Ivars Peterson reports from Chicago at the annual meeting of the American Association for the Advancement of Science (AAAS)

Shaking up quasicrystals

Normally, a crystalline material is made up of identical building blocks that stack neatly in a regularly repeating pattern. Thus, atoms occupy particular, well-defined positions within a crystal. In an amorphous material like glass, atoms tend to be scattered more or less randomly throughout a sample. Quasicrystals, discovered only two years ago, fall somewhere in between. Their building blocks don't appear to sit in a regular array, yet the sharp diffraction spots evident from X-ray or electron scattering experiments indicate a high degree of order and a fivefold symmetry (SN:3/23/85,p.188). Recent experiments show that the physical properties of quasicrystals have unique features that are quite unlike those of the corresponding crystalline forms.

One important property is how the material shakes or bends when it is "excited." These crystal lattice vibrations, which are called phonons, have a range of wavelengths and frequencies. To study this property, physicist Hartmut Zabel of the University of Illinois at Urbana-Champaign and his colleagues fired neutrons at samples of a quasicrystalline aluminum-manganese alloy. They observed changes in the energy and momentum of the scattered neutrons and used that information to deduce phonon characteristics. For comparison, they then heated each of their samples to transform them into their crystalline state and repeated the measurements.

The researchers found that for lower energies (or frequencies), both the crystalline and quasicrystalline forms had similar vibrational densities, indicating that their response at low temperatures to heat and their elastic properties or bending motions are about the same. At higher energies, however, the quasicrystalline structure shows a significantly higher density of vibrational states. Apparently, quasicrystals can have local lattice vibrations that either don't spread or are restricted to small regions of the lattice.

Zabel and his group also explored the magnetic properties of quasicrystals. A material's measured tendency to become magnetized (its magnetic susceptibility) is a good reflection of the arrangement and distribution of electrons within the material. The researchers observed that magnetism is much stronger in the quasicrystalline state than in the crystalline. "This enhancement could again be the result of an increased amount of localized electronic states," says Zabel. Now, further research is needed on larger crystals (SN:11/15/86,p.309) and at higher resolutions to obtain a more detailed understanding of the differences noted in these experiments.

Unmasking a 'Mona Lisa' coverup

The "Mona Lisa," on exhibit at the Louvre in Paris, no longer looks the way it did when Leonardo da Vinci finished his painting more than 450 years ago. Layers of discolored brown varnish, an extensive network of fine cracks and repeated restoration efforts have left their marks. To get an idea of how the masterpiece may have looked originally and to recover faint or lost details, physicist John F. Asmus of the University of California at San Diego has spent the last few years applying computer image processing techniques to a high-resolution photograph of the painting.

The first image processing step required converting the photograph into a digital image made up of 6 million pixels for each of the three colors: red, green and blue. Then, Asmus and his colleagues measured the amount of light at various wavelengths transmitted by a piece of ancient varnish. A mathematical procedure allowed the researchers to subtract the effect of the varnish from the digital image to create a brighter, more natural picture. A color reproduction of this transformed image appears in the spring issue of PERSPECTIVES IN COMPUTING.

Further digital manipulations helped remove some traces of the cracking pattern. Techniques such as enhancing the contrast and using false colors brought out fine details and spots where underlying patterns show through the upper layers of paint. The analysis revealed a string of dark spots below the neck, possibly a necklace that the artist eventually decided to obliterate before he was satisfied with his work. It also uncovered, in the picture's background, a faint, distant mountain ridge that may have been erased by a restorer.

Asmus's study of Leonardo's engrossing masterpiece is far from over. Still missing is a clear look at the Mona Lisa's lips to see how much of her celebrated, enigmatic smile is due to Leonardo and how much is the result of clumsy efforts by restorers trying to touch up the painting.

A rusty path to life's origin

One of the more notable gaps in theories concerning the origin of life on earth is the step from simple molecules, such as formaldehyde, cyanides and various amino acids, to complex polymers that can replicate themselves. A variety of credible, experimentally tested models have been proposed for the initial and final stages (SN:1/31/81,p.72; 4/21/84,p.247). What's missing, says Gustaf Arrhenius of the Scripps Institution of Oceanography in La Jolla, Calif., is a selective process for concentrating and converting a wide range of organic molecules into large, organized structures with the right biochemical properties.

Some scientists have suggested that amino acids, under the right conditions, spontaneously organize themselves into microscopic packets that have some of the electrical properties of primitive cells (SN:6/30/84,p.408). A more commonly held view is that the surfaces of minerals may have served as templates for the organization and combination of the molecular starting materials. Most of the attention, so far, has focused on clay minerals, usually aluminum silicates (SN:9/12/81,p.166). However, Arrhenius proposes that common minerals such as iron oxide hydroxides (rustlike compounds), manganates and iron-manganese phosphates are more likely candidates.

Unlike silicates, says Arrhenius, hydrous iron and manganese minerals grow and dissolve readily in response to small changes in acidity or electric potential. This allows these minerals periodically to release any polymers that may have formed. Clay minerals, he contends, lock up any internally synthesized polymers and "would thus seem to lead to a dead end from the point of view of molecular function and evolution." Furthermore, compounds containing transition elements such as iron and manganese are known to be generally more active than aluminosilicates as catalysts.

As a first step, Arrhenius and his group investigated the effect of ultraviolet light on two reaction systems, one consisting of iron sulfate dissolved in water saturated with carbon dioxide and the other a suspension of fine iron carbonate particles in water. In both cases, ferric oxide hydroxide appeared as a solid product along with some organic matter.

This demonstrates for the first time, says Arrhenius, "that ferrous carbonate in aqueous suspension is capable of producing organic compounds in [ultraviolet] radiation." However, the researchers have not yet been able to identify the specific carbon-containing compounds mixed in with the solid hydroxide product. More recent irradiation experiments show that a similar process occurs with manganese carbonate. Furthermore, analyses of natural, crystalline specimens of iron oxide hydroxide show the presence of organic matter, indicating that incorporation of organic compounds into the mineral may be a commonly occurring process in nature.