

# The Platinum Metals in the Measurement of Temperature

## THE NEW INTERNATIONAL TEMPERATURE SCALE OF 1968

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A revised definition of the temperature scale entitled the International Practical Temperature Scale of 1968 (IPTS-68) was introduced by the Comité International des Poids et Mesures (CIPM) in October 1968 to replace the IPTS-48. The new Scale was put into operation at the National Physical Laboratory on January 1st, 1969, and temperature values quoted in documents issued by the Laboratory from that date will be changed by the appropriate amounts. It is necessary to make these changes throughout science and industry, but as will be seen below the changes for many purposes will not be very significant. Platinum plays an important role in the new Scale for the construction of the platinum: 10 per cent rhodium-platinum thermocouple and the platinum resistance thermometer which are the chosen standard instruments for the realisation of the Scale below the freezing point of gold.

The difference in numerical values of temperature introduced by the IPTS-68 are shown in Table I. They result from the adjustments made to the IPTS-48 to give agreement with thermodynamic values of temperature obtained from gas-thermometer measurements. These adjustments consist of assigning the best available values of thermodynamic temperature to the defining fixed points and modifications to the interpolation procedures in the parts of the Scale where the platinum resistance thermometer is the specified interpolation instrument.

The IPTS-68 extends down to 13.81K, the triple point of equilibrium hydrogen, whereas the IPTS-48 stopped short at the boiling point of oxygen ( $T_{68}(\text{O}_2)=90.188\text{K}$ );

the extension is made in terms of the platinum resistance thermometer which is now the interpolation instrument of the Scale over the wide range from  $-259.34^\circ\text{C}$  (13.81K) to  $630.74^\circ\text{C}$ . The platinum to be used in the thermometer is required to be very pure; the completed thermometer must have a value of the resistance ratio  $\frac{R(100^\circ\text{C})}{R(0^\circ\text{C})}$  not less than 1.39250. This value corresponds to 1.3920 on the old scale.

To conform with common usage the Scale is expressed in Kelvin temperatures below 273.15K and in Celsius temperatures above. From 13.81K to 273.15K the resistance of the thermometer is measured at a number of fixed points and then the calibration is obtained by difference from the reference function

$$T_{68} = [A_0 + \sum_{i=1}^{20} A_i (\ln W)^i] \text{K}$$

where  $W = \frac{R(T)}{R(273.15)}$ . The coefficients

$A_0, \dots, A_{20}$  are specified in the text of the Scale. The function has been evaluated and is available in the form of a detailed table. The differences from the function,  $\Delta W$ , are expressed by a polynomial for each of the ranges 13.81K to 20.28K, 20.28K to 54.361K, 54.361K to 90.188K and 90.188K to 273.15K. The last mentioned range was formerly defined by the Callendar-Van Dusen equation but we now use the difference from the reference function given by the equation.

$$\Delta W = A + B \left( \frac{t_{68}}{100^\circ\text{C}} - 1 \right) \frac{t_{68}}{100^\circ\text{C}}$$

Where  $t_{68} = T_{68} - 273.15\text{K}$  and the constants A and B are determined by measurements of

**Table I**  
**Approximate Differences between IPTS-68 and IPTS-48 in kelvins**

$t_{68}^{\circ}\text{C}$	0	-10	-20	-30	-40	-50	-60	-70	-80	-90	-100
-100	0.022	0.013	0.003	-0.006	-0.013	-0.013	-0.005	0.007	0.012	(0.008 at O <sub>2</sub> point)	
0	0.000	0.006	0.012	0.018	0.024	0.029	0.032	0.034	0.033	0.029	0.022
$t_{68}^{\circ}\text{C}$	0	10	20	30	40	50	60	70	80	90	100
0	0.000	-0.004	-0.007	-0.009	-0.010	-0.010	-0.010	-0.008	-0.006	-0.003	0.000
100	0.000	0.004	0.007	0.012	0.016	0.020	0.025	0.029	0.034	0.038	0.043
200	0.043	0.047	0.054	0.054	0.058	0.061	0.064	0.067	0.069	0.071	0.073
300	0.073	0.074	0.075	0.076	0.077	0.077	0.077	0.077	0.077	0.076	0.076
400	0.076	0.075	0.075	0.075	0.074	0.074	0.074	0.075	0.076	0.077	0.079
500	0.079	0.082	0.085	0.089	0.094	0.100	0.108	0.116	0.126	0.137	0.150
600	0.150	0.165	0.182	0.200	0.23	0.25	0.28	0.31	0.34	0.36	0.39
700	0.39	0.42	0.45	0.47	0.50	0.53	0.56	0.58	0.61	0.64	0.67
800	0.67	0.70	0.72	0.75	0.78	0.81	0.84	0.87	0.89	0.92	0.95
900	0.95	0.98	1.01	1.04	1.07	1.10	1.12	1.15	1.18	1.21	1.24
1000	1.24	1.27	1.30	1.33	1.36	1.39	1.42	1.44			
$t_{68}^{\circ}\text{C}$	0	100	200	300	400	500	600	700	800	900	1000
1000		1.5	1.7	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2
2000	3.2	3.5	3.7	4.0	4.2	4.5	4.8	5.0	5.3	5.6	5.9
3000	5.9	6.2	6.5	6.9	7.2	7.5	7.9	8.2	8.6	9.0	9.3

W at 100°C and -182.962°C (90.188K). Thus the experimental procedure for calibration in this range of temperature is simpler than formerly, requiring calibration at three points only instead of four, since it is not dependent on measurements at the zinc point.

The Callendar equation is still used for the range from 0°C to 630.74°C but a correction term is added, so that the calibration procedure is to measure the resistance of the thermometer at the 0°C point (obtained by way of the triple point of water), the boiling point of water (100°C) and the freezing point of zinc (419.58°C). It will be observed that only the temperature assigned to the freezing point of zinc has been changed, being 419.505°C on the 1948 scale. The Callendar equation is then used to determine an intermediate value of  $t^1$

$$t^1 = 1/\alpha (W - I) + \delta \left( \frac{t^1}{100^{\circ}\text{C}} - 1 \right) \frac{t^1}{100^{\circ}\text{C}}$$

Now  $t^1$  is corrected by an amount which varies with temperature but is the same for all thermometers which meet the specification for the Scale

$$t_{68} = t^1 + 0.45 \left( \frac{t^1}{100^{\circ}\text{C}} \right) \left( \frac{t^1}{100^{\circ}\text{C}} - 1 \right) \left( \frac{t^1}{419.58^{\circ}\text{C}} - 1 \right) \left( \frac{t^1}{630.74^{\circ}\text{C}} - 1 \right)^{\circ}\text{C}$$

It is clear that the coefficient  $\alpha$  for a particular specimen of platinum will be unchanged on the new Scale but the  $\delta$  coefficient will be different because of the change in the value assigned to zinc point. For example a  $\delta$  coefficient of 1.492 on the old scale becomes about 1.497 on the new.

Over the range from 630.74°C to the gold point (1064.43°C) the platinum : 10 per cent rhodium-platinum thermocouple is used to define the Scale as in the IPTS-48, but now the values of the fixed points are modified. The emf temperature relation is

$$E = a + bt_{68} + ct_{68}^2$$

where the constants a, b and c are determined from the measurements made at 630.74°C ± 0.2°C, 961.93°C (F.P. of silver) and 1064.43°C (F.P. of gold).

Above the gold point the IPTS-68 is defined as before by the Planck law of radiation using the freezing point of gold as the reference temperature and a new value of  $c_2$ ,

the second radiation constant, of 0.014388 metre kelvin. The numerical values of temperature in this range show a net increase over the 1948 values, the higher value of the gold point causing an increase and the higher value of  $c_2$  a decrease.

The values of the freezing points of the metals relevant to this discussion and given either as defining fixed points of the temperature scale or in the list of secondary fixed points are set out in Table II with the corresponding IPTS-48 values for comparison.

The freezing points of silver and gold are defining fixed points of the Scale and therefore the temperatures assigned are the best available values of thermodynamic temperature. The other values in Table II are obtained from the IPTS-48 values corrected according to the differences in Table I and then rounded to the nearest kelvin.

The IPTS-68 embodies the decision of the CIPM to discontinue the use of "degree kelvin, symbol °K" in favour of the "kelvin" to describe the unit of thermodynamic tem-

**Table II**  
**New Freezing Points of Metals**

	IPTS-68	IPTS-48
Silver	961.93°C	960.8°C
Gold	1064.43	1063
Palladium	1554	1552
Platinum	1772	1769
Rhodium	1963	1960
Iridium	2447	2443

perature which is defined as "the fraction 1/273.16 of the temperature of the triple point of water". It is appropriate to refer to a temperature difference in kelvins even when the temperatures are expressed in degrees Celsius, and this practice has been followed in the text of the Scale.

The full text of the English version of the IPTS is obtainable from Her Majesty's Stationery Office. The official French text is obtainable from the International Bureau of Weights & Measures, F92, Sèvres, France.

## Palladium-Titanium Alloy in Chemical Plant

The natural resistance of titanium to corrosion in oxidising conditions has been extended to reducing conditions by the addition of small amounts of palladium, and the wider use of titanium in chemical plant which this permits has been the subject of comment in this journal, most recently on the work of Takamura in Japan (1).

Whereas Takamura used the 0.13 per cent palladium-titanium alloy in hot concentrated chloride solutions, W. R. Fischer, of Friedrich Krupp, Essen, has now shown that the Krupp standard alloy containing 0.2 per cent palladium is most generally useful in extended tests with a number of chloride solutions (2). Adequate protection against crevice corrosion and pitting was obtained. However, in exceptional cases an alloy with more than 0.2 per cent palladium may be necessary where particularly awkward angles occur in fabricated chemical plant.

Fischer measured weight losses and potentials of palladium-titanium alloys with 0, 0.1, 0.5, and 1.0 per cent palladium in hot sulphuric acid and hydrochloric acids and in

concentrated chloride solutions. His results show that 0.1 per cent palladium is inadequate to give titanium protection in reducing conditions but that 0.5 and 1.0 per cent alloys both give sufficient protection.

He warns that pilot tests to determine the most suitable palladium content are necessary in extreme conditions, where 0.2 per cent is insufficient. However, short-term tests may be inadequate as time is needed for the formation of the palladium-rich protective film.

The weldability of the alloys is comparable to that of ordinary titanium but the usual precautions are necessary. Pure dry argon should be used to prevent access of oxygen and nitrogen to the weld and iron and other metallic impurities must be excluded.

Fischer adds that a special palladium-tantalum-titanium alloy has yet higher corrosion resistance, especially in non-oxidising acids, and is available for special purposes.

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1 *Platinum Metals Rev.*, 1968, 12, (2), 53

2 W. R. Fischer, *Tech. Mitt. Krupp Werksber.*, 1969, 27, (1), 19