

Structure and Properties of Functional Materials

Exercise Set 9

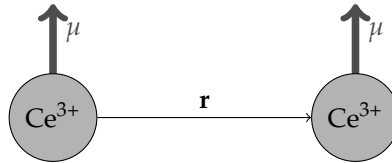
Friday, 22 March, 2013

1. *For discussion and collaboration*

Use Hund's rules to complete the following table, predicting the magnetic ground state of the $4f$ ions. Compare your answers to the experimental values provided. Can you explain any disagreement? (Bonus question: can you explain why the experimental value is missing for one ion?)

Ion	Config.	S	L	J	g_J	μ_{eff} / μ_B	$\mu_{\text{eff}}^{\text{experimental}} / \mu_B$
Ce ³⁺	$4f^1$						2.51
Pr ³⁺	$4f^2$						3.56
Nd ³⁺	$4f^3$						3.3–3.7
Pm ³⁺	$4f^4$						–
Sm ³⁺	$4f^5$						1.74
Eu ³⁺	$4f^6$						3.4
Gd ³⁺	$4f^7$						7.98
Tb ³⁺	$4f^8$						9.77
Dy ³⁺	$4f^9$						10.63
Ho ³⁺	$4f^{10}$						10.4
Er ³⁺	$4f^{11}$						9.5
Tm ³⁺	$4f^{12}$						7.61
Yb ³⁺	$4f^{13}$						4.5
Lu ³⁺	$4f^{14}$						0

2. (a) Explain why Cu_2O , which contains copper ions with a $3d^{10}$ electron configuration, is diamagnetic, while $\text{Cu}(\text{OH})_2$, which contains copper ions with a $3d^9$ electron configuration, is paramagnetic.
- (b) Modelling the system as a spin- $\frac{1}{2}$ paramagnet, estimate the magnetic susceptibility of $\text{Cu}(\text{OH})_2$ at 300 K. The unit cell, of volume 164.10 \AA^3 , contains four copper ions. (Experimental value: $\chi = 5.95 \times 10^{-4}$.)
3. Estimate the energy of the dipole-dipole interaction between two Ce^{3+} ions separated by 2 \AA , with parallel magnetic moments perpendicular to the interatomic separation \mathbf{r} :



Take the effective magnetic moment from the first question.

Express your answer as a temperature, and hence explain why dipole-dipole interactions cannot be responsible for our everyday experience of ferromagnetism.