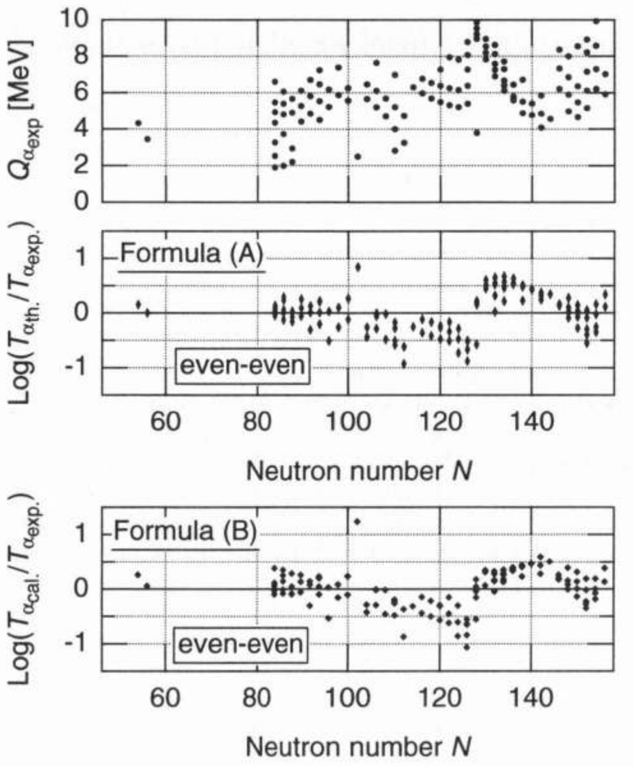

Figure 1. Experimental Q_α (upper). Differences between experimental and estimated $\log T_\alpha$ of Formula (A) (middle) and Formula (B) (lower). All data are for even-even nuclei.

with

$$\delta_{eo} = \begin{cases} 0 & \text{for even-even} \\ 1 & \text{for odd-}A \\ 2 & \text{for odd-odd.} \end{cases} \qquad (7)$$

Here, h_0 is taken from the average of differences of experimental half-lives from estimated ones (as $h=0$) for odd-A nuclei.

The results for two formulas are in the following.

Formula (A)

The values of parameters are $a = 1.55261$, $b = 0.73247$, $c = -0.21669$, $d = -31.9949$, and $h_0 = 0.56718$ for Q_α and T_α in MeV and second, respectively. The root-mean square (RMS) deviation of $\log T_\alpha$ from experimental ones of 120 even-even nuclei is 0.3625. The RMS deviation is 0.7708 for 151 odd-A nuclei and is 0.9845 for 63 odd-odd nuclei. Although 10^{-d} roughly corresponds to the collision frequency N_{coll} of the α particle which should be about 10^{20-22}, the above absolute value of d seems to be too large. In Figure 1 (the upper and middle parts), we show the experimental Q_α and the differences between the experimental and estimated T_α with the use of Formula (A).

Formula (B)

The values of fitted parameters are $N_{\text{coll}} = 10^{20.05}$, $d_0 = 2.0$ fm, and $h_0 = 0.61410$ for Q_α and T_α in MeV and second, respectively. The values of N_{coll} and d_0 are within reasonable values. The RMS deviation of $\log T_\alpha$ for 120 even-even nuclei is 0.3512. In Figure 1 (the lower part), we show the differences between the experimental and estimated T_α with the use of Formula (B). In the region $126 \leq N \leq 142$, the discrepancy of Formula (B) is reduced in comparison with one of Formula (A). Both of the middle and lower figures show distinct discontinuities at $N = 126$ because of the magicity. At $N = 102$ ($^{174}\text{Hf}_{102}$), large discrepancies are also seen. This nucleus is located on the vicinity of β-stability line and is isolated from the other even-even nuclei on the N-Z plane and have relatively larger deformation than the others. We show the differences between the experimental and estimated T_α for odd-A and odd-odd nuclei in Figure 2. The RMS deviation is 0.7500 for 151 odd-A nuclei, and is 0.9802 for 63 odd-odd nuclei.

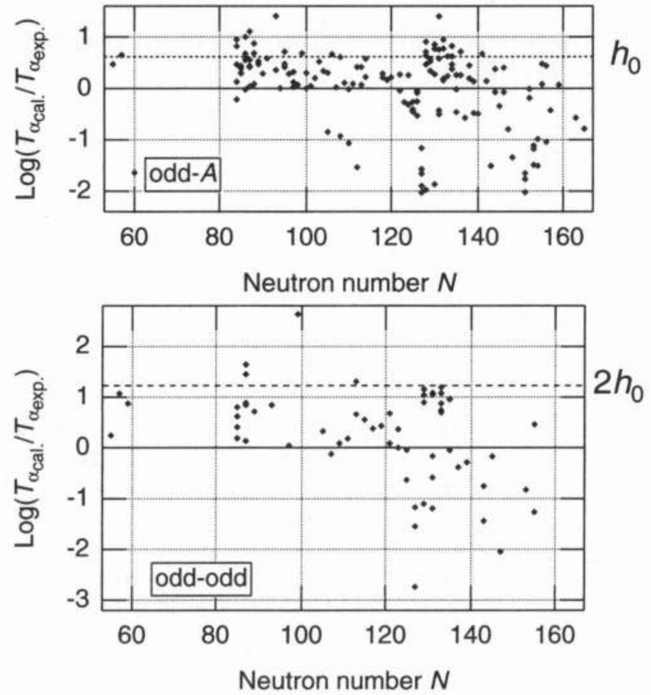

Figure 2. Differences between experimental and estimated T_α for odd-A nuclei (upper) and for odd-odd nuclei (lower). The even-odd hindrance factors h_0 and $2h_0$ are also seen as dashed lines.

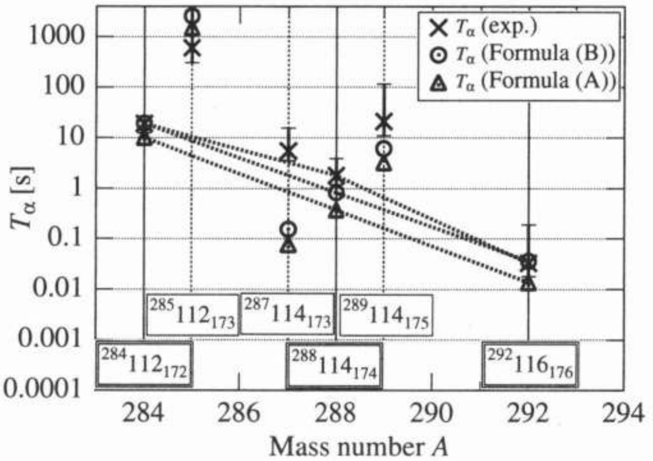

Figure 3. Estimated and experimental α-decay half-lives T_α in the superheavy nuclidic region. Dotted lines connect α-decay chains.

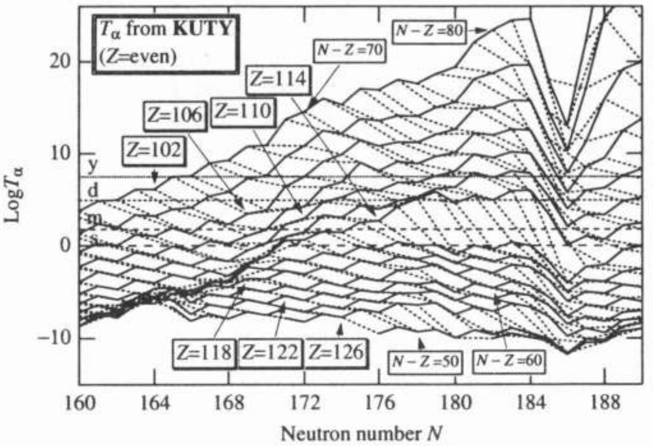

Figure 4. T_α of superheavy nuclei by KUTY formula[2,3] for even Z. We use Formula (B) to estimate T_α. The solid lines connect isotopes and dotted lines connect α-decay chains.

2.2. Estimation in the Superheavy Region. In order to compare the above two formulas, we show the experimental and estimated T_α for the superheavy nuclei in Figure 3. In this estimation, experimental Q_α are taken from Reference 1. These nuclei are not input data for parametrization because these were lacking or estimated data in the ENSDF file. This figure shows

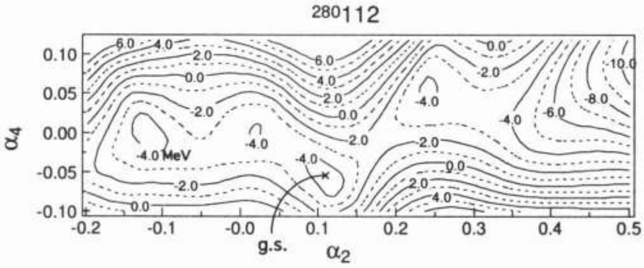

Figure 5. Calculated energy surface of ^{280}112. The ground-state shape of this nucleus is at about $\alpha_2 = 0.11$ and $\alpha_4 = -0.06$.

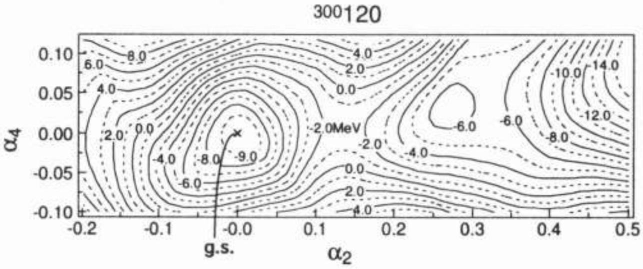

Figure 6. Calculated energy surface of ^{300}120. The ground-state shape of this nucleus is at about $\alpha_2 = \alpha_4 = 0.0$.

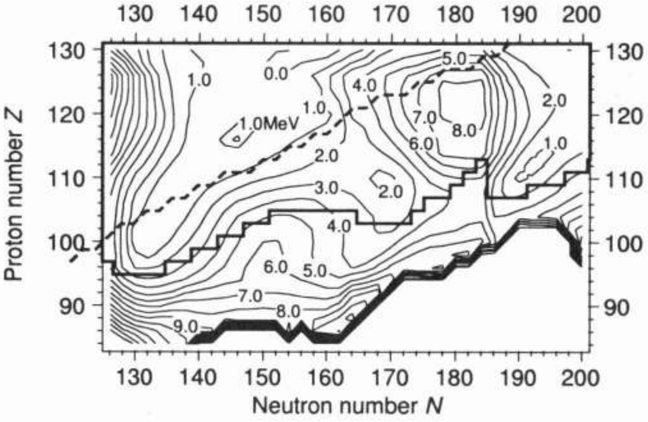

Figure 7. Fission-barrier heights for even-even nuclei. The dashed line is the proton-drip line of KUTY formula (even-Z). The neutron-rich nuclei located below the solid line may have the higher saddle point in the region $\alpha_2 > 0.5$.

that the estimated T_α are smaller than the measured ones. The values from Formula (B) are relatively larger than those from Formula (A) for the nuclei with large mass numbers.

With the use of Formula (B), we systematically calculate the T_α for superheavy nuclei. In order to estimate the Q_α of superheavy nuclei, we use the KUTY mass formula.[2,3] The result is shown in Figure 4. In this figure our α-decay half-lives present a feature of magicity at $Z = 114$ and at $Z = 126$ as relatively wide gaps between isotope lines, while a similar figure with the use of FRDM mass formula[10] has a larger gap only at $Z = 114$, and that with the use of ETFSI mass formula[11] shows no gap. (The results of FRDM and ETFSI are not shown in the figures.) The magicity at $N = 184$ is also seen as steep decreasing of isotope lines just beyond $N = 184$. The oscillations of the isotope lines are seen because of the even-odd hindrance effect.

3. Spontaneous Fission

Although our mass formula is constructed by considering only the equilibrium nuclear shapes, the potential energy surface for spontaneous fission can be calculated by the same method as used for obtaining the shell energies. The fission barrier heights are defined as the highest saddle points from the ground-state shell energies towards the prolate shapes. In this report we take the α_2, α_4, α_6 deformations in the range $-0.2 < \alpha_2 < 0.5$.

We show the energy surfaces against the nuclear deformation for two superheavy nuclei in Figures 5 and 6. For the nucleus ^{280}112, the height of the fission barrier is only about 2 MeV and its width is relatively narrow. The spontaneous-fission half-life is consequently expected to be rather short for this nucleus. On the contrary, for the nucleus ^{300}120, the fission barrier height is about 8 MeV, and this width is fairly wide. Therefore, the spontaneous fission of this nucleus is expected to have a very long partial half-life, much longer than the α-decay half-life.

We show the fission barrier heights in Figure 7 for even-even nuclei in the range $84 \leq Z \leq 130$ and $126 \leq N \leq 200$. The nuclei which locate below the solid line may have a higher saddle point in the region $\alpha_2 > 0.5$ because we limited the range on the present calculation.

This figure shows the "hill" of the barrier heights of the nuclei near ^{304}122. These barrier heights are about 8 MeV or more. Therefore these spontaneous-fission half-lives are expected to be very long. On the contrary, the "basin" of the barrier heights of the nuclei near ^{278}110 is also seen. These heights are about 2 MeV. There are also other neutron-deficient nuclei having relatively small fission barrier heights whose spontaneous-fission half-lives expected to be rather short.

Acknowledgment. The author thanks Prof. M. Yamada for valuable comments. The numerical calculations were mainly done with the computer VX at Media Network Center (MNC), Waseda University and with the VPP700 at Computer and Information Division, RIKEN. This work was financially supported by MNC of Waseda University as Specific Studies A in 2001.

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