A pinch of sodium

Sodium, ubiquitous on Earth in living organisms, oceans and minerals — all the way to table salt — may seem like one of the more ordinary elements. **Margit S. Müller** highlights why we, like the fairytale king, should not take it for granted.

In an old eastern European fairy tale a king asks his three daughters to describe their love for him. Whereas two of the daughters compare their affection to diamonds, pearls and gold, the third girl declares, "Father, I love you more than salt". Deeply offended to be likened to something so ordinary, the king banishes her. The princess disappears from the kingdom and, through a bit of witchcraft, so does all the salt. The story goes on to convince the king, and the reader, of the importance of seemingly mundane things in life, like salt. To make the same point without witchcraft, science had to go to much greater lengths.

The elements that make up what we refer to as table salt, sodium and chlorine, are both linked to Sir Humphry Davy. Davy discovered sodium in 1807 by isolating it from sodium hydroxide through electrolysis, and in 1811 he gave chlorine its name after unambiguously recognizing it as a pure element — although discovered in 1774 by the Swedish chemist Carl Wilhelm Scheele, chlorine was at the time considered to be a mixture with oxygen.

Sodium — an alkali metal, extremely reactive with oxygen and water — was thoroughly characterized in the years following its discovery. Reports dating back more than 150 years vividly describe[1,2] its chemical and physical properties, most notably its bright yellow flame and its oxidation with water that releases hydrogen gas so rapidly that sodium fragments seem to 'dance' on the water's surface. As well as containing valuable chemical information, these early reports illustrate much of the excitement arising from scientific curiosity: the reader can learn, for example, how hitting a spatula on sodium pieces sizzling on water will generate a loud bang along with a fountain of water and shattering of the bowl[1]. The intense yellow colour sodium imparts to flames went on to make for a beautiful application in fireworks.

©ISTOCKPHOTO.COM/STEVENALLAN

On a less festive note, in 1957, the first nuclear reactor that became a commercial power source in the USA was cooled using sodium. A better conductor of heat than water, it is a liquid with low vapour pressure around 260 °C, the temperature at which the reactor operated. Although the 'Sodium Reactor Experiment' took a disastrous turn a couple of years later, involving a damaged core and some radioactivity release, it demonstrated the possibility of using sodium as a coolant[3].

Yet the most essential role of sodium might be in biology. Although its involvement in hypertension and cardiac diseases has given it a bad name, sodium is actually keeping us alive. Our cells constantly balance high potassium and low sodium concentrations within cells (~140 mM K^+, ~15 mM Na^+) with an opposite distribution (~5 mM K^+, ~150 mM Na^+) outside. This balance is a fundamental part of almost everything we do, from seeing to thinking, not to mention breathing and the beat of our hearts. Proteins in the membrane of specific 'excitable' cells form sodium channels, opened by a trigger (a ligand binding, or a change in the membrane voltage) to enable a rapid influx of Na^+ ions into the cell. This regulates secretion in endocrine cells, contraction in muscle cells, and neurotransmission in nerve cells — the communication pathway within the brain.

In fact, disrupting this sodium influx is a very effective way of killing someone. Tetrodotoxin (TTX), a compound found in pufferfish (or fugu) that blocks voltage-gated sodium channels in nerve cells, is one of the most toxic substances on earth and has no known antidote. Intoxication with a sufficient dose — most commonly ingested through fugu dishes not prepared with enough care — will lead to death by respiratory failure within minutes to hours. The same characteristics, however, make TTX a very valuable research tool for studying neural networks that form the basis of the workings of the brain, of which we are just now beginning to gain an understanding.

Chemists have also recently gained a surprising insight into the nature of sodium itself. Yanming Ma and co-workers demonstrated[4] that compression dramatically changes the optical properties of the metal. Exposing sodium to increasing pressure causes a successive loss of visible light reflection, turning it into a transparent material at about 200 GPa. This transition is ascribed to a hybridization between *p* and *d* electrons, repelled by core electrons to occupy the interstices within the sodium lattice.

From fireworks and nuclear reactors to the human brain and structural insights, sodium is undoubtedly part of an exciting history of scientific discovery, with no end in sight just yet. ❐

References

1. Gmelin, L. *Handbuch der anorganischen Chemie* **2** (Heidelberg, 1853).
2. Kirchhoff, G. & Bunsen, R. *Annalen der Physik und Chemie* **186,** 161–189 (1860).
3. Daniel, J. A. Sr *Investigation of Releases from Santa Susana Sodium Reactor Experiment in July 1959* (Daniel & Associates, 2005).
4. Ma, Y. *et al. Nature* **458,** 182–185 (2009).

MARGIT S. MÜLLER is a PhD student in the Department of Pharmacology and Pharmacotherapy, Faculty of Pharmaceutical Sciences, University of Copenhagen, Universitetsparken 2 DK-2100, Copenhagen, Denmark. e-mail: mamu@farma.ku.dk.

This essay was selected as a winning entry in our writing competition, see this month's Editorial on p901 for more details.