Teaching students about iodine: an eye-catching article in 'Science in School'

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Iodine, with its characteristic purple vapors, has myriad applications—from the familiar disinfectant to innovative solar cells.

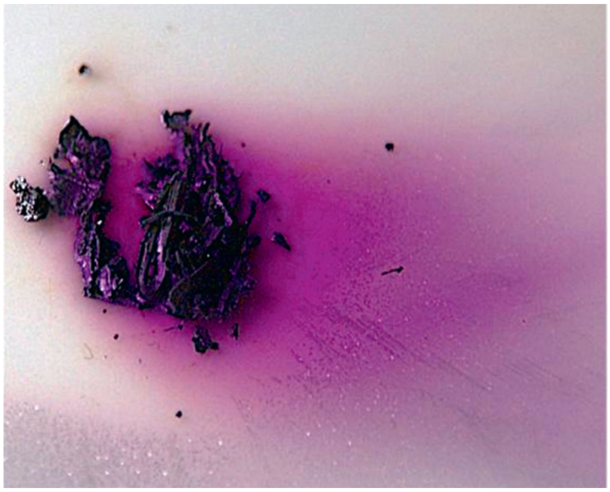
Iodine discovery

The discovery of iodine can be traced back to the 19th century and the Napoleonic wars. With the British imposing a blockade on European ports, the French were faced with shortages of saltpeter (KNO_3) for manufacturing gunpowder. Chemist Bernard Courtois investigated the potential of seaweed (brown algae, *Laminaria* sp.) as the potassium source for this crucial substance. He added concentrated sulfuric acid to seaweed ash and was surprised by the beautiful purple fumes that were produced.

Although Courtois suspected that his purple vapor was a new element, he did not have the financial means to follow up his research. It was left to his colleagues, including Joseph Gay-Lussac, to confirm his results and name the element iodine, from the Greek word *iodes*, which means purple or violet.

Gay-Lussac went on to investigate the chemistry of iodine, and despite the war, the French chemists found ways to correspond with British chemists, notably Sir Humphry Davy. Initially, Davy believed the vapor to be a chlorine compound, but soon concluded that it was indeed a new element.

With the help of X-ray absorption spectroscopy, we now know that seaweeds accumulate iodine as iodide (I^-), which acts as an antioxidant to protect them against oxidative damage caused by atmospheric ozone (O_3). This goes some way to explaining why trace amounts of molecular iodine (I_2) can be detected in the atmosphere of coastal regions and why iodine intake in these regions is dependent on seaweed abundance rather than proximity to the sea.



Iodine produces characteristic purple fumes
(Photo credit: Jurii/Wikimedia Commons; CC BY 3.0)

For much of the next century, iodine continued to be extracted from seaweed. Today, however, it is removed from natural iodine-containing brines in gas and oil fields in Japan and the USA, or from Chilean caliches (nitrate ores), which contain calcium iodate ($Ca(IO_3)_2$). The iodine is supplied to the market as a purplish-black solid.

Iodine chemistry

Iodine belongs to the halogens, and thus shares many of the typical characteristics of the elements in this group. Because of its high electronegativity, iodine forms iodides with most elements in its formal oxidation state, -1. Many iodine-containing compounds are frequently used as reagents in organic synthesis—mainly for iodination, oxidation, and C-C bond formation.

Iodine in the atmosphere originates mostly from biological and chemical processes in the ocean—such as the iodide antioxidant system in seaweeds. Most iodine is ultimately removed from the atmosphere by cloud formation. In the ocean, iodine is mainly dissolved and exists as iodate (IO_3^-, oxidized form) and iodide (I^-, reduced form). In the Earth's outer layer (the lithosphere), most iodine is in marine and terrestrial sediments; iodine levels are low in igneous rocks.

Industrial uses of iodine

Iodine and its compounds are used in myriad products, from food and pharmaceuticals, through to animal feed and industrial catalysts *(Figure 1)*. For instance, iodine is a potent antimicrobial. For more than a century, iodine tincture—a mixture of ethanol, water, iodine, and potassium iodide—was used as an antiseptic for wounds. This has now largely been replaced by water-soluble ionophores (iodine complexed with surfactants), which are less irritating to the skin. For example, povidone iodine, a mixture of polyvinylpyrrolidone and iodine, is used widely as a surgical scrub.

In the industrial production of acetic acid, iodine compounds such as rhodium iodide (the Monsanto process) or iridium iodide (BP's Cativa process) are used to catalyze the carbonylation of methanol.

Silver iodide (AgI), used in early photographic plates, is used today in cloud seeding to initiate rain and to control climate. Because AgI has a similar crystal structure to ice, it can induce freezing by providing nucleation sites. This was done at the 2008 Beijing Olympics to prevent rainfall during the opening and closing ceremonies.

With its high atomic weight (126.9) and large number of electrons, iodine is also an excellent X-ray absorber and is used in X-ray contrast media. These substances are generally safe to administer to humans and enable the visualization of soft tissues in X-ray examinations.

A more everyday application of iodine is in liquid-crystal displays for TVs, computers, and mobile phones, which use polarizing films to filter light. These films are commonly made of polyvinyl alcohol layers doped with iodine. Here, iodine acts as a cross-linker and ensures that the structure is polarizing.

Iodine in the energy industry

Iodine is used in one of the most promising solar cells on the market for the production of low-cost "green energy": the dye-sensitized titanium oxide solar cell. Also known as the Grätzel cell after one of its inventors, it consists of polyiodide electrolytes as the charge transport layer between the cathode and the anode (1).

Of the 37 known isotopes of iodine, all but one, ^{127}I, are radioactive. Most of these radioisotopes, which are produced via fission reactions in nuclear power plants and weapons, are short-lived, which makes them useful as tracers and therapeutic agents in medicine. For example, iodine isotopes can be used to image the thyroid gland, which absorbs radioactive iodine when it is injected into the bloodstream.

Unfortunately, radioactive ^{131}I, released from nuclear accidents—such as the disaster in Fukushima, Japan, in 2011—is also taken up by the thyroid. Because it is a high-energy β-particle emitter, it damages cells and induces cancer. To counteract this effect, nonradioactive potassium iodide (KI) tablets are ingested to saturate the thyroid's ability to take up radioactive iodine.

These are just a small sample of the many applications of iodine. Clearly, although the element has been known for only two hundred years, it is well established in modern chemistry, physics and medicine.

Acknowledgement

This article was adapted from a much longer publication in Angewandte Chemie International Edition (2).

References

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FIGURE 1 The major industrial uses of iodine