^{106}Sg, ^{107}Bh and ^{108}Hs çekirdekleri için Alfa Bozunum Enerjilerinin Belirlenmesi

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Özet. Hem teorik hem de deneysel bakış açısıyla, super ağır bölgenin özelliklerini anlamak için, buradaki çekirdeklerin alfa bozunum özelliklerini incelemek oldukça ilgi çekicidir. Nükleer fizikteki pek çok olguda başarılı sonuçlar veren yapay sinir ağları (YSA), super ağır çekirdeklerin deneysel alfa bozunum enerjileri üzerinde kullanılmış ve Sg, Bh ve Hs çekirdeklerinin alfa bozunum enerjileri bu yöntemle tahmin edilmiştir. Farklı modeldeki YSA'lar veriler üzerinde test edilmiştir. Bu çalışmanın sonuçları, YSA metodunun bu iş için uygun olduğunu göstermektedir. Sonuçlara ait ortalama kare hatalar, ½1-1,5 civarındadır. En iyi sonuçlar, bulanık mantık YSA modeli ile elde edilmiştir.

Anahtar Kelimler: Alfa bozunum enerjisi, super ağır çekirdekler, yapay sinir ağları

Determination of Alpha Decay Energies for ^{106}Sg, ^{107}Bh and ^{108}Hs nuclei

Abstract. Alpha decay properties of superheavy nuclei are challenging for understanding the properties of superheavy region from both theoretical and experimental side. Artificial neural network (ANN) which is successful in many phenomenon of nuclear physics has been employed for the experimental alpha decay energy data of superheavy nuclei in order to estimate unknown alpha decay energies for Sg, Bh and Hs nuclei. Different models of the ANN have been tested on the data. The results of the present study indicate that ANN is capable in this task. The mean square erros for the estimations are about 1-1.5%. The best result have been obtained by using fuzzy logic ANN model.

Keywords: Alpha decay energy, super heavy nuclei, artificial neural networks

1. INTRODUCTION

Investigation of superheavy nuclei beyond Fermium is one of the challenging topics in nuclear physics. Understanding of the structure and properties of the super heavy nuclei in super heavy region can provide significant information for the area of existing nuclei and chemical elements. Many nuclear research center have started preparing experiments for the synthesising super heavy elements since 1970. Some of them have been stimulated, such as $Z = 107\text{-}112$ at GSI [1-3], $Z = 110\text{-}113$ at RIKEN [4,5] and $Z = 113\text{-}118$ at Dubna [6-8]. The properties of the super heavy nuclei have been studied by using various nuclear models, such as the macroscopic-microscopic models, Skyrme-Hartree-Fock and relativistic mean field models [9,10]. For many super heavy nuclei alpha decay is main decay mode. The investigation of the properties of the super heavy nuclei is interesting for determination of the island of stability of these nuclei. So it

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is possible understanding new features of the nuclear structure. Alpha decay is a radioactive emission of alpha particle from the nuclei. This particle which is the hellium nucleus consists of two protons and two neutrons and is very stable nuclei due to it is doubly magic property. The theory of alpha decay was firstly interpreted as a consequence of quantum penetration of alpha particle by Gamow [11] in 1928.

In recent years, ANN has been used in many fields in nuclear physics [12,13], such as, discrimination between neutron and gamma-rays [14], developing nuclear mass systematic [15], estimating beta decay half-lives [16], beta decay energies [17], investigating two-photon Exchange effect [18], determination of gamma dose rates [19], determination and mapping the spatial distribution of radioactivity of natural spring water [20] and obtaining nuclear charge radii [21].

2. ARTIFICIAL NEURAL NETWORK (ANN)

ANN is a nonlinear mathematical method that mimics the human brain functionality [22]. It consists of several processing units called neurons. The neurons have adaptive synaptic weights. ANN is very powerful tool which can be used when standard techniques fail to estimate the correlation between the data. The layered feed-forward ANN consist of input, hidden and output layers. In each layers, there are neurons. Input layer neurons reveive the data from environment and the output layer neurons give the result as close as to the desired ones. The number of the neurons in these layers depend on the problem variables. There is no rule for the number of the hidden layer and neuron. Generally one hidden layer is enough for all type of the problem. The number of tne neurons in this layer differs to the problem nature.

ANN is composed of two main stages. These are training and test stages. The whole data belonging to the problem is divided into two part. One of them is used for the training and the other is used for the test. In this study, 80% and 20% of the data was used for the training and the test, respectively. In the training stage, the weights are adjusted to construct ANN by using the known problem data for training. Because of this, the weights play an important role for solving the problem. This stage continues until the acceptable error level reached. The error is calculated by the difference between desired and the ANN outputs. This is done by using mean square error (MSE) formula given below.

$$MSE = \frac{1}{N} \sum_{i=1}^{N} (D_i - O_i)^2$$

Where D_i and O_i are desired and estimated results, N is the total number of data points. After the succesful construction, ANN have been tested on the test data in the test stage by using the weights. The data used in this stage is new for the ANN. If the constructed ANN by the weights gives the result well for the test data, one can confidently says that ANN have generalized the data.

In this study, one input layer with three neurons, one output layer with one neuron has been used. The input neurons correspon to the neutron number (N), proton number (Z) and mass number (A) of the superheavy nuclei (Fig.1).
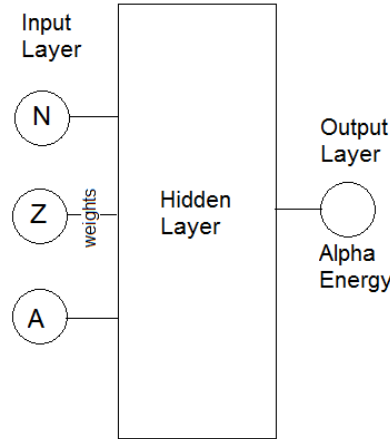

Figure 1. Three input and one output neuron ANN topology.

The aim of the work is to obtain alpha decay energies of the superheavy nuclei, Therefore, the output neuron gives this energy values for the selected superheavy nuclei, Sg, Bh and Hs. Except for these nuclei, the other superheavy ones have been used for the training. After adjusting the weights of the ANN by these nuclei, the alpha decay energy estimations have been tested on the Sg, Bh and Hs. Different model of neural network have been used for the comparison of the result. Among these models, multilayer perceptron neural network [22] with hidden layer neuron numbers 4, 6 and 10, modular neural network [23] with hidden layer number 2 and fuzzy logic (canfis) neural network [24] with bell type membership function and TSK fuzzy model have given the results better. The type of hidden neuron activation function was hyperbolic tangent. The

learning rule was Levenberg-Marquardt [25,26] algorithm. In the present study, neural network software NeuroSolutions v6.02 [27] has been used for the calculations.

3. RESULTS and DISCUSSION

Different model of neural networks have been used for the estimation of alpha decay energies of the super heavy Sg, Bh and Hs nuclei. The better results have been obtained by using multilayer perceptron (MP), modular and fuzzy logic types. In the training of the ANN, the nuclei with Z number between 100 and 117 except 106, 107 and 108 have been used. After adjusting the weights by using this data, the estimations have been performed on Sg, Bh and Hs. As can be seen in the Fig.1 that the constructed ANN have been first tested on the training data. For the MP ANN, several hidden neuron number (h) has been tried. The best results have been obtained for h=4, 6 and 10. In Fig.2a-c, the results for different neuron numbers have been shown. The MSE values are 0.148, 0.124 and 0.079 MeV for h=4, 6 and 10. On the training data set, the minumum MSE value has been obtained for h=10 among the MP ANN results. For modular ANN, the results has been shown in Fig.2.d. The MSE value is 0.0084 MeV which is the smallest one in this study for the training data. For fuzzy logic ANN, the results has been shown in Fig.2.e. The MSE value is 0.180 MeV which is the maximum deviation from the desired results.
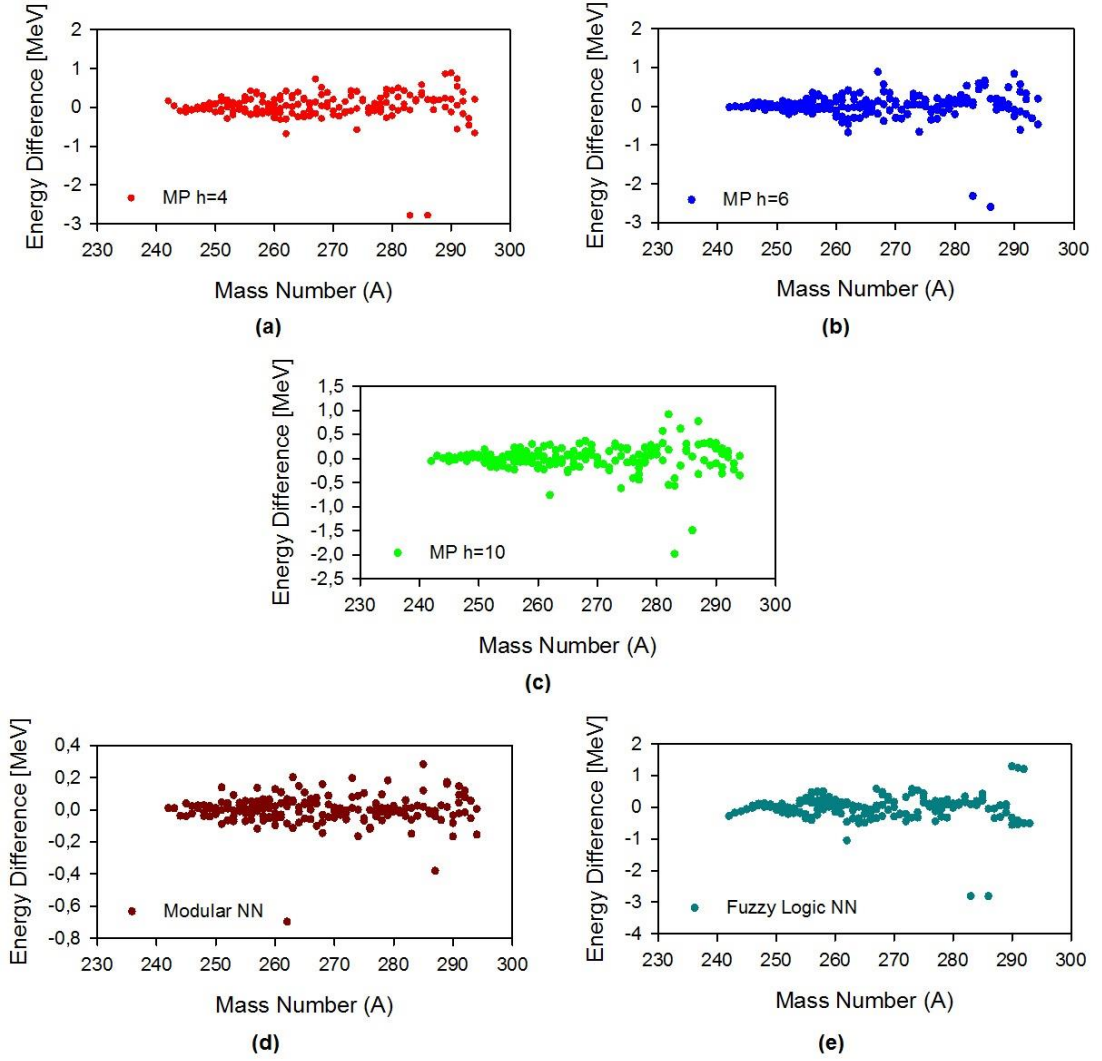
Figure 2. Difference between experimental and ANN estimated alpha decay energies for MP ANN h=4 (a), h=6 (b), h=10 (c), modular ANN (d) and fuzzy logic ANN (e).

In the test stage, the constructed ANN has been tested on the new data named as test data. The MSE values are 0.089, 0.110, 0.138, 0.089 and 0.067 MeV for MP h=4, h=6, h=10, modular and fuzzy logic ANN, respectively. The minimum deviation from the experimental values has been obtained by fuzzy logic model for the test data. The maximum deviations for MP h=4, h=6, h=10, modular and fuzzy logic ANN are 0.51, 0.67, 0.94, 0.67 and 0.55 MeV, respectively.

In Fig.3, the estimation has been shown for Sg nuclei. As can be clearly seen in the figure that the closest results to experimental values are for fuzzy logic ANN. The MSE value for this model of ANN is 0.068 MeV for Sg nuclei. Similar results have been given in Fig.4 and 5 for Bh and Hs nuclei. The MSE values for fuzzy logic model of ANN are 0.050 and 0.078 MeV for Bh and Hs nuclei, respectively. The energy values are in the order of about 10 MeV. The corresponding errors are about 0.1 MeV. Therefore the errors of the estimations are 1% which indicates the ANN method is capable for this task.
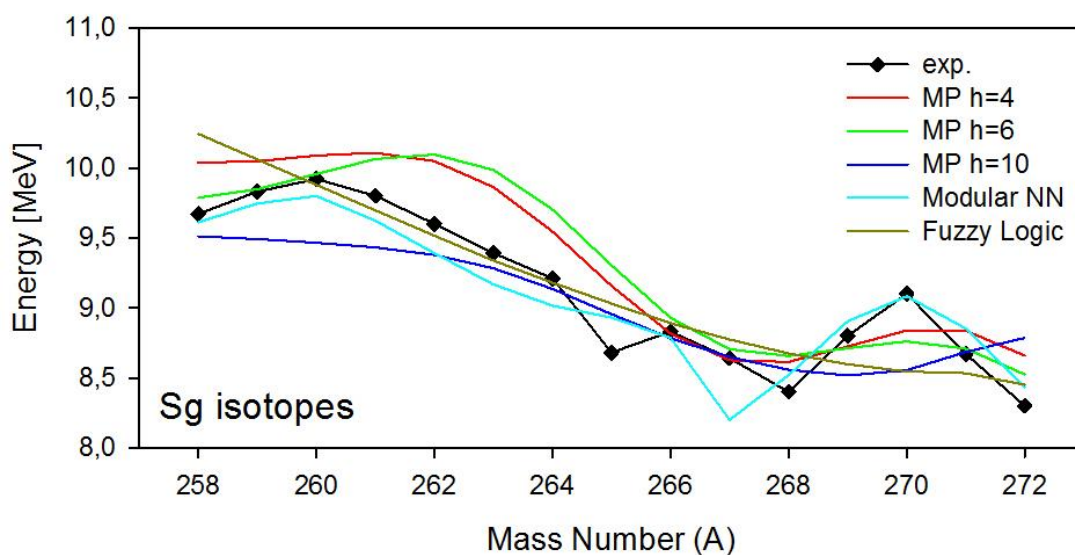

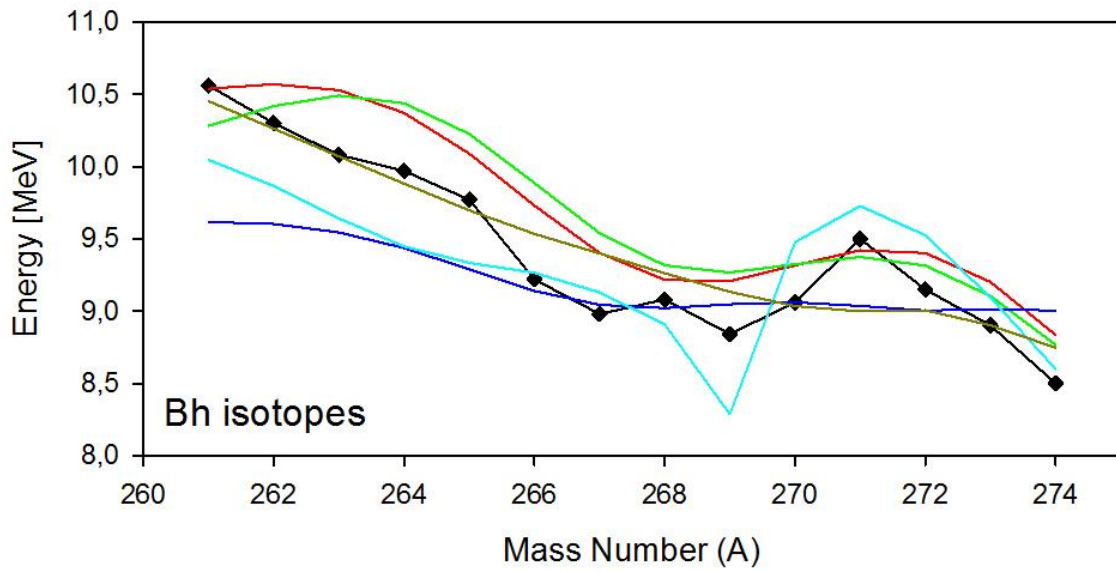**Figure 3.** Experimental and different model of ANN estimated alpha decay energies for Sg nuclei.

Figure 4. Experimental and different model of ANN estimated alpha decay energies for Bh nuclei.
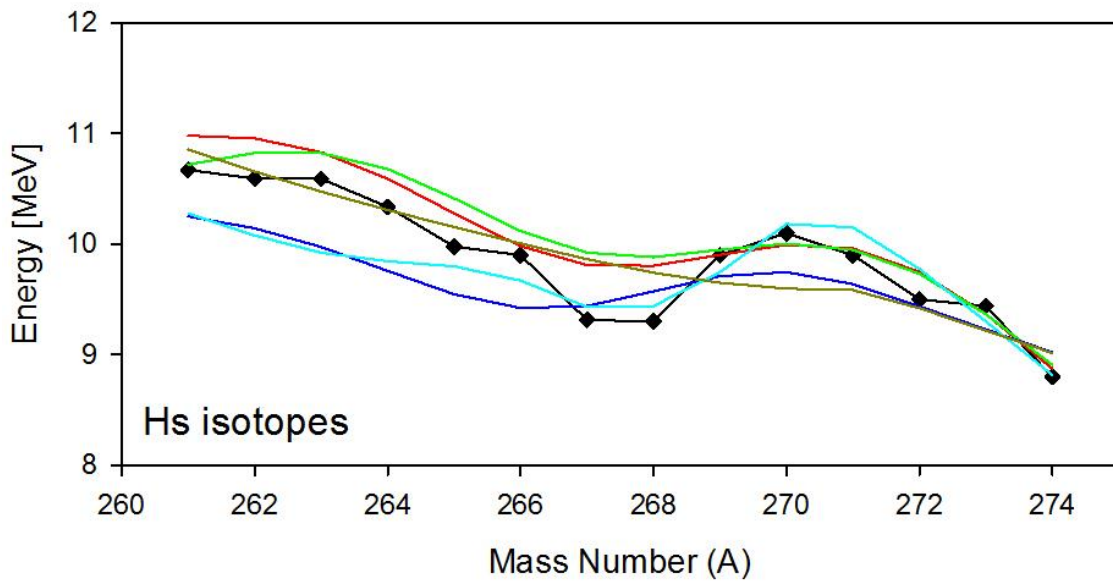

Figure 5. Experimental and different model of ANN estimated alpha decay energies for Hs nuclei.

4. CONCLUSIONS

Alpha decay energies of the nuclei have been obtained by using articial neural network (ANN) with different models. Some of the alpha decay enegy data of the super heavy nuclei have been used for construction of the ANN and the remains have been used for the test. Estimations

have been performed on super heavy Sg, Bh and Hs nuclei. According to the results, the estimations of the ANN method is compatible with the experimental results of the alpha decay energies. The mean square error values are in the order of 1-1.5 MeV. The fuzzy logic ANN give better results with MSE value of 0.068 MeV for Sg nuclei. This error is in 1% deviation which indicates the ANN method is capable for estimation of alpha energies of the nuclei.

REFERENCES

[1]. Hofmann, S., 1998 Rep. Prog. Phys. 61, 639

[2]. Hofmann, S. and Munzenberg, G., 2000. Rev. Mod. Phys. 72, 733

[3]. Hofmann, S. et al., 2004 Nucl. Phys. A 734, 93

[4]. Morita, K. et al., 2004 J. Phys. Soc. Jpn. 73, 2593

[5]. Morita, K. et al., 2007 J. Phys. Soc. Jpn. 76, 045001

[6]. Oganessian, Y, et al., 2006 Phys. Rev. C 74, 044602

[7]. Oganessian, Y., 2007 J. Phys. G: Nucl. Part. Phys. 34, R165

[8]. Oganessian, Y. et al., 2010 Phys. Rev. Lett 104, 142502

[9]. Dong, T. and Ren, Z., 2010 Phys. Rev. C 82, 034320

[10]. Bayram, T. and Yilmaz, A. H., 2013 Mod. Phys. Lett. A 28, 1350068

[11]. Gamow, G., 1928 Z. Phys A 51, 204

[12]. Medhat, M.E., 2012. Ann. Nucl. Energy 45, 73-79

[13]. Krzysztof, M. G. and Cezary, J., 2015. Journal of Physics G: Nuclear and Particle Physics 42, 034019

[14]. Akkoyun, S., Bayram, T. and Kara S. O., 2013. Cumhuriyet Science Journal 34, 42-51

[15]. Bayram, T., Akkoyun, S. and Kara, S. O., 2014. Ann. Nucl. Energy 63, 172-175

[16]. Costris, N., Mavrommatis, E., Gernoth, K.A. and Clark, J.W., 2007. arXiv:nuclth/ 0701096v1.

[17]. Akkoyun, S., Bayram, T. And Turker, T., 2014. Rad. Phys. Chem. 96, 186-189

[18]. Graczyk, K.M., 2011. Phys. Rev. C 84, 034314.

[19]. Yeşilkanat, C. M., Kobya, Y., Taşkın, H. And Çevik, U., 2014. Cumhuriyet Science Journal 35, 36-52.

[20]. C.M. Yeşilkanat, Y. Kobya, Determination and mapping the spatial distribution of radioactivity of natural spring water in the Eastern Black Sea Region by using artificial neural network method, Environ. Monit. Assess. 187 (2015) 589. doi:10.1007/s10661-015-4811-0.

[21]. Akkoyun, S., Bayram, T., Kara, S. O. and Sinan, A., 2013. Journal of Physics G: Nuclear and Particle Physics 40, 055105

[22]. Haykin, S., 1999. Neural networks: a comprehensive foundation, 2nd ed. Prentice-Hall, New Jersey.

[23]. Auda, G. And Kamel, M., 1999. International Journal of Neural Systems 9, 129-151

[24]. Bulsari, A., 1992. Complex System 6, 443-457

[25]. Levenberg, K., 1944. Q. Appl. Math. 2, 164-168.

[26]. Marquardt, D., 1963. SIAM J. Appl. Math. 11, 431.

[27]. Neurosolutions web site: www.neurosolutions.com.