Nuclear spin catalysis in biochemical reactions driven by biomolecular motors

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The magnetic isotope effect (MIE) was discovered in chemistry about fifty years ago [1]. Not long ago, MIEs were discovered in living nature, in the experiments with cells enriched with different isotopes of magnesium [2]. Furthermore, the catalytic MIEs were discovered in the experiments with myosin, the most important molecular motor of bioenergetics utilizing the energy of ATP to perform mechanical work. The rate of the enzymatic hydrolysis of ATP in the reaction media, enriched with the magnetic isotope, ^{25}Mg, is twice as high as it is in the reaction media, enriched with the nonmagnetic isotope, ^{24}Mg or ^{26}Mg. A similar nuclear spin effect was detected in the experiments with zinc as the enzyme cofactor. The rate of the ATP hydrolysis with the magnetic ^{67}Zn increases by 40–50%, compared to that with the nonmagnetic ^{64}Zn or ^{68}Zn. Similar catalytic effects of the magnetic ^{25}Mg were found in the experiments with H^+-ATPase isolated from yeast mitochondria and Mg-dependent ATPase of the myometrium plasma membrane [3]. The MIE unambiguously indicates that there is a limiting step in the chemo-mechanical process catalyzed by the molecular motors, which depends on the electronic spin state, and this step is accelerated by the nuclear spin of the magnetic isotope. The nuclear spin catalysis may be explained as follows. The energy released from the hydrolysis of ATP (~0.54 eV) is not enough for the electron-conformational transition of the enzyme macromolecule to the singlet excited state. This energy is sufficient for a transition to the lower triplet state (S = 1), but such a transition from the ground state (S = 0) is prohibited by the spin conservation law. The nuclear spin of the isotope removes this forbiddance, thereby accelerating the chemo-mechanical cycle in the enzymatic reaction, Detailed mechanisms of MIE in living cells and enzymatic reactions are the tasks for further investigations.

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[1] A.L. Buchachenko, R.Z. Sagdeyev, K.M. Salikhov. Magnetic and spin effects in chemical reactions, *Nauka*, Novosibirsk, **1978** (in Russian).

[2] L.V. Avdeeva, V.K. Koltover, *Moscow Univ. Chem. Bull.* **2016**, *71*, pp. 160-166.

[3] V.K. Koltover, *Russ. Chem. Bull.* **2021**, 70, pp. 1633-1639.