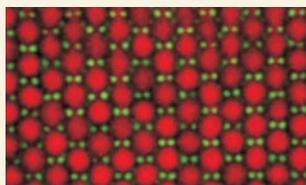


PHYSICAL CHEMISTRY

Isn't it ionic

Microscopic particles dispersed in solvents — known as colloidal suspensions — are attractive models for studying a wide range of phase transitions and nucleation phenomena. The suspended particles can be observed directly in three-dimensional space, and the interactions between them are easily modified. However, processes involving that seemingly most simple and ubiquitous of inorganic solids — ionic crystals formed from oppositely charged atoms — cannot be mimicked by colloids. Charged colloidal particles don't 'do ionic'; they prefer to aggregate instead.

But Mirjam E. Leunissen and colleagues, writing in this issue (*Nature* **437**, 235–240; 2005), show that colloids can be coaxed into forming ionic crystals after all. The authors observed that if salt is added to polymer spheres dispersed in an organic solvent mixture, the charge on the spheres can be controlled and the electrostatic interactions between them can be regulated. This enabled the preparation of binary mixtures of colloids that carried small, opposite charges and readily formed ionic crystals. When an electric field was applied, the crystal melted, and particles of



opposite charge moved towards opposite electrodes. The charged colloidal particles therefore clearly resemble ionic species. But there are differences. In particular, a diffuse layer of 'counter-ions' surrounds each particle, forming an overall charge-neutral unit that participates in the growth of the crystal. So the structure of the colloidal crystals is not dictated by charge neutrality, as in atomic systems, leaving the authors free to create remarkable

new binary structures. One example, a crystal comprising particles of positive (green, radius 0.36 μm) and negative (red, radius 1.16 μm) charge in the ratio 6:1, is shown in the image.

Colloidal crystals can also form from charged spheres made of different materials, such as a polymer and silica. It is then straightforward to burn the polymer spheres away to give all-silica structures. Given the ease with which these structures grow into large crystals, ionic colloids should prove an alluring proposition for those creating advanced materials such as photonic crystals.

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major carbon sources and sinks in the biosphere², with emphasis on protecting existing pools of stored carbon.

Bellamy and colleagues' observations are remarkable, and fall into four categories. First, consistent losses of SOC occurred independently of soil properties, challenging our knowledge about SOC stability. A new hypothesis suggests that the stability of SOC depends on the diversity and activity of soil microorganisms — if microbes have adequate energy resources, they can break down any organic structure irrespective of its physico-chemical stabilization³.

Second, the losses were proportional to carbon concentration, which implies a first-order decay of a homogeneous pool. This contradicts the view that SOC in carbon-rich soils contains a higher fraction of stable carbon than does that in carbon-poor soils. But it is unclear from which SOC fraction the lost carbon originated.

Third, SOC losses occurred in soils under all land-use conditions, and there is no apparent single factor other than climate change that could degrade non-agricultural soils. Fourth, the observation is contrary to the view⁴ that soils are an ultimate, large-scale sink for carbon.

The overall net loss of carbon identified by Bellamy *et al.* is unequivocal. But the authors can only speculate about where the carbon has gone. The reported changes in the top 15 cm correspond to average losses of 125 $\text{g C m}^{-2} \text{yr}^{-1}$, ranging from 66 $\text{g C m}^{-2} \text{yr}^{-1}$ uptake in extremely carbon-poor soils to 550 $\text{g C m}^{-2} \text{yr}^{-1}$ loss in carbon-rich (peat) soils. The SOC content may also have changed in soil layers not studied by Bellamy and colleagues. This may affect the magnitude of the overall carbon loss but is unlikely to negate the findings. Leaching of dissolved organic carbon cannot explain more than 10% of the loss^{5,6}, and it is likely that most of the rest has been converted to CO_2 .

Direct measurements of carbon flux do not yet provide a complete picture of the carbon cycle in ecosystems, and the 'mass balance' approach of Bellamy *et al.* is the only available evidence of change in the SOC pool. But the reasons for the loss remain unclear, irrespective of the pathways by which carbon is being lost. Re-inspecting the results, we think that the land-use factor has played a role — for example, only alteration in land use and gradual changes in land management can explain why croplands lost more carbon than other areas. Major land-use changes, such as the afforestation of carbon-rich soils, are not highlighted separately in Bellamy and colleagues' study.

Climate variation seems to be the second factor. Modelling studies suggest that significant changes in SOC stem from variations in precipitation and temperature on timescales of decades^{7,8}. But these conclusions are based only on laboratory studies and small-scale experiments. According to our current understanding of the sensitivity of soil respiration to warming, increased temperature alone seems to be too weak a driver. Carbon-rich soils lost most SOC. In the United Kingdom, these soils are often very wet and can easily be affected by changing precipitation patterns. The relative effects and combined impact of increased atmospheric CO_2 , warming, nitrogen deposition and altered precipitation are still disputed.

Bellamy and colleagues' observations are sure to stimulate further investigations to clarify the main uncertainties. International research projects such as CarboEurope, the Global Carbon Project and others⁹ are already under way with the aim of providing a better understanding of carbon balance in the biosphere. But this work is by no means straightforward. Soils are a nightmare to work with — they are dirty and highly varied in composition, and if a sample has been taken for analysis, that spot cannot be resampled.

The scientific and political implications

of the new findings¹ are considerable. The process of carbon loss from soils has been most comprehensively documented in the United Kingdom, both at regional level and under all forms of land use. But there have also been repeated warning signals from soil surveys in China¹⁰, Finland¹¹ and Flanders¹². These, however, attribute most of the SOC loss to changes in land use and management. In contrast, Bellamy *et al.* provide the first hint that regional climate variation may be contributing to a surprisingly large release of CO_2 from soils to the atmosphere. Further research into the carbon cycle and on reducing CO_2 emissions must take full account of areas where large pools of organic carbon are stored — or are being released. If we intend to stabilize the climate, such areas require much more serious consideration. ■

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