Title: Opposing Effects of *Decentration* and *Jingoism* on Understanding How Nuclear Properties Are Linked to Periodic Properties of All Atoms

Running title: "Equation Linking Nuclear Properties with Periodic Properties of All Atoms"

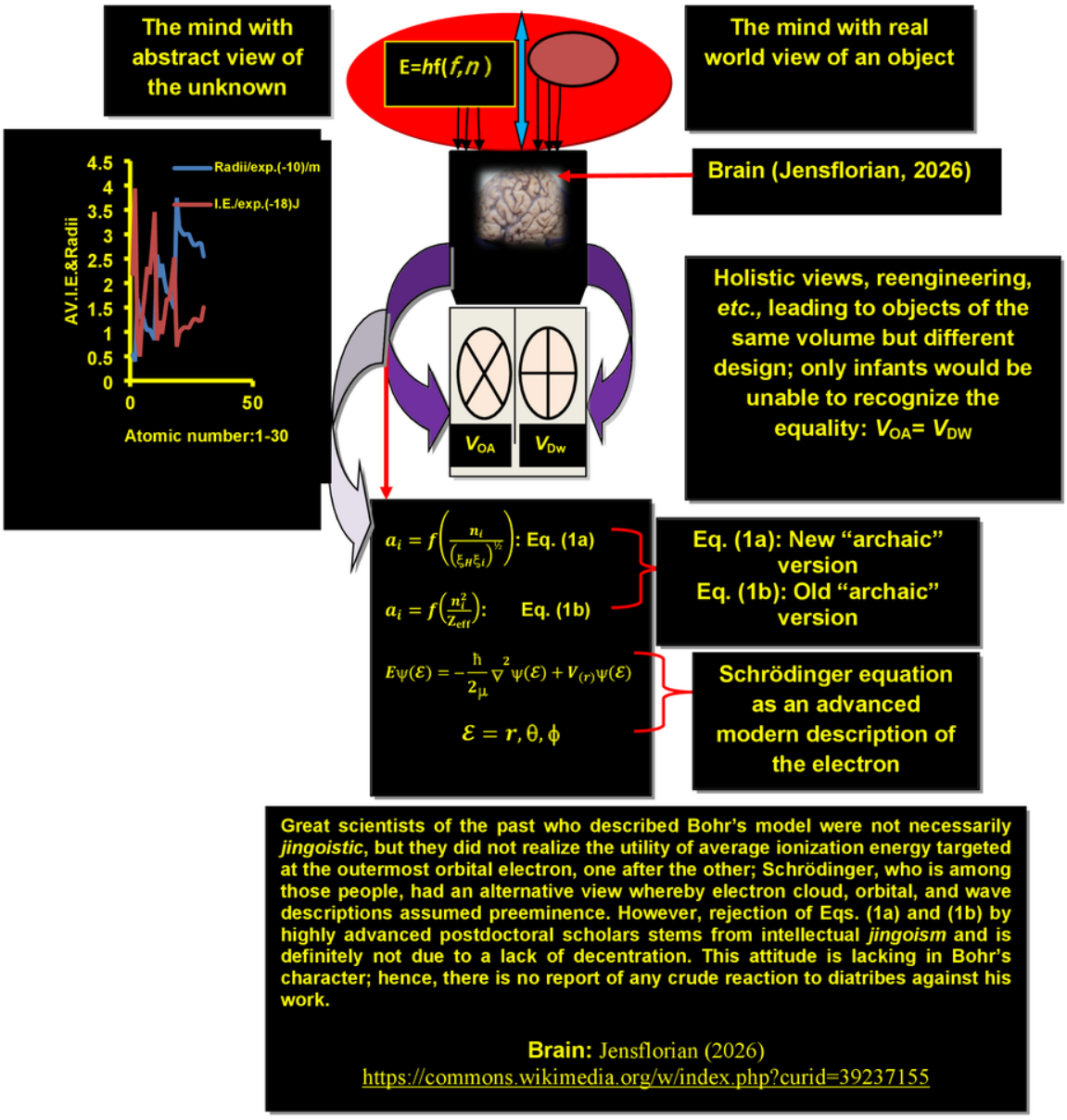
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Abstract

Atomic physics and nuclear matter physics were often studied separately until recently, when researchers linked hydrogenic properties to nuclear properties. What seemed a general presentation, such as $\xi_i n_i^2 / Z_{eff}^2$ (where ξ_i, n_i and Z_{eff} are the average ionization energy (IE) of any atom, hydrogenic and nonhydrogenic alike, and the principal quantum number, which is either equal to or greater than one, and effective nuclear charge, respectively), in the relational equation still pertains to the average ionization energy (ξ_H) of hydrogen. No equation relates nuclear properties to the IE of nonhydrogenic atoms. The barrier to the furtherance of Bohr's principle is due to mathematical *jingoism*, which nullifies the need for *decentration*. The goal of this study was to emphasize the need to be broad-minded in the search for knowledge by discovery coupled with an aura of intellectual *decentration*. The objectives included deriving an all-inclusive equation with a role for the mass radius of the proton to compute Bohr's radius of any atom and the effective nuclear charge (ENC for short) and conducting a reproducibility test; elucidating the importance of IE (or ENC) in medicine. The methods were theoretical and computational. The new equation generated atomic radii for all 30 elements of the periodic table. The percentage of the calculated ionization energy (IE) compared to the literature values ranged from 99.999957% to 100.003%. Since the computed values of ENC, IE, and radii were very similar to literature values despite the presence of the mass radius of the proton (Γ_P), it stands to reason, in conclusion, that the Γ_P explored in this study was consistently valid. IE (or ENC) has scientific and medical applications. Indeed, there should be no room for intellectual *jingoism* and disregard for intellectual *decentration* at a higher level. A future study should involve thirty other elements or fewer.

Keywords: Average ionization energy, Effective nuclear charge, Atomic radius of any atom, Mass radius of the proton, Intellectual *jingoism,* Intellectual *decentration*

Graphical abstract



Introduction

The history of the scientific discovery of Bohr's theory of the atom is replete with a lot of diatribe against it. According Kragh (2011) [1], it was common among British and American physicists, in particular, to deplore the lack of a clear physical picture in Bohr's theory, where "picture" meant a model that could be understood in terms of classical physics. Merle Tuve (A typical American) had been of the view that not only was it "quite irrational and absurd" from the viewpoint of classical physics, it also seemed to be methodologically flawed: Yes indeed. But the notion that the root mean square radius $\langle R_m \rangle$ given as $\langle R_m \rangle = 12^{\wedge}½/m_s$ [2] where m_s is the effective mass of a proton in GeV whose use requires multiplication by the charge of an electron ought not to be an exemption! "Various derived mathematical formalisms 'described' atomic states and transitions that lacked detailed processes; for instance, Kragh (2011) [1], in reference to Holton, was of the view that the descriptions that lacked details of the actual process of transition were features of all the formulations. "Many other critics, such as British William Hicks, John Nicholson, and William Peddie, held similar views [1]. To the top-notch physics at the professorial level, it may seem naïve for a secondary school student in highly advanced science nations to question why the volume of African palm wine he left in the open decreased in volume even though a much greater volume of pure water left in a similar circumstance decreased in volume. It seems the photoelectric effect predated the view held by Bohr that an electron can transit from a ground state energy level to a higher level, and if the photon absorbed is of sufficient energy (or better yet, frequency), it can be stripped off the metal atom. If postdocs have a sense of *decentration*, there is no way an electron can, on its own, know when to transition to a higher energy level while being inanimate. This paper addresses the need for everyone to understand that the quest for *decentration* is universal and that while it is common for infants to struggle with decentration, this is a natural occurrence; however, *decentration* is expected in adults. Unfortunately, it seems that, in attempting to maintain the status quo, highly advanced scholars have continued to use Slater's rules, atomic hardness (chemical hardness), *etc.*, without taking average IE as a platform for utilitarian assessment.

Research papers abound in the area of electron affinity and methods of measuring them, though most often as applicable to molecules [3-5]; the theory of Hard and Soft, Acid and Bases (HSAB) theory that initially described hardness and softness in terms of the experimental ionization potential and electron affinity of the reacting molecules has been in regular application in the screening of would-be toxins and detoxicants [6]. The concepts of electronegativity and chemical (or atomic) hardness are increasingly becoming regular in scientific and pharmaceutical research [7]. In all that research, there seemed not to be an understanding of the utilitarian value of effective nuclear charge, which determines the magnitude of all atomic properties, let alone the fact that there is a mathematically and computationally plausible means of relating nuclear properties to atomic properties until recently [8]; the fact that Slater's rule remains in vogue is suggestive of either a lack of awareness or outright rejection of alternative approaches, either due to a lack of decentration or due to intellectual *jingoism*.

Since average IE is a function of effective ENC, every other atomic property remains a function of the latter, an assertion that is to be established as the goal of this study. The enabling objectives include the derivation of an all-inclusive equation linking every atomic property, such as average IE and atomic radius of any atom other than hydrogenic atom, to the nuclear property, such as the mass radius of the proton; reaching a definitive conclusion that the mass radius of the

proton known in the literature [8, 9], which reproduces the ENC, Bohr's radius of any atom, and the corresponding average IE is a testament of the all-time validity of the former; restate the need for total absence of *intellectual jingoism* in favor of *decentration*; and ultimately elucidate the utilitarian value of ENC. By the end of the thesis, it would have been clear that, as opposed to *intellectual jingoism, decentration* is the key to discovering the relationship between nuclear properties and both hydrogenic and nonhydrogenic periodic properties.

Significance of the study

As in the past but with a broader inclusiveness, the nuclear property has now been linked not just to the periodic properties of hydrogen alone but to all elements. The fact that the average ionization energies of all 30 elements studied were reproduced when either Bohr's radii or the effective nuclear charges (ENCs) were substituted into relevant equations testified to the validity of the mass radius of the proton as a fundamental constant of ~ 1.102 fm. The study further reaffirms the need to pay greater attention to the utilitarian value of ENC *vis-à-vis* related periodic properties such as electronegativity, electron affinity, and chemical hardness, all of which are a function of the ENC, considering their scientific and paramedical applications. There is also an urgent need to establish a consistent experimental and theoretical approach that could yield consistent values of electron affinity in a way similar to IE.

Theory

In this section there are derivations that serve the basis for understanding how nuclear properties are linked to periodic properties of all atoms. It begins with what has been established in the literature [10] but seemed to be ignored.

$$a_i = \frac{e^2 n_i}{8\pi\varepsilon_0 \left(\xi_H \xi_i\right)^{½}} \tag{1}$$

Where e, n_i, ε_0, ξ_H, ξ_i, and a_i are respectively, the charge of an electron, any principal quantum number, permittivity in free space, average ionization energy of hydrogen atom, average ionization energy of any other atom, hydrogenic and nonhydrogenic alike, and Bohr's radius of any atom. *Bohr's radius for any atom* emphasizes the importance of tracing atomic size back to its original progenitor model, in contrast to 21st-century mathematicians who advocate a more mathematically complex approach.

Solving for ε_0 in Eq. (1) gives the following:

$$\varepsilon_0 = \frac{e^2 n_i}{8\pi a_i \left(\xi_H \xi_i\right)^{½}} \tag{2}$$

Meanwhile, the mass radius equation of a proton is given as follows [9]:

$$\Gamma_P = \frac{\alpha^2 e^2 m_P}{\pi\varepsilon_0 m_e^2 c^2} \tag{3}$$

Where α, m_P, m_e, and c are respectively, fine structure constant, mass of a proton, mass of an electron, and speed of an electron in a vacuum. Solving for ε_0 in Eq. (4) gives the following:

$$\varepsilon_0 = \frac{\alpha^2 e^2 m_P}{\pi m_e^2 c^2 \Gamma_P} \tag{4}$$

Pulling Eqs (2) and (4) together gives after solving for a_i the following:

$$a_i = \frac{m_e^2 c^2 \Gamma_P n_i}{8\alpha^2 m_P \xi_H^{1/2} \xi_i^{1/2}} \tag{5}$$

If the equation of fine structure constant given as $\alpha = e^2/2\,\varepsilon_0 c\,h$ is substituted into Eq. (5), one obtains the following:

$$a_i = \frac{m_e^2 \varepsilon_0^2 h^2 c^4 \Gamma_P n_i}{2e^4 m_P \xi_H^{1/2} \xi_i^{1/2}} \tag{6}$$

Equation (6) returns the permittivity in free space; besides, ε_0 is given as $\varepsilon_0 = 1/\mu_0 c^2$ such that substitution into Eq. (6) eliminates *c* in the following equation.

$$a_i = \frac{m_e^2 h^2 \Gamma_P n_i}{2e^4 \mu_0^2 m_P \xi_H^{1/2} \xi_i^{1/2}} \tag{7}$$

Equation (7) only offers a computational convenience because it contains fewer fundamental constants. It has been shown elsewhere [8] that the mass radius can be related to the average ionization energy of the hydrogen atom *via* the following equation.

$$\Gamma_P = \frac{m_P \mu_0^2 e^{10}}{32h^4 \varepsilon_0^3 \pi m_e \xi_H} \tag{8}$$

Solving for $\varepsilon_0$in Eq. (8) gives the equation as follows:

$$\varepsilon_0 = \left(\frac{m_P \mu_0^2 e^{10}}{32h^4 \pi m_e \xi_H \Gamma_P}\right)^{1/3} \tag{9}$$

Pulling Eqs (2) and (9) together gives the following after simplification.

$$a_i = \frac{n_i e^2}{8\pi \xi_H^{1/2} \xi_i^{1/2}} \left(\frac{32h^4 \pi\, m_e \xi_H \Gamma_P}{m_P \mu_0^2 e^{10}}\right)^{1/3} \tag{10a}$$

Simplification of Eq. (8a) gives the following equation.

$$a_i = \left(\frac{h^4 m_e \Gamma_P}{16\, m_P \mu_0^2 e^4 \pi^2}\right)^{1/3} \frac{n_i}{\xi_H^{1/6} \xi_i^{1/2}} \tag{10b}$$

While Eq. (10b) represents a simpler version, for the sake of those that dwells on complexity, one can substitute the equation ($\mu_0 = 1/\varepsilon_0\, c^2$) of vacuum magnetic permeability (μ_0) into it to give the following equation.

$$a_i = \left(\frac{h^4 m_e \Gamma_P \varepsilon_0^2 c^4}{16\, m_P e^4 \pi^2}\right)^{1/3} \frac{n_i}{\xi_H^{1/6} \xi_i^{1/2}} \tag{11}$$

Equation (11) allows a role for any particle whose mass is ≥ the mass of nucleons because $\Gamma_P/m_P = \Gamma_n/m_n \ldots = \Gamma_{(\infty-1)}/m_{(\infty-1)} = \Gamma_\infty/m_\infty$ where p and n symbolize the proton and neutron respectively. The fundamental premise of this supposition lies in Eq. (3), as in the literature [9].

The corollaries arising from the preceding equations (5, 7, &11) are as follows:

$$\Gamma_P = \frac{8 a_i \alpha^2 m_P \xi_H^{1/2} \xi_i^{1/2}}{m_e^2 c^2 n_i} \quad \text{(From Eq. (5))} \tag{12}$$

$$\Gamma_P = \frac{2 a_i e^4 \mu_0^2 m_P \xi_H^{1/2} \xi_i^{1/2}}{n_i m_e^2 h^2} \quad \text{(From Eq. (7))} \tag{13}$$

$$\Gamma_P = \frac{16\, a_i^3 m_P \mu_0^2 e^4 \pi^2 \left(\xi_H \xi_i^3\right)^{1/2}}{n_i^3 h^4 m_e} \quad \text{(From Eq. (11))} \tag{14}$$

The only drawback in the use of Eqs (12), (13), and (14) is that there is no other direct theoretical means and experimental (high-tech) instrumentation for measuring a_i unlike ξ_i.

Opposing Effects of Decentration and *Jingoism*

The pursuit of any aspect of knowledge involves the application of cognition to varying degrees, particularly in the natural sciences, mathematics, statistics, and all kinds of engineering. Therefore, this section must begin with the issue of cognition, without which even the researchers, editors, and reviewers may not function properly. This part of the section is intended to be advisory. Someone might want to know the answer to the question, "What is cognition?" This question forms the basis of an article by Bayne *et al.* (2019) [11]. The authors sought experts' views on this question from various disciplines. Two of the responses are provided below: Richard W. Byrne and Jennifer Mather define it as "all the activities and processes concerned with the acquisition, storage, retrieval, and processing of information, regardless of whether these processes are explicit or conscious" and "all the processes by which sensory input is transformed, reduced, elaborated, stored, recovered, and used," respectively. These definitions share the idea that acquiring knowledge and memory and the ability to recall what is known are the key to advancing from the known to the unknown. *For instance, if you are unaware of the soldier in front of you, whom you do not care for, it is unlikely that you can know about the Unknown Soldier, whom you definitely cannot care* for. This seemingly axiomatic idea may have prompted Galileo to question the notion of a flat Earth in favor of his own conception of its curvature. What we know about knowledge may be valid or invalid. Today's television is not as it was in the days following its invention.

It is not uncommon to see responses such as nonstandard forms on online submission platforms or in review reports. A reviewer may see $exp.(\pm x)$ (where x is any number), as a nonstandard form, even though most scientific calculators have such a symbol. This scenario does not constitute a lack of *intellectual decentration*, which is mainly found in infants. An observation in

an elementary school showed that a teacher solved for the volume (V=RT/P) of a gas given the values of other parameters, pressure (P) and temperature (T), including the universal gas constant (R) based on the equation $R = PV/T$. However, when asked to solve for P, given the values of other parameters, a significant number of students solved for V, implying that that was what was taught, which purely arose out of the absence of decentration in cognition! This is no longer a problem for infants. If this does not apply to adults with any level of academic credentials, one could infer an attitude of superiority based on class, race, *etc.*, which are key aspects of *jingoism* that shape such high-caliber scholars' attitudes toward new methods with a strong scientific foundation. Such an attitude does not encourage new intellectual and creative ideas. Individuals inclined to *jingoism* turn a blind eye to valid innovative ideas.

A top-notch scientist, including a cognitive psychologist, who criticizes infants, should be advised to find his or her way out of the classroom. The implication is that anyone involved in teaching should understand cognitive psychology to moderate their attitude toward students. In other words, claims that appear unusual should be verified before drawing any conclusion for or against a new development, especially in science and technology. To learn more about cognitive psychology, one can consult the literature [12, 13]. Improving on existing technologies would have been impossible if inventors and scientists lacked intellectual decentration—the capacity to question and examine current realities—and the ability to advance the current body of knowledge through discovery.

Until recently, there was a clear distinction between nuclear and atomic physics. However, a recent article revealed that hydrogenic periodic properties can be linked to nuclear properties, provided that atomic properties are a function of nuclear characteristics. Prior to this, mass-radius equations based on Einstein's mass-energy equivalence principle were derived in various ways, all of which yielded similar values for the parameter in question [8, 9]. The equations challenged the foundation of the methodologies used to determine the proton's mass radius. It appeared that a purely classical framework, as opposed to quantum chromodynamics (QCD) and related models, was used to extract the proton's mass radius, according to the authors' terminology. According to a recent publication, "the root mean square mass radii of the proton are produced by extracting the effective mass from different kinds of photoproduction and, strangely, center of mass energy without overt exploration of the equation ($\langle R_m^2 \rangle = 12/m_s^2$) that ought to contain the missing fundamental constant" [14]. The effective mass (m_s) in GeV was not given a concrete definition or explanation of how it can be applied. It requires multiplication by 1 eV (1.602176634310 exp. (–19) J). Even worse, $\hbar^2 c^2$ was absent, and the m_s value (1.24 GeV), which was supposedly extracted from GlueX data, could not be found in any table of values or in the text of the cited literature [15]. Incidentally other authors [16-18] determined the mass radius of the proton with slightly different approach but did not avoid the use of the controverted equation($\langle R_m^2 \rangle = 12/m_s^2$) advanced by Kharzeev (2021) [2]; they appeared not have clearly defined how the QCD frame work justifies the result generated. Meanwhile, the value of the mass radius of the proton was approximately given as 1.102 fm [9] in 2020 in a freely available journal article that cannot be cited, perhaps, on the basis of *intellectual jingoism*. If there is deliberate failure in applying *decentration* to assess an alternative approach such as $a_i = nh/\pi(8m_e\xi_i)^{\wedge}½$, that gives a similar result derivable from $a_0 = n^{\wedge}2.h^{\wedge}2.\varepsilon_o/\underline{\pi}.m_e.e^{\wedge}2.Z_{eff}$—the traditional Bohr equation for hydrogen and any other hydrogenic atom—is observed then, it

should be seen to be burned out of *intellectual jingoism*. It is usually a characteristic of classism, racism, political bias, egoism, *etc*., intended to continue hegemonistic superiority and imperialistic candor over those considered of lower being. They learn nothing from others, even when what others know supports their discovery or pristine knowledge. This is exactly what Albert Einstein suffered at the hands of Adolf Hitler, and such exists in the 21st century, often driven by an inordinate desire to accumulate wealth at the expense of general interest, to the point where policies that are characteristically *geronticide* hold sway through very low monthly stipends that have to be augmented *via* manual labor on the farm; otherwise, laziness becomes the characteristic of victims who labored in their youth serving their community. Note that research is capital-intensive! Thinking, reasoning, perceiving, imagining, and remembering are cognitive processes to the extent that they involve the use of concepts [11].

Methods

The study is theoretical and computational. The new equation was fitted to internet based first average ionization energies (I.E.s) for the computation of the atomic radii of any atom; fitting the original Bohr's equation to the radii generated in order to compute the effective nuclear charges (ENCs) to which was fitted kinetic energy equation (*i.e.* IE given as: $\xi_i = Z_{eff}^2 \xi_H / n_i^2$ where ξ_i, Z_{eff}, ξ_H, and n_i were average IE of any element, ENC, average IE for hydrogen, and principal quantum number respectively).

Results and Discussion

The review paper by Wilson (2021) [19] illustrated analytically what the author considered as the Schrödinger's steady-state equation for hydrogen atom. The illustration is given according to the following equations (Eqs (27) & (28) as in the author's article) but written in alphabetical order. $E_n = \frac{me^4}{32\pi^2\varepsilon_0^2\hbar^2 n^2} = \frac{E_i}{n^2} = \frac{v_e h}{r_n} = 2\pi m v_e \left(\frac{v_n}{n}\right)$ (a) and $E_n = \frac{-me^4}{32\pi^2\varepsilon_0^2\hbar^2} = \frac{-\hbar^2}{2ma_0^2}$ (b), respectively. The concern regarding the second part of the equations designated in this study as Eq. (b) is that the right hand side (RHS) of it does not derive directly from the left hand side (LHS), though the equality is correct. Both sides represent a true hydrogenic state. It behooves the author and the publisher, SDI, to state the origin of $-\hbar^2/2ma_0^2$. It may be premature to speculate that the article in which the formula appeared was backdated otherwise while the formula represents that of hydrogen only, a 2022b paper titled "Calculation of the Radius for Any Atom Based on the Planck Constant-Free Equation, Mathematical Complexity, and Atomism" [10] showed the following derivation, *viz.:* $a_i = n_i h/\pi^2\sqrt{8m_e\xi_i}$; solving for the kinetic energy (ξ_i) in the equation gives $\xi_i = n^2h^2/8\pi^2 m_e a_i^2$ which is equivalent to $\xi_i = \hbar^2 n_i^2/2m_e a_i^2$; however the latter is applicable to any atom. If n_i is equal to one, then the atom or ion is hydrogenic. If a negative sign is applied, the parameter expressed is the total energy in line with convention. This situation is where the Wilson equation is relevant, but did not show how it came about, as to imply an attempt by the publisher to give credit to him as the original author, which would also imply that the 2022a author of the above equations failed to attribute Wilson. This situation is against the backdrop of the case of plagiarism reported to the publisher of the journal, *Asian Journal of Research and Reviews in Physics*, 2022b, hosting the article titled "A Mathematical Relationship Between Hydrogenic Periodic Property and Nuclear Properties in Furtherance of Bohr's Theory" [8]; the response of the editor was that the plagiarized version does not bear an active DOI until the reply of the editor (who acknowledged my concern and took appropriate action) of the journal hosting the plagiarized version is forwarded to him/her. In this scenario the SDI editor

responded with a gift of a free virus dictator and cleaner rather than writing the editor of the plagiarizing journal.

Nevertheless, the publisher published Wilson article despite the reservation of the reviewer (Hoh FC): The review report at the instance of Physical science international-*Ms_PSIJ_70435 by FC HOH Uppsala University, Sweden* is given as follows: "The author clings to Bohr's hydrogen model in which the electron and proton are classical, Newtonian point particles. But this model has been replaced by the quantum-mechanical Schrödinger theory which reproduces Bohr's successful predictions and in addition also predicts many other results not obtainable from Bohr's model. In Schrödinger's theory, the electron is no longer a point particle but a cloud described by a wave function $\psi(\boldsymbol{x},t) = exp.(-iEt) \times (\boldsymbol{x})$, where $\boldsymbol{x}$ is the distance vector between the electron and the proton. In quantum theory, an observable is the eigenvalue of an operator. Thus, the energy operator $i\partial/\partial t$ operated on $\psi(\boldsymbol{x},t)$ yields the eigenvalue E. *In the Schrödinger equation (Eq. (27)) in the paper, a velocity v_e enters its right side. This is incorrect because there is no velocity operator in the Schrödinger theory for a hydrogen atom.* The author's recommendation to measure this is thus meaningless." However, the time-independent (steady-state) Schrödinger equation for the hydrogen atom in 3-Ds is written as: $E\psi(r,\theta,\phi) = -\frac{\hbar}{2\mu}\nabla^2\psi(r,\theta,\phi) + V_{(r)}\psi(r,\theta,\phi)$, where $\psi(r,\theta,\phi)$, μ, $\hbar$, ∇^2, E, and $V_{(r)}$, are the spartial wave function of the electron expressed in spherical polar coordinates, the reduced mass of the electron-proton pair, the reduced Planck constant, the Laplacian operator in spherical coordinates, the total quantized energy eigenvalue of the state, and electrostatic potential in line with Coulomb law ($= e^2/4\pi\varepsilon_0 r$). Wilson's steady-state version does not align with the reviewer's view, who did not present a personal contrasting view but instead opposed it based on what is known about Schrödinger's theory, which has proven unsuccessful for multi-electron atoms. Knowingly or unknowingly, this is a case of *jingoism* perpetuated by a publisher or an author against another author whose *pedigree may have been considered unworthy of attribution!*

In one instance, a reviewer (whose names need not be known or stated if known to ensure confidentiality) was of the view that several elements, as few as 20, are not enough to validate the equations derived, implying that as he/she did, all elements of the periodic table must have the periodic parameter of interest computed, making him stand alone in the rejection of the paper against four that supported; a researcher defines his or her scope of work, otherwise a single element can be the object of study. As if that was not enough, the reviewer accused the author of plagiarism. This was clearly a case of attempting to maintain existing knowledge and avoid challenging his/her perception of the correct knowledge, thereby highlighting the conviction that there are opposing effects of *decentration* and *jingoism* on understanding how nuclear properties are linked to periodic properties of all atoms. The article that was a victim has the title, given as "Renaissance of Bohr's Model *via* Derived Alternative Equation," in modified form following the recommendation of a highly supportive reviewer, and latter, published in the American Journal of Modern Physics. The former intended publisher of choice, Science Domain International, cannot deny this fact, even though in the recent past, it has been difficult to access its record of review history.

The time-independent (steady-state) Schrödinger equation for the hydrogen atom and nonhydrogenic atom in 3-Ds presents successful outcome for the former and other hydrogenic multi-proton elements unlike nonhydrogenic atoms because in the latter, the ENC is not known. The final solution to time-independent (steady-state) Schrödinger equation for hydrogenic atoms is given as: $E_n = -\left[\frac{m}{2\hbar^2}\left(\frac{e^2}{4\pi\varepsilon_0}\right)^2\right]\frac{1}{n^2} = -\frac{E_1}{n^2} \equiv -\frac{me^4}{8h^2\varepsilon_0^2 n^2}$; the equations are strictly for hydrogenic atoms such that, if hydrogen atom is the case the appearance of the square of ENC as nominator does not change the value of the total energy (E_n) as long as *n* is equal to one; if ENC is greater than one, the square of ENC as nominator while *n* is equal to one, alters the magnitude of E_n as applicable to higher hydrogenic atoms. Therefore, the challenge with multi-electron atoms *is* always the effective nuclear charge; such challenge ceases to be with the equations derived in this study and in the past.

Advocates of Schrödinger equation lack the utilitarian value of the ENC or reject the outstanding relevance of average ionization energies of higher atoms. The square of ENC (Z_{eff}), as the nominator, and the square of *n*, as the denominator, that is either greater than or equal to one, are applicable to multi-electron atoms. The average IE needs to be experimentally determined in order to accurately determine ENC as have been demonstrated in several articles [20, 21] as well as in this study shown as Eqs (5), (6), (10b), and (11). As shown in Table 1, the Bohr's radii for all first 30 elements are very similar to literature values [20, 21]; fitting the Bohr's famous equation to the radii produces all ENC; fitting $\xi_i = Z_{eff}^2 \xi_H / n_i^2$ where ξ_i, Z_{eff}, ξ_H, and n_i were average IE of any element, ENC, average IE for hydrogen, and principal quantum number respectively reproduces the literature values of all IEs of the first thirty elements (Table 1). Computed IE divide by literature IE multiplied by 100 gives the percentage of the computed IE compared to the literature values; it ranged from 99.999957 % to 100.003 %. The results showed that if the mass radius of the proton was less than approximately 1.102 fm (*e.g.*, ~ 0.55 fm [2] or greater than 1.102 fm, the Bohr's radius for hydrogen and any other atom cannot be accurately determined. It is therefore, clear that the correct mass radius of the proton is approximately 1.102 fm.

Table 1: Ground state outer most energy level effective nuclear charge determination based on the equations below for the first 30 elements of the Periodic Table

Elements & Electronic structure	**Radii/Å (Calculated)**	**Effective nuclear charge (ENC)**	**Average ionization energy**/*exp.* (– 18) **kJ/mol**	
			Archival values	**Calculated**
H $1s^1$	0.52900717175	~ 1	2.178627256	2.178685812
He $1s^2$	0.3934137293	1.344658652	3.939296829	3.939296829
Li [He]$2s^1$	1.68027025	1.259338312	0.8638124227	0.863812422
Be [He]$2s^2$	1.277802484	1.655990442	1.493654891	1.493654892
B [Be]$2p^1$	1.354683694	1.562009427	1.328929415	1.328929417
C	1.162651206	1.820003015	1.804175696	1.804175698

$[Be]2p^2$				
N $[Be]2p^3$	1.023396306	2.0676553252	2.328573934	2.328573933
O $[Be]2p^4$	1.057263296	2.001420751	2.18178228	2.181782282
F $[Be]2p^5$	0.9347176754	2.263815862	2.791366172	2.791366172
Ne $[Be]2p^6$	0.8401553134	2.518616101	3.455083637	3.455083637
Na $[Ne]3s^1$	2.581699402	1.84415915	0.8232952695	0.8232952697
Mg $[Ne]3s^2$	2.116487361	2.249512406	1.22497967	1.22497967
Al $[Ne]3s^23p^1$	2.392101354	1.990205158	0.9589613113	0.9589613113
Si $[Ne]3s^23p^2$	2.049775074	2.322582859	1.306013976	1.306013977
P $[Ne]3s^23p^3$	1.807208388	2.634324013	1.680133428	1.680133428
S $[Ne]3s^23p^4$	1.818203323	2.618393878	1.659874852	1.659874854
Cl $[Ne]3s^23p^5$	1.625145326	2.929444139	2.077666481	2.077666481
Ar $[Ne]3s^23p^6$	1.474462654	3.229016728	2.5254019382	2.524019383
K $[Ar]4s^1$	3.745337605	2.259907034	0.6954337613	0.6954337612
Ca $[Ar]4s^2$	3.156035819	2.681881729	0.9793859418	0.979385941
Sc $[Ar]3d^14s^2$	3.046198156	2.778583128	1.051287283	1.051287283
Ti $[Ar]3d^24s^2$	2.98619052	2.834418884	1.093963137	1.093963137
V $[Ar]3d^34s^2$	3.004257623	2.817373162	1.080844879	1.09341844879
Cr $[Ar]3d^44s^2$	2.999652688	2.82169827	1.084165957	1.084165957
Mn $[Ar]3d^54s^2$	2.861830397	2.957587846	1.191104673	1.191104673
Fe $[Ar]3d^64s^2$	2.7757711876	3.049349204	1.266161039	1.266161039
Co $[Ar]3d^74s^2$	2.779542081	3.045147205	1.262673907	1.262673907
Ni $[Ar]3d^84s^2$	2.823131462	2.998129883	1.223983346	1.223983346

Cu $[Ar]3d^9 4s^2$	2.807181439	3.015164849	1.237931875	1.237931875
Zn $[Ar]3d^{10} 4s^2$	2.545859071	3.3246596	1.50511261	1.505112611

Computed IE divide by literature IE multiplied by 100 gives the percentage of the computed IE compared to the literature values; it ranged from 99.999957 % to 100.003 %; $Z_{eff} = \left(2\xi_i/m_e\right)^{½} n_i/\alpha c$, where, $\alpha = e^2/2\,\varepsilon_0 ch$; $Z_{eff} = \left(8\xi_i/m_e\right)^{½} nh\varepsilon_0/e^2$ [20, 21]

It is very imperative to characterize elements in terms of chemical periodicity; this is down by plotting the Bohr's radii and the computed average IEs versus the atomic numbers. As shown in Figure 1, there was evidence of nonlinearity pointing to a characteristic chemical periodicity because the elements belong to different groups and periods. The reproduction of the chemical periodicity pattern (Figure 1) showed that the mass radius of the proton remains a fundamental constant because its substitution into all the equations did not yield conflicting values of the dependent variables, such as Bohr's radius of any atom.

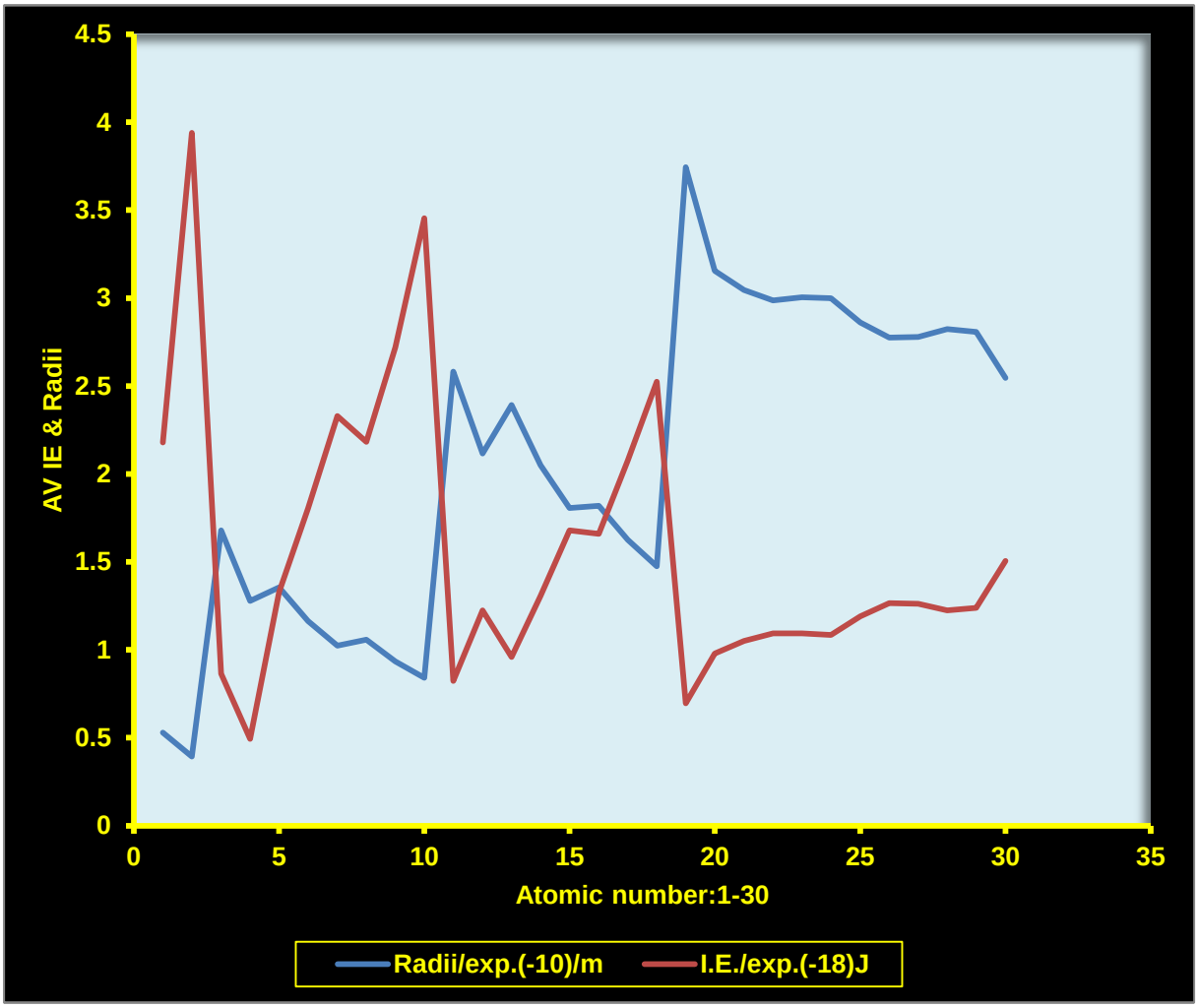


Figure 1: The plots of periodic properties versus atomic numbers of the first 30 elements. The plots illustrate the chemical periodicity among the elements from different groups. The results show that the presence of nuclear

property such mass radius of the proton as given aligns correctly with other fundamental physical constants in the novel equation that is inclusively applicable to all element of the multiplicity of electrons in such element. The outermost electron of any atom, therefore, falls within the purview of Bohr's model equation. AV IE designate average ionization energy

Terms such as mean effective charge (ž), principal quantum number (n*=2), the number of electrons (n) and the successive ionization potential (ϵ_i) of 2s and 2p in the L-shell respectively are given in the literature [22]; the equation of the successive ionization potential is given as: $ž = n^* \sqrt{\sum \epsilon_i / n}$ [22]. This kind of equation does not show a clear clue as to how it can be used to compute either the mean effective charge or the average ionization energy, taken one after the other at a given energy level. This equation contrasts sharply with the current approach in this study, as in the recent past, except for the inclusiveness of its application to all atoms and the role of the mass radius of the proton. It has been shown how ENC can be computed by fitting derived equations to IE values of different elements [20, 21]; the equations given alphabetically are as follows: $Z_{eff} = \left(8\xi_i / m_e\right)\text{^}½\, nh\varepsilon_0 / e^2$ [20]; $Z_{eff} = n\left(2\xi_i / m_e\right)\text{^}½ / \alpha\, c$ [21]: The ENC can be computed using any of the equations; fitting the equation $\xi_i = m_e Z_{eff}\text{^}2e\text{^}4/8h\text{^}2\varepsilon_o\text{^}2n\text{^}2$ to the ENC (Z_{eff}) values gives the average IE (ξ_i). The innovation in this study, in line with the decentration principle, is that, unlike previous equations [20, 21], it is a mathematical relationship between the mass radius of the proton and other periodic properties of all elements; such properties are Bohr's radius and IE of any atom in combination with those of hydrogen, without giving different values of the radius for each element. Chemical periodicity is maintained, as demonstrated in Figure 1. The implication is that the mass radius of the proton reported in the literature [8, 9, 14] is valid.

Scientific and medical importance of ENC

Importance of ionization energy and cognate effective nuclear charge While ionization potential is often used, it is, however, expedient to explore ionization energy (or average ionization) for direct computational purposes that reflect the true meaning of the energy barrier that has to be overcome to strip an electron from its outermost orbital location. Thus, ionization energy is always endothermic for all elements to varying degrees, referring, however, to elements in their ground state; electron affinity, on the other hand, is either endothermic or exothermic according to the kind of element defined by its group number. An element that has a near-zero or high endothermic electron affinity should also possess high ionization energy and a high effective nuclear charge, and *vice versa*. Related concerns such as electronegativity and chemical hardness are known in the literature. To this end, Dong *et al*. (2022) [7] provide instructive explanations and definitions: Ionization potential and electron affinity are regarded as atomic properties of paramount importance [7].

"Ionization potential E_i is defined as the energy of the reaction $A \rightarrow A^+ + e$ and the electron affinity E_a is minus the energy of the reaction $A + e \rightarrow A^-$. The ionization potential is defined as $E_i = E(1) - E(0)$, and the electron affinity is $E_a = E(0) - E(-1)$, where $E(0)$, $E(1)$, and $E(-1)$ indicate the atomic energy with 0, +1, and −1 charges, respectively. With references to the old literature, Dong *et al*., (2022) [7] noted the following views. The Mulliken electronegativity χ and chemical hardness are defined respectively as $\chi = -(E_i + E_a)/2$ and $\eta = (E_i - E_a)/2$; the first derivative of the outcome of expanding the energy E of a given atom in powers of the

number N of electrons ($i.e., E(N) = a + bN + cN^2 + oN^3$), is given as the chemical potential of the electron in the atom which is equal to minus Mulliken electronegativity, $\mathrm{d}E/\mathrm{d}N|_{\mathrm{N}=0} = \mu = -\chi$ [7]. "This electronegativity quantifies the ability of an atom to attract and retain electrons. The second derivative is the chemical hardness given as, $\eta = c = 0.5\, d^2E/dN^2\,|_{\mathrm{N}=0'}$ which describes the resistance of an atom to a change of its electronic state" [7]. Unfortunately, the effective nuclear charge is not considered relevant to the atomic properties discussed earlier. Scientists, natural and medical, may have found it unwise to adopt Slater's method, which overestimates ENC, even though there had not been any literature until recently, and now, with IE taken as a function of ENC, aided the computation of the latter by fitting the equation of it to experimentally known values of IE of elements.

Covalent reactions between nucleophilic and electrophilic reagents are however discriminatory, since there is a significant degree of selectivity associated with these interactions. However, the theory of Hard and Soft, Acid and Bases (HSAB) has proven to be a useful tool in predicting the outcome of such reactions. This concept utilizes the inherent electronic characteristic of polarizability to define, for example, reacting electrophiles and nucleophiles as either hard or soft. These HSAB definitions have been successfully applied to chemical-induced toxicity in biological systems. Thus, according to this principle, a toxic electrophile reacts preferentially with biological targets of similar hardness or softness. The soft/hard classification of a xenobiotic electrophile has obvious utility in discerning plausible biological targets and molecular mechanisms of toxicity [6]. Whatever be the case, the parameter ENC cannot and ought not to be extricated from any thought of drug design since it truly characterizes the atoms that make the molecules, be it either electrophile or neutrophile.

Thus, the HSAB (whose parameters are softness(σ) or hardness (η)) theory that initially described hardness and softness in terms of the experimental ionization potential and electron affinity of the reacting molecules, is not out of the question. HSAB parameters such as the softness (σ) or hardness (η) of an electrophile and its nucleophilic target are derivable based on extant methodologies. The values for σ and η are used in developed algorithm to calculate the electrophilic index (ω) of a toxicant, the value of which reflects the propensity of the electrophile to form adducts with a given biological nucleophiles [6]. *Molecules with atoms of high ENC are likely to exhibit strong nucleophilicity. In contrast, those possessing atoms of low ENC are likely to be strongly electrophilic. This study, like previous ones, shows how to compute the ENC and its Bohr radius for any atom!*

Coumestrol, a phytochemical, has been shown to have anti-inflammatory, neuroprotective, anti-oxidant, and anti-cancer properties. The effect of substitution at various positions of the coumestrol molecule was investigated using density functional theory (DFT) calculations. Full electron donor acceptor maps (FEDAM) and donor acceptor maps (DAM) identified the radical scavenging ability of these molecules [23]. The interest in the report is the application of DFT in medical research in that the latter covers atomic hardness and electron affinity, providing valuable quantum mechanical parameters used in rational drug design, toxicology prediction, and

radiation therapy optimization. In medical research, molecular hardness is explored to design drugs that target specific cellular receptors without causing off-target effect; a similar concept (or better yet, principle) such as Hard and Soft Acids and Bases (HSAB) determines the choice of "hard-hard" chemical species pair interaction and "soft-soft" chemical species pair that influence the design of drugs; the active sites of enzyme possess distinct hard or soft nucleophilic centers; matching the chemical "hardness" or "softness" of a drug candidate to the enzyme's active site nucleophiles optimizes electronic overlap and thermodynamic stability, ensuring high-affinity, selective binding. Strong nucleophiles are usually strongly electronegative, with high AEA and ENC, and *vice versa.* Thus, "hardness and softness" are functions of ENC.

Several DFT approaches with 6–311 + G(2df,2p) basis set at the B3LYP/6–31 + G(d,p) geometries (methods that best known to the authors) were examined to calculate accurate adiabatic electron affinity (AEA) for some hydantoin derivatives [4]. The results reveal that the electron donating groups decrease the AEA and vertical EA (VEA) value, whereas, the reverse is true in the case of the electron withdrawing groups [4]. The relevance of the result to this study is once again, the mention of DFT which explores chemical hardness and electron affinity; any nucleus that has very high effective nuclear charge for its outermost electron, invariably would strongly resist expulsion of such electron and also offer a compact electron cloud that cannot easily be distorted.

The energy change that occurs when an electron is added to the neutral atom (molecule) is known as the Electron affinity (EA). Essentially, EA measures the degree of attraction between an incoming electron and the atom's nucleus and the greater the attraction, the more energy will be released. The redox stability of compounds can be correlated to their adiabatic electron affinity (AEA) and adiabatic ionization potential (AIP). With reference to the literature, Wazzan & Safi (2023) [4] noted that AEA can also be called the electrode potential, which can be used as an auxiliary potential for the design of bioreductive anticancer drugs and for assessing biological activity. There should be a way of mathematically relating ENC to the EA for better qualitative and quantitative drug design.

Referring to the literature, Saffi & Wazzan (2023) [24] were of the view that EA values are not easily experimentally measurable despite experimental methods such as low-energy electron transmission spectroscopy (ETS), electron spin resonance (ESR), and Fourier Transform Ion Cyclotron Resonance Mass Spectrometry (FT-ICR); computational methods such as high-level *ab initio* and post-Hartree-Fock methods are available for atoms and small molecules only, while the DFT method, regarded as the most powerful, is available for medium and large molecules. These concerns notwithstanding, the electron affinity of chlorine reported in the 20th century is 85.84±1.0 kcal./mole achieved by measuring the ratio of ions to electrons leaving a hot tungsten surface in contact with a low pressure of gas containing chlorine atoms [3]. These challenges contrast sharply with spectroscopic methods of quantifying the IE of atoms, which ought to offer insight into what the AEA may be quantitatively, pursuant to the selection of molecules and, where applicable, atoms for drug design. This is a direct pointer to the importance of EA which may be endothermically large if the atom has low ENC and *vice versa*.

Secondary metabolites, some of which are essential signal molecules and energy sources such as fatty acids, are nutrients that play important roles in biomedicine, pharmacokinetics, and human metabolism. Reducing fatty acids is one of the main ways to control the synthesis of fatty aldehydes and fatty alcohols. This is where once again, the thermodynamic properties of adiabatic electron affinity, which describes the ability of fatty acids to obtain electrons, have become very important [5]. It is not an overstatement to opine that higher effective nuclear charge (ENC) correlates with increased electron affinity for any atom, whether considered individually or in conjunction with other atoms within a molecule if fundamental science is understood deliberately.

Although chemical potential ($\mu = -(IE+EA)/2$ of an electron is mentioned within the domain of the unfamiliar DFT and chemical thermodynamics, there is the question as to whether in fact the thermodynamical concept of a chemical potential can be defined for the electrons in few-electron systems as atoms and molecules. The conclusion is that such systems lack important characteristics of thermodynamic systems and do not align with the definition of a chemical potential. They are not analogous to the open systems of thermodynamics that can exchange particles with the environment. Thermodynamical (statistical mechanics) concepts like chemical potential, open systems, grand canonical ensemble, *etc.*, are not applicable to a few electron systems like an atom or molecule [25]. Yet, the chemical potential referred to in the literature [7] has connection with IE, EA, and ultimately electronegativity; included is also chemical hardness [7]. This scenario implies a case of unsettled concepts. This could create an unforeseen limitation in experimental or theoretical studies on drug design in the future. Given such a situation, IE and ENC concepts amenable to known methodologies should serve as a working guide in drug design or modeling because all compounds possess characteristics contingent on the periodic properties of the constituent elements. However, the greatest challenges are failure to apply *intellectual decentration*, a vital aspect of cognition, and resort to *intellectual jingoism* in order to maintain the status quo.

Conclusion

The equation that has the inclusive potential to link periodic properties such as atomic radii and average ionization energy (IE) of hydrogen in combination with the average IEs of other multi-electron elements to nuclear properties such as the mass radius of the proton was derived. Since the computed values of ENC, IE, and radii were very similar to literature values despite the presence of the nuclear property, the mass radius of the proton (Γ_P), in combination with the IE of hydrogen and any other atom, it stands to reason, in conclusion, that the Γ_P explored in this study was consistently valid. There is no doubt that ENC can give insights into the magnitude of AEA, electronegativity, and chemical hardness, all of which are essential in scientific and medical research. Indeed, there must not be any room for *intellectual jingoism* and disregard for *intellectual decentration* at a postdoctoral or higher level. This, more or less an advisory note, is useful to the core scientist who, with respect, strongly adheres to the American Slater's rule. Future studies should involve thirty other elements or fewer. One such study should include a search for a mathematical equation that can link electron affinity with ENC (or IE).

Author Contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

Dedication

This study is dedicated to the late USA Emeritus professor of chemistry (PhD, Physics) and 2019 chemistry laureate, in the person of John B. Goodenough, who is remembered not only for his exceptional discovery but also for his inspirational and motivational patriotic statement suggesting that to be a laborer on the farm to fill gaps is not the kind that cares for the elderly, but rather working hard to build up the next generation of scientists that would continue to advance their own country; the key point is that in his early 90s of age he does not know when it will be, so according to him he is working hard to ensure that his only Ph.D. student graduates, a student he called "a pretty nice boy," contrary to a geronticide state well known to mankind. Keep it up!

Disclaimer (Artificial Intelligence)

Author hereby declare that no generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript. To clarify, Quillbot edits the text produced by the author. ChatGPT and COPILOT generate a brand new text from scratch for the authors if prompted.

Competing Interests

There are no known competing financial interests, non-financial interests, or personal ties that could have influenced the work presented in this publication; the challenge is the 21st-century slavishness of less than 2 USD monthly pensions to be augmented through labor-intensive farming that does not enhance scholarship and gerontology intentionally as the only mark of hard work.

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