matters arising

Upper limits on production rate of NO per ion pair

RECENTLY, Fabian *et al.*[1] have suggested that the rate of production of NO per ion pair during a solar proton event should be 2–2.5 instead of the 1–1.5 used by other authors. They justify the larger rate because of rocket measurements of Arnold[2] taken during an auroral precipitation event. While Arnold's[2] measurements may be correct, we question the application of these rates to energetic solar protons as these particles mainly deposit their energy below 80 km. Here we place realistic upper bounds on the NO per ion pair production rate.

First, at altitudes between 80 and 120 km, each N or N^+ produced can potentially form one NO molecule and each N_2^+ can potentially form two NO molecules by well known ion chemistry[3–5]. Thus, by bounding the N, N^+ and N_2^+ production rates, we bound the NO production rate.

To calculate the maximum NO production rate, we follow the method of Porter *et al.*[6]. However, in this computation we assume that 20% of the $N_2(a^1\Pi_g)$ excitations form two NO molecules and that all excitations of N_2 and N_2^+ with thresholds above 9.76 eV, the dissociation energy, also form two NO molecules. This calculation yields an upper limit of 2.68 NO per ion pair for 10 keV electrons, which is larger and thus consistent with rates implied by the measurements of Arnold[2] as quoted by Fabian *et al.*[1]. Although there are some uncertainties in our calculations due to the cross-sections, we feel that our results are accurate to ±15%, in view of the use of self-consistent energy degradation methods by Porter *et al.*[6].

Second, we note that at altitudes below 80 km the maximum rate of NO production should be bounded by the production rate of N and N^+ formation because at these altitudes N_2^+ reacts almost exclusively to form water clusters and is removed[3]. In a second calculation we subtract the N_2^+-produced NO, leaving only the direct N and N^+ sources of NO and find a maximum production rate of 1.46 and 1.53 NO per ion pair for protons with energies of 20 and 200 MeV, respectively.

We thus conclude that in the altitude range below 80 km it is difficult to justify NO/ion pair rates greater than about 1.5. In fact, the NO per ion pair production rates for altitudes <80 km are probably close to the 1.2–1.3 calculated independently by Frederick[3] and Porter *et al.*[6]. However, in the thermosphere between 80 and 120 km, numbers as high as those quoted by Arnold[2] are clearly possible.

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Amount is not supply rate in energy intake control

ON the theory that rate of energy supply determines intake[1], it is not as Rothwell and Stock state, "logical to assume that isoenergetic stomach loads will have similar effects on voluntary energy intake" (ref. 2), or that—when energy intake does not compensate for changes in energy expenditure—the animals may be "regulating food intake to meet their requirements for some dietary component other than energy" (ref. 3). The amount of energy in the stomach (or anywhere else) does not necessarily have a one-to-one relationship to the instantaneous delivery rate of that energy. The relationship depends on the physiological characteristics of the energy store's turnover.

We have emphasised[4–7] the relevance of others' findings that the rate of passage of energy from the stomach (and onwards to the tissues) depends to a considerable extent on the form that the energy is in, for example, the energy density of the diet[8]. We have calculated the long-term effects of some dissociations between amount and supply rate[5,6] and in the same context pointed out further such mechanistic as well as thermodynamic calculations which are required by an unmodified energy-rate or power-measuring theory of energy intake control. The report by Rothwell and Stock[2] clearly indicates the importance for theory and practice of extending the simulation work with experimental work to determine the as yet poorly analysed short- and long-term implications of satiation by energy metabolism.

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ROTHWELL AND STOCK REPLY—If, as Booth claims, "the rate of energy supply determines intake", why do rats force-fed a balanced diet adjust voluntary intake such that their total energy intake is the same[1] as that of free-feeding controls? The rate of energy supply is radically different in these two situations and should therefore produce marked differences in intake; it certainly causes differences in energy retention because the force-fed rats become obese. This latter finding indicates that a greater fraction of absorbed energy is available to metabolism and should, also according to Booth[2], result in compensatory adjustments to energy intake. In our original paper[1] we suggested that the theory of intake control proposed by Booth and Toates[3,4] was unlikely to provide an explanation of our results. Given that neither the rate of energy supply nor the metabolic fate of that supply influences intake, we see no reason for modifying that statement and, as a comment on Booth's final sentence, suggest that it is

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