The spin-only magnetic moment formula, widely used for calculating the magnetic moment of some particular metal complexes, was developed by Debendra Mohan Bose, one of the pioneering physicists of the early twentieth century in India. The formula later became popular as the ‘Bose–Stoner formula’ as Edmund C. Stoner provided some theoretical explanations of its origin.

Electron, considering it a particle, has both spinning and rotational (orbital) motion around the nucleus in an atom. As any moving electrical charge generates a magnetic field, atoms/ions with unpaired electron(s), which are moving in their valence orbital, are magnetic. Naturally, the magnetic moment in atoms/ions should be contributed by both orbital and spinning motions of the unpaired electron(s). But the few first row (of the periodic table) transition metal complexes (and also some others) with some particular oxidation level (i.e., with particular electronic configurations) are exceptions to this idea. Transition metal d-orbitals are split into $t_{2g} - e_g$ and $e - t_2$ sets in octahedral ($O_h$) and tetrahedral ($T_d$) ligand fields, respectively. There is no orbital contribution to the magnetic moment for the unpaired electron(s) in the two orbitals in $e$ sets in any ligand fields (either $O_h$ or $T_d$). This is why the two orbitals in $e$ set are called non-magnetic doublets. In the case of the $t_2$ set (in both $O_h$ and $T_d$), where the orbitals are geometrically interconvertible, the unpaired electron(s) produce an orbital contribution to magnetic moment. This is subject to the condition that an electron in a particular orbital can be placed in any of the three orbitals (in the $t_2$ set) without violating the Pauli exclusion principle and altering the spin state. Following this the only electronic configurations $d^1, d^2, d^3$ (low spin), $d^5$ (low spin),

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$d^5$ (high spin) and $d^7$ (high spin) in $O_h$ field have orbital contribution. For $T_d$ field, the electronic configurations are $d^3$, $d^4$, $d^5$ and $d^6$. The rest of the electronic configurations show spin-only magnetic moment, and hence in these cases, the experimental values do not match well with the theoretical findings if it accounts for both orbital and spin contributions. For the calculation of this spin-only magnetic moment, the following formula is widely applied:

$$\mu_{\text{spin only}} = \sqrt{n(n + 2)} \mu_B,$$

(1)

where $n =$ number of unpaired electrons, and $\mu_B =$ Bohr magneton.

This excellent idea of spin-only magnetic moment for first-row transition metal complexes was introduced by the celebrated Indian physicist Prof. Debendra Mohan Bose (DM Bose) in 1927 [1]. The derivation of the formula [1] is the consequence of famous Curie’s law. If $\chi$ is the magnetic susceptibility, then from the Van Vleck formula:

$$\chi = \frac{Ng^2\mu_B^2 S(S + 1)}{3kT} \quad \text{(symbols bear usual meaning)}$$

$$= \frac{C}{T} \left[ C = \frac{Ng^2\mu_B^2 S(S + 1)}{3k} \right].$$

This is Curie’s law. Now, $g^2\mu_B^2 S(S + 1)$ is defined as $\mu_{\text{eff}}^2$.

Now, $\mu_{\text{eff}}^2 = g^2\mu_B^2 S(S + 1)$ and $\mu_{\text{eff}} = g\sqrt{S(S + 1)}\mu_B$.

For free electron $g \approx 2$.

So, $\mu_{\text{eff}} = 2\sqrt{S(S + 1)}\mu_B = \sqrt{4S(S + 1)}\mu_B$.

If number of unpaired electron is ‘$n$’, then $S = \frac{g}{2}$. Putting this in the above relation,

$$\mu_{\text{eff}} = \sqrt{n(n + 2)} \mu_B.$$ 

So it can be stated that if only the electron spins are considered.
then the $\mu_{\text{eff}}$ may be calculated with this spin-only magnetic moment formula. This was what D M Bose suggested. A similar conclusion was arrived at [1] from Curie–Weiss law.

Soon after the publication of D M Bose’s pioneering work [1] on the spin-only magnetic moment, Edmund C. Stoner of the University of Leeds tried to put forth some theoretical basis on it [2]. Stoner summarized the work of Laporte, Sommerfeld, Van Vleck, and others and drew out a theoretical explanation of D M Bose’s spin-only formula. As a result, the well-known spin-only magnetic moment formula (1), originally proposed by D M Bose [1], became popular as the ‘Bose–Stoner formula’ [3].

The spin-only formula is frequently used in chemistry to calculate the magnetic moment of some paramagnetic first-row transition metal complexes. The anomaly in experiment and theory (where both orbital and spin contributions are considered) in magnetic moment measurements of these complexes triggered Debendra Mohan to propose the formula. This spin-only formula nicely correlates the experimental and theoretical values of the magnetic moments, not only for first-row transition metals but also in other systems like high spin Gd(III) complexes (where the total orbital moment quantum number is zero). Later on, this formula was justified using the Van Vleck equation. Unfortunately, the discoverer of a formula of such prime importance has remained shaded for a long period, and the present generation of teachers and students, while very familiar with the formula, are not much familiar with its proposer.

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