RadD-v1.0

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The RadD-v1.0 code deduces radius parameter (r_0) for odd-A and odd-odd alpha emitters by employing interpolation or extrapolation procedures [1] using a recent update of evaluated r_0 parameters, as given in 2020Si16 [2] for ground-state to ground-state alpha transitions in 186 even-even nuclei. 2020Si16 evaluation [2], an update to 1998Ak04 [3], presents updated Q_α values (primarily from AME2016) half-lives, and other relevant quantities required for the deduction of r_0 parameters of even-even alpha emitters, with literature cutoff date of June-2020, with no new relevant references up to November 2020.. These r_o parameters deduced for odd-A and odd-odd nuclides can be used in the calculations of alpha hindrance factors by using ALPHAD program.

CALCULATION PROCEDURE

a. Odd-Z and Even-N Nuclides

The radius parameter (r_0) for an odd-Z and even-N nuclide is obtained from an unweighted average of radius parameters of ($Z-1, N$) and ($Z+1, N$) even-even nuclides as [1]:

$$r_0(Z,N) = \frac{\left[r_0(Z-1,N) + r_0(Z+1,N)\right]}{2}$$

and corresponding uncertainty is deduced from unweighted average of uncertainties given for even-even radii of ($Z-1, N$) and ($Z+1, N$) nuclides.

Illustration:

Radius parameter for odd-even nuclide ${}^{201}_{85}At$ is 1.5157 *fm 27*, which is deduced from the unweighted average of even-even radii ${}^{200}_{84}Po$ (1.5026 *fm 13)* and ${}^{202}_{86}Rn$ (1.5287 *fm 42*). The typical consol of RadD code for radius parameter calculation of ${}^{201}_{85}At$ nuclide is shown in Fig. 1.

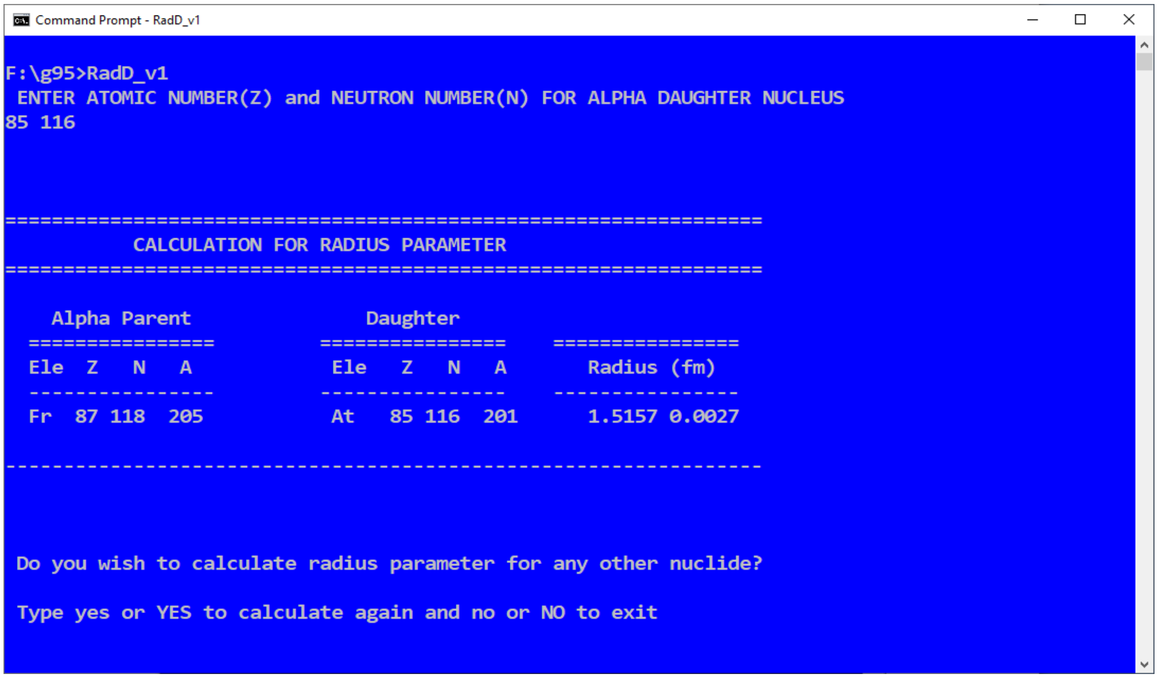

Fig. 1: Consol of RadD code for radius parameter calculation of ${}^{201}_{85}At$ nuclide

b. Even-Z and Odd-N Nuclides

Similarly, the radius parameter for an even-Z and odd-N nuclide is obtained from an unweighted average of radius parameters of $(Z, N-1)$ and $(Z, N+1)$ even-even nuclides [1].

$$r_0(Z,N) = \frac{\left[r_0(Z,N-1) + r_0(Z,N+1)\right]}{2}$$

and corresponding uncertainty is deduced from unweighted average of uncertainties given for even-even radii namely $(Z, N-1)$ and $(Z, N+1)$ nuclides.

Illustration:

Radius parameter for even-odd nuclide ${}^{201}_{84}Po$ is 1.4971 *fm 20*, which is deduced from the unweighted average of even-even radii of ${}^{200}_{84}Po$ (1.5026 *fm 13)* and ${}^{202}_{84}Po$ (1.4917 *fm 27*) nuclides. The typical consol of RadD code for radius parameter calculation of ${}^{201}_{84}Po$ nuclide is shown in Fig. 2.

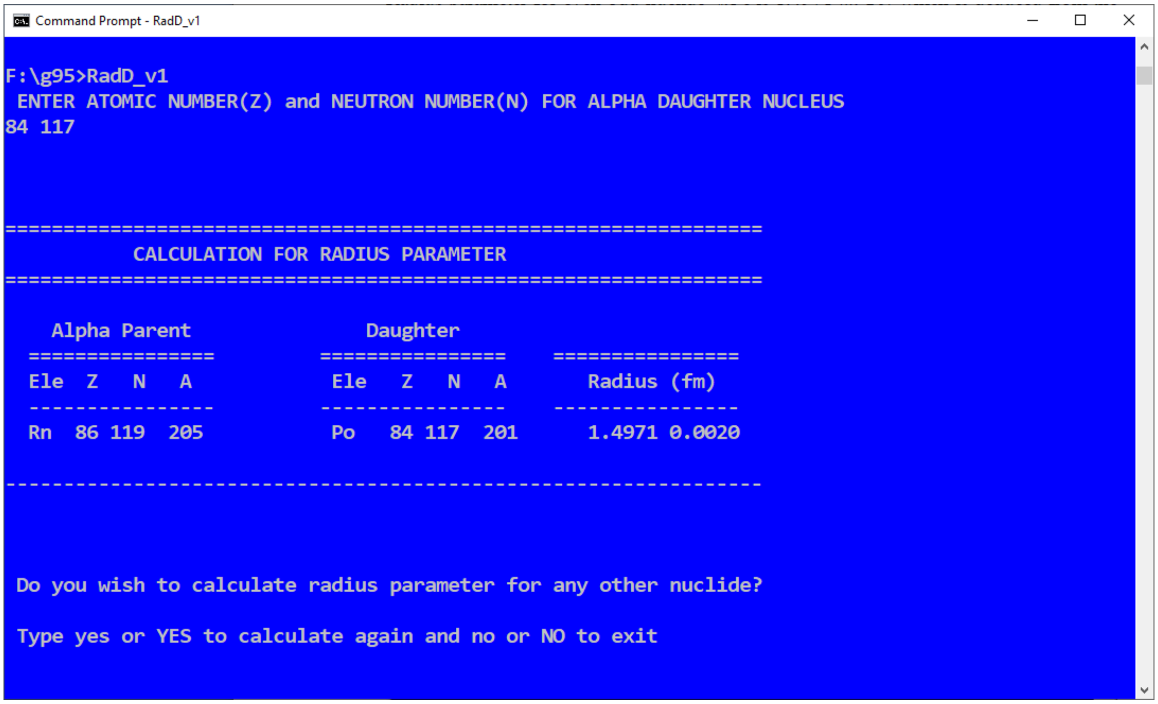

Fig. 2: Consol of RadD code for radius parameter calculation of ${}^{201}_{84}Po$ nuclide

c. Odd-Z and Odd-N Nuclides

The radius parameters for an odd-Z and odd-N nuclide (Z,N) can be deduced by following two approaches [1]. The deduction procedure for both the approaches is discussed below:

Method 1: Using unweighted average of neighboring odd-even radii

The radius of a given odd-odd nuclide (Z,N) is deduced from the radii of odd-even nuclei $(Z,N-1)$ and $(Z,N+1)$ as follows: step 1, we deduce the radius of $(Z,N-1)$ by taking unweighted average of radius parameters of even-even nuclides namely $(Z-1,N-1)$ and $(Z+1,N-1)$; step 2, we deduce radius of $(Z,N+1)$ by taking unweighted average of radius parameters of even-even nuclides namely ($Z-1, N+1$) and ($Z+1, N+1$); step 3, we take unweighted average of odd-even radii obtained in steps 1 and 2 above, to get the required radius of a given odd-odd nuclide.

Illustration:

Radius parameter for $^{202}_{85}At$: In order to deduce the radius parameter of odd-odd $^{202}_{85}At$ nuclide, first we have to deduce the radii of odd-even nuclides $^{201}_{85}At$ and $^{203}_{85}At$ as described in following steps (Step 1 & 2):

Step 1: Radius of $^{201}_{85}At$

$$r_0(85,116) = \frac{\left[r_0(84,116) + r_0(86,116)\right]}{2} = \frac{1.5026_{13} + 1.5287_{42}}{2} = 1.51565_{275}$$

Step 2: Radius of $^{203}_{85}At$

$$r_0(85,118) = \frac{\left[r_0(84,118) + r_0(86,118)\right]}{2} = \frac{1.4917_{27} + 1.5029_{36}}{2} = 1.4973_{315}$$

Step 3: Finally, the radius of given odd-odd nuclide $^{202}_{85}At$ is deduced as unweighted average of odd-even radii of $^{201}_{85}At$ and $^{203}_{85}At$ nuclides, obtained in step 1 & 2 respectively, i.e.

$$r_0(85,117) = \frac{1.51565_{275} + 1.4973_{315}}{2} = 1.5065_{30}$$

Method 2: Using unweighted average of neighboring even-odd radii

The radius of a given odd-odd nuclide (Z, N) is calculated from the radii of even-odd nuclei ($Z-1, N$) and ($Z+1, N$) as follows: step 1, we deduce the radius of ($Z-1, N$) by taking unweighted average of radius parameters of ($Z-1, N-1$) and ($Z-1, N+1$) even-even nuclides [1]; step 2, we deduce radius of ($Z+1, N$) by taking unweighted average of radius parameters of ($Z+1, N-1$) and ($Z+1, N+1$) even-even nuclides [1]; step 3, we take unweighted average of even-odd radii obtained in steps 1 and 2 to get the required radius of a given odd-odd nuclide.

Illustration:

Radius parameter for $^{202}_{85}At$: In order to deduce the radius parameter of odd-odd $^{202}_{85}At$ nuclide, first we have to deduce the even-odd radii of $^{201}_{84}Po$ and $^{203}_{86}Rn$ nuclides as described in following steps (Step 1 & 2):

Step 1: Radius of $^{201}_{84}Po$

$$r_0(84,117)=\frac{\left[r_0(84,116)+r_0(84,118)\right]}{2}=\frac{1.5026_{13}+1.4917_{27}}{2}=1.49715_{200}$$

Step 2: Radius of $^{203}_{86}Rn$

$$r_0(86,117)=\frac{\left[r_0(86,116)+r_0(86,118)\right]}{2}=\frac{1.5287_{42}+1.5029_{36}}{2}=1.5158_{39}$$

Step 3: Finally, the radius of given odd-odd nuclide $^{202}_{85}At$ is obtained as unweighted average of even-odd radii of $^{201}_{84}Po$ and $^{203}_{86}Rn$ nuclides obtained in step 1 & 2 respectively, i.e.

$$r_0(85,117)=\frac{1.49715_{200}+1.5158_{39}}{2}=1.5065_{30}$$

The method 1 and method 2 gives the same value of r_0 parameters. We incorporated both methods in the main source code, so radius parameter deduction by both methods will be displayed on screen as shown in console output (Fig. 3).

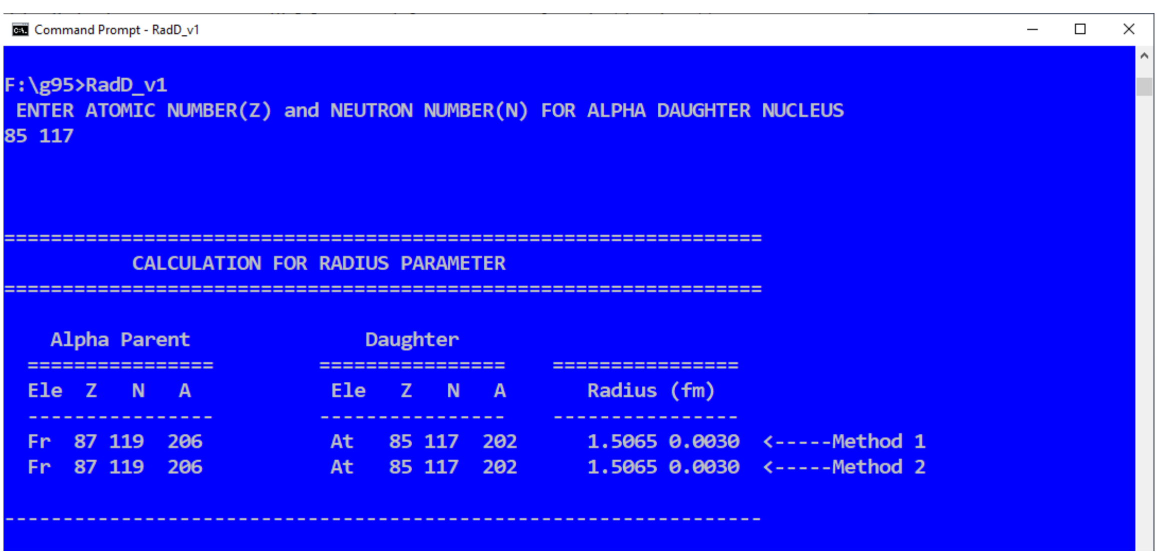

Fig. 3: Consol of RadD code for radius parameter calculation of $^{202}_{85}At$ nuclide

Input files:

(1) 2020_r0_EE.DAT

This is the main input file containing r_0 parameters of 186 nuclei listed in our recent evaluation of radius parameters of even-even alpha emitters (2020SI16) [2]. The data values listed in this file are appearing as per following format:

Column No.	Details of Input value
1-5	Parent Z
6-9	Parent N
10-18	Daughter radius parameter (r_0)
19-27	Uncertainty in daughter radius parameter

(2) ELE.IN

This file contains nuclide symbols along with their atomic numbers. This file is used to list nuclide symbols of alpha parent and alpha daughter nuclei.

Compilation Instructions

During execution of this program, a message will appear:

"ENTER ATOMIC NUMBER (Z) and NEUTRON NUMBER (N) FOR ALPHA DAUGHTER NUCLEUS"

Enter Z and N values for a nuclide whose radius parameter is required. The corresponding alpha daughter radius will be displayed on the screen with appropriate nomenclature of alpha parent and alpha daughter nuclides.

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References

[1] M. J. Martin, *Guidelines for Evaluators*, Appendix E, page 73 (October 2019).

[2] Sukhjeet Singh, Sushil Kumar, Balraj Singh, and A.K. Jain, Nuclear Data Sheets 167, 1 (2020).

[3] Y.A. Akovali, Nuclear Data Sheets 84, 1 (1998).