The Effect of Isospin on Nuclear Temperature in the *sd*-Space

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INTRODUCTION

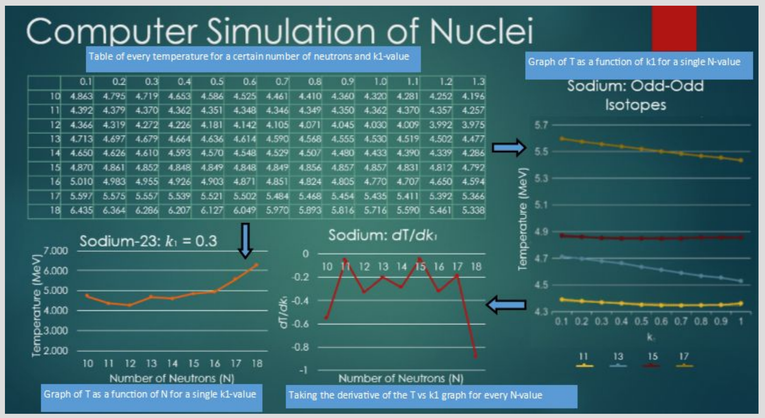
Nucleons (protons and neutrons) can be excited to a quantized energy level in a nuclear reaction just like electrons in a chemical reaction. The number of these quantized energy levels, E, per unit of energy, N, is known as the **level density**, $\rho(E)$.

- *$\rho(E)$=dN/dE. As E increases, so does the level density.*
- *Measuring sd-nuclei - from 8-20 nucleons.*
- *Exponential approximation of a bell curve function:*
- *$\rho(E)= e^{((E-E0)/T)}/T$. Effective Temperature T measures chaotic nuclear motion*

In realistic situations, two trends exist: staggering of the temperatures of odd-neutron and even-neutron nuclei, and a minimum temperature value at the number of neutrons equaling the number of protons. We attempt to determine what types of particle interactions are responsible for these trends.

RESEARCH METHODOLOGIES

1. We split a matrix of 63 particle interactions, with an amount of energy associated with each one, into 33 "Isospin-0" (proton-neutron) interactions and the remaining "Isospin-1" interactions. We hold one type of interaction constant, then multiply the energy associated with the other by 0, 0.1, 0.2, 0.3…..1.
2. Every nucleus at every interaction constant is run through NuShellX, which outputs a list of level densities.
3. From this list of level densities, one can use a program in mathematica to create the parameters E0 and T that best fit the values of E and ρ(E) by using the Least Square Regression method.
4. The E0 value is simply a shift of the graph representing ground state energy and is therefore ignored. With the temperature values, we graph the following:
   a. temperature as a function of the interaction constant for a given nucleus
   b. first derivative of the above for a given element
   c. temperature as a function of number of neutrons for a given element and interaction constant
5. Using these values, we can determine a correlation between a type of interaction and observed trends.



DATA AND FINDNGS

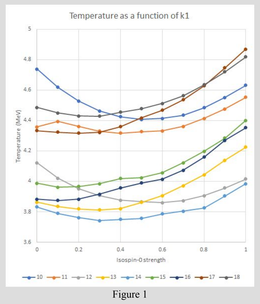


Figure 1

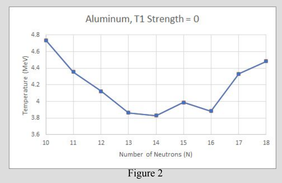


Figure 2

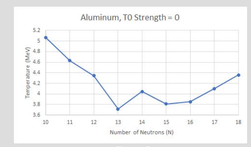


Figure 3

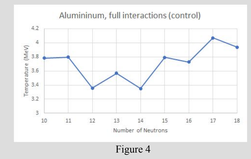


Figure 4

- Prior results show that pairing interactions are responsible for the minimum at N=Z, while they are not responsible for the staggering of the temperatures.
- Unlike separating the interaction matrix into pairing and non-pairing interactions, separating the matrix based on isospin has less valuable impact on the trends:
  a. Isolating the effect of either interaction (when the other's strength is 0) creates no staggering pattern (Figures 2, 3).
  b. There is a minimum at N=Z for when the isospin-1 interactions are isolated, but not the expected one at N=Z+1 or N=Z-1 (Figure 3).
  c. Relationship of Temperature with respect to the interaction strength is not linear, but instead is parabolic (Figure 1), and therefore taking the first derivative would be of no use.

DISCUSSION, ANALYSIS, AND EVALUATION

- **Staggering of the Temperatures**
  - Regardless of the type of particle interaction, dampening the effects of the interaction will cause there to be less of the staggering effect visible in the graph.
  - Therefore, as each type of interaction is actually a set of 30+ individual interactions, we can't say anything specific about what the type of interaction will do to the staggering of the nuclei.
- **Minimum at N=Z or N=Z +/- 1**
  - We could see that by isolating only the isospin-0 nuclei, the minimum existed at N=Z+1 for aluminum and N=Z for magnesium. That was not true when we isolated isospin-1 nuclei.
  - This means that only the proton-neutron interactions are responsible for the minimum.
- **Evaluation of Isospin Test**
  - Though it was a logical follow-up after the pairing test, it did not result in the valuable information we expected.

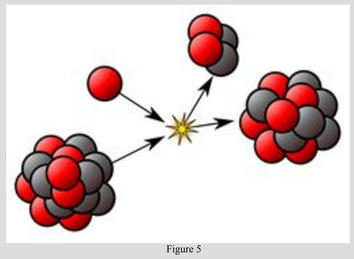


Figure 5

CONCLUSIONS, IMPLICATIONS, AND NEXT STEPS

Prior Research: Pairing v. Non-Pairing Interactions. Valuable trend implications.

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Current Research: Similar Target - Isospin-1 vs. Isospin-0. Very few trend implications .

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Next Step: Re-examine current research. Compare results from different values of nuclear angular momentum.

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Future Research: Examine other types of particle interactions - nucleus-deforming and spherical.

↓

Expand findings beyond *sd*-nuclei, as reactions that involve *p*, *f*, and other orbitals are also important

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Ultimate Goal: Create a mathematical model that can predict any level density curve for any nucleus.

ACKNOWLEDGEMENTS / REFERENCES

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References

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