PART I

SURFACE FILMS OF CERIN, FRIEDELIN, AND THEIR DERIVATIVES

PART II

THE STRUCTURE OF FRIEDONIC ACID

By

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PART I

SURFACE FILMS OF CERIN, FRIEDELIN, AND THEIR DERIVATIVES

INTRODUCTION

Previous work by Drake and Campbell[1] has indicated that friedelin is a polycyclic triterpenoid of the formula $C_{30}H_{50}O$, containing the group $\diagdown CHCOCH_2-$, but nothing definite was known concerning the position of the functional group in the molecule; dehydrogenation experiments have yielded no oxygen containing fragments to assist in the location of the carbonyl group. It is the purpose of this research to locate this functional group approximately by surface film studies, prior to an investigation of the reactions of certain friedelin degradation products.

Cerin has been identified by Drake and Shrader[2] as an hydroxy ketone of formula $C_{30}H_{50}O_2$, but the positions of the carbonyl and hydroxyl groups with respect to each other or the remainder of the molecule are not known. Unpublished work by G. K. Holmes has shown that the carbonyl group of cerin occupies the same position as in the friedelin molecule. It is the purpose of this research to approximately locate these groups with respect to each other and with respect to the remainder of the molecule by means of surface film studies.

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1. Drake and Campbell, J. A. C. S., **58**, 1681, (1936)

2. Drake and Shrader, J. A. C. S., **57**, 1854, (1935)

DISCUSSION OF RESULTS

Garin and friedelin have been shown to contain the 1,8 dimethyl

picene skeleton by dehydrogenation of friedelinol[3] and comparison of the

product formed with the synthetic compound[4]. Ruzicka and coworkers[5]

have proposed a skeleton formula for these triterpenoid compounds based

on the fact that they yield 1,8 dimethyl picene and other fragments of

known structure on dehydrogenation placing of the methyl groups is

guided by the isoprene rule. If it can be concluded from the previous

chemical evidence that friedelin contains the grouping $\diagdown CH_2COCH_2-$, it

follows that there are three possible positions which this grouping could

occupy in the skeleton proposed by Ruzicka as shown:
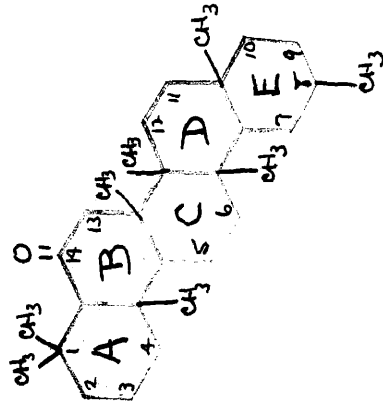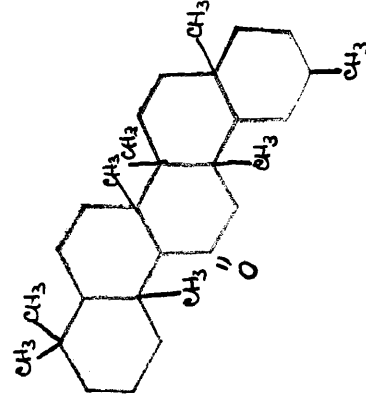
Formula I   Formula II   Formula III
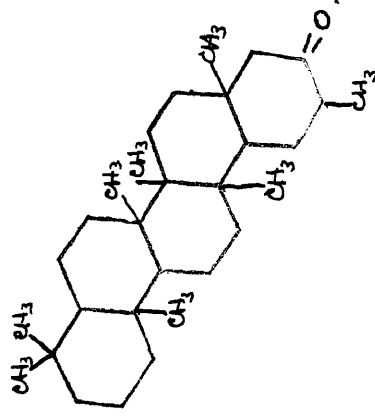
In placing the carbonyl group in the picene nucleus it is

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3. D. P. Houston; Ph. D. Thesis, Univ. of Maryland. (1938)

4. F. L. Howard; Ph. D. Thesis, Univ. of Maryland. (1938)

5. Ruzicka et al., Helv. Chim. Acta. 20, 325, (1937)

appreciated that only two methyl groups, namely those on the one and

eight position have been located with certainty.

If the structure proposed by Haworth and others (Formula IV) is

correct then other possibilities for placing the $\diagdown$CHOOH group in the

molecule exist, namely on the ten or eleven positions:
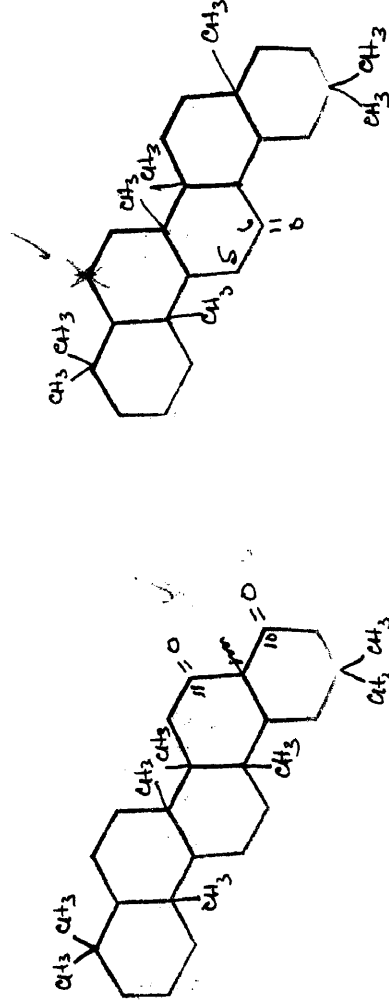
Formula IV   Formula V

Other workers in this field have suggested formula V as a possible

formula for these triterpenoids. Should this be true then the carboxyl

group could occupy position 6 in addition to those already cited.

A molecular model of the perhydropolymethyl picene was made

using wooden spheres to represent atoms. Carbon atoms measured 3.0 cms.

diameter while hydrogen atoms were 2.0 cms. diameter. Short pegs were

used so that the atoms touched one another. By placing the hydroxyl

group in the position shown in the formulas considered and directing the

group similar to its actual position in the substrate, the area of an

horizontal section was taken as the area occupied by that particular

structure on the surface of the liquid. The value in centimeters was

converted to angstrom units by comparing the diameter in centimeters of the carbon atom model used to the values found in the literature in angstrom units obtained for the internuclear distances of carbon atoms in aliphatic compounds.

Computation of the size of a molecule like formula I shows that it should occupy a surface area of about 56-60 sq. A° per molecule.

Formulas II and V should produce films in which the molecules lie flat on the surface and cover an area of 110-120 sq. A° per molecule, while formula III should yield films in which the molecules stand on end and cover an area of 47-48 sq. A° per molecule. A molecule corresponding to formula IV, where the carbonyl group may be on position 10 or 11 would yield films very similar to those produced by a molecule of structure as shown in formula I.

Figure I shows the relation between area per molecule and pressure applied to films of friedelin (Curve I), friedelinol (Curve II), friedelin oxime (Curve III), and friedonic acid (Curve IV). Friedelin, itself, was found unsuited for surface-film pressure measurements because of the extreme instability of the film, therefore friedelinol, the corresponding alcohol, friedelin oxime, and friedonic acid were used. When these curves are extrapolated to zero compression they occupy areas of,

Friedelinol — 53.0 sq. A° per molecule

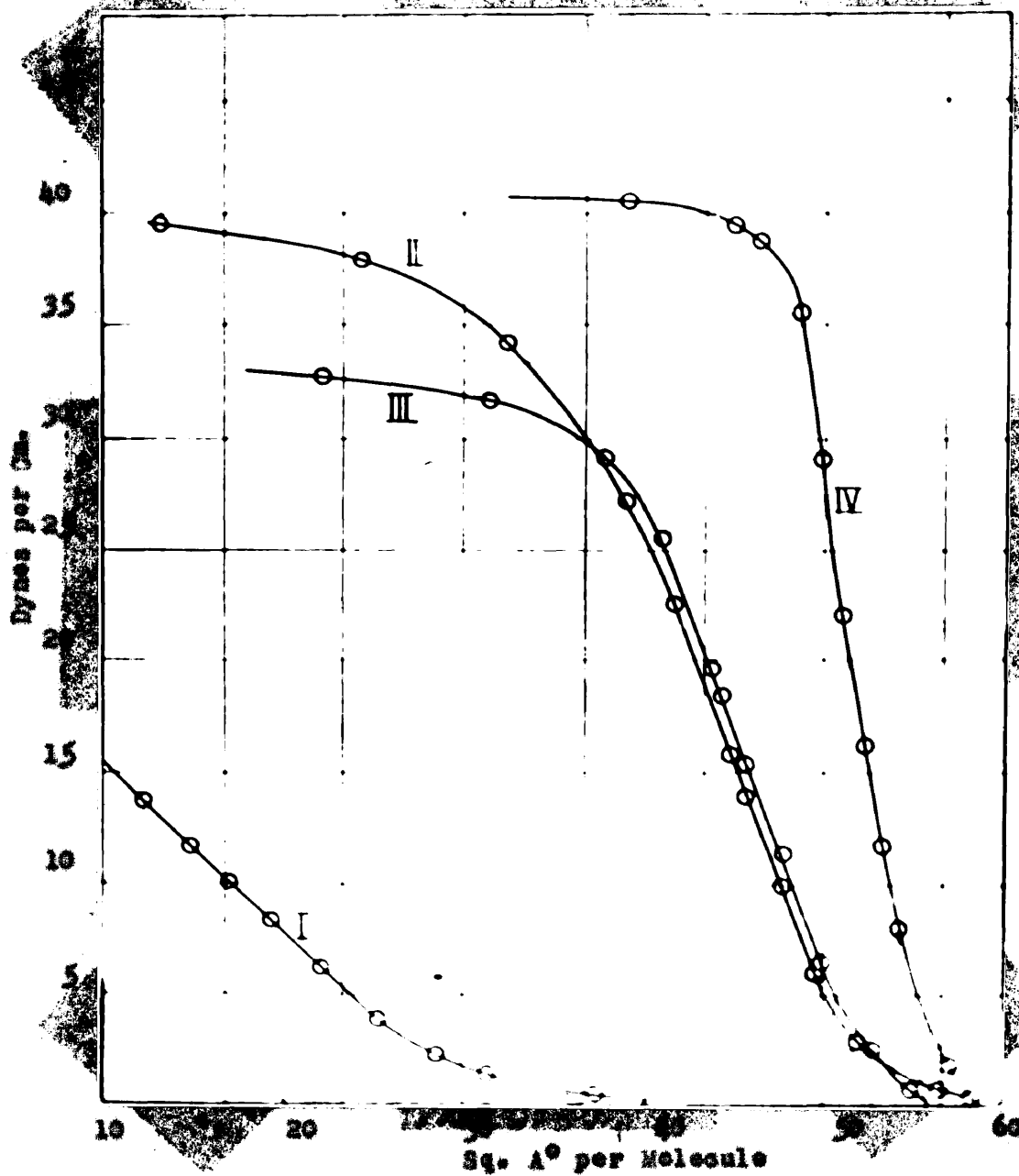Friedelin Oxime — 53.5 sq. A° per molecule

Friedonic Acid — 56.5 sq. A° per molecule

It has been shown by Ruzicka and Hofmann[6] that β-amyrin has its

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6. Ruzicka and Hofmann, Helv. Chim. Acta 20, 1155, (1937)

Figure 1

hydroxyl group at the two position. Dehydrogenation of β-amyrin methyl ether yields a methoxy dimethyl picene, which has been shown to be identical with synthetic 2-methoxy-1,8 dimethyl picene. Film pressure measurements on β-amyrin by Askew[7] have shown that β-amyrin forms a stable film in which the area per molecule at zero compression is 47 sq. A° as would be expected from molecular models. Even β-amyrone with its weakly hydrophilic carbonyl group gives a very slightly compressible film occupying an area of 49.5 sq. A° per molecule at zero compression. It seems reasonable that the large difference between Askew's results and those obtained from friedelin and its derivatives can not be explained by configurational differences, since from an examination of the molecular models the stereoisomers possible would occupy about the same area in a surface film. It is therefore unlikely that friedelin has its carbonyl at position 2. Formula III is also an unlikely structure since the carbonyl group is in about the same position with respect to the rest of the molecule as it is on position 2. Formula II has been considered as a possibility because of fragments obtained from dehydrogenation mixtures, but a molecule with this structure should lie flat on the surface and give a very unstable film occupying a much larger area than was actually observed. Unfortunately for purposes of comparison there is no existing data for compounds known definitely to have one and only one hydroxyl group in this locality.

Formula I, however, agrees very well with the film pressure data if we assume that the molecule lie on the surface at an angle. This assumption is supported by evidence from films of friedonic acid where a ring has been ruptured and the carboxyl group is farther from the end of

7.   Askew, J. C. S. 142, 1585, (1936)

the molecule than the carbonyl of friedelin. The carbonyl and α methylene groups are probably submerged in the liquid and the point of attachment of this group is nearer the center of the molecule than the carbonyl group. This structure causes films to occupy areas greater than those obtained from friedelinol or friedelin oxime and to be much more stable.

Figure III shows the relation between area per molecule and applied pressure for norfriedonic acid on distilled water (Curve V), friedelin oxime on .02 N sodium hydroxide (Curve IX), norfriedonic acid on .02 N sodium hydroxide (Curve X), and friedonic acid on .02 N sodium hydroxide (Curve XI). When these curves are extrapolated to zero compression they occupy areas of;

Norfriedonic acid on distilled water....59 sq. A° per molecule
Norfriedonic acid on .02 N NaOH.......67 sq. A° per molecule
Friedelin oxime on .02 N NaOH.........55 sq. A° per molecule
Friedonic acid on .02 N NaOH..........85 sq. A° per molecule

When friedonic acid is spread on .02 N sodium hydroxide the molecules lie almost flat on the surface due to the strong attraction between the acid and the sodium hydroxide as would be expected from a molecule of formula I. Norfriedonic acid films also yield data in agreement with this structure. However, friedelin oxime when spread on sodium hydroxide gives approximately the same values as those obtained on distilled water although salt formation occurs. This attractive force has little effect on the stability of the film or the area occupied. Inasmuch as the difference in anchorage to the surface does not affect the area of the film then the carboxyl group must be near the end of the molecule.

The experimental evidence, therefore, would indicate that the functional group of friedelin is in ring B of the polymethyl perhydrophenanthrene skeleton. Unfortunately, all of the triterpenoids of this general

Figure III
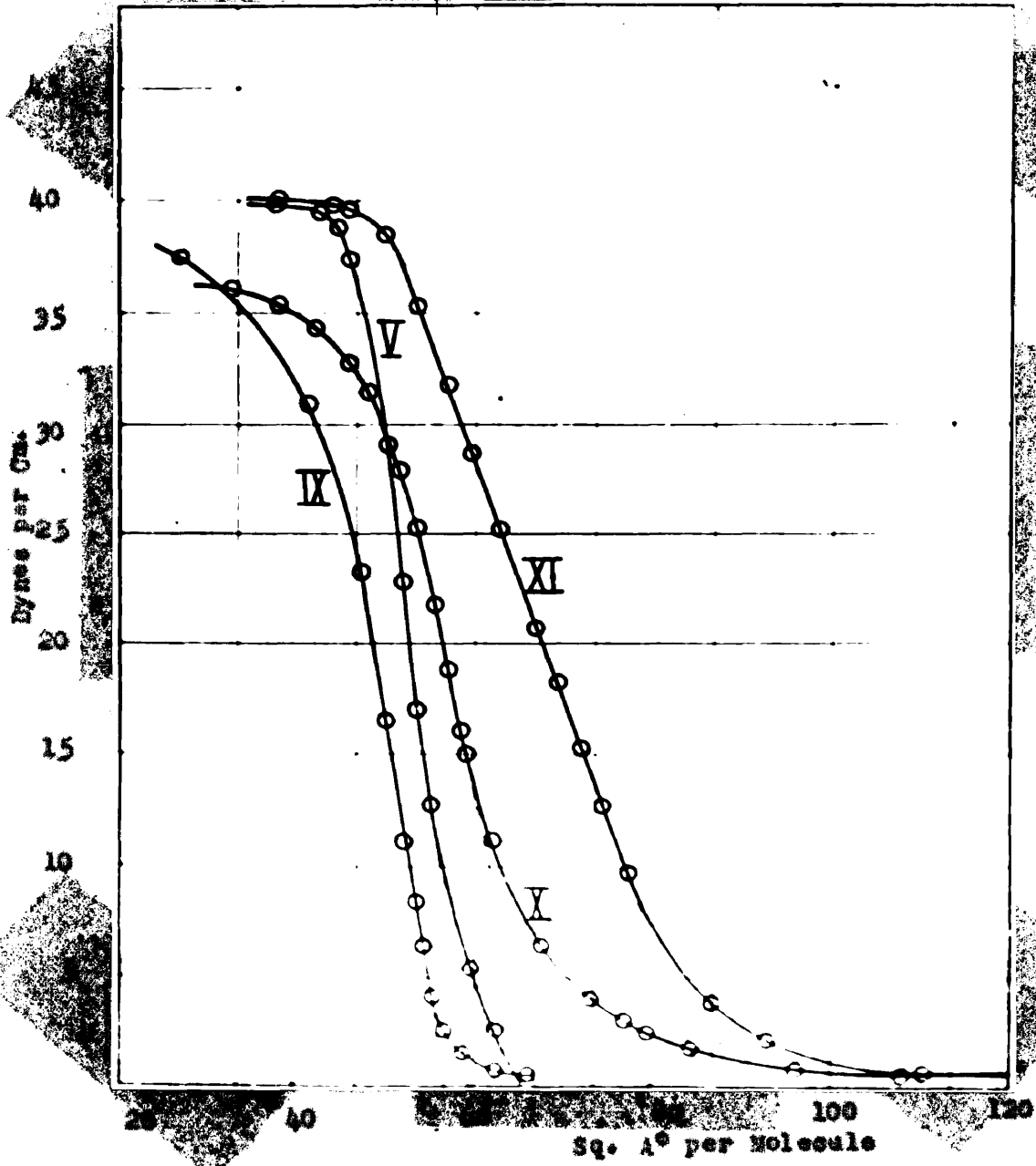
type which have been studied appear to have an hydroxyl group in ring A,
and no structures have been proposed for compounds of this type in which
an hydroxyl or a carbonyl group is located in ring B. It is appreciated
that too much reliance should not be placed upon conclusions drawn from
surface film pressure measurements, but from existing data it appears that
the location of the hydroxyl group in ring B in friedelinol is reasonable
and placing the group near the end of the molecule is practically demanded.

Since the positions of the methyl groups in formula X have not
been proven (with the exception of the 1 and 8 positions), formulae IV
and V could equally well be the true structure in view of the evidence
regarding the structure of the question which has been presented up to
the present time. Should formula IV be the true structure of the triter-
penoid skeleton of ceria and friedelin then the carbonyl group on
positions 10 or 11 would give surface film data in agreement with the
experimental results. We must therefore consider these formulas as
possible structures for friedelin along with formula I. Formula V, where
the additional possibility for placing the carbonyl group at position 6
exists, is not a probable structure for friedelin. If this were the
structure, the functional groups in friedelin derivatives would cause the
molecules to lie flat on the surface and produce films giving areas at
zero compression of approximately 110-120 sq. A° per molecule. It must
also be considered that formula IV and V could also have the carbonyl at
position 14 as is shown in formula I. Molecules of this structure would
also give surface film data in agreement with our experimental results.
We must await the outcome of future experiments on the further degradation
of friedonic and norfriedonic acids, and the results of a study of the
dehydrogenation of friedelinyl methyl ether before a more definite answer

can be given.

Figure II shows the relation between area per molecule and applied pressure for cerin (Curve VI), dihydro cerin (Curve VII); and a dibasic acid obtained from cerin by oxidation (Curve VIII). When these curves are extrapolated to zero compression they give values of,

Cerin .... 54 sq. A° per molecule

Dihydro cerin .... 52.5 sq. A° per molecule

Dibasic acid .... 56.5 sq. A° per molecule

It is therefore concluded from the curves shown that the hydroxyl group of cerin is not far removed from the carboxyl group and is probably near the end of the molecule. This is the only conclusion that can be safely drawn from these studies of the surface films of cerin and its derivatives. This conclusion seems to be supported by studies on surface films of chlorogenin by Holler[8]. Chlorogenin in which the hydroxyl groups, on the basis of chemical evidence, are located in different rings, occupies a large area per molecule in a surface film. Chlorogenin and its derivatives produce films in which the area at zero compression cannot be determined with accuracy because of the extreme instability of the film. Both of the hydroxyl groups exert an attractive force for the substrate and when this force is exerted from two distant points in the molecule it causes the molecule to lie flat on the surface producing an unstable film which occupies a large area per molecule. When two hydroxyl groups are relatively close in the molecule they exert their attractive force from one part of the molecule. If these hydroxyl groups are close to each other and are centrally located in the molecule then one could not dis-

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8. Holler, J. A. C. S. 60, 1629, (1938)

Figure II
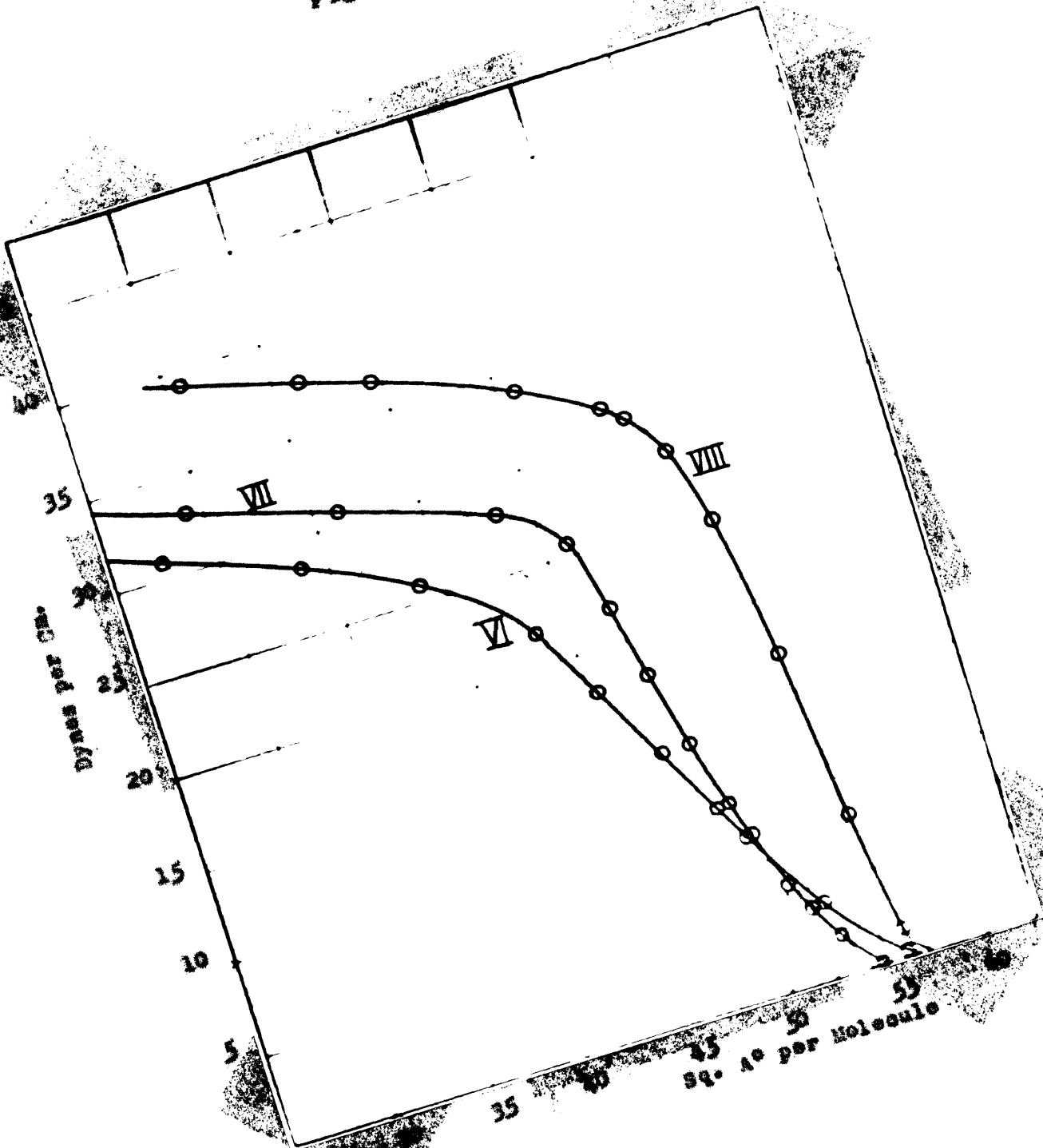
tinguish this from the example cited where the hydroxyls are removed from each other. On the other hand when these two relatively close hydroxyl groups are near the end of the molecule they exert a strong attractive force vertically and cause the molecules to stand on end forming a stable film in which the molecules stand on end and occupy relatively small areas at zero compression.

The nucleus of chlorogenin is undoubtedly different from that of cerin and friedelin, but it seems logical to conclude from the molecular model that the area occupied per molecule in surface films would be much larger if the hydroxyls of dihydro cerin were not relatively near each other in the molecule.
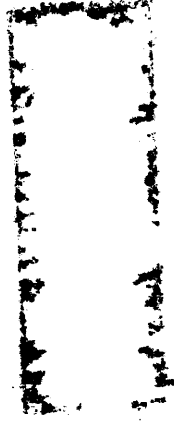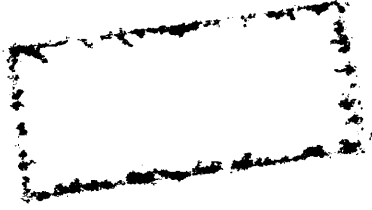
EXPERIMENTAL

The surface pressures were first measured on a Hydrophil Balance of the type used by Adam and coworkers[9] and later on a Cenco Hydrophil Balance. Very good agreement was found in the data obtained from these two balances. The general procedure used was that developed by Adam and coworkers[10]. One to two mg. of sample, weighed to .005 mg., was dissolved in carefully purified benzene at room temperature and the volume adjusted to 25 ml. in a volumetric flask. The solution was placed on the surface by means of a calibrated 1 ml. pipette. The films shown in Curves I through VIII were spread on distilled water; Curves IX, X, and XI, were spread on .02 N NaOH. All films were measured at room temperatures (21° - 26°).

The phenomenon of contraction was observed on all films, and was most pronounced with friedelinol and cerin. Films of the acidic substances were very stable, but showed some contraction at higher pressures. The films reported are equilibrium films. To check the technique and procedure, data was obtained for carefully purified stearic acid, the results, shown in Figure IV, obtained agree with the data of Adam and coworkers[11].

9. Adam and Jessop, Proc. Roy. Soc. 110, 423, (1926)

10. Adam et al., Biochem. J. 29, 1786, (1935)

11. N. K. Adam, The Physics and Chemistry of Surfaces, page 50 Oxford Univ. Press. (1938).

Figure V: Surface films of Stearic Acid on distilled water
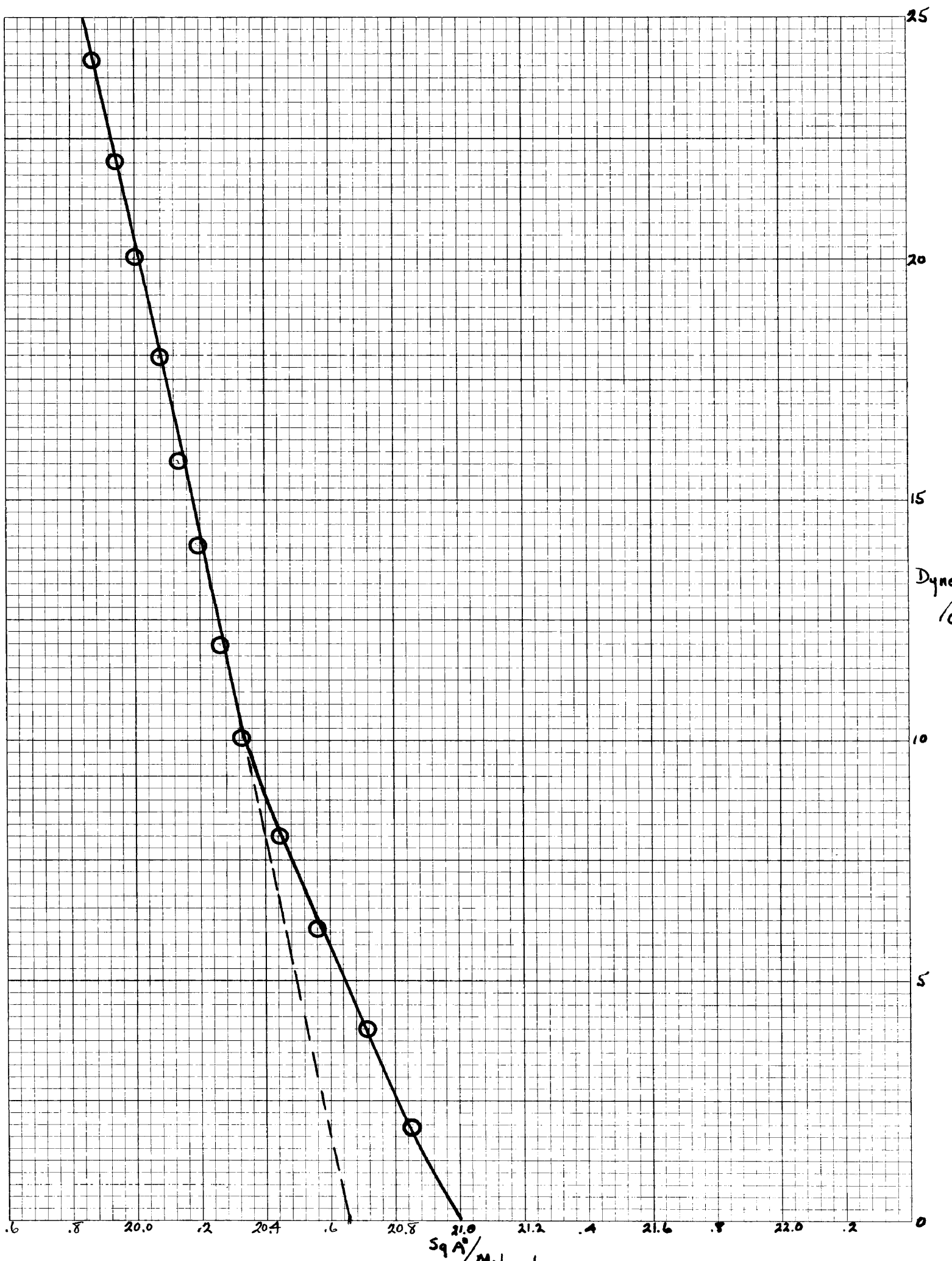
Sample Calculation - Friedonic Acid on Distilled Water

Data: Sample 2.022 mg. made up to 25 ml. in benzene (1 ml. of sol'n used)

Length of film = 40.0 cm.

Degrees torsion = 51.3°

Calculations:

(1) $\dfrac{2.002 \times 4}{1000}$ = .08088 mg. friedonic acid contained in 1 ml.

(2) $\dfrac{.08088 \times 10^{-3}}{458.4}$ $\times 6.062 \times 10^{23}$ = 10.70 x 10^{16} molecules in 1 ml.

(3) 40.0×14.0 = 560 sq. cm. area of film
       = 560 x 10^{16} sq. A° area of film

(4) $\dfrac{560 \times 10^{16}}{10.70 \times 10^{16}}$ = 52.4 sq. A° per molecule

(5) Read directly from calibration curve

    51.3 degrees torsion = 15.7 dynes per cm.

The hydrophil balance was calibrated by placing previously standardized aluminum weights on the lever arm provided on the balance, and observing the number of degrees torsion necessary to return the indicator to the zero position.

Data obtained and calculations made are summarized in the following tables:

Figure VI: Calibration Curve I for Cenco Hydrophil Balance
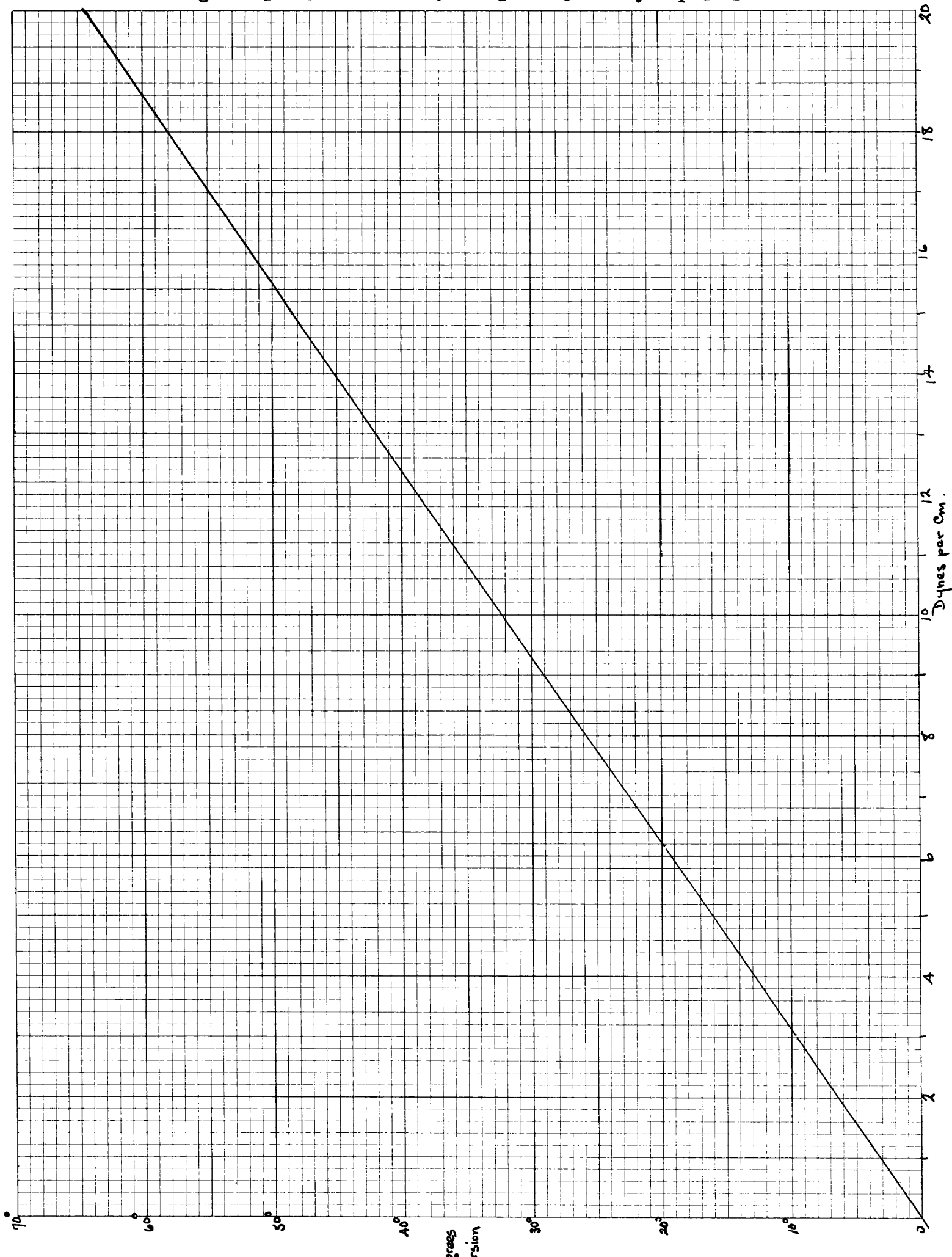
Figure VII: Calibration Curve II for Cenco Hydrophil Balance
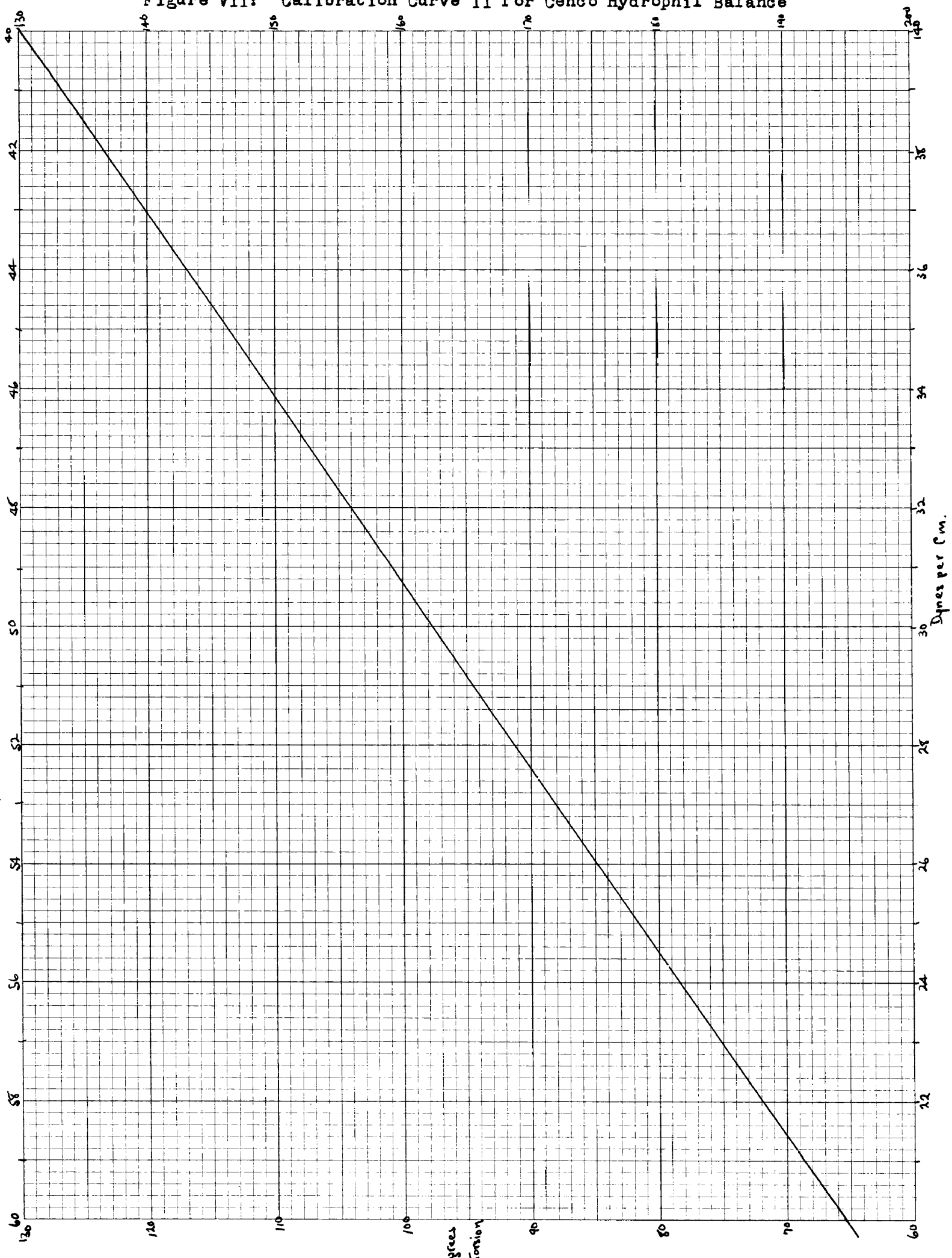
Calibration of Torsion Wire of Cenco Hydrophil Balance

Weight Used (Grams)	(Dynes)	Reading I	Reading II (degrees)	Reading III	Average	Dynes per cm.
24.3	23.8	353.7	353.7	353.7	353.7	1.87
50.0	49.0	347.4	347.2	347.1	347.2	3.86
75.8	74.2	341.0	340.7	340.6	340.8	5.84
99.9	97.9	334.8	334.7	334.7	334.7	7.70
126.0	123.5	323.1	327.9	328.1	328.0	9.72
150.8	147.8	321.9	322.0	321.9	321.9	11.62
176.3	172.8	315.3	315.3	315.3	315.3	13.59
200.3	196.3	309.3	309.3	309.3	309.3	15.44
224.9	220.4	303.2	303.2	303.2	303.2	17.35
251.5	246.5	296.7	296.5	296.8	296.7	19.39
274.8	269.3	291.0	290.8	291.0	291.0	21.18
301.6	295.6	284.1	284.1	284.1	284.1	23.22
327.1	320.6	278.0	277.8	277.8	277.8	25.21
351.0	344.0	272.2	271.9	272.0	272.0	26.76
377.9	369.8	265.7	265.5	265.4	265.5	27.08
400.6	392.6	259.6	259.3	259.5	259.5	30.70
502.1	492.1	234.0	233.9	233.9	233.9	38.76

Samples of substances used:

	Substance	Sample wt. (in mg.)	Total vol. (in ml.)	Mg. per ml.	Molecules per ml.
1.	Friedelin	1.836	25	.07344	10.44×10^{16}
2.	Friedelinol (1)	7.635	100	.07635	10.8×10^{16}
	Friedelinol (2)	2.127	25	.08508	12.08×10^{16}
3.	Friedelin oxime	2.047	25	.08188	11.24×10^{16}
4.	Friedonic acid (1)	2.022	25	.08088	10.70×10^{16}
	Friedonic acid (2)	7.788	100	.07788	10.32×10^{16}
5.	Cerin	1.987	25	.07948	10.91×10^{16}
6.	Dihydro cerin	7.781	100	.07781	10.62×10^{16}
7.	Norfriedonic acid	1.157	25	.04628	6.32×10^{16}
8.	Cerin dibasic acid	1.107	25	.04428	5.67×10^{16}
9.	Stearic acid	3.560	25	.1424	30.35×10^{16}

Data obtained from surface films:

Friedelin: On Distilled Water

Film Length (cm.)	Sq. A°/mol	Dynes on Float	Dynes/cm.
27.0	36.2	6.5	0.53
22.8	30.6	12.8	1.05
21.0	28.1	23.8	1.95
18.7	25.1	49.0	4.00
16.3	21.8	74.2	6.06
14.6	19.5	97.9	7.98
12.5	16.7	123.5	10.08
10.4	14.0	147.8	12.05
8.4	11.1	172.8	14.12
6.8	9.1	196.3	16.03
5.5	7.4	220.4	17.98
3.8	5.1	246.5	20.14

Friedelinol: On Distilled Water

Film Length (cm.)	Sq. A°/mol	Dynes on Float	Dynes/cm.
42.7	55.3	4.0	0.33
41.0	53.2	23.8	1.95
39.5	51.2	49.0	4.00
38.8	50.2	74.2	6.06
37.8	43.9	97.9	7.98
37.4	43.4	123.5	10.08
36.6	47.4	147.8	12.05
35.9	46.5	172.8	14.12
35.2	45.7	196.3	16.03
34.4	44.6	220.4	17.98
34.0	44.1	246.5	20.14

Friedelin Oxime: On Distilled Water

Film Length (cm.)	Sq. A°/mol	Degrees Torsion	Dynes/cm.
44	54.8	2.8	0.8
43	53.6	5.4	1.6
42	52.3	9.6	2.9
41	51.3	17.4	5.3
40	49.8	20.7	6.3
39	48.5	37.7	11.5
38	47.3	39.2	12.0
37	46.1	50.6	15.5
36	44.8	58.2	17.8
35	43.6	64.9	19.8
34	42.4	67.6	20.8
30	37.4	96.4	29.7
25	31.2	102.8	31.6
20	24.9	124.0	38.1
15	18.7	195.1	60.0

Friedelin Oxime: On N/50 NaOH

Film Length (cm.)	Sq. A°/mol	Degrees Torsion	Dynes/cm.
50	62.2	1.8	0.5
48	59.7	2.2	0.7
47	58.5	3.0	0.9
46	57.3	5.0	1.5
45	56.0	8.4	2.6
44	54.8	13.2	4.0
43	53.6	19.3	5.9
42	52.3	26.7	8.2
41	51.0	35.2	10.8
40	49.8	40.0	12.3
39	48.5	53.6	16.4
37	46.1	79.0	24.3
32	39.8	102.0	31.4
26	32.4	116.0	35.7

Friedemic Acid: On Distilled Water

Film Length (cm.)	Sq. A°/mol	Degrees Torsion	Dynes/cm.
44.0	57.6	1.3	0.4
43.0	56.3	9.5	2.9
42.0	55.0	21.8	6.7
41.0	53.7	35.4	10.9
40.0	52.4	51.3	15.7
39.0	51.0	68.5	21.0
38.0	49.7	91.3	28.1
37.0	48.4	116.0	35.7
36.0	47.1	127.2	39.1
35.0	45.8	128.2	39.5
34.0	44.4	129.8	39.9

Dibasic Acid from Ceria: On Distilled Water

Film Length (cm.)	Sq. A°/mol	Degrees Torsion	Dynes/cm.
46	56.8	5.0	1.5
45	55.5	26.1	8.0
44	54.3	55.0	16.9
43	53.1	80.3	24.7
42	51.8	94.3	29.1
41	50.6	102.0	31.4
40	49.4	105.0	32.3
37	45.7	110.0	33.8
34	41.9	115.0	35.2
32	39.5	119.6	36.8
30	37.0	123.7	38.0
25	30.8	128.0	39.4

Nonfriedemic Acid: On Distilled Water

Film Length (cm.)	Sq. A°/mol	Degrees Torsion	Dynes/cm.
28	62.0	7.5	2.3
27	59.8	13.7	5.5
26	57.6	28.7	8.8
25	55.4	40.5	12.4
24	53.1	55.5	17.0
23	51.0	73.2	22.5
22	48.7	93.2	28.7
21	46.5	112.7	34.6
20	44.3	122.7	37.7
19	42.1	127.0	39.0
18	39.9	128.0	39.4
17	37.7	128.5	39.5

Stearic Acid: On Distilled Water

Film Length (cm.)	Sq. A°/mol	Dynes on Float	Dynes/cm.
47.0	21.7	9.4	0.77
45.2	20.85	23.8	1.95
44.9	20.74	49.0	4.00
44.6	20.57	74.2	6.06
44.3	20.45	97.9	7.98
44.1	20.34	123.5	10.08
43.9	20.26	147.8	12.05
43.8	20.20	172.8	14.12
43.7	20.14	196.3	16.03
43.55	20.08	220.4	17.98
43.4	20.01	246.5	20.14
43.2	19.94	269.3	22.00
43.0	19.85	295.6	24.18

Dihydro Cerin: On Distilled Water			
Film Length Cm.	Sq. A° per mol	Dynes on Float	Dynes per Cm.
41.7	54.8	5.0	0.41
40.5	53.3	23.8	1.95
39.6	52.2	49.0	4.00
39.1	51.5	74.2	6.06
38.5	50.8	97.9	7.98
38.1	50.2	123.5	10.08
37.6	49.6	147.8	12.05
37.2	49.1	172.8	14.12
36.7	48.3	196.3	16.03
36.3	47.7	220.4	17.98
35.9	47.3	246.5	20.14
35.5	46.8	269.3	22.00
35.1	46.2	295.6	24.18
34.5	45.6	320.6	26.72
32.6	43.0	344.0	28.65
27.2	35.8	369.8	30.80
21.8	28.7	392.6	32.68
18.8	24.7	416.4	34.63
17.5	23.1	441.6	36.68
16.4	21.6	465.4	38.63
14.8	19.5	492.1	41.02
13.8	18.2	515.9	42.97
12.8	16.9	541.1	45.02

Norfriedenic Acid: On N/50 NaOH			
Film Length Cm.	Sq. A° per mol	Degrees Torsion	Dynes per Cm.
38	84.1	4.1	1.2
36	79.8	6.2	1.9
34	75.3	10.2	3.1
32	70.9	14.0	4.3
30	66.5	19.6	6.0
28	62.0	28.2	8.7
26	57.6	49.1	15.0
25	55.4	60.8	18.6
24	53.1	72.0	22.1
23	51.0	82.0	25.2
22	48.7	90.9	28.0
21	46.5	102.0	31.4
20	44.3	105.1	32.4
18	39.9	111.7	34.4
16	35.4	114.0	35.1
14	31.0	117.0	36.0
12	26.6	118.0	36.3
10	22.2	118.0	36.3

Cerin: On Distilled Water				Friedonic Acid: On N/50 NaOH			
Film Length (Cm.)	Sq. A° per mol	Dynes on Float	Dynes per Cm.	Film Length (Cm.)	Sq. A° per mol	Degrees Torsion	Dynes per Cm.
44.3	56.7	8.0	0.65	45.0	113.0	0.6	0.2
43.1	55.2	23.8	1.95	43.0	112.5	1.5	0.4
42.1	53.9	49.0	4.00	35.0	91.5	7.0	2.0
40.8	52.3	74.2	6.06	34.0	89.0	8.8	2.6
39.6	50.7	97.9	7.98	33.0	86.5	11.4	3.5
38.4	49.2	123.5	10.08	32.0	83.8	14.9	4.5
38.0	48.7	147.8	12.05	31.0	81.1	19.8	6.1
36.8	47.2	172.8	14.12	30.0	78.5	25.1	7.7
35.9	46.1	196.3	16.03	29.0	75.9	31.9	9.8
35.4	45.4	220.4	17.98	28.0	73.4	39.7	12.0
33.6	43.1	246.5	20.14	27.0	70.6	49.4	15.1
32.5	41.7	269.3	22.00	26.0	68.1	61.2	18.7
29.8	38.2	295.6	24.18	25.0	65.5	68.2	21.0
27.4	35.1	320.6	26.72	24.0	62.8	75.9	23.2
24.7	31.7	344.0	28.65	23.0	60.3	82.8	25.4
21.8	28.0	369.8	30.8	22.0	57.6	93.0	28.6
20.1	25.8	392.6	32.7	21.0	54.9	104.2	32.1
17.6	22.6	416.4	34.6	20.0	52.4	115.6	35.6
15.4	19.7	441.6	36.7	19.0	49.7	125.1	38.5
13.8	17.7	465.4	38.6	18.0	47.1	126.0	38.7
12.8	16.4	492.1	41.0	17.0	44.5	126.5	38.9
11.8	15.1	515.9	43.0	16.0	41.8	127.0	39.0
10.9	14.0	541.1	45.0				

SUMMARY

1. Measurements of surface films of friedelin and its derivatives indicate that the carbonyl group is located near the end of the molecule. Several possibilities for the structure of friedelin are considered.

2. Surface films of cerin and certain derivatives indicate that the hydroxyl and carbonyl groups are not far removed from each other and are probably near the end of the molecule.

3. This data agrees with chemical evidence obtained by previous workers on the structure of these compounds.

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11. N. K. Adam, The Physics and Chemistry of Surfaces, page 50 Oxford Univ. Press (1938)

PART II

THE STRUCTURE OF FRIEDONIC ACID

Oxidative degradation of friedelin has been shown by Drake and Campbell[1] to produce friedonic acid ($C_{30}H_{50}O_3$), a monobasic keto acid. The carboxyl group can be esterified easily, but no functional derivatives of the carboxyl group have been prepared; likewise the methyl ester does not show the ordinary reactions of the carboxyl group. The fact that friedonic could be reduced to an hydroxy acid which spontaneously loses water to form a lactone ($C_{30}H_{50}O_2$) indicates that a carboxyl group is present. It was the purpose of this research to obtain further evidence of the presence of the carboxyl group and to determine its relation in the molecule to the carboxyl group.

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1. Drake and Campbell, J. Am. Chem. Soc. **58**, 1681, (1936)

DISCUSSION OF RESULTS

The friedelin used in this research was obtained from cork by extraction with ethyl acetate, and was separated from cerin by the difference in solubility in chloroform.[2] The resulting "friedelin rich" fraction was purified by recrystallization from pyridine. It was found that this method of purification gave pure friedelin after five recrystallizations in a yield of 70% from the friedelin rich fraction. Pyridine was found to be a particularly good solvent for recrystallization because any residual brown resinous material present in the friedelin rich fraction was removed after only one recrystallization; furthermore, friedelin is very soluble in hot pyridine (boiling) and relatively insoluble in the cold solution. This method of purification gave better yields of friedelin and required much less time and material than the previous method[2] involving conversion to the benzoate or phenyl acetate and subsequent saponification of the enol ester produced.

Friedelin was oxidized by the method used by Drake and Campbell[1]; the method was altered, however, so that it could be used on larger quantities of material. By this modified procedure a yield of 43% pure friedonic acid was obtained based on the friedelin oxidized. The friedelin recovered from an oxidation was added directly to the next oxidation mixture.

Many oxidations were made on pure friedelin to obtain enough friedonic acid for degradation experiments. In one of these routine preparations a product was obtained which was recrystallized to a melting

2. Drake and Jacobsen, J. Am. Chem. Soc., **57**, 1570, (1935)

point of 126-127°. This substance, isomeric with friedonic acid, had been obtained before, but never in a large enough quantity for further investigation. This isomeric product was found to be unaffected by .02 N sodium hydroxide in the cold, indicating it to be a lactone; it could be converted to the corresponding methyl ester by saponifying in sodium methoxide and refluxing with methyl sulfate, and this methyl ester was found to be identical with the one produced by a similar treatment of friedonic acid. When friedonic acid was allowed to stand at room temperatures in sodium ethoxide solution for some time a very small quantity of this same product melting at 126-127° could be isolated. It is probable that this isomer of friedonic acid is an hydroxy lactone formed by interaction of the carbonyl and carboxyl groups. Many examples of this type of interaction are known; the most familiar one is the formation of γ-valerolactone from uvulinic acid.[3]

Methyl friedonate, reported by Drake and Campbell[1], was prepared from the crude acid fraction obtained from friedelin by oxidation of the isomerization of friedonic acid in alkaline alcoholic solution, it and melted at 249-251° C. When this preparation was duplicated an ester was obtained from pure friedonic acid which melted at 157-158° and analyses correspond to the formula $C_{31}H_{52}O_3$ as would be expected. Because of the isomerization of friedonic acid in alkaline alcoholic solution, it was considered that friedonic might isomerize and then form a methyl ester of the isomeric product, but preparation of methyl friedonate by several different methods yielded the same product. The methods used were treatment with sodium methoxide and methyl sulfate, with sodium methoxide and methyl iodide, and with diazomethane in dry ether. In the

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3. Whitmore, Organic Chemistry (New York: Van Nostrand, 1937)
p. 447.

latter case no alkali was present to cause isomerization. This apparent discrepancy between the methyl ester obtained in this research and the one obtained by Drake and Campbell[1] may be due to isomorphism or stereo-chemical differences.

Friedonic acid has been reduced catalytically with hydrogen and Adams' platinum catalyst to yield friedololactone. This product shows no depression in melting point when mixed with the product previously described by Drake and Campbell[1].

Friedonic acid was concluded to be a monobasic keto acid on the basis of its reduction to the corresponding hydroxy acid and subsequent lactone formation. Although numerous attempts were made to prepare carbonyl derivatives of friedonic acid none were successful. It was therefore concluded that either the carbonyl group is highly blocked or there is interaction between the carboxyl and carbonyl groups. Similarly methyl friedonate formed no carbonyl derivatives, even on treatment in a sealed tube.

Several compounds of this general type have been found to yield no functional carbonyl derivatives, yet have been shown to contain a carbonyl group conjugated with a double bond. Some of these α, β unsaturated ketones are peculiar in that they give no tetranitromethane test for unsaturation and give no functional derivatives of the carbonyl group. To decide between these possible structures the absorption spectra of a 1% solution of friedonic acid in cyclohexane was determined.[4]

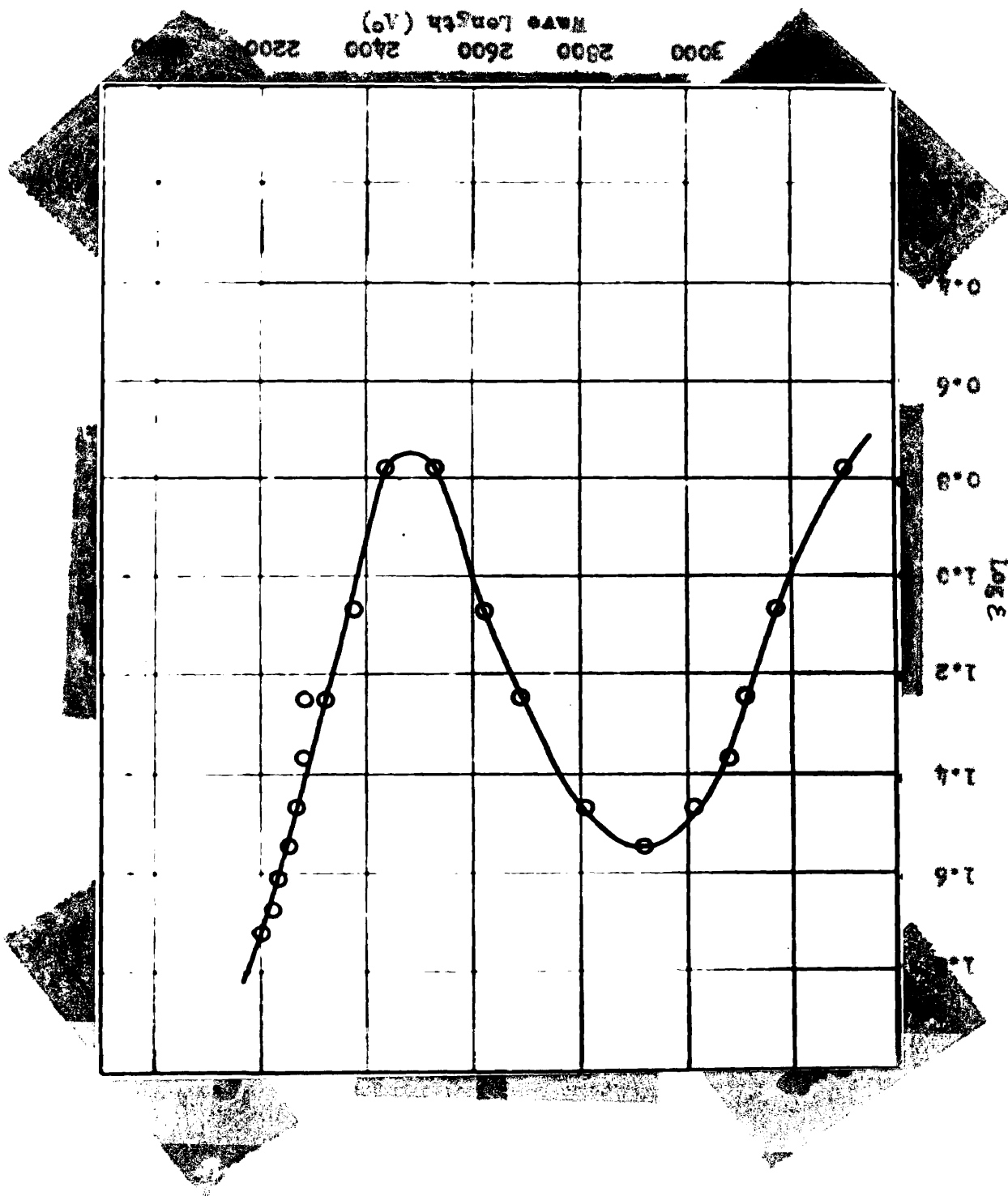Figure IV shows a plot of the data obtained from these absorption studies on friedonic acid. A maximum of absorption ($\log \mathcal{E} = 1.55$)

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is apparent at 2900 A° wave length. Another maximum may occur at 2300 A°, but the experimental data in this range is not accurate enough to justify any definite conclusions. Many alicyclic ketones, of which camphor is a notable example, show in the vicinity of 2930 A° a characteristic maximum of absorption (log = 1.57) due to the ketone function.[5] However, when a double bond is conjugated with this carbonyl group the maximum (log $\mathcal{E}$ = 4.1) is shifted to the vicinity of 2500 A°. It is apparent from this data that friedonic acid is not an α, β unsaturated ketone, but is probably a keto acid with a highly blocked carbonyl group.

When friedonic acid was heated in a melting point capillary to about forty degrees above its melting point, formation of bubbles in the viscous mass was observed. The evolution of gas became much more rapid as the temperature was raised. A larger quantity of friedonic acid was then heated in an atmosphere of nitrogen until no more bubbles were evolved and the gases produced were led through tubes containing anhydrone and ascarite in a manner similar to that employed in the usual carbon and hydrogen determination. In this manner it was found that one mole of friedonic acid yielded one mole of water and 0.85 mole of carbon dioxide. The product formed crystallized in beautiful crystals, which gave a strong tetranitromethane test for unsaturation. Analysis of this product corresponds to $C_{29}H_{48}$, and we shall call this substance norfriedelene. From its formula we conclude that it may have five rings and one double bond or four rings and two double bonds.

To decide between these two formulas, norfriedelene was hydrogenated by means of platinum (Adams' catalyst) and hydrogen and yielded a

5. Waters and Lowry, Physical Aspects of Organic Chemistry (New York: Van Nostrand, 1937) pp. 398-399.

product whose formula is $C_{29}H_{50}$ and which gives no tetranitromethane test for unsaturation. We have called this substance norfriedelene; furthermore, treatment of norfriedelene with a solution of one mole of perbenzoic acid in ether and chloroform yielded an oxide of formula $C_{29}H_{50}O$. This oxide could not be hydrolysed to the corresponding glycol. From this evidence, namely that norfriedelene adds one mole of hydrogen and reacts with one mole of perbenzoic acid, it seems reasonable to conclude that norfriedelene has five rings and one double bond.

We believe that the formation of norfriedelene takes place according to the following scheme:

$$\xrightarrow{\;250°\;} \quad + \; H_2O$$

$$\xrightarrow{\;250°\;} \quad + \; CO_2$$
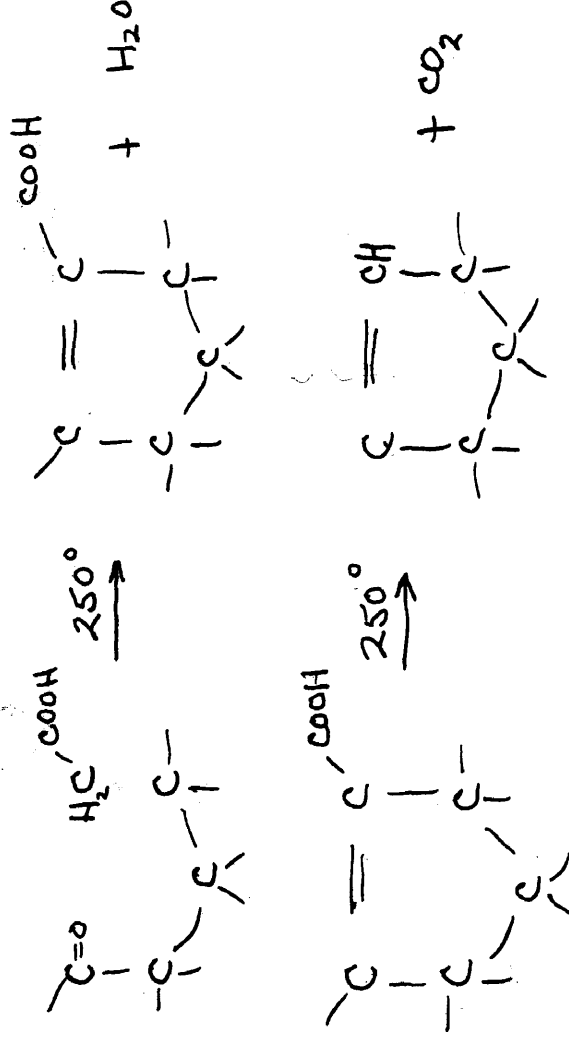
The carbonyl group condenses with the α-methylene group of the side chain after the manner of the Perkin reaction and the unsaturated acid produced becomes decarboxylated. This behavior is quite analogous to that of 12-keto cholanic acid[6], which, when heated to 300° loses water and carbon dioxide to yield dehydronorcholene. The pyrolysis of friedelic acid is very similar, but takes place much more readily and gives better

6. Wieland and Schlichting, Z. physiol. Chem. 150, 273, (1925)

yields. This reaction seems logical since the methylene group and the carbonyl group involved approach each other very closely in space, as can be seen from an examination of molecular models. The α,β unsaturated acid produced would be expected to lose carbon dioxide very easily on thermal treatment.[7]

To further degrade norfriedelene as well as to compare its properties with those of dehydronorcholene, the unsaturated compound was oxidised with potassium permanganate in glacial acetic acid. Wieland[8] under similar conditions obtained the next lower keto acid ($C_{29}H_{46}O_3$) from dehydronorcholene by oxidation. Norfriedelene, when oxidised with potassium permanganate in glacial acetic acid, yielded an acid whose analysis corresponds to the formula $C_{29}H_{48}O_3$ and which has properties very similar to those of friedonic acid. We shall refer to this acid as norfriedonic acid. This acid was converted to the methyl ester, and was reduced to norfriedololactone, which showed no depression in melting point when mixed with the product previously obtained by Drake and Campbell[1] directly from friedelin by oxidation. Carbonyl derivatives of norfriedonic acid as well as methyl norfriedonate can be prepared, the oxime of norfriedonic acid has been made, and the oxime and 2,4 dinitro phenyl hydrazone of methyl friedonate have been prepared in fairly good yields.

Friedonic acid when treated with thionyl chloride yielded an acid chloride which could not be crystallised. This acid chloride was reduced according to the procedure used by Rosenmund.[9] This treatment of

7. Hurd, The Pyrolysis of Carbon Compounds (New York: The Chem. Catalog Co., 1929) pp. 349-354.

8. Wieland and Wiedersheim, Z. physiol. Chem., 186, 229, (1930)

9. Rosenmund, Ber., 54, 437, (1921)

friedelin acid yielded a product of formula $C_{30}H_{50}O$, isomeric with friedelin, but differing from it in that it contains a highly reactive carbonyl group. This new product forms an oxime and a 2,4 dinitro phenyl hydrazone very readily in good yields, and when mixed with tetranitromethane gives no test for unsaturation. Although no Schiff's aldehyde test could be obtained, it is thought that this new substance is an aldehyde. This conclusion is reached because of the ease of formation of carbonyl derivatives and the ease of oxidation to the corresponding acid. The course of the reaction by which this aldehyde is formed is probably similar to the one involved in the production of norfriedelene from friedelic acid, that is, the α methylene group of the acid chloride, or the aldehyde formed by reduction, condenses with the carbonyl oxygen and yields an α,β unsaturated aldehyde which is saturated on further hydrogenation and yields a product containing the unit of structure shown:
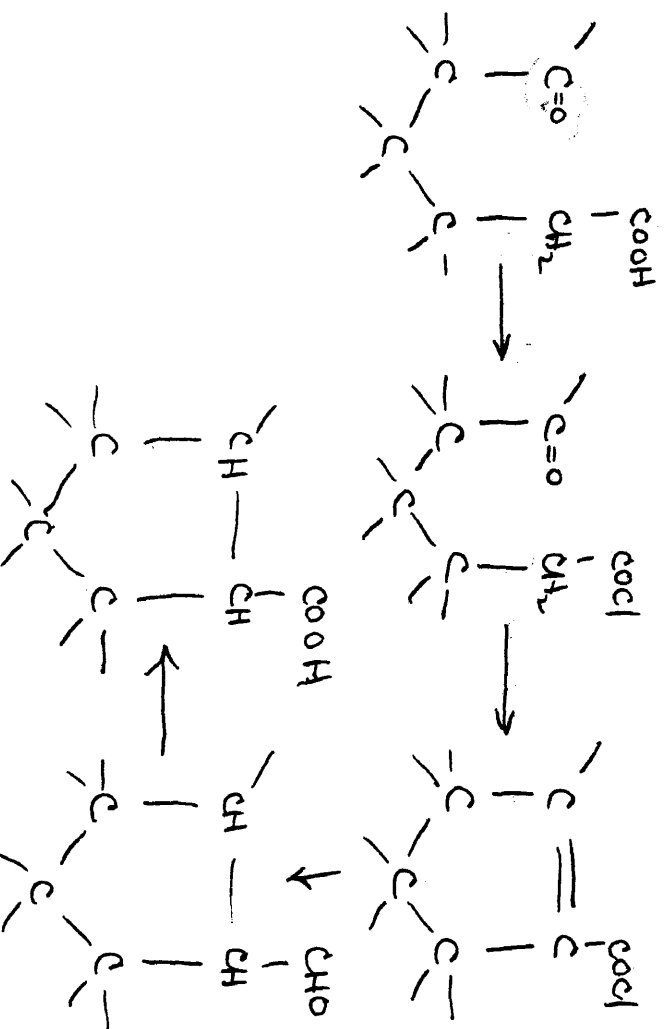

The aldehyde formed by Rosenmund reduction was oxidised with chromic anhydride in glacial acetic acid to an acid whose analyses check

fairly closely for $C_{30}H_{50}O_2$; this acid was converted to its methyl ester.

These two substances were very difficult to burn in a carbon and hydrogen analysis; only when an auxiliary platinum gauze contact was used in the front of the tube could acceptable carbon and hydrogen values be obtained. At best only carbon values of 0.4 to 0.5% low could be obtained. Hydrogen analyses were consistently good on these two compounds. Because this product from the Rosenmund reduction could be oxidized to an acid with two oxygen atoms and the same number of carbon atoms, it was concluded that it must be an aldehyde.

If the experimental data has been interpreted correctly, friedonic acid must be an epsilon keto acid with a highly blocked carbonyl group, and friedelin therefore must contain the unit of structure shown.
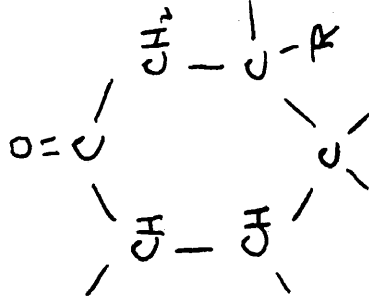
Friedonic acid
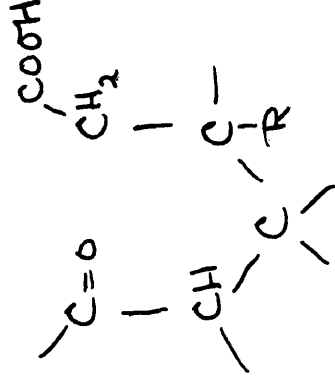
Friedelin

Preparation and Purification of Materials

The friedelin used in this research was extracted from 20-40 mesh cork with ethyl acetate by the method described by Drake and Jacobsen.[2] The crude ceria and friedelin was separated by crystallization from chloroform as previously described[2] and a "friedelin rich fraction was obtained.

Purification of Friedelin Rich Fraction.

The friedelin rich fraction from chloroform separation (38.3 gms.), melting at 249-255°, was crystallized five times from 450 ml. of pyridine to a melting point of 257-263° and gave a yield of 26.8 gms. (70%) of friedelin. Analysis of M. P. = 257°-263° and gave a yield of 26.8 gms. (70%) of friedelin. Analysis of the product confirmed its purity.

Oxidation of Friedelin.

Friedelin was oxidized using chromic acid as described by Drake and Campbell,[1] but their procedure was modified for use with larger quantities of material. Friedelin (24 gms.) of M. P. = 257°-263° was suspended in 2000 ml. of boiling glacial acetic acid in a 3 liter flask provided with an interchangeable ground glass joint for attaching a condenser. Chromic anhydride (12 g.) dissolved in 200 ml. of glacial acetic acid was added dropwise to the suspension through the condenser over a period of one and one-half hours. The mixture was then refluxed for 8 1/2 hours more. At the end of this time the glacial acetic acid was distilled off to a volume of 200 ml. and 2000 ml. of water was added to the boiling solution. The hot solution was filtered, the solid washed thoroughly with water and dried over potassium hydroxide to a constant weight. Yield = 24.5 gms. of light green solid. This solid was pulverized and shaken thoroughly with 800 ml. of cold ethyl ether. The residual precipitate of friedelin was filtered on a Buchner funnel, washed with cold ether, dried, and added directly, without purification.

to the next oxidation mixture. Yield = 5.0 gms. of recovered friedelin.

The ether solution was extracted repeatedly with 10% sodium hydroxide solution until no more sodium salt precipitated in the aqueous layer. The precipitated sodium salt was returned to the separatory funnel and washed twice with ether. The resulting mixture was centrifuged, the upper ether layer removed, and the lower aqueous sodium hydroxide layer containing most of the green color poured off. The resulting sodium salt was added to a separatory funnel and acidified with conc. hydrochloric acid. After cooling this mixture it was extracted twice with cold ethyl ether and the ether was evaporated to a thick gum which was then dissolved in 95% ethyl alcohol (25 cc.), seeded with a few crystals of friedonic acid, and cooled overnight. The resulting crystalline mass was filtered and washed with cold ethyl alcohol. Yield of crude friedonic acid = 7.3 gms. M. P. = 196-198°. Recrystallization of this product from ethyl alcohol yielded 6.0 gms. of friedonic acid melting at 205-207°. The combined ether extracts were washed with water until free from sodium hydroxide, whereupon the ether was removed to dryness. The solid residue was diluted with ethyl alcohol and filtered. The crystals were almost pure friedelin. Yield of friedelin = 3.5 gms. This friedelin was added directly to the next oxidation mixture.

Total friedelin recovered = 11.5 gms.

Friedelin oxidized = 12.5 gms.

Yield of friedonic acid = 6.0 gms. (48%)

EXPERIMENTAL

Hydroxyfriedonolactone. Friedonic acid (0.2 g.) was dissolved in 25 ml. of ethyl alcohol, containing 1 gm. of dissolved sodium, and was allowed to stand at room temperature 48 hours. The mixture was acidified, diluted with water, and filtered. On recrystallization of the solid from ethyl alcohol 0.1 gm. of friedonic acid was obtained. The filtrate from the crystallization was evaporated to dryness and triturated with a little ethyl alcohol in the cold. The undissolved crystals were filtered and recrystallized from ethyl alcohol to yield a small quantity of a nicely crystalline substance melting at 126-127°. When treated with .02 N sodium hydroxide this product showed no acidic properties. A mixed melting point the substance with hydroxyfriedonolactone obtained from friedelin by oxidation showed no depression.

Anal. Calc'd for $C_{30}H_{50}O_3$: C, 78.54; H, 11.00.

Found, C, 78.49, 78.65; H, 11.09, 11.08.

Methyl Friedonate.

Method I. One gram of friedonic acid (M. P. = 205-207°) was dissolved in 50 ml. of methyl alcohol containing 0.1 g. of dissolved sodium. Five ml. of methyl sulfate were added and the mixture refluxed one and one-half hours. Half of the solvent was evaporated, the mixture diluted with 100 ml. of water, and extracted twice with ether. The solid obtained by from methanol reformed the removal of the ether was recrystallized from methyl alcohol as silky needles, which after several recrystallizations melted at 157-158°.

Anal. Calc'd for $C_{31}H_{52}O_3$: C, 78.75; H, 11.09. Found; C, 78.59, 78.57; H, 11.08, 11.22. Theory methoxyl: 6.54. Found: 6.59, 6.52.

Method II. One gram of friedonic acid (M. P. = 205-207°) was dissolved in 50 ml. of methyl alcohol containing 0.1 gm. of dissolved sodium. Methyl iodide (5 ml.) was added and the mixture was refluxed three hours, about two-thirds of the solvent was evaporated, and the residue poured into water. This mixture was extracted with ether. The ether layer was washed with sodium bisulfite solution and then twice with water. The ether was removed to dryness and 0.82 gms. of solid produced was recrystallized from methyl alcohol to a melting point of 157-158°. A mixed melting point of this product with the product obtained using dimethyl sulfate showed no depression.

Method III. Nitroso methyl urea was prepared by the directions given in Organic Syntheses[11] and then diazomethane was prepared from this product by warming with 50% potassium hydroxide.[12] Friedonic acid (1 gm.) was dissolved in absolute ethyl ether and a solution of diazomethane in ether was added until the yellow color remained in the friedonic acid solution. The ether and excess diazomethane were evaporated on a steam bath in the hood. The solid residue was recrystallized from methyl alcohol to yield 0.98 gms. of a product of melting point 157-158°. This product showed no depression in melting point when mixed with the methyl friedonate previously prepared.

Reduction of Friedonic Acid. Friedonic acid (0.5 gm.) of M. P. = 205-207° and 0.5 gm. of Adam's platinum catalyst were mixed with 18 ml. of glacial acetic acid. This mixture was shaken and hydrogen was added to the system. After shaking for 12 hours the required amount of hydrogen had been taken up. The catalyst was filtered off and the resulting solution was

11. C. R. Noller, Organic Syntheses (New York: John Wiley and Sons, 1935) Vol. XV, p. 48.

12. Ibid Vol. XV, p. 3.

diluted with water (100 ml.). The jelly-like precipitate was filtered, dried, and recrystallized from ethyl acetate to a melting point of 308°-312°. This product showed no depression in melting point when mixed with friedololactone previously obtained ~~specials and express~~.

$\overset{3}{}$

$\overset{\text{Isomer A}}{}$

Methyl Friedonate from Hydroxyfriedonolactone.

One gram of "isomer A" hydroxyfriedonolactone (M. P. = 126-127°) was treated with sodium methoxide and dimethyl sulfate in the same manner as friedonic acid above, and yielded a product, which after several recrystallizations from methyl alcohol melted at 157-158°. A mixed melting point with methyl friedonate prepared from pure friedonic acid showed no depression.

Norfriedelene.

Friedonic acid (2.93 g.) was heated in an atmosphere of nitrogen for two and one-half hours at 250°. The water and carbon dioxide evolved were collected and weighed in absorption tubes. The melt was cooled and the solid material obtained was recrystallized three times from an ethyl acetate-benzene mixture to a constant melting point of 228.5-230°. The product, of which 1.82 g. were obtained, gave a yellow color with tetranitromethane showing the presence of unsaturation.

Anal. Calc'd for $C_{29}H_{48}$: C, 87.79; H, 12.21. Found: C, 87.75, 87.94; H, 12.28, 12.26.

Norfriedelane.

One-half gram of norfriedelene was dissolved in 50 ml. of ethyl ether-ethyl acetate mixture and 0.1 gm. of Adams' platinum oxide catalyst was added. The mixture was agitated and hydrogen was added at room temperature for five hours. After evaporation of the solvent the solid obtained was recrystallized from benzene to a constant melting point of 220-221°. This procedure yielded 0.44 gm. of product which gave no yellow color with tetranitromethane. A mixed melting point with norfriedelene showed the normal depression.

Anal. Calc'd for $C_{29}H_{50}$: C, 87.36; H, 12.65. Found: C, 87.41,

87.44; H, 12.79; 12.82.

Norfriedelic Acid.

Two grams of powdered norfriedelone, three grams of powdered potassium permanganate, and 120 ml. of glacial acetic acid, previously distilled from chromic anhydride, were stirred vigorously for eight hours at room temperature. Five grams of sodium bisulfite were added and the mixture diluted with 400 ml. of water. The acid was extracted with ether and the sodium salt formed on addition of 10% sodium hydroxide. The ~~centrifuged~~, separated, and acidified with hydrochloric acid. After several crystallisations from ethyl alcohol 0.75 gm. of acid melting at 215-217° was obtained. The residues from crystallisations contained 0.95 gm. of amorphous material which could not be induced to crystallise.

Anal. Calc'd for $C_{29}H_{48}O_2$: C, 78.31; H, 10.89. Found[13], C,

78.20, 78.27; H, 11.02, 11.03.

Methyl Norfriedelate.

Method I: Norfriedelic acid (0.15 gm.) was dissolved in 15 ml. of methyl alcohol containing 0.1 gm. of dissolved sodium. One ml. of dimethyl sulfate was added and the mixture refluxed one and one-half hours. After cooling, the crystalline mass was filtered and washed well with water. Several recrystallisations from methyl alcohol yielded a product melting at 166-167°.

Anal. Calc'd for $C_{30}H_{50}O_2$: C, 78.54; H, 11.00. Found[13]: C,

78.52, 78.63; H, 10.87, 10.94. Theory methoxyl: 6.78. Found[13], 6.97,

6.78. Theory M. W.: 458. M. W. found from methoxyl: 452, 458.

Method II: Norfriedelic acid (0.5 gm.) was dissolved in absolute

13. The author wishes to thank Leonard Smith for these analyses.

ether and a solution of diazomethane[11,12] in ether was added until the yellow color remained. The solution was then evaporated to dryness on the steam bath and the residue was recrystallized from methyl alcohol to yield 0.49 gm. of silky needles melting at 166-167°. This product showed no depression in melting point when mixed with the one obtained using dimethyl sulfate.

Norfriedelolactone. Norfriedelanic acid (0.1 gm.) was dissolved in 10 ml. of n-propanol; the mixture was refluxed, and .05 g. sodium added. After cooling, the mixture was diluted with 30 ml. of water and then made acid to congo red with conc. hydrochloric acid. The white precipitate was filtered and recrystallized from ethyl acetate to yield 10 mg. of a product melting at 233-290°. This product showed no depression in melting point when mixed with norfriedelolactone obtained by Drake and Campbell.

Norfriedelanic Acid Oxime. Norfriedelanic acid (0.25 gm.) and 0.15 gm. of hydroxylamine hydrochloride were dissolved in 10 ml. of ethyl alcohol. A solution of 0.15 gm. of potassium hydroxide in 5 ml. of ethyl alcohol was added and the mixture was refluxed 30 minutes. The resulting mixture was diluted with water (25 ml.) and acidified with 10% sulfuric acid. The solution was extracted twice with benzene and ethyl alcohol mixture (90-10). The solvent was removed and the solid residue was recrystallized from a benzene-ethyl alcohol mixture (50-90) to yield (0.22 gm.) of oxime melting at 270.5-273° and crystallized as colorless needles having parallel extinction.

Anal. Calc'd for $C_{29}H_{49}O_3N$: C, 75.75; H, 10.73. Found: C, 75.94, 75.93; H, 10.83, 10.90.

Methyl Norfriedelanate Oxime. Methyl norfriedelanate (0.2 gm.) and 0.15 gm. of hydroxylamine hydrochloride were dissolved in 5 ml. of pyridine and allowed to stand at room temperature for 24 hours. The mix-

ture was then diluted with water, filtered, and washed well with water. The product was recrystallized from methyl alcohol to yield 0.17 gm. of the pure acid (0.178) material melting at 193-195°, and on further purification.

Anal. Calc'd for $C_{20}H_{31}O_3N$: C, 76.04; H, 10.36. Found: C, 75.93, 75.85; H, 11.01, 10.72.

2,4 Dinitrophenylhydrazone of Methyl Norfriedonate.

Methyl friedonate (0.2 gm.) was dissolved in 5 ml. of ethyl cellosolve and 0.12 gm. of 2,4 dinitrophenylhydrazine was dissolved in 5 ml. of cellosolve was added to the solution. Two drops of conc. hydrochloric acid were then added and the mixture was refluxed for five minutes. The mixture was allowed to stand overnight to complete crystallization, and during which time crystals appeared; the yellow orange needles formed were crystallized from ethyl alcohol-benzene the (0.152) eq mixture to yield 0.15 gm. of a product melted at 233-234° and formed.

Anal. Calc'd for $C_{26}H_{35}N_4O_6$: C, 67.62; H, 8.38. Found: C, 67.36; H, 8.40.

Norfriedelonyl Formaldehyde.

One gram of friedonic acid and 5 ml. of thionyl chloride were heated to reflux on a steam bath for about 30 minutes. Excess thionyl chloride was removed in vacuo and the residue was placed in a dessicator over potassium hydroxide for 48 hours; the acid chloride could not be induced to crystallize. Xylene (15 ml.), previously dried over sodium, was added along with two grams of palladium-barium sulfate catalyst, and hydrogen was passed through the mixture at 150° for seven hours during which time 1 gm. of fresh catalyst was added. The hydrogen chloride evolved was collected and titrated with .05 N sodium hydroxide. The quantity of hydrogen chloride produced was approximately

14. Houben, Die Methoden der Organische Chemie, 3, 520, (1925)

85 per cent of that calculated for one mole per mole of substance. The solvent was removed under reduced pressure, and the partially crystalline mass was treated with ethyl acetate. After several recrystallizations which and crystalline from ethyl acetate 0.20 gm. of substance melted at 222-225° was obtained.

Anal. Calc'd for $C_{30}H_{50}O$: C, 84.43; H, 11.82. Found: C, 84.51, 84.66; H, 11.80, 12.10.

The residues from recrystallizations were dissolved in ether and the product obtained by treatment of this ether solution with sodium hydroxide and conc. hydrochloric acid, followed by crystallization of the solid produced from ethyl alcohol, yielded 0.3 gm. of Friedenic acid.

Oxime of Norfriedelanyl Formaldehyde. Forty mg. of norfriedelanyl formaldehyde was dissolved in 5 ml. of benzene containing 3 ml. of ethyl alcohol. Fifteen mg. of hydroxylamine hydrochloride dissolved in 3 ml. of ethyl alcohol was added and the mixture refluxed. Potassium hydroxide (12 mg.) dissolved in 2 ml. of alcohol was added, and the mixture was refluxed one hour, cooled, acidified with sulfuric acid, and diluted with water. The mixture was extracted with benzene and the solid remaining after removal of the benzene was recrystallized several times from ethyl acetate yielding 30 mg. of oxime melting at 255-259°.

Anal. Calc'd for $C_{30}H_{50}NOH$: C, 81.57; H, 11.65. Found: C, 81.50, 81.64; H, 11.62, 11.54.

2,4 Dinitrophenyl Hydrazone of Norfriedelanyl Formaldehyde.

Fifty mg. of norfriedelanyl formaldehyde was dissolved in 5 ml. of ethyl cellosolve and a solution of 25 mg. of 2,4 dinitrophenyl hydrazine in 5 ml. of ethyl cellosolve. One drop of conc. hydrochloric acid was added and the mixture was refluxed 15 minutes during which time yellow needles separated from the mixture. After several recrystallization

from benzene 36 mg. of bright yellow crystals melting with decomposition
at 312°-314° *was* were obtained. *This material crystallized as bright yellow needles having parallel extinction.*

     Anal. Calc'd for $C_{36}H_{54}N_4O_4$: C, 71.26; H, 8.97. Found: C,
71.13, 71.21; H, 8.84, 8.85. *To 0.3g. of I*

Norfriedelanyl Formic Acid. ~~Norfriedelanyl formaldehyde (0.3~~
~~gm.) was~~ *was added* dissolved in 50 ml. of glacial acetic acid at 100° ~~and~~ a solu-
tion of 60 mg. of chromic anhydride dissolved in 30 ml. of acetic acid.
~~were added.~~ The mixture was then evaporated to 20 ml. total volume and
diluted with 50 ml. of water. The crystals formed were filtered, ~~and~~ dried.
~~The solid was~~ dissolved in ether, and extracted twice with 10% sodium
hydroxide solution. The aqueous layer was centrifuged and acidified with
hydrochloric acid. The solid formed was filtered and recrystallized from
glacial acetic acid. ~~yielding 0.22 gm. of~~ *The product was* an acid, melted at 307~308°. *(0.22g), which crystallized*

     Anal. Calc'd for $C_{30}H_{50}O_2$: C. 81.37; H. 11.99. Found: C.
80.90, 81.10; H. 11.40, 11.46.

Methyl Norfriedelanyl Formate. Norfriedelanyl formic acid
(.04 g.) was dissolved in 10 ml. of methyl alcohol containing 0.05 gm. of
dissolved sodium. One ml. of dimethyl sulfate was added. The mixture
was refluxed one-half hour and crystals formed from the boiling mixture.
The cooled mixture was filtered, *and* the crystals were dried and recrystallized
from a mixture of pyridine and methyl alcohol. Twenty-five mg. of methyl
ester melting at 230~231.5° was obtained.

     Anal. Calc'd for $C_{31}H_{52}O_2$: C, 81.51; H. 11.49. Found: C.
81.15; H. 11.47.

SUMMARY

1. An isomer of friedonic acid, hydroxyfriedonolactone, has been isolated and its conversion to methyl friedonate has been described.

2. Pyrolysis of friedonic acid has been shown to result in the production of an unsaturated hydrocarbon, norfriedelene, which has been hydrogenated to norfriedelane.

3. Oxidation of norfriedelene was found to yield norfriedonic acid, a monobasic keto acid of which Carbonyl and carboxyl derivatives have been made.

4. Reduction of friedonyl chloride has been shown to result in the formation of an aldehyde isomeric with friedelin. The aldehyde has been oxidized to the corresponding acid.

5. Friedonic acid is apparently an epsilon keto acid containing a highly blocked carbonyl group.

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