Summary of 159 Hydrocarbons Isolated from One Representative Petroleum

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The American Petroleum Institute Research Project 6, which has completed its thirtieth year of operation, has had as its principal assignment the elucidation of the composition of naturally occurring petroleum with respect to the hydrocarbon components of which it is largely composed. The problem is to learn what petroleum is chemically—i.e., of what individual hydrocarbon compounds or groups of related hydrocarbon compounds it is constituted.

To achieve this goal of fractionation of hydrocarbons from petroleum, the project develops and operates fractionating processes to a degree of separating power much greater than is necessary in ordinary research operations. To identify the hydrocarbon compounds isolated from petroleum in this way, the project requires highly purified compounds for comparison. To provide these reference samples, and, at the same time to provide the samples needed by the laboratories of the petroleum industry for calibrating spectrometers, the project prepares highly purified hydrocarbons of the API Research series, for fundamental research measurements, and of the API Standard series, for industrial or applied research, testing, analysis, and control. On the highly purified API Research hydrocarbons, the project makes accurate measurement of the freezing point for determination of purity, and of the other physical properties important for record and identification.

The fractionating processes utilized in this work include: distillation in its several variations, regular, alternately at different pressures, at very low (molecular) pressures,

Table I. Hydrocarbons Isolated from One Representative Petroleum by the American Petroleum Institute Research Project 6 as of June 30, 1957

No.	Formula	Compound	Type[a]	Boiling Point at 1 Atm.[b], °C.	Purity of Best Sample Isolated[c], Mole %	Estimated Amount in Crude Petroleum[d], Vol. %	References to Research Papers in Which Work Is Described[e]
1.	CH_4	Methane	*n*-Paraffin	−161.49	[f]	[f]	
2.	C_2H_6	Ethane	*n*-Paraffin	−88.63	[f]	[f]	
3.	C_3H_8	Propane	*n*-Paraffin	−42.07	[f]	[f]	
4.	C_4H_{10}	Isobutane	Branched paraffin	−11.73	[f]	[f]	
5.	C_4H_{10}	*n*-Butane	*n*-Paraffin	−0.50	[f]	[f]	
6.	C_5H_{12}	2-Methylbutane	Branched paraffin	27.85	[f]	[f]	
7.	C_5H_{12}	*n*-Pentane	*n*-Paraffin	36.07	[f]	[f]	
8.	C_5H_{10}	Cyclopentane	Cyclopentane	49.26	[f]	0.05	84
9.	C_6H_{14}	2,2-Dimethylbutane	Branched paraffin	49.74	[f]	0.04	84
10.	C_6H_{14}	2,3-Dimethylbutane	Branched paraffin	57.99	97	0.08	8,84
11.	C_6H_{14}	2-Methylpentane	Branched paraffin	60.27	99.97	0.37	8,84,97
12.	C_6H_{14}	3-Methylpentane	Branched paraffin	63.28	99.9	0.35	8,84,97
13.	C_6H_{14}	*n*-Hexane	*n*-Paraffin	68.74	99.9	1.80	12,84,97
14.	C_6H_{12}	Methylcyclopentane	Cyclopentane	71.81	98.7	0.87	14,84
15.	C_7H_{16}	2,2-Dimethylpentane	Branched paraffin	79.20	97	0.02	21,84
16.	C_6H_6	Benzene	Benzene	80.10	99.6	0.15	12,84
17.	C_7H_{16}	2,4-Dimethylpentane	Branched paraffin	80.50	[f]	0.08	84
18.	C_6H_{12}	Cyclohexane	Cyclohexane	80.74	99.9	0.71	13,84
19.	C_7H_{14}	1,1-Dimethylcyclopentane	Cyclopentane	87.85	98	0.16	26,84
20.	C_7H_{16}	2,3-Dimethylpentane	Branched paraffin	89.78	58[g]	0.15[h]	84,127
21.	C_7H_{16}	2-Methylhexane	Branched paraffin	90.05	97	0.73[h]	26,84,127
22.	C_7H_{14}	1, *cis*-3-Dimethylcyclopentane[i]	Cyclopentane	90.77	85	0.87[h]	75,84,127
23.	C_7H_{14}	1, *trans*-3-Dimethylcyclopentane[i]	Cyclopentane	91.72	51[i]	0.21[i]	127
24.	C_7H_{16}	3-Methylhexane	Branched paraffin	91.85	93	0.51	75,84,127
25.	C_7H_{14}	1, *trans*-2-Dimethylcyclopentane	Cyclopentane	91.87	93	0.48[h]	75,84,127
26.	C_7H_{16}	3-Ethylpentane	Branched paraffin	93.48	98.7[g]	0.06	127
27.	C_7H_{16}	*n*-Heptane	*n*-Paraffin	98.43	99.9	2.3	18,84
28.	C_7H_{14}	Methylcyclohexane	Cyclohexane	100.93	99.8	1.6	18,84
29.	C_7H_{14}	Ethylcyclopentane	Cyclopentane	103.47	98	0.16	105
30.	C_8H_{16}	1,1,3-Trimethylcyclopentane	Cyclopentane	104.89	98.1	0.30	105
31.	C_8H_{18}	2,2-Dimethylhexane	Branched paraffin	106.84	50[g]	0.01	105
32.	C_8H_{18}	2,5-Dimethylhexane	Branched paraffin	109.10	55[g]	0.06[g]	125
33.	C_8H_{16}	1, *trans*-2, *cis*-4-Trimethylcyclopentane	Cyclopentane	109.29	84[g]	0.22	125
34.	C_8H_{18}	2,4-Dimethylhexane	Branched paraffin	109.43	41[g]	0.06[g]	125
35.	C_8H_{18}	2,2,3-Trimethylpentane	Branched paraffin	109.84	1.0[g]	0.004[g]	125
36.	C_8H_{16}	1, *trans*-2, *cis*-3-Trimethylcyclopentane	Cyclopentane	110.2	98.6	0.26	125
37.	C_7H_8	Toluene	Benzene	110.62	98	0.51	10,84
38.	C_8H_{18}	3,3-Dimethylhexane	Branched paraffin	111.97	86[g]	0.03	125

Table I. (*Contd.*)

No.	Formula	Compound	Type[a]	Boiling Point at 1 Atm.[b], °C.	Purity of Best Sample Isolated[c], Mole %	Estimated Amount in Crude Petroleum[d], Vol. %	References to Research Papers in Which Work Is Described[e]
39.	C_8H_{18}	2,3,4-Trimethylpentane	Branched paraffin	113.47	17[g]	0.005[g]	125
40.	C_8H_{16}	1,1,2-Trimethylcyclopentane	Cyclopentane	113.73	98	0.06	125
41.	C_8H_{18}	2,3,3-Trimethylpentane	Branched paraffin	114.76	10[g]	0.006[g]	125
42.	C_8H_{18}	2,3-Dimethylhexane	Branched paraffin	115.61	65[g]	0.07[g]	125
43.	C_8H_{18}	2-Methyl-3-ethylpentane	Branched paraffin	115.65	51[h]	0.06[g]	125
44.	C_8H_{16}	1, *cis*-2, *trans*-4-Trimethylcyclopentane	Cyclopentane	116.73	84[h]	0.01[h]	157
45.	C_8H_{16}	1, *cis*-2, *trans*-3-Trimethylcyclopentane	Cyclopentane	117.5	90[h]	0.07[h]	157
46.	C_8H_{18}	2-Methylheptane	Branched paraffin	117.65	90	0.90[h]	27,157
47.	C_8H_{18}	4-Methylheptane	Branched paraffin	117.71	34[h]	0.20[h]	157
48.	C_8H_{18}	3,4-Dimethylhexane	Branched paraffin	117.72	40[h]	0.13[h]	157
49.	C_8H_{18}	3-Methyl-3-ethylpentane	Branched paraffin	118.26	6[h]	0.02[h]	157
50.	C_8H_{18}	3-Ethylhexane	Branched paraffin	118.53	43[h]	0.09[h]	157
51.	C_7H_{14}	Cycloheptane	Cycloheptane	118.79	90	0.01[h]	157
52.	C_8H_{18}	3-Methylheptane	Branched paraffin	118.92	98[h]	0.30[h]	157
53.	C_8H_{16}	1, *trans*-4-Dimethylcyclohexane	Cyclohexane	119.35	75[h]	0.25[h]	157
54.	C_8H_{16}	1, 1-Dimethylcyclohexane	Cyclohexane	119.54	84[h]	0.06[h]	157
55.	C_8H_{16}	1, *cis*-3-Dimethylcyclohexane	Cyclohexane	120.09	84[h]	0.63[h]	42,157
56.	C_8H_{16}	1-Methyl-*trans*-3-ethylcyclopentane	Cyclopentane	120.8	57[h]	0.12[h]	157
57.	C_8H_{16}	1-Methyl-*cis*-3-ethylcyclopentane	Cyclopentane	121.4			
58.	C_8H_{16}	1-Methyl-*trans*-2-ethylcyclopentane	Cyclopentane	121.2	74[h]	0.14[h]	157
59.	C_8H_{16}	1-Methyl-1-ethylcyclopentane	Cyclopentane	121.52	65[h]	0.03[h]	157
60.	C_9H_{18}	1,1, *cis*-3, *trans*-4-Tetramethylcyclopentane	Cyclopentane	121.6	83[h]	0.04[h]	157
61.	C_8H_{16}	1, *trans*-2-Dimethylcyclohexane	Cyclohexane	123.42	98[h]	0.31[h]	48,157
62.	C_9H_{20}	2,2,5-Trimethylhexane	Branched paraffin	124.08	11[h]	0.002[h]	157
63.	C_8H_{16}	1, *cis*-4-Dimethylcyclohexane	Cyclohexane	124.32	76[h]	0.09[h]	157
64.	C_8H_{16}	1, *trans*-3-Dimethylcyclohexane	Cyclohexane	124.45	49[h]	0.07[h]	157
65.	C_8H_{14}	Methylbicyclo-[2.2.1]-heptane[m]	Bicycloparaffin	124.5	[f]	0.001	[k]
66.	C_8H_{18}	*n*-Octane	*n*-Paraffin	125.66	99.2	1.9	11,157
67.	C_8H_{16}	Isopropylcyclopentane	Cyclopentane	126.42	15[h]	0.01[h]	155
68.	C_9H_{18}	1, *trans*-2, *cis*-3, *trans*-4-Tetramethylcyclopentane	Cyclopentane	127.4	90	0.11	155
69.	C_8H_{16}	1-Methyl-*cis*-2-ethylcyclopentane	Cyclopentane	128.05	52[h]	0.04[h]	155
70.	C_8H_{16}	1, *cis*-2-Dimethylcyclohexane	Cyclohexane	129.73	45[h]	0.06[h]	155
71.	C_8H_{16}	*n*-Propylcyclopentane	Cyclopentane	130.95	49[h]	0.06[h]	155
72.	C_9H_{20}	2,3,5-Trimethylhexane	Branched paraffin	131.34	16[h]	0.03[h]	155
73.	C_8H_{16}	Ethylcyclohexane	Cyclohexane	131.78	94	0.37[h]	44,155
74.	C_9H_{20}	2,6-Dimethylheptane	Branched paraffin	135.21	98.6	0.05	52,70
75.	C_8H_{10}	Ethylbenzene	Benzene	136.19	96	0.19	28,84
76.	C_8H_{14}	*cis*-Bicyclo-[3.3.0.]-octane	Bicycloparaffin	136.5	95	0.06	[k]
77.	C_8H_{14}	Bicyclo-[3.2.1.]-octane	Bicycloparaffin	138	>90	0.008	[k]
78.	C_9H_{18}	1,1,3-Trimethylcyclohexane	Cyclohexane	136.63	99.9	0.2	37
79.	C_8H_{10}	*p*-Xylene	Benzene	138.35	99.8	0.10	24,84
80.	C_8H_{10}	*m*-Xylene	Benzene	139.10	99.9	0.51	24,84
81.	C_9H_{20}	2,3-Dimethylheptane	Branched paraffin	140.5	60	0.05	68
82.	C_9H_{18}	1, *trans*-2, *trans*-4-Trimethylcyclohexane	Cyclohexane	141.2	95	0.2	68
83.	C_9H_{20}	4-Methyloctane	Branched paraffin	142.48	80	0.1	56
84.	C_9H_{20}	2-Methyloctane	Branched paraffin	143.26	99.9	0.4	56
85.	C_9H_{20}	3-Methyloctane	Branched paraffin	144.18	95	0.1	56
86.	C_8H_{10}	*o*-Xylene	Benzene	144.41	99.7	0.27	24,84
87.	C_9H_{18}	1, *trans*-2, *cis*-4-Trimethylcyclohexane[m]	Cyclohexane	145.6	99	[f]	[k]
88.	C_9H_{16}	Bicycloparaffin[n]	Bicycloparaffin	146.7	99	[f]	[k]
89.	C_9H_{20}	*n*-Nonane	*n*-Paraffin	150.80	99.94	1.8	17,103[k]
90.	C_9H_{12}	Isopropylbenzene	Benzene	152.39	99.8	0.07[p]	61,84,111
91.	C_9H_{12}	*n*-Propylbenzene	Benzene	159.22	98	0.09[p]	84,111[k]
92.	C_9H_{12}	1-Methyl-3-ethylbenzene	Benzene	161.30	99[g]	0.17[p]	111[k]
93.	C_9H_{12}	1-Methyl-4-ethylbenzene	Benzene	161.99	94[g]	0.06[p]	111[k]
94.	C_9H_{12}	1,3,5-Trimethylbenzene	Benzene	164.72	99.9	0.12[p]	33,111
95.	C_9H_{12}	1-Methyl-2-ethylbenzene	Benzene	165.15	89[g]	0.09[p]	111[k]
96.	$C_{10}H_{22}$	4-Methylnonane	Branched paraffin	165.7	96	0.1	[k]
97.	$C_{10}H_{22}$	2-Methylnonane	Branched paraffin	166.8	99.9	0.3	[k]
98.	$C_{10}H_{22}$	3-Methylnonane	Branched paraffin	167.8	98	0.1	[k]
99.	$C_{10}H_{14}$	*tert*-Butylbenzene	Benzene	169.12	[f]	0.01[p]	111
100.	C_9H_{12}	1,2,4-Trimethylbenzene	Benzene	169.35	99.7	0.51[p]	33,97,111
101.	$C_{10}H_{14}$	Isobutylbenzene	Benzene	172.76	28[g]	0.008[g]	[k]
102.	$C_{10}H_{14}$	*sec*-Butylbenzene	Benzene	173.30	68[g]	0.017[g]	[k]
103.	$C_{10}H_{22}$	*n*-Decane	*n*-Paraffin	174.12	99.9	1.8	19[k]
104.	$C_{10}H_{14}$	1-Methyl-3-isopropylbenzene	Benzene	175.14	92[g]	0.08[g]	[k]
105.	C_9H_{12}	1,2,3-Trimethylbenzene	Benzene	176.08	99.8	0.19[g]	37,97[k]
106.	$C_{10}H_{14}$	1-Methyl-4-isopropylbenzene	Benzene	177.10	96	0.04[g]	[k]
107.	C_9H_{10}	Indan	Aromatic-cycloparaffin	177.8	41[g]	0.003[g]	[k]
108.	$C_{10}H_{14}$	1-Methyl-2-isopropylbenzene	Benzene	178.15	32[g]	0.009[g]	[k]
109.	$C_{10}H_{14}$	1,3-Diethylbenzene	Benzene	181.10	61[i]	[f]	[k]
110.	$C_{10}H_{14}$	1-Methyl-3-propylbenzene	Benzene	181.80	60[i]	[f]	[k]
111.	$C_{10}H_{14}$	*n*-Butylbenzene	Benzene	183.27	51[i]	[f]	[k]

Table I. (*Contd.*)

No.	Formula	Compound	Type[a]	Boiling Point at 1 Atm.[b], °C.	Purity of Best Sample Isolated[c], Mole %	Estimated Amount in Crude Petroleum[d], Vol. %	References to Research Papers in Which Work Is Described[e]
112.	$C_{10}H_{14}$	1-Methyl-4-propylbenzene	Benzene	183.30	43[i]	[f]	[k]
113.	$C_{10}H_{14}$	1,2-Diethylbenzene	Benzene	183.42	64[i]	[f]	[k]
114.	$C_{10}H_{14}$	1,3-Dimethyl-5-ethylbenzene	Benzene	183.58	87[i]	[f]	[k]
115.	$C_{10}H_{14}$	1,4-Diethylbenzene	Benzene	183.78	[f]	[f]	[k]
116.	$C_{10}H_{14}$	1-Methyl-2-propylbenzene	Benzene	184.80	87	[f]	[k]
117.	$C_{10}H_{14}$	1,4-Dimethyl-2-ethylbenzene	Benzene	186.83	75	[f]	[k]
118.	$C_{10}H_{18}$	*trans*-Decahydronaphthalene	Bicycloparaffin	187.25	[f]	[f]	[k]
119.	$C_{10}H_{14}$	1,3-Dimethyl-4-ethylbenzene	Benzene	188.20	58	[f]	[k]
120.	$C_{10}H_{14}$	1,2-Dimethyl-4-ethylbenzene	Benzene	189.48	90	[f]	[k]
121.	$C_{10}H_{14}$	1,3-Dimethyl-2-ethylbenzene	Benzene	190.01	60	[f]	[k]
122.	$C_{10}H_{12}$	1-Methylindan	Aromatic-cycloparaffin	190.6	34[h]	[f]	[k]
123.	$C_{10}H_{12}$	2-Methylindan	Aromatic-cycloparaffin	191.4			
124.	$C_{10}H_{14}$	1,2-Dimethyl-3-ethylbenzene	Benzene	193.91	84	[f]	[k]
125.	$C_{11}H_{24}$	*n*-Undecane	*n*-Paraffin	195.89	99.97	1.6	116[k]
126.	$C_{10}H_{14}$	1,2,4,5-Trimethylbenzene	Benzene	196.80	97.2	[f]	[k]
127.	$C_{10}H_{14}$	1,2,3,5-Tetramethylbenzene	Benzene	198.00	95.4	[f]	[k]
128.	$C_{11}H_{20}$	Dicycloparaffin[n]	Dicycloparaffin	202.5	[f]	[f]	[k]
129.	$C_{11}H_{16}$	1-Methyl-3-*n*-butylbenzene[m]	Benzene	204.1	98	0.06	[k]
130.	$C_{10}H_{14}$	1,2,3,4-Tetramethylbenzene	Benzene	205.04	99.9	0.2	79
131.	$C_{10}H_{12}$	4-Methylindan	Aromatic-cycloparaffin	205.5	68[i]	[f]	[k]
132.	$C_{11}H_{16}$	1,3-Dimethyl-4-*n*-propylbenzene[m]	Benzene	206.6	96	0.03	[k]
133.	$C_{10}H_{12}$	1,2,3,4-Tetrahydronaphthalene	Aromatic-cycloparaffin	207.57	98.5	0.03	79
134.	$C_{11}H_{16}$	1,2-Dimethyl-4-*n*-propylbenzene[m]	Benzene	208.5	99	0.03	[k]
135.	$C_{11}H_{16}$	Trimethylethylbenzene[m]	Benzene	212.3	97	0.04	[k]
136.	$C_{12}H_{26}$	*n*-Dodecane	*n*-Paraffin	216.28	99.9	1.4	74
137.	$C_{10}H_{8}$	Naphthalene	Dinuclear aromatic	217.96	99.9	0.06	74
138.	$C_{11}H_{14}$	2-Methyl-[1,2,3,4-tetrahydronaphthalene]	Aromatic-cycloparaffin	220.7	97	0.04	[k]
139.	$C_{11}H_{14}$	6-Methyl-[1,2,3,4-tetrahydronaphthalene]	Aromatic-cycloparaffin	229.03	99.5	0.09	79
140.	$C_{11}H_{14}$	5-Methyl-[1,2,3,4-tetrahydronaphthalene]	Aromatic-cycloparaffin	234.35	99.7	0.08	79
141.	$C_{13}H_{28}$	*n*-Tridecane	*n*-Paraffin	235.43	98	1.2	142
142.	$C_{11}H_{10}$	2-Methylnaphthalene	Dinuclear aromatic	241.05	99.9	0.2	74
143.	$C_{11}H_{10}$	1-Methylnaphthalene	Dinuclear aromatic	244.64	99.7	0.1	74
144.	$C_{14}H_{30}$	*n*-Tetradecane	*n*-Paraffin	253.52	98.5[r]	1.0	142
145.	$C_{12}H_{10}$	Biphenyl	Dinuclear aromatic	255.2	[f]	[f]	[k]
146.	$C_{12}H_{12}$	2,6-Dimethylnaphthalene	Dinuclear aromatic	262	[f]	[f]	[k]
147.	$C_{12}H_{12}$	Dimethylnaphthalene[m]	Dinuclear aromatic	268	[f]	[f]	[k]
148.	$C_{15}H_{32}$	*n*-Pentadecane	*n*-Paraffin	270.61	98.5[r]	0.8	142
149.	$C_{13}H_{14}$	Trimethylnaphthalene[m]	Dinuclear aromatic	288	[f]	[f]	[k]
150.	$C_{16}H_{34}$	*n*-Hexadecane	*n*-Paraffin	286.79	98[r]	0.7	142
151.	$C_{17}H_{36}$	*n*-Heptadecane	*n*-Paraffin	301.82	97[r]	0.6	142
152.	$C_{14}H_{16}$	Dinuclear Aromatic[n]	Dinuclear aromatic	312	[f]	[f]	[k]
153.	$C_{18}H_{38}$	*n*-Octadecane	*n*-Paraffin	316.12	[f]	0.50	156
154.	$C_{19}H_{40}$	*n*-Nonadecane	*n*-Paraffin	329.7	[f]	0.43	156
155.	$C_{20}H_{42}$	*n*-Eicosane	*n*-Paraffin	342.7	[f]	0.37	156
156.	$C_{21}H_{44}$	*n*-Heneicosane	*n*-Paraffin	355.1	[f]	0.32	156
157.	$C_{22}H_{46}$	*n*-Docosane	*n*-Paraffin	367.0	[f]	0.28	156
158.	$C_{23}H_{48}$	*n*-Tricosane	*n*-Paraffin	378.3	[f]	0.24	156
159.	$C_{24}H_{50}$	*n*-Tetracosane	*n*-Paraffin	389.2	[f]	0.21	156

[a]Compounds are classified according to the following types: *n*-paraffin; branched paraffin; cyclopentane (and its alkyl derivatives); cyclohexane (and its alkyl derivatives); benzene (and its alkyl derivatives); bicycloparaffin (having two cycloparaffin rings joined through two carbon atoms); dicycloparaffin (having two cycloparaffin rings joined through one carbon atom, or of unknown connection); dinuclear aromatic; aromatic-cycloparaffin (mixed type).

[b]Value for pure compound, as taken from tables and files of API Research Project 44, is not necessarily temperature at which compound appears in distillation of appropriate fraction of petroleum.

[c]Where amount of best sample isolated was sufficient, and sample was crystallizable, purity has been calculated from value of freezing point previously reported and present best values of freezing point for zero impurity and cryoscopic constants from API Research Projects 44 and 6. Where not evaluated cryoscopically, purity has been evaluated from spectrographic measurements or estimated.

[d]Values for amount in crude petroleum are rounded estimates subject to revision as new data become available from work in progress.

[e]Numbers refer to published papers of API Research Project 6, a list of which may be obtained from Petroleum Research Laboratory, Carnegie Institute of Technology, Pittsburgh 13, Pa.

[f]Not determined.

[g]Determined spectrographically from measurements made in Socony Mobil Laboratories, Paulsboro, N. J.

[h]Determined spectrographically from measurements made in laboratories of Humble Oil and Refining Co., Houston, Tex.

[i]This isomer, formerly labeled "*trans*," has following properties; boiling point at 1 atm., 90.77 °C.; refractive index, n_D^{25}, 1.4063; density at 25 °C., 0.7402 g./ml.

[j]This isomer, formerly labeled "*cis*," has following properties; boiling point at 1 atm., 91.72 °C.; refractive index, n_D^{25}, 1.4081; density at 25 °C., 0.7444 g./ml.

[k]Unpublished.

[m]Tentative; identification not complete.

[n]Identity not yet established.

[p]Determined spectrographically from measurements made in laboratories of Humble Oil and Refining Co., Baytown, Tex.; Socony Mobil Laboratories, Paulsboro, N. J.; Esso Research and Engineering Co., Linden, N. J.; Sun Oil Co., Norwood, Pa.

[r]Purification not carried to completion because, for identification, much purer samples were available from other sources.

Table II. Distribution, by Type and Boiling Range, of Hydrocarbons Isolated from One Representative Petroleum by API Research Project 6 as of June 30, 1957

	Fraction			
	Gas and gasoline	Kerosine	Light gas oil	Heavy gas oil and light lubricating distillate
	Approximate Range of Carbon Atoms per Molecule			
	1 to 10	11 and 12	13 to 17	18 to 25
	Boiling Range, °C.			
	To 180	180 to 230	230 to 300	> 300
Type of Compound	Number of Compounds			Total
n-Paraffins	10	2	4	8	24
Branched paraffins	37				37
Alkylcyclopentanes	22				22
Alkylcyclohexanes	13				13
Alkylbenzenes	20	20			40
Alkylcycloheptanes	1				1
Bicycloparaffins	4	2			6
Dinuclear aromatics	...	1	6	1	8
Aromatic-cycloparaffins	1	6	1	...	8
Total	108	31	11	9	159

Table III. Distribution, by Type of Compounds and Number of Carbon Atoms per Molecule, of 159 Hydrocarbons Isolated as of June 30, 1957.

	Number of Carbon Atoms per Molecule												
Type of Compound	1	2	3	4	5	6	7	8	9	10	11	12	
n-paraffins	1	1	1	1	1	1	1	1	1	1	1	1	
Branched paraffins				1	1	4	6	15	7	3			
Alkylcyclopentanes					1	1	5	13	2				
Alkylcyclohexanes						1	1	8	3				
Alkylbenzenes						1	1	4	8	22	4		
Alkylcycloheptanes							1						
Bicycloparaffins								3	1	1	1		
Dinuclear aromatics										1	2	3	
Aromatic-cycloparaffin									1	4	3		
Total	1	1	1	2	3	8	15	44	23	32	11	4	

	Number of Carbon Atoms per Molecule													
	13	14	15	16	17	18	19	20	21	22	23	24	Total
n-Paraffin	1	1	1	1	1	1	1	1	1	1	1	1	24
Branched paraffins													37
Alkylcyclopentanes													22
Alkylcyclohexanes													13
Alkylbenzenes													40
Alkylcycloheptanes													1
Bicycloparaffins													6
Dinuclear aromatics	1	1											8
Aromatics-cycloparaffin													8
Total	2	2	1	1	1	1	1	1	1	1	1	1	159

Table IV. Summary of Amount of Representative Petroleum Constituted by Hydrocarbons Isolated as of June 30, 1957

Fraction	Approx. Boiling Range, °C.	Est. % of Original Petroleum Constituted by Given Fraction	No. of Compounds Isolated	Estimated % Accounted for by Hydrocarbons Isolated	
				Of fraction	Of original petroleum
Gas and gasoline	To 180	37.2	108	85	31.5
Kerosine	180–230	13.1	31	35	4.6
Light gas oil	230–300	17.1	11	35	6.0
Heavy gas oil and light lubricating distillate	300–400	15.6	9	15	2.4
Lubricant fraction		10			
Residue		7			
Total petroleum		100	159		44.5

azeotropic with different added components (including fluorochemicals); extraction, with one or with two solvents; crystallization, with or without a solvent; adsorption, regular, or with one or two added components; and use of solid molecular or clathrate compounds.

The project has had under investigation continuously since 1928 a large lot of a representative petroleum from the midcontinent (Ponca City, Okla.) field (*1*). By systematic interlocking of the appropriate fractionating processes, the project has completed the isolation, as of June 30, 1957, of 159 hydrocarbon compounds from its representative petroleum.

HYDROCARBONS ISOLATED

Table I gives a list of the 159 hydrocarbons isolated as of June 30, 1957, including the numerical number (in order of ascending boiling point) of the given compound, and the number of the paper in the list of publications of the API Research Project 6 in which the work on the given compound is described.

Table II gives the distribution, by type and boiling range, of the 159 hydrocarbons isolated. Table III gives the distribution, by type of compounds and number of carbon atoms per molecule, of the hydrocarbons. Table IV summarizes amount of the representative petroleum, and of its principal fractions, constituted by the 159 hydrocarbons isolated.

Figure 1 gives a plot of the rate at which the compounds have been isolated over the years.

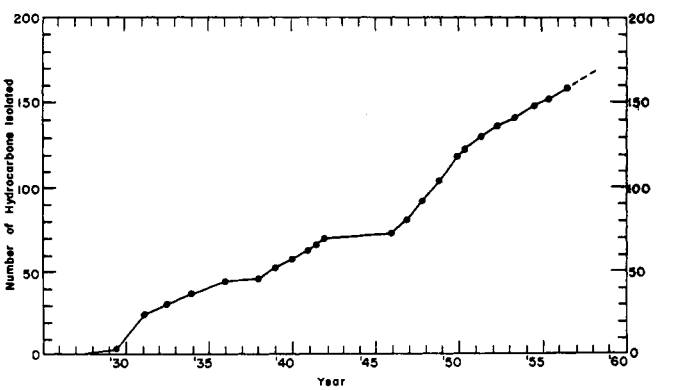

Figure 1. Number of hydrocarbon compounds isolated from representative petroleum of API Research Project 6 over the years

DISCUSSION

To unravel the secrets Nature has locked up in petroleum, to probe at the heart of its composition, and to lay open—as on the operating table—the components in a way which accurately discloses their identity, API Research Project 6 has had this one well-selected representative petroleum under exhaustive examination continuously since 1928. To learn how different petroleums vary in composition, the project some years ago completed a long, but less exhaustive, analysis of the hydrocarbons in the gasoline fraction of seven different, carefully selected, representative petroleums. These latter data permit translating the extensive results obtained on the project's one representative petroleum to other petroleums on which only a few key points of data need be known or obtained. The exhaustive fractionation, although very costly, fortunately needs doing only once, and is of such a fundamental nature as to be particularly well suited to cooperative action by the entire industry.

A detailed description of the petroleum under investigation and the fractionating processes used is given by Rossini, Mair, and Streiff (*1*). A complete list of the publications of API Research Project 6 is obtainable on request.

LITERATURE CITED

(1) Rossini, F. D., Mair, B. J., Streiff, A. J., "Hydrocarbons from Petroleum," Reinhold, New York, 1953.

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Viscosity of Aqueous Solutions of Phosphoric Acid at 25° C.

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Rapid growth in the industrial use of phosphoric acid has developed a widespread need for reliable information on the viscosity of its aqueous solutions. Important in the engineering design of equipment for handling phosphoric acid, viscosity must be considered also in laboratory studies of some of the other physicochemical properties of the acid.

Viscosity data from several sources (*10, 12, 13, 15*) were correlated and smoothed by graphical methods in 1946 to yield a compilation (*14*) that covered wide ranges of concentration and temperature. Error in the values for 25° C. was estimated as ±10%. Appearing also in 1946, a new set of measurements (*9*) was more precise but unfortunately covered only the concentration range below 12% of phosphoric acid.

An immediate need in connection with theoretical calculations relating to diffusion of phosphoric acid solutions prompted a remeasurement of viscosities at 25° C. over the concentration range 2 to 89% of phosphoric acid (0.21 to 85 molal).

VISCOSITY MEASUREMENTS

A series of 15 solutions, ranging from 0.21 to 6.93 molal, was prepared from reagent grade phosphoric acid and distilled water. Another series of 10 solutions, ranging from 9.89 to 84.77 molal, was prepared from triply crystallized phosphoric acid hemihydrate and conductance water. The difference in purity of the two sources of acid was quite small. At high concentrations, small amounts of phosphates other than orthophosphate were present. In the most concentrated solution, 0.3% of the total phosphorus was in nonortho forms.

The densities of the solutions at 25° C. were determined by means of 25-ml. pycnometers of the modified Gay-Lussac type. Each density was determined in duplicate, the weights being corrected for the buoyancy of air. Duplicates agreed to within 1 part in 10,000. Concentrations were taken from tables of densities (*7*).

Viscosities were determined by means of Cannon-Fenske viscometers (*4–6, 11*), which were calibrated with water or with solutions of sucrose (*2*). The viscosity of water at 25° C. was calculated (*8*) from the reliable value at 20° C. (*16*).

The measurements were made according to the standard procedure in a water bath and with the usual precautions (*1, 5*). Efflux times were measured by means of an electric timer that was read to 0.01 second. The temperature of the bath was held at 25° ± 0.005° C. Samples of solutions in the first series were filtered under slight pressure through fritted glass before they were charged to the viscometers.

Each measurement was made at least three times, usually with the same charge. Replicates agreed within 0.1%. Viscosities were corrected for kinetic energy losses by means of a conventional formula (*5*) in which the kinetic energy coefficient was taken as 0.56 (*3*), because the openings of the capillaries of the Cannon-Fenske instruments are trumpet-shaped (*5*).

The corrected viscosities are shown in Table I. At concentrations up to 6.93 molal, corresponding measurements with different viscometers agree closely, except those for 3.51 and 4.97 molal solutions. At concentrations above 6.93 molal, the results from the different viscometers agree less closely. The greater deviations among the more concentrated solutions may reflect changes in composition as a result of hygroscopicity. The viscosities of solutions more concentrated than 1 molal are from 0.7 to 2.0% higher than those reported in the 1946 compilation (*14*). The new viscosity values are in excellent agreement with those of Drucker (*9*) in the range of overlap (up to 1.4 molal).

The accuracy of the results depends upon the accuracy of the calibration, which, in turn, is limited by uncertainties in efflux times and in the viscosities of the standard liquids. These uncertainties are small, however, and the accuracy probably is of the same order as the precision.

Secondary values of viscosity are shown in Table II at integral values of concentration in weight per cent.