Magnetic Moment of Atom or Ion

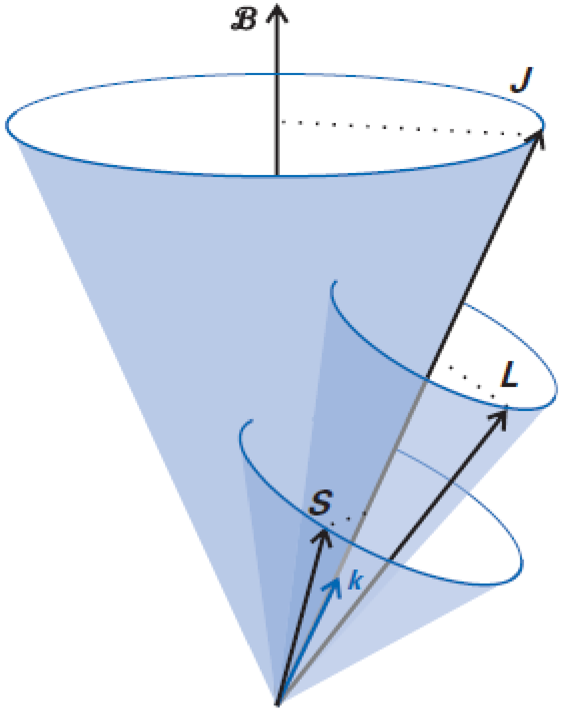


Fig. 7.23 The vector diagram used to calculate the Landé g-factor.

$$g_J(L,S) = 1 + \frac{J(J+1) + S(S+1) - L(L+1)}{2J(J+1)}$$

$\mathbf{m} = -gJ\ (L,S)(e/2me)\mathbf{J}$ (m points opposite to J)

$$m = gJ\ (L,S)\mu_B\sqrt{J(J+1)}$$

From Atkins and Friedman Molecular Quantum Mechanics

Magnetic Moments of Rare Earth Ions

Ion	Config.	S	L	J	$g_J(L,S)$	$g_J\sqrt{J(J+1)}$	m/m_B Exp. Ion
La^{3+}	4f0	0	0	0	0	0	0
Ce^{3+}	4f1	½	3	2½	6/7	2.54	2.52
Pr^{3+}	4f2	1	5	4	4/5	3.58	3.6
Nd^{3+}	4f3	1½	6	4½	8/11	3.62	3.5
Pm^{3+}	4f4	2	6	4	3/5	2.68	-
Sm^{3+}	4f5	2½	5	2½	2/7	0.84	1.5
Eu^{3+}	4f6	3	3	0	0	0	3.4
Gd^{3+}	4f7	3½	0	3½	2	7.94	8.0
Tb^{3+}	4f8	3	3	6	3/2	9.72	9.7
Dy^{3+}	4f9	2½	5	7½	4/3	10.63	10.6
Ho^{3+}	4f10	2	6	8	5/4	10.60	10.4
Er^{3+}	4f11	1½	6	7½	6/5	9.59	9.6
Tm^{3+}	4f12	1	5	6	7/6	7.57	7.3
Yb^{3+}	4f13	½	3	3½	8/7	4.54	4.5
Lu^{3+}	4f14	0	0	0	0	0	0

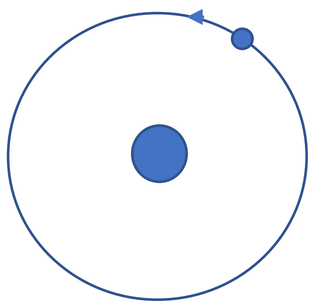
Experimental values in agreement with effective magnetic moment calculation except Eu^{3+}

Quenching of orbital angular momentum in solids

a) In atoms electrons have well-defined orbits. In solids, particularly metals, they don't.

b) It can also be shown that $\langle L \rangle = 0$ in ions due to crystal field effect.

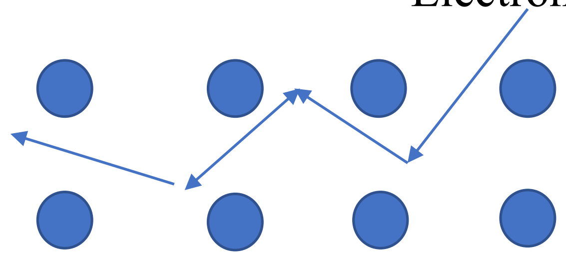
Free atom



$L \neq 0$

Solids

Electron trajectory



$L=0$

Magnetic moment in solids is almost entirely due to spin angular momentum

Transition Metal Ions

Table 5.2 *Calculated and measured effective magnetic moments for the first-row transition-metal ions.*

Ion	Configuration	$g\sqrt{J(J+1)}$	$g_S\sqrt{S(S+1)}$	m/μ_B	m_z/μ_B
Ti^{3+}, V^{4+}	$3d^1$	1.55	1.73	1.8	1
V^{3+}	$3d^2$	1.63	2.83	2.8	2
Cr^{3+}, V^{2+}	$3d^3$	0.77	3.87	3.8	3
Mn^{3+}, Cr^{2+}	$3d^4$	0.00	4.90	4.9	4
Fe^{3+}, Mn^{2+}	$3d^5$	5.92	5.92	5.9	5
* Fe^{2+}	$3d^6$	6.70	4.90	5.4	4
* Co^{2+}	$3d^7$	6.63	3.87	4.8	3
* Ni^{2+}	$3d^8$	5.59	2.83	3.2	2
Cu^{2+}	$3d^9$	3.55	1.73	1.9	1

From [21]. Reprinted by permission of John Wiley & Sons.

* Partial quenching

Source: Nicola Spaldin, Magnetic Materials