Erratum: High resolution β-NMR study of $^8Li^+$ implanted in gold [Phys. Rev. B 77, 214107 (2008)]

T. J. Parolin, Z. Salman, K. H. Chow, Q. Song, J. Valiani, H. Saadaoui, A. O'Halloran, M. D. Hossain, T. A. Keeler, R. F. Kiefl, S. R. Kreitzman, C. D. P. Levy, R. I. Miller, G. D. Morris, M. R. Pearson, M. Smadella, D. Wang, M. Xu, and W. A. MacFarlane

(Received 24 October 2019; published 18 November 2019)

DOI: 10.1103/PhysRevB.100.209904

The Knight shift of implanted radioactive ^{8}Li in metals can easily be measured by β-detected NMR in magnetic fields in the Tesla range [1,2]. However, because such shifts are small, on the order of 100 ppm, the effect of demagnetization is significant and further enhanced by geometry as samples are often in the form of thin films perpendicular to the applied field, yielding the maximum demagnetization factor $N = 1$. The values reported in Table I of the original paper erroneously use the paramagnetic Pauli susceptibility to calculate the demagnetization field. The correct treatment uses the full static uniform magnetic susceptibility. The group-11 metals are well known to be weakly diamagnetic [3,4] rather than paramagnetic [5], and the demagnetization field, thus, has the opposite sign. Using the values summarized in Table I, we calculate the additive correction to the shift in a thin film as

$$K^d\ (\text{ppm}) = 10^6\left(\frac{8\pi}{3}\chi\right)$$

to produce the corrected Table II. In the process, we correct an unrelated typographical error in $\mathcal{K}$ for Ag. We have used the originally reported uncertainties, but we note the two resonances in Cu are unresolved [6], so the uncertainties are likely underestimated. In contrast, the uncertainties in Ag include the effect of a slight systematic temperature dependence [1]. A final caveat is that the Korringa ratio in Au rests on a single value of $1/T_1$.

As a consequence of this correction, the dimensionless Korringa ratio for Au, defined as $\mathcal{K} = (K^c)^2 T_1 T/\mathcal{S}$, is significantly less than unity (free electrons), i.e., the relaxation is faster than expected from the shift. The discrepancy is even larger when the measured [7] conduction electron g factor is used since $\mathcal{S}$ is larger by a factor of $(g/g_0)^2 \approx 1.11$. A value of $\mathcal{K} > 1$ is generally considered to be the result of ferromagnetic electron correlations slowing the relaxation, whereas the measured $\mathcal{K} < 1$ indicates antiferromagnetic correlations, just opposite to the controversial reports of ferromagnetism in nanocrystalline Au [8]. Alternatively, an additional spin-lattice relaxation mechanism may operate at room temperature, effectively shortening T_1. To test this, measurements of the T dependence of $1/T_1$ in Au are essential.

TABLE I. The relative resonance shifts for ^{8}Li reported in Refs. [1,6], magnetic susceptibility [3,4], and the demagnetization shift correction for the group-11 metals.

	K^{raw} (ppm)		$\chi \times 10^6$	K^d
	S	O	(emu/cm^3)	(ppm)
Cu	120(3)	182(3)	−0.77	−6.45
Ag	120(12)	212(15)	−1.90	−15.9
Au	63(4)	131(4)	−2.75	−23.0

TABLE II. The corrected version of Table I of the original paper: Summary of β-NMR shifts K, hyperfine couplings A_{hf}, and Korringa ratios $\mathcal{K}$ for $^8Li^+$ in the group-11 metals, Cu (Ref. [6]), Ag (Ref. [1]), and Au (the original paper). The Korringa ratio from conventional NMR $\mathcal{K}_{\text{NMR}}$ from Ref. [9] is also shown for comparison.

	K^c (ppm)		A_{hf} (kG/μ_B)			$\mathcal{K}$	
Host	S	O	S	O	$A^O_{\text{hf}}/A^S_{\text{hf}}$	S site	$\mathcal{K}_{\text{NMR}}$
Cu	114(3)	176(3)	4.0(1)	12.3(2)	3.1(1)	1.01(4)	1.83(15)
Ag	104(12)	196(15)	5.0(6)	19.0(1.5)	3.8(6)	0.74(10)	2.22(20)
Au	40(4)	108(4)	1.5(2)	8.1(3)	5.4(6)	0.30(3)	1.40(16)

[1] G. D. Morris, W. A. MacFarlane, K. H. Chow, Z. Salman, D. J. Arseneau, S. Daviel, A. Hatakeyama, S. R. Kreitzman, C. D. P. Levy, R. Poutissou, R. H. Heffner, J. E. Elenewski, L. H. Greene, and R. F. Kiefl, Depth-Controlled β-NMR of ^{8}Li in a Thin Silver Film, Phys. Rev. Lett. **93**, 157601 (2004).

[2] W. A. MacFarlane, Implanted-ion β NMR: A new probe for nanoscience, Solid State Nucl. Magn. Reson. **68-69**, 1 (2015).

[3] E. Vogt, in *Magnetism and Metallurgy*, edited by A. E. Berkowitz and E. Kneller (Academic, New York, 1969), Vol. 1, Chap. 6, p. 249.

[4] C. M. Hurd, The magnetic susceptibility of silver and gold in the range 6–300 K, J. Phys. Chem. Solids **27**, 1371 (1966).

[5] A recent calculation for Cu can be found in M. d'Avezac, N. Marzari, and F. Mauri, Spin and orbital magnetic response in metals: Susceptibility and NMR shifts, Phys. Rev. B **76**, 165122 (2007).

[6] Z. Salman, A. I. Mansour, K. H. Chow, M. Beaudoin, I. Fan, J. Jung, T. A. Keeler, R. F. Kiefl, C. D. P. Levy, R. C. Ma, G. D. Morris, T. J. Parolin, D. Wang, and W. A. MacFarlane, β-NMR of isolated ^{8}Li implanted into a thin copper film, Phys. Rev. B **75**, 073405 (2007).

[7] P. Monod and A. Jánossy, Conduction electron spin resonance in gold, J. Low Temp. Phys. **26**, 311 (1977).

[8] G. L. Nealon, B. Donnio, R. Greget, J.-P. Kappler, E. Terazzi, and J.-L. Gallani, Magnetism in gold nanoparticles, Nanoscale **4**, 5244 (2012).

[9] A. Narath and H. T. Weaver, Effects of electron-electron interactions on nuclear spin-lattice relaxation rates and knight shifts in alkali and noble metals, Phys. Rev. **175**, 373 (1968).