Periodic Graphics

A collaboration between C&EN and Andy Brunning, author of the popular graphics blog *Compound Interest*

More online

To see more of Brunning's work, go to compoundchem.com. To see all of C&EN's Periodic Graphics, visit cenm.ag/periodicgraphics.

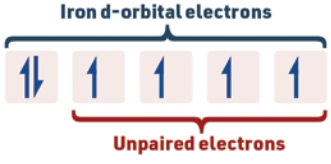
Permanent magnets explained

PERIODIC GRAPHICS

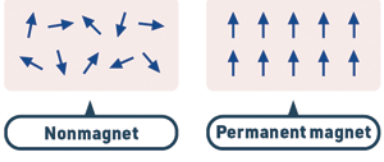
Magnets: How do they work? Here we examine the subatomic origins of magnetism and compare the compositions, strengths, and costs of the four types of permanent magnets.

Origins of magnetism

Electrons produce a magnetic field because of a quantum property called spin. When electrons pair up in atomic orbitals, they must have opposite spins, which means their magnetic fields cancel out. But when atoms have unpaired electrons, they can generate a magnetic field.



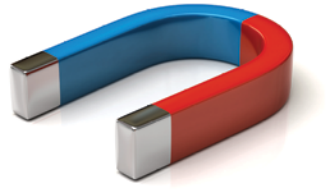
When atoms' magnetic fields point in random directions in a material, they cancel one another out. When the fields line up, an overall magnetic field is created—resulting in a permanent magnet.



Three elements show permanent magnetism at room temperature: iron, cobalt, and nickel.

Types of magnets

There are four main types of commercially used permanent magnets. Over 80% of the magnets produced worldwide by weight are ferrite magnets. But neodymium magnets account for over 60% of permanent magnet sales.



10 kJ m^{-3} (maximum energy product)

$20 per kilogram

Alnico magnets

Composition	Al, Co, Fe, and Ni alloys
Strength	
Cost	

Used in motors, guitar pickups, and microphones. Operate at the highest temperatures of any permanent magnet.

Samarium-cobalt magnets

Composition	$SmCo_5$ or Sm_2Co_{17}
Strength	
Cost	

Used in magnetic resonance imaging, guitar pickups, and satellites. Resist corrosion and operate at high temperatures.

Ferrite magnets

Composition	Ba or Sr iron oxides
Strength	
Cost	

Used in small motors, refrigerator magnets, and loudspeakers. Resist corrosion.

Neodymium magnets

Composition	$Nd_2Fe_{14}B$
Strength	
Cost	

Used in headphones, telephones, hard disks, and electric vehicles. Plated to prevent rusting.