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The ratio Influence of the polystyrene mixture and heating rate towards yield and pyrolysis results compound

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Abstract. The widespread use of plastics in the community has resulted in increased waste. Plastics are synthetic polymers that are formed as products of fossil fuel and that are difficult to decompose naturally. This research used the pyrolysis process on a fixed bed reactor to utilize plastic waste especially polystyrene type. The raw materials in this study are high impact polystyrene (HIPS), expanded polystyrene (EPS) and oriented polystyrene (OPS). The ratios of raw material (HIPS: EPS: OPS) are 1:0:0, 0:1:0, 0:0:1, 2:1:1, 1:2:1, 1:1:2, and 1:1:1 also heating rates at 2 °C/min, 4 °C/min, 6 °C/min, 8 °C/min and 10 °C/min. The highest yield at 0:0:1 ratio and with a heating rate of 10 °C/min. The heating rate of 10 °C/min generated the highest amount of yields in general at each ratio. Analysis of the compound using Gas Chromatography-Mass Spectrometry (GC-MS). The compound was dominated by aromatic hydrocarbons, with dominant compounds of ethylbenzene, p-xylene, styrene, 2-phenyl-1propene, 1,3-diphenyl propane and methyl styrene.

1. Introduction

Plastic waste management is a global issue that have impacts on environmental stability and economic development. Thermoplastic wastes consist primarily of polyethylene terephthalate, High-Density Polyethylene (HDPE), polyvinyl chloride (PVC), Low-Density Polyethylene (LDPE), polypropylene (PP) and polystyrene (PS) [1-6]. Polystyrene is commonly used for food packaging and protect electronic devices. The PS plastic pyrolysis process is a useful option for reducing waste plastic deposits [7-11].

Pyrolysis is one way of recycling plastic waste, i.e. by heating at high temperatures without oxygen. Pyrolysis for most of the plastics starts to occur at temperatures around 300°C and for thermosensitive resins even at lower temperatures[12].

The focus of this study was to determine the yield and chemical composition of various polystyrene pyrolysis results at specific heating rates.

2. Experimental

The research was performed using plastic waste cracking equipment. The main components of the equipment used were: fixed bed reactor, condenser, coolant basin, and pump. The raw materials used



were High Impact Polystyrene (HIPS) polystyrene plastic waste, Oriented Polystyrene (OPS) and Expanded Polystyrene (EPS). The size of the HIPS and OPS were $\pm 1\text{cm}^2$ and diameter EPS is 3-5 mm. The sample mass of every ratio was 100 g and the pyrolysis temperature is 350 °C. The raw materials ratios (HIPS : EPS : OPS) were 1:0:0, 0:1:0, 0:0:1, 2:1:1, 1:2:1, 1:1:2, 1:1:1. The heating rate was varied over a range of 2 °C/min, ranging from 2°C/min to 10°C/min. The pyrolysis process lasted to completion, characterized by the absence of any liquid dripping from the condenser (± 7 hours).

3. Results and discussions

3.1. The influence of heating rate and raw materials ratios to the yield of pyrolysis

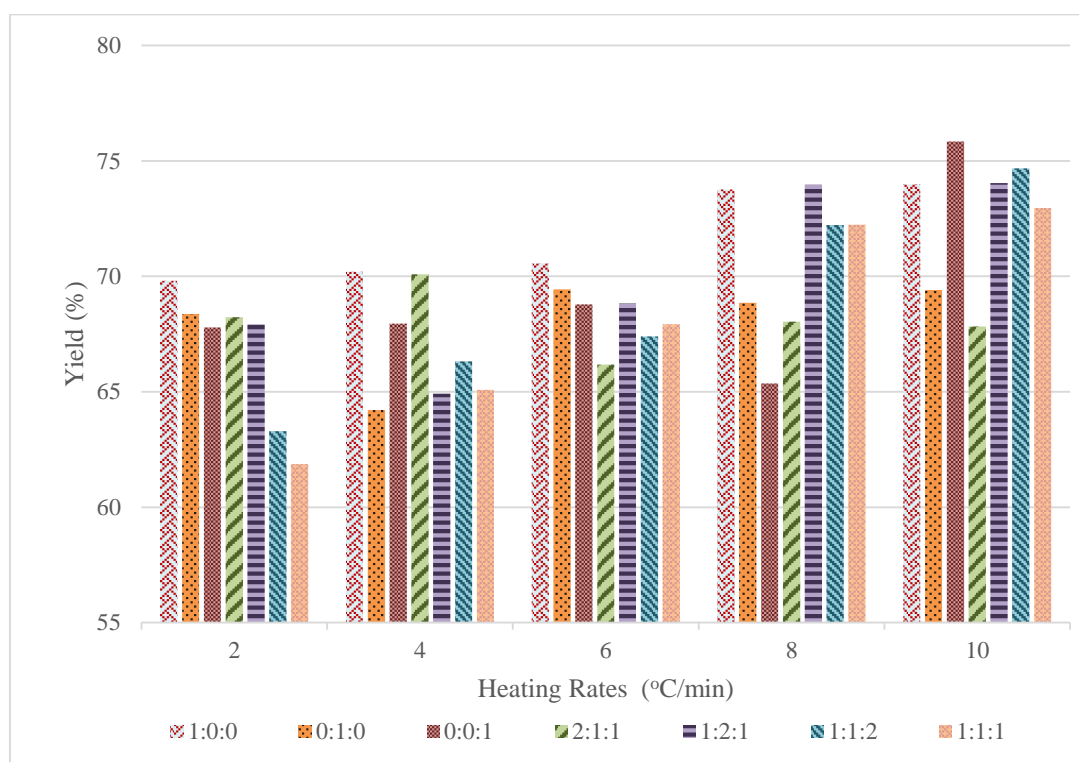


Figure 1. The influence of heating rates and raw materials toward yield

Based on Figure 1, the yield increases as the rate of heating increases. The highest yield on each raw material ratio was obtained at a heating rate of 10 °C/min. A slow heating rate would result in longer reached the cracking point, resulted in the composting process. Char was formed as a by-product of plastic cracking. The increasing of heating rate would minimize the char formation of the cracking product [13]. According to the results of the previous study, the higher the heating rate, the higher the yield of fuel product would be.

3.2. The influence of raw material ratio towards the composition of pyrolysis results compounds

The chemical composition of the oil of the result of pyrolysis of polystyrene was determined by the GC/MS (Gas Chromatography-Mas Spectroscopy) analysis. The analysis was evaluated by analyzing the effect of the raw materials ratios on the heating rate of 10 °C/min. The analysis results presented in Figure 2-8.

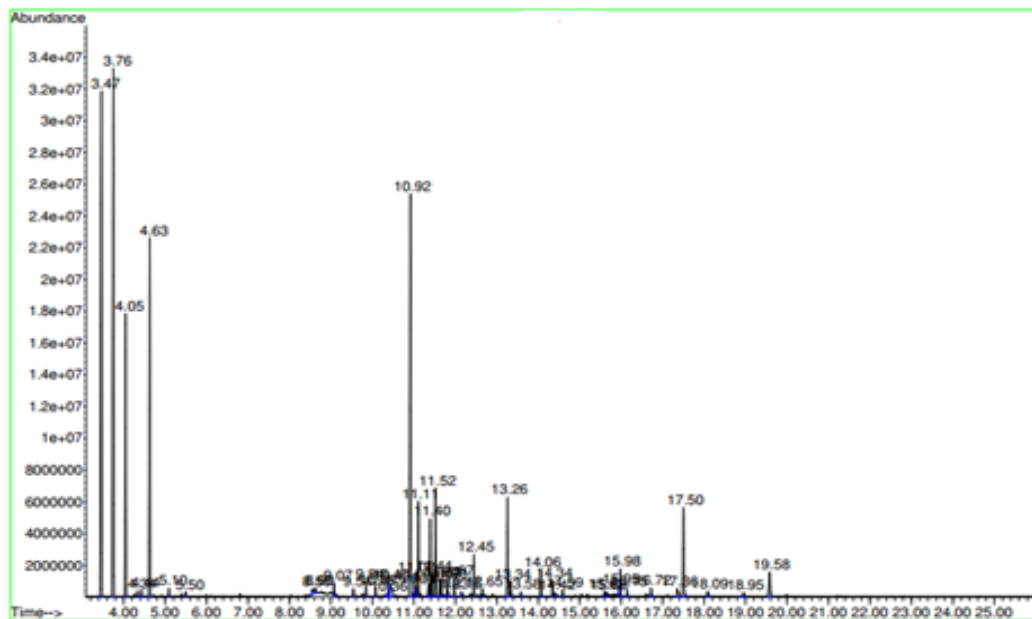


Figure 2. The Influence of ratio of raw material (1:0:0) to the pyrolysis compounds

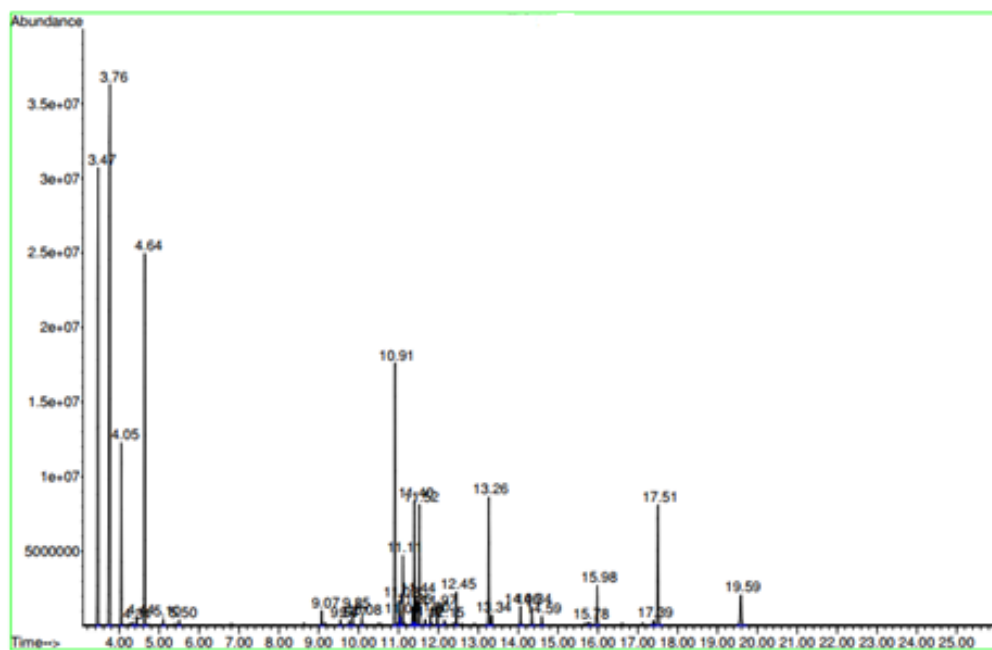


Figure 3. The Influence of ratio of raw material (0:1:0) to the pyrolysis compounds

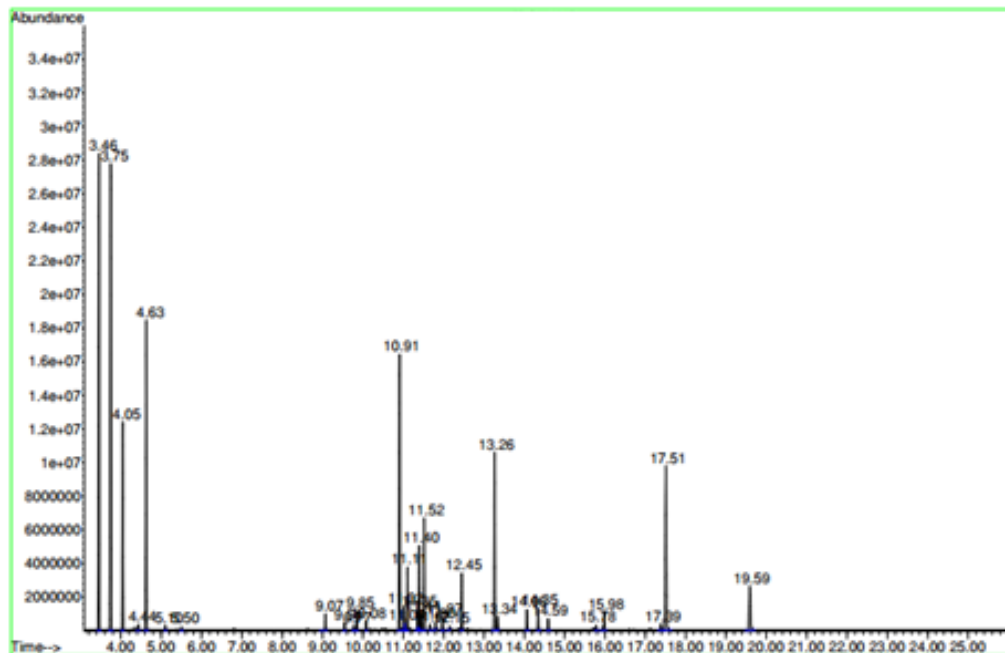


Figure 4. The Influence of ratio of raw material (0:0:1) to the pyrolysis compounds

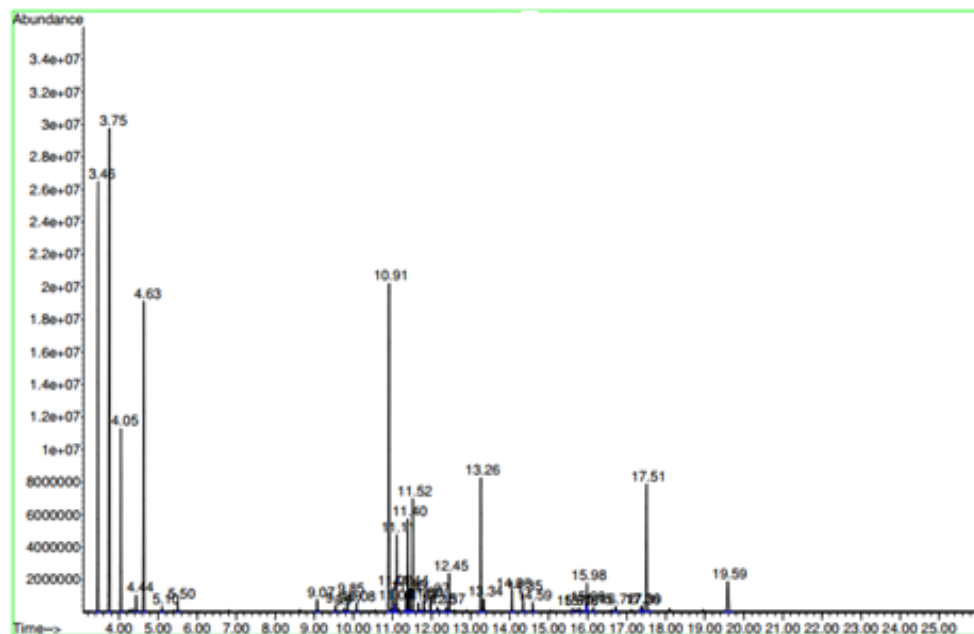


Figure 5. The Influence of ratio of raw material (2:1:1) to the pyrolysis compounds

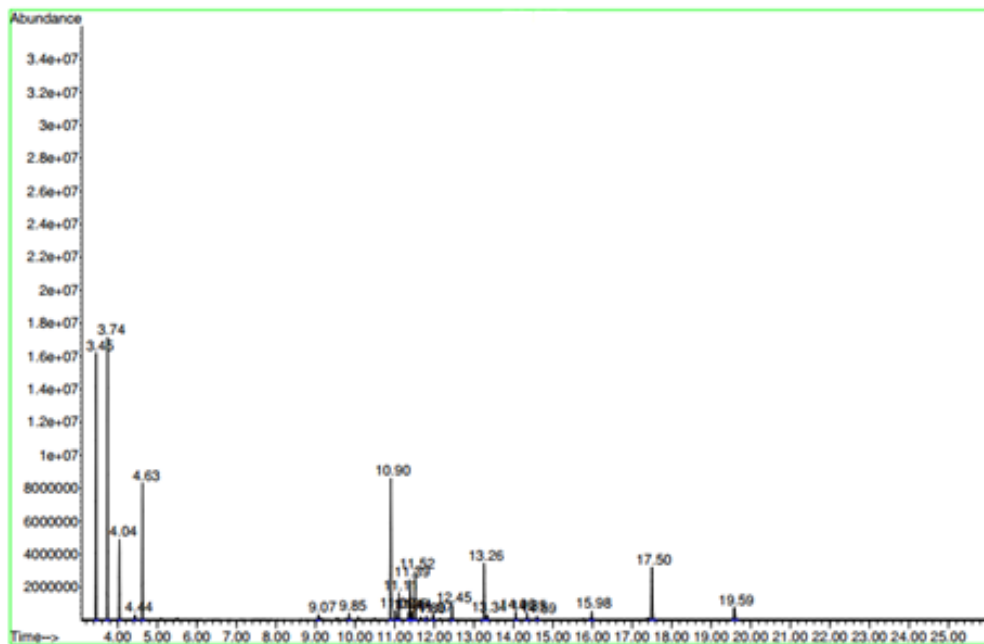


Figure 6. The Influence of ratio of raw material (1:2:1) to the pyrolysis compounds

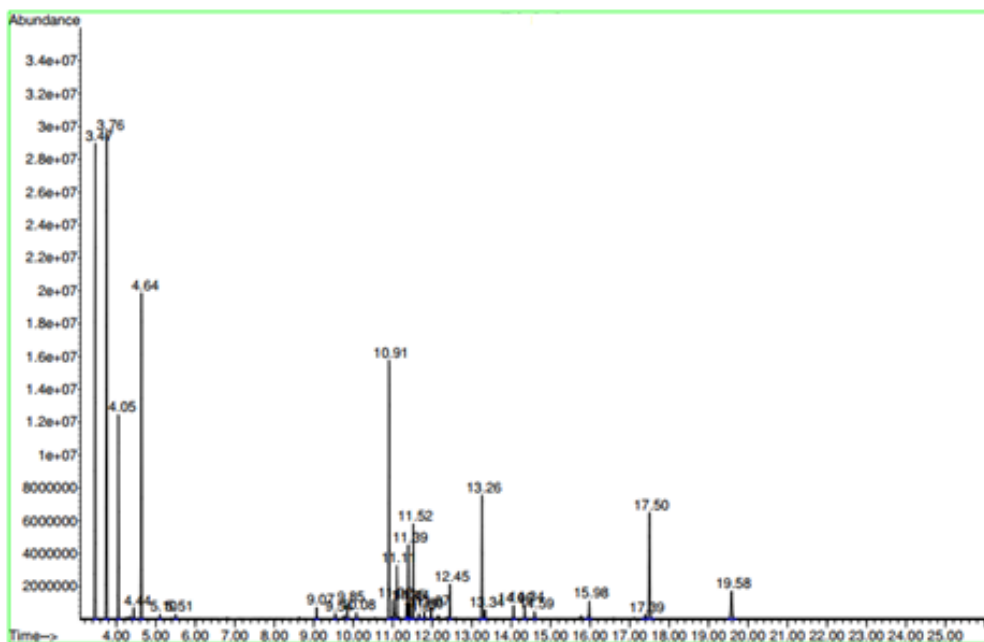


Figure 7. The Influence of ratio of raw material (1:1:2) to the pyrolysis compounds

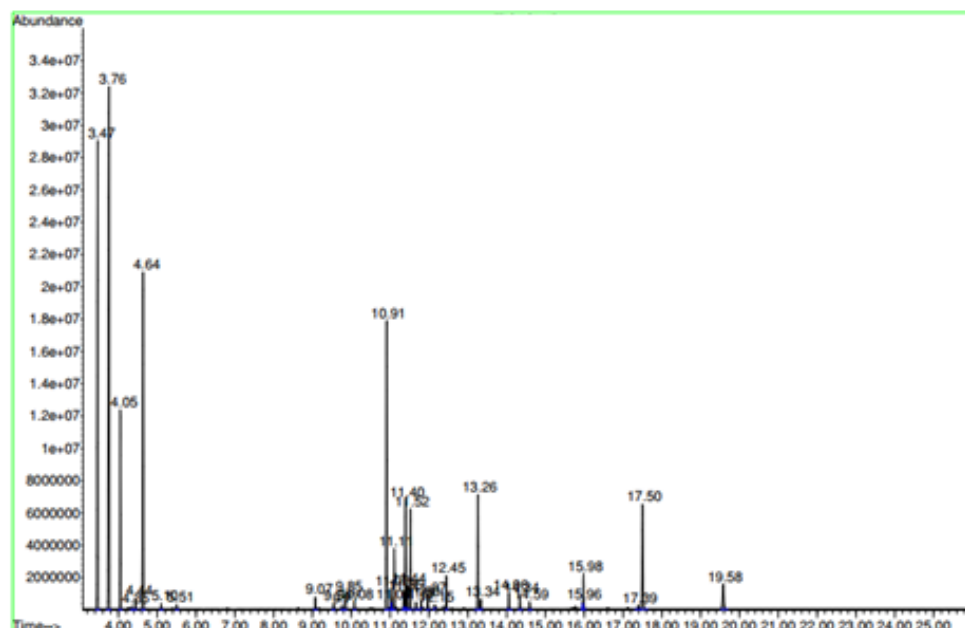


Figure 8. The Influence of ratio of raw material (1:1:1) to the pyrolysis compounds

From Figure 2-8, the compounds contained in the resulting liquid are dominated by aromatic hydrocarbons, with the dominant compounds ethylbenzene, p-xylene, styrene, 2-phenyl-1propene, 1,3-diphenyl propane and methyl styrene. The main products found were a hydrocarbon group having two rings (1,3 diphenyl propane) and hydrocarbon with one ring (ethylbenzene). In general, the dominant compound are presented in table 1.

Table 1: The dominant compounds of pyrolysis products of mixed polystyrene raw materials

Compounds	The Raw Materials Ratios (HIPS:EPS: OPS)						
	1:0:0 (A5)	0:1:0 (B5)	0:0:1 (C5)	2:1:1 (D5)	1:2:1 (E5)	1:1:2 (F5)	1:1:1 (G5)
Ethylbenzene	0.00%	23.85%	31.88%	26.36%	31.10%	31.28%	28.00%
p-xylene	29.02%	0.00%	0.00%	0.00%	0.00%	34.22%	37.08%
Styrene	31.16%	52.35%	31.52%	33.80%	34.59%	0.00%	0.00%
2-phenyl-1propene	16.32%	23.81%	18.28%	18.10%	15.99%	18.52%	18.10%
1,3-Diphenylpropane	23.50%	0.00%	18.32%	21.74%	18.31%	15.98%	16.81%

All samples were found to contain ethylbenzene, except for sample A5, which contained no ethylbenzene but had a higher 1,3-Diphenylpropane. Styrene monomers produced from pyrolysis of polystyrene when it hydrogenated produce ethylbenzene [14-15].

The random polystyrene chain termination process could produce an unstable methyl. Methyl are obtained from splitting of the styrene into methyl and methylbenzene or benzene. Then, both of these compounds could react again to form p-xylene. P-xylene could be formed from an unstable methyl reaction with benzene. The formation of p-xylene was affected by the raw materials used, especially HIPS. HIPS has additional ingredients used in the manufacturing process such as butadiene. Butadiene is an unsaturated hydrocarbon and participates in cracking. The cracking of butadiene produces methyl and ethyl, with the amount of methyl formed, p-xylene formed. The addition of the butadiene

copolymer would result in an ethyl chains-in the cracking process which further formed a methyl-chain [16-18].

4. Conclusion

Based on this study, it is concluded that the heating rate will affect the yield of products. On OPS and HIPS, the higher the heating rate, the higher the yield would be. On EPS, the enhancement of the heating rate would decrease the produced yield. The higher the OPS ratio, the higher the formation of ethylbenzene would be. The higher the EPS ratio, the higher the styrene structure would be, and the higher the HIPS ratio, the higher the formation of methyl- and ethyl- groups would be.

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