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Prediction of the Spin-Parities and the Magnetic Moments for the Ground States of Proton-rich Nuclei with Z = 21 - 30

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The present paper reports on the spin-parities and the magnetic moments for the ground states of 44 proton-rich isotopes with $Z = 21 - 30$ and $A = 36 - 57$, which are important for studies of either reaction rates in X-ray bursts or nuclear structure. These nuclear properties were calculated based on the single-particle shell model. The spins of the concerned nuclei were compared to available experimental data adopted from the NuDat database to evaluate the variations in the astrophysical rates of the *rp*-process reactions. We found discrepancies, due to the deformed nuclear structure, between the present results and those reported in the NuDat database. The spin uncertainties result in large variations, 13% – 200%, in the astrophysical rates of the *rp*-process reactions. In particular, the spin uncertainties of the ^{44}V and the $^{46-49}$Mn isotopes significantly affect the astrophysical rates of the reverse reactions of the proton captures $^{43}\mathrm{Ti}(p,\gamma)^{44}\mathrm{V}(p,\gamma)^{45}\mathrm{Cr}$, $^{45}\mathrm{Cr}(p,\gamma)^{46}\mathrm{Mn}(p,\gamma)^{47}\mathrm{Fe}$, $^{47}\mathrm{Mn}(p,\gamma)^{48}\mathrm{Fe}$, $^{47}\mathrm{Cr}(p,\gamma)^{48}\mathrm{Mn}(p,\gamma)^{49}\mathrm{Fe}$, and $^{48}\mathrm{Cr}(p,\gamma)^{49}\mathrm{Mn}(p,\gamma)^{50}\mathrm{Fe}$. Moreover, the magnetic moments of most of the isotopes were predicted for the first time. The results show that the magnetic moments are in the order of $\mu_p(1f_{7/2}) > \mu_p(2p_{3/2}) > \mu_n(1d_{3/2}) > \mu_n(1f_{7/2})$ for the nuclei having an unpaired nucleon in the proton/neutron shells. The present study suggests that reliable calculations and/or measurements for the properties of proton-rich nuclei are highly demanded.

Keywords: Unstable nuclei, rp-process, Proton capture, Photodisintegration, Reaction rates
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I. INTRODUCTION

Rapid proton capture (*rp*-process) is believed to proceed via a combination of (α, p) reactions, proton captures, and β^+-decays until the photodisintegration hinders the nuclear flow of nucleosynthesis in X-ray bursts (XRBs) [1–3]. This process strongly occurs at the quenching of the $\alpha p-$process around proton-rich Sc isotopes ($Z = 21$), leading to the branching of reaction flows due to the short β^+-decay half-lives of proton-rich nuclei [2]. If the proton captures, (p, γ), are not able to compete with the photodisintegrations and β^+-decays, the nucleosynthesis can shift towards the island of stability. Hence, the establishment of the $(p, \gamma) - (\gamma, p)$ equi-

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