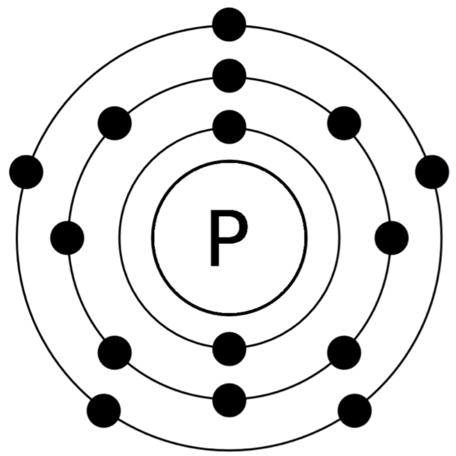
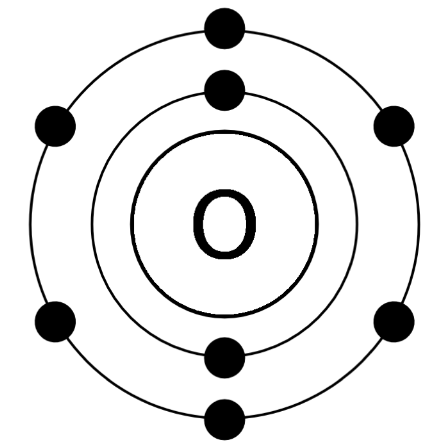
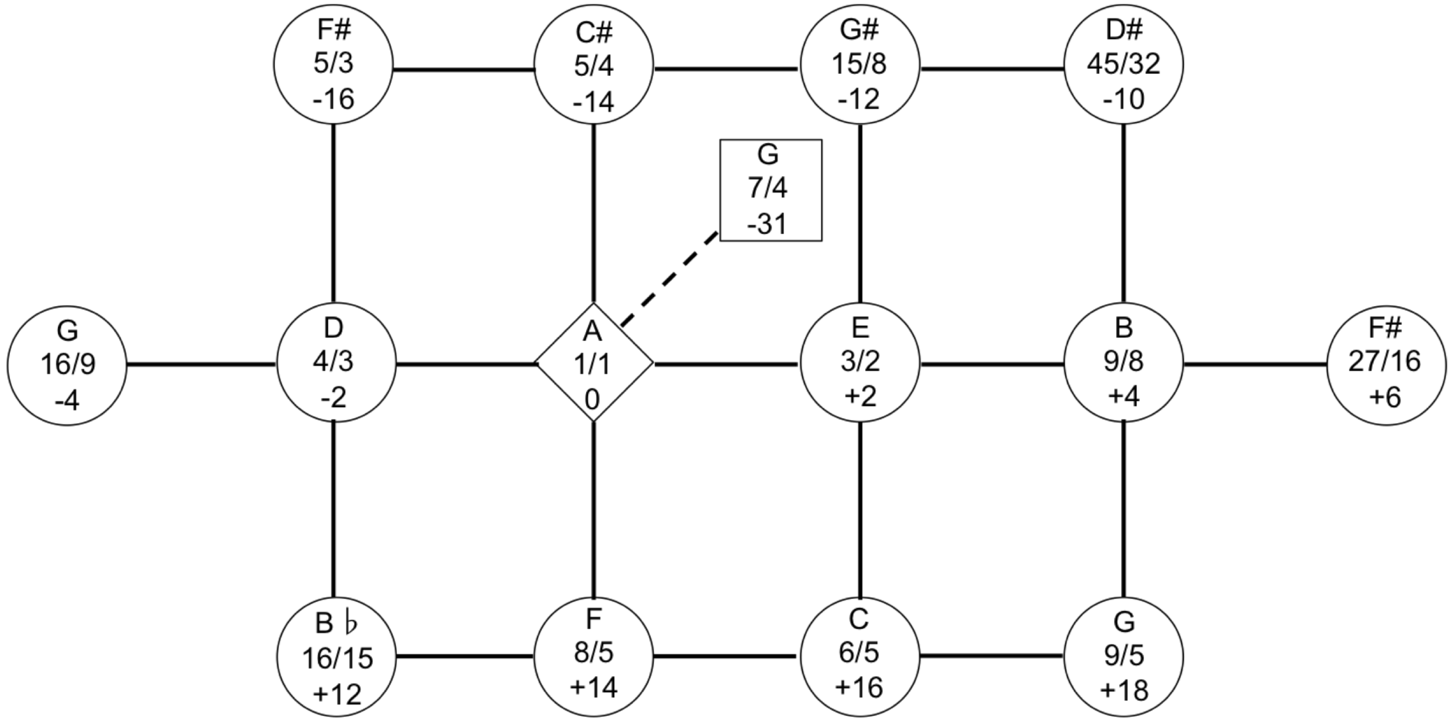
P O

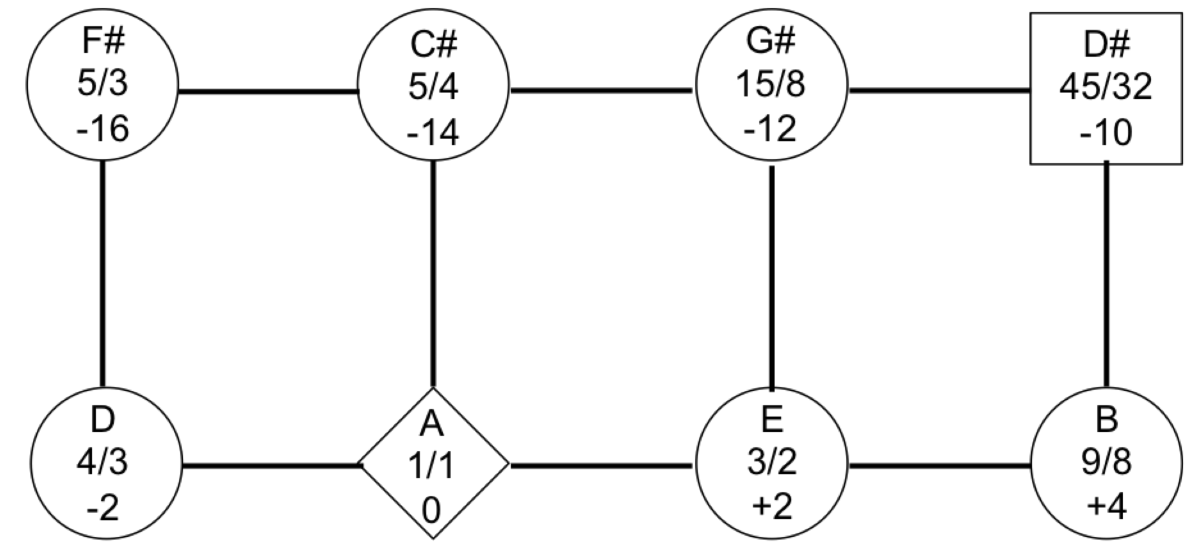
For nine or more performers

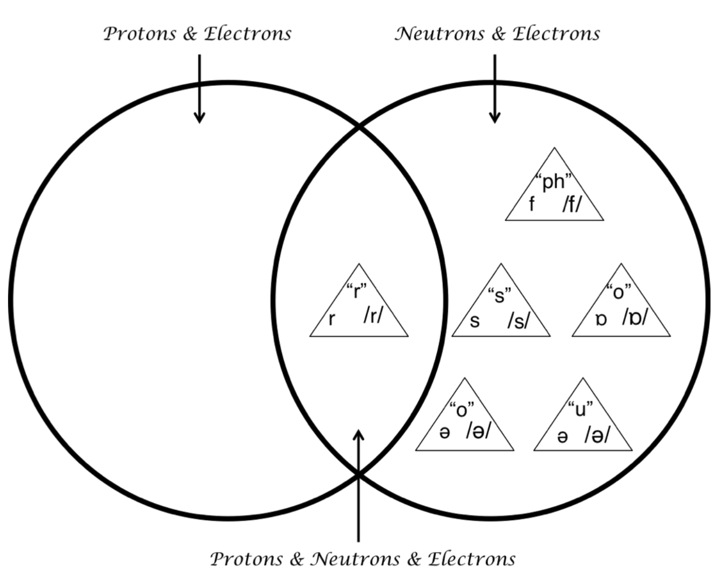
~Dedicated to Pauline Oliveros~

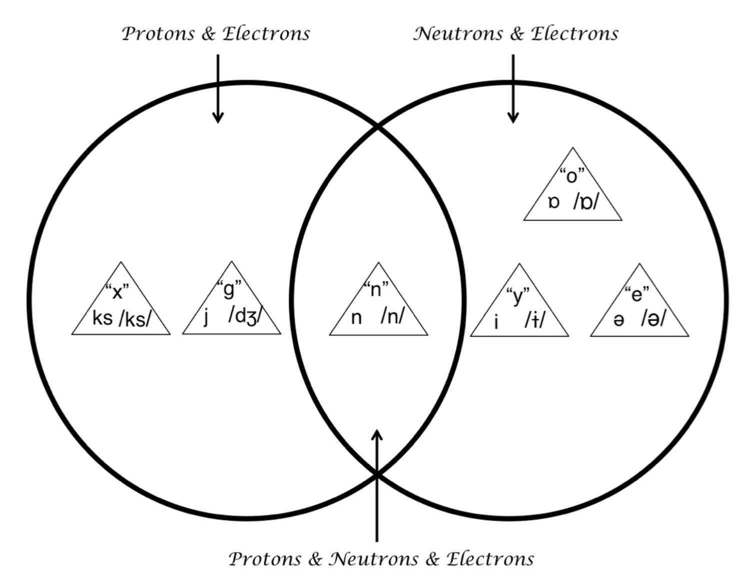












Overview

The front page of this score provides harmonic, rhythmic, and phonemic information derived from the chemical elements phosphorous (P) and oxygen (O). This information is intended to be interpreted musically by a group of nine or more performers such that their patterns of musical interaction are roughly analogous to the interaction of protons, neutrons, and electrons within each element as described in atomic theory.

Rhythmic resources

The score includes two-dimensional representations of the electron shell diagrams associated with phosphorous and oxygen. These diagrams represent the rhythmic content of the piece.

Harmonic resources

The tuning systems associated with phosphorus and oxygen are presented as tone lattices (or tonnetz) in which the number of pitches equals the element's atomic number: fifteen pitches for phosphorus and eight pitches for oxygen. Both lattices were constructed using an algorithm in which pitch ratios were added one at a time to a set of connected pitch points in harmonic space under the condition that each new point must have the smallest possible sum of harmonic distances to all points already in the set. Thus the tuning system for oxygen (the lattice on the right side of the page) is a subset of the tuning system for phosphorus (on the left).

Both lattices assume octave equivalency. The number of dimensions or planes in each lattice depends on the number of prime numbers involved in each tuning. Oxygen has a 5-limit tuning system, so only two planes: fifths along the horizontal axis and thirds along the vertical axis. The lattice associated with phosphorous branches into a new plane, introducing the interval of 7/4 (a just major seventh), which is connected to 1/1 by means of a dotted diagonal line.

Each node is enclosed by one of three shapes: a square, diamond, or circle. The diamond is reserved for the central reference pitch 1/1 in each lattice. The newest pitch in each matrix is enclosed by a square, while all other pitches are enclosed by a circle.

At each node in the tone lattices, the pitch-class values are written in three ways:

1) *the closest 12-TET approximation to each ratio is shown on top*
2) *the numerical just pitch-class ratio is in the centre*
3) *the number of cents deviation of the just ratio from its 12TET approximation (indicated in + or – cents) is listed on the bottom*

For example, in the tone lattice for phosphorus, the node of the pitch lattice that is enclosed in a square gives the values G, 7/4, and -31. This means that if the piece is performed in just intonation, the just pitch ratio associated with that point is represented numerically by the ratio 7/4 in relation to the central reference pitch 1/1. When 1/1 is set to the pitch referred to as 'A' in Western musical notation, the corresponding justly-tuned pitch class (written in relation to 12-TET) is G – 31 cents. If justly tuned instruments are not a viable option (which likely will be true for most performances of this work), performers can use the closest equal tempered pitch class, which in this case is G natural, which is listed at the top of the node.

Depending on the instrumental and/or vocal resources available, groups of musicians that include pitched instruments should agree on <u>either</u> a just tuning system or its 12-TET approximation, with everyone tuning to one another accordingly prior to performance.

Overview (continued)

Vocal resources

The score includes two diagrams that summarize the phonemes in the English words for elements fifteen and eight in the periodic table: phosphorous and oxygen. These phonemes constitute the vocal sounds that are available in each piece if the performing ensemble includes vocalists.

The vocal sounds are arranged into Venn diagrams, each with two intersecting sets that include stopped sounds (e.g. plosives or stops) in set A (the left circle) and continuants (e.g. nasal continuants, fricatives, and vowel sounds) in set B (the right circle), while nasal sounds (such as "n" and "m") and approximants (such as "l," "w," "r") that can be variously stopped or continuant are listed in the union of A and B ("A u B"). Phonemes in set A are available to proton and electron performers. Phonemes in set B are available to neutron and electron performers. Phonemes in set A u B are available to proton, neutron, and electron performers.

In each diagram, the constituent phonemes are written in three ways within a triangle:

1) *as they are normally written in the English word for each element (top of each triangle)*
2) *using the English phonetic respelling (bottom left)*
3) *using the corresponding alphabetic representation from the International Phonetic Alphabet (bottom right)*

Although the score provides phonetic representations for the standard North American English pronunciation of each element, performers who speak—and sing—in a different dialect of English can use the constituent phonemes in each element name as it occurs in their own pronunciation. Similarly, non-English vocalists and multi-lingual performers can use the constituent phonemes in the word for each element in their native language if they so desire.

Performance Instructions

This piece is in two movements: the first explores phosphorus as represented by the three diagrams printed on the left side of the front page of the score. The second movement explores a musical representation of oxygen as indicated by the diagrams on the right side of the page.

Prior to performance, musicians ought to be divided into three subgroups that correspond musically to the atomic functions of protons, neutrons, and electrons. In an ensemble of nine performers, the musicians should be divided evenly between the three groups. In ensembles with more than nine performers, additional performers can be assigned to the role of neutron, thereby creating musical isotopes of the elements being performed.

In general, performers playing non-pitched instruments (e.g. non-pitched percussion) are best suited to the roles of neutrons and electrons. Performers of pitched instruments (including voice) can be assigned to any of the three roles.

Performance Instructions *(continued)*

Neutrons

The piece begins with the neutron performers who produce sustained sounds, establishing a ground for the musical figures generated by the interaction of protons and electrons.

Neutron performers playing pitched instruments begin by sustaining the pitch enclosed by the square (7/4 or its 12-TET approximation of G natural) in the tuning system for phosphorus (the tone lattice on the left side of the page). After holding the starting pitch for some time, performers can move to contiguous pitches within the tonnetz: pitches that are connected to the starting pitch by dashed or solid lines. Neutron performers continue to move among connected pitches throughout the tone lattice, creating a shifting harmonic mass. Movements between contiguous pitches should be improvised during performance. In some instances, there are multiple paths available to the performers. It is preferable for neutron performers to move to new pitches at different times, though every effort should be made to remain relatively close to one another within the lattice (ideally within three or four contiguous pitches of one another in any direction). At times, performers will have to move through 1/1 in order to access all of the available pitches in the lattice (after leaving the starting pitch for example). But performers should pass through 1/1 relatively quickly unless they want to initiate the transition from phosphorus to oxygen or end the piece (see "Atomic Decay" and "Transmutation" below).

Neutron performers playing non-pitched instruments, such as percussion, play sustained sound washes: cymbal and gong rolls, bowed cymbals, brush sounds, rubs, scrapes, rattles, and other frictional sounds that can be sustained as long as the performative gestures that produce them are carried out. Neutron performers in this category may change the nature of their sustained sounds when musically appropriate, although the duration of the sound masses they create should be relatively long compared to the sounds of their proton and electron counterparts.

Vocalists in the neutron role should sound one continuant phoneme at a time. These are listed in set B (on the right), and A u B, in the Venn vocal diagrams provided. It is preferable for vocalists to sustain the phonemes using pitches indicated in the tuning system, particularly when using vowel sounds.

Decisions concerning timbre, rhythm, and dynamics are left to the discretion of the neutron performers, although the durations of the neutron sound masses they create should be relatively long compared to the sounds of their proton and electron counterparts. Close attention should be paid at all times to the interaction of all the parts and the totality of the group sound.

Protons

Proton performers enter some time after the neutrons have established the musical ground for the piece. Like their neutron counterparts, proton performers begin by sounding the pitch enclosed by a square in the lattice diagram associated with phosphorus and then move to contiguous pitches, endeavouring to remain close to one another within the lattice. Unlike neutrons, protons play notes of relatively short duration, moving quickly among contiguous pitches within the lattice, creating melodic fragments out of the pitch materials available in the given tuning system. The resulting melodic figures can be repeated and/or developed at the proton performers' discretion.

Proton performers should not all play simultaneously, but should instead listen to one another and to the entire group, finding musically appropriate places to enter into the music. Proton performers can imitate—and expand on—the melodic fragments being articulated by their proton co-performers. This is a good way of ensuring that the performers remain close to one another within the harmonic matrix. Decisions concerning timbre, rhythm, and dynamics are left to the discretion of the performers, though close attention should be paid at all times to the interaction of all the parts and the totality of the group sound.

Together, protons and neutrons comprise the musical nucleus of each piece. Proton and neutron performers have opportunities to solo when an electron makes a quantum leap as described below.

Performance Instructions *(continued)*

Electrons

Prior to performance, electron performers should determine which shell of the phosphorus electron diagram they are going to occupy at the outset. There should only be one electron performer per electron shell at the beginning of the piece.

Once the neutrons and protons have established the musical nucleus of the piece, the electrons stagger their entries beginning with the electron shell closest to the nucleus and expanding outward. Electrons orbit the musical nucleus, articulating time cycles by responding to selected pitches and/or sounds being generated by protons and neutrons. "Responding to" in this context means matching or complementing a particular pitch or sound emanating from the nucleus to the best of the electron performer's ability.

The number of electrons ("n") in the electron shells determines the number of repetitions of each pitch/sound per cycle. In phosphorus, the electron performer articulating the shell closest to the nucleus would repeat a given pitch or sound two times or multiples thereof. The performer in the next shell would repeat their sound eight times, and the performer in the outermost shell would repeat his or her pitch five times. After repeating a sound "n" times (or multiples thereof), electron performers can choose a different pitch or sound emanating from the nucleus, again repeating it "n" times or a multiple thereof.

Initially, it is preferable for electron performers to vary the tempo of their repeated sound events and/or the placement of repeated sounds within the cycle creating a sense of aperiodicity (this might be thought of as the musical equivalent of the Heisenberg Uncertainty Principle). However, at some point during the performance, all of the electron performers should strive to articulate their given number of pulses as evenly as possible and synchronize their time cycles with one another, a process referred to as "quantization" in this context.

Electron quantization

Electron quantization is accomplished during the course of musical performance through improvised musical interaction. The electron performer in the electron shell closest to the nucleus of the phosphorus atom spreads out his or her time/sound points within the time cycle such that they are maximally even for multiple repetitions of that cycle. In so doing, the performer in the first electron shell sets the tempo for the remainder of the movement. Electron performers in other shells follow suit, beginning with the second electron shell and moving to the outermost shell, articulating maximally even time cycles that lock in with those of their co-performers. In phosphorus, the three electron shells contain 2, 8, and 5 electrons, which will result in a polyrhythm when interpreted musically. The duration of individual electron time/sound points do not need to be standardized between shells as long as their entry points are maximally even and rhythmically consistent within each shell and all of the electron time cycles interlock with one another once they are quantized. Electron performers can occupy only one electron shell at a time. Movement between shells can take place by making musical "quantum leaps."

__Performance Instructions__ *(continued)*

Electron quantum leaps

Once all of the phosphorus electrons have become quantized, electron performers may make "quantum leaps" between adjacent electron shells by gaining or losing musical energy. Electrons gain energy by increasing the volume of the sound they are repeating. Once an electron performer has reached his or her maximum volume level (relative to the rest of the ensemble), s/he may leap to the closest electron shell *__away__* *from the nucleus, adjusting as quickly as possible to the quantized time cycle being articulated in the new shell by doubling or otherwise reinforcing the sound/time points already sounding within that shell. Conversely, quantized electrons lose musical energy by decreasing the volume level of the sound/pitch they are repeating. When their volume level has faded to silence, they may make a quantum leap to the next closest electron shell* *__towards__* *the nucleus and begin to play again, doubling the time/sound points being articulated in the new shell. When an electron performer leaves a particular shell, that shell remains empty (i.e. silent) until another electron performer makes a quantum leap to that shell.*

In an atom, electromagnetic radiation in the form of photons (i.e. light) is absorbed when electrons make quantum leaps away from the nucleus. Conversely, light is released when electrons make quantum leaps towards the nucleus. In this piece, when an electron gains musical energy and makes a quantum leap to the closest electron shell away from the nucleus, one proton or neutron performer should stop playing and listen to the ensemble, absorbing musical energy from their co-performers. That performer is to remain silent until the next quantum leap by an electron performer or until it feels musically appropriate to re-enter, sounding pitches from the tone lattice once again.

When an electron loses energy by fading to silence and then makes a quantum leap to an electron shell closer to the nucleus, a proton or neutron performer may play an improvised solo, striving to create musical energy/light within the piece. The solo continues until the next electron quantum leap or until the performer feels as though it is musically appropriate to stop soloing. In the event that more than one proton or neutron performer begins to solo at the same time, the performers should solo together, interacting with one another musically until another electron performer makes a quantum leap. The number and order of electron quantum leaps (and the resulting proton and neutron solos/silences) can be determined in advance or improvised during the course of musical performance. Electrons can make more than one quantum leap during a performance, moving variously towards or away from the nucleus.

One way of ensuring that everyone in the ensemble notices that a quantum leap is about to be made is for electron performers to stand (if possible) while they increase or decrease their volume level (if, that is, their instrument allows them to stand). The electron performer remains standing until one of his or her proton or neutron co-performers notices and either drops out or begins to solo depending on whether the electron performer making the quantum leap is getting louder (i.e. moving away from the nucleus) or quieter (i.e. moving towards the nucleus). A proton or neutron performer may wish to stand also in order to signal that s/he is responding to the electron performer making the quantum leap. When a proton or neutron performer has responded with the appropriate musical action (i.e. silence or solo), the electron performer should sit down and move to a new electron shell by doubling the time/sound points therein. If performers are unable to stand (or are already standing because of the nature of their instrument), they may use an alternative set of visual cues that are agreed upon prior to musical performance (the raising of hands, for example).

Valence electrons and ionization

Electrons in the outermost shell are valence electrons. After electron quantization, valence electrons have the option breaking free from their musical atom through the process of musical ionization. To do so, a valence electron should gain musical energy by increasing the volume of the time cycle s/he is articulating. Instead of a proton or neutron performer fading to silence in response (as normally would be the case in inner electron shells), the valence electron releases the built-up musical energy herself by playing an improvised solo. In so doing, the valence electron becomes a free electron, free to perform as s/he sees fit for the remainder of the performance, effectively leaving the outermost electron shell empty until another electron performer makes a quantum leap. There can be more than one valence electron in a given performance: electron performers from the inner shells who make a quantum leap (or a series of leaps) to the outermost electron shell also become valence electrons. As such, they too have the option of becoming free electrons.

__Performance Instructions__ (continued)

Atomic decay

When a performer—or group of performers—decide that they would like to end the first movement of the piece, they should make their way to 1/1 (or 'A'), sustaining that pitch until the end of the movement. Performers of non-pitched instruments have the option of sustaining a continuous sound mass and/or fading to silence. After all of the proton and neutron performers have made their way to 1/1, electrons should follow suit until everyone in the ensemble is sustaining a pitch/sound-mass centred on 1/1. At this point, the ensemble transitions from the first movement (phosphorus) to the second movement (oxygen) without pause.

Transmutation from phosphorus to oxygen

Once all of the proton, neutron, and electron performers (or at least those playing pitched instruments) are sounding the central reference pitch of 1/1 (or A), the group transitions to the second movement—the performance of oxygen as represented by the diagrams on the right side of the front page of this score. Performers repeat the entire process described above with two main differences: instead of beginning on the outermost pitch (enclosed by the square) and moving to 1/1 (enclosed by the diamond), the performers do the opposite: they begin on 1/1 (which they are still sounding from the end of the previous movement) and then move throughout the harmonic lattice associated with oxygen, eventually coming to rest on the node in the upper right hand corner of the lattice that is enclosed in a square. The other main difference stems from the fact that oxygen only has two electron shells whereas phosphorus has three, which means that the rhythmic interpretation of oxygen's electron shell diagram requires one fewer electron performer than in the first movement. Therefore, one performer who was an electron in the first movement should become a neutron in the second. The ensemble should agree ahead of time on which performer will change roles.

Otherwise, all of the performance instructions described above hold true: the neutron and proton performers articulate the musical nucleus of the piece by moving throughout the harmonic lattice associated with oxygen; the two electron performers orbit the musical nucleus, articulating time cycles that respond to selected pitches and/or sounds being generated by protons and neutrons; electrons begin by varying the timing of their entry points within their respective time cycles, but eventually become quantized, articulating maximally even time cycles of six and two sounded time points that interlock with one another (in Western notation, this would be notated as 6 eighth notes against two dotted quarter notes in a measure of 6/8 time); once quantized, electron performers can make quantum leaps between electron shells, prompting proton and/or neutron performers to solo (in the case of electron leaps towards the nucleus) or to become silent (when electrons make a quantum leap away from the nucleus). Valence electrons (electron performers in the outermost electron shell) have the option of breaking free of the musical atom by playing an improvised solo after building musical energy. They are then free to perform as they see fit for the remainder of the performance.

The piece ends after all performers sound the pitch 45/32 (D# if performing in 12-TET). The members of the ensemble can stop playing at once by means of a visual cue or performers can drop out one at a time.

Optional Variation: Spatialization

Depending on the nature of the performance space in which this piece is performed, ensembles have the option of arranging themselves spatially in such a way that they create a visual representation of the atomic shell diagrams associated with phosphorus and oxygen. For example, the members of the ensemble can arrange themselves with the three proton and three (or more) neutron performers forming an inward-facing circle in the centre of the performance area. Surrounding this central nucleus would be three concentric circles of chairs that represent the three electron shells in an atom of phosphorus. Each electron shell should include one electron performer and one reserved empty seat to allow electrons to make quantum leaps between shells. Electron performers can physically move from one shell to another during performance if their instruments allow. That being the case, musicians playing instruments that generally remain in a fixed position (e.g. piano, drum set, double bass, amplified instruments, etc.) are better suited to the proton or neutron roles, while musicians playing portable instruments (including voice) are better suited to that of electron.

Seeing as there is one fewer electron shell in oxygen, one of the electron performers from the first movement should relocate to the nucleus at the outset of the second movement. If a performance is spatialized and valence electron performers choose to ionize becoming free electrons, they have the option of moving throughout the performance space for the remainder of the performance (if their instrument allows).

Additional seats can be added to each electron shell for audience members, leaving enough room for electron performers to move comfortably between shells and being sure to reserve one seat for electron performers who make a quantum leap. The number of audience chairs per electron shell is variable depending on the mature of the performance space and the size of the audience. In addition to adding visual (and possibly musical) interest, a spatialized performance has the benefit of functioning as a musical score (or at least a representation of the score's rhythmic vocabulary) writ large. For example, the physical movement of electron performers between electron shells will clearly signal quantum leaps to rest of the ensemble and to the audience.

Alternatively, ensembles can set up in a typical proscenium fashion or in whatever configuration will work the best in a given performance situation.

Dedication

This piece is dedicated in loving memory to Pauline Oliveros (1932-2016) who was a mentor, musical collaborator, and a dear friend. The choice of phosphorous and oxygen for this composition was not arbitrary. In addition to the fact that the letter symbols for phosphorus (P) and oxygen (O) spell Pauline's initials, phosphorous emits light when it is exposed to oxygen. In combination, these elements are an apt metaphor for Pauline who brought so much light into this world through her music, her philosophy and practice of Deep Listening, and her remarkable generosity of spirit. Rest in peace PO.