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A little gold goes a long way

Just a little gold is proving valuable too, says S.Ananthanarayanan.

“Worth her weight in gold” and the “gold standard” have long been testimonials to say the yellow metal rocks. Yet, ***nanotechnology*** is showing that gold in minute quantities has uses that ladies and bankers never suspected!

The gold standard

Gold is valued because it is scarce, because of its ‘golden’ luster and the fact that it does not tarnish. Gold is then ‘for ever’ and in India the possession of gold has been regarded as the last word in ’security’. So powerful was the sway that gold held over international transactions that after World War II the Breton Woods Agreement of 1945, to regulate world trade, was based on gold as the scale to value currencies.

But at the physical level, the properties of gold are due to the distribution of electrons around its nucleus. The gold atom has 79 electrons around the nucleus, 78 in closed ‘shells’ and one electron in the outer shell. Metals generally have loosely bonded outer electrons and a ‘sea’ of almost free electrons at their surface. This accounts for the good conductivity of metals. The electrons are also able to absorb and re-emit (ie, reflect) light at different frequencies or colours and metals generally have a dull grey or ‘silvery’ colour.

But gold is different. While the inner electron shells of metal atoms ‘shield’ the outer electron from the nucleus and set it ‘free’, in gold, the effects of the Theory of Relativity kick in and some frequencies get blocked out for the outer electrons of gold. The result is that apart from very high electrical conductivity of the metal, light at the red side of the spectrum gets reflected more by the gold surface and the metal has a ‘golden’ colour.

Apart from being lustrous, gold is also the most inert of the metals and does not react with most chemicals, including nitric acid. This property, in fact is the way gold is purified and is also the way to test of the purity of gold, the ‘acid test’! This property also gives gold its great ability to resist corrosion and tarnishing, leading to its value in jewelry and also in industry. Silver, in fact has higher conductivity, but gold contacts are often preferred in electrical engineering and in electronics because gold contacts will not corrode. It is for the same reason that gold is often used for filling and capping teeth in dentistry.

Flip side

But along with the merits of being inert, gold has also been of little use as an agent to help initiate chemical reactions. Copper, silver and gold share features of atomic structure and are inert. But platinum is not one of the group and is able to act as a catalyst in chemical reactions. While it retains is inert quality in not forming lasting bonds with other elements, it is able to provide a ***fleeting*** stepping stone for other reactions to make progress. Here, gold, with its greater

inertness, would have been the star, but for the fact that it does not even engage in short-term liaisons which would enable gold to act as a ***catalyst***.

Catalysts are agents that help reactions that need to cross an 'energy barrier' to proceed. Hence, these reactions can progress if they are provided with the required energy or else they are blocked by the hill that is in their way. The catalyst provides an intermediate step, which the reactants can take without additional energy and provides a '***tunnel***', so to speak, through the hill. While catalysts need to stay away from the reaction itself, they do need to participate in some way, to help get things going.

Nanotechnology

Gold, in the normal state, has a surface that can be polished clean and does not react. But it does not retain this behaviour when it is in clusters of very few atoms, typically below 55 in number. Small numbers of atoms of many materials tend to clump together in specific numbers, which are called ***magic numbers***, where the combined energy tends to be the minimum and the cluster is most stable. A magic number of atoms will resist adding more atoms and the extra atoms generally form another magic number group. Or the whole may form into the next, higher magic number. The various regular geometries of carbon in forms like graphite, Fullerene (C60) and the extensions to nanotubes are examples of low energy combinations of atoms.

Scientists at the University of Cambridge have reported that clusters of 55 atoms of gold have proved effective in catalyzing the oxidation of styrene, an industrially attractive process. The activity of small particles of gold has been studied for nearly 20 years, but the effects were seen in combination with other materials or reagents. The present study, with 55 atom gold clusters on an inert base, shows that it is the gold that is promoting the chemical transformation of styrene.

Styrene provides 3 important products if a single atom of oxygen could be introduced into its structure. The challenge is to create a single, 'free' atom of oxygen, which usually exists as a combination of 2 atoms in a molecule. Gold surfaces do not activate oxygen in this way and support of materials like titanium oxide or sources of free hydrogen (to 'strip' the oxygen molecule) have been necessary.

The 55 atom nanoparticles, however, are found to activate oxygen and promote the partial oxidation of styrene. The discovery is industrially important, not only for producing styrene derivatives but also other processes that gold nanoparticles may be able to catalyse.

Just how could small clusters of gold be different from bulk gold? Clearly, it is in the way gold atoms at the surface of a particle are different if the particle is smaller. The atoms at the surface have fewer neighbours than atoms in the interior and they can take part in chemical action. The smaller the particle, the more the surface atoms, as a proportion. Also, the residual force at the surface from the bulk metal is less in the case of a smaller particle. It is also significant that the wave properties of the electron are of the same dimensions as a 55 atom nanoparticle. All this can radically change the way the atoms develop picks and pincers to prise apart and affect molecules that come within range!