A brighter beryllium

Although it is mainly known for its toxicity, beryllium possesses an array of properties that makes it attractive for a variety of non-industrial purposes. **Ralph Puchta** discusses why it is not always best avoided.

Since ancient times, people have been fascinated by the green or red of emeralds and the light blue of aquamarines. These gems are composed of the mineral beryl — a transparent beryllium aluminium cyclosilicate ($\text{Be}_3\text{Al}_2(\text{SiO}_3)_6$) — and bear traces of transition metals that endow them with striking colours. The mineral beryl is also at the origin of the German word 'brille' for eyeglasses.

It was while analysing beryl that the Frenchman Louis-Nicolas Vauquelin separated beryllium salts from aluminium salts in 1798. At the time he proposed the name 'glucinium', in reference to its sweet taste, but beryllium was finally adopted in French in 1957, in agreement with the other languages. Beryllium was prepared in its elemental form in 1828 by Friedrich Wöhler and Antoine Bussy who, independently, reacted beryllium chloride with potassium. In 1898, Paul Lebeau obtained elemental beryllium by electrolysis of a mixture of molten BeF_2 and NaF . Today, most beryllium is produced by the redox reaction of magnesium with BeF_2 , itself obtained from beryl.

Number four in the periodic table, beryllium is the smallest metal atom. It is typically protected by a thin layer of beryllium oxide (BeO), which renders it resistant against concentrated oxidizing acids — diluted hydrochloric acid, however, dissolves it, generating hydrogen in the process. The combination of its high melting point (1,287 °C), good elasticity, ability to scatter high-energy neutrons and other physical characteristics, has led to several practical applications.

Beryllium has traditionally been used to construct radiation windows for X-ray tubes, for example, as it hardly absorbs X-rays. This transparency to energetic particles also led to its use as a component in detectors of the Large Hadron Collider accelerator. Furthermore, beryllium serves in all kinds of nuclear applications, for example, as a

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neutron reflector in current power plants based on fission and in nuclear weapons.

Beryllium also takes part in natural nuclear processes in space, such as the fusion reactions that generate carbon. In old stars, during the 'triple alpha process', three ^4He nuclei (also called alpha particles) are transformed into one ^{12}C atom. At first, two ^4He nuclei fuse into the highly unstable ^8Be , which tends to simply decay into two ^4He nuclei again. However, under particular conditions, these beryllium nuclei are formed faster than they decay. Some can then fuse with an additional ^4He nucleus to form the stable ^{12}C atom. Our Sun will undergo this process in around six billion years, when it is around ten billion years old.

Beryllium alloys offer mechanical, thermal and electrical properties of interest to various practical usages. For example beryllium-copper alloys (which typically contain up to 2.5% of beryllium) become non-magnetic and can serve in gyroscopes or magnetic resonance imaging devices. Beryllium can also withstand lower temperatures than glass, a convenient characteristic for military and space applications.

Beryllium is used to dope semiconductors such as gallium arsenide by molecular beam epitaxy. In contrast, its oxide BeO is an electrical insulator, yet excellent heat conductor. Perhaps the most interesting new possible application for beryllium today is that beryllium ions may serve as processors for quantum computers. Such a computer has already been successfully tested for 160 programs, and operated accurately around

80% of the time. It seems likely that larger systems can be realized with a beryllium-based processing unit¹.

However, most practical applications are spoilt at an early stage by the toxicity of beryllium and its compounds, especially in the form of dust. When inhaled, small particles can cause berylliosis — a chronic lung disease that can take any time between a few months and several years to declare itself in the body, and cannot be treated². This does not mean that beryllium and its compounds should not be used at all, but they must be handled with care.

Current research with this element focuses on basic investigations, such as structural and mechanistic properties, and has recently been relying more on computational rather than experimental studies. Research carried out³ on tetra-coordinated complexes, for example, has provided further knowledge of the structural diversity of beryllium complexes. The possible coordination numbers of beryllium have also recently been clarified^{3,4} and mechanistic studies are underway to elucidate solvent-exchange processes^{5,6}.

As further insight into the structure and reactivity of beryllium compounds is gained, this element will no doubt play an increasing role in daily life applications. In light of this, one might be tempted to conclude — to Be, or not to Be, that is not the question. □

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References

1. Hanneke, D. *et al.* *Nature Phys.* **6**, 13–16 (2009).
2. Dehnicke, K. & Neumüller, B. *Z. Anorg. Allg. Chem.* **634**, 2703–2728 (2008).
3. Azam, S. S. *et al.* *J. Chem. Phys. Chem. B* **113**, 9289–9295 (2009).
4. Rudolph, W. W., Fischer, D., Irmer, G. & Pye, C. C. *Dalton Trans.* **38**, 6513–6527 (2009).
5. Puchta, R., Pasgreta, E. & van Eldik, R. *Adv. Inorg. Chem.* **61**, 523–571 (2009).
6. Budimir, A., Walther, M., Puchta, R. & van Eldik, R. *Z. Anorg. Allg. Chem.* **637**, doi:10.1002/zaac.201000418 (2011).