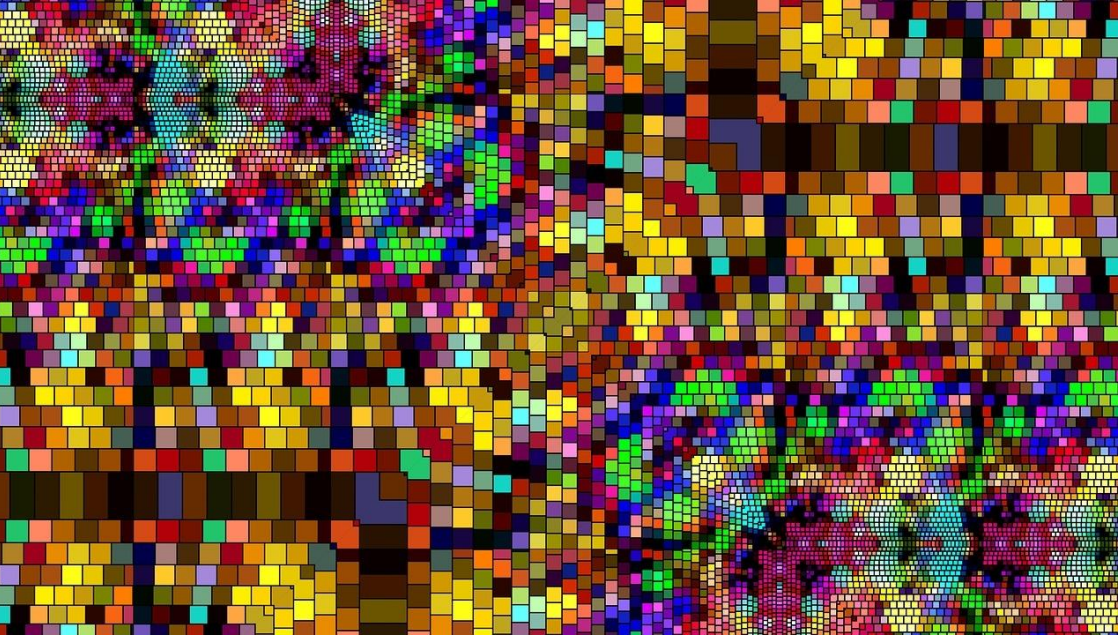
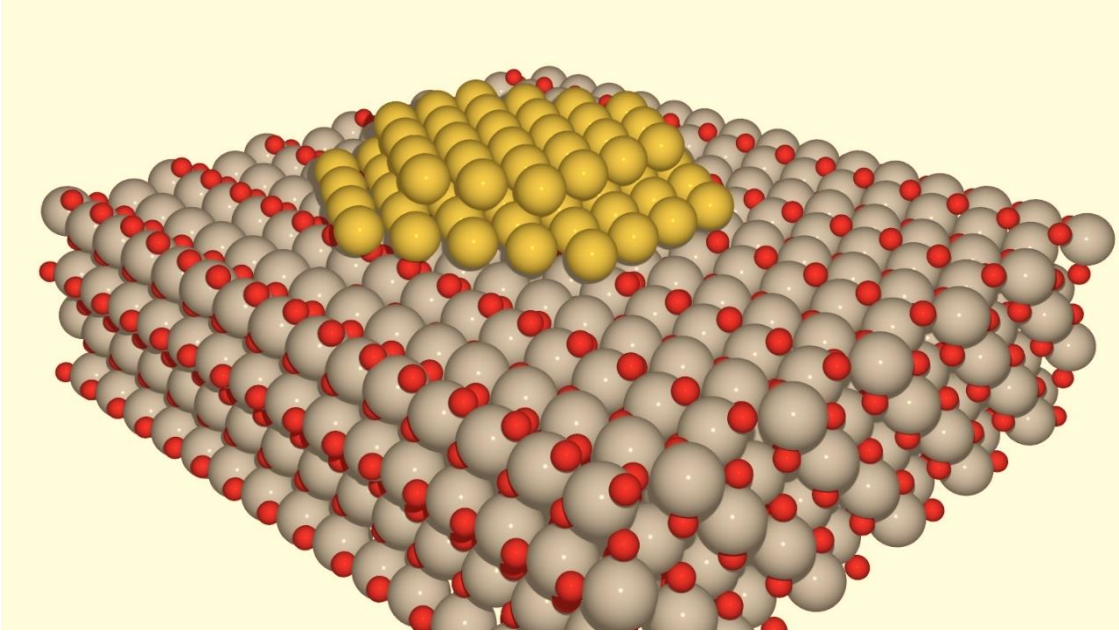


Problem 1. All the Mendeleev's Elements

Suggest the synthesis of a compound comprising as many different elements of Periodic Table as possible. The desired compound must be obtained in pure form and it should be possible to determine its chemical structure via physical methods.



Problem 2. Solution Atomic Layer Deposition

Atomic layer deposition, or ALD, is a thin film deposition technique based on self-limiting surface chemistry. In ALD, the solid surface is exposed in alternating manner to two (or more) gaseous reagents, or precursors, each of which adsorbs irreversibly by reacting with the chemically reactive groups on the surface. This results in atomic layer-by-layer deposition of the desired compound. The main obstacle of the wide ALD usage is need for high vacuum equipment. It is possible to change gas-phase ALD to the solution-based ALD.

Suggest solution ALD scheme of the few-layer FeSe deposition on the $SrTiO_3$ crystal surface.

Problem 3. Polonium Extraction

It is widely known that tobacco leaves contain polonium-210 as it is sorbed on the leaves surface. At the same time it can be used as a heat soure in thermoelectric materials, to eliminate static charge and in other applications. Suggest a method of extraction of polonium from tobacco leaves. Estimate the mass of the leaves to obtain 100 mg of polonium in metal form.

Problem 4. Silver Mirror Kinetics

Tollens' test, also known as the "silver mirror" reaction, is used to determine the presence of aldehyde groups in organic compounds. While the reaction is widely taught and demonstrated in schools, no further details are given on its mechanism, which you are invited to determine experimentally.

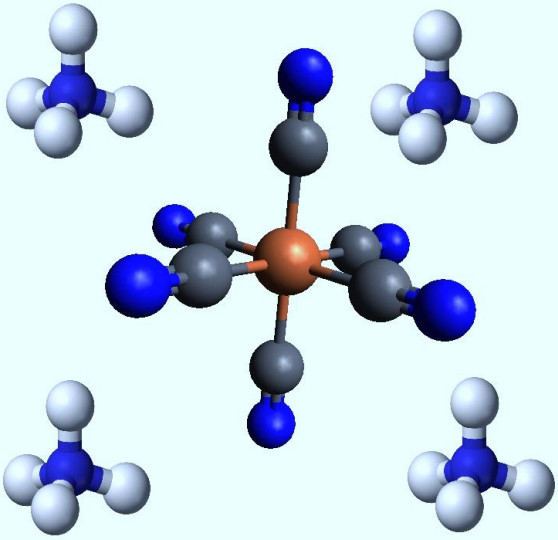
Problem 5. Cheese Test

While every school student knows about a qualitative test for an aldehyde, it may be also important to know how much aldehyde you have exactly. Suggest a method to determine aldehyde content in different cheeses.

Problem 6. Underwater Archaeology

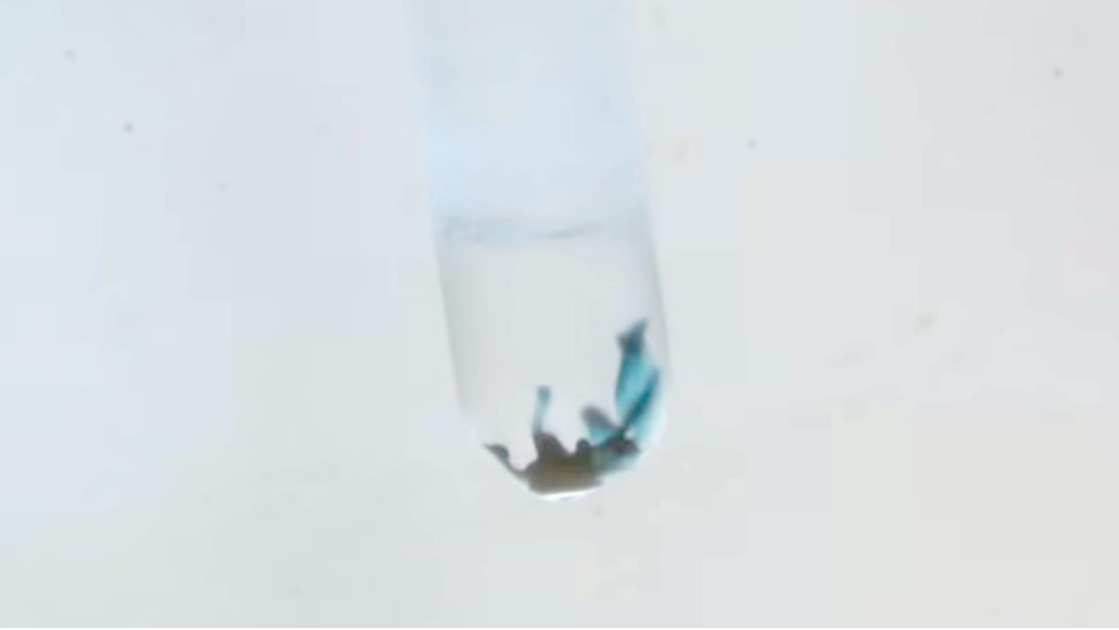
According to UNESCO, there are about three million ships sunk and currently submerged in water. Some museums lift the ships from the bottom and include them in their exhibitions, Vasa museum in Stockholm being one of such examples. Some small vessels have also been salvaged by other museums. However, as the ship is brought back to the surface, some treatment is required to preserve its structural integrity. Nowadays, the most common conservation method is treatment with polyethyleneglycol treatment. This doesn't prevent timber from oxygen absorption, so the vessels continue to deteriorate, albeit at a slower pace.

Suggest an explanation for that and propose an alternative conservation method with emphasis on chemical processes involved. Try to demonstrate your solution in practice.



Problem 7. This Crystal Field Splitting

A spectrochemical series of ligands is a list of ligands ordered on strength of the ligand-field splitting of d orbitals. Resulting difference in energy between the d orbitals (Δ) in different metal-ligand complexes affects the color of these complexes. For example, I- is a weak field ligand and CN- is a strong field ligand. Suggest the practical work for high school students with a maximum duration of 90 minutes that will help illustrate the spectrochemical ligand series using at least four ligands. This work should be cheap. Discuss whether it is correct to compare the strength of these ligands in chosen complexes.



Problem 8. Electride Zoo

Sodium electride solutions are commonly used chemicals. For example, Birch reduction utilizes the sodium solution in ammonia. What are the other elements that can form electride solutions? Obviously it couldn't be helium, and lithium is an electride-forming metal. Present theoretical considerations about the list of the elements that could form electride solutions.

Problem 9 Bond. Halogen Bond

The best-known type of directional bonding is a covalent bond, closely followed by a hydrogen bond. However, there are other similar interactions such as halogen bond, which forms between a strongly electron-donating atom and an electron-deficient halogen. Despite being discovered in the first half of the 20th century and appearing in rather mundane substances and mixtures, it has still not made its way into the school curricula due to the rarity of the atomic arrangement described. Deal with this unfortunate omission and suggest a method to measure halogen bond energy experimentally in your school lab.

Problem 10. Dirty Chemistry Done Dirt Cheap

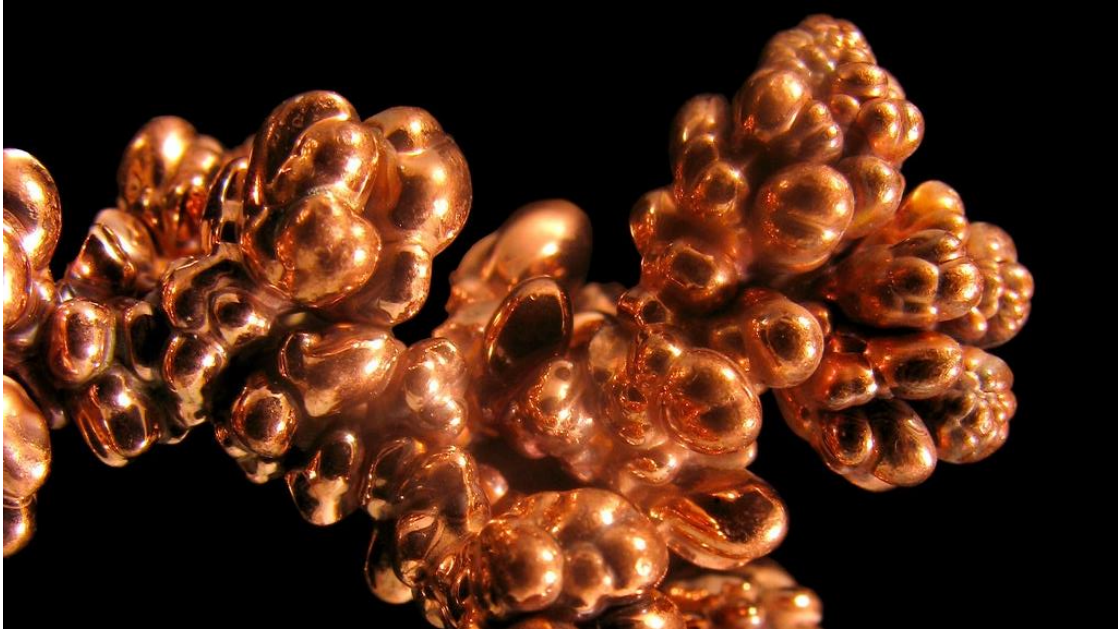
Generally the hard task of chemistry is to obtain pure material with exact chemical composition. But research isn't always going that way. $SrFe_{12}O_{19}$ is a widely used material for permanent magnets because of its coercivity. Substitute several iron atoms in crystal structure with aluminium and the coercivity will rise. Make additional substitution of several strontium atoms with calcium atoms and coercivity will rise even higher. There are tens of atoms that can be introduced in the structure of these materials and zillions of possible chemical compositions. The way to find material with record properties is to explore a large part of these compounds.

Instead of making thousands of syntheses one might consider synthesis of a mixture, containing trillions of particles with vastly different chemical composition and, using some physical methods, separate best of them and explore their composition using electron microscopy techniques.

Present a strategy to 1. obtain a mixture of particles with the same crystal type but different chemical composition 2. separate possible “record-holding” particles from mixture based on any reasonable criteria of your choice. You may choose any inorganic crystal type and you may not limit yourself to magnetic properties of material. The chosen properties must be dependent on chemical composition (e.g. not the particle size or shape)

Problem 11. Make Tomato Red Again

Atmosphere has a great influence on how food looks and tastes. For instance, to make meat look more appealing, it is often exposed to air so it gains a deep ‘fire engine red’ colour due to myoglobin oxidation. Is there any other type of food which changes colour depending on the gasses surrounding it? Propose other food products that can change colour under the influence of gas while maintaining nutritional properties.



Problem 12. Copper Crystal

Place an iron nail in the solution of some copper compound. Substitution reaction occurs and copper starts precipitating on the surface of iron resulting in dendrite-like structures. One can imagine whether it is possible to grow a considerably large copper monocrystal (or crystallite grain of dendrite) using this technique. How do specific copper compounds, concentration and other factors affect the size of copper crystallites?