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CHEM 1255
9/20/20

Satis FID – Using Gas Chromatography to Determine the Amount of Nicotine in Different Cigarette Brands

I submit this lab report as an original document. I assert that all ideas and discussion of data contained herein is my own work, unless otherwise referenced.

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Materials

The potassium hydroxide pellets were purchased from Fischer Scientific. Both the naphthalene (≥99%) and the methanol (≥99.9%) were purchased from Sigma Aldrich. Likewise, the nicotine was also purchased from Sigma Aldrich. For this experiment, 0.5611 grams of potassium hydroxide was dissolved partially in water and diluted with the methanol. 50 milligrams of naphthalene was then dissolved into the solution as well to produce the internal stock solution. The nicotine was used to prepare multiple standard solutions of differing concentration, by dissolving various amounts in the internal stock solution prepared. The cigarettes were supplied by the University of Pittsburgh. The insides of the cigarettes were removed, and 50 milligrams of the insides were dissolved into 2 milliliters of the internal stock solution.

Instrumentation

The main instrument used in the procedure of this experiment is the PerkinElmer Clarus 500 Gas Chromatograph, with an Elite-5 column (5% diphenyl – 95% dimethyl polysiloxane, 30 m × 25 mm × 25 μm). TotalChrom Workstation (Version 6.3.4) was used to program the process of the gas chromatograph. The gas chromatograph was programed to certain parameters. The injection volume was set to 0.5 μL, the temperature was set to 280 ℃, and the sampling rate was set to 12.5 samples/s.

Procedure

To create the standards used for the calibration curve, a solvent must first be produced to dissolve the nicotine in. This solvent is made by first measuring out 0.5592 g of KOH, transferring the KOH into a 200 mL volumetric flask, and dissolving completely in a small amount of water. Once the KOH is fully dissolved, the solution is diluted to the mark with methanol. This solution prepared is labeled as the solvent stock solution.

To make the internal standard stock solution, 49.8 mg of naphthalene is measured and transferred into a clean 100 mL volumetric flask. The naphthalene is then diluted to the mark with the solvent stock solution made earlier.

To create the nicotine standard stock solution, 49.6 mg of nicotine is weighed out and then transferred into a clean 25 mL volumetric flask. The nicotine is weighed by using a clean glass syringe. The nicotine is then dissolved to the mark with the internal standard stock solution.

To finally make the nicotine standard solutions, 10 mL samples of various concentrations of the nicotine standard stock solution must be prepared. The amounts of each volume needed to create these solutions is listed in the table below. Keep in mind that NSSS = Nicotine Standard Stock Solution and ISSS = Internal Standard Stock Solution.

Concentration (mg/mL)	Volume NSSS (mL)	Volume ISSS (mL)	Total Volume (mL)
0.0	0	10	10
0.2	1	9	10
0.6	3	7	10
1.0	5	5	10
1.5	7.5	2.5	10
2.0	10	0	10

Each of these solutions should be added into their own labeled GC vial.

The next samples that need to be prepared are the cigarette samples. In order to prepare the samples, the contents in the cigarette must be removed and weighed out to consider for use in further calculations. Next, the

contents should be ground thoroughly using a mortar and pestle, and about 50 mg of the contents must be separated out and placed into its own vial. This should be repeated once for every cigarette sample used in the experiment. The table below details which brands are going to be studied, the weights of the cigarette's content, and the amount of the contents separated out.

Brand	Mass of Cigarette Contents (mg)	Mass Separated (mg)
Newport	787	52
Pall Mall	788	53
L & M	697	51
Marlboro	650	50

As stated before, the mass separated for each cigarette should be placed in their own separate vial, resulting in a total of 10 solutions needed to be run through the GC.

For the final preparations of the samples, the samples should be dissolved in about 2 mL of the internal standard stock solution and sonicated for about 15 minutes to make sure all of the contents are dissolved.

To prepare the solutions for their run through the GC, the solutions must first be filtered to remove any undissolved particles present. This is done by running each solution through a 0.45-micron pore size syringe filter cartridge and placed into their own independently labeled autosampler vials. This should result in 10 autosampler vials being prepared. The vials are then capped and placed into their correctly labeled slots. Once they are all loaded, the GC should be checked to make sure that the correct program method and sequence are selected, both aptly labeled "nicotine in cigs". Lastly, make sure that the parameters for the program are set to the correct values. Once everything has been doublechecked, the GC can begin its run.

Sample Calculations*

*[] denotes main calculation and {} denotes uncertainty calculation

[1]

$$Area\ Ratio = \frac{Area_{Nico}}{Area_{Naph}}$$

$$Area\ Ratio_{Standard\ 2} = \frac{0.0169\ \text{V} \cdot \text{s}}{0.0553\ \text{V} \cdot \text{s}} = 0.306$$

[2]

$$C_N = \frac{(Area\ Ratio - b)}{m}$$

$$C_{N_{Newport}} = \frac{[0.849 - (-0.03594)]}{1.734634\ \frac{\text{mL}}{\text{mg}}} = 0.510\ \frac{\text{mg}}{\text{mL}}$$

[3]

$$m_N = V \cdot C_N$$

$$m_{N_{Newport}} = 2\ \text{mL} \cdot 0.510\ \frac{\text{mg}}{\text{mL}} = 1.02\ \text{mg}$$

[4]

$$m_{N_{Cigarette}} = \frac{m_{N_{Sample}}}{m_{Sample}} \cdot m_{Cigarette}$$

$$m_{N_{Cigarette_{Newport}}} = \frac{1.02\ \text{mg}}{52\ \text{mg}} \cdot 787\ \text{mg} = 15\ \text{mg}$$

{1}

$$\delta Area\ Ratio = Area\ Ratio \sqrt{\left(\frac{\delta Area_{Nico}}{Area_{Nico}}\right)^2 + \left(\frac{\delta Area_{Naph}}{Area_{Naph}}\right)^2}$$

$$\delta Area\ Ratio_{Standard\ 2} = 0.306 \sqrt{\left(\frac{5 \cdot 10^{-5}\ \mathrm{V \cdot s}}{0.0169\ \mathrm{V \cdot s}}\right)^2 + \left(\frac{5 \cdot 10^{-5}\ \mathrm{V \cdot s}}{0.0553\ \mathrm{V \cdot s}}\right)^2} = 9 \cdot 10^{-4}$$

{2}

$$\delta C_N = C_N \sqrt{\left(\frac{\sqrt{\delta Area\ Ratio^2 + \delta b^2}}{Area\ Ratio - b}\right)^2 + \left(\frac{\delta m}{m}\right)^2}$$

$$\delta C_N = 0.510\ \frac{\mathrm{mg}}{\mathrm{mL}} \sqrt{\left(\frac{\sqrt{0.001^2 + 0.03^2}}{0.849 - (-0.03594)}\right)^2 + \left(\frac{0.03\ \frac{\mathrm{mL}}{\mathrm{mg}}}{1.734634\ \frac{\mathrm{mL}}{\mathrm{mg}}}\right)^2} = 0.02\ \frac{\mathrm{mg}}{\mathrm{mL}}$$

{3}

$$\delta m_N = m_N \sqrt{\left(\frac{\delta V}{V}\right)^2 + \left(\frac{\delta C_N}{C_N}\right)^2}$$

$$\delta m_N = 1.02\ \mathrm{mg} \sqrt{\left(\frac{0.5\ \mathrm{mL}}{2\ \mathrm{mL}}\right)^2 + \left(\frac{0.02\ \frac{\mathrm{mg}}{\mathrm{mL}}}{0.510\ \frac{\mathrm{mg}}{\mathrm{mL}}}\right)^2} = 0.3\ \mathrm{mg}$$

{4}

$$\delta m_{N_{Cigarette}} = m_{N_{Cigarette}} \sqrt{\left(\frac{\delta m_{N_{Sample}}}{m_{N_{Sample}}}\right)^2 + \left(\frac{\delta m_{Sample}}{m_{Sample}}\right)^2 + \left(\frac{\delta m_{Cigarette}}{m_{Cigarette}}\right)^2}$$

$$\delta m_N = 15\ \mathrm{mg} \sqrt{\left(\frac{0.3\ \mathrm{mg}}{1.02\ \mathrm{mg}}\right)^2 + \left(\frac{0.1\ \mathrm{mg}}{52\ \mathrm{mg}}\right)^2 + \left(\frac{0.1\ \mathrm{mg}}{787\ \mathrm{mg}}\right)^2} = 4\ \mathrm{mg}$$

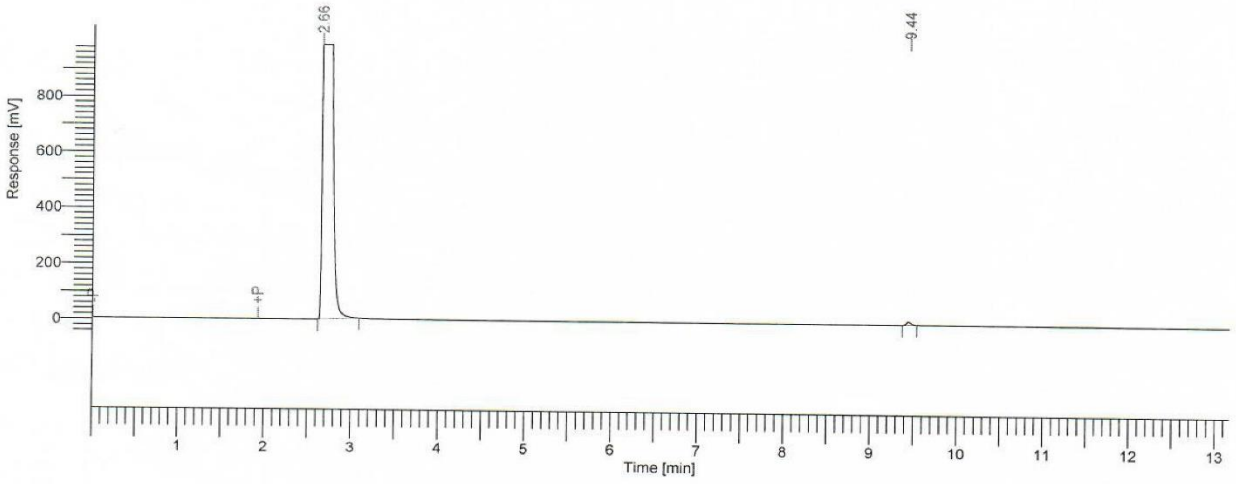
Discussion

1.

1.1.

Software Version	: 6.3.4.0700	Date	: 9/8/2020 2:40:18 PM
Sample Name	: 0	Data Acquisition Time	: 8/20/2020 12:02:27 PM
Instrument Name	: Clarus 500 FID	Channel	: A
Rack/Vial	: 0/1	Operator	: analytical
Sample Amount	: 1.000000	Dilution Factor	: 1.000000
Cycle	: 1		

Result File : c:\data\nicotine\alysia\am_82020_001.rst
Sequence File : C:\Sequences\alysia.seq



Nicotine in Cigarettes

Peak #	Component Name	Time [min]	Area [uV*sec]	Height [uV]	Area [%]	Norm. Area [%]	Cal. Range	Volt Range	BL	Raw Amount
1		2.657	8635099.30	988529.04	99.44	99.44		+	BB	----------
2		9.442	48321.41	12495.36	0.56	0.56			BB	0.0483
			8683420.71	1.00e+06	100.00	100.00				0.0483

Peak #	Adjusted Amount
1	----------
2	0.0483
	0.0483

Warning -- Signal level out-of-range in peak

1.2.

Software Version	: 6.3.4.0700	Date	: 9/8/2020 2:40:51 PM
Sample Name	: 0.2	Data Acquisition Time	: 8/20/2020 12:21:43 PM
Instrument Name	: Clarus 500 FID	Channel	: A
Rack/Vial	: 0/2	Operator	: analytical
Sample Amount	: 1.000000	Dilution Factor	: 1.000000
Cycle	: 2		

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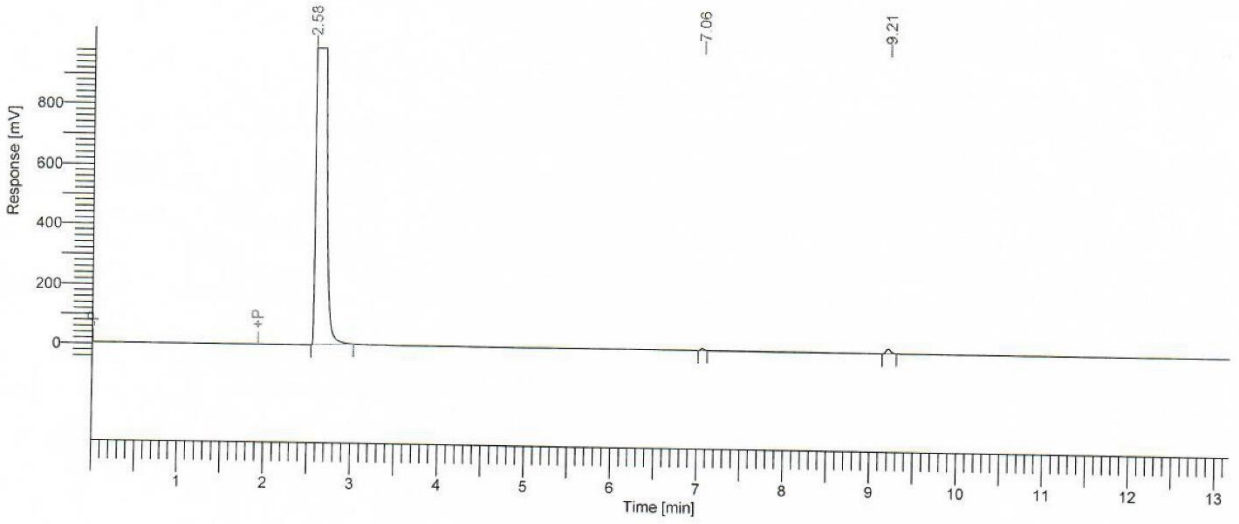
Sequence File : C:\Sequences\alysia.seq



Nicotine in Cigarettes

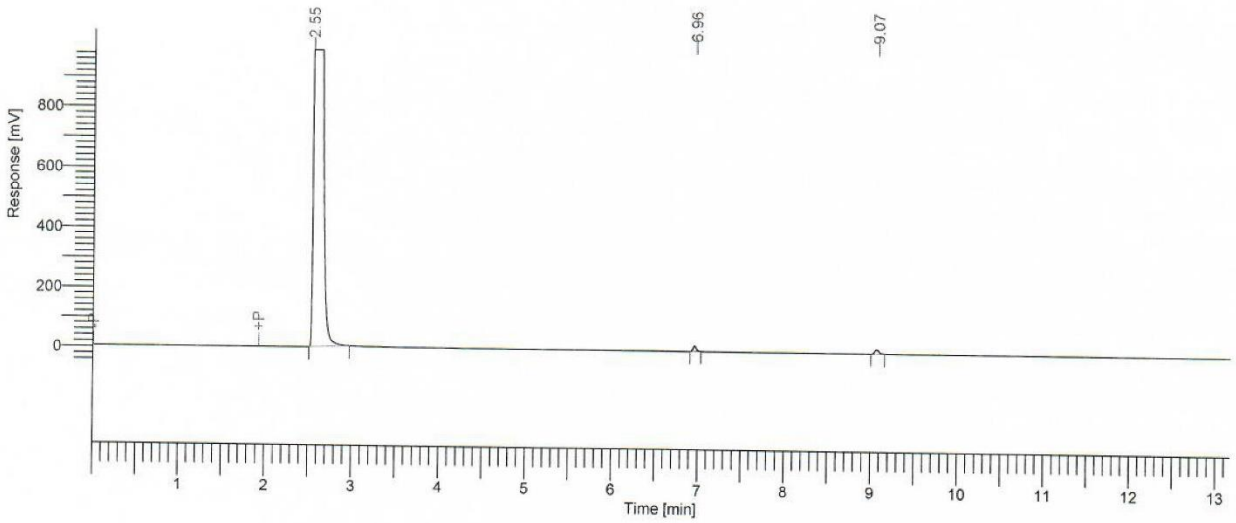
Peak #	Component Name	Time [min]	Area [uV*sec]	Height [uV]	Area [%]	Norm. Area [%]	Cal. Range	Volt Range	BL	Raw Amount
1		2.577	8819738.47	988565.23	99.19	99.19		+	BB	----------
2		7.057	16899.68	6725.12	0.19	0.19			BB	0.0169
3		9.208	55299.72	14797.54	0.62	0.62			BB	0.0553
			8891937.86	1.01e+06	100.00	100.00				0.0722

Peak #	Adjusted Amount
1	----------
2	0.0169
3	0.0553
	0.0722

1.3.

Software Version	: 6.3.4.0700	Date	: 9/8/2020 2:41:02 PM
Sample Name	: 0.6	Data Acquisition Time	: 8/20/2020 12:40:54 PM
Instrument Name	: Clarus 500 FID	Channel	: A
Rack/Vial	: 0/3	Operator	: analytical
Sample Amount	: 1.000000	Dilution Factor	: 1.000000
Cycle	: 3		

Result File : C:\Data\nicotine\alysia\am_82020_003.rst
Sequence File : C:\Sequences\alysia.seq



Nicotine in Cigarettes

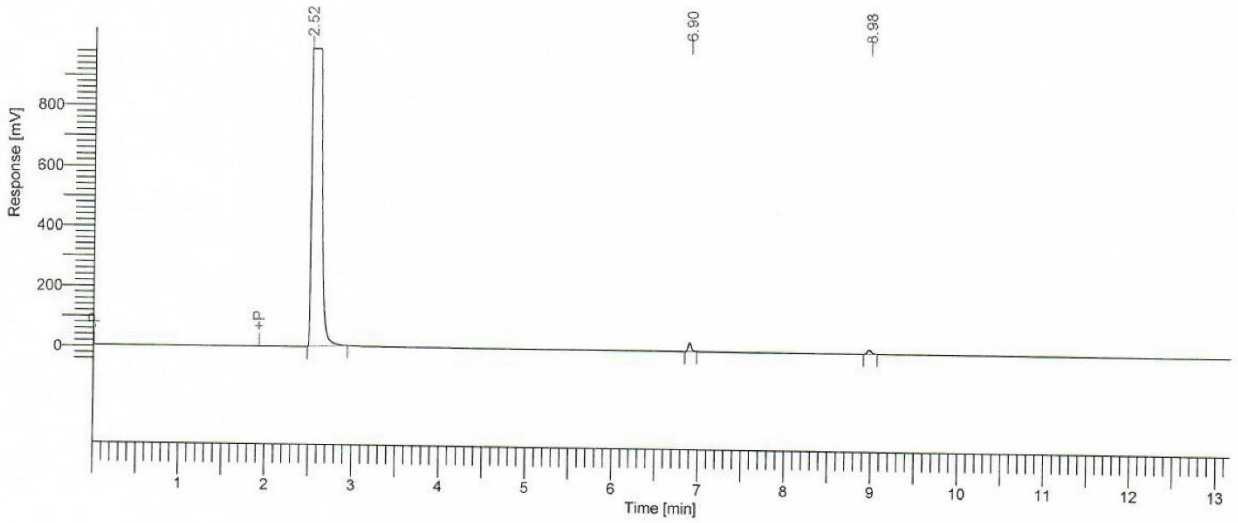
Peak #	Component Name	Time [min]	Area [uV*sec]	Height [uV]	Area [%]	Norm. Area [%]	Cal. Range	Volt Range	BL	Raw Amount
1		2.548	8172127.62	988542.44	98.84	98.84		+	BB	----------
2		6.961	47590.19	18349.32	0.58	0.58			BB	0.0476
3		9.069	47950.14	13478.41	0.58	0.58			BB	0.0480
			8267667.96	1.02e+06	100.00	100.00				0.0955

Peak #	Adjusted Amount
1	----------
2	0.0476
3	0.0480
	0.0955

1.4.

Software Version	: 6.3.4.0700	Date	: 9/8/2020 2:41:13 PM
Sample Name	: 1	Data Acquisition Time	: 8/20/2020 1:00:06 PM
Instrument Name	: Clarus 500 FID	Channel	: A
Rack/Vial	: 0/4	Operator	: analytical
Sample Amount	: 1.000000	Dilution Factor	: 1.000000
Cycle	: 4		

Result File : C:\Data\nicotine\alysia\am_82020_004.rst
Sequence File : C:\Sequences\alysia.seq



Nicotine in Cigarettes

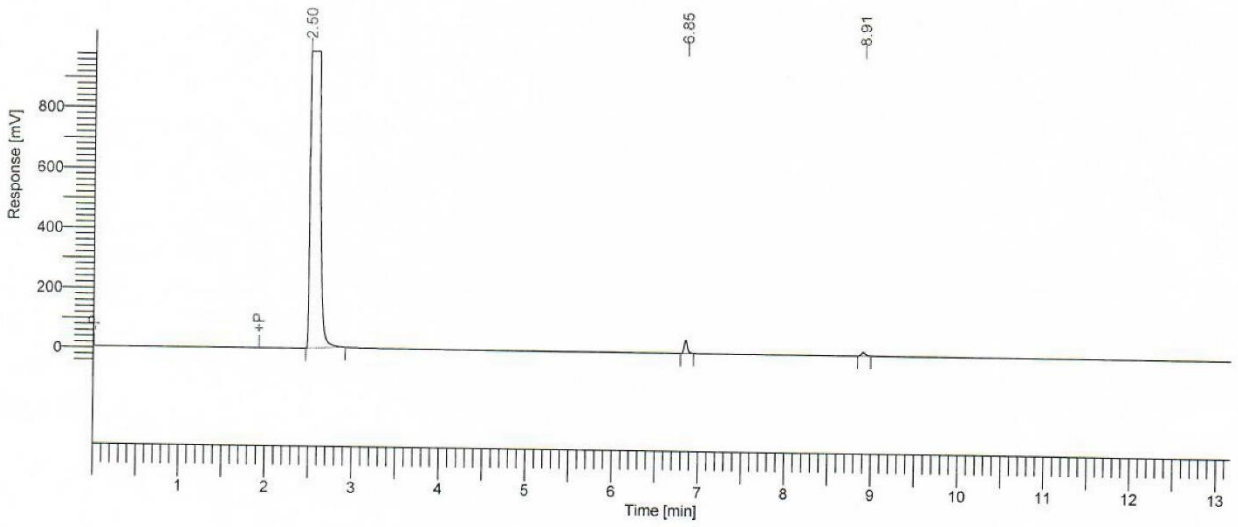
Peak #	Component Name	Time [min]	Area [uV*sec]	Height [uV]	Area [%]	Norm. Area [%]	Cal. Range	Volt Range	BL	Raw Amount
1		2.524	8116270.26	988539.33	98.58	98.58		+	BB	----------
2		6.900	72323.80	28602.95	0.88	0.88			BB	0.0723
3		8.979	44482.56	12670.67	0.54	0.54			BB	0.0445
			8233076.62	1.03e+06	100.00	100.00				0.1168

Peak #	Adjusted Amount
1	----------
2	0.0723
3	0.0445
	0.1168

1.5.

Software Version	: 6.3.4.0700	Date	: 9/8/2020 2:41:29 PM
Sample Name	: 1.5	Data Acquisition Time	: 8/20/2020 1:19:17 PM
Instrument Name	: Clarus 500 FID	Channel	: A
Rack/Vial	: 0/5	Operator	: analytical
Sample Amount	: 1.000000	Dilution Factor	: 1.000000
Cycle	: 5		

Result File : C:\Data\nicotine\alysia\am_82020_005.rst
Sequence File : C:\Sequences\alysia.seq



Nicotine in Cigarettes

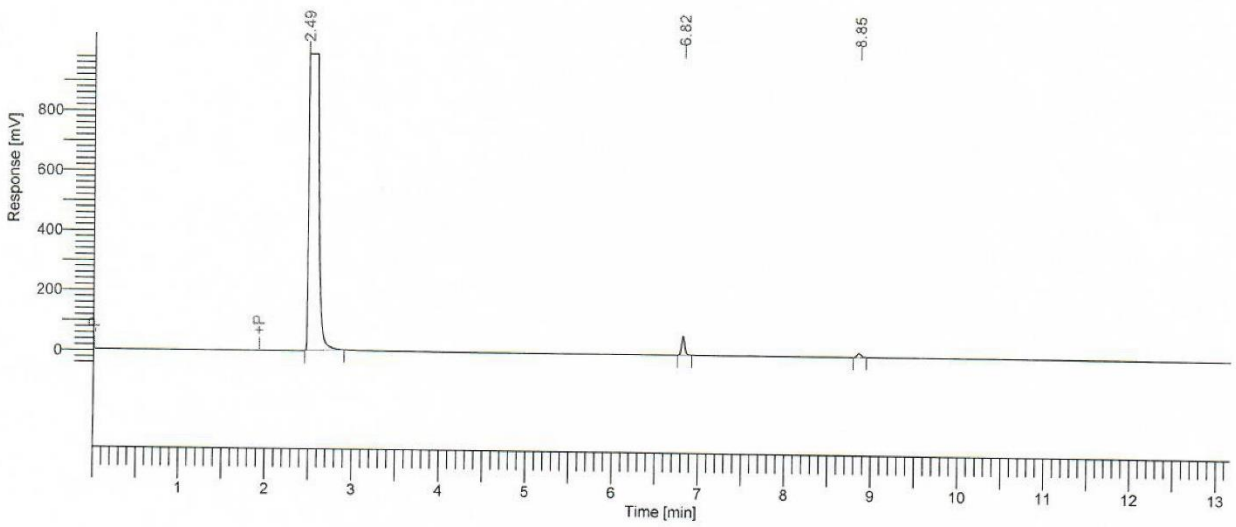
Peak #	Component Name	Time [min]	Area [uV*sec]	Height [uV]	Area [%]	Norm. Area [%]	Cal. Range	Volt Range	BL	Raw Amount
1		2.504	8079274.82	988565.01	98.10	98.10		+	BB	----------
2		6.853	113214.90	44454.88	1.37	1.37			BB	0.1132
3		8.907	43074.42	12485.85	0.52	0.52			BB	0.0431
			8235564.14	1.05e+06	100.00	100.00				0.1563

Peak #	Adjusted Amount
1	----------
2	0.1132
3	0.0431
	0.1563

1.6.

Software Version	: 6.3.4.0700	Date	: 9/8/2020 2:41:44 PM
Sample Name	: 2	Data Acquisition Time	: 8/20/2020 1:38:28 PM
Instrument Name	: Clarus 500 FID	Channel	: A
Rack/Vial	: 0/6	Operator	: analytical
Sample Amount	: 1.000000	Dilution Factor	: 1.000000
Cycle	: 6		

Result File : C:\Data\nicotine\alysia\am_82020_006.rst
Sequence File : C:\Sequences\alysia.seq



Nicotine in Cigarettes

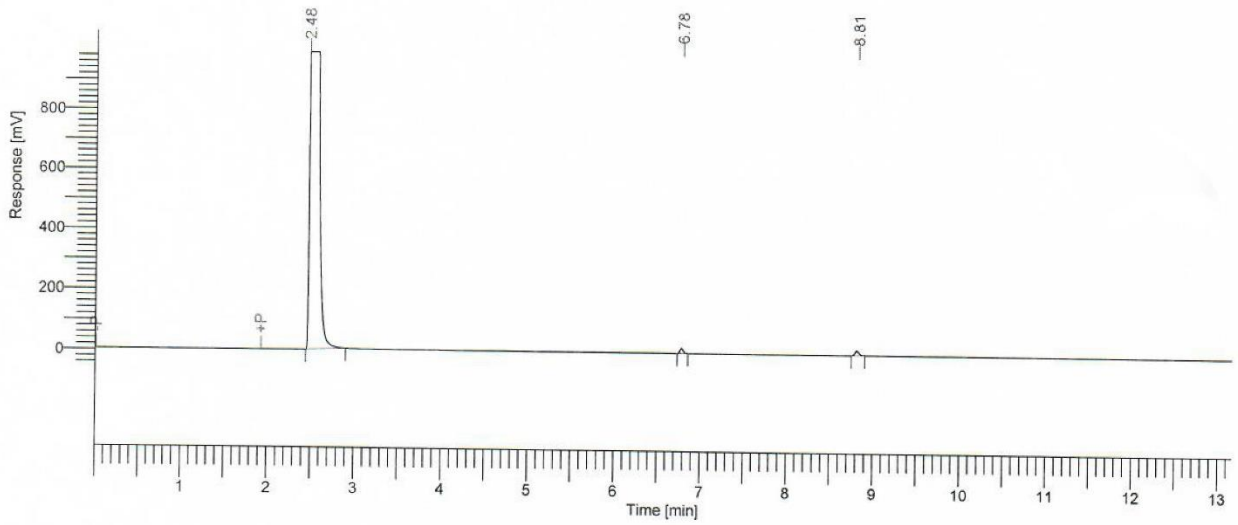
Peak #	Component Name	Time [min]	Area [uV*sec]	Height [uV]	Area [%]	Norm. Area [%]	Cal. Range	Volt Range	BL	Raw Amount
1		2.488	7867814.71	988595.18	97.40	97.40		+	BB	----------
2		6.820	162863.33	63714.49	2.02	2.02			BB	0.1629
3		8.854	47468.87	13960.76	0.59	0.59			BB	0.0475
			8078146.91	1.07e+06	100.00	100.00				0.2103

Peak #	Adjusted Amount
1	----------
2	0.1629
3	0.0475
	0.2103

1.7.

Software Version	: 6.3.4.0700	Date	: 9/8/2020 2:41:55 PM
Sample Name	: new	Data Acquisition Time	: 8/20/2020 1:57:40 PM
Instrument Name	: Clarus 500 FID	Channel	: A
Rack/Vial	: 0/7	Operator	: analytical
Sample Amount	: 1.000000	Dilution Factor	: 1.000000
Cycle	: 7		

Result File : C:\Data\nicotine\alysia\am_82020_007.rst
Sequence File : C:\Sequences\alysia.seq



Nicotine in Cigarettes

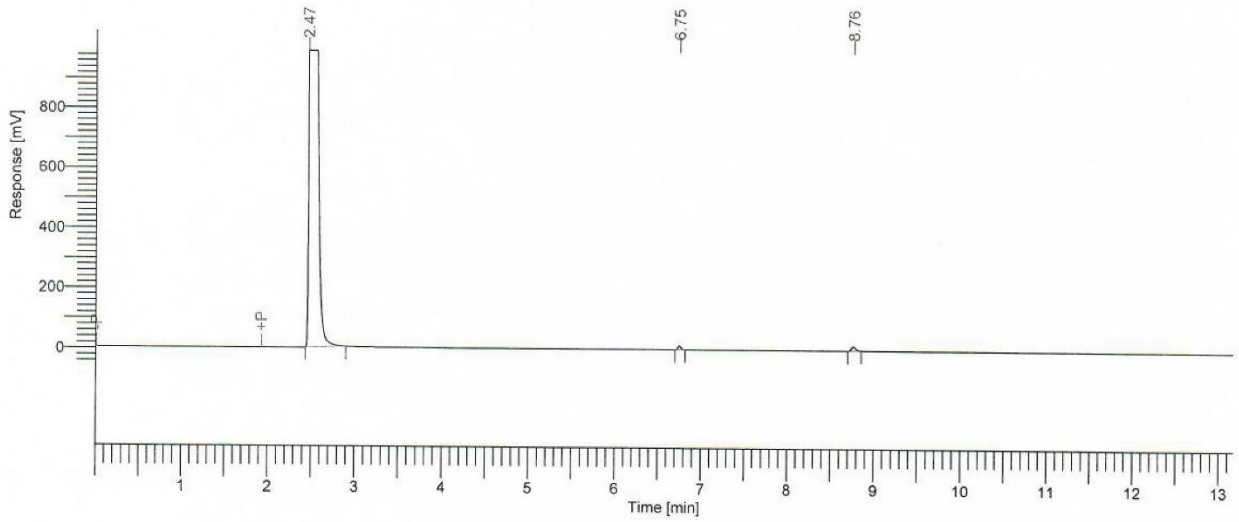
Peak #	Component Name	Time [min]	Area [uV*sec]	Height [uV]	Area [%]	Norm. Area [%]	Cal. Range	Volt Range	BL	Raw Amount
1		2.477	8027297.60	988591.94	98.87	98.87		+	BB	----------
2		6.784	42190.05	17205.03	0.52	0.52			BB	0.0422
3		8.813	49688.80	14700.48	0.61	0.61			BB	0.0497
			8119176.45	1.02e+06	100.00	100.00				0.0919

Peak #	Adjusted Amount
1	----------
2	0.0422
3	0.0497
	0.0919

1.8.

Software Version	: 6.3.4.0700	Date	: 9/8/2020 2:42:05 PM
Sample Name	: pall	Data Acquisition Time	: 8/20/2020 2:16:52 PM
Instrument Name	: Clarus 500 FID	Channel	: A
Rack/Vial	: 0/8	Operator	: analytical
Sample Amount	: 1.000000	Dilution Factor	: 1.000000
Cycle	: 8		

Result File : C:\Data\nicotine\alysia\am_82020_008.rst
Sequence File : C:\Sequences\alysia.seq



Nicotine in Cigarettes

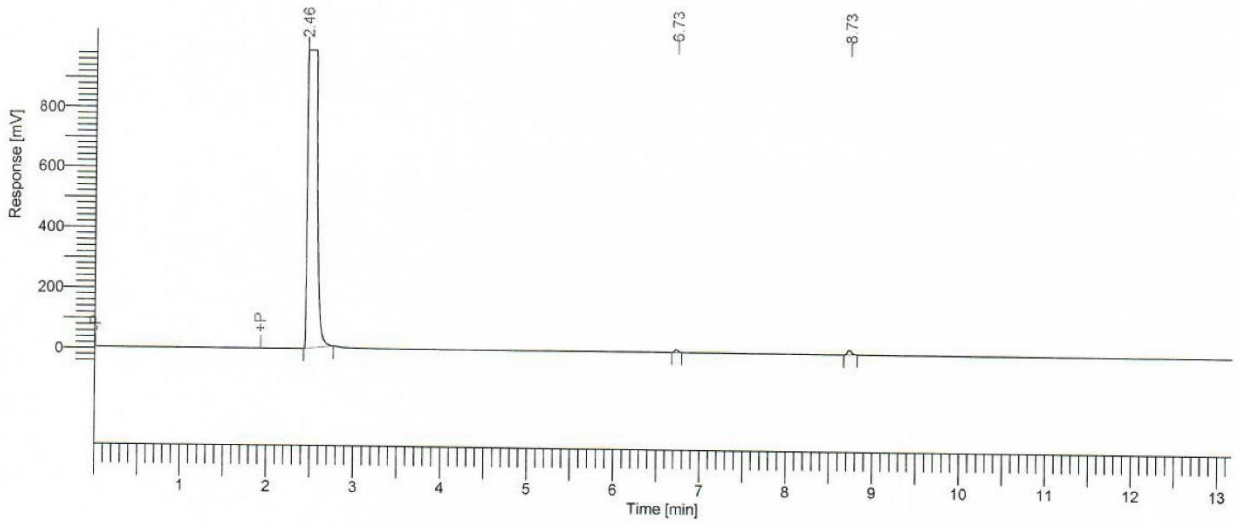
Peak #	Component Name	Time [min]	Area [uV*sec]	Height [uV]	Area [%]	Norm. Area [%]	Cal. Range	Volt Range	BL	Raw Amount
1		2.468	7821968.94	988608.73	98.98	98.98		+	BB	----------
2		6.751	32281.96	13290.52	0.41	0.41			BB	0.0323
3		8.765	48591.45	14466.44	0.61	0.61			BB	0.0486
			7902842.34	1.02e+06	100.00	100.00				0.0809

Peak #	Adjusted Amount
1	----------
2	0.0323
3	0.0486
	0.0809

1.9.

Software Version	: 6.3.4.0700	Date	: 9/8/2020 2:42:18 PM
Sample Name	: I&M	Data Acquisition Time	: 8/20/2020 2:36:04 PM
Instrument Name	: Clarus 500 FID	Channel	: A
Rack/Vial	: 0/9	Operator	: analytical
Sample Amount	: 1.000000	Dilution Factor	: 1.000000
Cycle	: 9		

Result File : C:\Data\nicotine\alysia\am_82020_009.rst
Sequence File : C:\Sequences\alysia.seq



Nicotine in Cigarettes

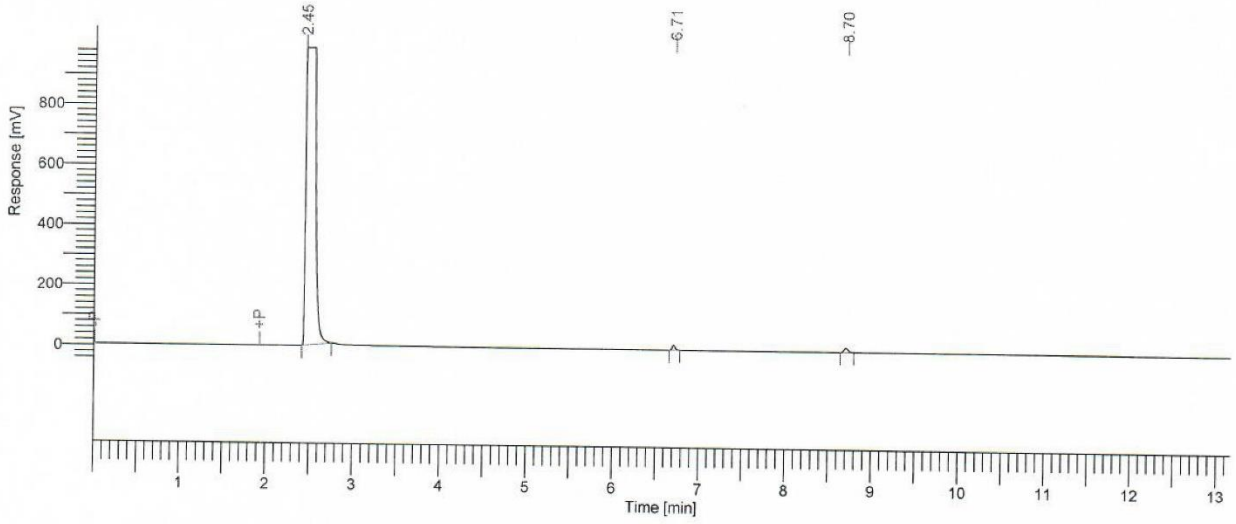
Peak #	Component Name	Time [min]	Area [uV*sec]	Height [uV]	Area [%]	Norm. Area [%]	Cal. Range	Volt Range	BL	Raw Amount
1		2.457	7721656.05	988100.62	99.02	99.02		+	BB	----------
2		6.725	27305.07	11475.86	0.35	0.35			BB	0.0273
3		8.729	48783.86	14450.24	0.63	0.63			BB	0.0488
			7797744.98	1.01e+06	100.00	100.00				0.0761

Peak #	Adjusted Amount
1	----------
2	0.0273
3	0.0488
	0.0761

1.10.

Software Version	: 6.3.4.0700	Date	: 9/8/2020 2:42:27 PM
Sample Name	: marlboro	Data Acquisition Time	: 8/20/2020 2:55:17 PM
Instrument Name	: Clarus 500 FID	Channel	: A
Rack/Vial	: 0/10	Operator	: analytical
Sample Amount	: 1.000000	Dilution Factor	: 1.000000
Cycle	: 10		

Result File : C:\Data\nicotine\alysia\am_82020_010.rst
Sequence File : C:\Sequences\alysia.seq



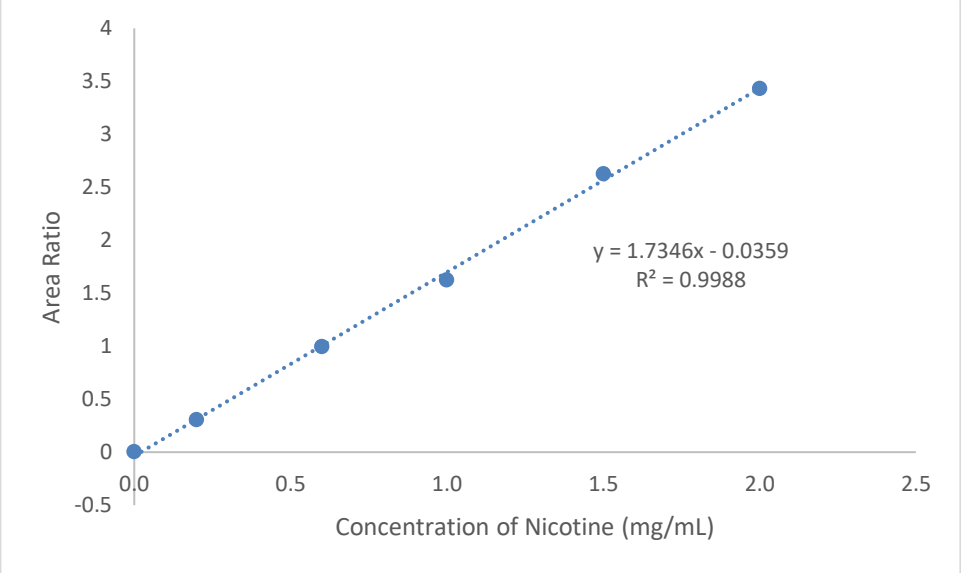
Nicotine in Cigarettes

Peak #	Component Name	Time [min]	Area [uV*sec]	Height [uV]	Area [%]	Norm. Area [%]	Cal. Range	Volt Range	BL	Raw Amount
1		2.448	7699738.83	988104.90	98.83	98.83		+	BB	----------
2		6.709	41548.44	17324.79	0.53	0.53			BB	0.0415
3		8.703	49712.27	14856.35	0.64	0.64			BB	0.0497
			7790999.54	1.02e+06	100.00	100.00				0.0913

Peak #	Adjusted Amount
1	----------
2	0.0415
3	0.0497
	0.0913

2. In order to determine the amount of nicotine present in the cigarette samples, a calibration curve must first be established. Using the data from the GC-FID scans of the standard solutions used in the lab, a calibration curve can be produced. In this case, the calibration curve will have axes comparing the concentration of nicotine in the standard solutions and the ratio of the areas of the peaks for naphthalene and nicotine.

Sample #	Concentration of Nicotine (mg/mL)	Peak Area of Nicotine (V*s)	Peak Area of Naphthalene (V*s)	Peak Area Ratio [1] {1}
1	0.0	N/A	$0.0483 \pm 5\times10^{-5}$	0
2	0.2	$0.0169 \pm 5\times10^{-5}$	$0.0553 \pm 5\times10^{-5}$	$0.306 \pm 9\times10^{-4}$
3	0.6	$0.0476 \pm 5\times10^{-5}$	$0.0480 \pm 5\times10^{-5}$	$0.992 \pm 1\times10^{-3}$
4	1.0	$0.0723 \pm 5\times10^{-5}$	$0.0445 \pm 5\times10^{-5}$	$1.62 \pm 2\times10^{-3}$
5	1.5	$0.1132 \pm 5\times10^{-5}$	$0.0431 \pm 5\times10^{-5}$	$2.63 \pm 3\times10^{-3}$
6	2	$0.1629 \pm 5\times10^{-5}$	$0.0475 \pm 5\times10^{-5}$	$3.43 \pm 4\times10^{-3}$



Number Type	Slope	Y-Intercept
Value	1.7346	0.0359
Uncertainty*	0.03	0.03

*Uncertainty values found through LINEST formula in excel.

3. The equation of the trendline allows for one unknown value to be solved as long as another value is known. In the case for this experiment, the area ratio can be found using the data from the GC-FID scans, therefore the concentration of nicotine can be determined using this data.

Sample	Peak Area of Nicotine (V*s)	Peak Area of Naphthalene (V*s)	Peak Area Ratio [1] {1}	Concentration of Nicotine (mg/mL) [2] {2}
Newport	$0.0422 \pm 5\times10^{-5}$	$0.0497 \pm 5\times10^{-5}$	$0.849 \pm 1\times10^{-3}$	$0.510 \pm 2\times10^{-2}$
Pall Mall	$0.0323 \pm 5\times10^{-5}$	$0.0486 \pm 5\times10^{-5}$	$0.665 \pm 1\times10^{-3}$	$0.404 \pm 2\times10^{-2}$
L & M	$0.0273 \pm 5\times10^{-5}$	$0.0488 \pm 5\times10^{-5}$	$0.559 \pm 1\times10^{-3}$	$0.343 \pm 2\times10^{-2}$
Marlboro	$0.0415 \pm 5\times10^{-5}$	$0.0497 \pm 5\times10^{-5}$	$0.835 \pm 1\times10^{-3}$	$0.502 \pm 2\times10^{-2}$

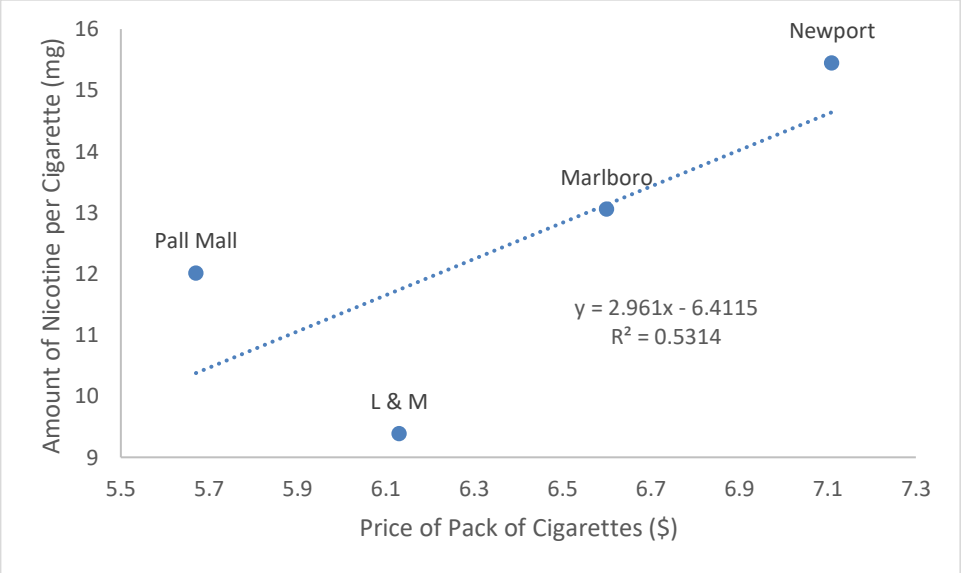
Now that the concentrations of nicotine in the cigarette samples are known, the data can now be used to determine the mass of nicotine in the cigarette samples, as well as the mass of nicotine in one cigarette.

Sample	Concentration of Nicotine (mg/mL) [2]	Volume of Sample (mL)	Mass of Nicotine in Sample (mg) [3] {3}	Mass of Sample (mg)	Mass of Cigarette (mg)	Mass of Nicotine in Cigarette (mg) [4] {4}
Newport	$0.510 \pm 2\times10^{-2}$	$2 \pm 1\times10^{-1}$	$1.02 \pm 3\times10^{-1}$	$52 \pm 1\times10^{-1}$	$787 \pm 1\times10^{-1}$	15 ± 4
Pall Mall	$0.404 \pm 2\times10^{-2}$	$2 \pm 1\times10^{-1}$	$0.808 \pm 2\times10^{-1}$	$53 \pm 1\times10^{-1}$	$788 \pm 1\times10^{-1}$	12 ± 3
L & M	$0.343 \pm 2\times10^{-2}$	$2 \pm 1\times10^{-1}$	$0.686 \pm 2\times10^{-1}$	$51 \pm 1\times10^{-1}$	$697 \pm 1\times10^{-1}$	9.4 ± 2
Marlboro	$0.502 \pm 2\times10^{-2}$	$2 \pm 1\times10^{-1}$	$1.00 \pm 3\times10^{-1}$	$50 \pm 1\times10^{-1}$	$650 \pm 1\times10^{-1}$	13 ± 3

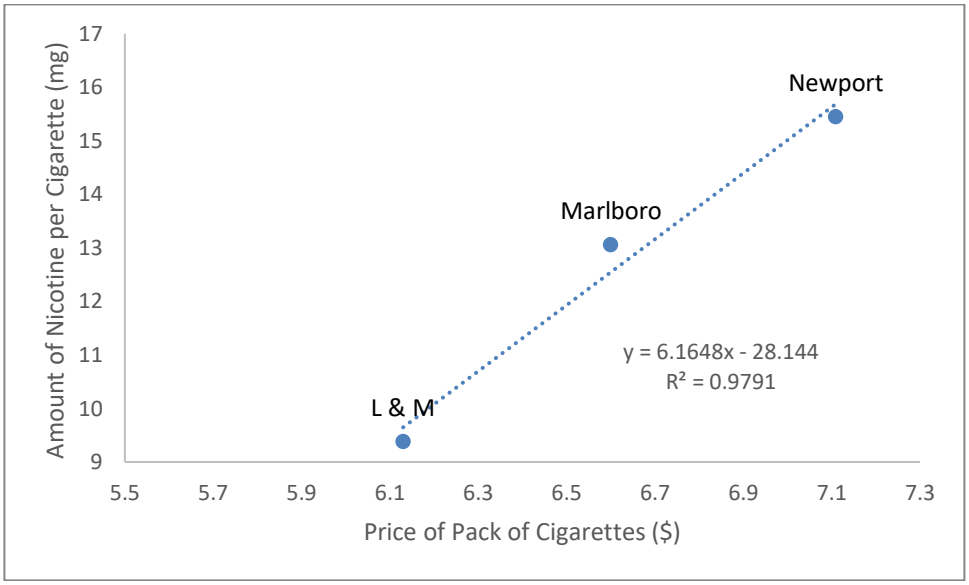
4. With the mass of the nicotine present in each cigarette sample known, the amount of nicotine compared to the price of the cigarettes can be determined, and in turn, determine the price equating to 1 mg of nicotine.

Sample	Mass of Nicotine in Cigarette (mg) [4] {4}	Minimum Retail Price per Pack ($)	Price per mg of Nicotine ($/mg)
Newport	15 ± 4	7.11	0.46
Pall Mall	12 ± 3	5.67	0.47
L & M	9.4 ± 2	6.13	0.65
Marlboro	13 ± 3	6.60	0.51

5.



Looking at the plot shown above, some amount of correlation can be obtained by comparing the price of the cigarettes versus the amount of nicotine per cigarette. The clear exception shown in the plot is Pall Mall, which has a high nicotine content per cigarette, but an unnaturally cheap price. By excluding the Pall Mall data, a linear trend can be seen and confirmed.



6. Naphthalene is used to increase the retention time. Similar shaped compounds, such as nicotine, will interact with the naphthalene in solution. If naphthalene were excluded from the experiment, it would be expected for the retention time to be drastically decreased.

7. KOH is used to prevent certain chemicals from dissolving into the methanol used in the solvent stock solution. Any amount of naphthalene or nicotine dissolving in the methanol would be removed from the prepared sample, and in turn affect the data received from the gas chromatographer.

8. A lot of the error mostly stems from the lack of precision in the collection and preparation of samples. While each sample may not have a large margin of error, the error from every single sample can accumulate very quickly, as is shown in the data above. A simple way to prevent this error is to simply find more precise ways to measure out the quantities that are needed.