The influence of particle anisometry on the magnetic characteristics of dipolar cubic colloids.

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Motivation

Colloidal Magnetic Cubes in Experiment

Kovalenko et al 2007

Wetterskog et al 2014

Meijer et al 2013

Ross et al 2011

Ross et al 2011
Motivation

Colloidal Magnetic Cubes in Experiment.

Motivation

Talking Point

How does a cube* have to be cubie, cubish, cubic to behave like a cube*? *magnetic
What we know already

Spherical particle ground state

Conclusion

Chain structure is the preferred GS-cluster for $N < 4$
Ring structure is the preferred GS-cluster for $N \geq 4$
What we know already

Spherical particle ground state

Conclusion

Chain structure is the preferred GS-cluster for \( N < 4 \)

Ring structure is the preferred GS-cluster for \( N \geq 4 \)
Chain structure is the preferred GS-cluster regardless of N.

What we know already

Cube particle ground state - [001]

Conclusion

Chain structure is the preferred GS-cluster regardless of N.
What we know already

Cube particle ground state - [001]

Conclusion

Chain structure is the preferred GS-cluster regardless of N.
Talking Point 1.1

How cubie does a cube* have to be to behave like a cube*?
What we now know

Super-quadrics
spheres to cubes

\[ \left| \frac{2x}{h} \right|^{2q} + \left| \frac{2y}{h} \right|^{2q} + \left| \frac{2z}{h} \right|^{2q} \leq 1 \quad q \in [1, \infty] \]

Effect of curvature parameter, \( q \)

- \( q = 1 \)
- \( q = 1.5 \)
- \( q = 2 \)
- \( q = 4 \)
- \( q = 6 \)
- \( q \to \infty \)
What we now know

Super-ball ground state - [001]

Ring

\[ u_r(q, N) = \frac{-\sin^3 \left( \frac{\pi N}{N} \right) }{d(q, N)^3} \left[ \sum_{k=1}^{N-1} \frac{\cos^2 \left( \frac{\pi k}{N} \right) + 1}{\sin^3 \left( \frac{\pi k}{N} \right)} + \frac{\text{mod}(N + 1, 2)}{2} \right] \]

Chain

\[ u_c(N) = -\frac{2}{N} \sum_{k=1}^{N-1} \frac{N - k}{k^3} \]
What we now know

Super-ball ground state - [001]

\[ u_r(q, N) = \frac{-\sin^3\left(\frac{\pi}{N}\right)}{d(q, N)^3} \left[ \frac{N-1}{2} \sum_{k=1}^{\frac{N}{2}} \frac{\cos^2\left(\frac{\pi k}{N}\right) + 1}{\sin^3\left(\frac{\pi k}{N}\right)} + \frac{\text{mod}(N + 1, 2)}{2} \right] \]

Inter-dipolar distance

\[ d(q, N) = \left[ \cot\frac{2q}{2q-1} \left( \frac{\pi}{N} \right) + 1 \right]^\frac{2q-1}{2q} \sin \frac{\pi}{N} \]
What we now know

Ring \( u_{ring}(N) \)

Inter-dipolar distance \( d[q,N] \)

\[
\sum_{k=1}^{N-1} \frac{N-k}{k^3}
\]

\[
\pi \left( \frac{N+1}{2} \right)
\]
What we now know

Super-ball ground state - [001]
What we now know

Ring-chain transition

\[ u_r(q, N) = u_c(N) \]

\[ \cot \frac{2q}{2q-1} \left( \frac{\pi}{N} \right) + 1 = \left[ \frac{\tilde{u}_r(N)}{u_c(N)} \right] \frac{2q}{3(2q-1)} \]

Large N approx

\[ N(q) = \pi^{2q} \left[ \frac{3(2q-1)\zeta(3)}{2q\zeta(2)} \right]^{2q-1} - \left[ \frac{(2q-1)\zeta(3)\pi^2}{\zeta(2)} + \frac{8q-3}{6} \frac{\zeta(2)}{\zeta(3)} \right] \]
What we now know

Ring-chain transition

Energy Difference $\Delta U^*(\text{Chain–Ring})$

-0.4 | -0.3 | -0.2 | -0.1 | 0 | 0.1

What we now know

$N$ vs $q$

$P$ (%) vs $q$

$N$ vs $N$

Ring-chain transition

Percentage deviation

Joe G. Donaldson, SIF-Rome, 25/09/2015
Conclusions

• The value of $q$ doesn’t need to deviate significantly from one (sphere) to exhibit properties similar to that of perfect dipolar cubes.

• Ring-chain GS transition occurs for $N$ increasing with increasing $q$. 
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