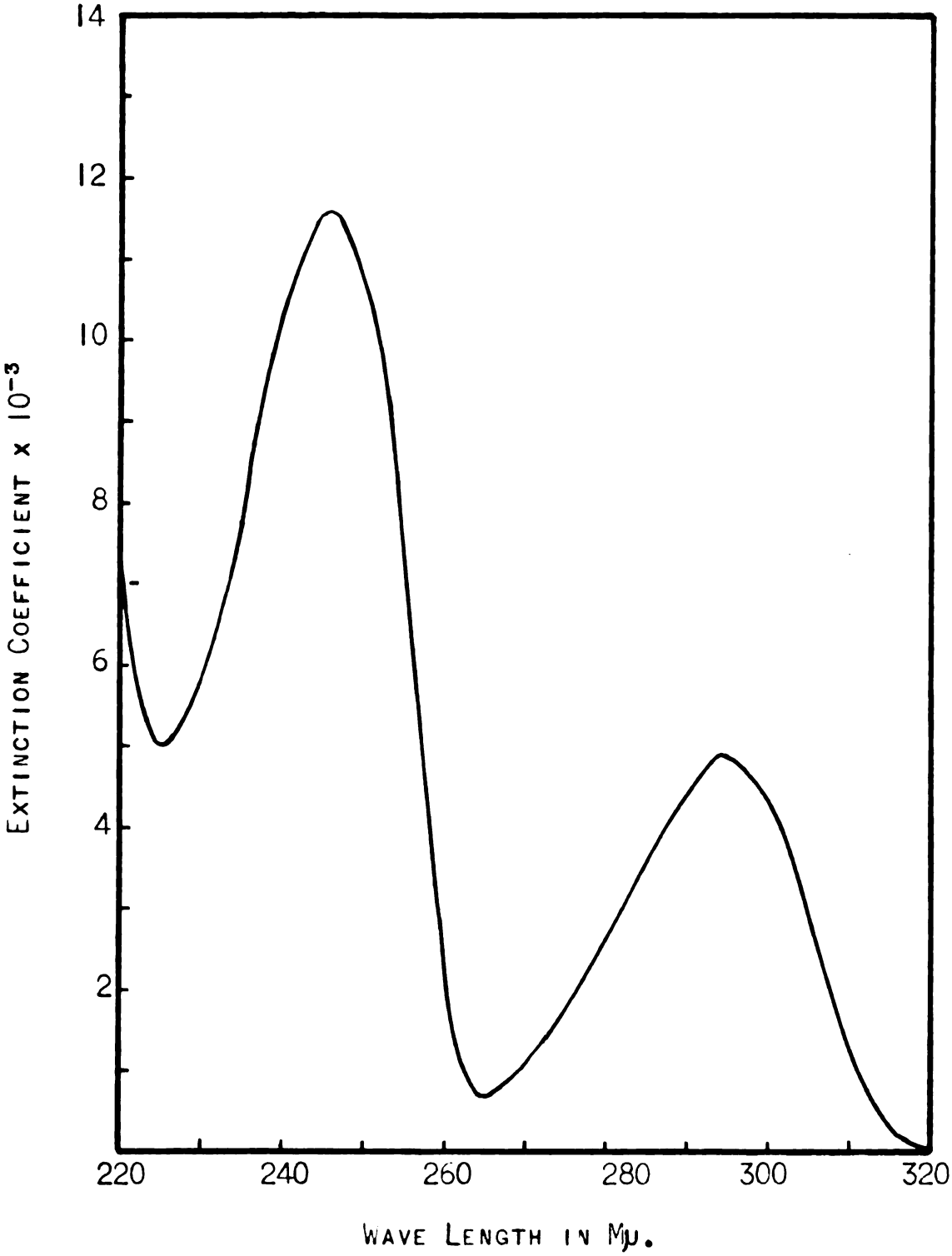


FIGURE 10. ULTRAVIOLET ABSORPTION SPECTRUM OF 5-O-METHOXYPHENYLTETRAZOLE

EXPERIMENTAL

Preparation of Substituted Benzoyl Chlorides

The acid chlorides were prepared by refluxing for several hours the substituted benzoic acid with a large excess of thionyl chloride. The unreacted thionyl chloride was distilled off and the product distilled in vacuo. In a typical preparation 80.4 g. (0.40 mole) of m-bromobenzoic acid and 119 g. (1.0 moles) of thionyl chloride were mixed and refluxed for 18 hours. The excess thionyl chloride was removed and 50 ml. of benzene added to the residue. The benzene was stripped off and the m-bromobenzoyl chloride distilled under reduced pressure. Physical constants and yields are given in Table IV.

Preparation of Substituted Benzamides

The amides were prepared by slowly adding the acid chloride to a large excess of aqueous ammonia solution. In a typical example 83.0 g. (0.378 mole) of p-bromobenzoyl chloride was added dropwise with vigorous stirring to 270 g. of 30% aqueous ammonia solution, kept at $0^{\circ}C$. in an ice-salt bath. The mixture was then allowed to stand at room temperature for 2 hours. The white precipitate was removed by filtration and washed with water until free of ammonia. The p-bromobenzamide was dried to constant weight and not further purified. Physical constants and yields are recorded in Table V.

TABLE IV

SUBSTITUTED BENZOYL CHLORIDES

($R\text{-}C_6H_4COCl$)

R	B.P. °C/mm	Percent Yield	Reference
m-Chloro	103-104/14	92.5	(16)
p-Bromo	123-126/15	94.5	(18)
m-Bromo	119-122/13	91.0	(18)
o-Bromo	120-122/14	84.5	(17)
o-Methoxy	135-138/13	89.5	(19)

TABLE V

SUBSTITUTED BENZAMIDES

($R\text{-}C_6H_4CONH_2$)

R	M.P. °C (corr.)	Percent Yield	Reference
m-Chloro	135.5-137	95.0	(21)
p-Bromo	192-192.5	99.4	(20)
m-Bromo	153-155	99.5	(20)
o-Bromo	160.5-161.5	92.0	(17)
o-Methoxy	130.5-131	87.4	(20)

Preparation of Substituted Benzonitriles

Dehydration of the amides was carried out by the procedure of Fahrenbach (8). For exampke, 55 g. (0.35 mole) of m-chlorobenzamide, 38 g. (0.20 mole) of sodium metabisulfite and 245 g. (1.6 moles) of phosphorus oxychloride were mixed in a three-necked flask. A vigorous reaction started immediately and the temperature rose to 70°C. After the initial reaction subsided the temperature was slowly raised to 95°C. on a steam bath, where it was maintained for one and one-half hours. The reaction was quenched with ice, and the solid was collected on a filter and washed free of acids with cold water. The crude m-chlorobenzonitrile was then distilled under reduced pressure.

In the preparation of o and p-bromobenzonitrile the crude product was purified by steam distillation rather than distilled under reduced pressure. Physical properties and yields are reported in Table VI.

Preparation of 5-Aryltetrazoles

All of the tetrasoles were prepared in a similar manner. The appropriate nitriles, sodium azide and glacial acetic acid in about a 3:4:4 molar ratio were mixed with 100 ml. of n-butyl alcohol. After heating the mixture under reflux for 6 days 300 ml. of water was added to the reaction mixture which was then distilled until about 100 ml. of liquid remained. The residue was made basic and any unreacted starting material removed and purified. The filtrate was acidified and the solid material removed by filtration. After thoroughly washing the crude product with water it was recrystallized from aqueous alcohol.

TABLE VI

SUBSTITUTED BENZONITRILES

($R\text{-}C_6H_4CN$)

R	B.P. °C/mm	M.P. °C (corr.)	Percent Yield	Reference
m-Chloro	99-100/15	40-41	76.0	(22)
p-Bromo	---	114-114.5	89.0	(23)
m-Bromo	112-114/14	39.5-40.5	81.0	(23)
o-Bromo	---	55-55.5	83.8	(17)
o-Methoxy	147-149/24	---	88.8	(24)

An example is the preparation of 5-p-methoxyphenyltetrazole. A mixture of 33 g. (0.25 mole) of p-methoxybenzonitrile, 22 g. (0.33 mole) of sodium azide, 20 g. (0.33 mole) of glacial acetic acid and 100 ml. of n-butyl alcohol was refluxed for four days. At this time 5 g. of sodium azide, 10 g. of glacial acetic acid and 10 ml. of n-butyl alcohol was added to the reaction mixture and refluxing continued for an additional two days. On completion of the reaction 300 ml. of water was added to the reaction mixture and all but about 100 ml. of the liquid was distilled under reduced pressure. The residue was made basic by the addition of 10% sodium hydroxide solution. A small amount of solid material was removed by filtration and the basic solution was extracted with two 50 ml. portions of benzene. From the solid and the benzene extracts unchanged starting was recovered. The unreacted nitrile totaled 1 g. after recrystallization from water. The basic solution was acidified with 3 N hydrochloric acid and the precipitate collected on a filter. After thoroughly washing with water the crude 5-p-methoxyphenyltetrazole was twice recrystallized from 20% aqueous isopropyl alcohol from which it separated as long thin needles.

Two preparations of 5-phenyltetrazole were made using isopropyl alcohol and secondary butyl alcohol as the solvent. All conditions and reagents were the same as described above, only the solvent being varied. The yield of purified product was 64% from isopropyl alcohol solution and 84% from secondary butyl alcohol solution. Both preparations gave a product melting at 218°C after one recrystallization from water.

The tetrazoles are described in Tables I, VII and VIII. Analytical data for the compounds are given in Table IX.

TABLE VII

PREPARATION OF 5-ARYLTETRAZOLES

($R\text{-}C_6H_4CN_4H$)

R	Grams Nitrile (moles)	Grams Sodium Azide (moles)	Grams Acetic Acid (moles)	Grams Nitrile Recovered (moles)	Yield Grams	Yield %
H	41.0 (0.40)	32.5 (0.50)	30 (0.50)	0	53	91
p-Cl	55.0 (0.40)	32.5 (0.50)	30 (0.50)	0	63	87
m-Cl	34.4 (0.25)	22 (0.33)	20 (0.33)	0	42	94
o-Cl	55.0 (0.40)	32.5 (0.50)	30 (0.50)	13 (0.095)	40	56
p-Br	44.5 (0.25)	22 (0.33)	20 (0.33)	0	47	84
m-Br	44.5 (0.25)	22 (0.33)	20 (0.33)	0	52	93
o-Br	44.5 (0.25)	22 (0.33)	20 (0.33)	18 (0.10)	25	45
p-MeO	33.0 (0.25)	22 (0.33)	20 (0.33)	1 (0.01)	34	77
o-MeO	33.0 (0.25)	22 (0.33)	20 (0.33)	26 (0.195)	5	11

TABLE VIII

5-ARYLTETRAZOLES

($R\text{-}C_6H_4CN_4H$)

R	M.P. °C (corr.)	Recrystallization Solvent	Percent Yield[a]
H	217-218	water	91
p-Cl	262-263	80% isopropyl alcohol	87
m-Cl	139-139.5	20% isopropyl alcohol	94
o-Cl	179-180	20% isopropyl alcohol	73
p-Br	278-279 dec.	95% isopropyl alcohol	84
m-Br	154.5-155	25% isopropyl alcohol	93
o-Br	183-183.5	20% isopropyl alcohol	74
p-MeO	238-238.5	20% isopropyl alcohol	81
o-MeO	158.5-159.5	8% isopropyl alcohol	52

a) Calculated from the net amount of nitrile used.

TABLE IX

ANALYSIS OF 5-PHENYLTETRAZOLES[a]

($R\text{-}C_6H_4CN_4H$)

R	Molecular Formula	Analysis							
		Calculated				Found			
		C	H	N	Hal.	C	H	N	Hal.
p-Cl	$C_7H_5N_4Cl$	46.6	2.8	31.0	19.6	46.7	2.9	31.1	19.6
m-Cl	$C_7H_5N_4Cl$	46.6	2.8	31.0	19.6	46.6	3.0	31.1	19.7
o-Cl	$C_7H_5N_4Cl$	46.6	2.8	31.0	19.6	46.7	2.9	31.3	19.7
p-Br	$C_7H_5N_4Br$	37.4	2.2	24.9	35.5	37.6	2.3	25.2	35.5
m-Br	$C_7H_5N_4Br$	37.4	2.2	24.9	35.5	37.6	2.3	24.9	36.0
o-Br	$C_7H_5N_4Br$	37.4	2.2	24.9	35.5	37.6	2.3	25.1	35.7
p-MeO	$C_8H_8ON_4$	54.5	4.6	31.8	--	54.5	4.6	31.9	--
o-MeO	$C_8H_8ON_4$	54.5	4.6	31.8	--	54.8	4.6	31.8	--

a) Analysis were done by Micro-Tech Laboratories, Skokie, Illinois.

Preparation of Silver Salts of the 5-Aryltetrazoles

The silver salts of the 5-aryltetrazoles were prepared by dissolving a weighed amount of the tetrazole in ethanol and adding an equivalent amount of alcoholic silver nitrate solution. The precipitated silver salt was washed several times with hot ethanol and then several times with hot 50% aqueous ethanol. Attempts were made to dissolve the silver salts by digesting in concentrated nitric acid and in 8 N nitric acid, however after 8 hours none of the salts had dissolved. None of the silver salts appeared to be sensitive to shock but they did decompose with a flash when heated over a flame on a spatula. On exposure to daylight no discoloration of the silver salts was observed.

Preparation of Amine Salts of the 5-Aryltetrazoles

Attempts were made to prepare amine salts with several of the tetrazoles. The amines used were ethylenediamine, 2-aminopyridine, benzylamine, piperidine and n-hexylamine. On addition of an alcoholic solution of the amine to an alcohol-ether solution of the tetrazole a powdery white precipitate formed which melted over a very wide and variable range of temperatures. Recrystallization from alcohol or an alcohol-hexane solution gave either an oil or a product which still melted over a very wide and variable range of temperatures.

Determination of the Apparent Dissociation Constants of the 5-Aryltetrazoles

The apparent acidic dissociation constants of all the tetrazoles prepared were determined by titration of a weighed sample of the

compound in aqueous methanolic solution with standard alkali. The titrations were carried out in a constant temperature bath set at 25°C.± .1°C. and the pH determined after each addition of alkali with a Beckman pH Meter, Model G. From these data the apparent acidic dissociation constants were calculated using the following expression (15):

$$K_a = C_{H^+} \frac{X}{X_e - X}$$

where C_{H^+} is the hydrogen ion concentration calculated from the pH corresponding to the addition of X ml. of alkali. The term X_e expresses the number of ml. of alkali required for neutralization of the acid.

The apparent acidic dissociation constants and equivalent weights of all the 5-aryltetrazoles are recorded in Tables I and II. Each dissociation constant is an average of eight values calculated from different points near the region of half neutralization of the compound. In every instance the titration curve exhibited the form normally obtained for the titration of a weak acid with a strong base. The equivalent weight of each compound was calculated from the value of X_e. The data obtained are given in Appendix I.

Since the apparent dissociation constants of o and p-methoxybenzoic acid in 50% aqueous methanol are not recorded in the literature these values were determined in the manner described above and are recorded along with the values given for the tetrazoles.

Ultraviolet Absorption Spectra of the 5-Aryltetrazoles

The ultraviolet absorption spectra of tetrazole and the 5-aryltetrazoles in 95% ethanol solution were determined using a Beckman

Model D-U Spectrophotometer. The data are given in Appendix II and are represented graphically in Figures 1 to 10. A summary of the location of absorption maxima and extinction coefficients is given in Table III.

SUMMARY

A modification of the procedure of Mihina and Herbst for the preparation of 5-substituted tetrazoles has been described whereby the necessity of using sealed tubes and benzene solutions of hydrazoic acid is eliminated.

A group of 5-aryltetrazoles has been prepared and the apparent acidic dissociation constants determined. The effect of substituents on the benzene ring of the 5-aryltetrazoles on the apparent dissociation constants has been discussed in relation to both the nature and position of the substituent.

The ultraviolet absorption spectra of the 5-aryltetrazoles have been determined and related to the observed acid strength of some of the compounds.

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APPENDIX I

POTENTIOMETRIC TITRATION DATA

Potentiometric Titration of 5-Phenyltetrazole
Sample weight: 0.3451 g.
Solvent: 100 ml. 50% methanol (vol.).
Sodium hydroxide: 0.1239 N

ml. base added	pH	ml. base added	pH
0.00	3.24	17.85	5.73
1.04	3.53	18.71	6.61
1.96	3.72	18.83	7.18
4.55	4.12	18.88	7.62
7.29	4.38	18.93	8.89
7.75	4.40	18.99	9.47
8.25	4.43	19.01	9.66
8.75	4.48	19.05	9.82
9.24	4.52	19.15	10.07
9.65	4.56	19.25	10.24
10.19	4.59	19.34	10.37
10.80	4.63	19.45	10.48
13.43	4.89	19.66	10.62
16.60	5.35	20.02	10.77

Potentiometric Titration of 5-Phenyltetrazole
Sample weight: 0.3863 g.
Solvent: 200 ml. 75% methanol (vol.).
Sodium hydroxide: 0.1239 N

ml. base added	pH	ml. base added	pH
0.00	3.50	20.80	6.60
1.00	3.82	21.00	6.92
9.00	4.78	21.10	7.30
9.50	4.81	21.15	7.65
10.00	4.83	21.20	8.03
10.50	4.88	21.25	8.83
11.00	4.91	21.30	9.28
11.50	4.93	21.40	9.79
12.00	4.98	21.50	10.02
12.50	5.02	21.70	10.28
20.00	6.09	22.00	10.51
20.50	6.33		

Potentiometric Titration of 5-o-Chlorophenyltetrazole
Sample weight: 0.4308 g.
Solvent: 100 ml. 50% methanol (vol.)
Sodium hydroxide: 0.1239 N

ml. base added	pH	ml. base added	pH
0.00	3.04	18.80	5.96
1.50	3.37	19.00	6.29
5.00	3.86	19.10	6.68
7.00	4.03	19.15	7.23
8.00	4.11	19.20	8.50
8.50	4.16	19.25	9.33
9.00	4.20	19.30	9.69
9.50	4.23	19.40	10.07
10.00	4.28	19.50	10.27
10.50	4.32	19.70	10.58
11.00	4.37	20.00	10.68
11.50	4.42	20.50	10.87
16.00	4.94	21.00	10.99
17.80	5.36	22.00	11.16
18.40	5.61	24.00	11.31
18.60	5.75		

Potentiometric Titration of 5-o-Chlorophenyltetrazole
Sample weight: 0.4882
Solvent: 200 ml. 75% methanol (vol.)
Sodium hydroxide: 0.1239 N

ml. base added	pH	ml. base added	pH
0.00	3.33	21.50	6.48
1.00	3.57	21.60	6.70
5.00	4.13	21.65	6.86
9.00	4.49	21.70	7.12
9.50	4.51	21.75	7.57
10.00	4.54	21.80	8.24
10.50	4.59	21.85	9.23
11.00	4.61	21.90	9.59
11.50	4.63	21.95	9.88
12.00	4.68	22.00	10.01
12.50	4.72	22.10	10.20
13.00	4.76	22.20	10.32
18.00	5.23	22.40	10.51
19.50	5.50	22.60	10.64
20.50	5.77	23.00	10.81
21.00	6.00	24.00	11.03

Potentiometric Titration of 5-m-Chlorophenyltetrazole
Sample weight: 0.4331 g.
Solvent: 100 ml. 50% methanol (vol.)
Sodium hydroxide: 0.1239 N

ml. base added	pH	ml. base added	pH
0.00	2.94	18.50	5.38
1.00	3.12	18.70	5.50
2.00	3.27	18.90	5.69
5.80	3.71	19.10	5.97
7.49	3.87	19.20	6.23
8.00	3.91	19.30	7.17
8.00	3.96	19.35	8.88
9.00	4.00	19.40	9.57
9.50	4.03	19.45	9.84
10.00	4.07	19.50	10.00
10.50	4.11	19.61	10.22
11.02	4.17	19.70	10.36
15.00	4.57	19.90	10.52
17.00	4.88	20.10	10.66
17.50	4.99	20.50	10.81
18.00	5.13	21.00	10.95
1830	5.28	22.00	11.11

Potentiometric Titration of 5-p-Chlorophenyltetrazole
Sample weight: 0.3876 g.
Solvent: 200 ml. 75% methanol (vol.)
Sodium hydroxide: 0.1239 N

ml. base added	pH	ml. base added	pH
0.00	3.40	16.61	5.88
0.97	3.57	17.12	6.65
2.00	3.76	17.24	7.39
4.98	4.13	17.30	8.47
7.00	4.34	17.35	9.14
7.50	4.39	17.41	9.62
8.00	4.43	17.46	9.82
8.50	4.50	17.53	10.02
9.00	4.53	17.65	10.19
9.50	4.58	17.77	10.31
10.00	4.63	17.88	10.42
14.50	5.20	18.01	10.52
15.61	5.45	18.24	10.63
16.23	5.67	18.58	10.73

Potentiometric Titration of 5-o-Bromophenyltetrazole
Sample weight: 0.6645 g.
Solvent: 150 ml. 50% methanol
Sodium hydroxide: 0.1239 N

ml. base added	pH	ml. base added	pH
0.00	3.07	23.00	5.72
2.00	3.39	23.40	6.08
10.00	4.09	23.60	6.53
10.50	4.13	23.70	7.17
11.00	4.17	23.76	8.48
11.50	4.20	23.80	9.27
12.00	4.23	23.85	9.54
12.50	4.27	23.90	9.72
13.00	4.31	24.00	10.00
13.50	4.33	24.20	10.27
20.00	4.93	24.50	10.56
22.00	5.31	25.00	10.76
22.50	5.48		

Potentiometric Titration of 5-m-Bromophenyltetrazole
Sample weight: 0.2125 g.
Solvent: 200 ml. 75% methanol (vol.)
Sodium hydroxide: 0.1239 N

ml. base added	pH	ml. base added	pH
0.000	3.43	7.400	5.99
0.500	3.59	7.605	7.40
3.000	4.21	7.650	8.02
3.250	4.25	7.675	8.82
3.500	4.31	7.700	9.32
3.750	4.37	7.725	9.59
4.000	4.41	7.750	9.72
4.250	4.47	7.800	9.97
4.500	4.53	7.900	10.20
4.750	4.58	8.000	10.37
7.000	5.43		

Potentiometric Titration of 5-*m*-Bromophenyltetrazole
Sample weight: 0.5488 g.
Solvent: 200 ml. 50% methanol (vol.)
Sodium hydroxide: 0.1239 N

ml. base added	pH	ml. base added	pH
0.00	3.08	19.00	5.53
0.50	3.13	19.20	5.73
1.00	3.20	19.40	6.04
5.00	3.62	19.50	6.38
7.50	3.83	19.55	6.66
8.00	3.89	19.60	7.09
8.50	3.93	19.65	8.72
9.00	3.98	19.70	9.33
9.50	4.01	19.80	9.80
10.00	4.04	19.90	10.07
10.50	4.08	20.00	10.22
11.00	4.12	20.20	10.41
11.50	4.17	20.60	10.67
16.50	4.76	21.20	10.87
18.00	5.08	22.00	11.03
18.50	5.25	24.00	11.27

Potentiometric Titration of 5-p-Bromophenyltetrazole
Sample weight: 0.2108 g.
Solvent: 200 ml. 75% methanol
Sodium hydroxide: 0.1239 N

ml. base added	pH	ml. base added	pH
0.000	3.53	7.450	6.43
0.500	3.70	7.500	6.81
3.000	4.34	7.525	7.09
3.250	4.40	7.550	7.45
3.500	4.46	7.575	7.74
3.750	4.51	7.600	8.31
4.000	4.56	7.625	8.63
4.250	4.61	7.650	9.12
4.500	4.67	7.700	9.61
4.750	4.72	7.750	9.85
7.000	5.61	7.800	10.02
7.200	5.82	7.900	10.23
7.400	6.25	8.000	10.40

Potentiometric Titration of 5-o-Methoxyphenyltetrazole
Sample weight: 0.3574 g.
Solvent: 100 ml. 50% methanol (vol.)
Sodium hydroxide: 0.1239 N

ml. base added	pH	ml. base added	pH
0.00	3.96	16.20	8.13
1.00	4.80	16.25	8.38
2.00	5.11	16.30	8.90
6.50	5.73	16.35	9.40
7.00	5.80	16.40	9.77
7.50	5.83	16.45	9.92
8.00	5.89	16.50	10.11
8.50	5.93	16.60	10.27
9.00	5.99	16.80	10.49
9.50	6.03	17.00	10.66
10.00	6.09	17.50	10.88
15.00	6.94	18.00	11.02
15.50	7.16	19.00	11.20
15.80	7.39	21.00	11.40
16.00	7.62	22.00	11.45
16.10	7.80		

Potentiometric Titration of 5-p-Methoxyphenyltetrazole
Sample weight: 0.3728 g.
Solvent: 150 ml. 50% methanol (vol.)
Sodium hydroxide: 0.1239 N

ml. base added	pH	ml. base added	pH
0.00	3.54	16.00	6.03
0.50	3.73	16.50	6.40
7.00	4.72	16.70	6.63
7.50	4.78	16.90	7.13
8.00	4.81	17.00	8.14
8.50	4.87	17.05	9.21
9.00	4.91	17.10	9.61
9.50	4.96	17.15	9.81
10.00	5.01	17.20	9.96
10.50	5.06	17.30	10.18
15.00	5.72	17.50	10.41

Potentiometric Titration of Benzoic Acid
Sample weight: 0.3280 g.
Solvent: 100 ml. 50% methanol (vol.)
Sodium hydroxide: 0.1239 N

ml. base added	pH	ml. base added	pH
0.00	3.50	21.40	6.80
1.00	3.98	21.50	6.92
5.00	4.65	21.60	7.14
9.00	4.97	21.65	7.28
9.50	5.00	21.70	7.45
10.00	5.03	21.75	7.80
10.50	5.07	21.80	8.29
11.00	5.10	21.85	8.98
11.50	5.13	21.90	9.40
12.00	5.17	21.95	9.64
12.50	5.20	22.00	9.78
13.00	5.23	22.10	10.01
16.00	5.50	22.20	10.18
19.00	5.87	22.40	10.39
20.50	6.23	22.80	10.64
21.20	6.60	24.00	10.98

Potentiometric Titration of o-Methoxybenzoic Acid
Sample weight: 0.3921 g.
Solvent: 100 ml. 50% methanol (vol.)
Sodium hydroxide: 0.1239 N

ml. base added	pH	ml. base added	pH
0.00	3.58	20.00	6.67
1.00	4.08	20.40	7.20
5.00	4.77	20.50	7.53
8.50	5.05	20.55	7.80
9.00	5.09	20.60	8.35
9.50	5.12	20.65	9.10
10.00	5.17	20.70	9.50
10.50	5.20	20.75	9.73
11.00	5.23	20.80	9.92
11.50	5.28	20.90	10.12
12.00	5.32	21.10	10.39
16.00	5.68	21.50	10.68
19.00	6.20	22.00	10.87

Potentiometric Titration of p-Methoxybenzoic Acid
Sample weight: 0.4421 g.
Solvent: 125 ml. 50% methanol (vol.)
Sodium hydroxide: 0.1239 N

ml. base added	pH	ml. base added	pH
0.00	3.82	22.00	6.77
1.00	4.41	22.50	7.04
6.00	5.19	22.90	7.58
10.00	5.49	23.00	7.87
10.50	5.50	23.05	8.02
11.00	5.52	23.10	8.36
11.50	5.54	23.15	8.68
12.00	5.57	23.20	8.98
12.50	5.60	23.25	9.30
13.00	5.63	23.30	9.51
13.50	5.66	24.40	9.78
19.00	6.13	23.60	10.13
21.00	6.47	24.00	10.48

APPENDIX II

ULTRAVIOLET ABSORPTION DATA

Ultraviolet Absorption Spectrum of Tetrazole
(5.00 mg/l in 95% ethanol)

λ(mμ)	Optical Density	$\epsilon \times 10^{-3}$	λ(mμ)	Optical Density	$\epsilon \times 10^{-3}$
340	0.0695	0.975	247	0.852	11.93
330	0.0995	1.392	246	0.856	11.98
320	0.1305	1.829	245	0.860	12.03
310	0.1915	2.684	244	0.880	12.31
305	0.2520	3.534	240	1.0285	14.39
300	0.2995	4.200	237	1.2755	17.87
295	0.3460	4.850	236	1.3525	18.93
290	0.3890	5.450	235	1.416	19.82
285	0.429	6.005	234	1.456	20.40
280	0.486	6.815	233	1.493	20.96
275	0.556	7.800	232	1.527	21.39
270	0.663	9.290	231	1.529	21.40
265	0.816	11.42	230	1.541	21.60
260	0.9795	13.70	229	1.543	21.62
259	0.9885	13.82	228	1.548	21.66
258	0.9870	13.81	227	1.526	21.38
257	0.9930	13.98	226	1.522	21.34
256	0.9785	13.68	225	1.488	20.84
255	0.968	13.53	224	1.463	20.48
250	0.880	12.31	223	1.443	20.22
249	0.862	12.07	222	1.417	19.82
248	0.850	11.89	221	1.419	19.86
			220	1.3945	19.54

Ultraviolet Absorption Spectrum of 5-Phenyltetrazole
(14.6 mg./l in 95% Ethanol)

λ(mμ)	Optical Density	$\epsilon \times 10^{-3}$	λ(mμ)	Optical Density	$\epsilon \times 10^{-3}$
340	0.0060	0.0619	264	0.624	6.43
330	0.0170	0.175	263	0.649	6.69
320	0.0125	0.129	262	0.680	7.00
310	0.0225	0.263	261	0.720	7.42
300	0.0905	0.933	260	0.758	7.81
290	0.2690	2.77	255	0.9965	10.26
285	0.3755	3.87	250	1.2915	13.30
280	0.4895	5.04	246	1.446	14.90
279	0.4950	5.10	245	1.470	15.14
278	0.507	5.22	244	1.500	15.46
277	0.518	5.34	243	1.530	15.78
276	0.528	5.44	242	1.544	15.91
275	0.540	5.56	241	1.548	15.96
274	0.547	5.64	240	1.523	15.70
273	0.550	5.67	239	1.518	15.63
272	0.559	5.75	238	1.482	15.27
271	0.562	5.79	237	1.461	15.07
270	0.563	5.80	236	1.421	14.64
269	0.566	5.84	235	1.380	14.21
268	0.570	5.87	230	1.113	11.63
267	0.579	5.96	225	0.795	8.20
266	0.592	6.10	220	0.548	5.65
265	0.598	6.16			

Ultraviolet Absorption Spectrum of 5-p-Chlorophenyltetrazole
(16.5 mg./l in 95% Ethanol)

λ(mμ)	Optical Density	$\epsilon \times 10^{-3}$	λ(mμ)	Optical Density	$\epsilon \times 10^{-3}$
340	0.0135	0.148	251	1.775	19.42
330	0.0210	0.230	250	1.838	20.14
320	0.0230	0.252	249	1.858	20.36
310	0.0245	0.268	248	1.864	20.42
300	0.0285	0.312	247	1.866	20.44
290	0.0415	0.455	246	1.854	20.32
285	0.0665	0.729	245	1.822	19.97
280	0.0990	1.084	244	1.789	19.60
275	0.1680	1.84	243	1.761	19.30
270	0.3335	3.67	242	1.706	18.68
265	0.718	7.86	241	1.641	17.99
260	1.186	12.99	240	1.588	17.39
255	1.631	17.88	235	1.2285	13.43
254	1.680	18.40	230	0.856	9.39
253	1.713	18.79	225	0.561	6.15
252	1.748	19.13	220	0.398	4.36

Ultraviolet Absorption Spectrum of 5-m-Chlorophenyltetrazole
(14.6 mg./l in 95% Ethanol)

λ(mμ)	Optical Density	$\epsilon \times 10^{-3}$	λ(mμ)	Optical Density	$\epsilon \times 10^{-3}$
340	0.0185	0.2474	242	1.141	14.04
330	0.0185	0.2474	241	1.136	13.96
320	0.0190	0.2536	240	1.130	13.90
310	0.0465	0.5715	239	1.119	13.76
305	0.0365	0.4490	238	1.104	13.58
300	0.0405	0.4985	237	1.073	13.20
295	0.0480	0.5900	236	1.042	12.83
290	0.0935	1.151	235	1.023	12.60
285	0.1100	1.352	234	0.987	12.14
280	0.1485	1.826	233	0.940	11.57
275	0.1560	1.919	232	0.912	11.22
272	0.1695	2.084	231	0.874	10.74
271	0.1755	2.160	230	0.832	10.25
270	0.1800	2.214	229	0.804	9.870
269	0.1935	2.378	228	0.776	9.550
265	0.2530	3.112	227	0.751	9.240
260	0.436	5.365	226	0.729	8.960
255	0.689	8.565	225	0.731	8.995
250	0.940	11.57	224	0.753	9.255
246	1.083	13.33	223	0.789	9.700
245	1.094	13.48	222	0.870	10.70
244	1.129	13.88	221	0.956	11.77
243	1.136	13.96	220	1.041	12.81

Ultraviolet Absorption Spectrum of 5-o-Chlorophenyltetrazole
(20.6 mg./l in 95% Ethanol)

λ(mμ)	Optical Density	$\epsilon \times 10^{-3}$	λ(mμ)	Optical Density	$\epsilon \times 10^{-3}$
340	0.0060	0.0526	238	1.0755	9.44
330	0.0055	0.0482	237	1.0855	9.52
320	0.0060	0.0526	236	1.0970	9.61
310	0.0050	0.0439	235	1.084	9.510
305	0.0050	0.0439	234	1.0955	9.60
300	0.0065	0.0570	233	1.0830	9.50
295	0.0110	0.0965	232	1.0695	9.37
290	0.0265	0.2522	231	1.0550	9.25
285	0.0465	0.4080	230	1.024	8.990
280	0.0670	0.5880	229	1.0180	8.920
275	0.0785	0.6890	228	0.9980	8.750
270	0.0825	0.7245	227	0.9805	8.605
265	0.1075	0.942	226	0.9650	8.465
260	0.200	1.754	225	0.946	8.300
255	0.360	3.072	224	0.9605	8.435
250	0.598	5.445	223	0.9730	8.540
245	0.826	7.255	222	0.9935	8.715
240	1.0135	8.895	221	1.0345	9.07
239	1.0525	9.23	220	1.091	9.57

Ultraviolet Absorption Spectrum of 5-p-Bromophenyltetrazole
(11.6 mg./l in 95% Ethanol)

λ(mμ)	Optical Density	$\epsilon \times 10^{-3}$	λ(mμ)	Optical Density	$\epsilon \times 10^{-3}$
340	0.0050	0.097	252	1.093	21.20
330	0.0065	0.126	251	1.094	21.22
320	0.0060	0.116	250	1.086	21.04
310	0.0055	0.107	249	1.015	20.84
300	0.0050	0.097	248	1.061	20.58
290	0.0125	0.242	247	1.033	20.04
285	0.0305	0.591	245	0.968	18.78
280	0.0620	1.203	240	0.769	14.91
275	0.1385	2.70	235	0.548	10.63
270	0.3250	6.30	230	0.3695	7.16
265	0.567	11.01	225	0.2490	4.83
260	0.856	16.61	223	0.2185	4.24
256	1.023	19.84	222	0.2080	4.03
255	1.036	20.06	221	0.2045	3.96
254	1.053	20.42	220	0.2080	4.03
253	1.078	20.88			

Ultraviolet Absorption Spectrum of 5-m-Bromophenyltetrazole
(12.4 mg./l in 95% Ethanol)

λ(mμ)	Optical Density	$\epsilon \times 10^{-3}$	λ(mμ)	Optical Density	$\epsilon \times 10^{-3}$
340	0.0080	0.146	245	0.689	13.23
330	0.0100	0.182	244	0.692	13.29
320	0.0100	0.182	243	0.693	13.30
310	0.0110	0.200	242	0.688	13.21
300	0.0140	0.255	241	0.678	13.01
290	0.0435	0.792	240	0.669	12.84
285	0.0485	0.883	235	0.598	11.48
280	0.0515	0.936	233	0.573	11.00
275	0.0640	1.229	232	0.570	10.94
270	0.0851	1.634	231	0.570	10.94
265	0.1560	2.84	230	0.571	10.97
260	0.3045	5.54	229	0.582	11.29
255	0.470	8.55	228	0.602	11.56
250	0.619	11.88	225	0.713	13.69
247	0.673	12.92	220	0.993	18.08
246	0.681	13.09			

Ultraviolet Absorption Spectrum of 5-o-Bromophenyltetrazole
(16.0 mg./l in 95% Ethanol)

λ(mμ)	Optical Density	$\epsilon \times 10^{-3}$	λ(mμ)	Optical Density	$\epsilon \times 10^{-3}$
340	0.0030	0.0423	265	0.0655	0.923
330	0.0050	0.0705	260	0.0955	1.347
320	0.0050	0.0705	255	0.1535	2.16
310	0.0055	0.0775	250	0.2340	3.30
300	0.0065	0.0916	245	0.3315	4.67
290	0.0210	0.296	240	0.423	5.96
285	0.0330	0.465	235	0.497	7.00
280	0.0400	0.564	230	0.583	8.21
275	0.0510	0.718	225	0.691	9.74
270	0.0549	0.774	220	0.868	12.23

Ultraviolet Absorption Spectrum of 5-p-Methoxyphenyltetrazole
(17.7 mg./l in 95% Ethanol)

λ(mμ)	Optical Density	$\epsilon \times 10^{-3}$	λ(mμ)	Optical Density	$\epsilon \times 10^{-3}$
340	0.0045	0.0448	260	1.682	16.75
330	0.0055	0.0548	259	1.700	16.92
320	0.0055	0.0548	258	1.678	16.70
310	0.0045	0.0448	257	1.692	16.85
305	0.0045	0.0448	256	1.648	16.40
300	0.0045	0.0448	255	1.639	16.31
295	0.0315	0.314	250	1.481	14.73
290	0.1430	1.42	245	1.200	11.94
285	0.3230	3.21	240	0.824	8.20
280	0.621	6.18	235	0.548	5.45
275	0.918	9.14	230	0.3305	3.29
270	1.2125	12.06	225	0.2190	2.18
265	1.576	15.69	222	0.2500	2.49
261	1.663	16.57	220	0.3585	3.57

Ultraviolet Absorption Spectrum of 5-o-Methoxyphenyltetrazole
(17.3 mg./l in 95% Ethanol)

λ(mμ)	Optical Density	$\epsilon \times 10^{-3}$	λ(mμ)	Optical Density	$\epsilon \times 10^{-3}$
340	0.0035	0.0356	260	0.2435	2.48
330	0.0040	0.0406	257	0.669	6.80
320	0.0060	0.0610	256	0.763	7.75
310	0.1250	1.270	255	0.780	7.92
305	0.3390	3.444	250	0.972	9.88
300	0.438	4.45	248	1.046	10.62
296	0.470	4.77	247	1.098	11.27
295	0.476	4.84	246	1.141	11.60
294	0.478	4.86	245	1.136	11.53
293	0.477	4.85	244	1.116	11.33
292	0.469	4.77	243	1.061	10.78
291	0.462	4.70	240	1.005	10.21
290	0.449	4.56	235	0.800	8.14
285	0.3605	3.66	230	0.586	5.95
280	0.2640	2.68	225	0.491	4.99
275	0.1760	1.79	224	0.497	5.05
270	0.1080	1.10	222	0.587	5.96
265	0.0760	0.772	220	0.791	8.04