Ask the Historian

Onion's Fusible Alloy

William B. Jensen

Department of Chemistry, University of Cincinnati
Cincinnati, OH 45221-0172

Question

What is the origin of the name "Onion's Fusible Alloy"?

Hans de Grys
Science Department
Lakeside School
SEATTLE, WA 98125

Answer

"Onion's Fusible Alloy" is the name given to a low melting (92°C) ternary alloy composed of 50% Bi, 30% Pb, and 20% Sn by weight and which is currently being marketed to high school chemistry teachers as a novelty item for use in demonstrations and laboratory experiments. It is actually one of an entire family of fusible ternary Bi/Pb/Sn alloy systems which melt at or just below the boiling point of water and which have been used since the 18th century for such purposes as temperature standards, solders, safety plugs for steam boilers, and valves for automatic sprinkler systems. On a more frivolous note, these alloys have also occasionally been used to make such joke items as trick spoons designed to melt when used to stir a cup of hot coffee or tea (1).

The first set of these alloys was reported by Sir Isaac Newton (1642-1727) in 1701 for use as temperature standards (2). In fact Newton recorded two compositional variations, the lowest melting of which is listed in the attached table and is now commonly referred to in the literature as "Newton's Metal." A similar set of low melting Bi/Pb/Sn alloys of varying composition were reported posthumously in 1772 by the German pharmacist, Valentin Rose the Elder (1736-1771), and are commonly referred to as "Rose's Metal," though the particular composition and melting point reported under this name varies considerably from one source to another (3). A final set of more than ten compositional variations for this system was reported by the French chemist, Jean D'Arcet (1725-1801), in 1775 and are known collectively as "D'Arcet's Alloys" (4). As with the case of Rose's Metal, the particular composition and melting point reported under this name varies considerably from source to source, though the French engineer, A. Guettier, in his 1871 treatise on alloys, felt that the terms Rose and

Example Fusible Alloy Systems

Year	Discoverer	Composition by Weight	mp/°C
1701	Newton	50% Bi, 20% Pb, 30% Sn	98
1772	Rose	50% Bi, 27.1% Pb, 22.1% Sn	95
1775	D'Arcet	49.2% Bi, 21.2% Sn, 27.6% Pb	95
Before 1888	Onion	50% Bi, 30% Pb, 20% Sn	92
1860	Wood	50% Bi, 25% Pb, 12.5% Sn, 12.5% Cd	70
1860	Lipowitz	50% Bi, 27% Pb, 13% Sn, 10% Cd	74
1935	French	41% Bi, 22.1% Pb, 10.6% Sn, 8.2% Cd, 18.1% In	46.9

D'Arcet Alloy were essentially synonymous and were best characterized by the idealized composition 50% Bi, 20% Pb, and 30% Sn by weight - a composition which happens to be identical to one of the variations first reported by Newton in 1701 (5).

A search of the literature dealing with fusible alloys from 1872 to the present revealed numerous references to the alloys of Newton, Rose and D'Arcet but only one to Onion's alloy (5-9). This occurs in an 1889 guide to alloys systems by Krupp and Wildberger, but provides no clue as to who Onion was or where he originally proposed his particular variation of the Bi/Pb/Sn system (6). Indeed the book in question has been scanned by Google and is currently available on the internet, which is where I suspect the laboratory supplier of this product got both the name and the recipe.

The particular compositions reported by Newton, Rose, D'Arcet and Onion were all the result of haphazard empirical investigation and it was not until 1898 that Charpy reported a complete ternary phase diagram for the Bi/Pb/Sn system which revealed (figure 1) the existence of a single ternary eutectic point at 96°C corresponding to the composition 52% Bi, 32% Pb, and 16% Sn by weight (10). This implies that many of the melting points given in the attached table and reported in references 5-9 - and especially the melting point reported for Onion's alloy - must either be inaccurate or the metals used in their preparation must be contaminated with other ingredients.

There are, of course, fusible alloys systems with melting points much lower than those reported for the Bi/Pb/Sn system, the most famous of which are those found in the quaternary Bi/Pb/Sn/Cd system (see table), as first reported by the American physician, Barnabas Wood, of Nashville, Tennessee, in 1860 and subsequently by Lipowitz the same year (11, 12). Wood's discovery attracted considerable attention and was subsequently reported in both the German and French literature as well (13). It was the Editor of *The American Journal of Science* - the Harvard mineralogist, James Dwight Dana - who first suggested that these alloys be called "Wood's Fusible Metal" in honor of their discoverer (14). Unfortunately, because of problems with cadmium toxicity, these alloys are no longer recommended for student use. Work in the 20th century has since revealed more complex alloys systems having even lower melting points, such as those reported by French in 1935 (see table), some of which are liquid at room temperature and are currently being explored as possible substitutes for liquid mercury (15).

We would obviously like to hear from any readers having further information on either Onion or his alloy (16).

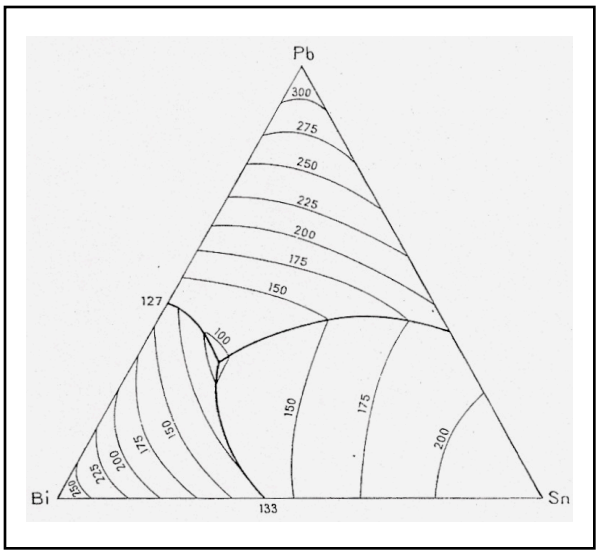

Figure 1. Phase diagram for the Bi/Pb/Sn system showing a ternary eutectic at 96° C (10). Compositions are in weight percentages.

Literature Cited

1. See, for example, J. H. Pepper, *The Playbook of Metals*, Routledge: London, 1861, p. 439.

2. I. Newton, "Scalum graduum Caloris," *Phil. Trans.* **1701**, *270*, 824-829. An English translation appears as I. Newton, "A Scale of the Degrees of Heat," *Phil. Trans., Abridged*, **1809**, *4*, 572-575. Both are reproduced in I. B. Cohen, Ed., *Isaac Newton's Papers & Letters on Natural Philosophy,* Harvard University Press: Cambridge, MA, 1958, pp. 259-268.

3. V. Rose, "Vermischung einiger Metalle, welche in knochende Wasser die laufende Gestalt des Quecksilbers annehmen," *Stralsund. Magaz.* **1772**, *2*.

4. J. D'Arcet, "Expériences sur l'alliage fusible de plomb, de bismuth, et d'etain," *Journal de médicine*, **1775**.

5. A. Guettier, *A Practical Guide for the Manufacture of Metallic Alloys*, Baird: Philadelphia, 1872, pp. 242-244.

6. A. Krupp, A. Wildberger, *The Metallic Alloys: A Practical Guide,* Baird: Philadelphia, 1889, p. 305.

7. L. Godefroy, *Le Bismuth et ses composés*, Dunod: Paris, 1887, pp. 24-30. Published as Part 24(1) of Volume 3 of Fremy, E., Ed., *Encyclopèdie chimique*, Dunod: Paris, 1882-1899.

8. Anon., *Bismuth*, United States Bureau of Standards, Circular 382, Government Printing Office: Washington, DC, 1930.

9. P. Pascal, Alliages ternaires ou plus complexes, in P. Pascal, Ed., *Nouveau traité de chimie minéral*, Vol. 20, Masson et Cie: Paris, 1963, pp 1911-1924.

10. G. Charpy, "Sur les états d'equilbre du système ternaire: plomb-etain-bismuth," *Compt. rend.*, **1898**, *126*, 1569-1573.

11. B. Wood, "Improved Alloy or Metallic Composition Suitable for a Metallic Cement in the Manufacture of Tin, Pewter, and Other Metals; Also Useful for Casting and Other Purposes," *J. Franklin Inst.*, **1860**, *40 (Third Series)*, 125-128.

12. A. Lipowitz, "Ueber Wood's leichtflüssiges Metall," *Dingler's Polytech. J.*, **1860**, *158*, 376-377.

13. Anon. "Sur une nouvelle alliage trés-fusible," *Répertoire chim. appl.,* **1860**, *2*, 313-314; Anon., "Wood's leichtflüssiges Metall," *Dingler's Polytech. J.*, 1**860**, *158*, 271-272.

14. Anon., "A New Fusible Metal," *Am. J. Sci.*, **1860**, *30 (Second Series*), 271-272.

15. S. J. French, "A New Low-Melting Alloy," *Ind. Eng. Chem.*, **1935**, *27*, 1464-1465.

16. Onion may be the name of a 19th-century company that specialized in the manufacture of this alloy.

Do you have a question about the historical origins of a symbol, name, concept or experimental procedure used in your teaching? Address them to Dr. William B. Jensen, Oesper Collections in the History of Chemistry, Department of Chemistry, University of Cincinnati, Cincinnati, OH 45221-0172 or e-mail them to jensenwb@ucmail.uc.edu

2010 Update

George Rizzi tells the author that he was recently surprised, on breaking a thermometer, to discover that the silver liquid inside was not mercury but rather a ternary Ga/In/Sn alloy called Galinstan, which melts at -19°C and boils above 1300°C.

Likewise, Dr. H. J. Wagner of the University of Paderborn has provided the missing information on Onions' alloy. This alloy was introduced as a packing material for a rotary steam engine first patented by the British engineer, William Onions, in 1812. This would explain why I was unable to find anything on it the chemical and metallurgical literature and, of course, it never occurred to me to look in the literature dealing with the history of the steam engine. This also means that it should be called "Onions' alloy" rather than "Onion's alloy," as it is universally, but incorrectly listed on the web and also referred to by its current manufacturer. Dr. Wagner has also kindly provided a number of relevant references:

1. H. W. Dickinson, A. Lee, *Transactions of the Newcomen Society*, **1925**, *4* (1925), 48-63 (especially pp. 53-55).

2. J. Millington, *An Epitome of the Elementary Principles of Natural and Experimental Philosophy*, Part I, Sherwood, Jones & Co: London, 1823, p. 336.

3. E. Galloway, *History of the Steam Engine From Its Earliest Invention to the Present Time*, 2nd ed., Steill: London, 1828, p.156.

4. R. Stuart, *Historical and Descriptive Anecdotes of Steam-Engines and of Their Inventors and Improvers*, Vol. II, Wightman & Cramp: London, 1829, p. 511.

5. Anon., "On the Preparation of Various Fusible Metals and on Using Them to the Most Advantage," *Gill's Technical Repository*, **1822**, *1*, 348-348.

6. A. H. Hiorns, *Mixed Metals or Metallic Alloys*, Macmillan: London, 1901.

7. A. A. Hopkins, *The Standard American Encyclopedia of Formulas*, Grosset & Dunlap: New York, 1953.