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LINEARITY OF PLOTS OF GAS CHROMATOGRAPHIC RETENTION DATA FOR OXYGEN-CONTAINING ORGANIC COMPOUNDS ON POROUS POLYMERS

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SUMMARY

The linearity of the relationship between retention data and carbon number for homologous series of oxygen-containing organic compounds has been investigated for the series of Porapak porous polymers in gas chromatography. A marked deviation from linearity occurs with the lower members of normal alcohols, aldehydes, acetates and methyl ketones.

INTRODUCTION

Since the mid-1960's and the pioneering work of Hollis[1,2] the use of porous polymers for gas chromatographic (GC) separations has become widespread. These polymer beads are considered to have separating powers normally associated with both gas–solid and gas–liquid chromatographies[3]. Hollis[1] considered the solubility of the compound in the polymer to be the most important factor determining retention behaviour, whereas Smith and Waddington[4] reported that a linear relationship exists between the logarithm of the retention times and the boiling points of compounds in a homologous series. Johnson and Barrall[5] showed that surface characteristics such as pore size distribution, pore volume and surface area are important in determining separating power of the polymer.

Of major concern when using porous polymer packings in gas chromatography is the irreproducibility of retention behaviour. This may result from various factors, the most important being the methods used to condition the column[4] and variations between batches of polymer[6,7]. The extent of the anomalous behaviour of these packings can be large. For example, Hollis[8] found that the elution order of C_2 hydrocarbons was dependent on the type of Porapak and temperatures employed. Recently, Castello and D'Amato[9] showed that the adjusted retention times of compounds vary with column temperature, in different ways, depending on the type of Porapak.

Porous polymers are often used for the separation of highly polar compounds such as alcohols[10] and for the determination of water in organic systems[2]. Therefore

it is necessary to characterize the retention behaviour of oxygen-containing organics as well as hydrocarbons.

Linearity of the plot of corrected retention time *versus* carbon number is a basic assumption in the methods of reporting retention behaviour. In a recent publication[11] we have shown that the method of Ševčik[12,13] provides a sensitive test of the linearity of such plots for the *n*-alkanes. This method employs the ratio, *A*, of the differences in uncorrected retention times for neighbouring *n*-alkanes in a homologous series, *i.e.*, the ratio of the antilogarithms of the slopes of the lines between successive pairs of *n*-alkanes; hence it gives a measure of the constancy of the slope of the *n*-alkane line.

Until recently this test of linearity had only been performed on the retention time data obtained for *n*-alkanes on stationary phases of different polarities. In a previous publication[14] we determined the linearity of plots of retention data for *n*-alkanes on porous polymers and found non-linearity for methane and ethane. In this paper we have investigated the linearity of retention time *versus* carbon number for series of normal alcohols, aldehydes, acetates and methyl ketones using the same range of porous polymer packings.

EXPERIMENTAL

The equipment used consisted of a Hewlett-Packard 5750 research chromatograph interfaced to a 16K PDP 11/40 digital computer. Interfacing was achieved by the use of an LPS 11 Laboratory Peripheral System comprising a 12-bit analog-to-digital converter, a programmable real-time clock with two Schmitt triggers and a display controller with two 12-bit digital-to-analog converters. All on-line programming was written in CAPS II Basic with LPS options. The sampling rate was 0.5 sec.

The retention times measured for the alkanes were used to calculate the dead times by the method of Grobler and Balizs[15]. This method has been shown to be simple and accurate[16]. The dead time, t_m, the slope, b, and intercept, C, were then used in eqn. 1 to estimate the uncorrected retention times, t_r, of the various compounds of carbon number Z:

$$\log (t_m - t_m) = bZ + C \tag{1}$$

The ratio, A, of the differences in retention times was calculated as an alternative method of assessing the linearity for the alkanes.

Samples of Porapak (N, P, PS, Q, QS, R, S and T) polymer beads (80–100 mesh) were obtained from Waters Assoc. They were packed in PTFE columns (6 ft. × 1/8 in. O.D.). A mixture of *n*-alkanes from methane to heptane in nitrogen was obtained from Commonwealth Industrial Gases Ltd. It was introduced to the column by a gas sampling valve. The oxygen-containing compounds were injected as liquids. The column oven was operated isothermally at temperatures below the limits recommended by the manufacturer.

RESULTS AND DISCUSSION

The results for *n*-alkanes are presented in Table I to aid discussion of the results

for normal alcohols, aldehydes, acetates and methyl ketones which are given in Table II–V respectively.

It is apparent from the data in Table I that the plot of retention time *versus* carbon number for the lower alkanes is non-linear. This is evident from the values of A calculated for the C_1–C_3 and C_2–C_4 n-alkanes. The values of A calculated for higher alkanes are essentially constant. On all porous polymers the A value is lower for the C_1–C_3 n-alkanes and higher for the C_2–C_4 n-alkanes than the constant value observed for the series of n-alkanes with carbon number $\geq$ 3. These results indicate that the retention times for methane and ethane are different from those expected for n-alkanes having carbon numbers of one and two, respectively. This suggests that there is curvature in the plot of corrected retention time *versus* carbon number for n-alkanes.

The values of A in Table II suggest that the non-linearity in the plot of retention time *versus* carbon number for the lower n-alcohols is not the same as for the corresponding n-alkanes. This is evident from the A values calculated for the C_1–C_3 and C_2–C_4 compounds in both series. In the case of the n-alcohols the A value for the C_1–C_3 compounds is higher than the constant value observed for higher alcohols. In addition, the value of A becomes essentially constant for the series of n-alcohols of carbon number $\geq$ 2.

The results for n-aldehydes (Table III) and acetates (Table IV) do not show a particular trend in A values with carbon number. The values of A calculated for C_2–C_4 methyl ketones are higher than the constant values observed for compounds of greater carbon number in this series.

Two major effects can be noted from the results presented in Tables I–V. First, the plots of retention time *versus* carbon number show non-linearity for n-alkanes, n-alcohols, n-aldehydes, acetates and methyl ketones of low carbon numbers. The origin of the non-linearity varies from one group of compounds to another. Since the boiling points of the oxygen-containing compounds are significantly greater than for the n-alkanes of the same carbon number, it is suggested that the non-linearity of the plots for lower members of these homologous series may result from the time of elution. That is, peaks eluated early will not conform to a linear relationship between corrected retention time and carbon number. This suggests that physical rather than chemical effects make a large contribution to the non-linearity.

Secondly, constant values of A are obtained from the retention times of ethanol and higher alcohols (Table II). Therefore, the injection of a mixture of C_2–C_5 n-alcohols should provide a good estimate of the column dead time for porous polymers. Estimation of dead time by this method may be preferable to the use of four n-alkanes of carbon number $\geq$ 4. The main advantages of the use of n-alcohols is that they can be injected as a liquid (whereas the vapours must be used if n-butane is to be included in the n-alkane mixture), and the retention times of the C_2–C_5 n-alcohols are shorter than those of C_5–C_8 n-alkanes if liquid mixtures are injected.

Since one of the main applications for porous polymer packings is to the separation of polar compounds, it is suggested that mathematical estimation of dead time using the retention times of C_2–C_5 n-alcohols is a useful method of determining system dead time for these columns. The use of homologous series of compounds other than n-alkanes for this purpose has also been shown to be effective[17].

TABLE I

RETENTION TIME DATA FOR C_1–C_7 n-ALKANES

Column conditions	Alkane	t (sec)	t_{calc}(sec)	t' (sec)	A
Porapak N	Methane	39.9	39.0	13.7	
Temperature, 100°C	Ethane	60.0	59.3	33.8	2.49
Carrier gas (helium),	n-Propane	110.0	111.3	83.8	2.64
52 ml/min	n-Butane	242.0	244.9	215.8	2.54
Dead time, 26.2 sec	n-Pentane	577.0	588.6	550.8	2.59
	n-Hexane	1443.8	1472.0	1417.6	2.58
	n-Heptane	3680.0	3743.3	3653.8	
Porapak P	Methane	78.4	79.6	12.0	
Temperature, 110°C	Ethane	95.8	95.8	29.4	1.88
Carrier gas (helium),	n-Propane	128.5	131.7	62.1	2.46
48 ml/min	n-Butane	209.1	211.6	142.7	2.20
Dead time, 66.4 sec	n-Pentane	382.0	389.2	315.6	2.23
	n-Hexane	767.5	784.3	701.1	2.32
	n-Heptane	1660.5	1662.9	1594.1	
Porapak PS	Methane	61.5	61.8	8.2	
Temperature, 110°C	Ethane	72.5	72.2	19.2	1.95
Carrier gas (helium),	n-Propane	94.0	95.3	40.7	2.47
50 ml/min	n-Butane	147.0	146.5	93.7	2.20
Dead time, 53.3 sec	n-Pentane	263.8	260.0	210.5	2.19
	n-Hexane	519.5	511.6	466.2	2.19
	n-Heptane	1080.3	1070.8	1027.0	
Porapak Q	Methane	71.5	70.1	25.0	
Temperature, 220°C	Ethane	90.5	87.7	44.0	1.42
Carrier gas (helium),	n-Propane	117.5	118.4	71.0	1.88
48 ml/min	n-Butane	168.3	172.2	121.8	1.77
Dead time, 46.5 sec	n-Pentane	258.0	266.1	211.5	1.79
	n-Hexane	419.0	430.3	372.5	1.79
	n-Heptane	707.9	717.1	661.4	
Porapak QS	Methane	58.2	58.3	15.7	
Temperature, 230°C	Ethane	69.5	69.4	27.0	1.64
Carrier gas (helium),	n-Propane	88.0	88.5	45.5	1.81
44 ml/min	n-Butane	121.5	121.1	79.0	1.69
Dead time, 42.5 sec	n-Pentane	177.5	177.0	135.0	1.70
	n-Hexane	272.8	272.4	230.2	1.71
	n-Heptane	436.0	435.7	393.5	
Porapak R	Methane	44.5	43.4	12.8	
Temperature, 180°C	Ethane	55.3	53.3	23.6	1.45
Carrier gas (helium),	n-Propane	71.0	71.8	39.3	2.01
40 ml/min	n-Butane	102.5	105.9	70.8	1.90
Dead time, 31.7 sec	n-Pentane	162.5	169.0	130.8	1.89
	n-Hexane	275.8	285.8	244.1	1.90
	n-Heptane	491.0	502.0	459.3	
Porapak S	Methane	58.5	57.7	15.4	
Temperature, 180°C	Ethane	72.3	70.7	29.2	1.59
Carrier gas (helium),	n-Propane	94.3	95.4	51.2	2.05
40 ml/min	n-Butane	139.5	142.0	96.4	1.91
Dead time, 43.1 sec	n-Pentane	225.8	230.3	182.7	1.90
	n-Hexane	389.8	397.1	346.7	1.91
	n-Heptane	703.3	712.7	660.2	
Porapak T	Methane	43.0	40.4	15.4	
Temperature, 120°C	Ethane	56.5	53.0	28.9	1.60
Carrier gas (helium),	n-Propane	76.5	77.9	48.9	2.20
38 ml/min	n-Butane	120.5	127.1	92.9	2.00
Dead time, 27.6 sec	n-Pentane	208.25	224.4	180.7	2.04
	n-Hexane	387.0	417.0	359.4	2.09
	n-Heptane	761.0	797.7	733.4	

TABLE II

RETENTION TIME DATA FOR ALCOHOLS

Column conditions	Alcohol	t(sec)	t_{calc}(sec)	t'(sec)	A
Porapak	Methanol	79.5	85.4	34.2	
Temperature, 180°C	Ethanol	122.5	129.6	77.2	2.51
Carrier gas (helium),	n-Propanol	230.5	222.2	185.2	2.01
33 ml/min	n-Butanol	448.0	416.6	402.7	2.01
Dead time, 45.3 sec	n-Pentanol	886.0	824.7	840.7	1.99
	n-Hexanol	1756.5	1681.5	1711.2	
Porapak P	Methanol	76.0	78.0	16.5	
Temperature, 190°C	Ethanol	88.0	92.0	28.5	2.58
Carrier gas (helium),	n-Propanol	119.0	116.4	59.5	1.60
30 ml/min	n-Butanol	168.5	159.1	109.0	1.64
Dead time, 59.5 sec	n-Pentanol	249.75	233.8	190.3	1.50
	n-Hexanol	371.75	364.8	312.3	
Porapak PS	Methanol	61.5	63.4	13.1	
Temperature, 180°C	Ethanol	71.5	75.1	23.1	2.70
Carrier gas (helium),	n-Propanol	98.5	95.8	50.1	1.59
35 ml/min	n-Butanol	141.5	132.5	93.1	1.66
Dead time, 48.4 sec	n-Pentanol	212.75	197.8	164.3	1.53
	n-Hexanol	321.5	313.6	273.1	
Porapak Q	Methanol	63.0	66.9	28.1	
Temperature, 200°C	Ethanol	97.0	101.6	62.1	2.40
Carrier gas (helium),	n-Propanol	178.5	173.8	143.6	2.03
37 ml/min	n-Butanol	343.75	324.2	308.9	2.03
Dead time, 34.9 sec	n-Pentanol	679.0	637.3	644.1	1.96
	n-Hexanol	1335.5	1289.4	1300.6	
Porapak QS	Methanol	73.0	74.7	34.0	
Temperature, 200°C	Ethanol	113.0	115.8	74.0	2.40
Carrier gas (helium),	n-Propanol	209.0	204.1	170.0	2.03
30 ml/min	n-Butanol	403.5	393.7	364.5	2.11
Dead time, 39.0 sec	n-Pentanol	813.0	801.1	774.0	2.17
	n-Hexanol	1700.0	1676.6	1661.0	
Porapak R	Methanol	56.5	59.5	22.6	
Temperature, 200°C	Ethanol	83.0	86.7	49.1	2.42
Carrier gas (helium),	n-Propanol	147.0	142.9	113.1	1.96
35 ml/min	n-Butanol	272.5	258.6	238.6	2.05
Dead time, 33.9 sec	n-Pentanol	529.25	497.3	495.4	1.92
	n-Hexanol	1022.9	989.7	989.0	
Porapak S	Methanol	58.5	62.3	19.3	
Temperature, 200°C	Ethanol	82.5	87.1	43.3	2.56
Carrier gas (helium),	n-Propanol	143.5	138.3	104.3	1.95
32 ml/min	n-Butanol	263.5	244.4	224.3	2.01
Dead time, 39.2 sec	n-Pentanol	504.5	464.0	465.3	1.90
	n-Hexanol	963.5	918.6	924.3	
Porapak T	Methanol	62.0	65.5	14.7	
Temperature, 180°C	Ethanol	73.75	79.8	26.5	3.13
Carrier gas (helium),	n-Propanol	110.5	105.4	63.2	1.56
34 ml/min	n-Butanol	168.0	151.1	120.7	1.58
Dead time, 47.3 sec	n-Pentanol	259.0	232.7	211.7	1.49
	n-Hexanol	395.0	378.6	347.7	

TABLE III

RETENTION TIME DATA FOR ALDEHYDES

Column conditions	Aldehyde	t (sec)	t_{calc} (sec)	t' (sec)	A
Porapak N	n-Propanal	82.5	82.7	80.5	
Temperature, 180°C	n-Butanal	156.1	155.2	154.1	1.76
Carrier gas (helium),	n-Pentanal	285.5	292.7	283.4	2.17
36 ml/min	n-Hexanal	566.6	554.0	564.5	1.71
Dead time, 2.1 sec	n-Heptanal	1048.3	1050.1	1046.3	
Porapak N	n-Propanal	104.8	105.9	64.0	
Temperature, 180°C	n-Butanal	143.2	146.3	102.4	1.78
Carrier gas (helium),	n-Pentanal	211.6	211.6	170.7	1.65
40 ml/min	n-Hexanal	324.6	317.5	283.7	1.54
Dead time, 40.9 sec	n-Heptanal	498.2	489.0	457.3	1.55
	n-Octanal	767.1	766.8	726.2	
Porapak PS	n-Propanal	37.5	38.1	23.9	
Temperature, 180°C	n-Butanal	50.6	52.2	37.0	1.75
Carrier gas (helium),	n-Pentanal	73.5	74.6	59.9	1.80
34 ml/min	n-Hexanal	114.75	109.9	101.1	1.38
Dead time, 13.6 sec	n-Heptanal	171.6	165.8	158.0	1.44
	n-Octanal	235.5	254.1	239.8	
Porapak Q	n-Propanal	60.9	62.4	50.3	
Temperature, 230°C	n-Butanal	97.25	100.2	86.7	1.86
Carrier gas (helium),	n-Pentanal	165.0	165.5	154.4	1.81
38 ml/min	n-Hexanal	287.3	278.2	276.7	1.63
Dead time, 10.6 sec	n-Heptanal	486.75	473.0	476.2	1.64
	n-Octanal	813.25	809.6	802.7	
Porapak QS	n-Propanal	44.9	46.0	38.8	
Temperature, 240°C	n-Butanal	69.1	71.5	62.9	1.78
Carrier gas (helium),	n-Pentanal	112.25	113.4	106.1	1.78
45 ml/min	n-Hexanal	189.1	182.2	183.0	1.52
Dead time, 61.1 sec	n-Heptanal	306.1	295.2	299.9	1.49
	n-Octanal	480.7	480.5	474.6	
Porapak R	n-Propanal	48.5	49.5	40.7	
Temperature, 220°C	n-Butanal	71.5	74.6	63.7	1.91
Carrier gas (helium),	n-Pentanal	115.5	114.7	107.7	1.58
40 ml/min	n-Hexanal	185.0	178.9	177.2	1.50
Dead time, 7.8 sec	n-Heptanal	289.5	281.7	281.7	1.50
	n-Octanal	446.5	446.3	438.7	
Porapak S	n-Propanal	85.6	86.9	67.2	
Temperature, 230°C	n-Butanal	127.7	130.7	109.3	1.81
Carrier gas (helium),	n-Pentanal	204.1	203.1	185.7	1.62
35 ml/min	n-Hexanal	328.1	322.2	309.8	1.61
Dead time, 18.4 sec	n-Heptanal	527.5	518.0	509.1	1.51
	n-Octanal	840.7	840.0	822.5	
Porapak T	n-Propanal	36.9	37.4	34.6	
Temperature, 190°C	n-Butanal	55.4	57.1	53.1	1.75
Carrier gas (helium),	n-Pentanal	87.7	87.7	85.4	1.61
40 ml/min	n-Hexanal	139.6	135.6	137.3	1.43
Dead time, 2.2 sec	n-Heptanal	213.7	210.2	211.5	1.55
	n-Octanal	326.2	326.5	324.0	

TABLE IV

RETENTION TIME DATA FOR ACETATES

Column conditions	Acetate	t (sec)	t_{calc} (sec)	t' (sec)	A
Porapak N	Methyl	85.9	86.2	59.6	
Temperature, 180°C	Ethyl	140.4	140.9	114.1	1.93
Carrier gas (helium).	n-Propyl	245.4	245.6	219.1	1.95
36 ml/min	n-Butyl	450.1	445.9	423.8	1.85
Dead time, 26.3 sec	n-Pentyl	829.6	829.2	803.1	
Porapak P	Methyl	55.6	55.7	18.7	
Temperature, 200°C	Ethyl	66.1	66.5	29.2	1.67
Carrier gas (helium),	n-Propyl	83.7	83.6	46.7	1.60
35 ml/min	n-Butyl	111.7	110.6	74.7	1.47
Dead time, 37.0 sec	n-Pentyl	152.9	153.2	115.9	
Porapak PS	Methyl	43.6	43.6	18.7	
Temperature, 190°C	Ethyl	54.6	54.7	29.7	1.60
Carrier gas (helium).	n-Propyl	72.25	72.3	47.3	1.62
36 ml/min	n-Butyl	100.8	100.4	75.9	1.54
Dead time, 24.9 sec	n-Pentyl	144.9	145.0	120.0	
Porapak Q	Methyl	65.3	65.6	41.5	
Temperature, 230°C	Ethyl	98.0	98.8	74.2	1.86
Carrier gas (helium),	n-Propyl	158.8	158.3	135.0	1.81
40 ml/min	n-Butyl	268.5	265.2	244.7	1.72
Dead time, 23.8 sec	n-Pentyl	456.9	456.9	433.1	
Porapak QS	Methyl	49.25	49.4	31.6	
Temperature, 240°C	Ethyl	72.25	72.9	54.6	1.82
Carrier gas (helium).	n-Propyl	114.1	113.6	96.5	1.72
40 ml/min	n-Butyl	186.25	184.3	168.6	1.68
Dead time, 17.6 sec	n-Pentyl	307.25	307.2	289.6	
Porapak R	Methyl	66.8	66.5	43.7	
Temperature, 200°C	Ethyl	104.5	104.6	81.6	1.88
Carrier gas (helium),	n-Propyl	175.6	175.8	152.7	1.94
40 ml/min	n-Butyl	313.2	308.8	290.4	1.77
Dead time, 22.6 sec	n-Pentyl	557.8	557.3	534.7	
Porapak S	Methyl	152.3	153.8	91.8	
Temperature, 200°C	Ethyl	236.0	240.2	175.9	2.07
Carrier gas (helium),	n-Propyl	410.4	406.6	350.3	1.91
38 ml/min	n-Butyl	743.8	724.7	683.4	1.80
Dead time, 60.1 sec	n-Pentyl	1341.6	1336.9	1281.5	
Porapak T	Methyl	39.5	39.7	19.6	
Temperature, 190°C	Ethyl	52.5	53.2	32.6	1.85
Carrier gas (helium),	n-Propyl	76.5	76.0	56.6	1.66
40 ml/min	n-Butyl	116.35	114.4	96.4	1.57
Dead time, 19.9 sec	n-Pentyl	178.9	179.1	158.9	

TABLE V

RETENTION TIME DATA FOR METHYL KETONES

Column conditions	Ketone	t(sec)	t_{calc}(sec)	t'(sec)	A
Porapak N	Methyl ethyl	159.5	162.0	112.3	
Temperature, 180°C	Methyl n-propyl	265.75	271.3	218.5	2.15
Carrier gas (helium),	Methyl n-butyl	494.0	484.6	446.8	1.86
36 ml/min	Methyl n-pentyl	919.0	901.1	871.8	1.89
Dead time, 47.2 sec	Methyl n-hexyl	1722.25	1714.3	1675.0	
Porapak P	Methyl ethyl	173.5	174.4	102.6	
Temperature, 180°C	Methyl n-propyl	244.1	247.8	173.2	1.90
Carrier gas (helium),	Methyl n-butyl	377.6	373.2	306.7	1.63
40 ml/min	Methyl n-pentyl	595.6	587.5	524.7	1.64
Dead time, 70.7 sec	Methyl n-hexyl	953.4	953.6	882.5	
Porapak PS	Methyl ethyl	64.2	64.5	34.0	
Temperature, 180°C	Methyl n-propyl	87.2	88.6	57.0	1.94
Carrier gas (helium),	Methyl n-butyl	131.9	129.8	101.6	1.60
34 ml/min	Methyl n-pentyl	203.6	199.9	173.1	1.62
Dead time, 30.1 sec	Methyl n-hexyl	319.6	319.2	289.0	
Porapak Q	Methyl ethyl	103.75	104.5	76.7	
Temperature, 230°C	Methyl n-propyl	161.6	164.2	134.6	1.91
Carrier gas (helium),	Methyl n-butyl	272.0	269.7	245.0	1.75
35 ml/min	Methyl n-pentyl	464.75	456.3	437.7	1.67
Dead time, 27.0 sec	Methyl n-hexyl	786.75	786.6	759.7	
Porapak QS	Methyl ethyl	75.9	76.3	55.2	
Temperature, 240°C	Methyl n-propyl	115.6	117.1	94.9	1.88
Carrier gas (helium),	Methyl n-butyl	190.0	187.9	169.3	1.67
40 ml/min	Methyl n-pentyl	314.0	310.7	293.3	1.69
Dead time, 20.7 sec	Methyl n-hexyl	523.8	523.7	503.1	
Porapak R	Methyl ethyl	71.9	72.3	49.9	
Temperature, 230°C	Methyl n-propyl	107.7	109.2	85.6	1.90
Carrier gas (helium),	Methyl n-butyl	175.5	173.2	153.6	1.65
40 ml/min	Methyl n-pentyl	287.4	284.2	265.5	1.70
Dead time, 22.0 sec	Methyl n-hexyl	476.9	476.6	454.9	
Porapak S	Methyl ethyl	134.6	135.6	96.0	
Temperature, 230°C	Methyl n-propyl	200.2	203.9	161.6	1.91
Carrier gas (helium),	Methyl n-butyl	325.2	320.3	286.6	1.61
35 ml/min	Methyl n-pentyl	526.6	519.0	488.0	1.64
Dead time, 38.6 sec	Methyl n-hexyl	857.4	857.5	818.8	
Porapak T	Methyl ethyl	62.4	62.7	40.9	
Temperature, 190°C	Methyl n-propyl	88.0	89.5	66.5	1.88
Carrier gas (helium),	Methyl n-butyl	136.0	133.8	114.5	1.53
40 ml/min	Methyl n-pentyl	209.25	207.0	187.7	1.62
Dead time, 21.5 sec	Methyl n-hexyl	327.6	327.7	306.0	

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