The International Temperature Scale 1990 (ITS-90) in Celsius, Kelvin, and Energy-Matter Units

(A Proposal from Earth/matriX)

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Abstract

In this essay, the author analyzes the ITS-90 thermodynamic temperature scale expressed in either Celsius or in Kelvin. The expression of the ITS-90 scale in Celsius reveals the significance of an imaginary centerpoint in the values of the sixteen reference materials/points of the ITS-90 scale. The expression of the ITS-90 scale in Kelvin reveals the significance of an incremental/decremental progression of the values of the sixteen reference materials/points of the ITS-90 scale. Counterposed to the expressions of the Celsius and Kelvin scales for the ITS-90 scale, the author illustrates how the Earth/matriX thermodynamic temperature scales (energy-matter, em) afford a range of values for the sixteen reference points/materials that reflect both a unitpoint and an incremental/decremental progression of values.

Introduction

Before any other affirmation, it is necessary to remind ourselves that the International Temperature Scale ITS-90 is *not* a *scale* as such. ITS-90 proposes precise calibration *standards* in the measurement of matter-energy using different temperature scales (Celsius, Kelvin, Rankine, Fahrenheit, among others). This is significant. ITS-90 encourages standards of measurement as of groupings along the different temperature scales. This is much like tuning a piano. In order to avoid errors, various points of measurement are fixed within the scales in order to avoid deviations along the range of the scale, especially along the scales' extremities.

ITS-90 represents an effort by scientists all over the world to measure the thermodynamic temperature scale in absolute terms, as of absolute zero (AZ), as exactly as possible throughout the entire range of temperatures. In order to achieve this goal, different designs in thermometers are needed so as to embrace the complete range of temperatures. Some of the thermometers involved in ITS-90 are helium gas thermometers, helium vapor pressure thermometers, SPRTs or standard platinum resistance thermometers and, finally, monochromatic radiation thermometers. So, not only is ITS-90 not a scale, but it reflects the use of distinct kinds of measuring devices (thermometers) together with different temperature scales.

ITS-90 Fixed Reference Points

Material	***Measurement Point***	***Temperature t_{90} (^{o} C)***
Helium	Vapor points	-270.14 to -268.15
Hydrogen	Triple point	-259.3467
Neon	Triple point	-248.5939
Oxygen	Triple point	-218.7916
Argon	Triple point	-189.3442
Mercury	Triple point	-38.8344
Water	***Triple point***	***0.0100***
Gallium	Melting point	29.7646
Indium	Freezing point	156.5985
Tin	Freezing point	231.928
Zinc	Freezing point	419.527
Aluminum	Freezing point	660.323
Silver	Freezing point	961.78
Gold	Freezing point	1064.18
Copper	Freezing point	1084.62
Platinum	Freezing point	1768.1

In the previous ITS-90 table, the second and third columns appear to be very orderly and comprehensible. Yet, when one considers the nature of the first column on the table, an immediate realization comes to mind that the elements listed there are in no particular order; neither alphabetically (which is common in treating elements in scientific literature) nor according to their atomic numbers. Also, the material *water*, it must be observed, has been placed on the list of materials as a supposed center point to the ordered negative/positive values listed on the third column.

Notably, the triple point of water (TPW) is not a center point, neither to the positive/negative values listed on the table, nor does it occupy such a position between absolute zero, the freezing point of water (FPW), and/or with regard to the boiling point of water (BPW) and absolute zero (AZ) on a thermodynamic temperature scale.

ITS-90 fixed reference points reveal an apparent progression of negative/positive temperature values of chosen elements, along with the triple point of water. The thermometers employed by ITS-90 are calibrated for use with very complicated mathematical formulae in order to be able to generate values between the fixed 16 reference points. A search for different kinds of thermometers involving the elements produces scores of thermometers: helium-lithium (isotope) thermometers; germanium standard thermometer; fluorine-boron thermometer; compound carbon thermometer; nitrogen thermometer; sodium thermometer; nickel thermometer; rhodium-iron thermometer; all-niobium inductance thermometer; zinc thermometer; gallium thermometer; krypton vapor pressure thermometer; rubidium thermometer; zircon thermometer; among many others.

Yet, some elements are not apparently employed in making thermometers based on themselves, such as the following elements for which I could not find any thermometers listed under these elements. Thermometers were not found for phosphorous; chlorine; vanadium; astatine; bromine; among many others. This does not mean that such thermometers do not exist, but that I did find them in my search. One would expect that since all elements undergo heat transfer or exchange, then any element could be employed as a thermometer. One would also expect that all thermometers are calibrated according to the ITS-90 standards, and that the sixteen fixed reference points represent a studied selection, and not an exhaustive listing of possibilities.

Control standards seek to reproduce results between different laboratories. One researcher states that most thermometers in industry are employed without calibrating them, or checking the exactness of their calibration. Thermometers are simply removed from the boxes that they arrive in and are used without confirming their calibrated exactness. Among other considerations, however, the calibration standards of ITS-90 involve taking into consideration the tiny effects of atmospheric pressure on the sample, as well as the depth of the temperature probe introduced into the sample. From the list of fixed reference points, one may observe that ITS-90 distinguishes triple points and also melting and freezing points of elements (whether heat is entering or leaving the sample under study).

These aspects represent standards for calibrating the measurement of temperature, and do not actually reflect the features of a temperature scale as such. ITS-90 thus reflects more how (comparisons of) heat measurements are made, rather than what defines the gradation in the measurement of heat. This becomes clear when we consider the fact that the temperatures of the referenced fixed points (triple, vapor, melting, and freezing points) are themselves expressed in the Kelvin and Celsius scales.

The Celsius and Kelvin scales are themselves based precisely on the triple point of water. Note an interesting aspect of the triple point of water: *"Only the triple point of Vienna Standard Mean Ocean Water (VSMOW) is known with absolute precision ---regardless of the calibration standard employed--- because the very definitions of both the Kelvin and Celsius scales are fixed by international agreement, in part, on this point". "…precise measurements show that the boiling point of VSMOW water under one standard atmosphere of pressure is actually 373.1339 K (99.9839 ^{o}C), when adhering strictly to the two-point definition of thermodynamic temperature. When calibrated to ITS-90, where one must* *interpolate between the defining points of gallium and indium, the boiling point of VSMOW water is about 10 mK less, about 99.974 °C." –Wikipedia.*

The International Temperature Scale 1990 ITS-90, replaced a long line of previous attempts throughout the twentieth century to regulate the measurements of matter-energy on an international level among different laboratories. Consider some of these historical moments.

-The International Temperature Scale of 1927 (ITS-27)
--The International Temperature Scale of 1948 (ITS-48)
The International Practical Temperature Scale of 1948 (Amended Edition of 1960) (IPTS-48)
-The International Practical Temperature Scale of 1968 (IPTS-68)
-The International Practical Temperature Scale of 1968 (Amended Edition of 1975) (IPTS-68)
-The 1976 Provisional 0.5 K to 30 K Temperature Scale (EPT-76)

"The International Temperature Scale of 1927 was adopted by the seventh General Conference of Weights and Measures to overcome the practical difficulties of the direct realization of thermodynamic temperatures by gas thermometry, and as a universally acceptable replacement for the differing existing national temperature scales. The ITS-27 was formulated so as to allow measurements of temperature to be made precisely and reproducibly, with as close an approximation to thermodynamic temperatures as could be determined at that time." –Internet web-site; public domain, fair use.

So, the long history behind an exact scale for the measurement of thermodynamic temperatures reflects the effort invested in the current scale, the ITS-90. ITS-90, as has already been noted, is rather "an equipment calibration standard". A popular interpretation of ITS-90 should suffice to make this point, but in this essay I shall elaborate on why this appears to be the case. "*Although "International Temperature Scale of 1990" has the word scale in its title, this is a misnomer that can be misleading. ITS–90 is not a scale; it is an equipment calibration standard. Temperatures measured with equipment calibrated per ITS–90 may be expressed using any temperature scale such as Celsius, Kelvin, Fahrenheit, or Rankine." -Wikipedia*

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