Helium under pressure

THERE MAY BE A WHOLE DIFFERENT FORM OF CHEMISTRY ON THE SURFACE OR WITHIN THE LARGEST STARS, WRITES **S ANANTHANARAYANAN**

Hydrogen is the simplest of elements, with just one proton contributing to its weight. Hydrogen gas is hence the lightest and often used to launch balloons. Helium is the second in the hierarchy of elements, with four heavy particles in its nucleus. Helium is also a light gas and used to fill lighter-than-air balloons.

A problem with hydrogen gas in balloons is that hydrogen is highly inflammable — this problem is amply avoided if one uses helium, as helium does not burn at all. In fact, in the matter of safety for balloons, helium goes to the other extreme. Helium, with neon, is the most inert of all elements and is not known to form any stable compound.

Intense search in the last few decades has resulted in instances of helium compounds and the most successful is the one with a positively charged hydrogen ion. This compound too, most readily decomposes, aggressively pushing its loosely bound hydrogen ion to neutralise other elements or compounds that can use the hydrogen ion. In theory, it is possible to conceive of compounds with lithium, caesium, fluorine, but the calculated energy of these compounds are high and the compounds must be only instantaneously stable.

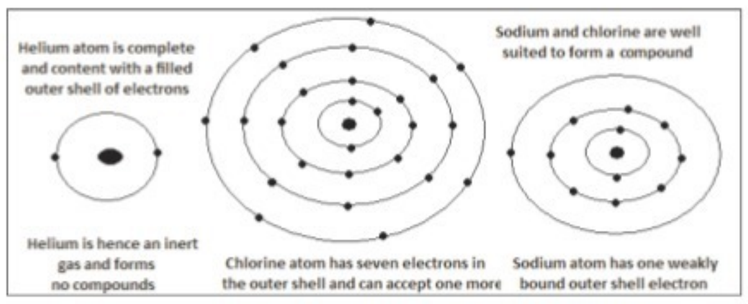
At least, all this is so in ordinary conditions. Short-lived compounds have been known to form under high pressure and there has been the expectation that a stable compound could arise under very high pressure. An international team of researchers from different institutes in Russia, China, Italy, Germany and USA, led by professor Artem R Oganov of the Skolkovo Institute in Moscow, have described in the journal Nature

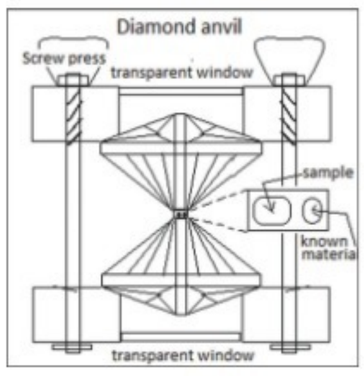
Artem R Oganov

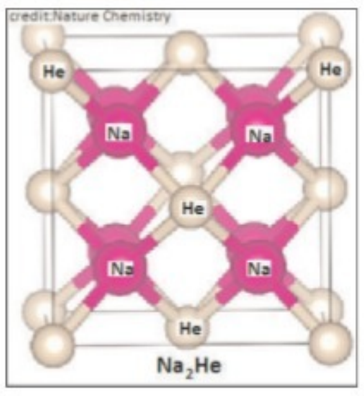
Chemistry, their quest for such compounds and success in finding one.

The principle in the combination of elements is that lower energy conditions are more stable. If the total energy of a pair of atoms together is less than the energy when they are separate, they will combine, rather than stay apart. Atoms are a group of positive charges, held together by short-range, nuclear forces, with an equal number of negative charges, the electrons, in orbit. Depending on the number of electrons, the atom is generally not in the lowest energy condition that is possible. It is found that electron shells are best packed in groups of two or eight. When an atom has more electrons than can be packed like this, electrons spill over into incomplete, outer shells.

The tendency to achieve the numbers of two or eight then drives a tendency of the atoms to combine with others, which have a complementary excess or shortfall, with respect to the numbers of two or







eight.

Helium, with two positive charges in the nucleus, has just two electrons in the first and only orbit, and this is the lowest and quite stable condition. This is to say that it takes a lot of work to pull an electron away from a helium atom and also that the helium atom is such a low energy entity that combining helium with another atom would take some work, rather than giving off some energy that is saved as a result of the marriage.

When atoms are under heavy pressure, however, there has been some work done in squeezing them together and the economics of combination can change. Under almost two million times atmospheric pressure, for instance, the heavier of the "noble" gases — so called because they are inert — become reactive, and xenon forms oxides, and krypton, xenon and argon combine with magnesium. The metal sodium has a single, loosely-bound electron in its outer orbit and is hence a good conductor of electricity. But under heavy pressure, sodium becomes an insulator.

With only one electron available for combination, the sodium atom, Na, forms a stable salt, sodium chloride – denoted as NaCl — or one sodium atom in combination with one chlorine atom, Cl. Combinations of different numbers of sodium atoms with more chlorine atoms are not possible.

But this changes under pressure, as unusual and stable combinations like Na3Cl, Na2Cl, Na3Cl2, NaCl3, and NaCl7 are formed when the pressure is raised! The group of researchers made use of an algorithm called Uspex (acronym for Universal Structure Predictor), developed by Oganov, which is able to work out the energy of formation and hence stability of structures that could be possible, given the characteristics of constituents.

The group carried out assays of helium combining with different elements, hydrogen, oxygen, fluorine, sodium, potassium, magnesium, lithium, rubidium and caesium

The results were that it is only sodium that forms a stable compound with helium at pressures which were practical.

The researchers loaded sodium in a medium of helium in the confines of a diamond anvil and subjected the sample to pressures in millions of atmospheres. The anvil consists of two opposing bits of diamond, between whose tips a sample of test material can be placed and compressed.

The hardness and transparency of diamond ensures that the pressure is transmitted and also allows the sample to be studied with the help of light or X rays. A material whose behaviour under pressure is known is placed in the anvil along with the sample, and this material enables the pressure applied to be measured. The diamond also allows lasers to be shone on the material for heating.

X rays consist of light waves whose wavelength is comparable to the distances between atoms in solids and the structure of materials can be deduced from the way X rays are scattered by the material. The Raman Effect is that vibration of atoms brings about changes in the wavelength of scattered light. The paper in Nature Chemistry describes the changes in the visual, X ray and Raman scattering as the pressure was increased showing that the sodium compound was formed and then the structure and properties of the crystals formed.

Our current belief, that it is in "Earth-like" conditions that life can arise, is rooted in the state of materials being manageable and organic chemical processes being possible only in the narrow temperature range that we have on Earth.

While helium does not participate in processes that take place on the Earth, it now appears that it could be chemically active in places, as on giant stars, where mega pressures are encountered. As helium is the second-most abundant element (after hydrogen) in the universe, this throws up the possibility that some radically different form of sentient entities may exist in distant worlds.

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PLUS POINTS

Mysteries of dark energy

Scientists might be about to uncover one of the universe's biggest mysteries.

A new experiment looks to use gravitational waves — tiny ripples in the fabric of space-time — to unlock the truth of why the universe is expanding so quickly and so unexpectedly.

Astronomers discovered in the 1990s that galaxies like our own Milky Way were flying apart super quickly. And they were even more shocked to find that they appeared to be accelerating, picking up speed as they were flung through the cosmos. They theorised that an unknown and mysterious force, known as dark energy, was the cause of the strange behaviour.

Almost a century ago Albert Einstein conjured up a similar concept in his calculations — the Cosmological Constant — but then discarded it, believing he had made a mistake. But there is another possibility — across intergalactic distances, gravity may not work the way it is supposed to.

Now scientists at the University of Edinburgh believe they have found how to resolve the puzzle by measuring the speed at which gravitational waves cross the universe.

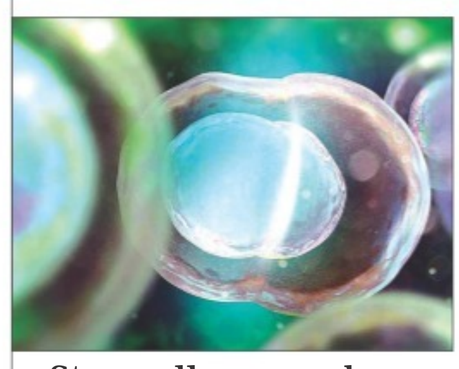
If the space-time ripples are shown to propagate at the speed of light, it would rule out alternative gravity theories that exclude dark energy. On the other hand, if their speed ever differs from that of light, the dark energy theory would have to be revised.

Such an experiment could be conducted at the Laser Interferometer Gravitational Wave Observatory in the US, whose twin detectors, placed 2,000 miles apart, confirmed the existence of gravitational waves for the first time two years ago.

Lucas Lombriser from the University of Edinburgh's School of Physics and Astronomy said, "Recent direct gravitational wave detection has opened up a new observational window to our universe. And our results give an impression of how this will guide us in solving one of the most fundamental problems in physics."

The new research has been published in the journal Physics Letters B. Gravitational waves are generated by some of the most powerful events in the universe, such as colliding black holes or super-massive neutron stars.

ANDREW GRIFFIN/THE INDEPENDENT



Stem cells research

Induced pluripotent stem cells are derived from adult stem cells, which are capable of transforming into many cell types.

The technique used to create them was developed by Nobel laureate Shinya Yamanaka in 2006, and has opened the doors to medical advances, including generating cartilage cell tissue to repair knees, retinal cells to improve the vision of those with eye diseases, and cardiac cells to restore damaged heart tissue.

Concerns that these cells could be more susceptible to genetic mutations have hampered their adoption in biomedical research and medicine but a new study by scientists at the National Human Genome Research Institute in the US could change that.

The work, published in Proceedings of the National Academy of Sciences, found that induced pluripotent stem cells, going by the acronym iPSC, are no more likely to develop genetic mutations than cells duplicated by sub-cloning, a process where single cells are cultured individually and then grown into a cell line or colony. The scientists examined two sets of donated cells — one set from a healthy person and the second from a person with a blood disease called familial platelet disorder. Skin cells from the donors were used to create genetically identical copies of the cells using both the iPSC and the sub-cloning techniques.

The researchers sequenced the DNA of the skin cells as well as the iPSCs and the sub-cloned cells and found that mutations occurred at the same rate in both cells.

THE STRAITS TIMES/ANN

DIVERSE FUNCTIONS

TAPAN KUMAR MAITRA EXPLAINS THE STRUCTURE OF THE EXTRACELLULAR MATRIX IN ANIMAL CELLS

Many kinds of cells — including most of those in our own body — spend all their lives linked to neighbouring cells. In addition, almost all cells have some sort of structure that is external to the plasma membrane but is nonetheless an integral part of the cell, both structurally and functionally. These extracellular structures consist mainly of macromolecules that are secreted by the cell. The chemical nature of the macromolecules differs among organisms but the extracellular structures of most eukaryotes have a common theme — they contain long, flexible fibres embedded in an amorphous, hydrated matrix of branched molecules that are usually glycoproteins or polysaccharides.

Animal cells have an extracellular matrix that takes on a variety of forms and plays important roles in cellular processes as diverse as division, motility, differentiation, and adhesion. In plants, fungi, algae, and prokaryotes, the extracellular structure is called a cell wall — although its chemical composition differs considerably among these organisms. Cell walls confer rigidity on the cells they encase, serve as permeability barriers, and protect cells from physical damage and from attack by viruses and infectious organisms.

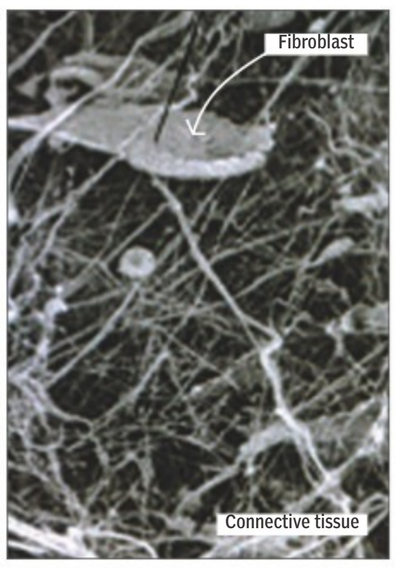
Let's first take a look at the adhesion of cells to each other and to the extracellular matrix, and the several kinds of junctions that link cells together into multi-cellular tissues. Then we will turn to the walls that surround plant cells and the specialised structures that allow direct cell-to-cell communication despite the presence of a wall between neighbouring cells. In each case, we will focus on the molecules involved and the contributions they make to the structural and functional properties of cells.

The extracellular matrix of animal cells takes on a remarkable variety of forms in different tissues. Bone consists largely of a rigid extracellular matrix that contains a tiny number of interspersed cells. Cartilage is another tissue constructed almost entirely of matrix materials, although the matrix is much more flexible than in bone. In contrast to bone and cartilage, the connective tissue surrounding glands and blood vessels has a relatively gelatinous extracellular matrix containing numerous interspersed fibroblast cells.

The ECM plays a role in determining the shape and mechanical properties of organs and tissues. The matrix does more than just provide structural support, however; it also influences properties such as tissue extensibil-

EXTRACELLULAR STRUCTURES OF EUKARYOTIC CELLS

Kind of Organism	Extracellular Structure	Structural Fibre	Components of Hydrated Matrix	Adhesive Molecules
Animals	Extracellular matrix	Collagens and elastins	Proteoglycans	Fibronectins and laminins
Plants	Cell wall	Cellulose	Hemicelluloses and extensins	Pectins



ity, cell shape and movement, and development of specialised cellular characteristics.

Despite this diversity of function, the ECM of animal cells almost always consists of the same three classes of molecules — structural proteins such as collagens and elastins, which give the ECM its strength and flexibility; protein-polysaccharide complexes called proteoglycans that provide the matrix in which the structural molecules are embedded; and adhesive glycoproteins such as fibronectins and laminins, which attach cells to the matrix.

The considerable variety in the properties of the ECM in different tissues results not only from differences in the types of structural proteins and the kinds of proteoglycans present but also from variations in the ratio of structural proteins —collagen, most commonly — to proteoglycans and in the kinds and amounts of adhesive glycoproteins present. We will consider each of these classes of ECM constituents in turn.

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It's not all about IQ

ANISHA DUTTA CHRONICLES THE VARIOUS FACETS OF HUMAN INTELLIGENCE

Humans have hundreds of mental abilities and the broad term used to describe them is intelligence. Common intelligence is the power to acquire knowledge using memory and performing actions, but it lacks in ability to explain overall outcomes. There are other sorts of Intelligence to act emotionally and socially. Emotional intelligence is the richness of our qualitative life to perceive, analyse and regulate emotions — they truly make us what we are. On the other hand, social intelligence relates to compatibility on social interactions.

Therefore, whether the so-called intelligent quotient defines one's intensity of intelligence is debatable. IQ is considered as the mental ability of one in comparison with the mental abilities of others in the same age group. But mere IQ cannot define a person completely in all respects. A person needs EI to realise, analyse and manage one's emotions. In fact, a combination of EI and SI account for the intelligence of a human.

To calculate the IQ of a person, a simple unitary method based on ratio is not applicable but a statistical procedure is followed with a chosen standard deviation and the mean being 100. An IQ of 100 means that 50 per cent of the population has a lower IQ while 50 per cent have a higher IQ with respect to that person.

A normal, average child has an IQ of 100 with 99.5 per cent of world population having an IQ between 60 and 140. Only one per cent people in the world can boast an IQ of more than 135 — Albert Einstein's IQ is said to have been 160! That said malnutrition lowers IQ levels, especially the deficiency of iodine in children. Therefore, IQ levels in third world countries could be raised with proper nutrition and eradication of diseases. Data also shows that people with a higher IQ generally have lower adult morbidity and mortality — researchers calculated that a 15 per cent lower IQ accounts for a one-fifth less chance live 76 years.

But let's turn our gaze to emotional intelligence. It has four distinct categories,

- perception of emotions involving non- verbal signals like facial expressions and body language.
- reasoning using emotion like to promote thinking and cognitive activity
- ability to understand emotions — to identify the exact root of emotions following attitude, temperament and delivery of language.
- managing emotions is the key to controlling oneself to deal with conflicts and adverse or favourable situations.

Tests on EQ reveal the intensity of mental disorder and are used to diagnose autism spectrum, schizophrenia, and other mental blockages and complications. Autistic children show evidences of very high IQ levels with precise perception and keen observation but they are devoid of EI and totally incapable to exhibit normal human behaviour. EQ can be raised by practicing meditation and SQ can be increased with more study on social interactions. But there is no way to increase one's IQ level — high IQ is only responsible for academic success.

Though IQ helps a person only for four per cent time during one's life, EQ and SQ are more helpful to shine in a particular career. Yet a minimum IQ level of 100 is mandatory for success. In fact, perfect combination of IQ, EQ and SQ can make a person reach the peak of excellence.

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