NUCLEAR STABILITY: WHAT DOES CHEMISTRY HAVE TO DO WITH IT?

Robson Fernandes de Farias
Universidade Federal do Rio Grande do Norte, Cx. Postal 1664, 59078-970, Natal-RN, Brasil.
Email: robdefarias@yahoo.com.br

ABSTRACT

This paper presents a possibility of approaching the theme "nuclear stability of the elements" that can be used in university courses of basic chemistry, or even in high school. *[African Journal of Chemical Education—AJCE 10(2), July 2020]*

INTRODUCTION

As is well known, as far as the constitution of the atomic nucleus is concerned, chemistry is usually focused only in the number of protons, which in turn determines the number of electrons in the electrosphere and therefore the chemical properties of the elements.

However, since chemistry is based on the study of chemical reactions, understands, even in a simplified way, aspects of nuclear stability is interesting (after all, without stable elements we wouldn't even exist, right?).

This paper presents a possibility of approaching the theme "nuclear stability of the elements" that can be used in university courses of basic chemistry, or even in high school.

METHODOLOGY

For each element only the key (most abundant, hence, most stable) isotope was considered. The atomic data were those available at the Royal Society of Chemistry Periodic Table [1].

For technetium, the radio isotope with large half live was considered [2]. To radon, the isotope ^{222}Rn was chose due to its larger half live (3.8 d) in comparison with ^{211}Rn (4.6 h) and ^{220}Rn (55.6 s) [1]. To uranium it was considered the most abundant (99,3%) isotope: ^{238}U [1]. To americium and curium, the isotopes with larger half live were chose: ^{243}Am and ^{248}Cm [1]. The same reasoning was used for other synthetic elements with more than one isotope. The chosen one was always the one with the longest half live (ie the most stable; the half-live is associated with the radioactive decay mode. Alpha decay was chosen).

The task to be performed by the students can be subdivided into the following steps:

a) Search the indicated sites (see references) for the main isotopes for the elements from Z = 1 to Z = 118;

b) Set up a Table (like Table 1);

c) Plot for the 118 elements the number of neutrons in the nucleus as a function of the atomic number (as in Figure 1);

d) Analyzing the Table as well as the graph produced, point out conclusions that can be obtained regarding the stability of the chemical elements.

RESULTS AND DISCUSSION

The employed data are summarized in Table 1. A plot of the number of neutrons in the nucleus as a function of the atomic number for elements 1-118 is shown in Figure 1.

Table 1. Key isotopes for the known chemical elements (1 to 118). N_p (Z) and N_n are, respectively, the number of protons and neutrons in the key isotope.

Element	Key isotope	N_p (Z)	N_n	N_n/N_p
hydrogen	^{1}H	1	0	0
Helium	^{4}He	2	2	1
Lithium	^{7}Li	3	4	1.3
Beryllium	^{9}Be	4	5	1.3
Boron	^{11}B	5	6	1.2
Carbon	^{12}C	6	6	1.0
Nitrogen	^{14}N	7	7	1.0
Oxygen	^{16}O	8	8	1.0
Fluorine	^{19}F	9	10	1.1
Neon	^{20}Ne	10	10	1.0
Sodium	^{23}Na	11	12	1.1
Magnesium	^{24}Mg	12	12	1.0
Aluminium	^{27}Al	13	14	1.1
Silicon	^{28}Si	14	14	1.0
Phosphorus	^{31}P	15	16	1.1
Sulfur	^{32}S	16	16	1.0
Chlorine	^{35}Cl	17	18	1.1
Argon	^{40}Ar	18	22	1.2
Potassium	^{39}K	18	21	1.2
Calcium	^{40}Ca	20	20	1.0
Scandium	^{45}Sc	21	24	1,1

Titanium	^{48}Ti	22	26	1.2
Vanadium	^{51}V	23	28	1.2
Chromium	^{52}Cr	24	28	1.2
Manganese	^{55}Mn	25	30	1.2
Iron	^{56}Fe	26	30	1.2
Cobalt	^{59}Co	27	32	1.2
Nickel	^{58}Ni	28	30	1.1
Copper	^{63}Cu	29	34	1.2
Zinc	^{64}Zn	30	34	1.1
Gallium	^{69}Ga	31	38	1.2
Germanium	^{73}Ge	32	41	1.3
Arsenic	^{75}As	33	42	1.3
Selenium	^{80}Se	34	46	1.4
Bromine	^{79}Br	35	44	1.3
Krypton	^{84}Kr	36	48	1.3
Rubidium	^{85}Rb	37	48	1.3
Strontium	^{86}Sr	38	48	1.3
Yttrium	^{89}Y	39	50	1.3
Zirconium	^{90}Zr	40	50	1.3
Niobium	^{93}Nb	41	52	1.3
Molybdenum	^{95}Mo	42	53	1.3
Technetium	^{98}Tc	43	55	1.3
Ruthenium	^{101}Ru	44	57	1.3
Rhodium	^{103}Rh	45	58	1.3
Palladium	^{106}Pd	46	60	1.3
Silver	^{107}Ag	47	60	1.3
Cadmium	^{114}Cd	48	66	1.4
Indium	^{115}In	49	66	1.3
Tin	^{120}Sn	50	70	1.4
Antimony	^{121}Sb	51	70	1.4
Tellurium	^{130}Te	52	78	1.5
Iodine	^{127}I	53	74	1.4
Xenon	^{132}Xe	54	78	1.4
Caesium	^{133}Cs	55	78	1.4
Barium	^{138}Ba	56	82	1.5
Lanthanum	^{139}La	57	82	1.4
Cerium	^{140}Ce	58	82	1.4
Praseodymium	^{141}Pr	59	82	1.4
Neodymium	^{142}Nd	60	82	1.4
Promethium	^{145}Pm	61	84	1.4
Samarium	^{152}Sm	62	90	1.5
Europium	^{153}Eu	63	90	1.4
Gadolinium	^{158}Gd	64	94	1.5

Terbium	^{159}Tb	65	94	1.4
Dysprosium	^{164}Dy	66	98	1.5
Holmium	^{165}Ho	67	98	1.5
Erbium	^{166}Er	68	98	1.4
Thulium	^{169}Th	69	100	1.4
Ytterbium	^{172}Yb	70	102	1.5
Lutetium	^{175}Lu	71	104	1.5
Hafnium	^{177}Hf	72	105	1.5
Tantalum	^{180}Ta	73	107	1.5
Tungsten	^{182}W	74	108	1.5
Rhenium	^{187}Re	75	112	1.5
Osmium	^{192}Os	76	116	1.5
Iridium	^{193}Ir	77	116	1.5
Platinum	^{195}Pt	78	117	1.5
Gold	^{197}Au	79	118	1.5
Mercury	^{202}Hg	80	122	1.5
Thallium	^{205}Tl	81	124	1.6
Lead	^{208}Pb	82	126	1.5
Bismuth	^{209}Bi	83	126	1.5
Polonium	^{209}Po	84	125	1.5
Astatine	^{210}At	85	125	1.5
Radon	^{222}Rn	86	136	1.6
Francium	^{223}Fr	87	136	1.6
Radium	^{226}Ra	88	138	1.6
Actinium	^{227}Ac	89	138	1.6
Thorium	^{230}Th	90	140	1.6
Protactinium	^{231}Pa	91	140	1.5
Uranium	^{238}U	92	146	1.6
Neptunium	^{237}Np	93	144	1.5
Plutonium	^{238}Pu	94	144	1.5
Americium	^{243}Am	95	148	1.6
Curium	^{248}Cm	96	152	1.6
Berkelium	^{247}Bk	97	150	1.5
Californium	^{251}Cf	98	153	1.6
Einsteinium	^{252}Es	99	153	1.5
Fermium	^{257}Fm	100	157	1.6
Mendelevium	^{258}Md	101	157	1.6
Nobelium	^{259}No	102	157	1.5
Lawrencium	^{262}Lr	103	159	1.5
Rutherfordium	^{265}Rf	104	161	1.5
Dubnium	^{268}Db	105	163	1.6
Seaborgium	^{271}Sg	106	165	1.6
Bohrium	^{272}Bh	107	165	1.5

Hassium	^{270}Hs	108	162	1.5
Meitnerium	^{276}Mt	109	167	1.5
Darmstadtium	^{281}Ds	110	171	1.6
Roentgenium	^{280}Rg	111	169	1.5
Copernicium	^{285}Cn	112	173	1.5
Nihonium	^{286}Nh	113	173	1.5
Flerovium	^{289}Fl	114	175	1.5
Moscovium	^{289}Mc	115	174	1.5
Livermorium	^{293}Lv	116	177	1.5
Tennessine	^{294}Ts	117	177	1.5
Oganesson	^{294}Og	118	176	1.5

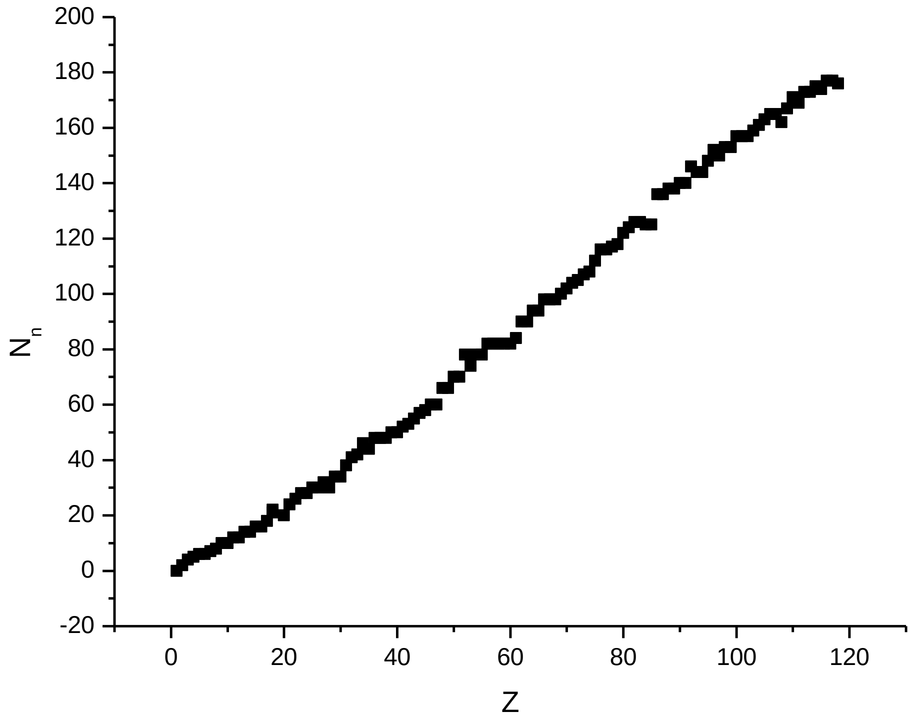

Figure 1. Number of neutrons in the nucleus (N_n) as a function of Z, for elements 1-118.

CONCLUSIONS

Based on both (Table and graph), some conclusions (some here, as examples, but, of course, the teachers and students could obtain another ones) can be pointed out:

1. The theoretical interpretation that the function of neutrons is to stabilize the atomic nucleus, acting as a "glue" that compensates for repulsion between protons makes sense, since the only element that has no neutrons in its nucleus is the one that has only one proton (H); However, we must remember that hydrogen has two more isotopes: ^{2}H and ^{3}H with one and two neutrons respectively;
2. For all elements (with the obvious exception of hydrogen), the number of neutrons is equal to or greater than the number of protons;
3. The ratio (number of neutrons) / (number of protons) slowly increases over the periodic table, from 1.0 to 1.6. This shows that it becomes progressively harder to "compensate" for interprotonic repulsion as the element becomes heavier;
4. The curve obtained (Figure 1) shows that the relationship between the increase of the number of protons and the number of neutrons is linear (r = 0.9980), illustrating the importance of neutrons to nuclear stability.

REFERENCES

1. https://www.rsc.org/periodic-table (consulted in December, 19, 2019).
2. https://www.webelements.com/technetium/isotopes.html (consulted in December, 19, 2019).