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How a Table within Quantum Field Theory Results in Numerous Periodic Tables

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Abstract

This is a story of elements, electrons, protons, neutrons and quarks together with their cousins, molecules and the zoo of fundamental particles, as we plot a route through the complexity and diversity of the Universe following requests from several editors of journals to produce a review article as a result of publication of "Implications of the link between the Periodic Table and the Standard Model" in 2018.

Keywords: Periodic table • Isotopes • Spectral energy • Quantum number

Introduction

We begin with the creation of the Periodic Table in 1869 by Dimitri Mendeleev and others, modified and extended in the 1890's by the discovery of further elements the inert gases. By now, Arrhenius had proposed negatively and positively charged ions in chemical solutions. Enter the revelations in physics of the electron, proton, neutron, radioactivity and isotopes in the early 20th century followed by an initially hesitant start to a theory via quanta of energy, photons, photoelectric effect, wave particle duality, wave functions called quantum mechanics with its apparently uncanny principle Heisenberg's Uncertainty Principle, the quantum tunneling of George Gamow and Paul Dirac's prediction of anti-matter.

So far, rather than coherence, scientific disciplines were diverging in several what seemed unconnected directions since Mendeleev's time. Waldemar Haffkine's efforts in understanding, diagnosing viral infections and bacteria and then producing a vaccine to combat cholera and bubonic plague had developed in India with some considerable success despite controversy over implementation at the turn of the 20th century. The awareness was raised again in the 1918 pandemic as is currently the case with the 2020 pandemic with coronavirus.

Great efforts were made to understand nuclear processes in the early 1940's resulting in the nuclear bombs on Japan to end the war. Yet within the Periodic Table, despite its extension following discoveries of the Lanthanides, Actinides and the Transuranic elements by Seaborg and others so many it was felt they had to be added as a footnote the theory of the formation of nuclei of the elements within stars remained unclear. There were early attempts, in 1929 by Charles Janet, to reconfigure the Periodic Table using spectroscopy in an attempt to connect the table with nucleosynthesis but they were largely ignored as cosmology and observational astronomy using large telescopes was in its infancy and some ideas were inconsistent.

All that changed on May 2 1952, when Paul W Merrill reported he had observed the signature spectrum of element 43 in the Andromeda galaxy so elements not usually observed on Earth could be made in stars. This launched nucleosynthesis developed by Hoyle, Fowler, Margaret and Geoffrey Burbidge a few years later. More elementary particles were being discovered and quantum mechanics evolved to accommodate these and to predict more complex as yet undiscovered states of condensed matter using the ideas of fields similar to the electromagnetic fields of Maxwell in 1865.

Schwinger and Feynman, amongst others, helped the theory to mature to describe particles as excitations of fields that could interact subject to rules of symmetry, symmetry breaking, least action and equivalence with the development of the theory of quantum chromo dynamics. In the early 1960's, Gell-Mann proposed that the protons and neutrons could be subdivided into three quarks whose centers were observed experimentally a few years later. In 1964 Higgs proposed a particle/field by which particles acquired mass and in 1965 Penrose proposed the existence of Black Holes. These were observed in 1971 as was the Higgs Boson in 2012. Using the mathematics of S U (3) × S U (2) × U (1) symmetry, gauge theory and Clifford Algebra, a mathematical framework predicted three generations of quarks, three types of leptons with their corresponding non zero mass neutrinos involved in the weak interaction and radioactivity. All six quarks were subsequently discovered and identified prior to 2000 including the W and Z bosons. The standard model in its current form had been verified with the mechanism of the strong force, that of asymptotic freedom, describing how the quarks were held within protons and neutrons by Frank Wilczek, and others. The Standard Model the classification of elementary particles was established subject to extensions at higher energies and further analysis of stars, galaxies, quasars, neutron stars and their formation and interaction with black holes using the gravity wave detectors developed in 2015 not forgetting those tiny particles proposed in 1977 by theoretical physicists and named axions by Wilczek that may, just may, be the source of dark matter/energy.

Quantum Field Theory and Special Relativity were becoming more aligned but the singularities of General Relativity remained one of many unanswered questions. Others included the boundaries of thermodynamics, Maxwell's demons, entropy, self-assembly mechanisms, information theory, the role of electrons, neutrinos including their mixing, and magnetic fields in the complex interactions known as nucleosynthesis. In Quantum Field Theory itself, there were phenomena of entanglement, superposition, decoherence and a non-zero vacuum expectation value from which transient

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states could emerge and disappear at the Planck scales of position, time and energy where theory predicted non-classical outcomes. These were being increasingly observed as experiments gained in sensitivity. How could such divergence be integrated within theory, empirical evidence and a multidisciplinary scientific landscape?

In 2010, by accident, Roberts considered inverting the Periodic Table to accommodate spatial variation relative to the nucleus and to extend it into plasma, fusion and particle physics with negative values of n for when the electric field was repulsive compared with positive values of n when the field was attractive as in condensed matter. This resulted in a manuscript "Proposed link between the Periodic Table and the Standard Model," and a framework that became known as the Roberts Janet Nuclear Periodic Table published in 2017 (Table 1).

	Limits to quantum energy states of electrons							↑	↑
Period11		$221^{6h}242$	$243^{7g}260$	$261^{8f}274$	$275^{9d}284$	$285^{10p}290$	$291^{11s}292$	$2(6)^2$	
Period10			$171^{6g}188$	$189^{7f}202$	$203^{8d}212$	$213^{9p}218$	$219^{10s}220$		$2(5)^2$
Period 9			$121^{5g}138$	$139^{6f}152$	$153^{7d}162$	$163^{8p}168$	$169^{9s}170$	$2(5)^2$	
Period 8		electron states occupied by atoms outside stars		$89^{5f}102$	$103^{6d}112$	$113^{7p}118$	$119^{8s}120$		$2(4)^2$
Period 7				$57^{4f}70$	$71^{5d}80$	$81^{6p}86$	$87^{7s}88$	$2(4)^2$	
Period 6					$39^{4d}48$	$49^{5p}54$	$55^{6s}56$		$2(3)^2$
Period 5					$21^{3d}30$	$31^{4p}36$	$37^{5s}38$	$2(3)^2$	
Period 4						$13^{3p}18$	$19^{4s}20$		$2(2)^2$
Period 3						$5^{2p}10$	$11^{3s}12$	$2(2)^2$	
Period 2							$3^{2s}4$		$2(1)^2$
	∞ ←	51 - 72	33 - 50	19 - 32	9 - 18	3 - 8	1 - 2	Group	
Period 1							11s2	$2(1)^2$	
	Zero positive electric potential								$2(0)^2$
	Infinite negative electric potential							$2(0)^2$	
	Reservoir energy states occupied by protons in plasma prior to fusion						2		$2(-1)^2$
							2	$2(-1)^2$	
						6	2		$2(-2)^2$
						6	2	$2(-2)^2$	
					10	6	2		$2(-3)^2$
					10	6	2	$2(-3)^2$	
				14	10	6	2		$2(-4)^2$
				14	10	6	2	$2(-4)^2$	
			18	14	10	6	2		$2(-5)^2$
			18	14	10	6	2	$2(-5)^2$	

Table 1. The Roberts-Janet Nuclear Periodic Table: Strong force cloaks quarks forming nuclei after trigger of fusion by weak force

During the San Antonio conference of November 2017, it was suggested that the number of quantum states occupied by electrons could be represented by n(n+1)+n(n-1) as compared to the conventional 2n2 using the mathematical framework of quantum field theory. This had been suggested by De Broglie in the 1930's but then ignored. Oscillations of states for positive n resulted in a repeating pattern which also applied to the s state containing two quantum states. Because of the inversion, this placed Hydrogen and Helium in Groups 1 and 2. The subsequent announcement by NASA of the discovery of metallic hydrogen in Jupiter's core in early March 2018, lead to the publication of "Implications of the link between the Periodic Table and the Standard Model" on March 30 2018.

The one to one correspondence between this Quantum Mechanical Table and the Roberts Janet Nuclear Periodic Table is a starting point for the translation between Quantum Field Theory and interdisciplinary scientific discourse. This correspondence began in the upper half of both tables, when it was shown that, at the completion of the last state in each set of quantum states for the individual elements within condensed matter, there was a drop in first ionization energy a closing of each state ready for the next to be filled as proton number increased. This appears to be a local increase of entropy as the energies of states can fluctuate, with changing proton number, before giving rise to some states being filled before others, yet ionized before as well as outlined in "The assembly and classification of the elements using the Roberts Janet Nuclear Periodic Table" in 2020. It must be emphasized at this point that, although both tables are flat two dimensional surfaces, energy states are multidimensional, dynamic and variable whose energy spacing varies in different parts of the table in accordance with the appropriate state or phase relevant to the section of the tables Heisenberg's Uncertainty Principle at work with virtual particles and anti-particles popping in and out of the vacuum field as quantum confinement becomes more acute. Symmetry breaking between types of anti-particles and particles may emerge at this point within the nucleus. This follows scepticism at the San Diego conference of February 2018 whilst at the Potsdam conference later that year, it was asserted that the states n(n+1) indicated periodicity and the n(n-1) states compactness (Table 2).

$2n^2 = n(n+1) + n(n-1)$ table								
						N(n+1)	**N(n-1)**	
22	18	14	10	6	2			
22	18	14	10	6	2	42	30	N=6
	18	14	10	6	2			
	18	14	10	6	2	30	20	N=5
		14	10	6	2			
		14	10	6	2	20	12	N=4
			10	6	2			
			10	6	2	12	6	N=3
				6	2			
				6	2	6	2	N=2
					2			
					2	2	0	N=1
					0			
					0	0	0	N=0
					2			
					2	0	2	N=-1
				6	2			
				6	2	2	6	N=-2
			10	6	2			
			10	6	2	6	12	N=-3
		14	10	6	2			
		14	10	6	2	12	20	N=-4
	18	14	10	6	2			
	18	14	10	6	2	20	30	N=-5
22	18	14	10	6	2			
22	18	14	10	6	2	30	42	N=-6

Table 2. Quantum mechanical table: The phrase "Strong force cloaks quarks forming larger nuclei after trigger of fusion by weak force"

A cursory glance at the Quantum Mechanical Table shows the two halves separated by two zeros. The zero under the n(n+1) column represents a cut off of no further quantum states for electrons in condensed matter though quantum tunneling can occur; whilst the second under n(n-1) indicates an infinite separation of protons or heavier nuclei from previous fusions prior to the next fusion event. The upper half of the table represents an increasing separation of states in the order of 10-8 to 10-6m, the elements in isolation within condensed matter, where the luxury of expansion culminates in first, second, and third etc ionization levels. The lower half of the table representing fusion, nucleosynthesis, particle physics and cosmology, however, has no such luxury: merely excited states within a much deeper potential well no escape as it were. The quantum states in this lower half, counter intuitively, become increasingly confined reminiscent and characteristic of the asymptotic freedom of the strong force, described earlier by Franck Wilzcek and others, as spatial distances reduce to 10-15m and beyond down in principle to the Planck scale and higher energies.

A more detailed comparison of the lower half of the two tables reveals that the Periodic n(n+1) states imply proton occupied states while n(n-1) Compactness states suggest neutron occupied states given that binding energy contributes 99 per cent of the mass with the inherent appearance of virtual particles from the non-zero vacuum energy and the watershed between fusion and fission. The numerical structure of these series indicates that the neutron series precedes that of the proton series by one term; a necessary prerequisite for fusion to convert Hydrogen to Helium and further heavier elements by electron capture, r, s, and p processes of nucleosynthesis. Identical and independent magic numbers of stability emerge from combinations of n(n-1) states for neutrons and n(n+1) states for protons the Nuclear Shell Model of Maria Goeppert Meyer and Eugene Weinger's magic numbers as presented in "The assembly and classification of the elements using the Roberts Janet Nuclear Periodic Table" in 2020. However, this appears merely to be the superficial result observed for high stability whilst beneath is the constantly occurring fluctuation of particle/anti-particle states from the vacuum energy a boiling cauldron of fluctuating states down to the Planck scale in which the neutron states created appear more numerous than the proton states as we head down the table.

The more the particles become confined, the freer they become, yet more ordered, creating a sea of short lived particles within the proton which appears to have a much higher abundance of anti-down quarks than anti up quarks the appearance, simultaneously, of symmetry breaking and anti-matter. At present, the sea of particles describing the neutron is unclear. In both neutrons and protons, tetra quarks and pentaquarks may appear as quantum confinement cascades to second and third generation quarks including states comprising two, three or more gluons known as glue balls or odderons. Doubtless many more discoveries are yet to be made as the Standard Model evolves. The magic numbers for both neutrons and protons appear to be local highs of order and entropy within an ocean of states configuring various nuclei. Increasing numbers of neutrons can induce instability and radioactivity, as clusters of alpha particles appear on the surface of neutron heavy nuclei ready to decay at any moment, spontaneous decay of neutrons or merely emission of gamma rays from excited states: each channel with its own probability and half-life.

This description continues down the Roberts Janet Table incorporating

phenomena such as super novae explosions and white dwarf creation. For those white dwarfs that exceed the Chandrasekhar limit, further confinement occurs with the formation of neutron stars with the protons and neutrons preserving their identity. For larger explosions, black holes, from which no electromagnetic radiation can escape, appear at the centre of remnants; at orders of magnitude many times bigger, quasars result as matter is sucked into super massive black holes. The table is now approaching the interface between quantum field theory and general relativity; does radioactivity now become suspended as the confinement proceeds? Can information escape from such a configuration once it has formed by increased entropy in whatever form?

"What does this have to do with chemistry?" I hear you ask.

"Patience is required in this interdisciplinary landscape as chemistry shortly returns with a vengeance accompanied by biology. Let us continue."

The event horizon of a black hole would appear to represent a boundary condition for the compression/confinement to trigger a phase change with wave functions becoming increasingly symmetric and allowing further ordering as confinement continues an interface between quantum field theory and relativity though the issue of time as part of the space geometric remains. Anyons, proposed in 1984 by Wilzcek and others, observed experimentally in 2016 would appear to play a role. Emitted Hawking radiation, connected to the black hole by quantum entanglement, allows the entanglement entropy to increase continuously until the black hole dies, according to relativity, but according to Page the entanglement entropy reaches a maximum then reduces to zero when the black hole dies and fermions reappear with antisymmetric wave functions particle physics and quantum field theory avoiding singularities. This latter change of entropy appears to be the case with current models. The butterfly effect can operate at the planetary scale of atoms but dissolves at the quantum scale in a set of infinities as the universe continually decoheres, healing it and preserving information entropy in all its forms, according to Los Alamos. The boundary/event horizon of black holes remains a source of debate in current models as is the mechanism of the interplay of fermions and bosons that maybe causes the entropy to increase and then decrease such is the nature of the current discussion between quantum field theory and general relativity. This represents the lower limit of the Roberts Janet Table.

The journey back to the upper echelons of the top half of the Roberts Janet table is both cataclysmic and rapid. Mergers of neutron stars with black holes or other neutron stars, as evidenced by gravitational wave detectors, dramatically reduce the free state of the quarks' asymptotic freedom. They become trapped as neutrons and protons as quantum confinement is reduced by several orders of magnitude. What emerges is relatively few protons surrounded by extremely large numbers of neutrons isotopes of low atomic number but almost infinite mass number. Radioactivity is now re-ignited and these isotopes decay rapidly by various channels producing in principle an extremely large atomic number, almost infinite, as entropy decreases rapidly and then fission splits these nuclei into smaller elements further to produce ultimately those elements of the Periodic Table. This implies that islands of stability of higher nuclei is a relative term within such potentially extremely short half-lives though further magic numbers are predicted at 184, 258 and 350 in "The assembly and classification of the elements using the Roberts Janet Nuclear Periodic Table." By successive supernovae events the recycling of the nuclei coupled with the distribution of debris from neutron star/black hole events may give rise to the observed distribution and range of isotopes observed within the Milky Way galaxy though this may be different for other galaxies in other regions within the Universe.

Having arrived at the upper end of the Roberts Janet table and the Quantum Mechanical table, the focus shifts to combinations of elements within molecules. If ever there was a time in science to emphasise the oscillating nature of energy states within condensed matter, this is it. With experimental ingenuity and technique ever improving, energy levels can be manipulated to create new materials; these include high temperature super conductors, properties of graphene and low temperature behaviour in high magnetic fields to name but a few in this field of materials science and engineering.

Then there is the role of topology in enabling molecules to fold and align in so many different ways with implications for self-assembly and entropy. This inevitably leads into disciplines which include organisms already familiar with quantum field theory or more particularly its applications those of bacteria, viruses and plants. One illustration is from the Proceedings of the National Academy of Sciences DOI 10.1073/pnas 2018240118 (2021).

Photosynthetic organisms harvest light from the Sun to produce the energy they need to survive using quantum mechanics and exploiting quantum effects.

In a microorganism, green sulphur bacteria, these bacteria need light to survive but even small amounts of oxygen can damage the delicate photosynthetic equipment so they must minimise the damage when the bacteria encounter oxygen. Movement of energy was tracked through a photosynthetic protein under different conditions with and without oxygen.

The experimenters found that the bacteria use a quantum mechanical effect vibronic mixing to move energy between two different pathways depending on whether or not oxygen is present. This mechanism involves vibrational and electronic characteristics in molecules coupling to one another. The vibrations mix so completely with the electronic states that their identities become inseparable (entanglement/superposition). The bacterium can then guide the energy where it needs to go.

If there is no oxygen around, the bacterium matches the energy difference between two electronic states in an assembly of molecules and proteins called the FMO complex, with the energy of a bacteriochlorophyll molecule. This encourages the energy to flow through the "normal" pathway towards the photosynthetic reaction centre packed full of chlorophyll. In the presence of oxygen, the organism has evolved to steer the energy through a less direct route where it can be quenched. (Equivalent to placing the palm of the hand on a vibrating guitar string to dissipate the energy) Some of the energy is lost but it protects the entire system.

To achieve this, a pair of cysteine residues in the photosynthetic complex acts as a trigger. They each react with the oxygen in the environment by losing a proton which disrupts the vibronic mixing. This means energy now preferentially moves through the alternative pathway where it can be safely quenched. This is similar to blocking two lanes on a superhighway and diverting some traffic to local roads where there are many more exits.

The protein can turn the vibronic coupling on and off in response to changes in the cell.

Jack Higgins Dept. of Chemistry Chicago, "The protein uses the quantum effect to protect the organism from oxygen damage. The simplicity of the mechanism suggests it might be found in other photosynthetic organisms across the evolutionary landscape. If more organisms are able to dynamically modulate quantum mechanical couplings in their molecules to produce larger changes in physiology, there could be a whole new set of effects selected by nature that we do not yet know about."

Another example is the discovery and harvesting of new deep sea microbes in the Pacific Ocean that human cells cannot register or recognize they exist. Published on March 12, 2021 in Science immunology, this study challenges the view that human cells can recognise any bacteria they interact with.

"These novel microbes are completely immune silent to human immune systems. The immune system of mammals has the ability to detect microbial bacteria from our home habitat not habitats that are foreign like the deep ocean. This suggests pattern recognition strategies may be defined locally not globally," said Randi Rotjan co-lead study author.

"The locality of quantum field theory oblivious of non-essential, irrelevant conditions elsewhere" which could become relevant if habitats

mix? This leads to questions concerning the boundaries for immune systems in general, including viral mutations and astrobiology.

Similar effects of nature that come to mind include; genetic diseases, cluster migraines, the nature of evolutionary sexuality across all living organisms and neural networks within the human brain which when stimulated by music longitudinal vibrations can induce pleasure and reduction of stress contributing to general well-being. This takes the focus in the direction of consciousness and psychology. There are also the neural networks developed in the soil and root systems of forests involving root hairs, fungi and essential chemical nutrients. There is a distinction between sibling saplings and non-sibling saplings of similar species receiving support from a mother tree in research based in the Canadian forests. A possibly related phenomenon is the periodic emergence of Cicada insects every 13 or 17 years along the American east coast illustrating the presence of some signal, as yet not clear, from root systems of trees to the hatching of these insects and their larvae, feeding off the ecosystem provided by the trees and their roots.

The sudden electrical surge at the point of fertilization of a human embryo and the attendant production of zinc and calcium leads back to nucleosynthesis being a pre-requisite for the evolution of life with the production of carbon essential for organic material present in plants and elsewhere.

This suggests that both the Quantum Mechanical table and the Roberts Janet Nuclear Periodic table when applied to molecules and organic compounds act as an entrance into the world of quantum biochemistry, neuroscience and drug delivery with its own pathways and causality now just beginning to be explored and discovered a veritable quantum land for Alice and Bob to explore and discover with many empirical and thought experiments.

The current direction of travel of scientific discourse thus appears to be one of subtle convergence, underwritten by quantum field theory, illustrated by the phase changes within the frameworks of both the Quantum Mechanical Table and the Roberts Janet Nuclear Periodic Table [1-3].

Conclusion

The result of this journey, through the processes within the Universe, is the following thought experiment. Suppose Lavoisier of the 1700's had been conducting his measurements on a planet in a galaxy several billion light years from Earth, he would have observed the same chemical elements as here on Earth but may have measured slightly different atomic weights as his sensitivity may, just may, have been, even at that time, sufficient to detect the subtle differences within the ratio of isotopes of the elements on that planet compared to Earth. Such differences arise from the consequence that the material from each supernova explosion, coupled with the debris of the local region in space created from mergers of neutron stars with black holes and/or previous supernova explosions in that region, is unique when compared with any other region of space.

The role of any Periodic Table is to classify and list the atomic weight of each element of condensed matter in a region defined by relevant boundary conditions as a tool for quantitative calculations and a predictor of chemical properties. The correspondence between the Quantum Mechanical Table and the Roberts Janet Nuclear Periodic Table implies not only a local variation of mass number for each relevant local region in space, but that mass number itself is not a fundamental phenomenon which is constantly changing in the nth decimal place as radioactivity proceeds in the evolution of the Universe. Numerous, an extravagantly large number, of Periodic Tables result. No wonder then, Mendeleev, at the inception of the Periodic Table, used chemical properties in some cases to over-ride atomic weight in his classification.

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