Institute of Physical Chemistry
Polish Academy of Sciences

address: Kasprzaka 44/52
01-224 Warsaw, Poland
tel.: +48 22 3432000
fax/tel.: +48 22 3433333, 6325276
email: ichf@ichf.edu.pl
WWW: http://www.ichf.edu.pl/

Warsaw, 14 November 2012

Thermodynamics really from scratch – in a new textbook

Classes in thermodynamics do not belong to the students' favourite ones. Inappropriately lectured, thermodynamics is usually associated with a set of facts loosely related to each other. A new textbook on thermodynamics, written by two professors from the Institute of Physical Chemistry of the Polish Academy of Sciences, Warsaw, transmits the most important ideas of thermodynamics in an unsophisticated way presenting it as a field of science with consistent, logical and clear structure.

Lectures in thermodynamics belong to a canon of classes both in university faculties of physics, chemistry and biology, and in engineering studies. Most textbooks on thermodynamics do not take care of mathematical exactness. As a result, students usually associate thermodynamics with a set of observations and concepts that are not related to each other. A new textbook on thermodynamics written by Professors Robert Hołyst and Andrzej Poniewierski from the Institute of Physical Chemistry, Polish Academy of Sciences (IPC PAS), combines mathematical exactness, so priced by physicists and engineers, with a plenty of examples highly valued by chemists and biologists.

"In the thermodynamics course proposed in the book we do our best to appeal first of all to the readers' intuition that is based on observations of the daily life phenomena. In a possibly simple way we try to transmit the most important ideas that subsequently can be much easier combined with exact, yet somewhat abstract mathematical formulae. Such a method of presenting problems in thermodynamics, supplemented with numerous examples and exercises, is based on many years' experience in lecturing the subject", says Prof. Poniewierski.

Thermodynamics is so commonly used in many areas, because it is extremely practical. In the times of alchemy only one method for speeding up reactions was known: heating up. Without thermodynamics the alchemists did not know that many reactions could be significantly accelerated by increasing pressure only.

At present, thermodynamics tells chemists exactly, which chemical reactions and under which conditions will take place spontaneously, and when some catalyst is needed to decrease kinetic barriers preventing the course of reactions. Thermodynamics allows for producing new chemical substances and identifying energy efficient manufacturing processes. It is an indispensable physicist's tool to understand the properties of systems under study, a biologist's tool to describe processes in cells, and an engineer's tool to design more efficient engines and motors.

At the same time, thermodynamics is a rigorous, excellently formalised and completed field of mathematics. David Hilbert, a famous German mathematician, said once that from among all the areas of physics, thermodynamics had been the easiest one for axiomatisation.

“In the faculties of physics, thermodynamics is often taught in combination with statistical physics”, remarks Prof. Hołyst. “As a matter of fact, thermodynamics does not need statistical physics at all. That’s why our textbook does not have it. We present thermodynamics as a consistent structure originating from the theory of differential forms”.

The first part of the book introduces concisely the formalism of differential forms. Mastering mathematical foundations of thermodynamics allows one to notice interrelationships between various aspects of this discipline. “For example, there is no need to refer to non-measureable – and therefore legendary – entropy, if you know that all you can infer from entropy can be also inferred from Gibbs free energy that can be measured, for instance, by testing battery voltage”, remarks Prof. Hołyst, adding: “We do our best to have the reader understand that conversion of entropy into free Gibbs energy is dictated by human comfort only. Ultimately, we learn thermodynamics to measure something”.

Subsequent parts of the book present and discuss topics related to phase transitions and thermodynamics of chemical reactions. All chapters are illustrated with numerous chemical examples and problems making the understanding easier, they also provide information on how to solve these problems.

The assumptions of contemporary thermodynamics relate to systems at equilibrium. They do not describe open systems, i.e., those which do not have a state of equilibrium, such as man or, probably, the Universe. “While writing our textbook, we tried to think in a perspective, keeping in mind not only students but also the development of the field. We believe that only a really deep understanding of thermodynamics of closed systems on a basic, mathematical level, will enable students to go beyond the axioms of thermodynamics and will aid them in formulating the assumptions of – today yet non-existing – thermodynamics of open systems which do not have the state of equilibrium”, sums up Prof. Hołyst.

The textbook “Thermodynamics for Chemists, Physicists and Engineers” has been published recently in English language by Springer Verlag.

This press release was prepared thanks to the NOBLESSE grant under the activity “Research potential” of the 7th Framework Programme of the European Union.

The Institute of Physical Chemistry of the Polish Academy of Sciences (http://www.ichf.edu.pl/) was established in 1955 as one of the first chemical institutes of the PAS. The Institute's scientific profile is strongly related to the newest global trends in the development of physical chemistry and chemical physics. Scientific research is conducted in nine scientific departments. CHEMIPAN R&D Laboratories, operating as part of the Institute, implement, produce and commercialise specialist chemicals to be used, in particular, in agriculture and pharmaceutical industry. The Institute publishes approximately 200 original research papers annually.

CONTACTS:

Prof. **Robert Hołyst**
Institute of Physical Chemistry of the Polish Academy of Sciences
tel. +48 22 3433123
email: holyst@ichf.edu.pl

Prof. **Andrzej Poniewierski**
Institute of Physical Chemistry of the Polish Academy of Sciences
tel. +48 22 3433248
email: aponiewierski@ichf.edu.pl

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A textbook in thermodynamics “Thermodynamics for Chemists, Physicists and Engineers”, by Prof. Robert Hołyst and Prof. Andrzej Poniewierski from the Institute of Physical Chemistry, Polish Academy of Sciences, combines mathematical exactness with a lot of examples and exercises. (Source: IPC PAS, Grzegorz Krzyżewski)