Do the Elements Sign their Name in the Spectral Lines?

by Tzimon Barto

I am a concert pianist and writer. A decade ago I began a work of fiction that would make answer to the novel, *The Glass Bead Game*. In this last book by Hermann Hesse, a group of intellectuals who run a boarding school for boys cultivates a game that is an abstract synthesis of arts and sciences, requiring years of study in the disciplines of music, mathematics, and cultural history. Although the game itself is the chief protagonist of the novel, it is never described in detail, and no examples of it are given. I resolved to invent the substance and procedure of the imaginary game myself. In doing so, I believed I could discover previously unknown relations among phenomena of the physical world, music theory, and linguistics.

I first became interested in spectrography as one part of the game after I established convincing analogies that involved the additive and subtractive mixtures of six colored beams of light, the first six intervals of the musical overtone series, and the twelve English vowels. I decided to use the same analogical approach with music theory as a system of measurement in investigating the behavior of spectral lines as emitted by ninety-six of the ninety-eight naturally-occurring elements*. The numbers of music theory are more flexible than those of pure math: one has recourse, for example, to four different types of “3” (major, minor, augmented, diminished), all of which still retain “3’s” value. Johannes Kepler, taking advantage of music theory’s flexibility, ultimately demonstrated that the planets orbit the sun in an elliptical, and not a rigidly circular, fashion. Ever since Isaac Newton, scientists have looked for a pattern behind the spectral lines, but, because they did not have the technology necessary for a thorough overview until relatively recently, were unable to find one.

When I first studied the printouts available online of several elements’ spectral emissions, I was struck by how obviously the lines formed myriad intervals among themselves, not unlike the intervals in music theory. By using a musical “measuring rod,” might I find some new, previously unknown pattern – even teleology – behind the mysterious rune-like lines?

I set out by reviewing the spectral data of the simplest elements, hydrogen through oxygen. Consistent with my earlier research, I restricted myself to studying only those colored lines visible to the human eye – from magenta-red, with the longest wavelengths, 714 nanometers, to blue-violet, with the shortest, 390 nanometers.

Of course, the proof of any theory depended on establishing which interval(s) of spectral lines were to be measured, and what paradigm, applied to the ninety-six elements, would enable me to assign one of eight musical intervals to each. After many attempts and misses, I adopted the procedure to be described now, one that led to the detection of a design operating behind the emissions of elements hydrogen to oxygen.

I showed these early findings to Dr. Anton Zeilinger at the University of Vienna. He encouraged me to enlarge the scope of my research to include all of the elements.

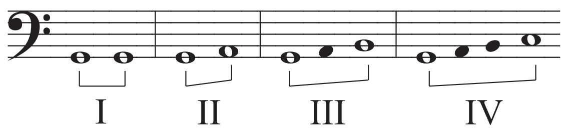
This paper documents the result of that more exhaustive investigation, and, I hope, might inspire others to explore music theory for discovering new patterns or even laws in natural phenomena.

I invite you to examine with me a new way of looking at spectral lines. It is first necessary, however, to learn or review a modicum of music theory, which now follows.

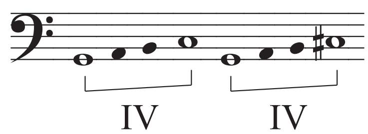
*Elements At (astatine) 85 and Fr (francium) 87 have no available intensity-tables.

The Musical Interval

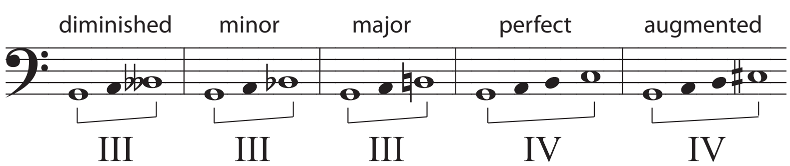
An interval is the distance between two musical notes, identified by the number of steps between them. Below are the intervals of the prime (also called tonic or unison), second, third, and fourth, as measured from a fundamental, fixed note, *g*.



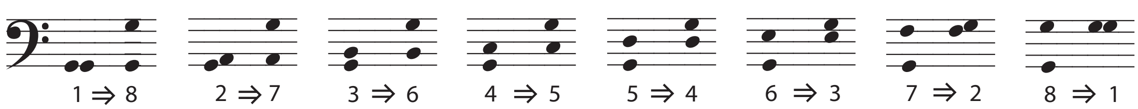
The interval from *g* up to *c* consists of four notes, so it is called a fourth. The alteration of one or both of an interval's two notes with a flat or sharp (which denotes, respectively, the lowering or raising of a note by a half-step) does not change the interval's name: *g* to *c* and *g* to *c-sharp* are both fourths.



The number of half-steps between an interval's two notes shows whether it is diminished, minor, major, perfect or augmented.



There are four basic groups of intervals: the prime (1), second (2), third (3), and fourth (4). The intervals of the fifth (5), sixth (6), seventh (7), and eighth (8) are not new ones, but inversions of the basic four, as shown below.



The intervals are grouped according to their numbers and inversions as in this table:

Principal interval	1	2	3	4
Inverted interval	8	7	6	5

If an interval exceeds the range of an octave, the above table continues as follows (every number plus 7):

8	9	10	11
15	14	13	12

15	16	17	18
22	21	20	19

22	23	24	25
29	28	27	26

. . . to 99.

All the tables are summarized as follows:

	I	II	III	IV
Principal interval	1	2	3	4
Inverted interval	8	7	6	5
	8	9	10	11
	15	14	13	12
	...			
	...	98	97	96

In this way, the following interval-groups are created:

I: 1, 8, 15, 22, 29, 36, 43, 50, 57, 64, 71, 78, 85, 92

II: 2, 7, 9, 14,16, 21, 23, 28, 30, 35, 37, 42, 44, 49, 51, 56, 58, 63, 65, 70, 72, 77, 79, 84, 86, 91, 93, 98

III: 3, 6, 10, 13, 17, 20, 24, 27, 31, 34, 38, 41, 45, 48, 52, 55, 59, 62, 66, 69, 73, 76, 80, 83, 87, 90, 94, 97

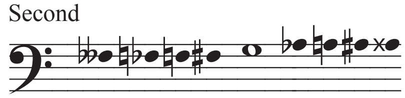
IV: 4, 5, 11, 12, 18, 19, 25, 26, 32, 33, 39, 40, 46, 47, 53, 54, 60, 61, 67, 68, 74, 75, 81, 82, 88, 89, 95, 96

The Range of an Interval

Below are shown all possible ranges of the four intervals using the fundamental *g* as the note from which the distance to the interval's second note is measured.

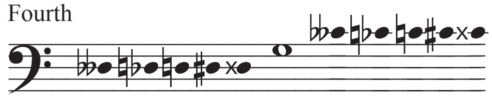
Prime

Second



Third

Fourth

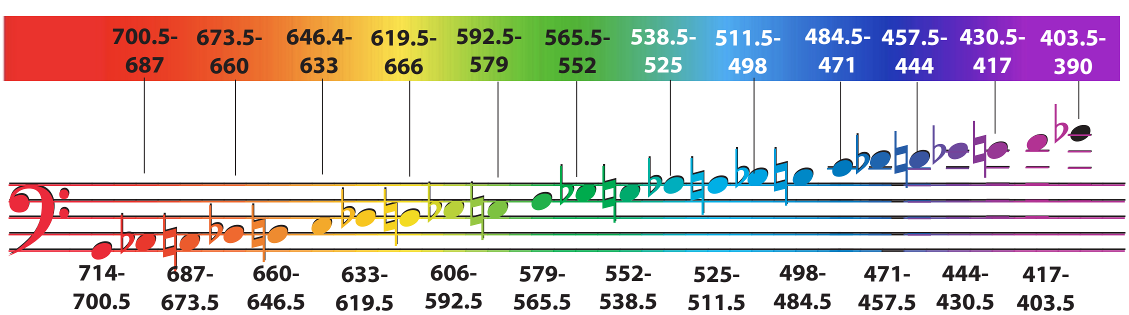


The Relation Between Musical Intervals and the Spectral Lines of the Elements

Each element in the periodic table has an atomic number equal to the number of protons in the nucleus of that element's atom. For example, **H (**hydrogen) has the number 1; **He** (helium) 2; **Li** (lithium) 3; **Be** (beryllium) 4; **B** (boron) 5; **C** (carbon) 6; **N** (nitrogen) 7; **O** (oxygen) 8; etc. The elements are assembled according to their atomic numbers in groups of eight, just like musical intervals.

The sharply distinct colored lines emitted by the elements in a gaseous state within that portion of the electromagnetic spectrum visible to the human eye are called *spectral lines*. They are characterized by their wavelengths and intensities.

After we isolate the area of the spectrum between 714 nanometers (magenta) and 390 nanometers (blue-violet), then divide it into twenty-four equal segments, 13.5 nanometers each, we can establish a relationship between the twenty-four segments and the twenty-four steps of a two-octave chromatic scale (starting with *g*).



This fixed note, *g*, is comparable to the *0-1* of a ruler. Having established this, we can now determine a correlation between spectral lines and musical intervals by laying the two-octave chromatic scale of twenty-four steps over the area from 714 to 390 nanometers, then measuring upward from the bottommost note, *g*, to either that segment of nanometers where the spectral line is at its weakest, or where it is at its strongest.

Theorem 1:

The element's atomic number and the interval formed by the fixed note *(g)* with the note corresponding to the spectral line with the *least* total intensity belong to the same interval-group. For the area of least total intensity, I use the sum of all its element's energy-levels combined.

Examples:

The least total intensity (8) of hydrogen is in the area of 403.5-390 nanometers.

This area corresponds to the note, *g-flat2* (see below). The interval formed by the fixed *g* with *g-flat* is an augmented prime.

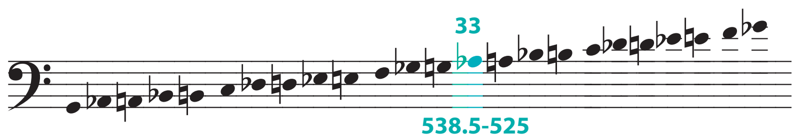
Hydrogen's interval formed by the fixed note with the area of least total intensity corresponds to the musical interval of the prime (1).

The emission spectrum of hydrogen looks like this:

Silicon’s atomic number, 14, belongs to interval-group II.

The least total intensity (33) of silicon is in the area of 538.5-525 nanometers.

This area corresponds to the note, *g-flat2* (see below). The interval formed by the fixed *g* with *a-flat* is a minor second.



Silicon’s interval formed by the fixed note with the area of least total intensity corresponds to the musical interval of the second (2).

Niobium’s atomic number, 41, belongs to interval-group III.

The least total intensity (116) of niobium is in the area of 660-646.5 nanometers.

This area corresponds to the note, *b* (see below). The interval formed by the fixed *g* with *b* is a major third.

Niobium’s interval formed by the fixed note with the area of least total intensity corresponds to the musical interval of the third (3).

Theorem 2:

The element's atomic number and the interval formed by the fixed note *(g)* with the note corresponding to the spectral line with the *greatest* spectral intensity belong to the same interval-group. For the area of greatest intensity, I use the sum of all its element's energy-levels combined.

Examples:

Lithium's atomic number, 3, belongs to interval-group III.

The greatest total intensity (8) of lithium is in the area of 673.5-660 nanometers.

This area corresponds to the note, *b-flat* (see below). The interval formed by the fixed *g* with *b-flat* is a minor third.

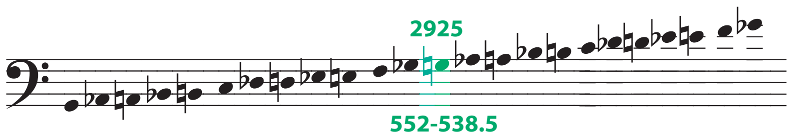
Lithium's interval formed by the fixed note with the area of greatest total intensity corresponds to the musical interval of the third (3).

The emission spectra of lithium looks like this:

Phosphorus’s atomic number, 15, belongs to interval-group I.

The greatest total intensity (2925) of phosphorus, is in the area of 552-538.5 nanometers.

This area corresponds to the note, *g2* (see below). The interval formed by the fixed *g* with *g* is a prime.



Lithium’s interval formed by the fixed note with the area of greatest total intensity corresponds to the musical interval of the third (3).

Germanium’s atomic number, 32, belongs to interval-group IV.

The greatest total intensity of germanium is in the area of 484.5-471 nanometers.

This area corresponds to the note, *c2* (see below). The interval formed by the fixed *g* with *c2* is a perfect fourth.

Germanium’s interval formed by the fixed note with the area of greatest total intensity corresponds to the musical interval of the fourth (4).

Avoiding Redundancy

Remember that the fixed note *g* is synonymous with the *0-1* of a ruler or the area of the musical prime.

In several cases where an element belongs to interval-group III or IV, but its least or greatest total intensity is first discovered in the area of the prime, one must proceed to the area of the next least or next greatest intensity until that of the third or fourth group is confirmed. If one did not leave the area of the prime in measuring either the third or fourth, the process would be redundant, since one would be needlessly repeating the measuring system's base (the ruler's *0-1*), already established by the fixed *g*. Interval-groups III and IV require more distance from the *g* or the prime, while interval-groups I and II do not.

An example of the above involves the second theorem, which deals with the area of greatest total intensity: The element rhodium, whose atomic number is 45, belongs to interval-group III, according to the paradigm laid out in Table 7 above. The area of its greatest total intensity is that of a *g-flat2*, forming an augmented prime with the fixed *g*. Since the area of a prime may not be repeated in a measurement involving those intervals whose characteristics depend on a significant distance from the prime, we find that the next area of greatest total intensity is that of an *e-sharp2*, a diminished major third, and belongs to interval-group III.

This rule for avoiding redundancy is not required for elements belonging to interval-groups I and II, since their definition depends on the area of the prime.

As my research shows, almost all the naturally-occurring elements*, by means of their atomic numbers as well as of the areas of both the greatest and least total intensity of their emissions, "sign their name" after the pattern of the four principal musical intervals.

Sources: NIST Atomic Spectra Database and NIST Standard Reference Database

This study is based primarily on the intensities of each element's spectral lines as gathered from all energy levels combined. For this reason, while hydrogen and the illustration of its spectral lines have but one energy level, lithium has two, and therefore, its illustration combines the intensities of both levels.

* Specifically, 89 elements out of 96 according to Theorem 1; 90 elements out of 96 according to Theorem 2 (recall that there are no intensity-tables for numbers 85 and 97.)