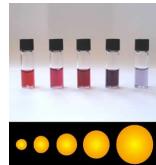


Nanotechnology: What's All the Buzz About

Nanotechnology is the science and technology of small things – in particular things that are less than 100nm in size. One nanometer is 10^{-9} or one billionth of a meter. Scientists have discovered that materials at small dimensions-small particles, thin films, etc., can have significantly different properties than the same materials at larger scale. There are endless possibilities for improved devices, structures, and materials if we can understand these differences, and learn how to control materials and structures at the nanoscale. There are different views of what is included in nanotechnology but most agree that three things are important: 1) Small size – 1 to 100 nanometers or less, 2) Unique properties because of the small size, and 3) Ability to control the structure and composition in order to control these properties.

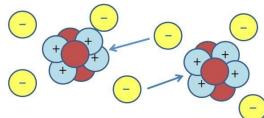
Examples of How Properties Change at the Nanoscale

Optical Properties: Bulk gold appears yellow in color. Nanosized gold appears as different colors depending on particle size. Many other materials behave similarly. The ability to change the optical properties of materials is a powerful tool in the development of nanotechnology products

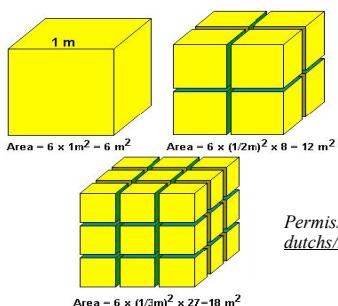


Douma, M., curator. (2008). Gold. In Cause of Color. Retrieved 1/30/2012, <http://www.webexhibits.org/causesofcolor/3.html>.

Forces: gravitational forces become negligible and electromagnetic forces dominate.



Surface Area to Volume Ratio: For smaller particles, a greater proportion of material is exposed on the surface. This becomes even more important in the nanoscale, where a large fraction of the atoms become “surface atoms” where they are more accessible to chemical reactions



Permission granted by S. Dutch; <http://www.uwgb.edu/dutchs/EarthSC202Notes/ROCKCYCL.HTM>

More Nanotechnology Resources
www.nnn.org/education-training
Learn more about Nanotechnology
www.nanooze.org



National Nanotechnology
Coordinated Infrastructure



Allotropes of Carbon

Graphite – atomic planes slide easily over each other making it a natural lubricant.

Image courtesy of R.Weller/Cochise College

Diamond – rarely occurs naturally

hardest naturally occurring sub-

Image courtesy of R.Weller/Cochise College

Buckminsterfullerene C₆₀ – nicknamed “bucky ball”

Image at US DOE: <http://www.osti.gov/accomplishments/smalley.html>

Carbon 100 times stronger than steel

nanotubes – 100 times stronger than steel

Reference ♦ CHEMISTRY ♦ Information

Formulas

Density = $\frac{\text{mass}}{\text{volume}}$	$D = \frac{m}{V}$
Equilibrium constant for $aA + bB \rightleftharpoons cC + dD$	$K_{\text{eq}} = \frac{[C]^c[D]^d}{[A]^a[B]^b}$
Ionization constant of water = $(\frac{\text{hydrogen ion concentration}}{\text{concentration}})(\frac{\text{hydroxide ion concentration}}{\text{concentration}})$	$K_w = [\text{H}^+][\text{OH}^-]$
pH = -logarithm (hydrogen ion concentration)	$\text{pH} = -\log[\text{H}^+]$
Molarity = $\frac{\text{moles of solute}}{\text{liter of solution}}$	$M = \frac{\text{mol}}{\text{L}}$
Molality = $\frac{\text{moles of solute}}{\text{kilogram of solvent}}$	$m = \frac{\text{mol}}{\text{kg}}$
Boiling point elevation = $(\frac{\text{molal boiling point constant}}{\text{constant}})(\text{molality})$	$\Delta T_b = K_b m$
Freezing point depression = $(\frac{\text{molal freezing point constant}}{\text{constant}})(\text{molality})$	$\Delta T_f = K_f m$
$(\frac{\text{Volume of solution a}}{\text{solution a}})(\text{molarity of solution a}) = (\frac{\text{volume of solution b}}{\text{solution b}})(\text{molarity of solution b})$	$V_a M_a = V_b M_b$
(Pressure)(volume) = (moles)(ideal gas constant)(temperature)	$PV = nRT$
$\frac{(\text{Initial pressure})(\text{initial volume})}{(\text{Initial moles})(\text{initial temperature})} = \frac{(\text{final pressure})(\text{final volume})}{(\text{final moles})(\text{final temperature})}$	$\frac{P_1 V_1}{n_1 T_1} = \frac{P_2 V_2}{n_2 T_2}$
Total pressure of a gas = $(\frac{\text{sum of the partial pressures of the component gases}}{\text{of the component gases}})$	$P_T = P_1 + P_2 + P_3 + \dots$
Heat gained or lost = $(\text{mass})(\frac{\text{specific heat}}{\text{heat}})(\frac{\text{change in temperature}}{\text{temperature}})$	$Q = mc_p \Delta T$
Final mass = $(\text{initial mass})(\frac{1}{2})(\text{number of half-lives})$	$m_f = m_i(\frac{1}{2})^n$
Enthalpy of reaction = $(\frac{\text{enthalpy of products}}{\text{of products}}) - (\frac{\text{enthalpy of reactants}}{\text{of reactants}})$	$\Delta H = \Delta H_f^\circ(\text{products}) - \Delta H_f^\circ(\text{reactants})$
Percent error = $(\frac{\text{accepted value} - \text{experimental value}}{\text{accepted value}})(100)$	
Percent yield = $(\frac{\text{actual yield}}{\text{theoretical yield}})(100)$	

10^n	Prefix	Symbol	Decimal
10^{24}	yotta-	Y	1 000 000 000 000 000 000 000 000
10^{21}	zetta-	Z	1 000 000 000 000 000 000 000 000
10^{18}	exa-	E	1 000 000 000 000 000 000 000 000
10^{15}	peta-	P	1 000 000 000 000 000 000 000 000
10^{12}	tera-	T	1 000 000 000 000 000 000 000 000
10^9	giga-	G	1 000 000 000
10^6	mega-	M	1 000 000
10^3	kilo-	k	1 000
10^2	hecto-	h	100
10^1	deca-	da	10
10^0	(none)	(none)	1
10^{-1}	deci-	d	0.1
10^{-2}	centi-	c	0.01
10^{-3}	milli-	m	0.001
10^{-6}	micro-	μ	0.000 001
10^{-9}	nano-	n	0.000 000 001
10^{-12}	pico-	p	0.000 000 000 001
10^{-15}	femto-	f	0.000 000 000 000 001
10^{-18}	atto-	a	0.000 000 000 000 000 001
10^{-21}	zepto-	z	0.000 000 000 000 000 000 001
10^{-24}	yocto-	y	0.000 000 000 000 000 000 000 001

Periodic Table of Elements

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18		
1 H Hydrogen 1.00794	2 He Helium 4.002602	3 Li Lithium 6.941	4 Be Beryllium 9.01182	5 B Boron 10.811	6 C Carbon 12.0107	7 N Nitrogen 14.007	8 O Oxygen 15.9994	9 F Fluorine 18.998432	10 Ne Neon 20.1797	11 Na Sodium 22.9897932	12 Mg Magnesium 24.305	13 Al Aluminum 26.981538	14 Si Silicon 28.0855	15 P Phosphorus 30.9737	16 S Sulfur 32.065	17 Cl Chlorine 35.455	18 Ar Argon 39.948		
Solid Hg Liquid H Gas Rf Unknown	Lanthanoids Actinoids	Metals Alkaline earth metals Transition metals Poor metals Other nonmetals Noble gases																	
20 K Potassium 39.0963	21 Sc Scandium 44.959812	22 Ti Titanium 47.857	23 V Vanadium 50.915	24 Cr Chromium 51.9951	25 Mn Manganese 54.93845	26 Fe Iron 55.845	27 Co Cobalt 58.933195	28 Ni Nickel 58.934	29 Cu Copper 63.545	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.04	33 As Arsenic 74.9215	34 Se Selenium 78.95	35 Br Bromine 79.904	36 Kr Krypton 83.798			
37 Rb Rubidium 85.4679	38 Sr Strontium 87.62	39 Y Yttrium 88.9055	40 Y Yttrium 91.224	41 Nb Niobium 92.9058	42 Tc Technetium 95.95	43 Ru Ruthenium 101.07	44 Rh Rhodium 102.9055	45 Pd Palladium 105.42	46 Ag Silver 107.862	47 Cd Cadmium 112.411	48 In Indium 114.818	49 Tl Thallium 118.710	50 Sn Antimony 121.760	51 Sb Stibium 124.870	52 Te Tellurium 127.95	53 I Iodine 126.9047	54 Xe Xenon 131.293		
55 Cs Cassium 132.904519	56 Ba Barium 137.327	57 Hf Hafnium 178.49	58 Ta Tantalum 180.9478	59 T Tungsten 183.94	60 W Rhenium 185.207	61 Re Rhenium 186.23	62 Os Osmium 190.23	63 Ir Iridium 192.217	64 Pt Platinum 195.084	65 Au Gold 196.95559	66 Hg Mercury 200.59	67 Tl Thallium 204.933	68 Pb Lead 207.2	69 Bi Bismuth 208.9640	70 Po Polonium (208.9624)	71 At Astatine (209.9637)	72 Rn Radon (222.9176)		
77 Fr Francium (223)	78 Rb Rubidium (223)	79 Db Dubnium (260)	80 Sg Sesquibismuth (260)	81 Bh Bohrium (264)	82 Hs Hassium (267)	83 Mt Meitnerium (268)	84 Rg Rutherfordium (271)	85 Uub Ununbismuth (272)	86 Uut Ununtritellium (273)	87 Uup Ununquadium (289)	88 Uuh Ununhexium (289)	89 Uus Ununseptium (290)	90 Uuo Ununoctium (294)						
		57-71	89-103																
For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.																			
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57 La Lanthanum (138.90547)	58 Ce Cerium (140.115)	59 Pr Praseodymium (141.90765)	60 Nd Neodymium (144.242)	61 Pm Promethium (145.90536)	62 Sm Samarium (150.156)	63 Eu Europium (151.954)	64 Gd Gadolinium (157.23)	65 Tb Terbium (158.9255)	66 Dy Dysprosium (162.500)	67 Ho Holmium (164.93032)	68 Er Erbium (167.259)	69 Tm Thulium (168.93421)	70 Yb Ytterbium (173.054)	71 Lu Lutetium (174.9668)					
89 Ac Actinium (227)	90 Th Thorium (232.03808)	91 Pm Protactinium (231.03568)	92 U Uranium (238.02891)	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (252)					

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