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Conversion of Waste Plastic into Liquid Hydrocarbons (ENERGY) by $Cuco_3$ Catalyst: Application of Scientific Research on Plastic Pollution

Manvir Singh[1] Sudesh Kumar[1] Moinuddin Sarker[2]
1.Department of Chemistry Banasthali University Rajasthan india
2.Waste Technologies LLC, Department of Research & Development, 1376 Chopsey Hill Road, Bridgeport, CT-06606, USA

Abstract
Waste plastics were converted into valuable liquid hydrocarbon fuel. it is can be used as different purpose of energy-source such as petrol engines, diesel engines, generators, vehicles and its good source of chemicals etc. Plastics have many properties like light weight, high durability so its demand increases in every sector. Pyrolysis of the waste plastic (hdpe) was carried out with $CuCO_3$ catalysts and temperature range from 0 °C to 390 °C. The collected liquid hydrocarbons fuel was characterized by FT-IR, NMR, GCxGCMS spectrometer and fuel density was 78 g ml^{-1} and conversion was very good. The research paper exhibits concentrating on application for solving daily life issues and problems of plastic.
Keywords: Pyrolysis, Liquid hydrocarbons fuel, $CuCO_3$ catalysts, Conversion, Glass reactor, GCxGCMS.

Introduction

First time plastic was invented by Alexander Parkes in 1862 that has a high molecular weight (Brydson 1999). A molecule formed by repetition of simple units is called polymer. Plastic is also called polymer for example polyethylene (Chanda 2000). The plastic is produced from non-sustainable coal or oil. It is a non-sustainable product. Plastic usages are increasing in automobiles, consumer packaging and government is spending on its infrastructure. India is expected to be among top 10 packaging consumers in the world by 2016 with demand set to reach $ 24 billion (Physical properties of plastics). India's plastic industries believe, it is on the track to more than double its 20 million metric tons polymer consumption by 2020 (plastic consumption to double in India 2016). It was stated that like plastic recycling system can turn a menace into employment opportunity for millions of people. As India has a great resource of man-power and technology. Plastic recycling can be developed more to ensure the safety of the environmental (Indian industry looks to double plastics use 2020). The Technology help to save land recourse by utilizing waste plastic to generate valuable energy. Presently, a majority of the waste plastic is land filled and it is not sustainable because waste plastic takes very long time to decay (Plastic Europe, The compelling Facts about Plastic, 2007, 2008). Waste plastic can chemically compare to petroleum. The elemental composition of petroleum: Carbon 83-87 %, Hydrogen 10-14 %, Nitrogen 0.1-2 %, Sulfur 0.05-6 %, Metals < 0.1 % the most common metals are iron, copper and vanadium (Chemical composition of petroleum). Calculate the percent composition of carbon and hydrogen by below equation.

$$\text{Percent composition} = \frac{\text{n} \times \text{molar mass of the element}}{\text{molar mass of the compound}} \times 100\%$$

Where n is the number of mole of the element in 1 mole of the compound. The molar mass of carbon is 12.01 gm the molar mass of hydrogen is 1.008 gm (Percent composition). To calculate the percent composition of carbon and hydrogen in hdpe or ldpe plastics [molecular formula of $(C_2H_4)n$].

$$\text{Percent of carbon} = \frac{2 \times 12.01}{26.03} \times 100 = 92.27814$$

$$\text{Percent of hydrogen} = \frac{2 \times 1.008}{26.03} \times 100 = 7.72186$$

Total 92.27814+7.72186=100

Calorific value of a fuel is directly connected to its carbon content. Hence greater the percentage of carbon greater is the calorific value of the fuel and better is the quality of fuel. High percentage of hydrogen also increases the calorific value of fuel (Energy sources). Plastic includes carbon and hydrogen, the main thing which makes plastic waste valuable is longer carbon chains than those in gasoline and diesel fuels. Therefore, it's possible to convert waste plastic into liquid hydrocarbon fuels.

Materials and method

A. Materials

Waste plastic (hdpe) collected from local markets. The waste plastic (hdpe) was white and transparent. Collected waste plastic (hdpe) was washed with liquid soap complete dust free and then dried in the sunlight. Waste water treated by acidic and alkali. Dried wastes plastic (hdpe) was cut into small pieces using grinder machine. Sample

sizes are usually 3-4 mm. These grounded wastes were placed into the glass reactor prior to the experimental procedure.

B. Method

90 grams the dried waste plastic (hdpe) and 10 grams $CuCO_3$ (purchase CDH chemical, catalogue no. 027833) catalysts material was put kept into a round shape glass reactor. Then the round shape glass reactor has been put into an insulated furnace which has protected the loss of heat and gives heat. Further, a condenser unit was set up with the reactor and the other end with the fuel collection device. In the furnace is temperature controller and temperature display. Then the temperature was increased slowly. Heating starts from 0 °C temperature to up to 390 °C. Inside the glass reactor, the solid waste plastic was converted into the vapors and then passes throw a glass pipe to a condenser and distillate and then liquid hydrocarbon collected. Waste plastic (hdpe) into liquid hydrocarbon fuel conversion rate is 86% (104 ml) and its density 78 g ml^{-1}. It was observed that, it is only accelerating the degradation process but not creating any reaction against waste plastic. During the waste plastic conversation into liquid hydrocarbon fuel vapor are not converting to liquid fuel due to as a light gas (C_1-C_4) and its boiling point is -°C temperature. The light gases are 10% of the total production process and 4% solid residues recovered from the production process. Experimental took about 4 h 35 min.

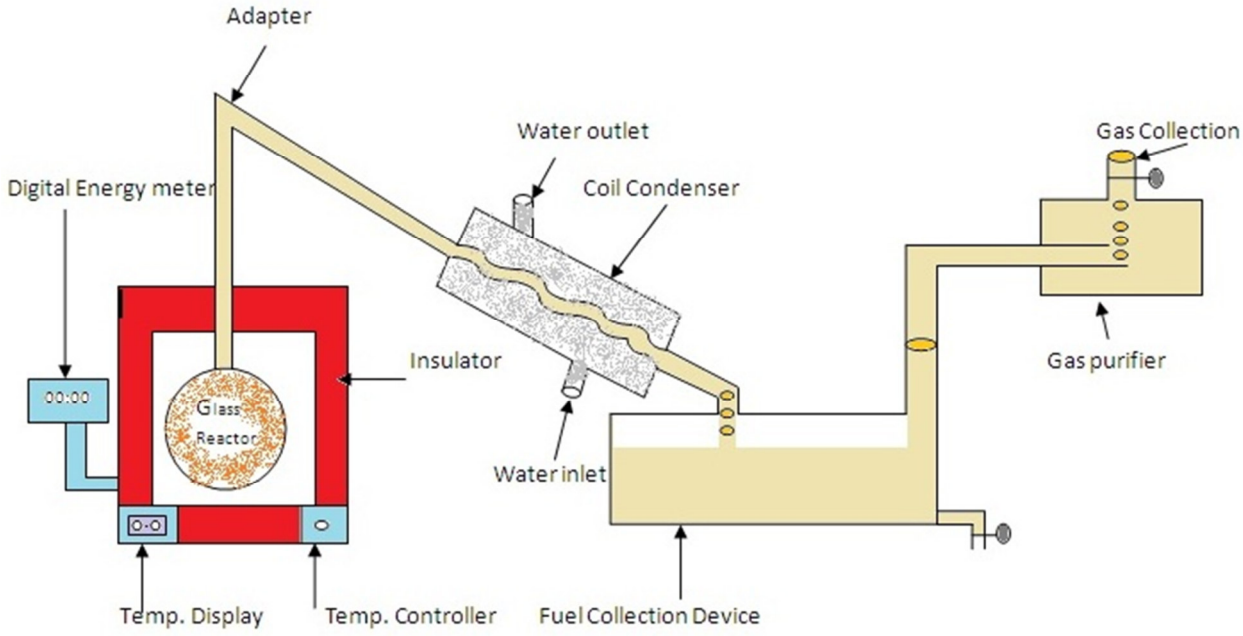


Figure 1 Production process diagram of waste plastic (hdpe) into liquid hydrocarbons

Result and Discussions

Analytical technique

FT-IR ALPHA-T Brucker spectrum was used for liquid fuel analysis. NMR spectrometer 400 MHz Brucker was used for liquid fuel analysis. ^{1}HNMR, ^{13}CNMR method are used for liquid analysis by NMR instrument. Deuterium chloroform ($CDCl_3$) solvent was used for sample preparation. Leco pegasus 4D GCxGC TOF MS, Split injection: 4mm restek siltek liner with siltek wool, one microliter at 250°C, primary column: 30m x 0.25mm x 0.25µm restek rtx-5MS column, primary column is non-polar and separates all compounds by boiling point, secondary column: 1m x 0.1mm x 0.1µm restek rxi -17, secondary column is polar and separates all compounds by polarity, constant flow helium gas 1.5 ml/min, split ratio 1:150. GC x GC oven program: 70 °C 1.0 m hold, 10°/min to 280°, 5 min hold, secondary oven offset 10, total run time: 27.0 min, modulation period 4 sec, hot pulse 0.9 sec, cold pulse 1.1 sec, GCxGC TOF MS parameter: source temperature 200°C, electron ionization 70 eV, mass range 35 to 600 u, acquisition rate 100 spectra/sec (4D).

Liquid hydrocarbon fuel analysis

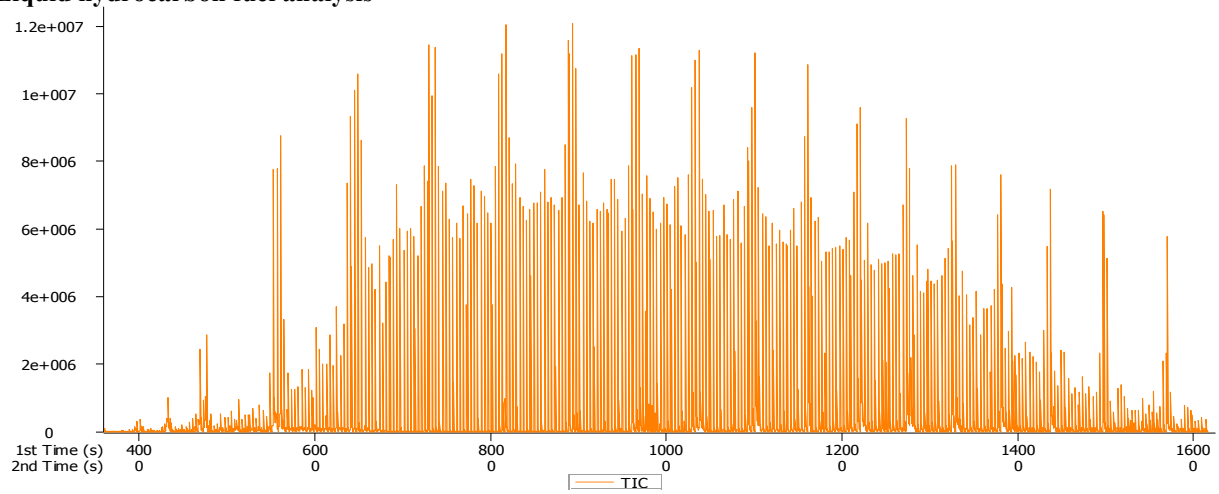


Figure 2 GCxGCMS 1 D chromatogram waste plastic (hdpe) into liquid hydrocarbons

Table 1 Chromatogram waste plastic (hdpe) into liquid hydrocarbons GCxGCMS 1 D chromatogram compound list

Peak List as per classification

Peak	Name	Classifications	S/N	Similarity as per NIST library match	Primary and secondary column R.T. (s)	Area
1	Nonane	Saturate	4420.7	917	476 , 0.920	19228474
2	Benzene, 1-ethyl-3-methyl-		3433.5	876	536 , 1.020	5195124
3	Benzaldehyde	Aromatic(Benzenes ,Napthalenes)	2270.3	865	540 , 1.110	2712695
4	1-Decene		9899.6	941	552 , 0.950	96422690
5	Bicyclo[5.3.0]decane		3509.3	799	556 , 0.980	10497598
6	Benzene, 1-ethyl-4-methyl-	Aromatic(Benzenes ,Napthalenes)	25980	873	556 , 1.040	15737948
7	Decane	Saturate	13479	789	560 , 0.940	19472606
8	Cycloheptane, bromo-		2573.4	803	564 , 0.980	22146618
9	Benzene, 1,2,3-trimethyl-	Aromatic(Benzenes ,Napthalenes)	9522.3	904	568 , 1.030	6964391
10	Benzene, 1-ethenyl-2-methyl-	Aromatic(Benzenes ,Napthalenes)	2277.3	854	568 , 1.050	3477830
11	2-Decyne		1726.1	840	580 , 0.980	24951273
12	Benzene, 1-methyl-2-(1-methylethyl)-		2495.9	848	592 , 1.020	3129755
13	Benzene, 1,2,3-trimethyl-	Aromatic(Benzenes ,Napthalenes)	5633.9	885	596 , 1.050	5160647
14	Cyclodecane	Cyclic /branched	2594	850	600 , 0.970	38667277
15	Oxalic acid, isobutyl nonyl ester	Cyclic /branched	2513.8	823	604 , 0.940	11032287
16	Cyclopentene, 1-butyl-	Cyclic /branched	2873	852	608 , 0.980	10470297
17	Benzene, cyclopropyl-	Aromatic(Benzenes ,Napthalenes)	4434.9	880	612 , 1.080	3651327
18	Decane, 2-methyl-	Cyclic /branched	2587.5	883	616 , 0.940	20963341
19	2-Undecyne	Cyclic /branched	2047.8	849	616 , 0.990	8165961
20	Benzene, 1-methyl-3-propyl-	Aromatic(Benzenes ,Napthalenes)	12959	857	616 , 1.030	11579702
21	Bicyclo[3.2.1]oct-2-ene, 3-methyl-4-	Aromatic(Benzenes ,Napthalenes)	7387.1	850	620 , 1.040	11200449
22	1-Decene, 9-methyl-	Cyclic /branched	5854.8	836	624 , 0.950	18241098
23	Benzene, 1-methyl-3-propyl-	Aromatic(Benzenes ,Napthalenes)	16774	879	632 , 1.050	7747624
24	1,10-Undecadiene	Cyclic /branched	5980	857	636 , 0.970	91436006
25	Benzaldehyde, 3-methyl-	Aromatic(Benzenes ,Napthalenes)	2994.4	866	636 , 1.140	2276909
26	Benzene, 2-ethyl-1,4-dimethyl-	Aromatic(Benzenes ,Napthalenes)	23723	920	640 , 1.060	11079778
27	Unknown 1	Aromatic(Benzenes ,Napthalenes)	1992.7	676	640 , 1.170	1587002
28	1-Undecene		12920	940	644 , 0.980	154439932
29	Undecane	Saturate	24836	941	648 , 0.970	93598080
30	Benzene, 1-methyl-2-(1-methylethyl)-	Aromatic(Benzenes ,Napthalenes)	25239	909	648 , 1.070	9047564
31	7-Propylidene-bicyclo[4.1.0]heptane		1849.9	706	652 , 1.020	2457483
32	Cyclohexane, 1-methyl-2-propyl-		7552.5	799	656 , 0.980	55730151
33	Benzene, 1-butenyl-, (E)-	Aromatic(Benzenes ,Napthalenes)	7197.1	896	656 , 1.080	9428757
34	2-Undecene, (Z)-	Cyclic /branched	3298.6	914	664 , 0.970	30732081
35	5-Undecyne	Cyclic /branched	6147.5	831	664 , 0.990	69601236
36	Ethanone, 1-(2,5-dimethylphenyl)-		3541.1	766	664 , 1.040	350565
37	Bicyclopentylidene		1917	761	668 , 1.050	6345748
38	Benzene, 1-methyl-2-(1-methylethyl)-	Aromatic(Benzenes ,Napthalenes)	8281.9	870	668 , 1.080	17855703
39	5-Undecene, (E)-	Cyclic /branched	2621.6	864	672 , 0.970	62922708
40	2-Undecyne	Cyclic /branched	2170.7	828	672 , 1.000	27632616
41	Octane, 5-ethyl-2-methyl-	Cyclic /branched	2146.2	819	676 , 0.950	442917544
42	Benzene, 2-ethyl-1,3-dimethyl-	Aromatic(Benzenes ,Napthalenes)	7621.8	857	680 , 1.070	3741023
43	1-Decyne	Cyclic /branched	3801	779	684 , 0.980	68370377
44	Unknown 2	Cyclic /branched	6158.4	553	684 , 1.000	4223526
45	Unknown 3	Cyclic /branched	1619.2	694	684 , 1.020	7965150
46	Benzene, (2-methyl-2-propenyl)-	Aromatic(Benzenes ,Napthalenes)	1832.6	858	684 , 1.090	2920667
47	5-Ethyldecane	Cyclic /branched	5382.8	835	688 , 0.960	24600063
48	Cyclopropane, 1-hexyl-2-propyl-, cis-	Cyclic /branched	4440.7	861	692 , 0.970	486342663
49	1H-Indene, 1-ethylideneoctahydro-, trans-	Cyclic /branched	2553	781	692 , 1.030	7902586
50	Octane, 4-ethyl-	Cyclic /branched	5526.9	860	696 , 0.960	34781626
51	Cyclopentene,1-hexyl-	Cyclic /branched	6110.8	871	696 , 1.000	61598486
52	Benzene, 1,3-diethyl-5-methyl-	Cyclic /branched	12893	891	696 , 1.050	13512883
53	Penta-2-en-4-yne,-2,5-dicyclopropyl	Aromatic(Benzenes ,Napthalenes)	2917	754	696 , 1.070	6667926
54	Benzene, 1-ethenyl-4-ethyl-	Aromatic(Benzenes ,Napthalenes)	4959.5	830	700 , 1.110	3397167
55	2-Ethyl-1-dodecanol	Cyclic /branched	5513.3	833	704 , 0.970	63714592
56	1H-Indene, 2,3-dihydro-4,7-dimethyl-	Aromatic(Benzenes ,Napthalenes)	7364.2	755	704 , 1.090	1426624

Peak	Name	Classifications	S/N	Similarity as per NIST library match	Primary and secondary column R.T. (s)	Area
57	Benzene, pentyl-	Aromatic(Benzenes ,Napthalenes)	9672.5	868	708 , 1.060	30760061
58	Benzene, 2,4-diethyl-1-methyl-	Aromatic(Benzenes ,Napthalenes)	2122.4	700	708 , 1.080	1648549
59	Undecane, 3-methyl-	Cyclic /branched	6269.8	908	712 , 0.960	22904002
60	Cycloundecene(Z)	Cyclic /branched	5000.4	863	712 , 1.010	43425243
61	Benzene, 1,2,3,5-tetramethyl-	Aromatic(Benzenes ,Napthalenes)	2700.7	762	712 , 1.090	1022397
62	1H-Indene, 2,3-dihydro-4-methyl-	Aromatic(Benzenes ,Napthalenes)	29546	862	712 , 1.120	12587361
63	anti-10-Methyl-endo-tricyclo[5.2.1.0(2.6)]decane	Cyclic /branched	2224.4	778	716 , 1.040	18449709
64	Benzene, 1-butynyl-	Aromatic(Benzenes ,Napthalenes)	3806.4	880	716 , 1.130	2285682
65	1,12-Tridecadiene	Cyclic /branched	6378.5	842	720 , 0.990	102071321
66	Cyclododecene, (E)-	Cyclic /branched	1967.7	830	720 , 1.010	28142776
67	2,4-Octadiyne		8061.7	727	720 , 1.060	1002213
68	Benzene, (1-methylbutyl)-	Aromatic(Benzenes ,Napthalenes)	8061.7	723	720 , 1.070	3458429
69	1-Undecene, 2-methyl-	Cyclic /branched	9269	740	724 , 0.980	78109177
70	Unknown 4	Cyclic /branched	3153.7	691	724 , 1.050	3286629
71	Benzene, 1-methyl-4-(1-methylpropyl)-	Aromatic(Benzenes ,Napthalenes)	14125	783	724 , 1.070	8944415
72	Unknown 5	Aromatic(Benzenes ,Napthalenes)	1711.9	665	724 , 1.090	3568093
73	Naphthalene, 1,2,3,4-tetrahydro-	Aromatic(Benzenes ,Napthalenes)	14550	881	724 , 1.140	5981040
74	Cyclododecane	Cyclic /branched	14224	902	728 , 1.010	70416839
75	anti-10-Methyl-endo-tricyclo[5.2.1.0(2.6)]decane		2132.6	744	728 , 1.070	13301700
76	cis, cis-2-Ethylbicyclo[4.4.0]decane	Cyclic /branched	2297	748	732 , 1.020	25067720
77	3-Methylene-1,5,5-trimethylcyclohexene		2476.8	730	732 , 1.050	7151392
78	Benzene, 1-methyl-3-(1-methyl-2-propenyl)-	Aromatic(Benzenes ,Napthalenes)	3042.4	810	732 , 1.090	1519337
79	Dodecane	Saturate	30986	855	736 , 0.990	33273337
80	Unknown 6		3724	638	736 , 1.070	1444286
81	Cyclohexene, 1-ethyl-4,5-divinyl-		3082.5	728	736 , 1.080	8374378
82	1H-Indene, 1,3-dimethyl-	Aromatic(Benzenes ,Napthalenes)	4836.3	830	736 , 1.130	1453435
83	3-Dodecene, (E)-		4627.9	941	740 , 0.980	31608166
84	1,13-Tetradecadiene	Cyclic /branched	7652.3	825	740 , 1.010	41872726
85	Bicyclo[5.1.0]octane, 8-(1-methylethylidene)-	Cyclic /branched	2400.6	802	740 , 1.040	37856659
86	1H-Indene, 2,3-dihydro-1,2-dimethyl-		26240	884	740 , 1.100	18631461
87	Benzene, (1-methylpentyl)-	Cyclic /branched	5953.9	811	744 , 1.060	2991736
88	Benzene, 1,3-diethyl-5-methyl-	Cyclic /branched	7584.6	808	744 , 1.080	4868596
89	2-Dodecene, (Z)-	Cyclic /branched	7869.8	935	748 , 0.990	108215480
90	Benzene, 1,4-diethyl-2-methyl-	Cyclic /branched	11669	789	748 , 1.080	3548768
91	trans-Cinnamyl bromide	Cyclic /branched	5369.2	731	748 , 1.100	260257
92	Naphthalene	Aromatic(Benzenes ,Napthalenes)	32097	921	748 , 1.190	15319888
93	Decane, 5-propyl-		2844.2	855	752 , 0.970	21340659
94	Cyclododecene, (E)-	Cyclic /branched	8688.6	835	752 , 1.010	105104038
95	6,7-Dimethyl-1,2,3,5,8,8a-hexahydronaphthalene	Cyclic /branched	3252	729	752 , 1.060	4461809
96	1H-Indene, 2,3-dihydro-1,6-dimethyl-	Cyclic /branched	34226	894	752 , 1.110	10608988
97	5-Decene, 4-ethynyl-, (E)-	Cyclic /branched	2234.7	784	756 , 1.040	11739188
98	Bicyclo[6.1.0]nonane, 9-(1-	Cyclic /branched	2597.8	779	764 , 1.040	14710554
99	Benzene, 1-methyl-2-(1-ethylpropyl)-	Cyclic /branched	7456.5	776	764 , 1.060	10700556
100	Penta-2-en-4-yne,-2,5-dicyclopropyl	Cyclic /branched	2443.7	778	764 , 1.080	5782529
101	Undecane	Cyclic /branched	6451.2	851	768 , 0.970	26500658
102	Naphthalene, 1,2,3,4-tetrahydro-2-methyl-	Cyclic /branched	4012.6	812	768 , 1.120	2759394
103	1,13-Tetradecadiene	Cyclic /branched	4728.8	831	772 , 0.990	99893839
104	Unknown 7	Cyclic /branched	2859.2	526	772 , 1.020	874676
105	Cyclodecane	Cyclic /branched	4810.6	817	776 , 0.990	44227292
106	Cyclohexane, hexyl-	Cyclic /branched	8544.2	830	776 , 1.010	23476203
107	Benzene, (1-ethylbutyl)-	Cyclic /branched	5785.1	747	776 , 1.070	9062188
108	Undecane, 2,4-dimethyl-	Cyclic /branched	9461.6	864	780 , 0.970	61453269
109	1,Z-5,E-7-Dodecatriene	Cyclic /branched	1696.3	741	780 , 1.040	31574427
110	Benzene, (1-ethyl-1-propenyl)-	Cyclic /branched	10334	819	780 , 1.120	15448547
111	Cyclopentene,1-heptyl-	Cyclic /branched	6545.4	826	784 , 1.010	48603522
112	1H-Indene, 2,3-dihydro-1,5,7-trimethyl-	Cyclic /branched	6150.7	747	784 , 1.100	2748786
113	Cyclopropane, 1-ethyl-2-heptyl-	Cyclic /branched	6054.3	857	788 , 0.980	52616072
114	7-Tetradecyne	Cyclic /branched	3617.1	852	788 , 1.020	32616571
115	Benzene, (1,3-dimethylbutyl)-	Cyclic /branched	7019.1	760	788 , 1.070	44235445
116	Naphthalene, 1,2,3,4-tetrahydro-1,1-	Cyclic /branched	4655.5	782	788 , 1.090	6577307
117	Tridecane, 4-methyl-	Cyclic /branched	8550.5	904	792 , 0.970	56225514
118	Bicyclo[3.1.1]hept-2-ene-2-ethanol, 6,6-	Cyclic /branched	2240.9	713	792 , 1.050	34211549
119	Cyclohexene,3-hexyl-	Cyclic /branched	5287.7	865	796 , 1.030	1101788568
120	Benzene, 1-methyl-3-(1-methyl-2-propenyl)-		14813	876	796 , 1.120	10794758
121	Benzene, (1-methylpentyl)-	Cyclic /branched	10787	776	800 , 1.070	14967857
122	Cyclopentane, 3-hexyl-1,1-dimethyl-	Cyclic /branched	3649.4	800	804 , 0.990	80183791
123	8-Hexadecyne	Cyclic /branched	7640.7	843	804 , 1.020	55221628
124	Unknown 8	Cyclic /branched	2575.5	648	804 , 1.050	24509743
125	Unknown 9	Cyclic /branched	6161.4	689	804 , 1.110	686721
126	1-Tridecene	Cyclic /branched	11485	928	808 , 1.010	96017575
127	9-Octadecenal	Cyclic /branched	1896.8	836	808 , 1.050	484762006
128	1,7,7-Trimethyl-2-vinylbicyclo[2.2.1]hept-2-	Cyclic /branched	14150	806	808 , 1.090	11248388
129	1H-Indene, 2,3-dihydro-1,2-dimethyl-	Aromatic(Benzenes ,Napthalenes)	20545	816	808 , 1.140	14060940
130	Naphthalene, 1,2-dihydro-3-methyl-	Aromatic(Benzenes ,Napthalenes)	5916.3	737	808 , 1.160	8817581
131	2,3-Dihydro-1-oxo-1H-phenalene		15094	716	812 , 1.010	1548956
132	Perhydrophenalene, (3aà, 6aà, 9aà, 9bá)-	Cyclic /branched	1737.3	704	812 , 1.060	8540595
133	Unknown 10	Cyclic /branched	7667.8	536	812 , 1.080	4826918
134	Tridecane	Saturate	31997	774	816 , 1.010	31291723
135	Naphthalene, 1,2,3,4-tetrahydro-1,1-	Aromatic(Benzenes ,Napthalenes)	8718	786	816 , 1.130	15454739
136	Tridecane		4377.4	908	820 , 0.980	82869549
137	Cyclooctane, cyclohexyl-		3885.7	787	824 , 1.010	91145958

Peak	Name	Classifications	S/N	Similarity as per NIST library match	Primary and secondary column R.T. (s)	Area
138	Unknown 11		2936.6	695	824 , 1.090	18301764
139	1H-Indene, 2,3-dihydro-4,7-dimethyl-	Aromatic(Benzenes ,Napthalenes)	20942	857	824 , 1.140	5632628
140	Bicyclo[10.1.0]tridec-1-ene	Cyclic /branched	2585.3	824	828 , 1.060	375124928
141	Naphthalene, 1,2,3,4-tetrahydro-1,1-		18240	854	828 , 1.120	11143512
142	1-Octanol, 2-butyl-	Cyclic /branched	4893.9	827	832 , 0.980	79322285
143	Bicyclo[4.1.0]heptane, 3,7,7-trimethyl-, [1S-	Cyclic /branched	4520.8	824	832 , 1.020	136320086
144	Unknown 12	Cyclic /branched	1689.2	524	832 , 1.070	1273939
145	Naphthalene, 1,2,3,4-tetrahydro-6-methyl-	Aromatic(Benzenes ,Napthalenes)	4390.1	858	832 , 1.170	6498385
146	Cyclotridecane	Cyclic /branched	1793.5	781	836 , 1.010	17637780
147	Naphthalene, 2-methyl-	Aromatic(Benzenes ,Napthalenes)	46402	917	836 , 1.200	19546358
148	Naphthalene, 5-ethyl-1,2,3,4-tetrahydro-	Cyclic /branched	9883.9	820	840 , 1.120	9872356
149	Benzene, (3-propoxy-1-propenyl)-	Cyclic /branched	7662.9	758	844 , 1.070	13617327
150	Tridecane, 5-propyl-	Cyclic /branched	5847.9	843	848 , 0.980	76007238
151	Cyclopropane, 1-methyl-2-octyl-	Cyclic /branched	4964.4	811	852 , 0.990	20449448
152	Cyclododecene, 1-methyl-	Cyclic /branched	3513.6	857	852 , 1.030	338679708
153	Cyclopropa[1,2:1,3]dicyclopenten-3(3aH)- 1,2,3b,6-tetrahydro-3a,6,6-trimethyl-	Cyclic /branched	8867.8	742	852 , 1.080	22242680
154	Benzene, 2-(2-butenyl)-1,3,5-trimethyl-	Cyclic /branched	2195.9	710	852 , 1.100	5726407
155	Naphthalene, 6-ethyl-1,2,3,4-tetrahydro-	Cyclic /branched	7124.4	842	852 , 1.130	13845909
156	Naphthalene, 2-methyl-	Aromatic(Benzenes ,Napthalenes)	53968	930	852 , 1.220	19924468
157	Tetradecane	Cyclic /branched	11090	869	856 , 0.980	47939302
158	Unknown 13	Cyclic /branched	3486	514	856 , 1.040	681743
159	Bicyclo[2.2.1]heptane, 7,7-dimethyl-2-	Cyclic /branched	1756.2	706	856 , 1.050	70606740
160	3,5-Dodecadiyne, 2-methyl-	Cyclic /branched	4193.2	767	860 , 1.080	23350777
161	(1,4-Dimethylpent-2-enyl)benzene	Cyclic /branched	3935.2	700	860 , 1.110	3018052
162	Naphthalene, 1,2,3,4-tetrahydro-1,1-	Cyclic /branched	11189	812	860 , 1.140	9833499
163	4-Undecene, 4-methyl-, (Z)-	Cyclic /branched	4850	709	864 , 1.000	38784738
164	Unknown 14	Cyclic /branched	4992.8	632	864 , 1.010	15184619
165	Cyclopropene, 2,3-dimethyl-3-phenyl-	Aromatic(Benzenes ,Napthalenes)	1911	781	868 , 1.160	941876
166	Unknown 15	Aromatic(Benzenes ,Napthalenes)	1911	644	868 , 1.170	303411
167	Tridecane, 3-methyl-	Cyclic /branched	6835.6	888	872 , 0.980	59312053
168	3-Octadecyne	Cyclic /branched	3169	852	872 , 1.020	2132949569
169	Unknown 16	Cyclic /branched	2397.4	630	872 , 1.110	2755387
170	Naphthalene, 6-ethyl-1,2,3,4-tetrahydro-	Aromatic(Benzenes ,Napthalenes)	8605.6	821	872 , 1.150	12090981
171	Naphthalene, 1,2,3,4,4a,5,8,8a-octahydro-4a-	Cyclic /branched	2382.6	701	876 , 1.060	63113596
172	Benzene, heptyl-	Cyclic /branched	9797.9	838	876 , 1.080	28525145
173	Unknown 17	Cyclic /branched	2360.3	646	876 , 1.110	6794255
174	Unknown 18		2114	497	876 , 1.120	434119
175	9-Octadecyne	Cyclic /branched	5844.9	846	880 , 1.020	108753033
176	Unknown 19	Cyclic /branched	4184.5	615	880 , 1.070	2862311
177	Benzene, 1-methyl-3-hexyl-		18705	767	880 , 1.090	36072825
178	3-Tridecen-1-yne, (Z)-		2751.3	765	884 , 1.070	38437962
179	1H-Inden-1-one, 2,3-dihydro-3,4,7-trimethyl-		2889.8	710	884 , 1.120	6216356
180	Naphthalene, 5-ethyl-1,2,3,4-tetrahydro-	Aromatic(Benzenes ,Napthalenes)	3582.6	796	884 , 1.160	12809600
181	Cyclotetradecane		14625	912	888 , 1.030	351141115
182	Cyclopropa[1,2:1,3]dicyclopenten-3(3aH)- 1,2,3b,6-tetrahydro-3a,6,6-trimethyl-		8147.6	749	888 , 1.110	5982280
183	Unknown 20	Aromatic(Benzenes ,Napthalenes)	3123.8	638	888 , 1.170	142476
184	Tetradecane	Saturate	27713	738	892 , 1.020	30306781
185	1H-Inden-1-one, 2,3-dihydro-3,4,7-trimethyl-	Aromatic(Benzenes ,Napthalenes)	5701.6	745	892 , 1.140	11861138
186	Tetradecane	Saturate	16601	942	896 , 1.010	171670847
187	(1-Methylpenta-1,3-dienyl)benzene	Aromatic(Benzenes ,Napthalenes)	3544.6	710	896 , 1.170	12237650
188	Unknown 21	Cyclic /branched	3762.2	692	900 , 1.030	77556075
189	5,9-Tetradecadiyne		1795.6	741	900 , 1.080	6293001
190	Naphthalene, 1,2,3,4-tetrahydro-6-propyl-	Aromatic(Benzenes ,Napthalenes)	8330.8	785	900 , 1.130	12309237
191	Biphenyl	Aromatic(Benzenes ,Napthalenes)	10401	923	900 , 1.230	4561258
192	7-Tetradecene, (E)-	Cyclic /branched	3734	814	904 , 1.000	116979890
193	Unknown 22	Cyclic /branched	11389	541	904 , 1.020	5291483
194	Bicyclo[6.1.0]nonane, 9-(1-	Cyclic /branched	2873.6	790	904 , 1.070	538537969
195	1,1,3a-Trimethyl-1a,3a,5,6-tetrahydro-1H-cyclopropa[c]pentalen-4-one		4243.9	706	904 , 1.100	58414940
196	Ethanone, 1-(2-methylphenyl)-		2427.1	817	904 , 1.300	2973920
197	Unknown 23		4670.7	560	908 , 1.090	113832
198	E-1,6-Undecadiene	Cyclic /branched	8024.4	812	912 , 1.010	410957658
199	1H-Inden-1-one, 2,3-dihydro-3,4,7-trimethyl-	Aromatic(Benzenes ,Napthalenes)	5692.2	731	912 , 1.120	10511570
200	Naphthalene, 1,2,3,4-tetrahydro-5,7-	Aromatic(Benzenes ,Napthalenes)	2683	808	912 , 1.160	4698037
201	Tridecane, 3-ethyl-	Cyclic /branched	6196.5	857	916 , 0.990	33611573
202	Cyclohexene, 1-octyl-	Cyclic /branched	8204.9	824	916 , 1.040	56817055
203	Humulen-(v1)	Cyclic /branched	5191.5	768	916 , 1.080	34268541
204	Naphthalene, 1-ethyl-	Aromatic(Benzenes ,Napthalenes)	31886	898	916 , 1.220	33521467
205	Cyclotetradecane	Cyclic /branched	6725.1	882	920 , 1.020	144549316
206	Naphthalene, 1,2,3,4-tetrahydro-6-propyl-	Aromatic(Benzenes ,Napthalenes)	5639	719	920 , 1.140	8600016
207	Cyclohexane, 1-(cyclohexylmethyl)-2-	Cyclic /branched	9818.2	822	924 , 1.030	38754688
208	Pentadecane	Cyclic /branched	8484.3	877	928 , 0.990	58790809
209	Z-10-Pentadecen-1-ol	Cyclic /branched	4259.9	764	932 , 1.030	91867447
210	Unknown 24	Cyclic /branched	2754.3	552	932 , 1.080	5332687
211	Cyclopropa[1,2:1,3]dicyclopenten-3(3aH)- 1,2,3b,6-tetrahydro-3a,6,6-trimethyl-	Cyclic /branched	7257.2	709	932 , 1.090	27018114

Peak	Name	Classifications	S/N	Similarity as per NIST library match	Primary and secondary column R.T. (s)	Area
212	Unknown 25	Aromatic(Benzenes ,Napthalenes)	2238.3	521	936 , 1.130	22554046
213	Naphthalene, 1,2,3,4-tetrahydro-6-propyl-	Aromatic(Benzenes ,Napthalenes)	5382.7	775	936 , 1.150	22741846
214	Acenaphthylene, 1,2,2a,3,4,5-hexahydro-	Aromatic(Benzenes ,Napthalenes)	1775.3	736	936 , 1.210	3668651
215	Naphthalene, 2,6-dimethyl-	Aromatic(Benzenes ,Napthalenes)	38721	944	936 , 1.230	25701975
216	Cyclopentane, 1,1'-(1,4-butandiyl)bis-	Cyclic /branched	12542	721	940 , 1.030	152715527
217	Unknown 26	Cyclic /branched	12542	637	940 , 1.040	3465197
218	11-Tridecyn-1-ol	Cyclic /branched	4496.8	742	940 , 1.060	81049920
219	Diphenylmethane	Aromatic(Benzenes ,Napthalenes)	2072.5	817	940 , 1.240	1564715
220	Ethanone, 1-(2-methylphenyl)-		3345.3	729	940 , 1.310	3897852
221	Tetradecane, 3-methyl-	Cyclic /branched	7326.9	908	944 , 1.000	61426848
222	Spiro[3.6]deca-5,7-dien-1-one,5,9,9-trimethyl	Cyclic /branched	20990	795	944 , 1.090	31192189
223	1-Phenyl-1-heptyne	Aromatic(Benzenes ,Napthalenes)	5125.8	771	944 , 1.190	9518349
224	Unknown 27		5923	625	948 , 1.110	3718555
225	Cyclopentadecane	Cyclic /branched	6228.9	872	952 , 1.020	62405120
226	Cyclohexene, 1-octyl-	Cyclic /branched	3876.7	874	952 , 1.060	23109164
227	Benzene, octyl-	Cyclic /branched	2197.9	775	952 , 1.090	47510403
228	Unknown 28	Cyclic /branched	9180.7	688	952 , 1.100	5675825
229	Unknown 29	Aromatic(Benzenes ,Napthalenes)	2478.4	692	952 , 1.170	2148287
230	1H-Indene, 1-methyl-3-propyl-	Aromatic(Benzenes ,Napthalenes)	5065.3	748	952 , 1.190	5211461
231	Naphthalene, 2,6-dimethyl-	Aromatic(Benzenes ,Napthalenes)	17060	915	952 , 1.250	13973609
232	Biphenylene, 1,2,3,6,7,8,8a,8b-octahydro-4,5-	Aromatic(Benzenes ,Napthalenes)	3464.4	776	956 , 1.140	28828231
233	Cyclopentadecane	Cyclic /branched	12679	896	960 , 1.040	70487893
234	Unknown 30	Aromatic(Benzenes ,Napthalenes)	3549.3	682	960 , 1.130	6761554
235	Unknown 31	Aromatic(Benzenes ,Napthalenes)	2885.9	632	960 , 1.200	1661470
236	Naphthalene, 2-(1-methylethyl)-	Aromatic(Benzenes ,Napthalenes)	7720.5	800	960 , 1.220	4060813
237	Unknown 32	Cyclic /branched	26042	648	964 , 1.040	19941654
238	7-Pentadecyne	Cyclic /branched	1884.1	741	964 , 1.070	44423280
239	Naphthalene, 2,6-dimethyl-	Aromatic(Benzenes ,Napthalenes)	10252	886	964 , 1.270	7840552
240	Pentadecane	Saturate	25912	930	968 , 1.030	99877080537
241	Cyclopentadecane	Cyclic /branched	4665	852	972 , 1.030	31407536
242	7-Pentadecyne	Cyclic /branched	3024.5	832	972 , 1.050	62669436
243	1H-Indene, 3-ethenyl-2,3-dihydro-1,1-	Aromatic(Benzenes ,Napthalenes)	2462	788	972 , 1.190	4648887
244	1H-Inden-1-one, 2,3-dihydro-3,4,7-trimethyl-	Aromatic(Benzenes ,Napthalenes)	2462	711	972 , 1.200	5121486
245	1H-Cyclopenta[1,3]cyclopropa[1,2]benzene, octahydro-7-methyl-3-methylene-4-(1-methylethyl)-, [3aS-(3aà,3bá,4á,7à,7aS*)]-	Aromatic(Benzenes ,Napthalenes)	6864.5	778	976 , 1.110	24019819
246	1,1'-Biphenyl, 4-methyl-	Aromatic(Benzenes ,Napthalenes)	9210.6	900	976 , 1.240	3493985
247	1,8-Cyclopentadecadiyne	Aromatic(Benzenes ,Napthalenes)	4603.4	709	980 , 1.140	13159890
248	7-Pentadecyne	Cyclic /branched	6365.7	799	984 , 1.040	101270783
249	Naphthalene, 1-propyl-	Aromatic(Benzenes ,Napthalenes)	19028	860	984 , 1.220	11029701
250	1,1'-Biphenyl, 4-methyl-	Aromatic(Benzenes ,Napthalenes)	3089.7	861	984 , 1.240	1539169
251	Sulfurous acid, 2-ethylhexyl hexyl ester	Cyclic /branched	7698	795	988 , 1.000	53615497
252	Unknown 33	Cyclic /branched	2343.1	591	988 , 1.040	3083634
253	Biphenylene, 1,2,3,6,7,8,8a,8b-octahydro-4,5-	Aromatic(Benzenes ,Napthalenes)	1743.5	777	988 , 1.160	12408288
254	Acenaphthene	Aromatic(Benzenes ,Napthalenes)	7080.9	881	988 , 1.310	4134697
255	Cyclotetradecane	Cyclic /branched	5114.9	801	992 , 1.030	184675693
256	Unknown 34	Cyclic /branched	2401.7	554	992 , 1.040	2328165
257	Longipinene epoxide	Cyclic /branched	2104.5	772	992 , 1.080	107160831
258	Unknown 35	Cyclic /branched	3636.2	668	996 , 1.050	26555739
259	Naphthalene, 1,4,5-trimethyl-	Aromatic(Benzenes ,Napthalenes)	23548	899	996 , 1.230	29873415
260	Decane	Cyclic /branched	11380	859	1000, 1.010	61874827
261	Benzene, (1-ethylheptyl)-	Cyclic /branched	12222	740	1000, 1.090	58370158
262	Unknown 36		12222	625	1000, 1.100	36647215
263	Unknown 37	Aromatic(Benzenes ,Napthalenes)	3624.7	699	1000, 1.160	5491199
264	Unknown 38	Cyclic /branched	1899	690	1004, 1.080	19075304
265	1-Isopropenylnaphthalene	Aromatic(Benzenes ,Napthalenes)	4207.3	772	1004, 1.290	5065935
266	Pentadecane, 2-methyl-	Cyclic /branched	6230.5	885	1008, 1.010	20217108
267	Cyclopentadecane	Cyclic /branched	4870.6	860	1008, 1.040	105673593
268	Benzene, 1-(1-methyl-2-propenyl)-4-(2-methylpropyl)-	Aromatic(Benzenes ,Napthalenes)	5181.3	768	1008, 1.160	4755882
269	n-Nonylcyclohexane	Cyclic /branched	7416.4	720	1012, 1.050	2111180
270	Cyclopentadecanol	Cyclic /branched	3459.8	808	1012, 1.070	12158264
271	Bicyclo[3.1.1]heptane, 2,6,6-trimethyl-3-(2-propenyl)-, (1à,2á,3à,5à)-		1655	800	1012, 1.100	22059027
272	Naphthalene, 1,4,5-trimethyl-	Aromatic(Benzenes ,Napthalenes)	19047	883	1012, 1.250	19586450
273	Pentadecane, 3-methyl-	Cyclic /branched	5298.3	902	1016, 1.010	50124197
274	7-Octadecyne, 2-methyl-	Cyclic /branched	4263.3	834	1016, 1.060	42300967
275	Spiro[3.6]deca-5,7-dien-1-one,5,9,9-trimethyl		21308	708	1016, 1.100	46981227
276	1H-Indene, 3-ethyl-1-(1-methylethyl)-	Aromatic(Benzenes ,Napthalenes)	1809.9	784	1016, 1.210	5770127
277	3-Hexadecene, (Z)-	Cyclic /branched	2805.1	881	1020, 1.030	19013283
278	Unknown 39		5799.3	695	1020, 1.120	1985926
279	Cyclohexene, 1-nonyl-		3524.9	843	1024, 1.080	35322519
280	Benzene, nonyl-		10209	859	1024, 1.110	16964976
281	Unknown 40	Aromatic(Benzenes ,Napthalenes)	5850.6	602	1024, 1.180	6885530
282	1-Hexadecanol		9405.2	918	1028, 1.050	130692467
283	Unknown 41		1936.7	636	1028, 1.120	8348626
284	Hexane, 2-phenyl-3-propyl-		6277.4	722	1028, 1.130	8382713
285	á-Vatirenene		1986.1	717	1028, 1.160	7684416
286	Naphthalene, 1,4,5-trimethyl-	Aromatic(Benzenes ,Napthalenes)	10199	892	1028, 1.260	8572880
287	Hexadecane	Saturate	18578	916	1032, 1.050	205969156
288	Unknown 42		4658.7	598	1032, 1.070	1428438
289	Unknown 43		6322.4	679	1032, 1.140	3783189
290	Unknown 44	Aromatic(Benzenes ,Napthalenes)	2026.3	666	1036, 1.230	8409488
291	2-Ethyl-1-dodecanol		7184.6	855	1040, 1.010	66445408
292	11-Hexadecen-1-ol, acetate, (Z)-		2486.3	794	1040 , 1.07	40959437
293	1,1'-Biphenyl, 2-ethyl-	Aromatic(Benzenes ,Napthalenes)	4143.2	731	1040, 1.250	3145562

Peak	Name	Classifications	S/N	Similarity as per NIST library match	Primary and secondary column R.T. (s)	Area
294	Naphthalene, 1,4,5-trimethyl-	Aromatic(Benzenes ,Napthalenes)	7887.7	857	1040, 1.260	7034158
295	Unknown 45	Aromatic(Benzenes ,Napthalenes)	1924.2	651	1044, 1.220	2258009
296	Unknown 46	Cyclic /branched	4710.7	584	1048, 1.040	40241639
297	Unknown 47	Cyclic /branched	4245.8	612	1048, 1.050	3803954
298	Unknown 48		2206.9	690	1048, 1.150	5633371
299	Heptadecane	Cyclic /branched	3393.7	876	1052, 1.020	45173689
300	Oxalic acid, butyl cyclohexylmethyl ester	Cyclic /branched	20898	811	1052, 1.050	832190901
301	8-Hexadecyne		2222.7	766	1052, 1.080	32254929
302	Unknown 49		9143.9	536	1056, 1.060	3729305
303	Unknown 50		5940	663	1056, 1.110	22629358
304	Naphthalene, 2-butyl-	Aromatic(Benzenes ,Napthalenes)	5898.1	834	1056, 1.240	24934882
305	Unknown 51	Aromatic(Benzenes ,Napthalenes)	1886.2	685	1056, 1.260	1230088
306	Naphthalene, 1,4,5-trimethyl-	Aromatic(Benzenes ,Napthalenes)	3524.6	822	1056, 1.300	3200745
307	Fluorene	Aromatic(Benzenes ,Napthalenes)	12731	900	1056, 1.340	5310780
308	cis-7-Tetradecen-1-yl acetate		1957.7	724	1060, 1.060	90245738
309	Unknown 52		1902.4	496	1060, 1.070	2738964
310	Pentadecane	Cyclic /branched	9166.7	891	1064, 1.020	118797460
311	4,6,6-Trimethyl-2-(3-methylbuta-1,3-dienyl)-3-oxatricyclo[5.1.0.0(2,4)]octane		12721	760	1068, 1.120	33964381
312	Unknown 53	Aromatic(Benzenes ,Napthalenes)	3209.7	692	1068, 1.270	4803992
313	9H-Fluorene, 2-methyl-	Aromatic(Benzenes ,Napthalenes)	4922.9	824	1068, 1.320	3735411
314	Naphthalene, 1-(2-propenyl)-	Aromatic(Benzenes ,Napthalenes)	8745.4	893	1068, 1.340	9890453
315	Naphthalene, 2-methyl-1-propyl-	Aromatic(Benzenes ,Napthalenes)	5701.8	795	1072, 1.250	13033095
316	Tetradecane, 1-iodo-	Cyclic /branched	6807.7	842	1076, 1.020	27251515
317	3-Heptadecene, (Z)-	Cyclic /branched	4370.3	768	1076, 1.040	46647582
318	Cyclopentane, undecyl-	Cyclic /branched	2813.6	797	1076, 1.060	93017447
319	Unknown 54		3431	672	1076, 1.080	25054540
320	1H-Indene, 5-hexyl-2,3-dihydro-		4423.3	755	1076, 1.180	8738885
321	1,1'-Biphenyl, 2-ethyl-	Aromatic(Benzenes ,Napthalenes)	3246.8	754	1076, 1.290	4498918
322	Cyclododecanemethanol	Cyclic /branched	3694.8	766	1084, 1.040	45287605
323	Spiro[3.6]deca-5,7-dien-1-one,5,9,9-trimethyl		19496	702	1084, 1.120	35470293
324	1-Decanol, 2-hexyl-	Cyclic /branched	4618.9	863	1088, 1.020	106230659
325	1,1'-Biphenyl, 2-ethyl-	Aromatic(Benzenes ,Napthalenes)	5163	821	1088, 1.320	5587345
326	8-Heptadecene	Cyclic /branched	6200.6	884	109 , 1.060	68469203
327	Benzene, decyl-		7239.6	798	1092, 1.140	13911074
328	Benzene, 1,1'-(1,3-propanediyl)bis-	Aromatic(Benzenes ,Napthalenes)	6093.9	846	1092, 1.280	11978759
329	1-Decanol, 2-hexyl-		7902.8	821	1096, 1.050	67067718
330	Benzene, (1-methylnonyl)-		5757.7	742	1096, 1.150	23603026
331	Naphthalene, 1-methyl-7-(1-methylethyl)-	Aromatic(Benzenes ,Napthalenes)	3199	809	1096, 1.290	2836405
332	Heptadecane	Saturate	20558	897	1100, 1.070	160436681
333	3-Heptadecene, (Z)-	Cyclic /branched	7914.7	825	1104, 1.060	53310961
334	2,2'-Dimethylbiphenyl	Aromatic(Benzenes ,Napthalenes)	2385.1	819	1104, 1.320	2802684
335	5-Heptadecene, 1-bromo-	Cyclic /branched	2137.8	772	1108, 1.080	47471523
336	Caryophyllene oxide		1725.6	737	1108, 1.120	55386626
337	Naphthalene, 1,2,3,4-tetramethyl-	Aromatic(Benzenes ,Napthalenes)	1910	752	1108, 1.270	5230075
338	8-Heptadecene	Cyclic /branched	3358.9	875	1112, 1.050	42725338
339	Unknown 55	Cyclic /branched	2520.5	623	1112, 1.070	3700705
340	Benzene, 1,1',1",1'"-(1,5-hexadiene-1,3,4,6-tetrayl)tetrakis-	Aromatic(Benzenes ,Napthalenes)	1689.4	745	1112, 1.330	1374328
341	Unknown 56		1685.3	681	1116, 1.130	14652446
342	Unknown 57	Aromatic(Benzenes ,Napthalenes)	4789.6	688	1116, 1.260	2149631
343	E,Z-2,13-Octadecadien-1-ol	Cyclic /branched	1944.7	804	1120, 1.090	51470604
344	Unknown 58		2547.4	520	1120, 1.170	2498732
345	1,2,3,3a,8,9,9a,9b-Octahydrocyclopenta[def]phenanthrene	Aromatic(Benzenes ,Napthalenes)	2170.7	750	1120, 1.260	8607644
346	Naphthalene, 1,2,3,4-tetramethyl-	Aromatic(Benzenes ,Napthalenes)	1861.3	811	1120, 1.290	1595906
347	E-2-Octadecadecen-1-ol	Cyclic /branched	6277.1	761	1124, 1.060	59480424
348	Unknown 59	Aromatic(Benzenes ,Napthalenes)	1762	672	1124, 1.290	1752101
349	Tetradecane, 4-ethyl-	Cyclic /branched	9118.5	880	1128, 1.030	188920180
350	Unknown 60		5187.6	688	1128, 1.250	8415183
351	Naphthalene, 1,6-dimethyl-4-(1-methylethyl)-	Aromatic(Benzenes ,Napthalenes)	2162	725	1128, 1.270	1268575
352	2,2'-Dimethylbiphenyl		3290.7	727	1128, 1.340	808095
353	5-Octadecene, (E)-	Cyclic /branched	3650.9	846	1132, 1.040	34816695
354	Cyclopropa[1,2:1,3]dicyclopenten-3(3aH)-one, 1,2,3b,6-tetrahydro-3a,6,6-trimethyl-		9892.8	720	1132, 1.130	13217881
355	Heptadecane, 2-methyl-	Cyclic /branched	8030.7	924	1136, 1.030	94775829
356	9H-Fluorene, 2-methyl-		13184	893	1136, 1.370	9728892
357	E-7-Octadecene	Cyclic /branched	1910.9	752	1140, 1.060	9566735
358	1-Eicosanol	Cyclic /branched	1704.4	827	1140, 1.070	87523398
359	Unknown 61		1900.8	679	1140, 1.270	2002709
360	9H-Fluorene, 9,9-dimethyl-		5047.7	771	1140, 1.340	2474012
361	1,1'-Biphenyl, 2-ethyl-		1694.5	758	1140, 1.350	6028198
362	Cyclohexane, undecyl-	Cyclic /branched	4002.9	747	1144, 1.080	11318780
363	9H-Fluorene, 1-methyl-		3352.4	900	1144, 1.400	1917563
364	9-Eicosyne	Cyclic /branched	3185.6	801	1148, 1.090	60042786
365	2,8-Decadiyne		18751	726	1148, 1.140	33214457
366	Azulene, 1,4-dimethyl-7-(1-methylethyl)-		1728.6	718	1148, 1.280	2216082
367	9H-Fluorene, 9,9-dimethyl-		3885.4	825	1148, 1.370	3138709
368	Unknown 62		2533.7	615	1152, 1.160	3677395
369	Unknown 63	Cyclic /branched	5462	586	1156, 1.080	51611021
370	Benzene, undecyl-		4465.4	782	1156, 1.160	12342493
371	Unknown 64		2581.7	462	1156, 1.230	2766450
372	2,2'-Dimethylbiphenyl		1791.7	772	1156, 1.390	529352
373	Octadecane	Saturate	17692	915	1160, 1.090	169671000
374	Benzene, (1-methyldecyl)-		4302	710	1160, 1.180	31852556
375	9H-Fluoren-9-one		1755.5	826	1160, 1.490	1219135
376	1-Octadecanol		5852	802	1164, 1.070	28410351
377	1-Octadecanol	Cyclic /branched	3244.6	871	1172, 1.070	63661720

Peak	Name	Classifications	S/N	Similarity as per NIST library match	Primary and secondary column R.T. (s)	Area
378	Unknown 65	Cyclic /branched	2588.4	699	1180, 1.090	6040638
379	Naphthalene, 1-hexyl-		3441.3	796	1180, 1.290	3221559
380	Unknown 66		1919.8	545	1184, 1.190	3770387
381	Pentadecane, 8-hexyl-	Cyclic /branched	8823.3	876	1188, 1.050	85244181
382	Naphthalene, 2-hexyl-		4647.2	796	1188, 1.280	5660539
383	Phenanthrene	Phenanthrene	29635	942	1188, 1.510	11268311
384	4-Phenanthrenol, 1,2,3,4-tetrahydro-4-	Phenanthrene	3878.3	777	1192, 1.400	3564796
385	Octadecane, 2-methyl-	Cyclic /branched	4174.6	897	1196, 1.050	73818121
386	Bicyclo[10.6.0]octadeca-1(12),15-diene		7233.3	773	1196, 1.160	16098219
387	Unknown 67		1716.9	633	1196, 1.220	778819
388	Cyclododecanemethanol	Cyclic /branched	6506.6	824	1200, 1.090	83681429
389	1-Octadecanol	Cyclic /branched	1917.9	779	1204, 1.100	27666148
390	1,13-Tetradecadiene		5691.5	789	1204, 1.110	55765930
391	Unknown 68		1957	645	1204, 1.220	1989562
392	2,8-Decadiyne		17628	725	1208, 1.170	45928420
393	2-Ethyl-1-dodecanol	Cyclic /branched	4016.6	882	1212, 1.070	303721845
394	Unknown 69	Cyclic /branched	3510.4	526	1212, 1.090	19368015
395	9H-Fluorene, 9,9-dimethyl-	Phenanthrene	4310.2	875	1212, 1.420	8837433
396	Anthracene, 9,10-dihydro-9,10-dimethyl-	Phenanthrene	2513.6	729	1216, 1.410	2455980
397	Benzene, dodecyl-		4099.1	803	1220, 1.200	11398821
398	9H-Fluorene, 9,9-dimethyl-	Phenanthrene	4085.2	876	1220, 1.460	2219688
399	Nonadecane	Saturate	2460.9	749	1224, 1.090	34386697
400	Benzene, (1-methylundecyl)-		8028	730	1224, 1.180	8247448
401	1-Nonadecene	Cyclic /branched	4425.4	900	1228, 1.100	68455384
402	Eicosane, 2-methyl-	Cyclic /branched	2516.6	854	1232, 1.070	27978849
403	1-Docosene	Cyclic /branched	2001.7	858	1236, 1.080	58310372
404	Unknown 70		1996.1	588	1236, 1.200	989088
405	Oxalic acid, di(cyclohexylmethyl) ester	Cyclic /branched	14619	791	1240, 1.110	19563662
406	Pentadecane, 2,6,10-trimethyl-	Cyclic /branched	7152.7	851	1244, 1.070	75981879
407	Heptacosane		3853.2	925	1244, 2.330	43936831
408	9-Nonadecene	Cyclic /branched	4558.6	811	1248, 1.110	91238249
409	Nonadecane, 2-methyl-	Cyclic /branched	3238.8	929	1252, 1.070	42769210
410	Unknown 71	Cyclic /branched	2768.3	690	1252, 1.140	29980773
411	Unknown 72		5970.6	686	1252, 1.190	3282012
412	Phenanthrene, 1-methyl-	Phenanthrene	4568.6	922	1256, 1.540	4306205
413	Eicosane, 2-methyl-	Cyclic /branched	1773.7	880	1260, 1.080	31942210
414	5H-Dibenzo[a,c]cyclohepten-5-ol	Phenanthrene	3031.2	795	1260, 1.440	7767514
415	Unknown 73	Cyclic /branched	4447.7	699	1264, 1.120	797297072
416	Unknown 74		2018.4	699	1264, 1.150	24350280
417	Unknown 75		9137.7	696	1264, 1.200	13976900
418	1-Eicosene	Cyclic /branched	6506.4	759	1268, 1.110	132905053
419	9,12-Octadecadienal		2407.9	763	1268, 1.160	60127573
420	Eicosane	Saturate	8949.9	939	1272, 1.130	200763969
421	Phenanthrene, 1-methyl-	Phenanthrene	8059.4	917	1272, 1.610	5649189
422	Benzene, tridecyl-	Aromatic(Benzenes ,Napthalenes)	11570	707	1276, 1.220	9124343
423	1-Octadecyne		2745.6	814	1280, 1.150	100581593
424	Benzene, (1-methyldodecyl)-	Aromatic(Benzenes ,Napthalenes)	8828.2	762	1280, 1.220	9061139
425	Nonadecane	Cyclic /branched	3319	851	1284, 1.100	109222697
426	1-Eicosene	Cyclic /branched	3169.5	703	1284, 1.120	84744780
427	Cyclooctane, cyclohexyl-	Cyclic /branched	7402	763	1292, 1.140	70871020
428	Pentadecane	Cyclic /branched	5927.6	873	1296, 1.100	70213516
429	5-Tridecene, (Z)-	Cyclic /branched	2084.9	748	1296, 1.120	50536192
430	Unknown 76	Cyclic /branched	10551	618	1296, 1.140	1059137
431	Cycloeicosane	Cyclic /branched	8354.3	841	1300, 1.140	102523858
432	Unknown 77	Cyclic /branched	2454.6	683	1304, 1.160	3572632
433	Unknown 78		2058.1	697	1308, 1.370	3014060
434	Nonadecane, 2-methyl-	Cyclic /branched	2502.2	871	1312, 1.110	88133060
435	Cyclododecanemethanol	Cyclic /branched	8878	799	1312, 1.170	240378649
436	Cyclohexane, 1,1'-(1,4-butanediyl)bis-		8746.7	779	1320, 1.170	16792084
437	Unknown 79	Aromatic(Benzenes ,Napthalenes)	10170	637	1320, 1.240	5218131
438	Benzene, (1,2,2-trimethylpropyl)-	Aromatic(Benzenes ,Napthalenes)	10170	747	1320, 1.250	3014854
439	Heneicosane	Saturate	6775.3	941	1328, 1.160	163966492
440	Cyclooctane, 1,2-diethyl-		2536.3	717	1332, 1.160	25224026
441	Cyclohexene, 3-nonyl-	Cyclic /branched	2990.8	831	1332, 1.210	26105134
442	Benzene, tetradecyl-	Aromatic(Benzenes ,Napthalenes)	14618	879	1332, 1.270	8244695
443	Unknown 80	Aromatic(Benzenes ,Napthalenes)	2200.1	600	1332, 1.280	1149173
444	Phenanthrene, 2,5-dimethyl-		2624.5	868	1332, 1.680	3589228
445	1-Nonadecene	Cyclic /branched	2724.8	893	1336, 1.160	146360408
446	Benzene, (1,3-dimethylbutyl)-	Aromatic(Benzenes ,Napthalenes)	6920.4	730	1336, 1.280	7370008
447	Unknown 81	Cyclic /branched	3053.7	542	1340, 1.180	3076788
448	2-Tetradecyne	Cyclic /branched	1815.5	748	1340, 1.200	18149517
449	Octadecane	Cyclic /branched	3022.5	867	1344, 1.150	13272241
450	Unknown 82	Cyclic /branched	1978.6	556	1344, 1.220	6389376
451	Unknown 83	Aromatic(Benzenes ,Napthalenes)	1947.8	697	1344, 1.280	2411141
452	Eicosane, 2,4-dimethyl-	Cyclic /branched	6027.5	846	1352, 1.160	42908330
453	Oxalic acid, di(cyclohexylmethyl) ester	Cyclic /branched	11427	810	1352, 1.210	30070774
454	Pyrene		1889.7	873	1352, 1.880	702495
455	Eicosane, 2-methyl-	Cyclic /branched	1631.6	824	1364, 1.180	35556215
456	Benzene, 1,1'-[oxybis(methylene)]bis[4-	Aromatic(Benzenes ,Napthalenes)	2491.7	724	1364, 1.330	2275292
457	Oxalic acid, cyclohexylmethyl propyl ester	Cyclic /branched	7115.7	815	1368, 1.250	20073582
458	1-Octene, 3,7-dimethyl-	Cyclic /branched	3697.7	809	1372, 1.220	0
459	1-Tricosanol		4767.5	749	1376, 1.240	47206597
460	Benzene, 1-methyl-3-hexyl-	Aromatic(Benzenes ,Napthalenes)	7828.2	715	1376, 1.370	4957613
461	Docosane	Saturate	5918.1	944	1380, 1.250	121781447
462	Cyclooctane, 1,2-diethyl-		1674.2	810	1384, 1.260	94890978
463	Unknown 84	Aromatic(Benzenes ,Napthalenes)	2483.3	694	1384, 1.370	1984467
464	Pyrene		4219.6	896	1384, 2.120	2269790

Peak	Name	Classifications	S/N	Similarity as per NIST library match	Primary and secondary column R.T. (s)	Area
465	Benzene, pentadecyl-	Aromatic(Benzenes ,Napthalenes)	9440.2	864	1388, 1.380	5713686
466	Cyclotetracosane	Cyclic /branched	5063.2	870	1392, 1.260	63782465
467	Benzene, (1,3-dimethylbutyl)-	Aromatic(Benzenes ,Napthalenes)	4500.1	759	1392, 1.400	5570871
468	Heptacosane		3545.4	926	1392, 2.440	28245176
469	Pentadecane		3676.7	825	1400, 1.230	44068750
470	1,1'-Bicycloheptyl		1850.5	799	1400, 1.330	4035310
471	Cyclohexane, 1-ethyl-1,3-dimethyl-, trans-	Cyclic /branched	3737.3	788	1404, 1.310	6065747
472	Cyclohexane, 1-methyl-3-pentyl-	Cyclic /branched	7075.4	836	1408, 1.310	16515478
473	Docosane	Cyclic /branched	2512.9	779	1412, 1.250	8496945
474	Cyclooctane, (1-methylpropyl)-	Cyclic /branched	2217.8	771	1416, 1.300	20760982
475	Unknown 85	Cyclic /branched	2217.8	593	1416, 1.310	4394470
476	Docosane, 2,21-dimethyl-		2910.4	840	1420, 1.260	34292624
477	Ethanone, 1-(1-methylcyclohexyl)-		1921	810	1424, 1.360	5854926
478	1-Octadecanol		4706.8	766	1432, 1.330	139568905
479	Tricosane	Saturate	4104.4	571	1436, 1.350	35381184
480	Unknown 87		2474.9	673	1436, 1.400	6440184
481	Unknown 88	Aromatic(Benzenes ,Napthalenes)	3175.3	678	1436, 1.510	5522024
482	Unknown 89		2682.7	558	1440, 0.810	48771238
483	1-Docosene	Cyclic /branched	3241.5	876	1448, 1.370	48479823
484	Benzene, hexadecyl-	Aromatic(Benzenes ,Napthalenes)	5757.3	891	1448, 1.530	5261138
485	Benzene, (1-methylpentadecyl)-		2371.1	785	1452, 1.550	1825053
486	Tetradecane, 1-iodo-	Cyclic /branched	2210.4	838	1464, 1.340	13895635
487	Cyclohexane, 1,1'-(1,2-dimethyl-1,2-	Cyclic /branched	1945.2	805	1464, 1.430	8713102
488	Cyclohexane, 1-isopropyl-1-methyl-	Cyclic /branched	3935.8	843	1472, 1.440	8486233
489	Decane, 2,3,5,8-tetramethyl-	Cyclic /branched	1954.1	824	1492, 1.440	3198016
490	Tetracosane	Saturate	5438.3	880	1496, 1.470	101044613
491	Cyclopentadecane		2813.2	754	1496, 1.490	92926991
492	n-Heptadecylcyclohexane	Cyclic /branched	2735	822	1500, 1.520	21374587
493	Benzene, 1-methyl-3-hexyl-		2465.2	719	1500, 1.670	2100339
494	n-Heptadecylbenzene		2445.3	804	1516, 1.710	2749140
495	Oxalic acid, di(cyclohexylmethyl) ester	Cyclic /branched	2806.7	856	1540, 1.590	7434440
496	Heptacosane		2160.3	906	1552, 2.840	24482356
497	Octadecane		2236.2	900	1564, 1.580	18751316
498	Pentacosane	Saturate	7097.5	919	1568, 1.630	83010039
499	Cyclohexane, (1-methylethyl)-		1826.3	781	1572, 1.690	3474905
Total						1.23296E+11

waste plastic (hdpe) into liquid hydrocarbons (figure 2 and table 1) was analyzed by GCxGC TOF MS spectrometer in accordance with the various retention time and S/N (signal by noise) different types of saturated hydrocarbon compounds such as (Nonane, Undecane, Dodecane, Tridecane, Pentadecane), benzene derivatives compounds such as (Benzaldehyde, Benzene, 1-ethyl-4-methyl-, Benzene, 1,2,3-trimethyl-, Benzene, 1-ethenyl-2-methyl-, Benzene, 1,2,3-trimethyl-) and cyclobenzene derivatives compounds such as (Cyclodecane, Oxalic acid, isobutyl nonyl ester, Cyclopentene, 1-butyl-, Decane, 2-methyl-) are appeared in the analysis result index. Above GCxGC TOF MS report show that liquid hydrocarbon consists 9.742% saturated hydrocarbons, 53.983% branched/cyclic hydrocarbons, 10.99% aromatics hydrocarbons (benzene, Nepthalines), 0.245% phenanthrene hydrocarbons and 25.04% unclassified hydrocarbon. Based on the retention time and S/N numbers following hydrocarbon compounds, as follows such as at the initial phase of the analysis at retention time (primary and secondary column) 476, 0.920 and S/N number 4420.7 compound is Nonane, retention time 536, 1.020 and S/N number 3433.5, compound is Benzene, 1-ethyl-3-methyl-, retention time 540, 1.110 and S/N number 2270.3, compound is Benzaldehyde, retention time 552, 0.950 and S/N number 9899.6, compound is 1-Decene, retention time 556, 0.980 and S/N number 3509.3, compound is Bicyclo[5.3.0]decane, retention time 556, 1.040 and S/N number 25980, compound is Benzene, 1-ethyl-4-methyl-, retention time 560, 0.940 and S/N number 13479, compound is Decane, retention time 564, 0.980 and S/N number 2573.4, compound is Cycloheptane, bromo-, retention time 568 , 1.030 and S/N number 9522.3, compound is Benzene, 1,2,3-trimethyl-, retention time 568 , 1.050 and S/N number 2277.3, compound is Benzene, 1-ethenyl-2-methyl- respectively.

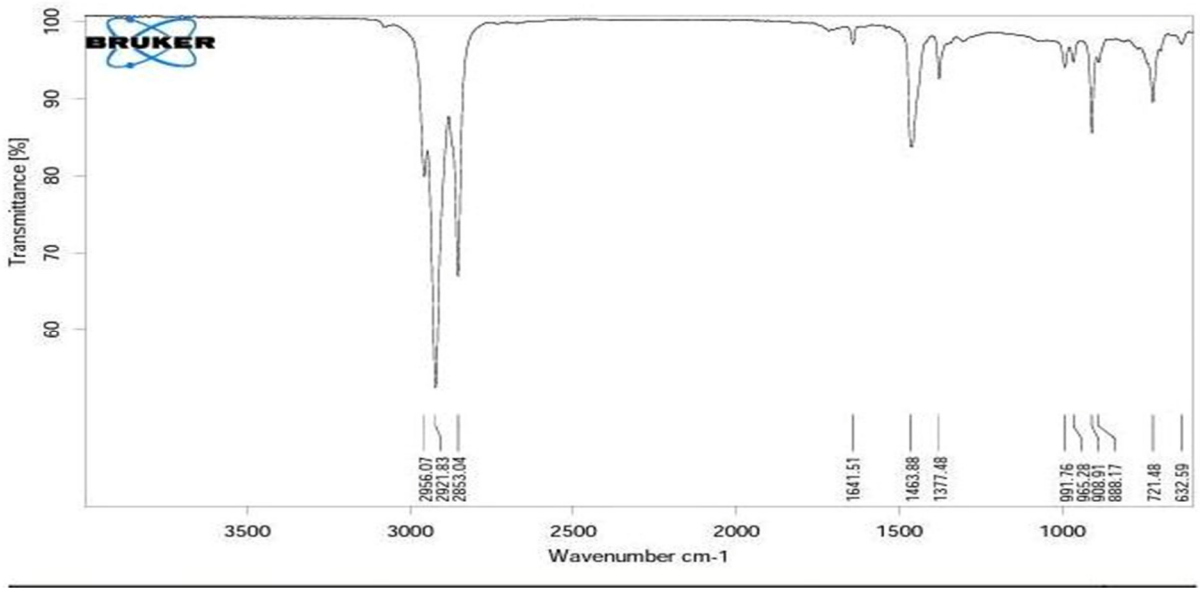


Figure 3 FT-IR Spectrum of waste plastic (hdpe) into liquid hydrocarbons

Table 2 FT-IR spectrums waste plastic (hdpe) into liquid hydrocarbons functional group name

Number of Peak	Wave Numbers (cm^{-1})	Functional Group Name
1	2956.07	$-CH_3$
2	2921.83	$-CH_3$
3	2853.04	$-CH_3$
4	1641.51	C=C
5	1463.88	C=C
6	1377.48	$-CH_3$
7	991.76	-CH=CH
8	965.28	-CH=CH
9	908.91	-CH=CH-(cis)
10	888.17	-CH=CH
11	721.48	-C-H
12	632.51	

FT-IR analysis of liquid hydrocarbon fuel (Figure 2 and Table 1) according to their wave numbers and spectrum band following types of functional groups are appeared in the analysis. We noticed that in the spectrum field wave numbers 2956.07 cm^{-1}, 2921.83 cm^{-1} and 2853.04 cm^{-1} functional group is $-CH_3$, wave numbers 1641.51 cm^{-1} and 1463.88 cm^{-1} functional group is C=C, wave number 1377.48 cm^{-1}, functional group is CH_3, wave numbers 991.76 cm^{-1}, 965.28 cm^{-1}, 908.91 cm^{-1} and 888.17 cm^{-1} functional group is $-CH=CH_2$, wave number 721.51 cm^{-1} functional group is –C-H. Energy values are calculated by $E=h\upsilon$, where h=plank constant, h $=6.626x10^{-34}$ J, υ= Frequency in Hertz (sec^{-1}), Where $\upsilon=c/\lambda$, c=Speed of light, where, $c=3x10^{10}$ m/s, $W=1/\lambda$, where λ is wave length and W is wave number in cm^{-1}. Therefore the equation $E=h\upsilon$, can substitute by the following equation, E=hcW. According to their wave number energies value are calculated such as for 2956.07 (cm^{-1}) calculated energy, $E=5.87x10^{-20}$ J, wave number 2921.83 (cm^{-1}) calculated energy, $E=5.80x10^{-20}$ J, wave number 2853.04 (cm^{-1}) calculated energy, $E=5.67x10^{-20}$ J, wave number 1641.51 (cm^{-1}) calculated energy, $E=3.26x10^{-20}$ J, wave number 1463.88 (cm^{-1}) calculated energy, $E=2.90x10^{-20}$ J respectively.

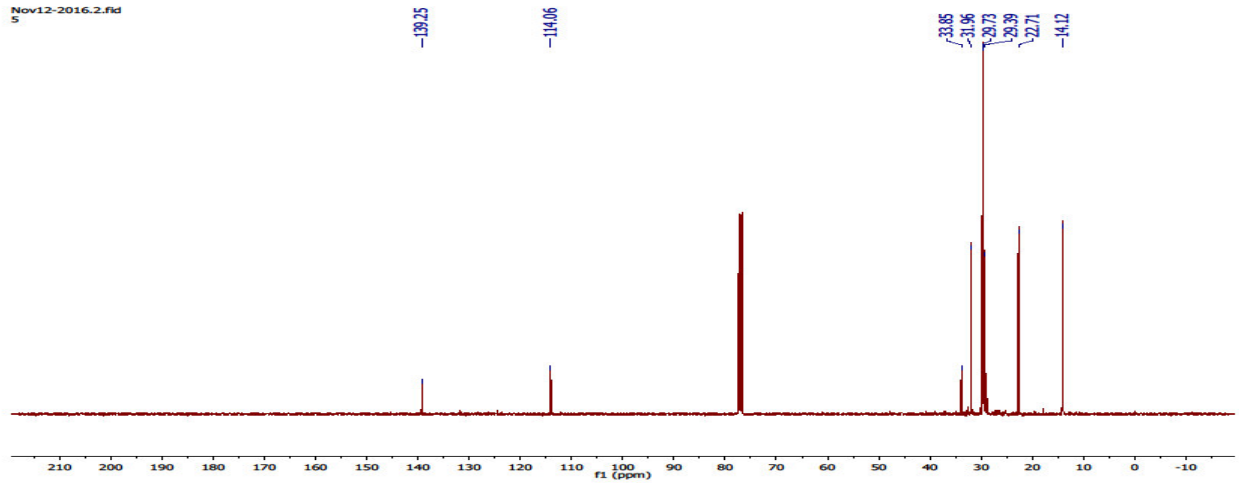


Figure 4 ^{13}CNMR spectrum waste plastic (hdpe) into liquid hydrocarbon fuel

^{13}CNMR spectrum (Figure-4) show more chemical shift (ppm) due to combination of different types of carbon. Chemical Shift in ^{13}C NMR spectrum resembles to proton NMR spectrum. Each carbon nucleus has its own chemical environment due to non-equivalent nuclei, it feels a different magnetic field, and absorbs at different applied magnetic fields strength. In ^{13}CNMR spectrum 14.12 signal and carbon is CH_3, 22.71 signal and carbon is CH_2, 29.39, 29.73 signals and carbon is CH_2, 31.96 signal and carbon is R_3-C.

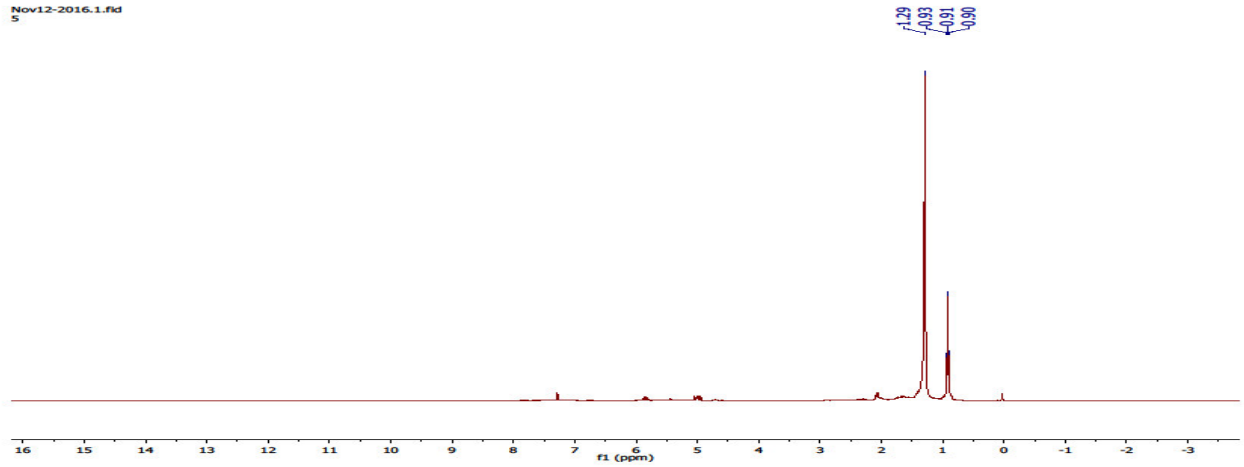
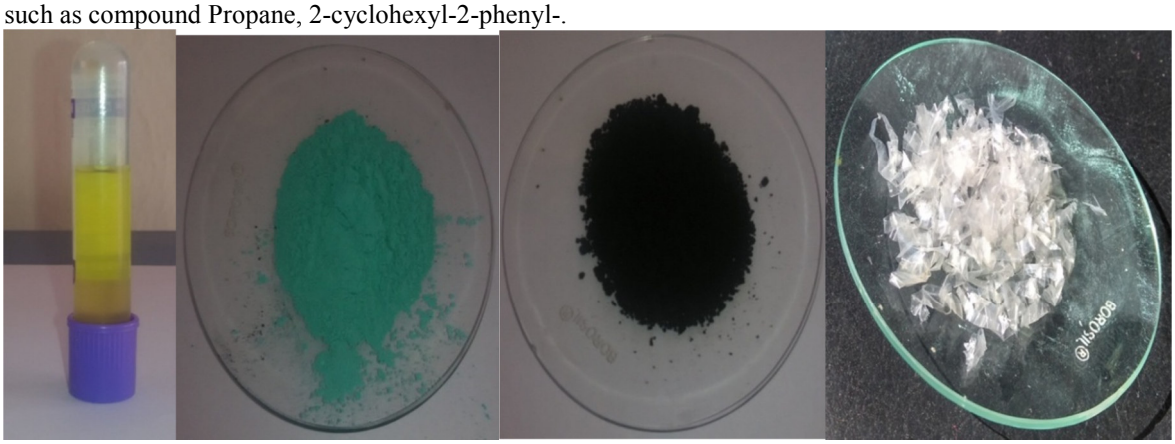


Figure 5 ^{1}H NMR spectrum waste plastic (hdpe) into liquid hydrocarbon fuel

^{1}HNMR spectrum (Figure-5) show that 4 peaks. Four types of proton are present in liquid hydrocarbons such as compound Propane, 2-cyclohexyl-2-phenyl-.



Picture 1 waste plastic (hdpe) into liquid hydrocarbon fuel, Picture 2 $CuCO_3$ catalysts, Picture 3 Residue, Picture 4 waste hdpe plastic

Conclusion

In the present investigation successful catalytic pyrolysis conversion of waste plastic (hdpe) was carried out under reaction condition, waste plastic (hdpe) degrade in the presence of $CuCO_3$ catalyst resulted in different fractions. Collected liquid hydrocarbon fuel density was 78 g ml^{-1} and fuel was characterized by GCxGC TOF MS, FT-IR, ^{13}CNMR and ^{1}HNMR. Analysis results show accordance of aliphatic and aromatic hydrocarbons withought including such as cupper metals. Long chain hydrocarbons have broken down into smaller hydrocarbons by pyrolysis conversion process. Liquid hydrocarbons, gaseous and solid residue are very good source of chemicals. Liquid hydrocarbons fuel has a high flammable capacity and its contents highly combustible.

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