Decay Characteristics of Neutron Excess Neon Nuclei

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Abstract

In neutron star mergers, neutron excess nuclei and the r-process are important factors governing the production of heavier nuclear systems. An evaluation of neon nuclei suggests that the heaviest Z = 10 nucleus will have mass 44 with filling of the $2p_{1/2}$ neutron shell. A = 33 – 44 neon isotopes have limited experimental half-life data, but the model predicts beta decay half-lives in the range of 0.635 – 1.97 ms. Based on previous calculations for Z = 9, 20, 26, and 30 systems, these results likely overestimate the half-lives of A = 33 – 44 neutron excess neon nuclei.

1.0 Introduction

The nucleosynthesis of heavy elements occurs by three basic processes that add protons or neutrons to a nuclear system[1,2]. The p-process adds protons and the s- or slow process and r- or rapid process adds neutrons. Capture of protons by nuclear systems produces predominantly proton-rich nuclei that tend to decay by positron emission and electron capture[1,2]. Neutron capture creates neutron-rich nuclei, and the resulting nuclear systems depend upon the rate of neutron addition and the beta decay rates of the residual nuclei.

In the s-process neutron capture chain, the time between successive neutron captures is sufficiently long for the product nucleus to beta decay to a stable system. Within the r-process, the time between neutron captures is too short to permit decays except for very rapid beta transitions. Therefore, the r-process must occur in an environment that has a high density of neutrons. The s-process typically occurs in red giant stars. The r-process occurs in a variety of astronomical events, including supernovae explosions and stellar mergers.

Binary neutron star or neutron star and stellar-mass black hole mergers can form a massive rotating torus around a spinning black hole[1]. The matter ejected from these structures and from supernovae explosions is an important source of rapid neutron capture (r-process) nucleosynthesis[1]. Fully understanding the r-process requires knowledge of the properties of neutron excess nuclei involved in creating heavy nuclear systems. Unfortunately, the majority of these neutron excess systems have never been studied[2].

Closing this knowledge gap was a motivation for funding facilities for rare-isotope beams constructed at research facilities located around the world. These facilities are located at RIKEN (Japan)[3,4], GSI

(Germany)[5], and Michigan State University (US)[6]. These facilities enable a new class of experiments to determine the physical properties needed by theoretical models of the structure of unstable neutron excess nuclei. Theoretical studies would complement the forthcoming experiments that will provide critical information on the unstable nuclei that must be understood in order to explain nuclear abundances observed in the universe[2]. In particular, the study of neutron excess systems and their decay properties are significant considerations in understanding the r-process, and its importance in producing the observed elements in the universe.

The study of neutron excess systems is also important for studying nuclear decay properties, nuclear structure under extreme conditions, and nuclear reaction mechanisms. Existing theoretical models have not been extensively applied to many of these neutron excess nuclei.

This paper attempts to partially fill this void by calculating the decay properties of neutron excess systems that are important in nucleosynthesis. These theoretical studies should also assist in planning future experiments associated with neutron excess systems that are far removed from the line of stability.

Neutron excess nuclei that merit study occur throughout the periodic table[2-7] including nuclei in the $Z \leq 32$ range[7]. Although neutron excess nuclei occur throughout the periodic table, this paper focuses on neon systems as part of a continuing investigation of neutron excess nuclei that are of potential astrophysical significance. Previous publications addressed neutron excess calcium[8], iron[9], fluorine[10], and zinc systems[11].

The study of light nuclear systems including neon is important for a comprehensive astrophysical interpretation of nucleosynthesis. For example, Terasawa et al. [12] studied the role of light neutron-rich nuclei during r-process nucleosynthesis in supernovae.

In the neighboring fluorine systems, Recio-Blanco et al. [13] noted the importance of these nuclei in nucleosynthesis, but observed that knowledge of excess neutron Z=9 systems and their associated properties are not well established. Mowlavi et al. [14] also investigated the nucleosynthesis of fluorine with a focus on asymptotic giant branch stars. Ref. 1 noted that most previous studies of the r-process have concentrated on the synthesis of heavy unstable nuclei. However, in extreme environments such as those encountered in a supernova, light-mass nuclei are also expected to provide an important role in the production of r-process elements. Specifically, Ref. 12 noted that light neutron excess systems can significantly affect the heavy-element abundances.

A recent study of fluorine isotopes in intermediate-mass stellar systems[15,16] concluded that oxygen fusion could occur at lower densities than initially assumed. This result suggests that intermediate-mass stars are more likely to encounter thermonuclear excursion rather than undergoing gravitational collapse. The resulting white dwarf stars would predominantly contain oxygen, neon, and magnesium. This result was a direct consequence of the nuclear structure of ^{20}F, and its influence on the beta decay to the ^{20}Ne system[15,16]. Refs. 15 and 16 further support the study of neutron excess neon systems in understanding the nucleosynthesis of heavier elements.

Additional neutron excess systems in neon and neighboring nuclei were conducted by fragmentation of

345 MeV/nucleon ^{48}Ca ions at the RIKEN Radioactive Isotope Beam Factory[17]. No events were observed for ^{32,33}F, ^{35,36}Ne, and ^{38}Na and only one event for ^{39}Na after extensive investigation. Ref. 17 suggests that ^{31}F and ^{34}Ne are the heaviest bound isotopes of fluorine and neon, respectively. The calculations summarized in this paper suggest that neon nuclei more massive than ^{34}Ne could exist.

An et al.[18] perform a theoretical study of Z = 8 - 12 isotopes in the relativistic mean field model. Ref. 18 notes that the last bound neutron-rich nuclei with Z = 8, 9, 10, 11, and 12 varies with the theoretical models with upper limit mass values of 28, 33, 43, 45, and 46, respectively. The neon A = 43 mass limit is close to the predictions of this paper.

2.0 Calculational Methodology

A variety of models could be applied to the investigation of neutron excess nuclei. These vary in sophistication, but the proposed model utilizes a basic single-particle approach. This is a reasonable first step because there are uncertainties in the nuclear potential that likely are more significant than the limitations introduced by a single-particle approach.

Since the method for calculating single-particle energies in a spherically symmetric potential is well-established only salient features are provided. The model used to describe the particle plus core system represents an application of the standard method of Lukasiak and Sobiczewski[19] and Petrovich et. al.[20]

The binding energy E_{NLSJ} of a particle in the field of a nuclear core is obtained by solving the radial Schrödinger Equation

$$\left[\frac{h^2}{2(2\pi)^2\mu}\left(\frac{d^2}{dr^2}-\frac{L(L+1)}{r^2}\right)-E_{NLSJ}-V_{LSJ}(r)\right]U_{NLSJ}(r)=0 (1)$$

where r is the radial coordinate defining the relative motion of the nuclear core and the particle; $V_{LSJ}(r)$ is the model interaction; E_{NLSJ} is the core plus particle binding energy; $U_{NLSJ}(r)$ is the radial wave function; and L, S, and J are the orbital, spin, and total angular momentum quantum numbers, respectively. The N quantum number is the radial quantum number, and μ is the reduced mass.

The method of searching for E_{NLSJ} is provided by Brown, Gunn, and Gould[21], and the methodology of Ref. 22 is utilized to obtain a converged solution. Refs. 8 - 11, and 20 provide a more complete description of the model, its numerical solution, and further definition of the individual terms appearing in Eq. 1.

3.0 Nuclear Interaction

Nuclear stability with respect to alpha decay, beta decay, positron decay, and electron capture is addressed using the method previously published by the author and coworkers[20] that is similar to the approach of Ref. 23. The single-particle level spectrum is generated using a Woods-Saxon potential. Parameters of the potential are obtained from a fit to the particle levels in ^{209}Pb and ^{209}Bi performed by Rost[24]. The central potential strength of the Rost interaction[24] has a standard form and can be explicitly defined as

$$V_0 = 51.6\left[1 \pm 0.73\frac{N-Z}{A}\right]MeV \quad (2)$$

where the upper (lower) sign applies to protons (neutrons). The remaining parameters were held constant and are given by Rost[24]: r_0 = 1.262 (1.295) fm, r_{so} = 0.908 (1.194) fm, a = 0.70 (0.70) fm, and γ = 17.5 (28.2) for protons (neutrons) [20, 24]. V_{so} is related to γ by the relationship[24]:

$$V_{so} = \frac{\gamma V_0}{180} \quad (3)$$

The scaling relationship of Eq. 3 yields reasonable fits to observed single-particles levels in ^{120}Sn and ^{138}Ba. The pairing correction term of Blomqvist and Wahlborn[25] is used in the calculations presented herein. The pairing correction improves the predicted energies of occupied levels in ^{120}Sn, ^{138}Ba, and ^{208}Pb[20].

When applied to specific nuclei, this methodology requires modification. For example, Ray and Hodgson[26] note that ^{40}Ca and ^{48}Ca require different potentials to properly fit their single-particle level structure. Schwierz, Wiedenhöver, and Volya[27] also investigated ^{40}Ca and ^{48}Ca and noted that a proper fit to the single-particle levels required a different potential for each energy level. Difficulties in the selection of an appropriate potential is an additional motivation for the utilization of single-particle levels and was noted in studies of neutron excess calcium[8], iron[9], fluorine[10], and zinc[11] nuclei. Similar issues also apply to neon systems.

In view of the results of Refs. 26 and 27, the following modification is made to obtain the neon potential strength (V_A):

$$V_A = 51.6\lambda\left[1 \pm 0.73\frac{N-Z}{A}\right][1 \pm a(A)]MeV \quad (4)$$

where λ is a potential strength multiplier that is selected to ensure consistency with available data, and a(A) is a constant that is introduced to account for the variations in potential strength with A[26, 27]. In previous excess neutron nuclei calculations for calcium[8], iron[9], and zinc[11], a value of λ = 1.0 was utilized. A λ value of 1.5 for fluorine[10] was determined by the available experimental data[28, 29]. Given the proximity of fluorine, a value of λ = 1.5 is also utilized for neon. Since the paper's primary purpose is investigation of the neutron excess nuclei, determining a common a(A) value for the heaviest neon systems is desirable.

The heaviest mass A = 10 isotope[28, 29] suggested experimentally is ^{32}Ne. Given the expected order of energy levels, ^{32}Ne would have a $1f_{7/2}$ neutron single-particle level structure. Isotopes heavier than ^{32}Ne would require filling of the $1f_{7/2}$ and the more weakly bound $2p_{3/2}$ and $2p_{1/2}$ neutron single-particle levels. The possibility of bound neon isotopes with A ≥ 32 is addressed in subsequent discussion.

Calculations incorporated into the Japanese nuclear data compilation[30] provide a calculated half-life for

^{34}Ne. Ref. 18 suggests that the last bound neutron-rich neon nucleus has a value of A = 43.

4.0 Calculation of Half-Lives

Using Eq. 4, single-particle levels are calculated for A ≥ 17 neon isotopes. A ≥ 17 neon nuclei were evaluated for stability with respect to alpha decay, beta decay, positron decay, and electron capture. These calculations were performed to ensure that the nuclear structure contained no interloping states or structural defects, and that any decay modes in conflict with data were identified.

The decay modes and half-lives of 44 ≥ A ≥ 17 neon isotopes are summarized in Table I and compared to available data[28, 29] and calculations incorporated in the Japanese data compilation[30]. The alpha decay energies are calculated using the relationship based on Ref. 31

$$Q_\alpha = 28.3MeV - 2S_n - 2S_p (5)$$

where S_n and S_p are the binding energies of the last occupied neutron and proton single-particle levels, respectively. Alpha decay half-lives can be estimated from Q_α using standard relationships[19]. Fortunately, no alpha decay modes occurred in the Table I summary of 44 ≥ A ≥ 17 neon isotope decay properties.

The beta decay half-lives are determined following the log ft methodology of Wong[31]. Allowed (first forbidden) transition half-lives were derived using the values of log ft = 5 (8). Given the uncertainties in the calculated level energies, second and higher order forbidden transitions were not determined. Positron and electron capture half-lives were determined following the approach of Ref. 19.

5.0 Model Issues

Spherical single-particle energy calculations produce reasonable results for alpha, beta, positron, and electron capture transitions[8-11,23-27]. However, these calculations are not expected to accurately model the very short-lived double proton decay mode of ^{16}Ne[28,29]. Since ^{16}Ne is far removed from the neutron excess neon isotopes of interest in this paper, they are not addressed. In addition, very heavy neon isotopes have the potential to decay via neutron emission modes. However, these decays have not been observed[28-30]. The single-particle model is not the best approach for neutron emission calculations, and these decay modes are not included in this paper. Therefore, the results for the heaviest neutron excess nuclei only include the alpha decay, beta decay, positron decay, and electron capture modes.

Except as noted previously, the single-particle model should provide reasonable results for the systems considered in the paper. Since the focus of this paper is the more massive neon nuclei, single-particle methods provide the desired results for the most important nuclei considered in this study, and their decay via the alpha decay, beta decay, positron decay, and electron capture pathways.

6.0 Results and Discussion

Using Eq. 4, the a(A) value was varied in increments of 0.001 - 0.005 to assess the applicability of the proposed model to predict the decay properties of most 44 ≥ A ≥ 17 neon isotopes. In view of uncertainties in the model and associated interaction, a smaller increment was not deemed to be justified for most neon systems. However, for nuclei that have half-lives that deviate from stability trends in neighboring systems, a smaller increment was utilized. For example, a(A) was adjusted in increments of 0.00001 for the stable ^{20}Ne, ^{21}Ne, and ^{22}Ne systems.

The issues associated with fitting all calcium, iron, fluorine, and zinc nuclei with a single potential[26, 27] were noted in Refs. 8-11. These considerations are also applicable to the neon systems considered in this paper.

Table I summarizes the complete set of 44 ≥ A ≥ 17 isotopes considered in this paper. The lighter 32 ≥ A ≥ 17 fluorine isotopes fill the $1p_{1/2}$ (^{17}Ne and ^{18}Ne), $1d_{5/2}$ (^{19}Ne – ^{24}Ne), $2s_{1/2}$ (^{25}Ne and ^{26}Ne), $1d_{3/2}$ (^{27}Ne – ^{30}Ne), and $1f_{7/2}$ (^{31}Ne and ^{32}Ne) neutron single-particle levels. These systems are the heaviest neon systems noted in Ref. 28. ^{31}Ne and ^{32}Ne partially fill the $1f_{7/2}$ neutron single-particle shell. Given the extrapolation used in formulating the single-particle potential of Eq. 4, the results become more uncertain due to the paucity of data for A>32 neon isotopes. The heavier 44 ≥ A ≥ 33 neon isotopes that complete the $1f_{7/2}$, and fill the $2p_{3/2}$, and $2p_{1/2}$ neutron single-particle levels are also summarized in Table I. These systems represent the heaviest possible neutron excess systems that would occur in the Z=10 system.

Table I

Calculated Single-Particle and Experimental Decay Properties of Neon Systems with 17 ≤ A ≤ 44

Nuclide	a(A)	Half-Life (Decay Mode)[a,b]	
		Experiment	This Work
^{17}Ne	+0.005	109 ms (β^+)[a]	108 ms (β^+)[c]
^{18}Ne	+0.055	1.667 s (β^+)[a]	1.69 s (β^+)[c]
^{19}Ne	+0.051	17.22 s (β^+)[a]	17.1 s (β^+)[c]
^{20}Ne	+0.06003	Stable[a]	Stable
^{21}Ne	+0.02149	Stable[a]	Stable
^{22}Ne	-0.01347	Stable[a]	Stable
^{23}Ne	-0.008	37.1 s (β^-)[a]	37.9 s (β^-)[d]
^{24}Ne	-0.050	3.38 min (β^-)[a]	3.33 min (β^-)[d]
^{25}Ne	+0.003	0.61 s (β^-)[a]	0.601 s (β^-)[d]
^{26}Ne	+0.011	197 ms (β^-)[a]	197 ms (β^-)[d]
^{27}Ne	+0.015	31 ms (β^-)[a]	30.8 ms (β^-)[e]
^{28}Ne	+0.020	19.9 ms (β^-)[a]	20.1 ms (β^-)[e]
^{29}Ne	+0.016	15.6 ms (β^-)[a]	15.6 ms (β^-)[e]
^{30}Ne	+0.062	6.3 ms (β^-)[a]	6.36 ms (β^-)[e]
^{31}Ne	+0.110	3 ms (β^-)[a]	3.00 ms (β^-)[e]
^{32}Ne	+0.066	4 ms (β^-)[a]	4.02 ms (β^-)[e]
^{33}Ne	+0.119	[f]	1.97 ms (β^-)[e]

Table I (Continued) Calculated Single-Particle and Experimental Decay Properties of Neon Systems with 17 ≤ A ≤ 44			
Nuclide	a(A)	Half-Life (Decay Mode)[a,b]	
		Experiment	This Work
^{34}Ne	+0.119	1.70 ms (β^-)[b]	1.70 ms (β^-)[e]
^{35}Ne	+0.119	[f]	1.49 ms (β^-)[e]
^{36}Ne	+0.119	[f]	1.32 ms (β^-)[e]
^{37}Ne	+0.119	[f]	1.18 ms (β^-)[e]
^{38}Ne	+0.119	[f]	1.06 ms (β^-)[e]
^{39}Ne	+0.119	[f]	0.960 ms (β^-)[e]
^{40}Ne	+0.119	[f]	0.872 ms (β^-)[e]
^{41}Ne	+0.119	[f]	0.801 ms (β^-)[e]
^{42}Ne	+0.119	[f]	0.736 ms (β^-)[e]
^{43}Ne	+0.119	[f]	0.682 ms (β^-)[e]
^{44}Ne	+0.119	[f]	0.635 ms (β^-)[e]

[a]Ref. 28.
[b]Ref. 30, based on calculations.
[c]Allowed $1d_{5/2}$(p) to $1d_{5/2}$(n) positron decay transition.
[d]Allowed $1d_{5/2}$(n) to $1d_{5/2}$(p) beta decay transition.
[e]Allowed $1d_{3/2}$(n) to $1d_{5/2}$(p) beta decay transition.
[f]No data provided in Refs. 28 – 30.

The neutron excess systems summarized in Table I were based on an evaluation of alpha, beta, electron capture, and positron decay modes. Other decay modes that could possibly occur in neutron excess systems (e.g., n and 2n) are not readily evaluated using a single particle model, and were not evaluated. The results of Table I must be viewed with this limitation. However, since the neutron and proton decay modes tend to be much shorter than the alpha, beta, electron capture, and positron decay modes[28, 29], the model results provide upper bounds on the half-lives of neutron excess neon isotopes.

6.1 32 ≥ A ≥ 17 Neon Isotopes

The ^{17}Ne and ^{18}Ne systems fill the $1p_{1/2}$ neutron shell and were best fit with a(A) values of 0.005 and 0.055, respectively. As noted previously, ^{16}Ne was not evaluated since this nucleus decays by double proton emission that is not readily evaluated using the single-particle approach utilized in this paper.

^{19}Ne to ^{24}Ne systems were best fit with a(A) values between -0.05 and about 0.06 with an average value of about 0.01. The ^{19}Ne to ^{24}Ne nuclei fill the $1d_{5/2}$ neutron shell. ^{25}Ne and ^{26}Ne fill the $2s_{1/2}$ neutron shell and are best fit with a(A) values of 0.003 and 0.011, respectively with an average value of 0.007.

^{27}Ne to ^{30}Ne systems were best fit with a(A) values between 0.015 and 0.062 with an average value of about 0.028. The ^{27}Ne to ^{30}Ne nuclei fill the $1d_{3/2}$ neutron shell.

The heaviest known neon neutron excess systems (i.e., ^{31}Ne, and ^{32}Ne) partially fill the $1f_{7/2}$ neutron shell.

There is no experimental half-life data for A > 32 neon systems.

The ^{31}Ne, and ^{32}Ne systems were best fit with a(A) values of 0,110 and 0.066, respectively with an average value of about 0.088. This average value for the heaviest known neon systems is smaller than the limiting values noted for calcium (0.090)[8], iron (0.115)[9], fluorine (0.115)[10], and zinc (0.095)[11]. To determine a limiting value for neon, the Japanese data compilation[30] was utilized for the ^{34}Ne system. The ^{34}Ne value is used to extrapolate the half-lives of ^{33}Ne and heavier neon nuclei. The selected value of 0.119 is similar to the 0.115 value utilized in the neighboring fluorine system[10].

Table I lists the half-life of the limiting beta decay transition (i.e., the transition that has the shortest beta decay half-life). For example, ^{26}Ne has six beta decay transitions that are possible within the scope of the aforementioned single-particle model (i.e., allowed $1d_{5/2}$(n) to $1d_{5/2}$(p) [197 ms], allowed $1d_{5/2}$(n) to $1d_{3/2}$(p) [2.30 s], allowed $2s_{1/2}$(n) to $2s_{1/2}$(p) [265 ms], first forbidden $1p_{3/2}$(n) to $1d_{5/2}$(p) [3.96 d], first forbidden $1p_{1/2}$(n) to $1d_{5/2}$(p) [1.93 h], and first forbidden $1p_{1/2}$(n) to $2s_{1/2}$(p) [75.0 d] transitions). For ^{26}Ne, the limiting beta decay mode is the allowed $1d_{5/2}$(n) to $1d_{3/2}$(p) [197 ms] transition.

As noted in Table I, the model predicts the proper decay mode for the known 32 ≥ A ≥ 17 neon nuclei[28]. The results for the known systems summarized in Table I suggest that the model predictions of the neutron excess neon systems are reasonably credible. For Z = 10 systems filling the $1p_{1/2}$ shell, the ^{17}Ne and ^{18}Ne positron decay half-lives are underestimated by about 0.9 % and 1.4 %, respectively. Both systems decay by an allowed $1d_{5/2}$(p) to $1d_{5/2}$(n) positron decay transition.

For nuclei filling the $1d_{5/2}$ neutron shell, model predictions for ^{19}Ne, ^{23}Ne, and ^{24}Ne are within about 2 % of the experimental positron or beta decay half-lives[28]. ^{20}Ne, ^{21}Ne, and ^{22}Ne are correctly determined to be stable systems. ^{19}Ne decays by an allowed $1d_{5/2}$(p) to $1d_{5/2}$(n) positron decay transition. The ^{23}Ne and ^{24}Ne systems decay by an allowed $1d_{5/2}$(n) to $1d_{5/2}$(p) beta decay transition.

The $2s_{1/2}$ systems, ^{25}Ne and ^{26}Ne, are within 2% of their respective experimental beta decay half-lives[28]. Both ^{25}Ne and ^{26}Ne decay by an allowed $1d_{5/2}$(n) to $1d_{5/2}$(p) beta decay transition.

^{27}Ne, ^{28}Ne, ^{29}Ne, and ^{30}Ne fill the $1d_{3/2}$ neutron shell. The ^{27}Ne, ^{28}Ne, ^{29}Ne, and ^{30}Ne systems decay by an allowed $1d_{3/2}$(n) to $1d_{5/2}$(p) beta decay transition, and their beta decay half-lives are within 1% of the measured values[28].

The $1f_{7/2}$ systems, ^{31}Ne and ^{32}Ne, are within 1% of their respective experimental beta decay half-lives[28]. Both ^{31}Ne and ^{32}Ne decay by an allowed $1d_{3/2}$(n) to $1d_{5/2}$(p) beta decay transition. These are the heaviest neon nuclides that have measured decay half-life values and beta decay transition information[28].

6.2 44 ≥ A ≥ 33 Neon Isotopes

As noted in the previous section, the limiting a(A) value of 0.119 was derived from the Japanese data compilation (best calculated value) from ^{34}Ne. This a(A) value was used for all 44 ≥ A ≥ 33 neon systems.

Table I also summarizes calculated single-particle and available experimental decay properties of neon systems with 44 ≥ A ≥ 33. Although experimental data for 44 ≥ A ≥ 33 neon systems are not available[28-30], these are nuclei of interest in astrophysical applications[1-7, 12-16].

The existence of $44 \geq A \geq 33$ neon systems as predicted by the proposed model is dependent on the characteristics of the interaction of Eq. 4. Although the existence of some of these systems may be an artifact of the model interaction, their study is of critical importance to understanding the role of neutron excess neon systems in nucleosynthesis.

The ^{33}Ne – ^{38}Ne systems complete filling the $1f_{7/2}$ neutron single-particle energy level. These systems have beta decay half-life values that decrease from 1.97 to 1.06 ms, respectively. Although no data is available for the ^{33}Ne – ^{38}Ne systems, the calculated beta decay half-life for ^{34}Ne is 1.70 ms in agreement with the calculations of Ref. 30. The ^{33}Ne – ^{38}Ne systems decay through an allowed $1d_{3/2}$(n) to $1d_{5/2}$(p) beta decay transition.

The ^{39}Ne – ^{42}Ne systems fill the $2p_{3/2}$ neutron shell. These systems also decay through an allowed $1d_{3/2}$(n) to $1d_{5/2}$(p) beta decay transition. The ^{39}Ne – ^{42}Ne beta decay half-lives decrease from 0.960 to 0.736 ms, respectively.

The ^{43}Ne and ^{44}Ne systems fill the $2p_{1/2}$ neutron shell. In a similar manner, these systems decay through an allowed $1d_{3/2}$(n) to $1d_{5/2}$(p) beta decay transition. The ^{43}Ne and ^{44}Ne half-lives are 0.682 and 0.635 ms, respectively.

No neon isotopes with $A > 44$ are predicted by the model. This occurs because the $2p_{1/2}$ neutron single-particle level is the last bound neutron state, and only 34 neutrons are bound in neon systems. However, in view of the model potential uncertainties, the calculated properties of the heaviest neon systems summarized in Table I are not definitive.

The predicted A = 33 – 44 neon isotopes have no experimental half-life data, but the model predicts beta decay half-lives in the range of 0.635 – 1.97 ms. Based on calculations in Z = 9, 20, 26, and 30 systems[8-11], these results likely overestimate the beta decay half-lives of these neutron excess neon nuclei. The model results are also likely to be an overestimate of the half-lives because the single-particle level calculations do not evaluate the short-lived neutron decay modes in the A = 33 – 44 neon nuclei.

7.0 Conclusions

Single-particle level calculations suggest that neutron excess neon isotopes terminate with ^{44}Ne and filling of the $2p_{1/2}$ neutron single-particle level. The $33 \leq A \leq 44$
neon systems have predicted beta decay half-lives in the 0.635 – 1.97 ms range, and likely overestimate the actual half-life values.

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