ALPHAD and ALPHAD-RadD codes
Update of Akovali's 1998Ak04 Table of r_0 values

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Background:

- 2012-13: McMaster: started work on update of Akovali's 1998 Table of radius parameters r_0 values, as an undergraduate student project, with Ervin Thiagalingam, but after work on ~20 or so nuclides he left our group.
- 2014: Sukhjeet Singh visited McMaster for ENSDF work for about 4 weeks, and agreed to work on the project, with his graduate student Sushil Kumar.
- 2015: NSDD meeting in Vienna: RadD code was presented by Sukhjeet: deduced r_0 values through a code for odd-A and odd-odd-A by interpolation of values for neighboring even-even nuclides. Suggestions were made at the meeting to extend this code and merge with the ALPHAD code.
- 2015 October IAEA-ENSDF-codes meeting: Sukhjeet presented first version of new ALPHAD code with the original ALPHAD and RadD code merged, but still using the 1998Ak04 Table of r_0 values.
- 2016-2018:

  1. Improvement of original ALPHAD code
  2. Huge task of updated Table of r_0 values for all the e-e alpha emitters.
  3. Finally ALPHAD-RadD code with updated table: April 2018.

Improvement of original ALPHAD code

Two problems were noticed in the original ALPHAD code:

1. When value of I(α) missing in the Alpha record in the input .ensdf formatted file, the output report file assumed 100% intensity, thus giving an extremely low (and unrealistic) hindrance factor. Fortunately this value was not transferred to the output .ensdf file. Still it looked misleading in the report file. This error was pointed out at the IAEA-ICTP training workshop in 2016, while I was displaying the workings of the ALPHAD code.
2. When an unplaced alpha happens to be present in an .ensdf formatted dataset, the deduced r_0 parameter for an even-even system was totally wrong. Unplaced alpha is very rare situation, but still needed repair.

   Example: ^{238}Pu to ^{234}U α-decay dataset: it has a questionable unplaced alpha line. Deduced r_0 parameter=0.95356(9) (wrong result). Removing this record in the .ens file gave a correct r_0 parameter=1.50749(12), consistent with systematics in this A / Z region.

   Above two bugs in the ALPHAD code were resolved by Tim Johnson (NNDC), Sukhjeet and Sushil in India, with my participation in checking and communication. Note that IAEA-NDS webpage still has the old version.

Update of r_0 table for even-even alpha emitters

Update procedures:

1. new Q(α) values from AME-2016 (2017Wa10)
2. newly reported even-even systems
3. revised half-lives, α-branching ratios, I(α) to ground state.

A total of 183 e-e alpha emitter systems were identified as of early 2018; ranging From ^{106}Te (Z=52) to ^{294}Og (Z=118) alpha decays.

~ 22 systems more than those in the 1998 Table. Since then two new decays have become available, where ^{108}Xe and ^{104}Te nuclei are newly discovered at CARIBU, ANL facility:

^{108}Xe $\rightarrow$ ^{104}Te $\rightarrow$ ^{100}Sn chain : PRL 121, 182501 (Oct 30, 2018): 2018Au04.

Download .ens files from ENSDF for relevant alpha-decays.

Update .ens files for above mentioned 4 quantities: evaluate if needed.

Download from XUNDL database, or create new .ens files for newly-discovered systems not yet in the ENSDF database.

Consulted NSR database for new articles on relevant input quantities.

Run ALPHAD code on each system to obtain r_0 parameter.

ALPHAD-RadD code: final version

ALPHAD code (after the two bugs were removed) was merged with the RadD code together with the updated 2018 r_0 parameter file. ALPHAD-RadD code was sent to the IAEA-NDS in April 2018; operating on Windows, Linux and Mac systems.

The default in this code is to use r_0 deduced by its RadD routine, but the code offers the flexibility of inputting user-selected r_0 value.

Two main Tables and systematics graphs were created for documentation and an intended publication in Nuclear Data Sheets journal:

1. r_0 parameter table.
2. Input file listing the relevant quantities used to obtain r_0 values.
3. Systematics plots: for all Z, and separate plots by Z

Table of r_0 parameters for alpha decays: July 2018

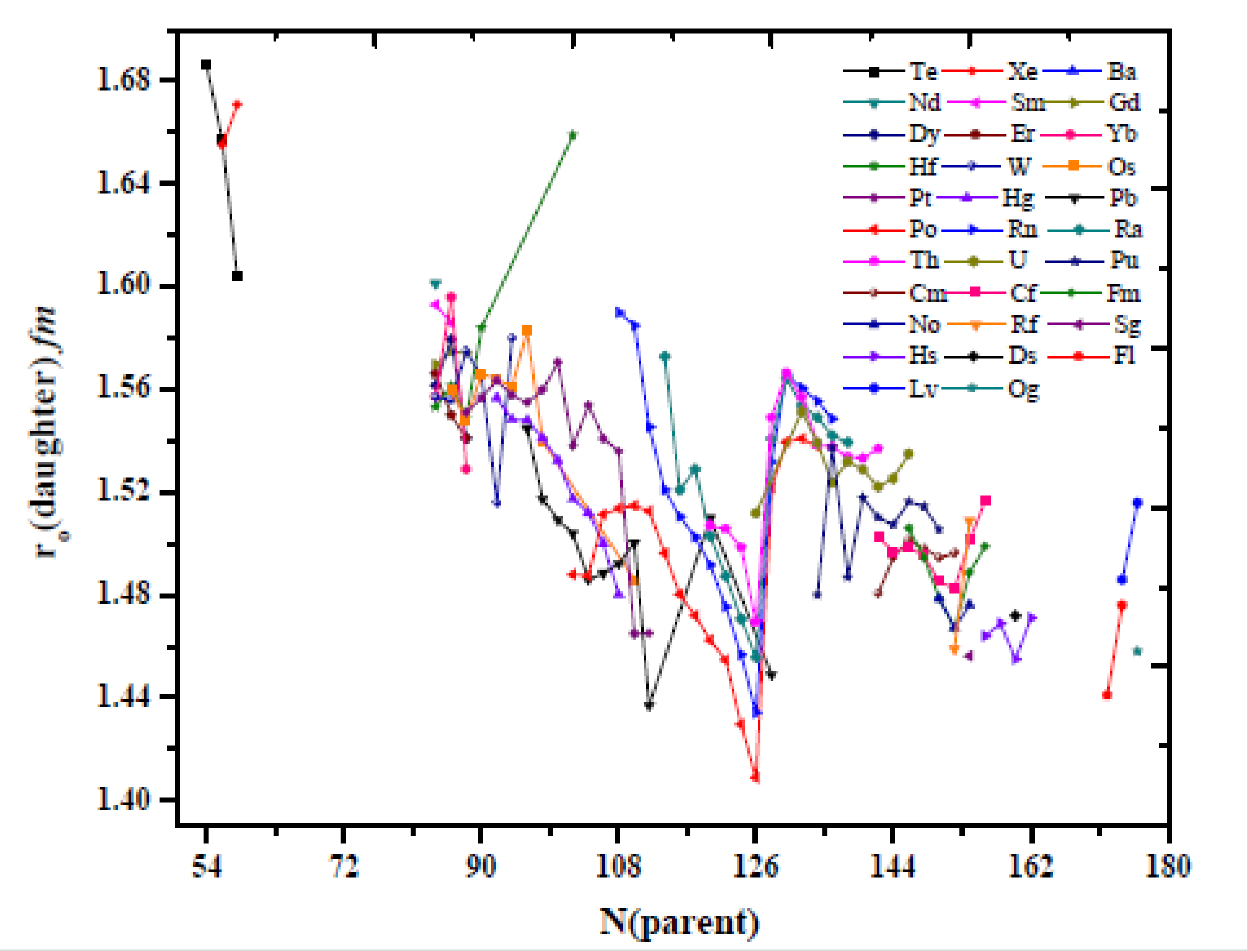
Continuation of Table I

Parent Nuclide				Daughter Nuclide				Daughter r_0
Element	Z	N	A	Element	Z	N	A	(fm)
	80	106	186		78	104	182	1.500(17)
	80	108	188		78	106	184	1.480(15)
Pb	82	96	178	Hg	80	94	174	1.545(35)
	82	98	180		80	96	176	1.5174(41)
	82	100	182		80	98	178	1.5093(64)
	82	102	184		80	100	180	1.504(11)
	82	104	186		80	102	182	1.486(10)
	82	106	188		80	104	184	1.4885(32)
	82	108	190		80	106	186	1.4923(55)
	82	110	192		80	108	188	1.5005(86)
	82	112	194		80	110	190	1.437(22)
	82	120	202		80	118	198	1.510
	82	128	210		80	126	206	1.449(21)
Po	84	102	186	Pb	82	100	182	1.488(22)
	84	104	188		82	102	184	1.4877(77)
	84	106	190		82	104	186	1.5114(26)
	84	108	192		82	106	188	1.5137(13)
	84	110	194		82	108	190	1.5147(13)
	84	112	196		82	110	192	1.5126(28)
	84	114	198		82	112	194	1.4962(19)
	84	116	200		82	114	196	1.4803(16)
	84	118	202		82	116	198	1.4720(20)
	84	120	204		82	118	200	1.4625(22)
	84	122	206		82	120	202	1.4547(10)
	84	124	208		82	122	204	1.42967(74)
	84	126	210		82	124	206	1.408790(38)
	84	128	212		82	126	208	1.5217(17)
	84	130	214		82	128	210	1.53958(10)
	84	132	216		82	130	212	1.54084(69)
	84	134	218		82	132	214	1.53788(19)

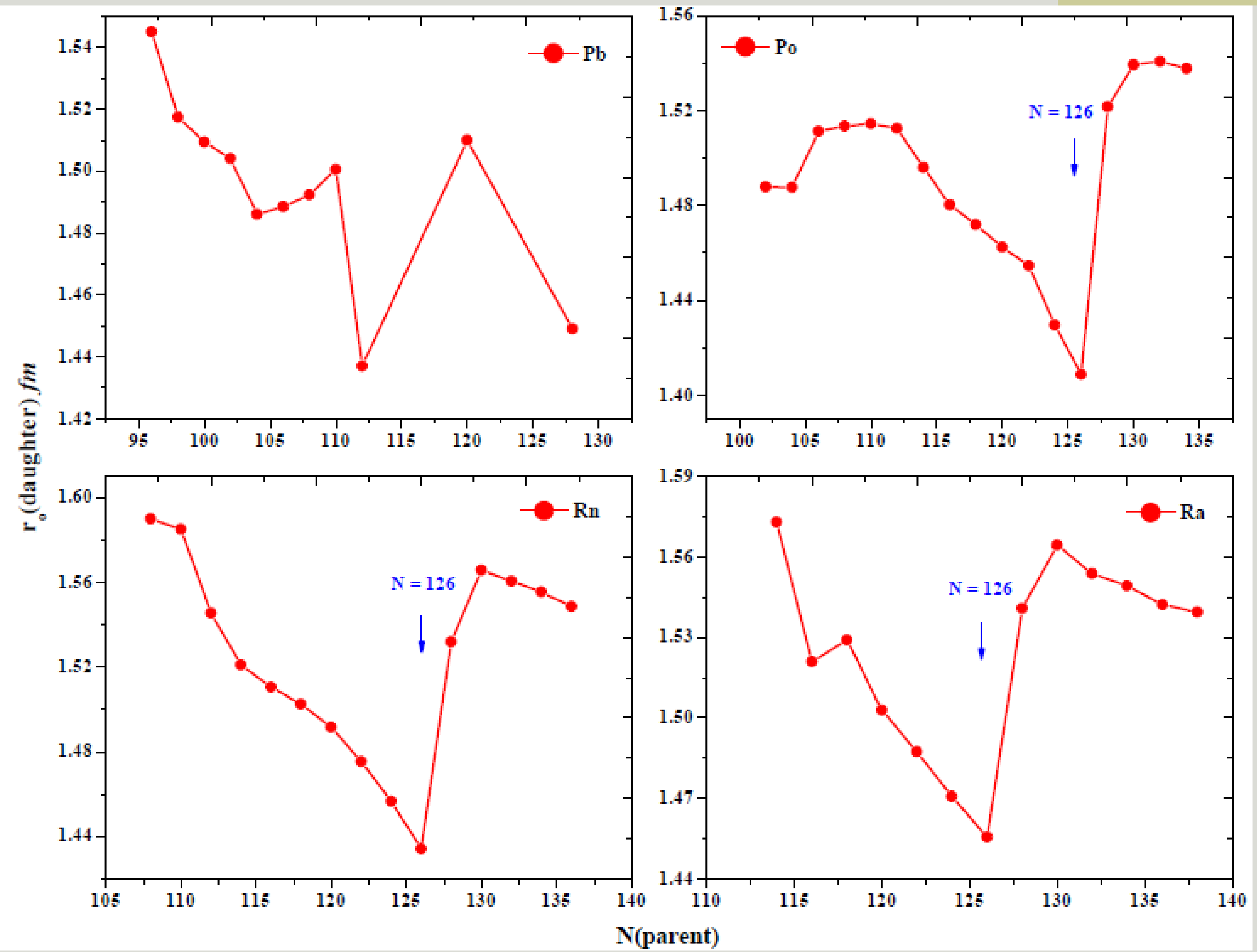
Input data for r_0 parameters

	(2017SI08).	
$^{264}Hs \rightarrow ^{260}Sg$	Q_α = 10591(20). $\%\alpha$ = 50 (1999AK02). $T_{1/2}$ = 0.61 *ms* (+47-19) (2011SA41). $I\alpha$: Assumed as 100	1.464(23)
$^{266}Hs \rightarrow ^{262}Sg$	Q_α = 10346(16).$\%\alpha$ = 76(9), $T_{1/2}$ = 2.97 *ms* (+78-51) (2012AC04). $I\alpha$: Assumed as 100	1.469(13)
$^{268}Hs \rightarrow ^{264}Sg$	Q_α = 9623(16). $\%\alpha$ = 100. $T_{1/2}$ = 0.4 *s* (+18-2) (2014NI14). $I\alpha$: Assumed as 100	1.455(50)
$^{270}Ds \rightarrow ^{266}Hs$	Q_α = 11117(28). $\%\alpha$ = 100 (2005GU33). $T_{1/2}$ = 0.20 *ms* (+7-4) (2012AC04). $I\alpha$: Assumed as 100	1.472(16)
$^{270}Hs \rightarrow ^{266}Sg$	Q_α = 9070(40), $\%\alpha$ = 75(25), $T_{1/2}$ = 7.6 *s* (+49-22) (2013OG03). $I\alpha$: Assumed as 100	1.471(20)
$^{286}Fl \rightarrow ^{282}Cn$	Q_α = 10370(30). $\%\alpha$ = 60(11) (2017OG01). $T_{1/2}$ = 166 *ms* (+40-27) (2016HO09). $I\alpha$: Assumed as 100	1.441(14)
$^{288}Fl \rightarrow ^{284}Cn$	Q_α = 10072(13). $\%\alpha$ = 100, $T_{1/2}$ = 0.64 *s* (+14-10) (2016HO09). $I\alpha$: Assumed as 100	1.476(10)
$^{290}Lv \rightarrow ^{286}Fl$	Q_α = 11000(70). $\%\alpha$ = 100 (2016HO09). $T_{1/2}$ = 8.3 *ms* (+35-19) (2017OG01) $I\alpha$: Assumed as 100	1.486(24)
$^{292}Lv \rightarrow ^{288}Fl$	Q_α = 10774(15). $\%\alpha$ = 100, $T_{1/2}$ = 12.8 *ms* (+70-33) (2016HO09). $I\alpha$: Assumed as 100	1.516(12)
$^{294}Og \rightarrow ^{290}Lv$	Q_α = 11840(70). $\%\alpha$ = 100 (2016HO09). $T_{1/2}$ = 0.69 *ms* (+64-22) (2017OG01). $I\alpha$: Assumed as 100	1.458(25)

r_0 parameters for alpha decays



r_0 parameters by atomic number



ALPHAD-RadD code vs. ALPHAD

Datasets for even-even α emitters: statement about deduced r_0 parameter by assuming HF=1.0 for g.s. to g.s. α transition automatically inserted in the dataset.

In ALPHAD code: the insertion of deduced r_0 *is done manually in the dataset.*

Datasets for odd-A and odd-odd-A α emitters: r_0 is automatically deduced by the code (option: users are prompted to provide their r_0 parameter of their choice), and the HFs are deduced. The statement for r_0 parameter gets inserted in the dataset, together with the deduced HF values.

In ALPHAD code: r_0 needs to be deduced manually following a certain recipe as given in M.J. Martin's memo, then edited in the input file.

Conclusions

The coding part of ALPHAD-RadD is done and available on IAEA webpage.

Original ALPHAD on IAEA webpage still needs to be replaced by its corrected version, and perhaps, after ALPHAD-RadD code is fully tested, it should replace ALPHAD.

Paper on this work was submitted in July 2018 for Nuclear Data Sheets.

About 2 weeks back, we received some comments about typos in the file listing the relevant input quantities to deduced r_0 parameters.

This list file was created manually in MS-WORD from 183 .ensdf formatted files, then converted to Latex for publication purpose. We are quite confident about the updated .ensdf files, but manual work and computer translation may have been the cause of some of these typos. We are going through a complete checking of the "list" file, so that r_0 values are consistent with all the data in this list. Expected revised draft of paper: early January 2019.

Less likely, but possible that some of the r_0 values may change, in which case another version of the ALPHAD-RadD code with revised r_0 table will be released.