When Water Does Not Boil at the Boiling Point

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Every schoolchild learns that, under standard pressure, pure water always boils at 100°C. But as some specialist scientists know very well, this is not the case. My own introduction to the anomalous variations of the boiling point came through the history of science, in the course of researching for my book on the history of thermometry (*Inventing Temperature*, 2004). By the early 19th century, many reputable scientists reported significant variations in the boiling point of water, including a temperature difference of over 1°C between samples of water boiling in metallic and glass vessels (Gay-Lussac), and "superheating" up to 112°C in de-gassed water (De Luc). I have confirmed many of these observations in my own reproductions of the historical experiments, and also made some further extensions of those experiments. Some highlights of the experiments will be presented in video clips. These results raise three interesting questions.

(1) What is the explanation for these variations? The effect of different vessels is explained relatively easily, in terms of the number and quality of nucleation sites found on different types of surfaces. The effect of de-gassing is more difficult to explain, and to my knowledge it has not been investigated extensively.

(2) Why are these variations not commonly known, especially when most of us boil water on a daily basis? Our everyday experience of water-boiling is actually very limited in kind. In terms of education, most of us are not taught about the intricacy of boiling because it is not considered an important subject in most of modern science. The best knowledge of the actual phenomenology of boiling today exists in mechanical and chemical engineering, rather than physics or chemistry. The theoretical framework used by the engineers (best represented by the "boiling curve") is incommensurable with that used by the physicists (best represented by the phase diagram, whose sharp boundary-lines provide no space for phenomena like superheating).

(3) If the boiling point of water is not constant, how was it possible to use it as a "fixed point" for the calibration of thermometers for such a long time? The success of early thermometry and thermal physics was serendipitous, and iterative. Initially scientists happened to work under those particular circumstances which make the temperature of boiling quite fixed; by means of thermometers graduated on that basis, they were able to make investigations which came back to correct their own starting points.