Simple Harmonic Relationship of Atom Tones Translated From Their Spectral Lines

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Abstract

The transposition of audible raw data sounds generated from the visible spectral lines of atoms by my mentor, Jill Linz, has paved the way for myself and other students to engage in their own original research. This study focuses on an investigation of the harmonic structure inherent in most physical aspects of nature and the atom tones translated from their spectral lines in which I used sonification programs, such as amadeus and audacity, to conduct this experiment. The raw data sounds were imported into these programs and then manipulated from an amplitude by time graph to an amplitude by frequency graph in which the observable factor was the frequencies in Hertz of the most prominent peaks in each atom tone previously transposed. These frequencies were then used in an equation that showed the harmonic structure in terms of intervals. I had hypothesized that the way the graphs were constructed could be a result of that specific atom's electron configuration, whether it be the amount of balanced electrons or the amount of electron layers. Ultimately, these hypotheses were proven wrong as there was no evidence of harmonic structure within the peaks of the most prominent frequencies.

Introduction

Atom music is an education tool my mentor developed to use for a sonification exercise in her class. (Linz, 2019). Sonification is the data-dependent generation of sound in which the resulting waveform is transposed into the audible domain. Audification is the direct transposition of data into this audible domain, in which the resulting sound is a rough noise that can be manipulated into a periodic signal. (Vogt, 2008). The simplicity of the spectral mapping to audible tones makes it easy to create tones for each atom. This in turn makes it easy to create musical sounds and scales that allow for investigations into both the scientific and musical realms (Linz, 2019). However, while my mentor used other Digital Signal Processing methods with grounds in parameter mapping, another form of sonification in which timbre and rhythm were applied to these raw data sounds transposed to create a sound that is not just noisy, but rather pleasant and musical to the ear, while I only used to Audification based sounds.

Data to be used in the sonication process was derived from the visible spectrum found in each atom's spectral lines. The visible spectrum for the human eye ranges from 400nm to 700nm, both of which correspond to the colors violet and red respectively. Using the basic equation $v=\lambda f$ in which v is the speed of light, λ is the wavelength, and f is the frequency of the waves, a scale was determined that inversely puts 700 nm to 0 Hz and decreases/increases in equal increments until it reaches 400 nm to 1000 Hz. Using the wavelengths of the spectra lines unique to each atom, a scale was created that converted these wavelengths to a frequency that could be used in the sonication process. The deliberate blending of sinusoidal waves to create complex sounds that are perceived by the ear as being rich in harmonics was reminiscent of the way atomic spectra represent the pattern of sinusoidal waves that are perceived by the eye as complex color (Linz, 2019).

Statement of Purpose

To investigate the relation between harmonic structure inherent in most physical aspects of nature and the atom tones translated from their spectral lines.

Hypotheses

- The harmonic patterns of the sonification graphs is a direct result of the amount of valence electrons in the outermost shell.
- The harmonic patterns of the sonification graphs is a direct result of the number of electron shells.

Methodology

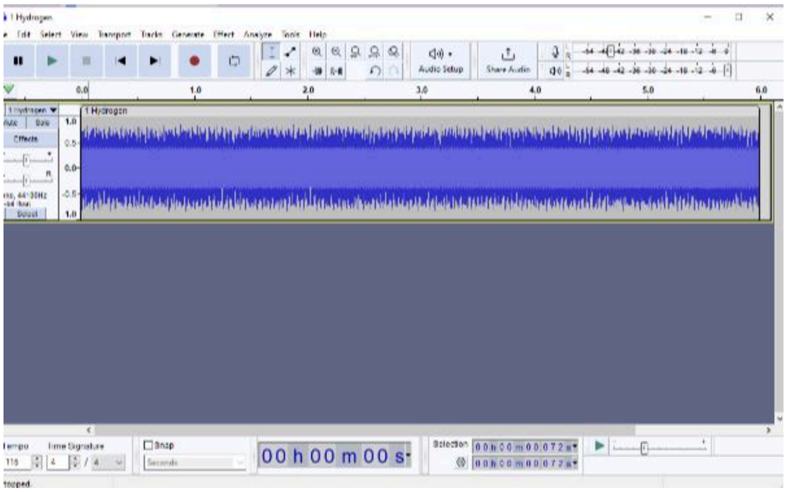


Figure 1

Using the computer program that was used to construct the Raw Data Sounds, amadeus or its free counterpart audacity. First, the Raw Data Sound has to be imported into the program, (Figure 1). Nothing else is to be touched in the program as we are not looking at the changing the physical and auditory aspects of the waveform itself, but rather observing it in its original form. Then, a section of the graph is highlighted, the analyze button is pressed, and the plot spectrum is selected (Figure 2). A frequency analysis of the most prominent peaks of the waveform is generated (Figure 3). This part shifts the graph from an amplitude by time graph into an amplitude by frequency graph using Fourier's Transformations. In this section, the size of the graph is changed from 128 to 8192 as it allows for the peaks to become more distinguishable. Using your mouse cursor, put it over the peaks on the graph and record the value in the Peak box and not the cursor box as the value in Peak box is based on the actual value of the peak closest to you cursor. For this experiment, only the highest value of every wave of the graph was used as it was viewed as having the most important value in hertz as compared to the values before and after it. Figure 1 through 3 show the element hydrogen, and as we can see it only has 3 prominent peaks.

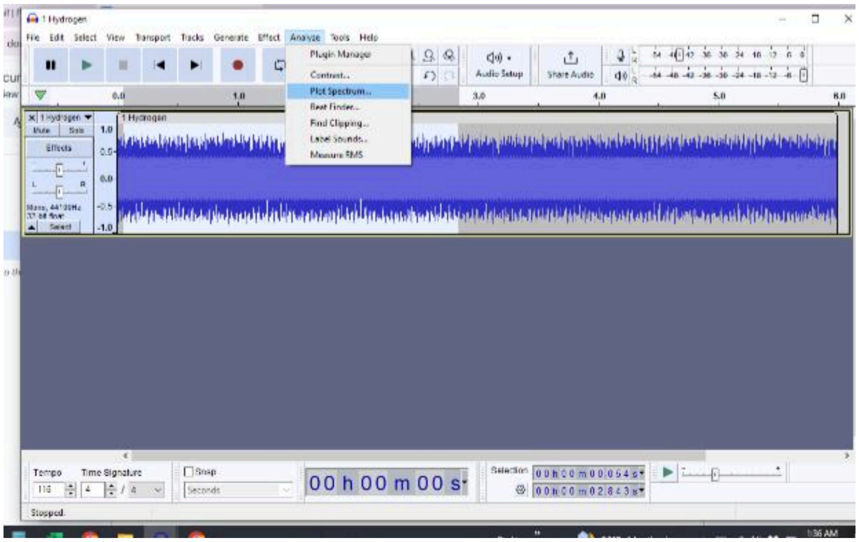
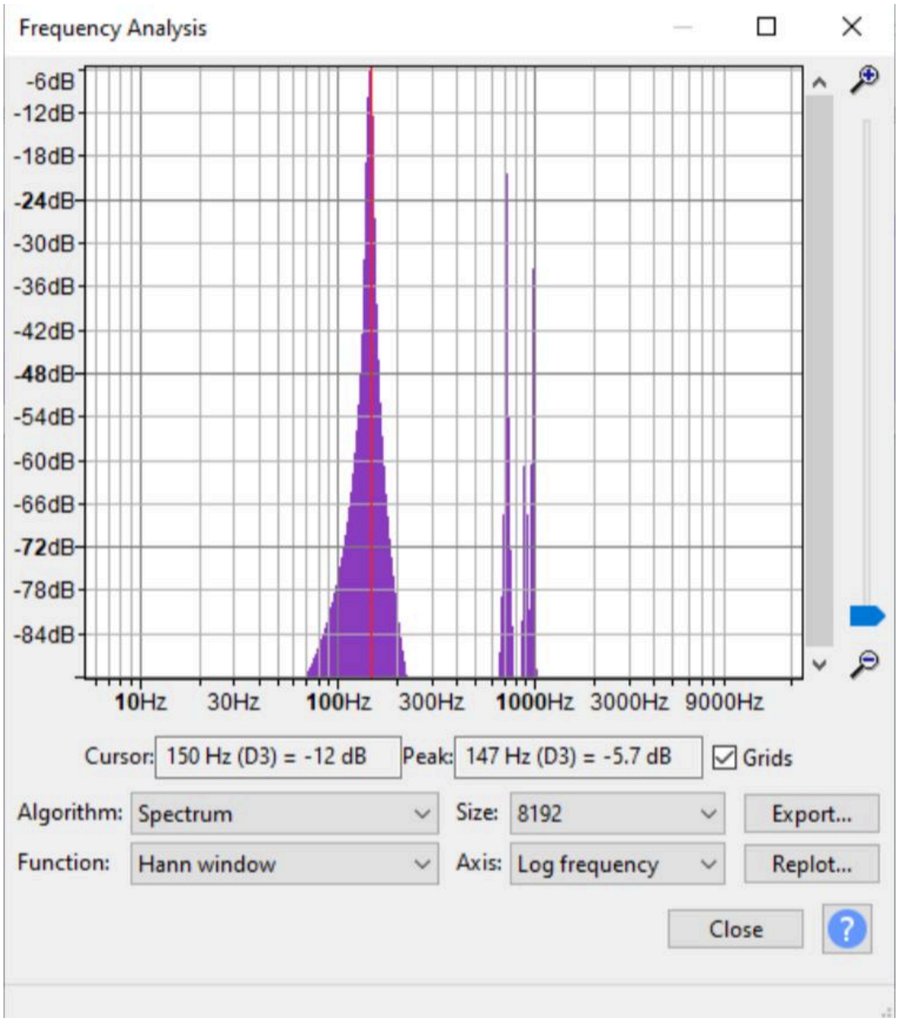


Figure 2



Cursor: 150 Hz (D3) = -12 dB

Peak: 147 Hz (D3) = -5.7 dB

☑ Grids

Algorithm: Spectrum

Size: 8192

Function: Hann window

Axis: Log frequency

Figure 3

After all the lines were valued for the elements in periods one through six and in groups 1 and 18, an equation derived by Pathagoras was implemented to find the ratio that would allow us to decide if there was harmonic structure. This equation is $R=f_{n+1}/f_n$ in which:

f_1= 100

f_2= 200

f_3= 300

f_4= 400

f_5= 500

f_6= 600

The application of this will produce a number which will allow for the classification of the spectral lines to be harmonious or not. These numbers are depicted in Table 5.

Table 5: Numerical Values of Harmonic Characteristics

Value	Harmonic
$f_2/f_1=2$	Octave
$f_3/f_2=1.5$	Perfect fifth
$f_4/f_3=1.33$	Perfect fourth
$f_5/f_4=1.25$	Major Third
$f_6/f_5=1.2$	Minor Third

These values were determined to the fourth decimal and rounded to the second decimal for perfect fourth and major third and rounded to the first decimal for octaves, perfect fifths, and minor thirds.

Data

For this experiment, the most prominent peaks were collected for both the first and the eighteenth group too. Table one represents the Alkali Metal and Hydrogen and Table two represents the Noble Gasses.

Table One: Alkali Metals and Hydrogen

Hydrogen	Lithium	Sodium	Potassium	Rubidium	Cesium
147	101	371	394	233	94
713	303		555	263	671
887	507		635	281	
966			684	309	
			715	426	
			737	449	
			789	523	
			984	545	
				579	

				600	
				616	
				666	
				932	

Table 2: Noble Gasses

Helium	Neon	Argon	Krypton	Xenon	Radon
111	24	13	370	9	53
375	136	83	483	28	82
663	165	109	884	61	125
843	200	826		89	146
992	223	912		109	314
	245	948		142	757
	261			161	862
	280			185	
	309			215	
	324			228	
	384			281	
	534			324	
	553			357	
	681			405	

	705			443	
	724			486	
	762			529	
	821			552	
				586	
				629	
				649	
				670	
				707	
				744	
				779	
				805	
				846	
				873	
				899	
				936	
				974	
				1016	

Table 3: Application of Pythagoras's Interval Ratio for Group 1 Elements

Hydrogen	Lithium	Sodium	Potassium	Rubidium	Cesium

4.8503	3	-	1.4086	1.1288	7.1383
1.2440	1.6732		1.1441	1.0684	
1.0891			1.0772	1.0996	
			1.0453	1.3786	
			1.0308	1.05399	
			1.0706	1.1648	
			1.2471	1.0421	
				1.0624	
				1.0362	
				1.0267	
				1.0812	
				1.3994	

Table 4: Application of Pythagoras's Interval Ratio for Group 18 Elements

Helium	Neon	Argon	Krypton	Xenon	Radon
3.3784	5.6667	6.3846	1.3054	3.1111	0.98795
1.768	1.2132	1.3133	1.8302	2.1786	1.5244
1.2715	1.2121	7.57798		1.459	1.168
1.1767	1.115	1.1041		1.2247	2.1507
	1.0987	1.0789		1.3026	2.4108
	1.0653			1.1338	1.1387
	1.0728			1.1491	

	1.1036			1.1622	
	1.0485			1.0605	
	1.1852			1.2325	
	1.3906			1.153	
	1.0356			1.019	
	1.2315			1.1345	
	1.0352			1.0938	
	1.02695			1.0971	
	1.0525			1.0885	
				1.0435	
				1.0616	
				1.0734	
				1.0318	
				1.0652	
				1.0552	
				1.0523	
				1.047	
				1.0334	
				1.0509	
				1.0319	
				1.0298	

				1.0412	
				1.0085	
				1.0431	

Results

I provided both the most prominent spectral lines and their frequencies (Table 1 and 2) as well as the analysis of their harmonic nature (Tables 3 and 4). Within Tables 3 and 4, there are scarce amounts of data points that are colored. Below I have provided a legend which deciphers this code and categories that jump between the two spectral lines as harmonic.

octave (2)
perfect 5th (1.5)
perfect 4th (1.33)
major third (1.25)
minor third (1.2)

As the harmonics confined within the data is not consistent or even common, it can be concluded that harmonic structures inherent in most physical aspects of nature are not inherent in the atomic tones that are translated from their spectral lines as shown by Figures 4 and 5, in which the graphs have no relation at all.

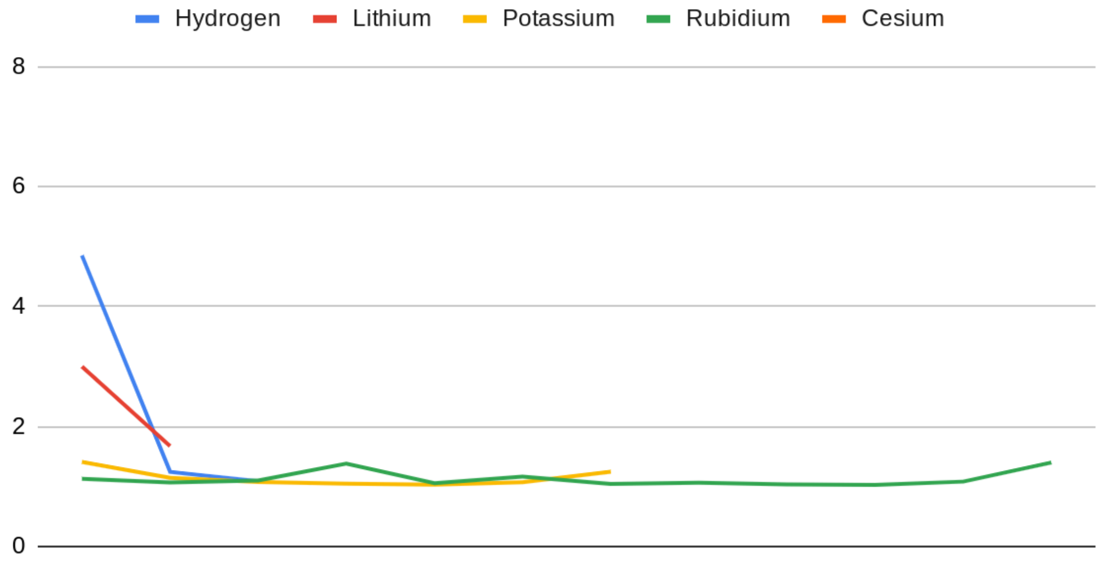
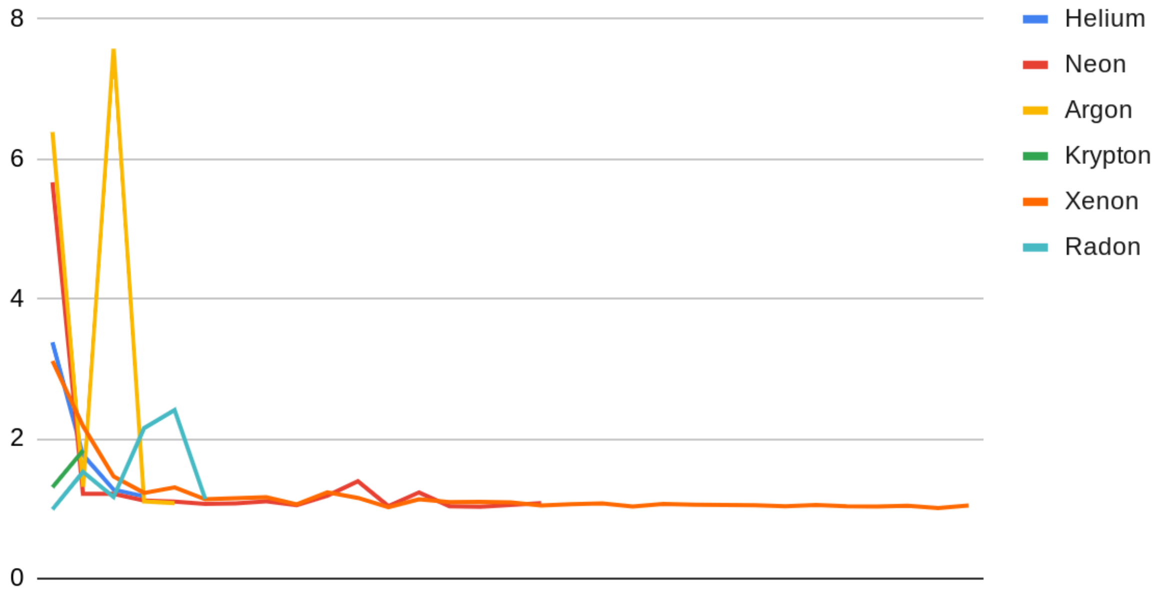


Figure 4: Application of Pythagoras's Interval Ratio For Group 1 Elements Graph

Figure 5: Application of Pythagoras's Interval Ratio for Group 18 Elements Graph



Figures 6 and 7 show the values of the Alkali Metals with Hydrogen and the Noble Gasses in graphical form. The elements with less frequencies (Lithium, Sodium, and Cesium) are more direct and systematic than the ones with more frequencies. These 3 elements all have 3 or less frequencies stemming from their spectral line with sodium being a point because it only has one. It's also important to note that these elements are all Alkali Metals. In contrast, the elements with 4 to 31 frequencies have a degree of randomness and changing direction. This translates to how the raw data sounds in the audible domain. The lesser the amount of frequencies present in the element, the more pleasant the sound is and the more frequencies present in the element, the more noisy and harsh it sounds.

Figure 6: Frequencies of Prominent Spectral Lines For Group One Elements

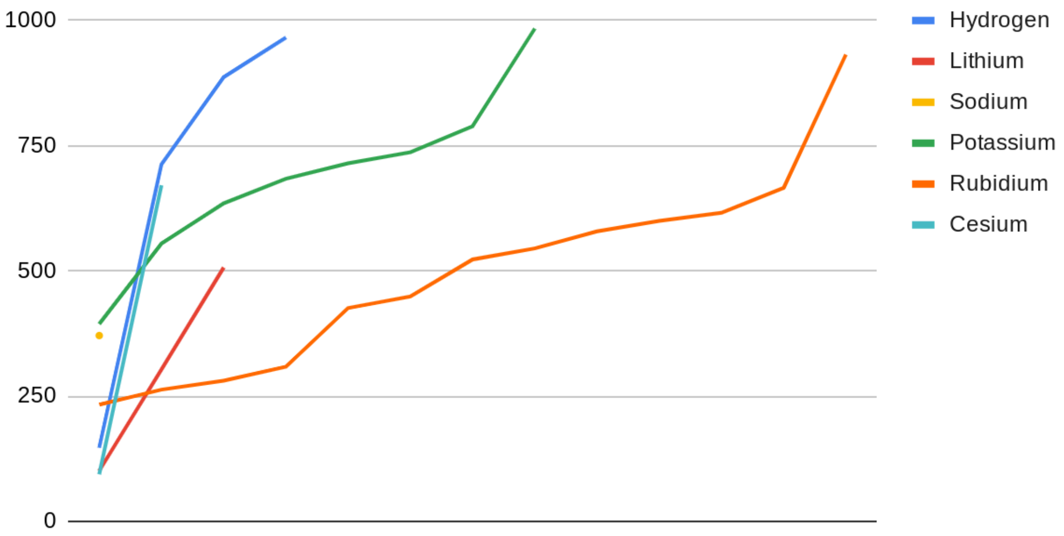
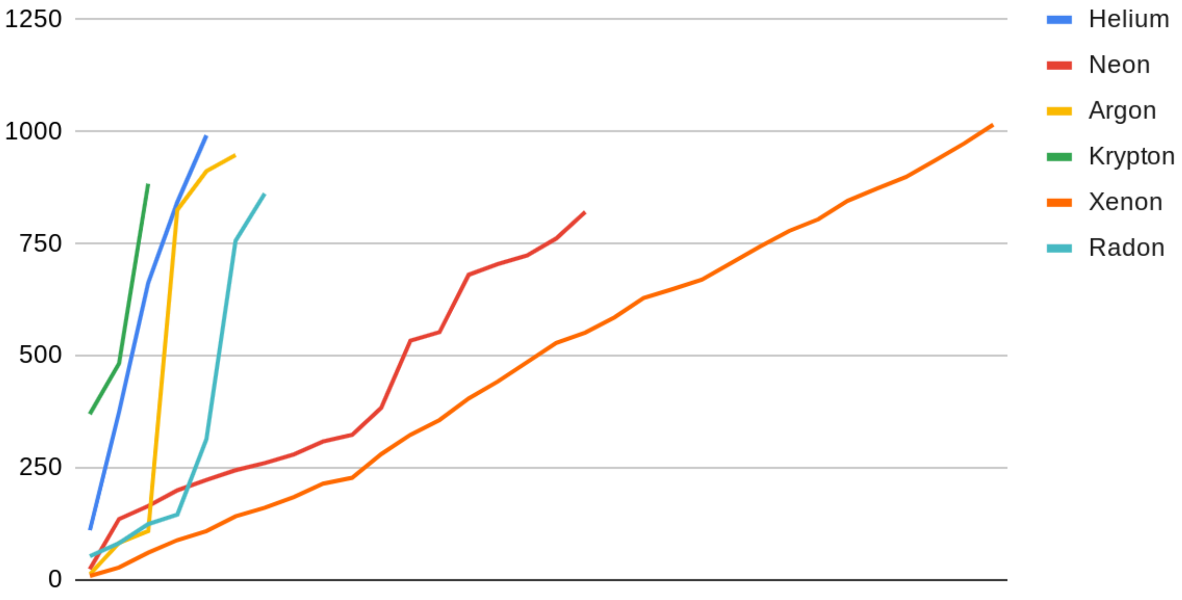


Figure 7: Frequencies of Prominent Spectral Lines in Group Eighteen Elements



Conclusion

The primary reason for this research was to investigate whether original research my mentor conducted prior showed harmonic nature in the amplitude by frequency spectral lines graph. Since no harmonic relations were found between the spectral lines of the atom tones, my hypotheses were unsupported as there is no clear pattern established in a group of atoms to determine whether it was the amount of electron shells nor the amount of valence electrons in the outermost shell. However, on the auditory side of this experiment, iit was concluded that the amount of peak frequencies in the amplitude by frequency graph transposed from a raw data sound determined whether or not the atom had a pleasant sound in the amplitude by time graph. Future research should seek to look at harmonic relationships between molecules composed of various atom tones. However, with this new idea there must be new methods different from the sonication methods used to create the raw data sounds in order to accurately and nicely transpose the data points into the audible domain.

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