Then the antiproton's fate should be sealed: within a few picoseconds it will reach an *s*-state by means of rapid radiative and Auger transitions (ejection of the second electron) followed by collisional Stark mixing, from which annihilation on the atomic nucleus occurs. However, in the PS205 LEAR experiments some 3 per cent of the 5-MeV antiprotons that were directed onto pure helium targets survived for several microseconds[2], far longer than this argument suggests. This anomalous lifetime, which was not seen in other noble gases, was dramatically reduced in the presence of small quantities of impurity atoms, and was 14 per cent smaller in ^{3}He than in ^{4}He, suggesting that the enhancement occurred after the antiproton was captured.

Similar anomalous lifetimes had been observed with negative pions and kaons in liquid helium bubble chambers in the 1960s, and were attributed to the formation of long-lived atomic states by Condo[6] and Russell[7]. Russell had even proposed that this phenomenon could be investigated with the intrinsically stable antiproton instead of the unstable mesons, but his suggestion was not pursued until the kaon lifetime anomaly was rediscovered in 1988.

In Condo and Russell's picture, an antiproton captured by a helium atom will preferentially occupy an orbit with the same radius as that of the 1*s* electron that it replaces. Its principal quantum number will therefore be $n = (M^*/m_e)^{1/2} \approx 38$, where M^* is the antiproton's reduced mass. Some antiprotons will be captured in high-angular-momentum Rydberg states ($l \sim n - 1$), for which the radiative lifetime is a factor of $(m_e/M^*)\, n^3 l^2 \approx 3 \times 10^4$ larger than typical electronic radiative lifetimes (these are about 100 ps), in agreement with the PS205 observations. Moreover, Auger transitions are strongly suppressed because the ionization energy of the electron ($I_0 = 24.6$ eV) requires a change of the antiproton's principal quantum number (and hence also its angular momentum) by six units. Thus, the exotic atom remains electrically neutral during the radiatively dominated first phase of its de-excitation, which suppresses Stark mixing and ensures that the antiproton survives up to 30 million times longer than otherwise expected.

The intuitive picture of Condo and Russell has been developed in several calculations[8–10] which show that there is a spectrum of such metastable antiprotonic states in the vicinity of $(n, l) = (38, 37)$, together with nearby levels that have short Auger lifetimes. Morita *et al.* have now provided striking confirmation of this picture. Their latest experiment[3] involves laser excitation of the electric dipole transition from the metastable ($n = 39, l = 35$) level to the Auger-dominated ($n = 38$, $l = 34$) state. Forced annihilations are observed when an on-resonance laser beam illuminates the helium target 1.8 μs after entry of an antiproton. Modelling the system as a simple Bohr atom indicates that the energy of this transition is about 2 eV, and the model predictions for the wavelength of the emitted photon are close to the measured value of 597.259±0.002 nm.

From the observed decay time of the forced annihilations a 7-ns lifetime can be estimated for the lower level, which is again in good agreement with the calculated Auger transition rate to the ($n = 32$, $l = 31$) state of the positively charged antiprotonic helium ion. Annihilation then follows within picoseconds via Stark mixing. The decay time sets a bound on the width of the transition that is about an order of magnitude smaller than the measured value of $\Delta\lambda/\lambda = 3 \times 10^{-5}$, where λ is wavelength.

However, the models indicate that it should also be possible to drive transitions between two metastable states, such as ($n = 39, l = 36$) to ($n = 38, l = 35$), which would therefore be several orders of magnitude sharper. Assuming that these transitions are subsequently observed, antiprotonic helium will be amenable to spectroscopy with the high precisions attained on hydrogen, positronium and muonium.

Spectroscopy of metastable antiprotonic helium will surely lead to advances in precision measurements of fundamental constants and tests of discrete symmetries, such as charge–parity–time (CPT). Perhaps a precise value of the 'antiprotonic Rydberg constant' could be determined — from this, one might extract the antiproton's mass (and charge) with a precision rivalling that of ion trap measurements. If hyperfine structure could be measured, we could deduce a new value of the antiproton's magnetic moment, which is currently only known with a precision of a few parts per thousand.

On a more prosaic level, physicists can entertain themselves with the speculation that laser-driven cycles among the metastable states might enable antiprotons to survive in proximity with matter for long periods of time. The PS205 collaboration is now working towards a systematic study of the metastable state spectrum. □

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DAEDALUS

Quick Release

As currently practised, toilet training is entirely negative. It is concerned to stop, or at least delay, the reflex emptying of the bowel. Only a fortunate few ever learn the converse skill, that of emptying the bowel at will. The rest of us must depend on artificial aids such as purgatives, which take hours to work.

And yet, in circumstances of sudden desperate fear, human beings and many other animals can empty the bowel instantly and automatically. This reflex must have evolved to reduce our weight, making it easier to run away, and possibly to make the path slippery for a pursuer. The mechanism of such automatic reactions is usually not nervous but hormonal. Fear pumps some hormonal alarm signal into the bloodstream; all over the body, local receptors react to it and prepare for the sudden emergency. The hair stands on end, the heart races, the muscles tense and the bowels loosen.

So, says Daedalus, constipation could be cured by striking sudden terrible panic into the bowels of the patient. The same result could be obtained less drastically by injecting the hormonal alarm signal itself, if it could be isolated. A variant that acted on the bowels alone, without spreading panic throughout the body, would be even better. Daedalus is now in search of it.

DREADCO's virtual-reality experts are creating computer-simulated 'virtual predicaments' of appallingly realistic horror. Brave constipated volunteers are being subjected to these bowel-loosening ordeals, while the hormonal contents of their blood are extracted and identified. Synthetic analogues will then be tested on cultures of bowel and other tissues. From the results, a drug will be designed to bind to the bowel receptors, but not to any of the other fear receptors dotted around the body.

The final product, DREADCO's 'Quick Release', will trigger immediate defecation, but no other manifestation of fear. It will give us all a wonderful new control over our unruly bodies. Divers about to climb into deep-sea gear, pilots of small aircraft about to take off, prospective long-distance bus travellers, nervous examination candidates and visitors to towns badly supplied with public lavatories, will all welcome the ability to 'dump the tanks' while it is still feasible. A prolific source of personal embarrassment will be ended; constipation will vanish overnight; urban dog owners and nurses of bed-ridden patients will gain new control of their hapless charges. But a terrible new practical joke will be born: the secret spiking of the victim's food or drink with Quick Release. David Jones