A New Approach for Calculating the Alpha-Decay Half-Life for the Heavy and Super-heavy Elements and an Exact A Priori Result for Beyllium-8

W. A. Surdoval,[1] D. A. Berry[2]

[1] National Energy Technology Laboratory, United States Department of Energy, 626 Cochrans Mill Road, P.O. Box 10940, Pittsburgh, PA 15236-0940

[2] National Energy Technology Laboratory, United States Department of Energy, 3610 Collins Ferry Road, P.O. Box 880. Morgantown, WV 26507-0880

A new general method for calculating the alpha decay half-life is presented. The method predicts an a priori exact value for the beryllium-8 half-life. Beryllium-8 is an exception to the current alpha decay theory captured in the Geiger-Nuttal law. The new method predicts the beryllium-8 alpha half-life using only constants and measured isotopic mass. The method also reliably predicts all the heavier isotope alpha decay half-lives consistent with the Geiger-Nuttal law. With respect to current theory, the inability of the Geiger-Nuttal Law to predict the alpha-decay half-life in the case of beryllium-8 has led to consideration of other decay mechanisms for this isotope, such as fission for example. One result is that given the consistency of the new method presented here for all isotopes including an exact a priori result for beryllium-8, the evidence strongly suggests that the beryllium-8 decay is in fact an alpha decay. A second result is that the method definitively demonstrates that the entire rest mass of the two helium-4 electrons is converted to energy in the decay process and this energy becomes part of the emitted alpha particle kinetic energy.

Key words: Alpha Decay; Half-Life; Beryllium-8; Geiger-Nuttal Law

DOE/NETL-2021/2719

Author to whom correspondence should be addressed:
wayne.surdoval@netl.doe.gov

Table of Contents

A New Approach for Calculating the Alpha-Decay Half-Life for the Heavy and Super-heavy Elements and an Exact A Priori Result for Beyllium-8 1

1. Introduction 2

2. Conceptual Approach 3

3. Calculational Elements 3

3.a Physical Constants and Measured Mass Used in the Calculation for Beryllium-8 3

3.b Nuclear Energies Used in the Calculation 4

3.c The Equations Used in the New Calculational Method 5
4. Alpha-Decay Half-Life for Beryllium-8 and Bismuth-209 7
4.a The Alpha Decay Half-Life Calculation for Beryllium-8 7
4.b The Alpha Decay Half-Life Calculation for Bismuth-209 9
5. Energy values of the Mass Defect Term EΔm for the heavy elements. 11
TABLE: Alpha Decay Effective Mass Defect ($E\Delta meffective$) for Isotopes (Z≥52) 11
6. Conclusion 12
7. References 13
8. Acknowledgement 14
9. Disclaimer 14

1. Introduction

The current methodology for calculating the alpha-decay half-life is captured by the Geiger-Nuttal law[1]. The Geiger-Nuttal law is based on a tunneling model but in application it is a fitted equation. The empirical principle underpinning the equation is that half-life correlates well to the alpha particle energy with a less energetic alpha particle resulting in a longer half-life. This works relatively well for a range of fitted parameters for the heavy elements starting with several tellurium isotopes (Z= 52). Beryllium-8 (Z = 4), by far the lightest alpha emitter, does not follow this principle. It's alpha-decay energy is very small which per the Geiger-Nuttal law indicates it should have a very long half-life, but its half-life is in fact very short, contradicting the current understanding of the alpha-decay mechanism. In this paper a new approach which is also based on tunneling has been developed. Using this approach, an exact answer was arrived at with only a priori physical constants and measured masses. The predicted beryllium-8 half-life is calculated as $8.19\ x\ 10^{-17}$ seconds which is in exact agreement with the measured value of $8.19x10^{-17}$ seconds $(\pm 0.37x10^{-17})$. This strongly suggests that beryllium-8 is a traditional alpha-decay rather than the fission of beryllium-8 into two helium atoms. In addition to the beryllium calculation, the new approach works well for the alpha-decay of the heavy elements starting with tellurium-106 in agreement with the Geiger-Nuttal law, The method was tested with a selection of alpha decays up to and including oganesson-295 (even though the isotopic mass of oganesson-295 is not entirely reliable). The new approach predicts that the alpha-decay half-lives for oganesson-295 and oganesson-294 should be the same order of magnitude. The half-lives are currently reported as several orders of magnitude different. A third result is that the rest mass of the two helium-4 electrons is completely converted to energy in the decay process and becomes part of the emitted alpha particle kinetic energy.

2. Conceptual Approach

.

Conceptually, developing the calculational approach started with a tunneling equation based on a the Gammow[2] or Fowler-Nordheim[3] analysis of tunneling. In simple terms, the analysis evaluates the behavior of the tunneling particle from its intrinsic frequency in the nucleus to its entering the potential well barrier established by the charge of the nucleus and the transmission coefficient characterizing the particles ability to tunnel through the barrier resulting in emission as a free particle Gammow performed the original analysis for alpha-particle tunneling and Fowler and Nordheim for electron tunneling. The governing equations of the two methods are essentially the same but the details are different specifically with respect to the energies involved and the nature of the tunneling particle.

In this paper the fundamental approach in terms of the equation for tunneling is essentially the same as for the Gammow and Fowler-Nordheim analyses. The difference is the energies involved. Finding the correct energies was the core of the problem. Beryllium-8 was used as the test case given it is the case for which conventional theory has difficulty. A second objective was to use only known constants and masses making the calculation a priori. The question then becomes does the same method that works for beryllium-8 also work for the heavier isotopes.

3. Calculational Elements

3.a Physical Constants and Measured Mass Used in the Calculation for Beryllium-8

The masses listed are for the beryllium-8 decay. For other decays the appropriate mass should be used. Some isotopic masses are not well established which can affect the calculations The masses relevant to the beryllium-8 decay are accurately measured.

The physical constants and measured physical parameters used in this calculation are found in 2018 CODATA[4], NUBASE2016[5], and AME2016[6].

Isotopic Be_4^8 mass $= 8.00530510$ u (parent mass for the beryllium-8 decay)

Isotopic He_2^4 mass $= 4.00260325413$ u (daughter mass for the beryllium-8 decay but also important to the general calculation)

Alpha particle (m_α) mass = 4.001506179127 u

u =1.6605390666 E-27 kg

$m_p = 1.67262192369\ E\text{-}27$ kg

$m_n = 1.67492749804\ E\text{-}27$ kg

$c = 2.99792458\ E8$ meters/second

$\hbar$ = reduced Planck constant = $1.054571817E - 34$ Joule sec

q = 1.602176634 E-19 C

ε_o = 8.8541878128 E-12 $C\ V^{-1}m^{-1}$

3.b Nuclear Energies Used in the Calculation

The following are the nuclear energies relevant to the nucleus and the nucleus potential well barrier.

Equations (1) and (2) are the mass defect for the alpha-particle and helium-4 respectively. The mass defect represents the binding energy in the nucleus that becomes available during a disruptive process such as fission or alpha decay. Equation (1) is the mass defect of the alpha particle while it is still part of the nucleus. It does not include the mass of the two electrons associated with a helium-4 atom. Equation (2) is the mass defect of the helium-4 atom or the mass of the alpha particle plus the mass of the two electrons. Helium-4 as an atom does not have a role in the decay. Although labeling this term as $E_{\Delta m_{He_2^4}}$ is not strictly precise relative to its use, it is correct in terms of the energy value and is an a priori term which is used in the a priori calculation of the beryllium-8 alpha decay half-life. Equation (2) is a concise way to include the mass of the two unattached electrons that exist after the alpha decay of the electron free alpha particle. This will become more clear later in the paper. The term ($E_{\Delta m_{He_2^4}}$) becomes an exceptionally important term in the analysis of the heavy elements and will be relabeled $E_{\Delta m_{effective}}$) which is why it is being emphasized, The two excess electrons play a significant part in the decay. The discussion of Eq's (5) and (6) will further clarify what happens to the two electrons and their contribution to the decay process.

$$E_{\Delta m_\alpha} = (2m_n + 2m_p - (m_\alpha)c^2 = 28295611\ eV \qquad (1)$$

$$E_{\Delta m_{He_2^4}} = \left(2m_n + 2m_p - m_{He_2^4}\right)c^2 = 27273692\ eV \qquad (2)$$

All mass defects are calculated in the same way for any isotope and it is the available energy that results from the rest mass of the nucleons exceeding the actual measured mass of an isotope. It is generally considered a form of binding energy that becomes available on disruption of nucleon binding.

Equation (3) is the mass defect for the any isotope. The energy and masses shown here are specific to beryllium-8 but the equation is general on substituting the correct number of nucleons and the measured mass for any isotope.

$$E_{\Delta m_{Be_4^8}} = \left(4m_n + 4m_p - m_{Be_4^8}\right)c^2 = 54455546\ eV \tag{3}$$

Equation (4) evaluates the difference in mass excess between the parent and daughter isotope. Mass excess is a different form of available energy in the nucleus. Both the mass defect and the mass excess play a role in the alpha decay in this approach. The energy and masses shown here is for the case of beryllium-8 decay but the equation is general on substituting the appropriate isotopic mass for the parent and daughter.

$$E_{(\Delta m_{excess})_{p\to d}} = \left(m_{Be_4^8} - m_{He_2^4} - 4u\right)c^2 = 2516753\ eV \tag{4}$$

Equation (5) determines the kinetic energy of the emitted alpha particle.

$$E_\alpha = \left(\left((\Delta m_{excess})_{p\to d}\right)c^2\right) - \left(\left(\Delta m_{(excess)_\alpha}\right) + (2m_e)\right)c^2 = \text{alpha kinetic energy} \tag{5}$$

It is calculated in the same way for any decay. The term $\left(\Delta m_{(excess)_\alpha}\right) + (2m_e)$ in the equation for the kinetic energy of the alpha particle (E_α) indicates that the rest mass of the two helium-4 electrons is entirely converted to energy in the decay process.. The rest mass energy of the two electrons becomes part of the emitted alpha-particle kinetic energy and the electrons no longer exist as particles.

Equation (6) is the difference in mass defect of the parent and daughter isotope. Again the energy and masses shown is for the beryllium-8 decay but the equation is general.

$$E_{\Delta\Delta m_{p\to d}} = \left(\Delta m_{Be_4^8} - \Delta m_{He_2^4}\right)c^2 = \left(E_{\Delta m_{He_2^4}} - E_\alpha\right) = 27181855\ eV \tag{6}$$

This equation proves to be a general result. The difference in mass defect of the parent and daughter isotopes is always equal to the difference of the mass defect of helium-4 and the kinetic energy of the alpha particle regardless of the parent and daughter. This is not specific to the beryllium-8 decay.

3.c The Equations Used in the New Calculational Method

The calculation is based on the following tunneling equation,

$$t_{\frac{1}{2}} = \frac{\ln(2)\ \exp\left(f\left(r_q\right)\right)}{frequency} \tag{7}$$

The frequency used in Equation (1) is written as,

$$frequency = \frac{2E}{\pi^2\hbar} \tag{8}$$

The energy (E) corresponding to this frequency is the difference between the mass defect of the alpha particle and the difference in mass excess of the parent and the daughter isotopes. This energy is written as $\left(\Delta m_{\alpha} - \ E_{(\Delta m_{excess})_{p\rightarrow d}}\right)c^2$ and is evaluated using Eq's. (1) and (4).

A fine point regarding he electrons should be noted. The alpha particle is charged and does not carry electrons with it when emitted and so they do not enter into the mass defect calculation for the alpha particle. The alpha particle is charged but the daughter isotope is not. So there is a question concerning what happened to the two electrons? As previously discussed the two electrons that are lost in the alpha-particle emission show up in the emitted alpha particles kinetic energy.

This frequency of Eq. (8) is the fundamental mode of the alpha particle in the nucleus. This frequency is a fundamental mode covering a full cycle (two wavelengths) and as a fundamental mode is proportional to inverse π^2. Including the explicit energy term it is written,

$$frequcncy = \frac{2\left(\left(E_{\Delta m_{\alpha}} - E_{\Delta \mathrm{m}_{\mathrm{excess}}}\right)\right)}{\pi^2 \hbar} \tag{9}$$

The next term to be discussed is the potential barrier function $f\left(r_q\right)$. This is a function that represents the ratio of the width of the coulombic nuclear potential barrier (r_b) written as,

$$r_b = \frac{2Zq^2}{4\pi\varepsilon_0\left(E_{\Delta m_{excess}}\right)} \tag{10}$$

and the corresponding length dimension of the fundamental mode of the alpha particle in the potential barrier. This is given by,

$$r_f = \frac{2\pi q^2}{4\pi\varepsilon_o\left(E_{\Delta m_{He_2^4}} - E_{\alpha}\right)c^2} \tag{11}$$

The energy involved in the creating the nuclear potential well barrier is created by the difference in mass excess energy of the parent and daughter isotopes involved in the decay evaluated using Eq. (4). This is the available energy for existence of the barrier. The alpha particle also requires available energy for escape. It must have energy available to maintain a frequency in the nucleus and energy available to maintain a frequency in the barrier. Although the governing equation for tunneling is essentially the same regardless of the particle, the specific energies involved in the process are quite different. The essence of the problem is finding these energies.

The barrier function $f(r_q)$ is the ratio of Eq's. (10) and (11). This function reduces to,

$$f(r_q) = \left(\frac{Z}{\pi}\right)\left(\frac{E_{\Delta m_{He_2^4}} - E_\alpha}{E_{\Delta m_{excess}}}\right) \tag{12}$$

The term labeled Z is the atomic number of the parent isotope.

An objective of this work was to find a single calculational method for alpha-decay which is applicable to both the heavier (≥Z=52) elements, which the Geiger-Nuttal law predicts reasonably well, and for beryllium-8 the Geiger-Nuttal law does not predict at all.

The following two example calculations is presented for beryllium-8 and bismuth-209 and are dependent solely on physical constants and measured parameters. This is an interesting comparison given that beryllium-8 is one of the shortest half-lives and bismuth-209 the longest known alpha half-life. The ratio of the alpha decay half-lives of bismuth-209 and beryllium-8 is 43 decades (10^{43}). The method needs to be very robust to reasonably account for both cases with the identical a priori calculation.

4. Alpha-Decay Half-Life for Beryllium-8 and Bismuth-209

Beryllium-8 can be considered a two-particle system. Its nucleus is composed of two helium-4 atoms. If the two extremely stable helium-4 particles behave as individual particles in the beryllium-8 nucleus and the phenomena governing the two-body interaction is accounted for, obtaining an exact answer is conceivable. In the case of the many nucleon problem (n-body) an exact answer is unrealistic (probably not possible) even with a more complex approach.

4.a The Alpha Decay Half-Life Calculation for Beryllium-8

The governing tunneling equation is Eq. (7)

$$t_{\frac{1}{2}} = \frac{\ln(2)\ \exp\left(f\left(r_q\right)\right)}{frequency} \tag{7}$$

The frequency is given by Eq. (9)

$$frequcncy = \frac{2\left(E_{\Delta m_\alpha} - E_{(\Delta m_{excess})_{p\to d}}\right)}{\pi^2 \hbar} \tag{9}$$

$$frequcncy = \frac{2(28295611\text{ eV} - 2516753\text{ eV})(1{,}602176634\ E\!-19\text{ Joule/eV})}{(\pi^2)(1.054571817\ E\!-34\ \text{ Joule-sec})}$$
$$= 7.93648426\ E21\ \text{sec}^{-1}$$

The barrier function $f\left(r_q\right)$ is evaluated using Eq. (12),

$$f\left(r_q\right) = \left(\frac{Z}{\pi}\right)\left(\frac{E_{\Delta m_{He_2^4}} - E_\alpha}{E_{\Delta m_{excess}}}\right) \tag{12}$$

The emitted alpha particle kinetic energy is,

$$E_\alpha = \left(\left((\Delta m_{excess})_{p\to d}\right)c^2\right) - \left(\left(\Delta m_{(excess)_\alpha}\right) + (2m_e)\right)c^2 = 91837\ eV \tag{5}$$

Evaluating the barrier function,

$$f\left(r_q\right) = \left(\frac{4}{\pi}\right)\left(\frac{27273692\text{ eV} - 91837\text{ eV}}{2516753\text{ eV}}\right) = 13.75145383$$

Evaluating the tunneling equation, Eq. (7)

$$t_{\frac{1}{2}} = \frac{\ln(2)\ \exp\left(f\left(r_q\right)\right)}{frequency} \tag{7}$$

$$t_{\frac{1}{2}} = \frac{\ln(2)\ \exp(13.75145383)}{7.93648426\ E21\ \text{sec}^{-1}} = 8.19\ E\text{–}17\ \text{seconds}$$

The measured value reported in NUBASE2016[5] for the Be_4^8 alpha-decay half-life is

$$8.19x10^{-17}\ \text{seconds}\ (\pm 0.37x10^{-17}).$$

4.b The Alpha Decay Half-Life Calculation for Bismuth-209

As a test case for the heavier elements, bismuth-209 decay to thallium-205 is selected. This decay is the longest alpha decay half-life that has been successfully measured. The bismuth-209 nucleus is much more complex than beryllium-8 and it will not behave as a two-body system. If the same method using a priori energies and masses gives reasonable results then it can be reasonably concluded that the calculational approach is robust.

Using the general tunneling equation,

$$t_{\frac{1}{2}} = \frac{\ln(2)\ \exp\left(f\left(r_q\right)\right)}{frequency} \tag{7}$$

$$E_{(\Delta m_{excess})_{p\to d}} = \left(m_{Bi_{83}^{209}} - m_{Tl_{81}^{205}} - 4u\ \right)c^2 = 5562138\ eV$$

$$E_\alpha = \left(\left((\Delta m_{excess})_{p\to d}\right)c^2\right) - \left(\left(\Delta m_{(excess)_\alpha}\right) + (2m_e)\right)c^2 = 3137222\ eV$$

Calculating the frequency,

$$frequcncy = \frac{2\left(E_{\Delta m_\alpha} - E_{(\Delta m_{excess})_{p\to d}}\right)}{\pi^2 \hbar} \tag{9}$$

$$frequcncy = \frac{2(28295611\ \text{eV} - 5562138\ \text{eV})(1{,}602176634\ E\text{–}19\ \text{Joule/eV})}{(\pi^2)(1.054571817\ E\text{–}34\ \text{Joule-sec})}$$
$$= 6.998907783\ E21\ \text{sec}^{-1}$$

It should be noted that the frequencies among all isotopes are of the same order of magnitude.

Evaluating the barrier function,

$$f(r_q) = \left(\frac{Z}{\pi}\right)\left(\frac{E_{\Delta m_{He_2^4}} - E_\alpha}{E_{\Delta m_{excess}}}\right) \quad (12)$$

$$f(r_q) = \left(\frac{83}{\pi}\right)\left(\frac{27273692 \text{ eV} - 3137222\text{eV}}{5562138 \text{ eV}}\right) = 114.6463451$$

Evaluating Eq. (7)

$$t_{\frac{1}{2}} = \frac{\ln(2)\ \exp\left(f(r_q)\right)}{frequency} \quad (7)$$

$$t_{\frac{1}{2}} = \frac{\ln(2)\ \exp(114.6463451)}{6.998907783\ E21 \text{ sec}^{-1}} = 6{,}110408276\ E27 \text{ seconds}$$

The measured value reported in NUBASE2016[5] for the Bi_{83}^{209} alpha-decay half-life is

$$6.339\ E26 \text{ seconds} .$$

This predicted half-life is longer than the actual reported value but not by much.

It turns out that the exact value for the half-life of the heavier elements correlates systematically to the helium-4 mass defect term $E_{\Delta m_{He_2^4}}$ used in the calculation of the barrier function $f(r_q)$.

5. Energy values of the Mass Defect Term $E_{\Delta m}$ for the heavy elements.

The following table tabulates the effective value of the mass defect ($E_{\Delta m_{effective}}$) that gives exact half-lives for the heavy elements using the method presented in this paper. For heavy isotopes these values are systematic and for atomic number Z=60 through Z=99 reasonably constant. This table should provide an appropriate value of the effective mass defect for an accurate calculation. The value of ($E_{\Delta m_{effective}}$) replaces the energy ($E_{\Delta m_{He_2^4}}$) defined by Eq. (2) and used in Eq. (12).

The half-life exponents have been highlighted to emphasize the vast difference in the magnitude of the half-lives for the various isotopes. Even isotopes with the same atomic number (note for example the polonium isotopes given in the table) have large orders of magnitude half-life difference.

TABLE: Alpha Decay Effective Mass Defect ($E_{\Delta m_{effective}}$) for Isotopes (Z≥52)

Parent→Daughter	$E_{(\Delta m_{excess})_{p\to d}}$ (eV)	E_α (eV)	$t_{\frac{1}{2}}$ (seconds)	$E_{\Delta m_{effective}}$ (eV)	
$Te_{52}^{105} \to Sn_{50}^{101}$	7060725	4635809	6.2E **-7**	20122550	
$Te_{52}^{106} \to Sn_{50}^{102}$	6706758	4281841	7E **- 5**	20914047	
$Nd_{60}^{144} \to Ce_{58}^{140}$	4330143	1905227	7.22E **22**	25338081	
$Sm_{62}^{146} \to Nd_{60}^{142}$	4953406	2528490	2.144E **15**	24112571	
$W_{74}^{180} \to Hf_{72}^{176}$	4932634	2507718	5.676E **25**	25541715	
$Ac_{89}^{225} \to Fr_{87}^{221}$	8360160	5935244	8.64E **5**	24233249	
$Po_{84}^{212} \to Pb_{82}^{208}$	11379039	8954123	2.99E **-7**	23997430	
$Po_{84}^{208} \to Pb_{82}^{204}$	7640207	5215292	9.139E **7**	24903377	
$Po_{84}^{186} \to Pb_{82}^{182}$	10924563	8499647	3.4E **- 5**	24887033	
$Th_{90}^{232} \to Ra_{88}^{228}$	6506486	4081570	4.431E **17**	24807709	
$U_{92}^{238} \to Th_{90}^{234}$	6694834	4269918	1.409E **17**	24868518	
$Pu_{94}^{240} \to U_{92}^{236}$	7680635	5255719	2.0691E **11**	24924865	
$Cf_{98}^{251} \to Cm_{96}^{247}$	8600485	6175569	2.838E **10**	26741089	
$Es_{99}^{253} \to Bk_{97}^{249}$	9164039	6739123	1.769E **6**	25606470	
$Ds_{110}^{270} \to Hs_{108}^{266}$	13534609	11109693	1.6E **- 4**	27149238	
$Mc_{115}^{290} \to Nh_{113}^{286}$	12826674	10401758	6.5E **- 1**	27869547	
$Og_{118}^{294} \to Lv_{116}^{290}$	14233230	11808314	7E **- 4**	28073130	
$Og_{118}^{295} \to Lv_{116}^{291}$	14121451	11696535	1.81E **- 1**	29925143	

As can be seen from the table, the effective mass defect $E_{\Delta m_{effective}}$ is very consistent for Z=60 through Z=99 and starts to gradually increase for Z > 110. For tellurium (Z=52), which is the only pure alpha emitter less than Z=60 (other than beryllium-8), the effective mass defect is still a reasonable value and consistent for the two isotopes of tellurium listed. The vast majority of alpha-emitters of practical interest are in the Z = 60 to Z = 98 range. The effective mass defect starts to increase in the Z = 110 range but the masses for these elements are less well known. It could be speculated that the maximum mass defect available for alpha decay is the value for $E_{\Delta m_{He_2^4}}$ which is $27273692\ eV$ and the half-life values for the super-heavy isotopes could be estimated on this basis. One further observation is that the method predicts that the half-life for oganesson-294 and oganesson-295 should be the same order of magnitude rather than three orders of magnitude different. It is suggested that the value for oganesson-294 is most likely closer to the correct half-life based on the more reasonable effective mass defect relative to darmstadtium-270 and moscovium-290 as shown in the table. As speculated, the super-heavy isotopes may converge on $E_{\Delta m_{He_2^4}} = 27273692$ eV. This a priori mass defect produced an exact result for beryllium-8 suggesting it has theoretical significance. In a certain respect. from this analysis of alpha decay, beryllium-8 seems to behave more like a super-heavy isotope than the more intermediate weight isotopes

6. Conclusion

The existing theory explaining alpha decay is based on a tunneling mechanism. This theory led to the Geiger-Nuttal law. In practice the Geiger-Nuttal law is an empirically fitted equation. It predicts alpha-decay half-lives of heavy isotopes reasonably well for various ranges of atomic number when limited ranges are specifically fitted. The Geiger-Nuttal law does not predict the beryllium-8 half-life. The beryllium-8 decay is contrary to the underlying correlated physical principle of the Geiger-Nuttal law that a smaller alpha particle kinetic energy predicts a longer half-life. Beryllyium-8 has a very short alpha particle kinetic energy and a very short half-life. Because of this contradiction it has been suggested that the decay of beryllium-8 is actually a fission not an alpha decay..

One result of this paper establishes that beryllium-8 is an alpha decay and can be predicted using the same calculational method that is also used for the heavy and in particular super-heavy isotopes. In fact, the calculation for beryllium-8 is a priori exact.

A second result is that the ability to predict the alpha decay half-life a priori and exactly strongly suggests that the beryllium-8 nucleus behaves like a two particle system composed of two helium-4 nuclei. If the alpha decay of beryllium-8 were an n-body problem a relatively simple method would not be able to produce an exact result, in fact a much more complex method most likely wouldn't either.

A third result is that the rest mass of the two extra post alpha decay electrons that are neither associated with the daughter product or the emitted alpha particle is entirely converted to energy and combines with the mass excess of the alpha particle to become the kinetic energy of the emitted alpha particle.

A fourth result is that a strong and systematic correlation parameter exists for the isotopes that undergo alpha decay. The correlation of the isotopes that undergo alpha decay with $E_{\Delta m_{effective}}$ on substituting for $E_{\Delta m_{He_2^4}}$ in the a priori method gives a reliable predictive tool. In fact even without this substitution, the results would be reasonable if the calculation for the heavy and super-heavy isotopes were done a priori. The example of polonium, as indicated in the table, demonstrates that even with many orders of magnitude different half-lives the polonium isotopes correlate well with $E_{\Delta m_{effective}}$.

A fifth result is that the method can be used as a predictive tool for the more difficult to produce and measure isotopes such as oganesson. It should have an $E_{\Delta m_{effective}}$ comparable to darmstadtium and moscovium for example. All the super-heavy isotopes are artificially produced and Darmstadtium and muscovium isotopes are hardly abundant, but the amount of oganesson available for study has only been several atoms..

7. References

[1] H. Geiger and J.M. Nuttall (1911) "The ranges of the α particles from various radioactive substances and a relation between range and period of transformation," Philosophical Magazine, Series 6, vol. 22, no. 130, pages 613-621

[2] G. Gamow, (1928) "Zur Quantentheorie des Atomkernes," Z. Physik, vol. 51, page 204

[3] Fowler, R.H.; Dr. L. Nordheim (1928-05-01). "Electron Emission in Intense Electric Fields," Proceedings of the Royal Society A., vol. 119 (781), pages 173–181

[4] Eite Tiesinga, Peter J. Mohr, David B. Newell, and Barry N. Taylor (2019), "The 2018 CODATA Recommended Values of the Fundamental Physical Constants" (Web Version 8.0). Database developed by J. Baker, M. Douma, and S. Kotochigova. Available at http://physics.nist.gov/constants, National Institute of Standards and Technology, Gaithersburg, MD 20899

[5] Audi, Georges, F. G. Kondev, Meng Wang, W. J. Huang, and S. Naimi. "The NUBASE2016 evaluation of nuclear properties." *Chinese physics C* 41, no. 3 (2017): 030001

[6] Wang, Meng, G. Audi, F. G. Kondev, W. J. Huang, S. Naimi, and Xing Xu. "The AME2016 atomic mass evaluation (II). Tables, graphs and references." *Chinese Physics C* 41, no. 3 (2017): 030003.

8. Acknowledgement

The author would like to thank Dr. Cynthia Powell, formerly Research Director, National Energy Technology Laboratory and currently at the Pacific Northwest National Laboratory for her unwavering encouragement.

9. Disclaimer