

# 1 Active transport

The concentration of potassium  $K^+$  ions in the internal sap of a plant cell (for example, a fresh water alga) may exceed by a factor of  $10^4$  the concentration of  $K^+$  ions in the pond water in which the cell is growing. The chemical potential of the  $K^+$  ions is higher in the sap because their concentration  $n$  is higher there. Estimate the difference in chemical potential at 300K and show that it is equivalent to a voltage of 0.24V across the cell wall. Take  $\mu$  as for an ideal gas. Because the values of the chemical potential are different, the ions in the cell and in the pond are not in diffusive equilibrium. The plant cell membrane is highly impermeable to the passive leakage of ions through it. Important questions in cell physics include these: How is the high concentration of ions built up within the cell? How is metabolic energy applied to energize the active ion transport?

**David adds** You might wonder why it is even remotely plausible to consider the ions in solution as an ideal gas. The key idea here is that the ideal gas entropy incorporates the entropy due to position dependence, and thus due to concentration. Since concentration is what differs between the cell and the pond, the ideal gas entropy describes this pretty effectively. In contrast to the concentration dependence, the temperature-dependence of the ideal gas chemical potential will not be so great.