

Waste Polyethylene Terephthalate (PETE) And Polystyrene (PS) Into Fuel

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Abstract: Waste plastics are harmful, toxic, and non-biodegradable. Environmental impacts of waste plastics are raised concern about all over the world for safe and friendly environment. Due to dense population and environmental effects of the major city in the world dumping, incineration and land filling are faced difficulties and challenges. At this circumstances vast of waste plastics are remained vulnerable and as solid hazardous materials in the environment. Incineration could be happen ruptures and bad atmospheric impacts with poisonous gases such as Carbon monoxide, Carbon dioxide, Oxide of Nitrogen are released in the environment. Lack of land, dumping and incineration space some development countries throwing the waste plastics into the deep sea water. As a result sea animal and mammal such as fish and other sea animal are eating waste plastics assumed as a jelly fish. Every year numerous sea animals are dying causes of waste plastics ingestion. Natural State Research, Inc., has developed methods are able to conversion PP and PS waste plastics materials to the valuable fuel materials by thermal process with ZnO and Al₂O₃ catalysts. Temperature range was 200 - 400 °C. Product fuel density is 0.90 g/ml. Fuel was analysis by GC/MS, FTIR and DSC for fuel characterization. Total conversion rate was including light gas and liquid product 78.3% and input electricity was required 0.721KWh.

Keywords: PETE, PS, fuel, thermal degradation, catalyst, hydrocarbon, waste plastics, GC/MS

1. Introduction

Plastic materials are present in almost every area of daily life. However, the significant growth of plastic consumption also led to increasing amounts of waste plastics. Mixed plastic waste (MPW) usually contains polymers such as polyethylene (PE), polypropylene (PP), polystyrene (PS), poly (ethylene terephthalate) (PET), poly (vinyl chloride) (PVC), acrylonitrile-butadiene-styrene (ABS), and others. ABS represents about 3-5 wt % of the MPW.[1] Its thermal degradation into fuel oil occurs differently with respect to other polymers due to the presence of nitrogen (N) coming from the acrylonitrile units. N remains in ABS degradation oil [2] and leads to the corrosion of engine parts and the formation of very harmful compounds when the oils are used as fuel [3-4]. The development of different viable recycling technologies for plastic waste materials is becoming increasingly important. There is growing interest in thermolysis and catalytic polymer degradation as methods of producing various fuel fractions from polymer wastes. Pyrolysis is one of the best methods for preserving valuable petroleum resources in addition to protecting the environment by limiting the volume of nondegradable waste. Pyrolysis of waste plastics is favored because of the high rates of conversion into oil, which can be obtained. The gaseous products coming from the pyrolysis process with high caloric value may be used as fuel in the process.

Recycling by pyrolysis has high potential for heterogeneous waste materials, which cannot be economically separated [5]. Polystyrene (PS), polyethylene (PE), and poly (vinyl chloride) (PVC) constitute a significant portion of municipal solid waste (7 wt % or 25 vol %; numbers vary with country and municipality). PE is the most abundant waste plastic (50-60 wt %), followed by PS (16-20 wt %). Polypropylene (PP) is the third-most-abundant waste plastic (10-16 wt %); however, it was not included in the present study, because its combustion and emissions bear pronounced similarities with those of PE [6, 7]. There has been considerable work conducted on pyrolysis of polymers, some of which aimed at pyrolytic recycling of plastics to monomers and fuels. The chemistry of plastic pyrolysis was reviewed by Wall et al.[8] who concluded that thermal treatment at sufficiently high temperature results in breaking polymer chains and subsequent formation of smaller molecules. Some polymers, e.g., acrylics, decompose thermally and generate high yields of monomers. However, the most common plastics such as polyethylene and polypropylene do not appear to give high yields of monomers but rather a mixture of many different hydrocarbons with proportions depending on the process conditions (mostly temperature and catalyst). In most cases, it is not practical to isolate a single chemical or a fraction from those mixed hydrocarbons or oxygenated compounds derived from other polymers. The most straightforward application for the whole product stream is the use as fuel. Thermal conversion of plastics, both pyrolysis and gasification, has been extensively studied, and commercial processes have been developed [9,10] to convert waste plastics to fuels[11]. The low-grade uses for mixed-plastic recycled materials have led to research in alternative processes for plastics recycling. For example, there has been research interest in the pyrolysis of waste plastic, in which the plastic is heated in an inert atmosphere to produce mainly a gas and an oil/wax product; for some plastics, a char product is also formed. The oil/wax can be used as a fuel or chemical feedstock, and the gas has sufficient calorific value to be used as a process fuel. The thermal recycling of waste plastics by pyrolysis represents an environmentally attractive route for recycling, by preserving valuable petroleum resources and diverting nondegradable waste

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away from waste landfill disposal[12]. The processes proposed for plastic waste pyrolysis are flexible and may treat both mixtures of plastics and mixtures of these with residual materials (such as wood and agro forest wastes and tire derived fuel).[13-21] It may also operate auto thermally, under a controlled O₂ content.[22] The use of acid catalysts in the pyrolysis reactor itself effectively decreases the temperature required for cracking and for modifying product distribution.[23-32] This second objective is also attained through the catalytic reforming of the thermal pyrolysis product stream [33-40]. Pyrolysis is a transformation technology with good perspectives for treating both polyolefins (2/3 of waste plastics) and remaining waste plastics, and it has undergone important development.

2. Materials

PETE and PS waste plastic was collected from Natural State Research dining section. Collected waste plastic was cleaned and cut into small pieces for liquefaction process. PS and PETE waste plastics with activated carbon were placed into reactor chamber for liquefaction process. Catalyst was use Zinc oxide (ZnO) and Aluminum Oxide (Al₂O₃) as 1% for liquefaction process. Activated carbon, ZnO and Al₂O₃ was collected from VWR.COM Company and all was powder format.

3. Process Description

PETE and PS mixture to fuel production was under laboratory fume hood in batch process at temperature 200 - 400 °C. Sample was 70 gm polystyrene and 30 gm polyethylene terephthalate. Catalyst was using ZnO 1%, Al₂O₃ 1% and activated carbon was 10%. Total sample was use for experiment 100 gm. Experimental process was shown figure 1 for visual understanding. PS and PETE waste plastic mixture was placed in to reactor chamber and reactor made by Pyrex glass. PS and PETE waste plastic mixture placed into reactor chamber and reactor chamber placed into inside the reactor for heating purpose. Before start the heat condensation was connected into reactor for fuel collection. Process diagram was shown into figure 1 for visual understanding. Plastics materials, catalyst and activated carbon were placed at a time inside the reactor chamber. Reactor was hook up with condensation and light gas collection system. Sample was heated up 200 – 400 °C and process was continued until finished the sample. PS and PETE waste plastic melting temperature is above the 200 °C for that reason in this experiment start temperature was 200 °C. Two types of catalyst were used for reaction acceleration and quality product collection. Activated carbon was use for dye removing because plastic has different types of additive or color. Waste plastics heated up then turn into melt, then turn into liquid slurry when temperature was increased slowly from 200 °C to 400 °C. When temperature was increased gradually produced vapor travel into condensation unit and collected liquid fuel. Product fuel was clean up by using filtering system and keep into container for final use. Production period produce light gas was cleaned by 0.25 (N) sodium hydroxide solution, 0.25 (N) sodium bicarbonate and water. Light gas was collected into Teflon bag for analysis purpose. In this experiment wax material was not produce that much and it was little. Wax material was comes with liquid fuel as a

sediment but sediment was separated by filtering system. PETE waste plastic has oxygen content 33% and this oxygen content cannot turn over fuel. After finished the fuel production residue was collected from reactor chamber and keep into separate container for analysis purposed. Catalyst recovery is under process and light gas and residue analysis under process. Product fuel density is 0.90 g/ml. Product fuel weight is 63.1 gm and volume is 70 ml. Total residues was leftover including catalyst and activated carbon 33.7 gm. But actual residue was 21.7 gm. Because 10 gm activated carbon and catalyst was 2 gm. During fuel production period light gas was generated 15.2 gm sample. Total experiment run time was 4.35 hours and electricity was required 0.721 KWh.

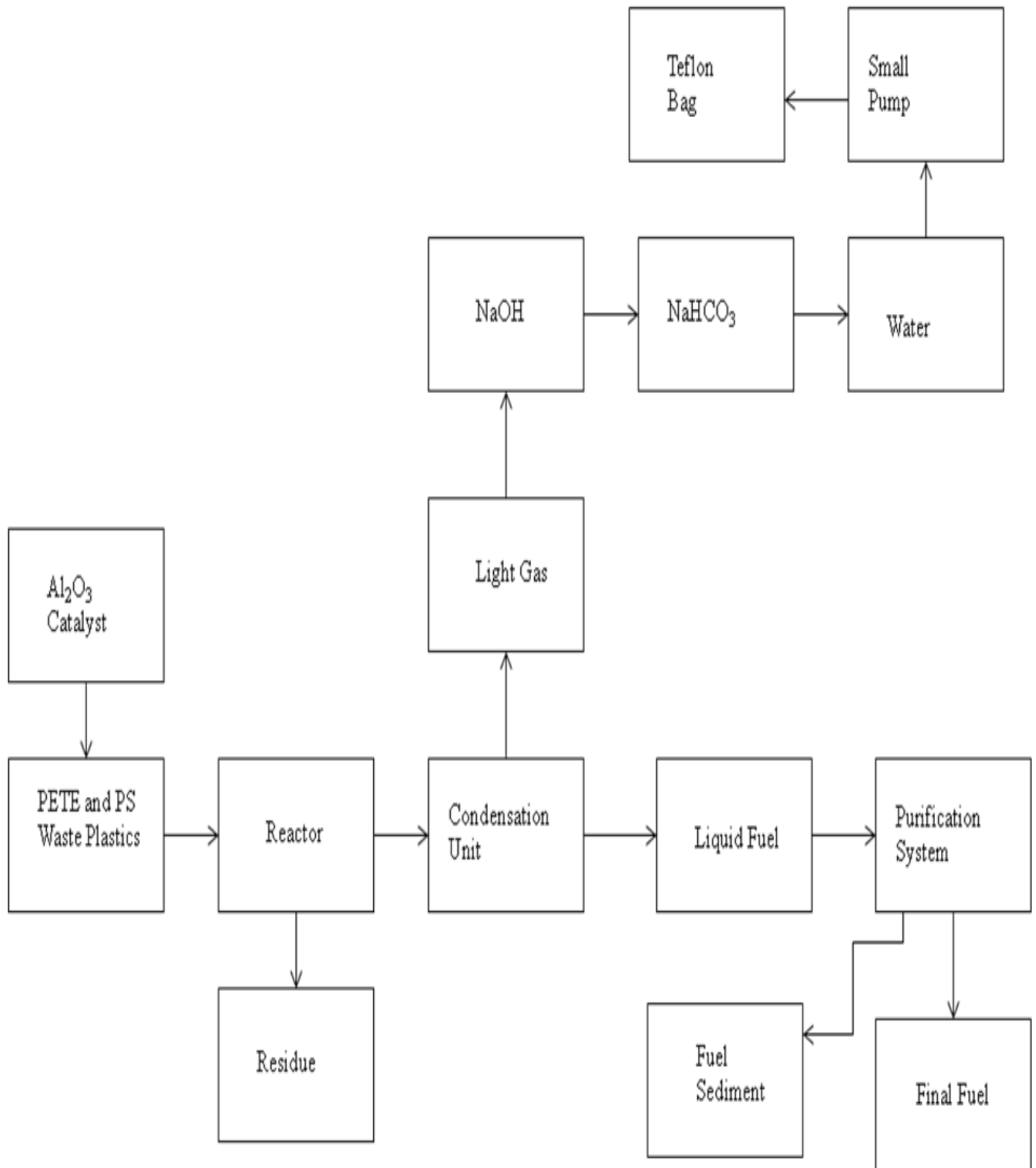


Figure 1: PS and PETE mixture to fuel production

4. Result and Discussion

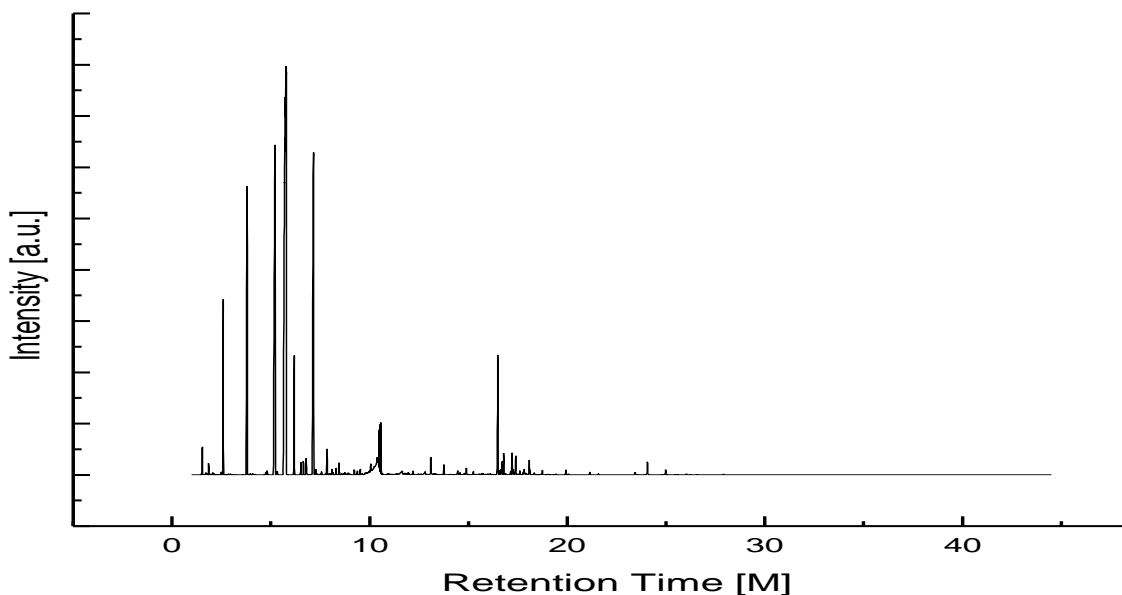


Figure 2: GC/MS chromatogram of PETE and PS mixture to fuel

Table 1: GC/MS chromatogram compounds list of PETE and PS mixture to fuel

Peak Number	Retention Time (M.)	Trace Mass (m/z)	Compound Name	Compound Formula	Molecular weight	Probability Percentage	NIST Library Number
1	1.48	41	Cyclopropane	C ₃ H ₆	42	50.4	18854
2	1.53	44	Acetaldehyde	C ₂ H ₄ O	44	73.0	227634
3	1.71	43	Pentane	C ₅ H ₁₂	72	37.4	114462
4	1.73	55	1-Butene, 3-methyl-	C ₅ H ₁₀	70	14.9	114463
5	1.77	55	Cyclopropane, 1,1-dimethyl-	C ₅ H ₁₀	70	26.4	34618
6	1.91	67	Cyclopentene	C ₅ H ₈	68	21.9	19032
7	1.96	43	1-Pentanol, 2-methyl-	C ₆ H ₁₄ O	102	22.4	19924
8	2.03	43	Acetic acid	C ₂ H ₄ O ₂	60	76.7	291347
9	2.07	41	1-Hexene	C ₆ H ₁₂	84	29.9	227613
10	2.12	57	Hexane	C ₆ H ₁₄	86	68.9	61280
11	2.16	41	Pentane, 3-methylene-	C ₆ H ₁₂	84	34.5	19323
12	2.33	56	1-Pentene, 2-methyl-	C ₆ H ₁₂	84	25.5	19326
13	2.38	67	3-Hexyne	C ₆ H ₁₀	82	17.0	19282
14	2.41	67	2,4-Hexadiene, (Z,Z)-	C ₆ H ₁₀	82	13.4	113646
15	2.45	56	1-Pentene, 2,4-dimethyl-	C ₇ H ₁₄	98	39.2	913
16	2.59	78	Benzene	C ₆ H ₆	78	46.6	291514
17	2.76	67	Bicyclo[3.1.0]hexane	C ₆ H ₁₀	82	27.5	457
18	2.82	56	1-Hexene, 5-methyl-	C ₇ H ₁₄	98	22.6	231717

19	2.85	41	1-Heptene	C ₇ H ₁₄	98	33.7	107734
20	2.94	43	Heptane	C ₇ H ₁₆	100	56.0	61276
21	2.96	81	1,4-Hexadiene, 2-methyl-	C ₇ H ₁₂	96	19.9	840
22	3.01	41	(Z)-3-Heptene	C ₇ H ₁₄	98	19.8	113674
23	3.05	41	2-Propenoic acid, 2-methyl-, 3-hydroxypropyl ester	C ₇ H ₁₂ O ₃	144	44.9	4142
24	3.08	57	2-Hexene, 5,5-dimethyl-, (Z)-	C ₈ H ₁₆	112	47.0	114220
25	3.20	67	Cyclopentane, ethylidene-	C ₇ H ₁₂	96	19.1	114403
26	3.24	55	Cyclohexane, 1,4-dimethyl-	C ₈ H ₁₆	112	6.05	118122
27	3.29	79	(1,3-Dimethyl-2-methylene- cyclopentyl)-methanol	C ₉ H ₁₆ O	140	6.47	190162
28	3.36	41	Cyclopentane, ethyl-	C ₇ H ₁₄	98	48.7	940
29	3.44	81	1,4-Heptadiene	C ₇ H ₁₂	96	16.4	113639
30	3.57	81	1,4-Pentadiene, 3,3- dimethyl-	C ₇ H ₁₂	96	8.99	63084
31	3.62	67	5,10- Dioxatricyclo[7.1.0.0(4,6)]de cane	C ₈ H ₁₂ O ₂	140	8.60	189956
32	3.80	91	Toluene	C ₇ H ₈	92	62.4	291301
33	3.83	57	Cyclohexanol, 2-methyl-, cis-	C ₇ H ₁₄ O	114	8.81	114160
34	3.90	82	7- Methylbicyclo[4.2.0]octane	C ₉ H ₁₆	124	7.59	210902
35	3.96	45	Paraldehyde	C ₆ H ₁₂ O ₃	132	77.0	151452
36	4.01	56	1-Heptene, 2-methyl-	C ₈ H ₁₆	112	66.4	113675
37	4.09	41	1-Octene	C ₈ H ₁₆	112	14.8	191147
38	4.21	43	Octane	C ₈ H ₁₈	114	22.7	229407
39	4.30	55	2-Octene	C ₈ H ₁₆	112	16.5	118191
40	4.34	95	1-Methylcycloheptene	C ₈ H ₁₄	110	9.76	113672
10	4.41	41	3-Octene, (Z)-	C ₈ H ₁₆	112	12.3	227617
42	4.49	81	1,4-Hexadiene, 3-ethyl-	C ₈ H ₁₄	110	26.3	1483
43	4.52	43	2-Propyltetrahydropyran	C ₈ H ₁₆ O	128	10.4	114830
44	4.59	67	1-Methylcycloheptene	C ₈ H ₁₄	110	6.02	113672
45	4.68	83	2,3-Dimethyl-2-heptene	C ₉ H ₁₈	126	23.6	113495
46	4.76	54	Cyclohexene, 4-ethenyl-	C ₈ H ₁₂	108	32.5	227540
47	4.82	43	2,4-Dimethyl-1-heptene	C ₉ H ₁₈	126	65.3	113516
48	5.02	81	1,4-Octadiene	C ₈ H ₁₄	110	19.4	113431
49	5.22	91	Ethylbenzene	C ₈ H ₁₀	106	38.9	158804
50	5.33	91	p-Xylene	C ₈ H ₁₀	106	44.0	113952
51	5.71	104	Styrene	C ₈ H ₈	104	51.0	291542
52	5.75	78	1,3,5,7-Cyclooctatetraene	C ₈ H ₈	104	43.3	113230
53	6.19	105	Benzene, (1-methylethyl)-	C ₉ H ₁₂	120	38.0	228742
54	6.52	117	Benzene, cyclopropyl-	C ₉ H ₁₀	118	13.0	238986
55	6.65	91	Benzene, propyl-	C ₉ H ₁₂	120	76.2	113930
56	6.79	77	Benzaldehyde	C ₇ H ₆ O	106	86.4	291541
57	7.16	117	α-Methylstyrene	C ₉ H ₁₀	118	43.2	2021
58	7.32	105	4-Ethylphenethylamine	C ₁₀ H ₁₅ N	149	10.2	134563
59	7.38	43	Octane, 3,5-dimethyl-	C ₁₀ H ₂₂	142	18.2	114062
60	7.49	43	Octane, 3,3-dimethyl-	C ₁₀ H ₂₂	142	6.51	61706

61	7.56	105	Benzene, (1-methylpropyl)-	C ₁₀ H ₁₄	134	17.8	228188
62	7.77	117	Benzene, 1-methyl-4-(2-propenyl)-	C ₁₀ H ₁₂	132	12.4	113549
63	7.84	117	Benzene, 2-propenyl-	C ₉ H ₁₀	118	20.4	114744
64	7.98	117	Indane	C ₉ H ₁₀	118	14.1	118485
65	8.09	91	Benzene, 3-butenyl-	C ₁₀ H ₁₂	132	81.1	232267
66	8.31	91	1,2,3,4,5,8-Hexahydronaphthalene	C ₁₀ H ₁₄	134	28.1	113559
67	8.45	105	Acetophenone	C ₈ H ₈ O	120	70.4	34989
68	8.59	43	2-Undecanethiol, 2-methyl-	C ₁₂ H ₂₆ S	202	4.37	9094
69	8.65	43	Isopinocarveol	C ₁₀ H ₁₆ O	152	7.57	292836
70	8.79	117	Indan, 1-methyl-	C ₁₀ H ₁₂	132	13.2	150963
71	8.83	41	3-Undecene, (Z)-	C ₁₁ H ₂₂	154	8.87	142598
72	8.91	105	Benzeneethanol, á-methyl-	C ₉ H ₁₂ O	136	13.8	232022
73	8.95	43	1H-Indene, 1-ethyl-2,3-dihydro-1-methyl-	C ₁₂ H ₁₆	160	51.1	34632
74	8.99	105	Benzene, (1,2-dimethylpropyl)-	C ₁₁ H ₁₆	148	37.8	158146
75	9.03	105	4,7-Methano-1H-inden-1-ol, 3a,4,7,7a-tetrahydro-, acetate	C ₁₂ H ₁₄ O ₂	190	12.8	187542
76	9.22	117	Benzene, 1-methyl-4-(2-propenyl)-	C ₁₀ H ₁₂	132	9.13	113549
77	9.33	91	7-Ethylidenebicyclo[4.2.1]nona-2,4-diene	C ₁₁ H ₁₄	146	21.5	99215
78	9.33	117	Benzene, 1-butenyl-, (E)-	C ₁₀ H ₁₂	132	15.0	113927
79	9.53	105	Vinyl benzoate	C ₉ H ₈ O ₂	148	9.55	231943
80	9.59	91	Benzene, (3-methyl-3-butenyl)-	C ₁₁ H ₁₄	146	32.0	113578
81	9.63	118	Benzene, (1-ethyl-2-propenyl)-	C ₁₁ H ₁₄	146	35.0	113986
82	9.68	129	(1-Methylenebut-2-enyl)benzene	C ₁₁ H ₁₂	144	30.8	210059
83	10.06	105	Benzoic acid, ethyl ester	C ₉ H ₁₀ O ₂	150	64.7	107716
84	10.37	105	Benzenecarboxylic acid	C ₇ H ₆ O ₂	122	31.8	227847
85	10.49	105	Benzenecarboxylic acid	C ₇ H ₆ O ₂	122	56.1	227847
86	10.87	117	trans-1-Phenyl-1-pentene	C ₁₁ H ₁₄	146	19.6	113579
87	10.98	115	2-Naphthalenol	C ₁₀ H ₈ O	144	8.41	113306
88	11.05	118	Valeric acid, 4-phenyl-	C ₁₁ H ₁₄ O ₂	178	14.2	99257
89	11.13	105	4-Diazodamantanone	C ₁₀ H ₁₂ N ₂ O	176	12.3	138399
90	11.30	119	Ethanone, 2-bromo-1-(4-methylphenyl)-	C ₉ H ₉ BrO	212	15.5	92330
91	11.37	91	Benzene, hexyl-	C ₁₂ H ₁₈	162	66.3	113954
92	11.48	83	Cyclohexanecarboxylic acid, 3-pentadecyl ester	C ₂₂ H ₄₂ O ₂	338	10.4	280600
93	11.64	91	Benzoic acid, 4-methyl-	C ₈ H ₈ O ₂	136	43.2	286799
94	11.73	91	Benzene, 2,4-diethyl-1-methyl-	C ₁₁ H ₁₆	148	6.42	113580

95	11.78	119	p-Toluic acid, 5-tridecyl ester	C ₂₁ H ₃₄ O ₂	318	7.58	299805
96	11.90	43	1-Nonene, 4,6,8-trimethyl-	C ₁₂ H ₂₄	168	4.00	6413
97	11.96	142	Benzene, 1-cyclopenten-1-yl-	C ₁₁ H ₁₂	144	14.4	114813
98	12.02	41	9-Octadecenoic acid (Z)-, phenylmethyl ester	C ₂₅ H ₄₀ O ₂	372	5.60	67841
99	12.14	43	1-Nonene, 4,6,8-trimethyl-	C ₁₂ H ₂₄	168	4.08	6413
100	12.19	142	Naphthalene, 2-methyl-	C ₁₁ H ₁₀	142	29.8	291510
101	12.30	91	Benzene, 4-hexenyl-	C ₁₂ H ₁₆	160	9.32	113586
102	12.39	91	Benzene, cyclohexyl-	C ₁₂ H ₁₆	160	26.1	114210
103	12.46	104	Benzene, 3-cyclohexen-1-yl-	C ₁₂ H ₁₄	158	69.6	114816
104	12.51	41	Tricyclo[6.4.0.0(3,7)]dodeca-1,9,11-triene	C ₁₂ H ₁₄	158	22.9	298964
105	12.62	97	Bicyclo[3.2.0]heptan-2-one, 6-hydroxy-5-methyl-6-vinyl-	C ₁₀ H ₁₄ O ₂	166	6.28	154968
106	12.66	133	4-Ethylbenzoic acid, allyl ester	C ₁₂ H ₁₄ O ₂	190	7.18	293317
107	12.81	105	4-Ethylbenzoic acid	C ₉ H ₁₀ O ₂	150	47.8	160286
108	13.10	154	Biphenyl	C ₁₂ H ₁₀	154	71.7	114218
109	13.25	43	Tetradecane	C ₁₄ H ₃₀	198	16.6	113925
110	13.31	168	Diphenylmethane	C ₁₃ H ₁₂	168	31.1	114004
111	13.75	167	Diphenylmethane	C ₁₃ H ₁₂	168	55.2	114004
112	14.46	167	Benzene, 1,1'-ethylidenebis-	C ₁₄ H ₁₄	182	20.2	22224
113	14.52	43	Pentadecane	C ₁₅ H ₃₂	212	10.0	34728
114	14.58	168	1,1'-Biphenyl, 3-methyl-	C ₁₃ H ₁₂	168	35.0	261749
115	14.73	41	cis-5-Methyl-2-isopropyl-2-hexen-1-al	C ₁₀ H ₁₈ O	154	4.38	139662
116	14.79	180	1,2-Diphenylethylene	C ₁₄ H ₁₂	180	36.4	7372
117	14.89	91	Benzene, 1,1'-(1,2-ethanediyl)bis-	C ₁₄ H ₁₄	182	92.5	113286
118	15.25	105	Benzene, 1,1'-(1-methyl-1,2-ethanediyl)bis-	C ₁₅ H ₁₆	196	70.2	34633
119	15.40	179	Phenanthrene, 9,10-dihydro-1-methyl-	C ₁₅ H ₁₄	194	45.3	80195
120	15.54	167	1,1'-Biphenyl, 2-ethyl-	C ₁₄ H ₁₄	182	18.1	7577
121	15.64	105	7-Tetradecene	C ₁₄ H ₂₈	196	6.96	70643
122	15.69	167	Benzene, 1,1'-ethylidenebis-	C ₁₄ H ₁₄	182	39.0	22224

123	16.49	92	Benzene, 1,1'-(1,3-propanediyl)bis-	C ₁₅ H ₁₆	196	93.9	133399
124	16.57	129	Thiocarbamic acid, N,N-dimethyl, S-1,3-diphenyl-2-butenyl ester	C ₁₉ H ₂₁ NO S	311	25.7	192892
125	16.65	194	1,2-Diphenylcyclopropane	C ₁₅ H ₁₄	194	32.0	135351
126	16.71	115	Benzene, 1,1'-(3-methyl-1-propene-1,3-diyl)bis-	C ₁₆ H ₁₆	208	31.8	9505
127	16.78	105	Benzene, 1,1'-(1-methyl-1,3-propanediyl)bis-	C ₁₆ H ₁₈	210	89.4	149665
128	17.21	91	Naphthalene, 1,2,3,4-tetrahydro-2-phenyl-	C ₁₆ H ₁₆	208	35.5	9510
129	17.27	105	Benzene, (1-methyl-3-butenyl)-	C ₁₁ H ₁₄	146	22.6	61229
130	17.39	194	1,2-Diphenylcyclopropane	C ₁₅ H ₁₄	194	47.9	135351
131	17.61	91	Benzene, 1,1'-(1,4-butanediyl)bis-	C ₁₆ H ₁₈	210	90.3	118778
132	17.77	208	Naphthalene, 1,2,3,4-tetrahydro-1-phenyl-	C ₁₆ H ₁₆	208	73.3	38961
133	17.89	41	Trichloroacetic acid, pentadecyl ester	C ₁₇ H ₃₁ Cl ₃ O ₂	372	3.81	280517
134	18.08	115	Benzene, 1,1'-(3-methyl-1-propene-1,3-diyl)bis-	C ₁₆ H ₁₆	208	31.3	9505
135	18.33	117	Benzene, 1,1'-(1-butene-1,4-diyl)bis-, (Z)-	C ₁₆ H ₁₆	208	43.1	63166
136	18.74	203	Naphthalene, 1-phenyl-	C ₁₆ H ₁₂	204	23.3	156081
137	19.43	104	1-Pentene, 1,5-diphenyl-	C ₁₇ H ₁₈	222	22.3	63202
138	19.93	204	Naphthalene, 2-phenyl-	C ₁₆ H ₁₂	204	39.4	101249
139	20.06	218	9-Phenyl-5H-benzocycloheptene	C ₁₇ H ₁₄	218	35.3	200996
140	21.14	218	9-Phenyl-5H-benzocycloheptene	C ₁₇ H ₁₄	218	21.0	200996
141	21.58	230	m-Terphenyl	C ₁₈ H ₁₄	230	46.8	35280
142	21.93	230	p-Terphenyl	C ₁₈ H ₁₄	230	66.9	221130

143	23.44	207	1-Propene, 3-(2-cyclopenteny)-2-methyl-1,1-diphenyl-	C ₂₁ H ₂₂	274	29.4	154233
144	23.57	91	Benzenebutanoic acid, α -oxo-, ethyl ester	C ₁₂ H ₁₄ O ₃	206	6.99	211356
145	24.06	91	(2,3-Diphenylcyclopropyl)methyl phenyl sulfoxide, trans-	C ₂₂ H ₂₀ OS	332	64.8	142947
146	25.46	91	Benzene, 1,1'-[3-(2-phenylethylidene)-1,5-pentanediy]bis-	C ₂₅ H ₂₆	326	3.48	15248
147	26.03	306	1,1':2',1":2",1'''-Quaterphenyl	C ₂₄ H ₁₈	306	29.0	14543
148	27.90	306	1,1':3',1"-Terphenyl, 5'-phenyl-	C ₂₄ H ₁₈	306	54.2	113345

Gas chromatography and mass spectroscopy (GC/MS) analysis of polyethylene terephthalate (PETE) and polystyrene (PS) mixture to fuel (Figure 2 and table 1) following types of compound are detected depends on retention time (t) and trace mass (m/z). Initial pace of the analysis index numerous aliphatic and aromatic compounds are appeared, some compounds are elaborated here as references such as Cyclopropane (C₃H₆) (t=1.48, m/z=41) molecular weight is 42 and probability is 50.4%, Acetaldehyde (C₂H₄O) (t=1.53, m/z=44) molecular weight is 44 and probability is 73%, Pentane (C₅H₁₂) (t=1.71, m/z=43) molecular weight is 72 and probability is 37.4%, Cyclopentene (C₅H₈) (t=1.91, m/z=67) molecular weight is 68 and probability is 21.9%, Acetic acid (C₂H₄O₂) (t=2.03, m/z=43) molecular weight is 60 and probability is 76.7%, 2-methyl-1,4-Hexadiene, (C₇H₁₂) (t=2.96, m/z=81) molecular weight is 96 and probability is 19.9%, (Z)-3-Heptene (C₇H₁₄) (t=3.01, m/z=41) molecular weight is 98 and probability is 19.8%, Paraldehyde (C₆H₁₂O₃) (t=3.96, m/z=45) molecular weight is 132 and probability is 77%, 1-Octene (C₈H₁₆) (t=4.09, m/z=41) molecular weight is 112 and probability is 14.8%, 1,4-Octadiene (C₈H₁₄) (t=5.02, m/z=81) molecular weight is 110 and probability is 19.4%, 1,3,5,7-Cyclooctatetraene (C₈H₈) (t=5.75, m/z=78) molecular weight is 104 and probability is 43.3%, 1-methylethyl-Benzene (C₆H₁₂) (t=6.19, m/z=105) molecular weight is 120 and probability is 38%, α -Methylstyrene (C₉H₁₀) (t=7.16, m/z=117) molecular weight is 118 and probability is 43.2%, 2-propenyl-Benzene (C₉H₁₀) (t=7.84, m/z=117) molecular weight is 118 and probability is 20.4%, 3-butenyl-Benzene (C₁₀H₁₂) molecular weight is 132 and probability is 81.1%, Acetophenone (C₈H₈O) (t=8.45, m/z=105) molecular weight is 120 and probability is 70.4%, Isopinocarveol (C₁₀H₁₆O) (t=8.65, m/z=43) molecular

weight is 152 and probability is 7.57%, (Z)-3-Undecene (C₁₁H₂₂) (t=8.83, m/z=41) molecular weight is 154 and probability is 8.87%, 1-ethyl-2,3-dihydro-1-methyl-1H-Indene (C₁₂H₂₆) (t=8.95, m/z=43) molecular weight is 160 and probability is 51.1%, 1-butenyl- (E)-Benzene (C₁₀H₁₂) (t=9.33, m/z=117) molecular weight is 132 and probability is 15%. At the Ultimate pace of the analysis index some compounds are described as well such as compound 1-ethyl-2-propenyl-Benzene (C₁₁H₁₄) (t=9.63, m/z=118) molecular weight is 146 and probability is 35%, 2-Naphthalenol (C₁₀H₈O) (t=10.98, m/z=115) molecular weight is 144 and probability is 8.41%, 1-cyclopenten-1-yl-Benzene (C₁₁H₁₂) (t=11.96, m/z=142) molecular weight is 144 and probability is 14.4%, 3-cyclohexen-1-yl-Benzene (C₁₂H₁₄) (t=12.46, m/z=104) molecular weight is 158 and probability is 69.6%, Diphenylmethane (C₁₃H₁₂) (t=13.75, m/z=167) molecular weight is 168 and probability is 55.2%, 1,1'-(1,2-ethanediyl)bis-Benzene (C₁₄H₁₄) (t=14.89, m/z=91) molecular weight is 182 and probability is 92.5%, 1,1'-ethylidenebis-Benzene (C₁₄H₁₄) (t=15.69, m/z=167) molecular weight is 182 and probability is 39%, 1,1'-(1-methyl-1,3-propanediyl)bis-Benzene (C₁₆H₁₈) (t=16.78, m/z=105) molecular weight is 210 and probability is 89.4% and finally compound 1,1':3',1"-Terphenyl, 5'-phenyl-(C₂₄H₁₈) (t=27.90, m/z=306) molecular weight is 306 and probability is 54.2% etc.

Table 2: FT-IR spectrum functional group list of PETE and PS mixture to fuel

Number of wave	Wave Number	Compound/Functional Group
1	3647.98	Free OH
2	3435.53	Intermolecular H bonds
3	2938.23	C-CH ₃
4	2375.85	
5	2336.00	
6	2077.45	C-C= -C-C= -CH
7	1944.59	
8	1874.92	Non-Conjugated
9	1600.89	Conjugated
10	1283.76	
11	1177.69	-Formates
12	912.26	-CH=CH ₂
13	714.23	-CH=CH-(cis)
14	620.35	

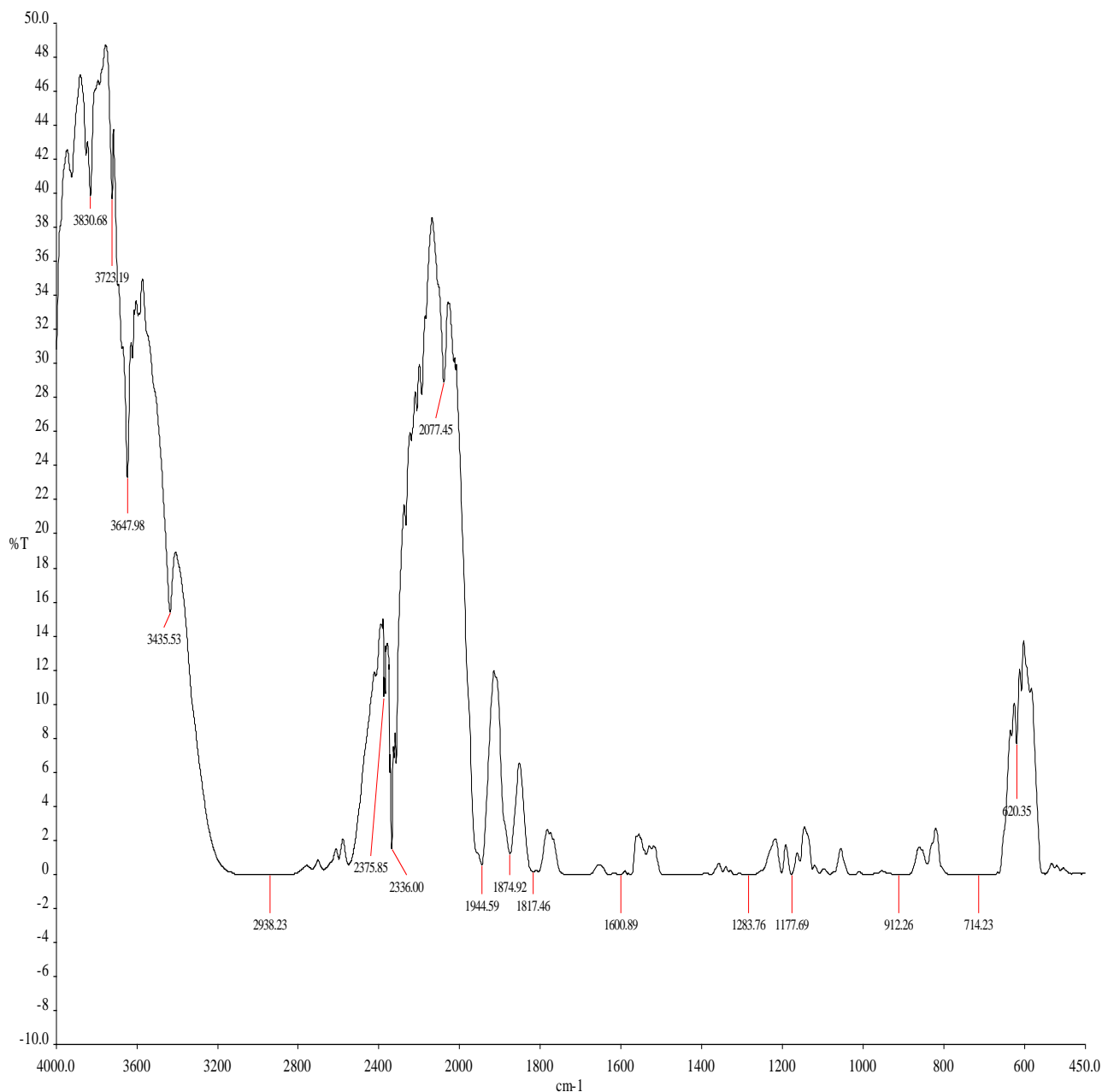


Figure 3: FT-IR spectrum of PETE and PS mixture to fuel

FT-IR analysis of 70% PS, 30% PETE, 1% (1g) Al_2O_3 , 1% (1g) ZnO and 10g Activated Carbon to fuel according to their wave number and spectrum band following types of functional groups are appeared in the analysis (Figure 3 and table 2). In the spectrum field we noticed that higher wave number are emerged in the initial phase and middle index of the spectrum in higher wave number small and bulky both functional groups are available and in low wave number double bond and single bond functional groups are available such as methane group, trans and alkene group etc. Hereafter wave number 3647.98 cm^{-1} functional group is Free OH, wave number 3435.53 cm^{-1} , functional group is Intermolecular H bonds, wave number 2938.23 cm^{-1} functional group is C- CH_3 , wave number 2077.45 cm^{-1} , functional group is C-C=C-C= -CH, wave number 1874.92 cm^{-1} , functional group is Non-Conjugated, wave number 1600.89 cm^{-1} , functional group is Conjugated, wave number

1177.69 cm^{-1} functional group is ~Formates, wave number 912.26 cm^{-1} , functional group is - $\text{CH}=\text{CH}_2$ and ultimately wave number 714.23 cm^{-1} functional group is - $\text{CH}=\text{CH}$ -(cis) etc. Energy values are calculated, using formula is $E=hu$, Where h =Planks Constant, $h = 6.626 \times 10^{-34}$ J, u =Frequency in Hertz (sec^{-1}), Where $u=c/\lambda$, c =Speed of light, where, $c=299,792,458$ m/s, $W=1/\lambda$, where λ is wave length and W is wave number in cm^{-1} . Therefore the equation $E=hu$, can substitute by the following equation, $E=hcW$. According to their wave number several energy values are calculated such as for wave number 3647.98 (cm^{-1}) calculated energy, $E=7.18 \times 10^{-20}$ J, wave number 2938.23 (cm^{-1}) calculated energy, $E=5.84 \times 10^{-20}$ J, wave number 2077.45 (cm^{-1}), calculated energy, $E=4.12 \times 10^{-20}$ J, wave number 1819.38 (cm^{-1}), calculated energy, $E=3.61 \times 10^{-20}$ J, wave number 1600.89 (cm^{-1}), calculated energy, $E=3.14 \times 10^{-20}$ J, wave number 912.26 (cm^{-1}), calculated energy, $E=1.80 \times 10^{-20}$ J

and ultimately wave number $714.23 \text{ (cm}^{-1}\text{)}$, calculated energy, $E=1.42 \times 10^{-20} \text{ J}$ respectively.

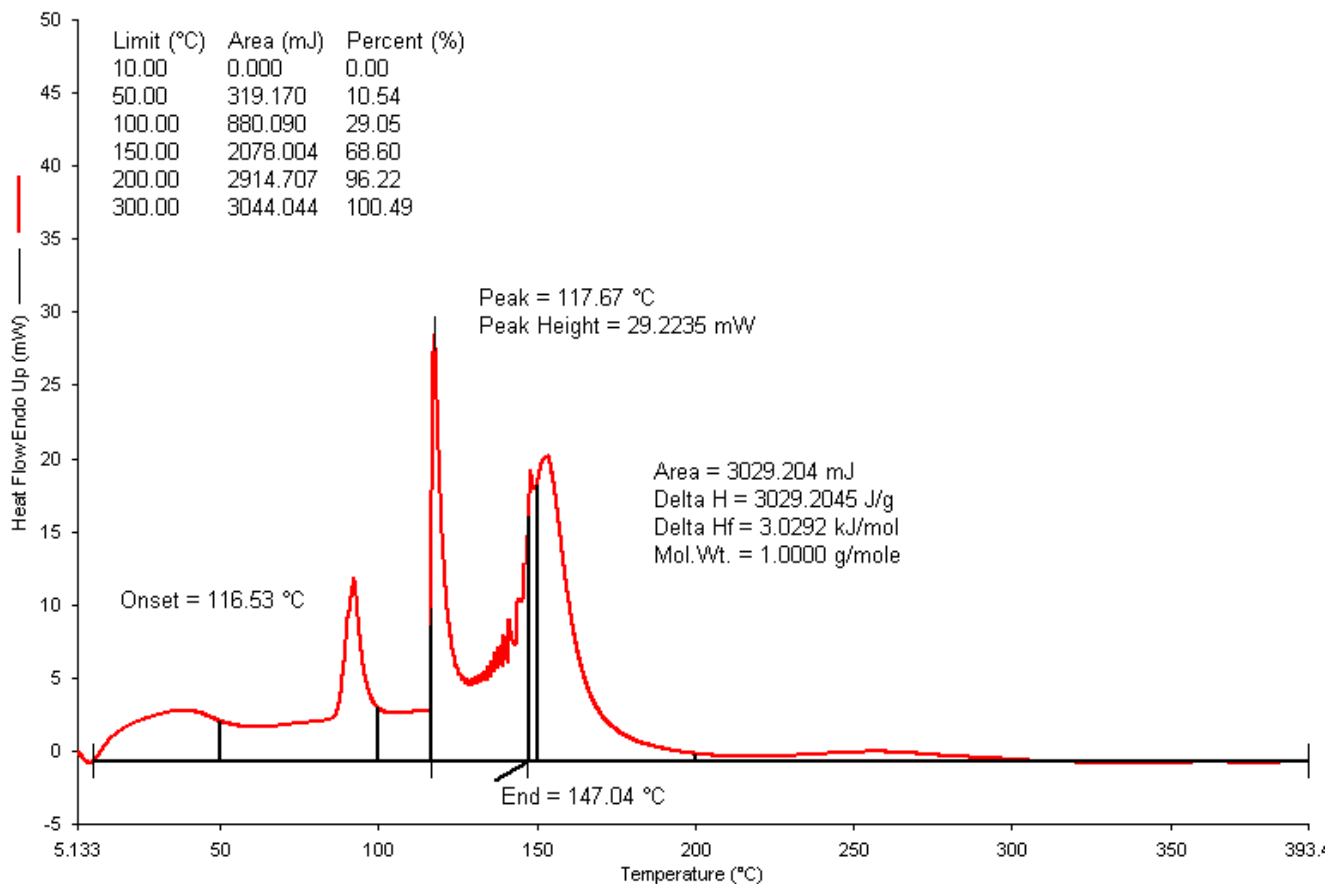


Figure 4: DSC graph of PETE and PS mixture to fuel

70% PS, 30% PETE, 1% (1g) Al_2O_3 , 1% (1g) ZnO and 10g Activated Carbon to fuel was analysis (figure 4) by Differential Scanning Calorimeter (DSC). DSC program was set up for analysis proposes such as uses temperature ranges was $5 \text{ }^\circ\text{C}$ to $400 \text{ }^\circ\text{C}$, nitrogen gas flow was 30 psi, ramping rate was $20 \text{ }^\circ\text{C}$ per minute, aluminum 10 μL pan were used for sample holder. The DSC analysis following parameters are appeared below and describes in shortly. The fuel sample started to evaporate at the different temperature ranges in different percentages such as $10 \text{ }^\circ\text{C}$ to $50 \text{ }^\circ\text{C}$ evaporated fuel percentages is 10.54% and energy is 319.170 mJ, at the ranges of $50 \text{ }^\circ\text{C}$ to $100 \text{ }^\circ\text{C}$ evaporated fuel percentages 29.05% and energy is 880.090 mJ, at $150 \text{ }^\circ\text{C}$ evaporated percentage rate is 68.60%, at $200 \text{ }^\circ\text{C}$ evaporated percentage rate is 96.22% and energy is 2914.707 mJ, and ultimately at $300 \text{ }^\circ\text{C}$ fuel evaporated percentage is 100.49% and produced energy is 3044.044 mJ etc. Analysis indicated the onset temperature of the fuel is $116.53 \text{ }^\circ\text{C}$ and its represents the boiling temperature of the fuel and peak height is 29.2235 mw. In addition other parameters are also appeared in the analysis such as on behalf energy /enthalpy occupied grid area 3029.204 mJ, $\Delta H = 3029.2045 \text{ J/g}$, $\Delta H_f = 3.0292 \text{ kJ/mol}$ and sample Molar weight is 1.0000 g/mole and eventually peak fallen end point temperature is $147.04 \text{ }^\circ\text{C}$ as well.

5. Conclusion

PETE and PS to fuel production was batch process experiment with catalyst and activated carbon. PETE waste plastic has 33% Oxygen and PS waste plastic has high percentage additives. PETE and PS mixture to fuel production percentage was 63.1% and light gas production was 15.2%. Total conversion rate was 78.3 %. Left over residue percentage was 21.7% and left over residue was solid black and hard. PETE and PS waste plastic to fuel production period was notice that waxy materials did not block the condensation pipe. In this experiment were used two types of catalyst and activated carbon. Product fuel color is light yellow and fuel is ignited. Fuel was analysis by GC/MS, FTIR and DSC. GC/MS chromatogram was showed product fuel has hydrocarbon group compounds including benzene content, oxygen content, nitrogen content, halogenated and alcoholic group. FTIR analysis was provided us functional group and band energy. DSC analysis was provided heat enthalpy value in to fuel. PETE and PS mixture can convert into liquid hydrocarbon fuel and this fuel can use internal combustion engine. Fuel can use for refinery process as a feed stock. This experiment can remove PETE and PS waste plastic problem from environment at the same time and produce renewable energy for future generation.

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