The Analysis of Electronic Cigarette E-Liquids by GC-MS

Application Note

INTRODUCTION

There are over 35 million electronic cigarette users worldwide with the global vapour product market at over £17 billion pounds[1]. Although they are widely used, there is limited characterisation of the composition of e-liquids used during vaping. As vaping becomes an increasing trend, regulations are being introduced for electronic cigarettes and e-liquid manufacturers worldwide. The Tobacco Products Directive 2014/14/EU has recently introduced a limited guideline on the manufacturing of e-liquids[2]. These guidelines are more focused on the concentration of nicotine, caffeine, taurine and colourings rather than flavourings and impurities. Although there are labelling requirements in place, there is no current regulation on a comprehensive list of ingredients; the majority of e-liquids only define propylene glycol, vegetable glycerin and nicotine as ingredients.

Scion Instruments developed a method for the quick and easy compositional analysis of e-liquids by gas chromatography with mass spectrometry. Along with the vendor listed compounds, various flavour compounds and impurities were identified.

EXPERIMENTAL

A Scion 436 GC was coupled with the Scion Single Quad Mass Spectrometer (SQ MS) and 8400 Autosampler. Mass Spec Work Station software was used for instrument control, data acquisition, data processing and spectral library comparisons. Four commercially available e-liquids were purchased and analysed both neat and a 1 in 2 dilution (in methanol). Table 1 details the analytical conditions of the GC-MS system.

**Table 1.** Analytical conditions of the GC-MS

Conditions	
S/SL	220°C, Split 1:10, 0.1µL
Column	Scion-5MS 30m x 0.25mm x 1.0µm
Oven Programme	40°C (5 mins), 10°C/min to 220°C (5 mins)
Carrier Gas	Helium 1mL/min constant
Transfer Line	250°C
Source	230°C
MS	Full Scan, 45-500amu

The four flavours of e-liquid were bubble-gum, pear drop, cherry tree and blueberry. The nicotine content of the bubble-gum, pear drop and cherry tree was 6mg with the blueberry e-liquid containing 3mg of nicotine.

Pure nicotine was used to prepare a calibration curve for the quantification of nicotine in all e-liquids. The calibration standards prepared were at 0.5, 1,3,5 and 10mg.

RESULTS

Initially, all e-liquid samples were injected neat. Figure 1 shows the chromatogram obtained for the bubble-gum e-liquid. The remaining samples also gave a similar chromatogram, in regards to propylene glycol, vegetable glycerin and nicotine.

Peak ID	Compound
1	Propylene Glycol
2	Glycerin
3	Nicotine
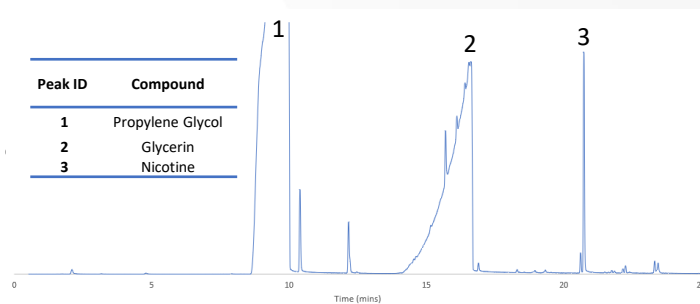
Figure 1. Neat injection of bubble-gum flavoured e-liquid

As shown in Figure 1, the propylene glycol, glycerin and nicotine were the three main compounds in the chromatogram. These were the only ingredients listed on all four samples and were confirmed by a NIST spectral library match. Propylene glycol and glycerin were overloaded, due to the amount they constitute in the matrix of all samples, and therefore result in poor chromatography. Due to the overloading of the glycerin in particular, there are other potential compounds that are being masked. To overcome this issue, all samples were diluted in methanol (1in2) and a scan segment based full scan method was utilised. The original full scan method was adjusted in mass spec work station as follows. A whole scan range from 0.5-28 minutes remained the same whilst three individual scan segments were added; 0.5-8 minutes, 9.75-14 minutes and 18-28 minutes. Additionally, during the middle two scan segments the first masses were increased to 80 and 77 respectively.

Figure 2 shows the scan segment acquisition method. The graph is automatically generated in the software. The orange bar shows the scan segment used to reduce the intensity of the propylene glycol whereas the dark green bar shows the scan segment used to eliminate the glycerin, allowing previously masked peaks to be detected.
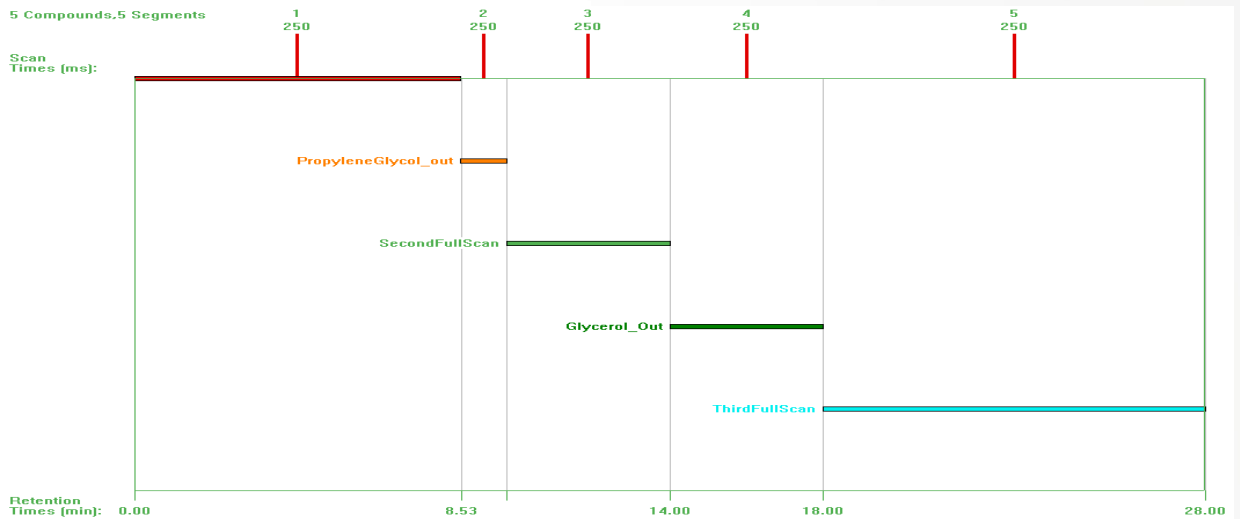
Figure 2. Scan segments of the full scan method utilised in mass spec work station

All diluted e-liquid samples were then analysed using the scan segment method. Figures 3a-3d show the chromatogram from each e-liquid.
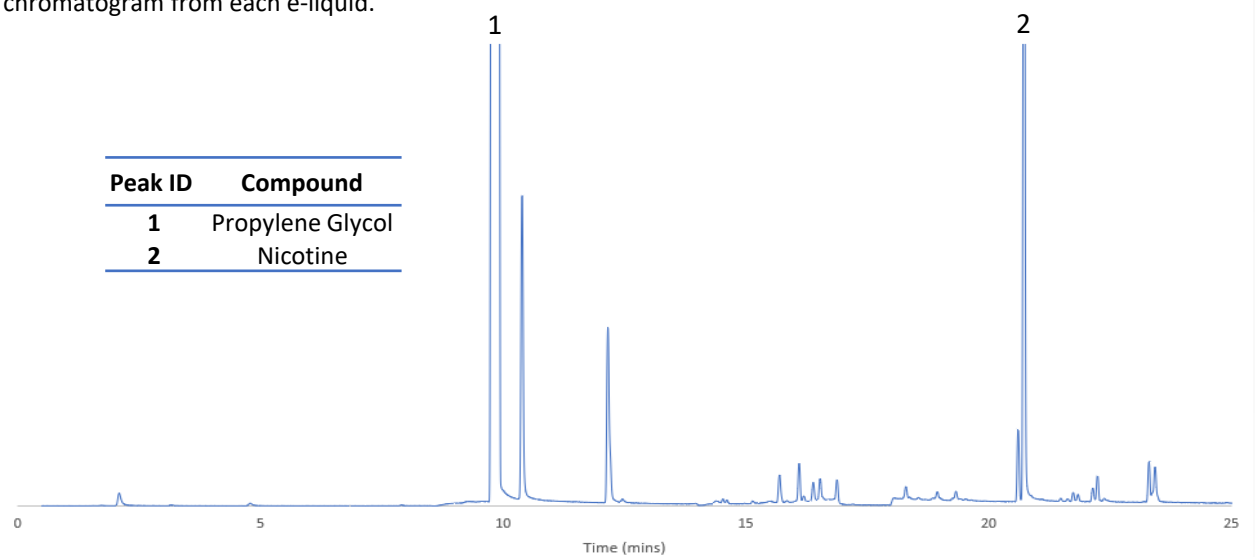

Peak ID	Compound
1	Propylene Glycol
2	Nicotine

Figure 3a. Injection of the diluted bubble-gum flavoured e-liquid

Peak ID	Compound
1	Propylene Glycol
2	Nicotine
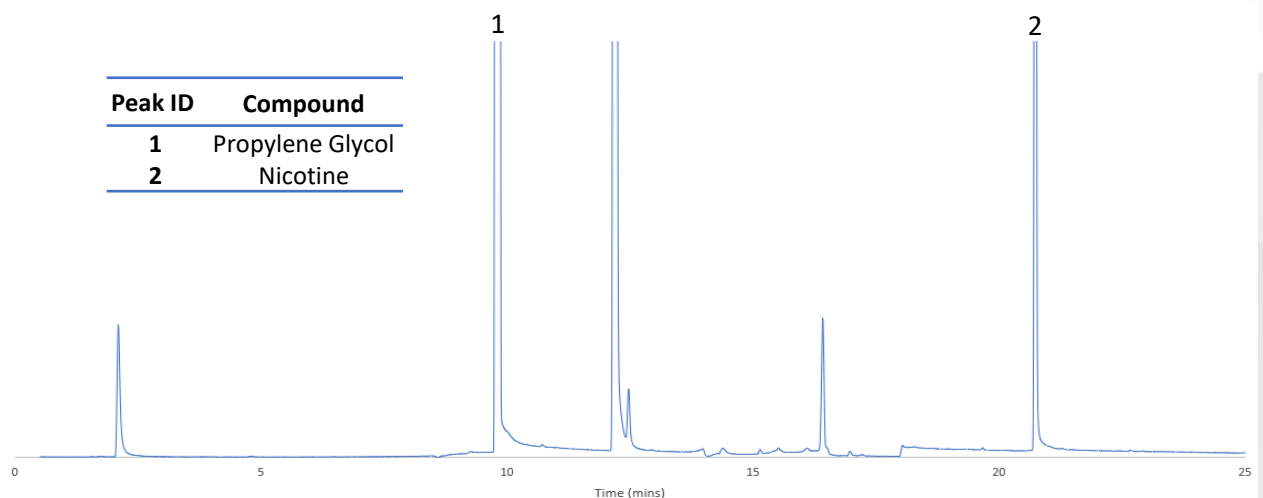
Figure 3b. Injection of the diluted pear drop flavoured e-liquid

Peak ID	Compound
1	Propylene Glycol
2	Nicotine
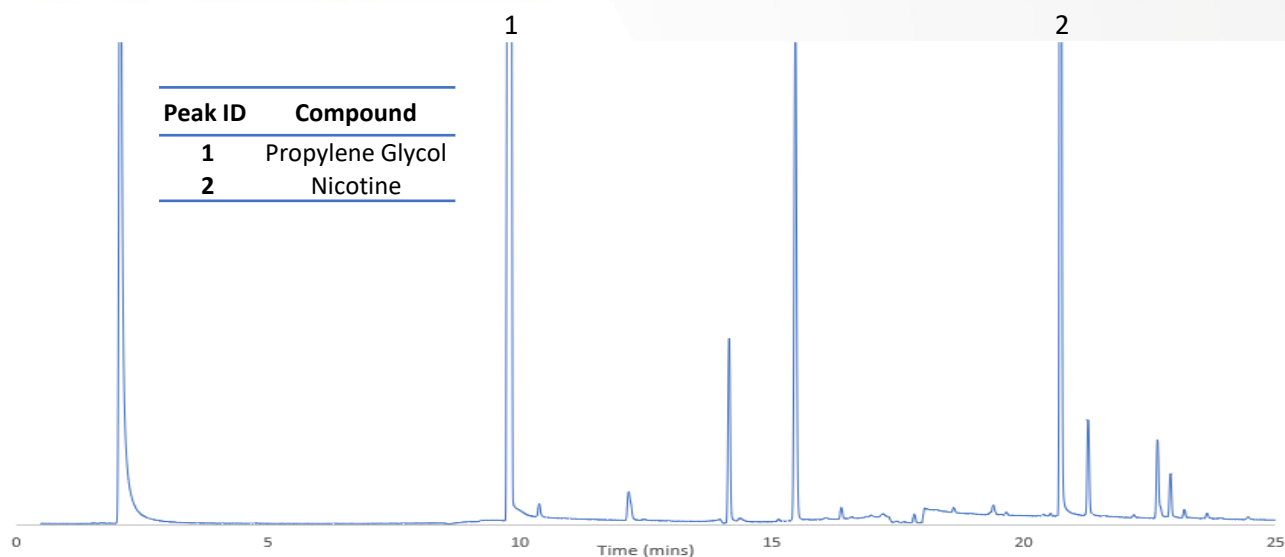
Figure 3c. Injection of the diluted cherry-tree flavoured e-liquid

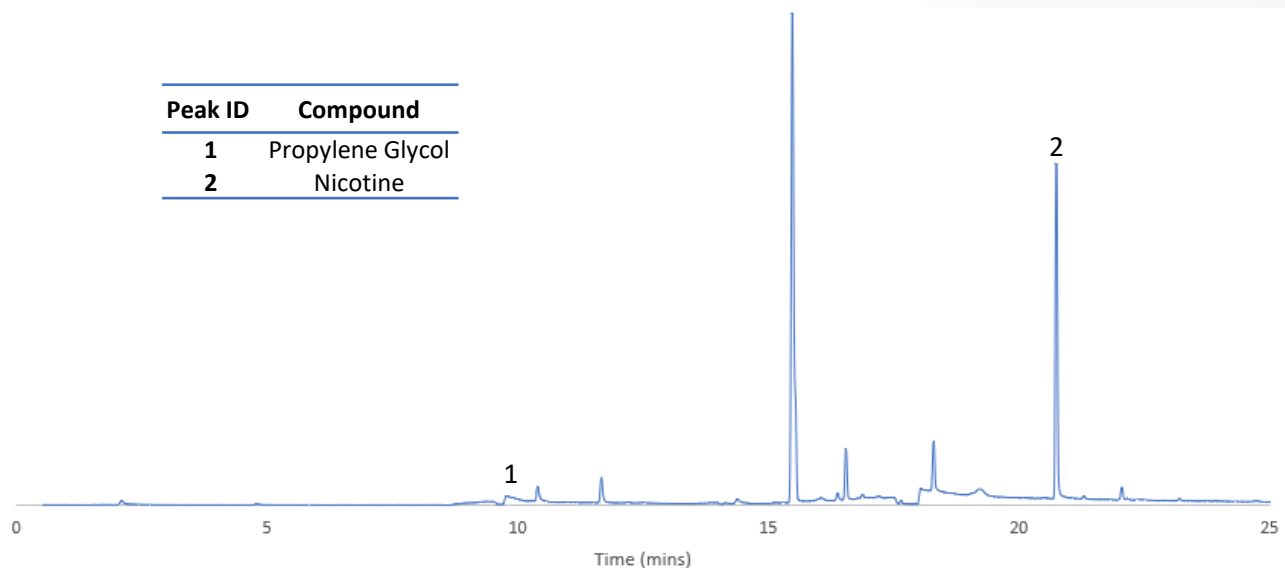| Peak ID	Compound
1	Propylene Glycol
2	Nicotine

Figure 3d. Injection of the diluted blueberry flavoured e-liquid

As shown in Figures 3a-3d, the chromatography vastly improved by diluting the sample and running a scan segment acquisition. Previously masked peaks are now identifiable, without modification to the instrument. All samples were easily separated and resolved, with the propylene glycol and glycerin overloading minimalised/ eliminated. Using a scan segment method prevents extensive sample preparation and lengthy sample processing.

All e-liquids exhibit similar profiles with the exception of the cherry tree e-liquid which has a noticeably larger peak at approximately 2 minutes (discussed later).

The NIST spectral library was used to identify and confirm each component in all samples. The results of which are shown in Table 2, with comparison of all e-liquids analysed.

The original neat injection was used to identify and confirm the propylene glycol, glycerin and nicotine with all other peaks identified using the diluted, scan segment chromatogram.

Table 2. Comparison of the identified composition of e-liquids (+ = present in the sample, x = not present in the sample)

Peak Name	Retention Time	Bubble-gum	Pear Drop	Cherry Tree	Blueberry
Ethanol	2.079	+	+	+	+
Ethyl Acetate	4.790	+	x	+	+
Toluene	7.907	+	x	x	x
Propylene Glycol	9.768	+	+	+	+
Ethyl Butyrate	10.393	+	x	+	+
Butyl Acetate	10.708	x	+	x	x
Ethyl Isovalerate	11.664	x	x	x	+
Isoamyl Acetate	12.164	+	+	+	x
2-methyl butyl acetate	12.206	x	x	+	+
Propylene Glycol Diacetate	12.459	+	+	+	x
Diglycerol	13.992	+	+	+	x
Benzaldehyde	14.162	x	x	+	x
Ethyl Hexanoate	14.610	+	+	x	x
Benzyl Alcohol	15.476	x	+	+	+
Butyl Isovalerate	15.532	x	x	x	+
γ-terpinene	15.939	x	x	x	+
Allyl Hexanoate	16.097	+	+	x	x
Glycerin Diacetate	16.386	+	+	+	+
Glycerin	16.487	+	+	+	+
Linalool Acetate	16.527	+	x	x	+
Maltol	16.877	+	x	x	+
Menthol	18.022	+	x	x	+
Ethyl Maltol	18.290	+	x	x	+
Terpineol	18.298	x	x	x	+
Citral	19.254	+	x	x	x
Benzaldehyde Propylene Glycol Acetal	19.398	x	x	+	x
Cinnamaldehyde	19.531	+	x	x	x
Anise Camphor	19.662	x	x	+	x
Estragole	19.658	x	+	x	x
Piperonal	20.542	x	x	+	x
Eugenol	20.604	+	x	x	+
Nicotine	20.738	+	+	+	+
Vanillin	21.285	+	+	+	+
Methyl Ionone	21.627	+	x	+	+
Ethyl Vanillin	22.045	+	+	+	+
γ-decalactone	22.155	+	+	+	+
Raspberry Ketone	23.191	x	x	+	+
Citric Acid	24.460	x	x	+	x
Vanillin Propylene Glycol Acetal	25.261	x	x	x	+

As expected, all e-liquids contained the base ingredients listed on the packaging (propylene glycol, vegetable glycerin and nicotine. However, 36 other ingredients were also detected between the four samples. Ethanol is a common impurity that was identified in all e-liquid samples with toluene only being identified in the bubble-gum flavoured e-liquid. These impurities are not regulated compounds during e-liquid manufacturing and are routinely used as solvents for the addition of flavouring additives to e-liquids[3]. Ethanol was identified at 2.079 minutes. As stated earlier, this peak was significantly greater in the cherry tree sample when compared to the other three e-liquids analysed.

All compounds contained glycerin diacetate which is an additive commonly found in products containing artificial flavourings. Additionally, all samples contain vanillin and ethyl vanillin which provides the e-liquids with a vanilla base flavour as well as γ-decalactone which contributes to a peach flavour. No samples contain the exact same flavour profile however, bubble-gum, pear drop and cherry tree all contain isoamyl acetate which gives a banana flavour. Select flavours were only present in individual e-liquids; piperonal is only present in the Cherry Tree e-liquid and is the main compositional providing the cherry flavour. The majority of the flavour compounds detected in the e-liquids are naturally occurring,

including menthol (peppermint oil), terpineol (pine oil) and eugenol (cinnamon/nutmeg).

Figure 4 details the calibration curve for the prepared nicotine standards.
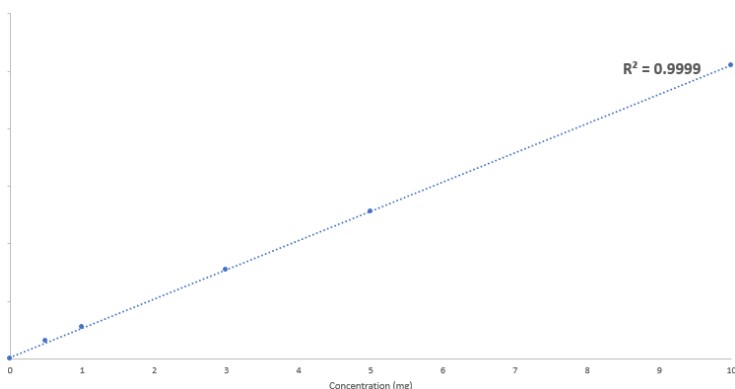
Figure 4. Calibration curve of nicotine

Nicotine has excellent linearity on the Scion 436 GC with SQ MS. The software was used to calculate the concentration of each e-liquid sample with Table 3 detailing the results.

Table 3. Listed concentration and actual concentration of nicotine

Sample	Listed Concentration	Actual Concentration	Deviation (%)
Bubble-gum	6mg	5.6mg	-7
Pear Drop	6mg	6.3mg	+5
Cherry Tree	6mg	5.9mg	-1.7
Blueberry	3mg	3mg	0

As shown in Figure 4, the actual concentration of nicotine in each sample showed variation with the exception of the blueberry sample which contained exactly 3mg of nicotine. However, the variances in nicotine in the remaining samples were no greater than a 7% difference. Manufacturing regulations does not stipulate a deviation acceptance criteria but rather limitations to the amount of nicotine allowed in the e-liquids, which is currently set to 20mg in Europe, significantly lower than the concentration of analysed e-liquids[2].

CONCLUSION

The Scion 436 GC with 8400 autosampler and single quad mass spectrometer was used to analyse four commercially available e-liquid samples. A full scan method was developed with a scan segment acquisition for the complete composition analysis and characterization of flavours and impurities in e-liquids. Optimisation of the scan segment method eliminated time consuming data processing associated with complex chromatograms and eliminated the requirement for extensive sample preparation. Although no e-liquids exhibited the same flavour profile, there were common flavours which were present in all e-liquids, including base flavours such as vanilla and banana. Additionally, there was minimal variance in the nicotine content between listed nicotine concentration and calculated nicotine concentration.