Data Analysis and Machine Learning, Project 3: An evaluation of decay rates of nuclei.

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Contents

1 Introduction

Nuclear decay rates depend strongly on by which process they decay, and theoretically some decay rates might be more predictable than others. The decays that are governed by the strong force and other processes that can be somehow modelled classically, such as α and might be easier to predict than the ones governed by the weak force, such as $\beta-$ and $\beta+$.

Nevertheless, there might be some predictable trends between nuclear properties such as proton- and neutron numbers (Z, N), the neutron and proton binding energy (S_n/S_p) and the total lifetime of unstable nuclei. It is also interesting to see whether it is possible to predict if a nuclei is stable or not.

Using data fetched from the nds[1] database, as well as betarates from NSCL[2] and writing a script to scrape the internet for total lifetimes from the Lund/LBNL data search[3] I want to attempt to find any systematics of these lifetimes by using different statistical methods.

Firstly, I will introduce the raw data and plots to give the reader an overview with what we have to work with, and then try to model it with a nevral network. As "stable" is a hard state to make numerical in an useful fashion, I will split the project into two of firstly try to predict whether the nuclei is stable or not (binary), and then, if unstable, it will try to predict its lifetime.

2 The input data

For any short-hand notation in the pandas dataframe, please feel free to refer back to table 1.

[1] https://www-nds.iaea.org/amdc/, the 2016 and 2012 dataset.
[2] Dataset no. 9 from https://groups.nscl.msu.edu/charge_exchange/weakrates.html
[3] http://nucleardata.nuclear.lu.se/toi/listnuc.asp?sql=&Z=75 for different Z's (proton numbers), see code.

Symbol	**Definition**	**Calc. / unit**
Z	Proton number	
N	Neutron number	
A	Mass number	$N + Z$
Element	Element name	
Ebinding	Binding energy	MeV
Atomic mass	Atomic mass	u
S(n)	Neutron separation energy	MeV
S(2n)	Separation energy of two neutrons	MeV
S(p)	Proton separation energy	MeV
S(2p)	Separation energy of two protons	MeV
Q(a)	Q-value, i.e. energy balance, of α decay.	MeV
Q(B-)	Q-value of $\beta-$ decay.	MeV
T9	Temperature. One value is chosen.	as a factor times 10^9K
rho	Density. One value is chosen.	
EC	Electron capture cross section (probability)	
lifetime	Half life, $T_{1/2}$	$\log_{10}[sec]$

Table 1: Short hand notations of pandas dataframe columns of data.

There are also certain numbers of neutrons and protons that tend to be more stable, known as magic numbers[1]. These are $2, 8, 20, 28, 50, 82$ (and 126, at least for neutrons). When you fill these "shells" they are analogous to the electron shells and at the magic numbers, nuclei tend to be tighter bound and more stable. This is known as "shell effects" and are of great importance both for stability calculations and mass models.

References

[1] The nuclear shell model, for more information please consult the Krane textbook below or Wikipedia at https://en.wikipedia.org/wiki/Nuclear_shell_model

[2] Krane: An older but solid book on the basics of nuclear physics. Krane, Kenneth S: "Introductory nuclear physics", Wiley, New York, NY, 1988.