ANALYTICAL CHEMISTRY

Forever blowing bubbles

The delightful iridescence and evanescence of soap bubbles arises from the fact that their walls are nothing but a film of water sandwiched between two layers of surfactant molecules. This unusual construction also endows soap bubbles with a uniquely large ratio of surface area to contained liquid. Tinakorn Kanyanee *et al.* (*Anal. Chem.* doi:10.1021/ac052198h; 2006) set out to exploit this feature — by ‘wiring up’ soap bubbles and using them as the functional heart of a fully automated detection system for trace gases.

The authors’ bubble factory uses a sealed, transparent plastic box with water at the bottom to keep the environment moist and so prolong bubble life. Soap solution is first supplied to the box through the inner of two concentric tubes. As the

solution spreads from this tube’s slightly recessed tip, it coats the tip of the surrounding outer tube, through which a controlled blast of air is delivered, inflating the soap film and creating a bubble. Precise metering of the air pulse ensures that the bubble is inflated just enough to touch two opposing stainless-steel electrode rods that jut into the box. The bubble-box reproducibly generates long-lived bubbles of uniform size and wall-thickness, so that the conductance measured between the electrodes for a given bubble geometry depends on the bubble’s chemical composition.

To use their system for trace-gas analysis, the authors added the oxidizing agent hydrogen peroxide to the soap solution and exposed the resulting bubble to air containing

traces of sulphur dioxide. The sulphur dioxide readily diffused into the bubble, where it was oxidized and sulphuric acid was produced. The presence of acid increased the bubble’s electrical conductance.

This effect enabled quantitative determination of part-per-billion levels of sulphur dioxide within minutes. The approach should also be applicable to a range of other soluble and reactive gases. But as

Kanyanee and colleagues point out, the wider message is that soap bubbles are an attractive, yet largely unexplored, tool for concentrating trace gases to enable their detection. Whether these species are then detected through conductance measurements, or through bursting the bubble and analysing its liquid by other means, there is, in that sense, more to this story than mostly froth and bubble.

Magdalena Helmer

T. KANYANEE

QUANTUM PHYSICS

A ménage à trois laid bare

Brett D. Esry and Chris H. Greene

Quantum bodies that can’t settle down together in pairs get on fine in a cosy threesome. This startling claim about the private life of particles has just seen its first experimental confirmation.

In 1970, Vitaly Efimov, possessor of a freshly minted Russian PhD in theoretical nuclear physics, predicted a bizarre quantum-mechanical effect¹: a system consisting of three particles, none of whose two-particle subsystems is stable, can, under certain circumstances, produce an infinite number of bound energy levels. That prediction has been a source of concern for theorists ever since. Yet time and again, attempts to disprove the ‘Efimov effect’ have only verified its existence, albeit — until now — purely theoretically. In this issue, more than 35 years on from the initial prediction, Kraemer *et al.* (page 315)² present the first convincing experimental evidence for the effect.

The question explored by Efimov was simple: if each possible pair of particles in a three-particle system is just shy of binding (so there are no bound states), what is the nature of the energy spectrum of the three particles? The answer, that the number of bound states in which the three particles can exist is infinite, is initially surprising. But it can be rationalized by noting that if two particles are already infi-

tesimally close to forming a bound state, just the faintest whiff of an additional attraction will be sufficient to push them over the edge to confederation. A third attracting particle accomplishes precisely that, no matter how far away from the other two it may roam, or how weak its additional attraction may be. Unsurprisingly, given this qualitative argument, three-body Efimov states have been theoretically found³ to be extremely ‘floppy’, with all imaginable triangular shapes — equilateral, isosceles, scalene (Fig. 1, overleaf) — and even linear configurations being comparably probable.

The Efimov effect is distantly related to Llewellyn Hillel Thomas’s 1935 proof⁴ that, in its ground state, a system of three particles that interact only within a vanishingly small range collapses to an infinitely small size, and its binding energy becomes infinitely large. Efimov discussed the link particularly clearly in a 1971 article⁵ that derived an effective potential-energy curve for such a system as a function of a three-particle ‘hyperradius’, R , which is proportional to the root-mean-square distance of the three particles from their centre of mass.

The three-body potential-energy function turns out to be proportional to R^{-2} , and it has a universal, negative coefficient of proportionality. The properties of such a potential are well known, because a similar form governs the motion of a charged particle in the field of a permanent dipole (where two charges of equal and opposite sign are separated by a small distance).

The allowed energy levels of a quantum system can be determined by solving the radial, time-independent Schrödinger equation (which yields the energy levels, E_n , of a quantum system). When the equation is solved for a system with an R^{-2} potential, the allowed energy levels that result follow on iteratively from each other according to the rule $E_{n+1} = E_n \exp(-2\pi/s_0)$, where s_0 is a constant related to the strength of the so-called effective dipole moment with a value slightly greater than one. Thus, as n increases, the binding energies of successive levels decrease exponentially. This scaling also carries over to other observable parameters, such as the size of the state. Thomas’s collapsed states are the infinitely tightly bound states that occur as n approaches $-\infty$, whereas the Efimov states are those states that are only just bound, arising as n approaches $+\infty$. In real physical systems, the fact that the range of interparticle interactions can never be zero prevents a Thomas collapse, so this effect will, one presumes, never be observed. There is, however, no similar obstacle to observing the Efimov effect.