Note

NOMENCLATURE IN THERMAL ANALYSIS, PART IV

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The recommendations in the earlier reports of the Nomenclature Committee of the International Confederation for Thermal Analysis (ICTA) [1–3] and its Sub-Committees [4–7] have been well received and have been accepted by such international and national bodies as IUPAC [8], ISO [9], ASTM [10] and AFNOR [11]. An integrated version of the second and third reports [2, 3] is currently being considered for adoption by IUPAC [12]. The unofficial and accurate translations that have appeared in several other languages [3] are welcomed. A Working Group on Symbols has now been established under the Chairmanship of Dr. J. H. Sharp, UK, and a Sub-Committee on nomenclature in the Chinese language, convened by Dr. D. T. Y. Chen, Hong Kong, has issued its first publication [13].

It has become evident since the first report [1] was published that the definition of *thermal analysis* given therein is not entirely satisfactory; moreover, over the years several new techniques have emerged or minor techniques have assumed increasing importance. The Committee, having considered both these factors, presented the following report to the Fifth International Conference on Thermal Analysis, Kyoto, Japan, in August 1977, where it was accepted at the Business Session. Council of ICTA have therefore directed that it be published as a definitive document of ICTA with the request that the recommendations herein be adhered to in all publications in the English language.

I. Definition of Thermal Analysis

The definition given in the first report has certain shortcomings and it is recommended it be replaced by:

Thermal Analysis. A group of techniques in which a physical property of a substance* is measured as a function of temperature whilst the substance is subjected to a controlled temperature programme.

* Throughout this report *substance* is to be understood in the sense of *substance and/or reaction product(s).*

In addition to being more accurate, this definition has the advantage that it can be adapted to define **all** thermoanalytical techniques by alteration of only a few words in each instance.

It follows from the above definition that some non-thermoanalytical techniques, such as X-ray diffraction or infrared spectroscopy, can, when used in a specific manner, yield thermoanalytical information: these special cases are not considered below.

II. Individual Thermoanalytical Techniques

a. Classification

In the light of the new definition some one hundred techniques known to the Committee have been assessed and those previously defined [1], those that gave come into prominence in the interim and those showing prospect of future

Table 1

Classification of thermoanalytical techniques

Physical property	Derived technique(s)	Acceptable abbreviation
Mass	Thermogravimetry	TG
	Isobaric mass-change determination	
	Evolved gas detection	EGD
	Evolved gas analysis	EGA
	Emanation thermal analysis	
	Thermoparticulate analysis	
Temperature	Heating-curve determination*	
	Differential thermal analysis	DTA
Enthalpy	Differential scanning calorimetry+	DSC
Dimensions	Thermodilatometry	
Mechanical characteritics	Thermomechanical analysis	TMA
	Dynamic thermomechanometry	
Acoustic characteristics	Thermosonimetry	
	Thermoacoustimetry	
Optical characteristics	Thermoptometry	
Electrical characteristics	Thermoelectrometry	
Magnetic characteristics	Thermomagnetometry	

* When the temperature programme is in the cooling mode, this becomes *Cooling-curve determination.*

+ The confusion that has arisen about this term seems best resolved by separating two modes (*Power-compensation DSC* and *Heat-flux DSC*) as described in the definition given in the text.

development were classified to bring out interrelationships. The arrangement finally adopted for the defined techniques (Table 1) shows clearly the interrelationships between them and can be readily adapted to incorporate additional physical properties and/or techniques as necessary: various modes of certain techniques can also be distinguished. Derivative techniques are not listed, since derivative curves can be calculated or recorded for most measurements.

b. Definitions

On the basis of the above definition for *Thermal Analysis* the techniques listed in Table 1 can be defined as follows:

Thermogravimetry (TG). A technique in which the mass of a substance is measured as a function of temperature whilst the substance is subjected to a controlled temperature programme.

The record is the thermogravimetric or TG curve; the mass should be plotted on the ordinate decreasing downwards and temperature *(T)* or time *(t)* on the abscissa increasing from left to right.

Isobaric mass-change determination. A technique in which the equilibrium mass of a substance at constant partial pressure of the volatile product(s) is measured as a function of temperature whilst the substance is subjected to a controlled temperature programme.

The record is the isobaric mass-change curve; the mass should be plotted on the ordinate decreasing downwards and temperature on the abscissa increasing from left to right.

Evolved gas detection (EGD). A technique in which the evolution of gas from a substance is detected as a function of temperature whilst the substance is subjected to a controlled temperature programme.

Evolved gas analysis (EGA). A technique in which the nature and/or amount of volatile product(s) released by a substance are/is measured as a function of temperature whilst the substance is subjected to a controlled temperature programme.

The method of analysis should always be clearly stated.

Emanation thermal analysis. A technique in which the release of radioactive emanation from a substance is measured as a function of temperature whilst the substance is subjected to a controlled temperature programme.

Thermoparticulate analysis. A technique in which the release of particulate matter from a substance is measured as a function of temperature whilst the substance is subjected to a controlled temperature programme.

Heating-curve determination. A technique in which the temperature of a substance is measured as a function of the programmed temperature whilst the substance is subjected to a controlled temperature programme in the heating mode.

Sample temperature should be plotted on the ordinate increasing upwards and programmed temperature or time on the abscissa increasing from left to right.

Two derivative curves, *heating-rate curves* (for dT/dt) against T or t) and *inverse heating-rate curves* (for dt/dT against T or t), can be obtained.

Differential thermal analysis (*DTA*). A technique in which the temperature difference between a substance and a reference material is measured as a function of temperature whilst the substance and reference material are subjected to a controlled temperature programme.

The record is the differential thermal or DTA curve; the temperature difference (ΔT) should be plotted on the ordinate with endothermic reactions downwards and temperature or time on the abscissa increasing from left to right.

The term *quantitative differential thermal analysis (quantitative DTA*) covers those uses of DTA where the equipment is designed to produce quantitative results in terms of energy and/or any other physical parameter.

Differential scanning calorimetry (*DSC*). A technique in which the difference in energy inputs into a substance and a reference material is measured as a function of temperature whilst the substance and reference material are subjected to a controlled temperature programme.

Two modes, *power-compensation differential scanning calorimetry (power-compensation* DSC) and *heat-flux differential scanning calorimetry (heat-flux* DSC), can be distinguished depending on the method of measurement used.

Thermodilatometry. A technique in which a dimension of a substance under negligible load is measured as a function of temperature whilst the substance is subjected to a controlled temperature programme.

The record is the thermodilatometric curve; the dimension should be plotted on the ordinate increasing upwards and temperature or time on the abscissa increasing from left to right.

Linear thermodilatometry and *volume thermodilatometry* are distinguished on the basis of the dimensions measured.

Thermomechanical analysis (*TMA*). A technique in which the deformation of a substance under non-oscillatory load is measured as a function of temperature whilst the substance is subjected to a controlled temperature programme.

The mode, as determined by the type of stress applied (compression, tension, flexure or torsion), should always be stated.

Dynamic thermomechanometry. A technique in which the dynamic modulus and/or damping of a substance under oscillatory load is measured as a function of temperature whilst the substance is subjected to a controlled temperature programme.

Torsional braid analysis is a particular case of dynamic thermomechanometry in which the material is supported on a braid.

Thermosonimetry. A technique in which the sound emitted by a substance is measured as a function of temperature whilst the substance is subjected to a controlled temperature programme.

Thermoacoustimetry. A technique in which the characteristics of imposed acoustic waves are measured as a function of temperature after passing through a substance whilst the substance is subjected to a controlled temperature programme.

Thermoptometry. A technique in which an optical characteristic of a substance is measured as a function of temperature whilst the substance is subjected to a controlled temperature programme.

Measurement of total light, light of specific wavelength(s), refractive index and luminescence lead to *thermophotometry*, *thermospectrometry*, *thermorefractometry* and *thermoluminescence*, respectively; observation under the microscope leads to *thermomicroscopy*. Other terms may have to be added.

Thermoelectrometry. A technique in which an electrical characteristic of a substance is measured as a function of temperature whilst the substance is subjected to a controlled temperature programme.

The most common measurements are of resistance, conductance or capacitance.

Thermomagnetometry. A technique in which the magnetic susceptibility of a substance is measured as a function of temperature whilst the substance is subjected to a controlled temperature programme.

III. Conclusion

Development of any subject involves change, and older concepts have to be modified as new ideas emerge. In effect, therefore, this report updates and amplifies the first report, presenting a logical classification scheme that can be enlarged as required. It should be noted that only the **definitions** of those techniques discussed in the first report [1] are modified: the **names,** with the exception of thermodilatometry for dilatometry, remain. Similarly, the guide-lines enunciated in the first report and in the policy document [14] have been followed in proposing names for techniques considered here for the first time.

The current constitution of the Committee is: *Chairman:* Dr. R. C. Mackenzie, UK; *Vice-Chairman:* Dr. T. Daniels, UK; *Secretary:* Dr. C. J. Keattch, UK; *Members:* Dr D. Dollimore, UK, Dr. J. H. Sharp, UK, Dr. F. W. Wilburn, UK; *Corresponding Members:* Dr. J. H. Flynn, USA, Dr. B. O. Haglund, Sweden, Dr. J. O. Hill, Australia, Prof. H. Kambe, Japan, Dr. M. D. Karkhanavala, India, Dr. G. M. Kline, USA, Dr. H. G. McAdie, Canada; *Ex-Officio Members:* Prof. P. D. Garn, USA, Dr. H. G. McAdie, Canada, Dr. C. B. Murphy, USA, Dr. J. P. Redfern, UK, Dr. O. T. Sørensen, Denmark. Mr. J. A. Forrester, UK, served as a member till mid 1976 and Prof. G. Lombardi, Italy, was, as Secretary of ICTA, an *ex-officio* member until August 1977.

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Appendix

The Committee have been consulted on the distinction between *quantitative* DTA and *heat-flux* DSC. In their opinion a system with multiple thermocouples (Calvet-type arrangement) or with a controlled heat leak (Boersma-type arrangement) would be *heat-flux DSC* whereas systems without these or equivalent arrangements would be *quantitative DTA*.