



Division I Report to IUPAC Council

for 2010-2011 Biennium

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Highlights and Major Points

- A Division meeting was held in Zurich in June 2010 and nominations for renewal of the Division membership were submitted in January 2011, but are as yet unconfirmed.
- The Division is primarily responsible for 21 projects and participates in 7 other interdivisional and committee projects. Paramount is the work of the Subcommittee on Symbols, Terminology, and Units – the Green Book and associated publications.
- A new project on physisorption of gases 2010-009-1-100 is the fourth in a related series with the first resulting in the most highly cited *PAC* article **1985**, 57, 603. Notably, Jean Roquerol and Kenneth Sing have been members of all four task groups.
- A recently completed project on the definition of the hydrogen bond has created much debate. The Recommendation from the project will be the subject of a podium discussion at the September *Horizons in Hydrogen Bond Research* meeting.
- There has been continued debate with Division II over the inclusion of stable isotope terminology in the Green Book. Subcommittees from Divisions I and II will meet with ICTNS at the San Juan GA to resolve differences.
- Student physical chemistry video and chemistry cartoon competitions were launched for IYC 2011. The chemistry cartoon competition attracted more than 60 entries from 8 countries and was judged by representatives from Divisions I, II, V, VII, and VIII.
- The bulk of Divisional projects still arise from channels remaining from the former Commission structure but the current TM, AM and NR Committee structure is only partially useful for new project generation, after efforts made to utilize its potential.

Division I Aims

The Objectives of the Division are to organize and promote the international collaboration between scientists in physical and biophysical chemistry and related fields in order to

- address problems and formulate recommendations on nomenclature, symbols, units, terminology and conventions in physical and biophysical chemistry, disseminate the recommendations, encourage their translation as well as monitor their acceptance by the chemical community
- establish and stimulate the use of methodologies, standards and reference materials in physical and biophysical chemistry
- encourage the compilation and documentation of critically evaluated physical chemical data
- recognize new developments in physical and biophysical chemistry and its fields of applications
- promote future oriented activities important for the contribution of physical and biophysical chemistry to science and technology and to the needs of the world community

Committee Membership (2010-2011) and Meetings

The composition of the Division Committee given below is designed to cover all major areas of physical and biophysical chemistry and to enable identification of topics in which the Division can make new contributions. The Subcommittee on Symbols, Terminology and Units listed below is responsible for the Green Book and its revisions. The Division is supported by an Advisory Subcommittee of 48 members listed on the IUPAC website. The Division Committee periodically corresponds with its members giving notice of annual meetings, distributing news items about divisional activities, and encouraging participation.

President: A. J. McQuillan (New Zealand)

Vice-President: K. Yamanouchi (Japan)

Secretary and Chair of Subcommittee on Symbols, Terminology and Units: R. Marquardt (France)

Past President: M. J. Rossi (Switzerland)

Titular Members: J. H. Dymond (UK), A. Friedler (Israel), R. Guidelli (Italy), J. Hou (China), B. D. Sykes (Canada), A. K. Wilson (USA).

Associate Members: K. Bartik (Belgium), V. Barone (Italy), A. R. Goodwin (USA), G. R. Moore (UK), M. Rico (Spain), V. Misković-Stanković (Serbia)

National Representatives: K. Battacharyya (India), S. J. Kim (Korea), V. Yu. Kukushkin (Russia), A. J. Mahmood (Bangladesh), O. V. Mamchenko (Ukraine), M. Witko (Poland), A. Mombrú (Uruguay), N. Soon (Malaysia), V. Tsakova (Bulgaria), F. H. Quina (Brazil).

Subcommittee on Symbols, Terminology and Units: R. Marquardt (France), J. Stohner (Switzerland), R. J. Hinde (USA), M. I. Choudhary (Pakistan), J. G. Frey (UK), Y. K. Ha (Korea), Y. Kuroda (Japan), A. A. Milchev (Bulgaria), F. Pavese (Italy), M. Quack (Switzerland), D. Schomburg (Germany), S. Smith (Australia), A. J. Thor (Sweden).

Michel Rossi chaired the Nominations Committee and elections were held towards the end of 2010 for TM, NR and AM positions becoming vacant in the 2012-2013 biennium.

Nominations for the 2012-2013 Membership were forwarded in January 2011 for Bureau approval. The lack of Executive approval to date of these nominations is a matter of concern.

The 'off-year' Division Committee meeting was held in Zurich 19-20 June, 2010 after an earlier planned meeting was postponed due to the Iceland volcanic eruption. The two day meeting was attended by eight TMs and the minutes of the meeting are posted on the Division I webpage. http://old.iupac.org/divisions/I/I_10min.pdf
The meeting was valuable for TMs, new and old, to work through the tasks of the Committee, to discuss Divisional IYC 2011 activities, and to identify challenges to be addressed.

Current Projects

The Division presently is primarily responsible for 21 projects (project numbers-100) of which 3 are funded partly by other divisions and committees. The Division also participates in 7 interdivisional and committee projects. A summary listing of all current projects and brief project reports appears at the end of this biennial report. Reports on projects are periodically collected by TM project monitors. A compilation of project reports has recently been sent to Anders Kallner of the Evaluation Committee. Details of some current projects now follow.

A **core activity** of the Division and its Subcommittee on Symbols, Terminology and Units (Commission I.1) under chair **Roberto Marquardt** is the publication and updating of the **Green Book**. The 3rd Edition published by the RSC in 2007 is in the second printing and over 1000 copies have been sold or distributed. A pdf version of the Green Book is now accessible via the IUPAC web page. Two projects which have capitalized on the 3rd Edition publication are:

2008-007-3-100: [Preparation for the translation of the *Green Book*](#) This project aimed to prepare structurally identical documents in German, French, Italian, Turkish, Japanese, Chinese, Romanian, and Portuguese. While this project is now completed it has led at this point to the Japanese version having been published, the French version is almost finished and should go to print this year, the Italian version is advanced, and the Portuguese version has been initiated. A publisher for the German version has been found.

2007-032-1-100: [Green Book - Abridged Version](#) This project aimed to create an abridged student's version of the Green Book. The project is progressing with about 80% of the work done and it is hoped the manuscript will be ready by the end of 2011. A four page Concise Summary of Quantities, Units and Symbols in Physical Chemistry prepared by Jürgen Stohner and Martin Quark, published by the RSC in 2009 may to a limited extent serve this purpose. A Japanese version of the four page summary is also available.

Compilation of critically-evaluated **Data Bases** remains a core Division I activity. The most notable has been the Atmospheric Chemistry data base consisting of a series of projects originating in 1989 from a subcommittee of the Commission on Chemical Kinetics (I.4) of the IUPAC Division on Physical Chemistry, which continues today as the IUPAC Subcommittee for Gas Kinetic Data Evaluation for Atmospheric Chemistry under chair **Tim Wallington**. See the frequently visited associate website (<http://www.iupac-kinetic.ch.cam.ac.uk/>). This critically-evaluated kinetics data plays a valuable role in complex climate simulation schemes. The current project is 2009-031-1-100: [Evaluated Kinetic Data for Atmospheric Chemistry](#) **Michel J. Rossi** has been a key link in facilitating the sustained role that IUPAC has had in compiling this important climate-related resource.

The Division has supported a series of projects for the Thermodynamics community through continued links with the International Association of Chemical Thermodynamics (IACT) which was formed in 2003 from Commission I.2 following the restructuring of IUPAC. The present IACT chair is **Anthony Goodwin**. Current thermodynamics projects include the longstanding 2000-026-1-100: [Critical compilation of vapour liquid critical properties](#) led by **Ken Marsh** is up to Part 12 of a series in *J. Chem. Eng. Data*, and 2007-024-2-100: [Guidelines for reporting of phase equilibrium measurements](#) led by **Robert Chirico** aims to come up with a set of recommendations for phase equilibria measurements and reporting of such data. The provisional recommendations from this project are currently posted for public review comments. A third thermodynamics-related project 2007-039-1-024: [Extension of ThermoML - the IUPAC standard for thermodynamic data communications](#) (with Division V) extends the 2003-2006 original project, to create an XML-based dictionary for storage and exchange of thermophysical and thermochemical data, to data for speciation and complex equilibria that occur in aqueous and non-aqueous solvents as well as thermodynamic properties of biomolecules and biomaterials. Two *J. Chem. Eng. Data* publications have resulted from this project and Provisional Recommendations are currently up for public comment.

Interdivisional activities have resulted in joint projects including 2008-037-2-300: [Standard Photochemical Processes](#) jointly with Division III which aims to establish a series of well-defined and completely characterized photochemical reactions that serve as model processes for scaling and adopting light-induced transformations. 2008-006-3-100: [Critical evaluation of thermodynamic properties of hydrogen storage materials: metal organic frameworks and metal or complex hydrides](#) jointly with Divisions II and III addresses the synthesis and storage performance of hydrogen storage materials relevant to hydrogen as an energy source. The materials covered have been primarily complex hydrides and metal organic frameworks and data has been collected from published work. 2001-015-1-100: [Standard potentials of radicals](#) is longstanding and jointly with Division II. This has proved to be a challenging project but the individual radical evaluations have now been completed, entered into a web site, and tabular summaries prepared. The present focus is on publishing the inorganic portion.

New Projects

2010-048-3-100: [Common values of nuclear electric quadrupole coupling terms for appropriate nuclei in functionalized hydrocarbons](#) led by **Steve Cooke** seeks to establish and disseminate standard nuclear electric quadrupole coupling constants for quadrupolar nuclei in gas phase, functionalized hydrocarbons.

2010-033-2-024: [JCAMP-DX-CD: Standardization of Data and Meta-data formats for Circular Dichroism and Synchrotron Radiation Circular Dichroism Spectroscopy, and interface with the Protein Circular Dichroism Data Bank](#) led by **Bonnie Wallace** is a joint project with CPEP. A new online facility has been set up for circular dichroism data sharing and this project aims to create IUPAC standardized formats for conventional and synchrotron CD data sharing.

2010-009-1-100: [Physisorption of Gases, with special reference to the evaluation of surface area and pore size distribution](#) led by **Matthias Thommes** follows a succession of Division I

projects related to the adsorption of gases on solids. It is notable that the most highly cited (Web of Science) *PAC* article **1985**, 57, 603-619 is by K. S. W. Sing, et al on Reporting physisorption data for gas/solid systems with special reference to the determination of surface area and porosity. This project came from the former divisional Commission (I.6) on Colloid and Surface Chemistry including Catalysis. There have been two other Technical Reports (TR) from this group: Recommendations for the characterization of porous solids, by J. Rouquerol, et al, in *PAC* **1994**, 66, 1739-1758 and a current TR Liquid intrusion and alternative methods for characterization of macroporous materials, by J. Rouquerol et al. is under review. It is admirable that **Jean Rouquerol** and **Kenneth Sing**, after having contributed to all earlier projects on gas/solid adsorption, are task group members of the current Division I project.

2009-032-1-100: [Categorizing Halogen Bonding and Other Noncovalent Interactions Involving Halogen Atoms](#) led by **Pierangelo Metrangolo** and **Guiseppe Resnati** has similarities with the recently completed project 2004-026-2-100: [Categorizing hydrogen bonding and other intermolecular interactions](#) (see below). The halogen bonding project is expected to be concluded this year which is the bicentenary of the discovery of iodine. This was pointed out by Metrangolo and Resnati in a recent *Nature Chemistry* article on Tracing Iodine. <http://www.nature.com/nchem/journal/v3/n3/full/nchem.998.html>

Projects Recently Completed

The final outcomes of an IUPAC project on a modern definition of the hydrogen bond 2004-026-2-100: [Categorizing hydrogen bonding and other intermolecular interactions](#) are soon to appear in *Pure and Applied Chemistry* as a Recommendation and a Technical Report. Copies of these articles will be available at the *Horizons in Hydrogen Bond Research* meeting <http://www.hbond.de/> at Göttingen in September where there will be a podium discussion on the new IUPAC definition. This project, which created much debate, was led by **E. Arunan** and **Steve Scheiner**. A project website <http://ipc.iisc.ernet.in/~arunan/IUPAC1/> has been maintained listing comments and links to the widespread publicity received. These have included 2010 articles in *C&E News* (ACS), *Chemistry World* (RSC), and *Newsblog* (Nature).

2008-014-1-100: [Experimental Thermodynamics Vol. VIII. Applied Thermodynamics of Fluids](#) led by **Jan Sengers** was recently completed with the December 2010 publication, by RSC under the auspices of both IUPAC and IACT, of Applied Thermodynamics of Fluids which is an update and reprint of Experimental Thermodynamics, Volume 5, first published in 2000. See book announcement in [Chem. Int. 33\(2\), 2011](#) This book serves as a guide to scientists or technicians who use equations of state for fluids. Concentrating on the application of theory, the practical use of each type of equation is discussed and the strengths and weaknesses of each are addressed.

2001-036-1-300: [Glossary of terms in photocatalysis and radiation catalysis](#) with Division III and led by **Silvia Braslavsky** was completed in March 2011 with the IUPAC Recommendations published in *PAC* 2011, 83(4), 931-1014, doi:[10.1351/PAC-REC-09-09-36](https://doi.org/10.1351/PAC-REC-09-09-36) This glossary of terms covers phenomena considered under the general descriptions *photocatalysis* and *radiation catalysis*. A clear distinction is made between phenomena related to either *photochemistry* and *photocatalysis* or *radiation chemistry* and *radiation catalysis*.

Interdivisional Activities

The Division has representatives on a number of IUPAC committees including CCE, COCI, CPEP, ICTNS, the Editorial Advisory Board of PAC, as well as on several divisional subcommittees.

There has been a continuation of correspondence and debate between the Division II Commission (II.1) on Isotopic Abundances and Atomic Weights (CIAAW), the Division I Commission (I.1) on Physicochemical Symbols, Terminology, and Units, and ICTNS about the suggested inclusion of stable isotope terminology into the Green Book. It has been proposed by Commission I.1 that section 3.10.1 (on fractions) of the Green Book be expanded in the next printing to include the relative difference of isotope ratios ('isotope delta') although this proposal has not fully addressed the concerns of CIAAW. This was discussed at the Warsaw Bureau meeting in April and a joint meeting of ICTNS, I.1, and II.2 will be held during the San Juan Meeting to discuss the CIAAW concerns and the general matter of the practical implementation of the terms of reference of ICTNS including the approval of publications bearing the IUPAC logo.

The Division has had an active involvement through **Michel J. Rossi** and **Angela Wilson** in the Interdivisional Subcommittee on Materials Chemistry. This group involving Divisions I, II, and IV met at Cornell in October 2009 in order to provide an in-depth analysis and discussion of the current status of materials chemistry in IUPAC. It was advised at the 2010 Sofia Bureau meeting that the Subcommittee should act as a forum rather than seek Divisional status. This group has been involved in promoting the Materials Science symposia at the San Juan Congress.

IYC 2011 Activities

For the International Year of Chemistry which is a joint UNESCO/IUPAC venture the Committee was challenged to provide some Division I activities. One of the outcomes of the Zurich 'off-year' meeting in June was to launch IYC 2011 student physical chemistry video and student chemistry cartoon competitions at the end of 2010 with winners to be invited to the 2011 IUPAC Congress.

<http://www.chemistry2011.org/participate/activities/show?id=324>

<http://www.chemistry2011.org/participate/activities/show?id=361>

These competitions closed at the end of May. The videos are being judged by Division I TMs while representatives from other divisions and CCE under **Assaf Friedler** are judging the chemistry cartoons. The cartoon competition was more successful with over 60 entries from eight countries. *C&E News* have requested information about the cartoon competition outcome and the winning cartoons.

Challenges

1. It is increasingly difficult to recruit the leading chemists who are willing to give their time to contribute authoritatively to the work of IUPAC project task groups.
2. The Division has had a decline in new project starts in recent years and this is a matter of active strategy discussion. There has also been limited success in new project starts

- in the biophysical area to better reflect the increasing importance of biological aspects of chemistry.
3. The present projects in Division I still rely largely on channels remaining from the old Commission structure, as can be seen in this report. The current TM, AM and NR structure is only partially useful for new project generation in spite of efforts being made to draw from its potential.
 4. We ask what the reborn Evaluation Committee seeks to achieve in the recently suggested procedures for project monitoring and retrospective evaluation. These tasks impose an additional burden on Divisions who at present appear to be handling project monitoring and other higher priority matters well enough.
 5. The orderly process of early membership renewal which begun in mid 2010 seems to have become stalled after nominations submitted in January 2011 have still to be confirmed. Incoming nominated members, wishing to make plans to attend the GA, have been deterred by this lack of IUPAC credibility.
 6. It remains a major concern and embarrassment that IUPAC has not been able to address longstanding concerns about the state of the IUPAC website(s) and the continued co-existence of old and new websites.

Projects Summary

Number: Title (Chair, jointly with Divisions)

(a) Current Projects

2010-048-3-100: [Common values of nuclear electric quadrupole coupling terms for appropriate nuclei in functionalized hydrocarbons](#) (Cooke)

This project started in May 2011.

2010-009-1-100: [Physisorption of Gases, with special reference to the evaluation of surface area and pore size distribution](#) (Thommes)

This project started in March 2010 and was announced in *CI* in the March-April 2011 issue p.22.

2009-032-1-100: [Categorizing Halogen Bonding and Other Noncovalent Interactions Involving Halogen Atoms](#) (Metrangolo)

The Task Group has been active in conference presentations on halogen bonding to stimulate discussion about a draft provisional recommendation. A workshop on the project topic will be held in Sigüenza, Spain 21-22 August, 2011. *Cryst. Growth Des.* will have a special issue on halogen bonding towards the end of 2011.

2009-031-1-100: [Evaluated Kinetic Data for Atmospheric Chemistry](#) (Wallington)

The project was announced in *CI* in the 2010 May-June issue and is proceeding according to plan. The group met in June 2010 to update over 1000 data sheets for gaseous and heterogeneous reactions of importance in atmospheric chemistry and to upload the data to the [website \(http://www.iupac-kinetic.ch.cam.ac.uk/\)](http://www.iupac-kinetic.ch.cam.ac.uk/). The group has also published a further paper J. N. Crowley et al., *Atmos. Chem. Phys.* 10, 9059-9223 (2010) in the series on Evaluated Kinetic and Photochemical Data for Atmospheric Chemistry.

2008-045-2-100: [A critical evaluation of the viscosity and density of molten copper and tin](#) (Assael, Wakeham)

This project was completed with the publication of Assael et al., *J. Phys. Chem. Ref. Data* 39, 033105 (2010). New correlations on the density and viscosity of Sb, Bi, Pb, and Ag have also been derived.

2008-006-3-100: [Critical evaluation of thermodynamic properties of hydrogen storage materials: metal organic frameworks and metal or complex hydrides](#) (Sun, I, II, & III)

Synthesis and storage performance data on several hundreds of hydrogen storage materials have been collected from published references. The materials covered have been primarily complex hydrides and metal organic frameworks. Ten journal papers have been published on during 2009-2010 on related measurements.

2007-055-2-100: [Ultrafast intense laser chemistry](#) (Yamanouchi)

There was a meeting of the Task Group at the 2010 Pacificchem Conference and assignments were confirmed. On the basis of the assignments, sub-sections of the Technical Report are now being written. A one year extension of the project is requested.

2007-048-2-100: [Assessment of theoretical methods for the study of reactions involving global warming gas species degradation and byproduct formation](#) (Ramasami)

The second revision of the Technical Report from this project is presently under review.

2007-032-1-100: [Green Book - Abridged Version](#) (Marquardt)

The project is progressing. Almost all chapters have been reduced according to the minutes of the 2008 meeting, but processing of the changes in the electronic files is not finished. About 80% of the work is ready but the work of some task group members is lagging. The manuscript should be ready for submission in late 2011.

2007-024-2-100: [Guidelines for reporting of phase equilibrium measurements](#) (Chirico)

A Recommendation was submitted for *PAC* in May and is presently undergoing review.

2007-002-1-100: [Guidelines for modulated-temperature differential scanning calorimetry \(MTDSC\)](#) (Grolier)

All necessary information has been collected for inclusion in the final document. Task group members have still to agree on the final text. Hopefully, the final document will be ready by end of June beginning of July 2011.

2006-050-3-100: [Wet surface vibrational spectroscopy experiments](#) (McQuillan, I&CCE)

This project has proceeded more slowly than originally anticipated with the main difficulty being the development of suitable teaching experiments for surface-enhanced IR. The project should be completed later this year with the outcome to be posted on the IUPAC website.

2006-023-3-100: [Recommendations for nomenclature and databases for biochemical thermodynamics](#) (Alberty)

Draft Recommendations have been prepared although but not yet accepted for publication. An extension until March 2011 has been approved.

2006-021-2-100: [Liquid intrusion and alternative methods for the characterization of macroporous solids](#) (Roquérol)

A Technical Report has been submitted to *PAC* and is close to the end of the review process.

2004-036-1-100: [Establishing recommended data on thermodynamic properties of hydration for selected organic solutes](#) (Sedlbauer)

This project is funded jointly by IUPAC and IAPWS (International Association for the Properties of Water and Steam). A manuscript for publication in *J. Phys. Chem. Ref. Data* has been prepared and is being discussed for submission later this year. The results of the project were presented at two conferences in 2010.

2004-035-1-100: [A database of water transitions from experiment and theory](#) (Tennyson)

The published outputs from this group on the Critical Evaluation of the Rotational-Vibrational Spectra of Water Vapor are J. Tennyson, et al., *J. Quant. Spectrosc. Rad. Transf.*, 110, 573-596 (2009).

DOI: [10.1016/j.jqsrt.2009.02.014](#) and J. Tennyson, et al., *J. Quant. Spectrosc. Rad. Transf.*, 111, 2160-2184 (2010). DOI: [10.1016/j.jqsrt.2010.06.012](#). A project update was reported in *Chem. Int.* Sept-Oct 2009 with a further update posted on the webpage in Sept 2010.

2004-026-2-100: [Categorizing hydrogen bonding and other intermolecular interactions](#)

(Arunan, Scheiner)

This project is almost completed as the *PAC* Recommendation and TR are about to appear.

2003-024-1-100: [Selected free radicals and critical intermediates: thermodynamic properties from theory and experiment](#) (Ruscic)

2001-028-1-100: [Electrochemical impedance spectroscopy - terminology, nomenclature and data exchange formats](#) (Stoynov)

The project is near to the end. The first version of the projects recommendations was ready years ago. Asking for a prolongation of the project up to the end of the year to finish the project successfully.

2001-015-1-100: [Standard potentials of radicals](#) (Stanbury, I&II)

The individual radical evaluations have now completed, entered them into the web site, and prepared the tabular summaries. They are now focused on publishing the inorganic portion.

2000-026-1-100: [Critical compilation of vapour liquid critical properties](#) (Marsh)

Ken Marsh, Costa Tsonopoulos and Eugene Nikitin are working on part 12 that will update the early parts (2, 3, 5, and 6; published in 1995 and 1996) on hydrocarbons. A no-cost extension of 12 months has been requested.

(b) Other Interdivisional Projects

2010-033-2-024: [JCAMP-DX-CD: Standardization of Data and Meta-data formats for Circular Dichroism and Synchrotron Radiation Circular Dichroism Spectroscopy, and interface with the Protein Circular Dichroism Data Bank](#) (Wallace, I&CPEP)

This project began in September 2010 and is making good progress. The creation of the JCAMP format for CD spectroscopy, coordinating the fields with those included in the PCDDDB, has been completed. Currently parsers are being written to convert all outputs of all instrument manufacturers to this JCAMP format. The project will be presented (and crediting IUPAC) at the CD2011 meeting in Oxford in July.

2008-037-2-300: [Standard Photochemical Processes](#) (Griesbeck, I&III)

This project was listed in 2008 but started in August 2010.

2007-039-1-024: [Extension of ThermoML - the IUPAC standard for thermodynamic data communications](#) (Frenkel, I&V)

There are two publications from this project in *J. Chem. Eng. Data* 2010, 55(4), 1564-1572 and 2011, 56, 307-316 and Provisional Recommendations have been submitted for public review comments until 31 August.

2007-010-2-500: [International harmonized protocol for standard preparation, irradiation and measurement for assuring metrological traceable results in neutron activation analysis](#) (Bode, I&V)

2004-005-2-500: [Comparable pH measurements by metrological traceability](#) (Camoës, I, V, & VI)

A review article on the pH of Seawater by G.M. Marion, F.J. Millero, M.F. Camões, P. Spitzer, R. Feistel, C.-T.A. Chen has been accepted for publication in *Marine Chemistry*. As an outcome of the IUPAC project the project “Metrology for ocean salinity and acidity/Ocean metrology” coordinated by P. Spitzer has been approved as a Joint Research Project under the European Metrology Research Program 2010, starting September 2011.

2003-056-2-500: [Standard definitions of terms relating to mass spectrometry](#) (Murray, I&V)

2001-036-1-300: [Glossary of terms in photocatalysis and radiation catalysis](#) (Braslavsky, I&III)

Project completed in March 2011. Recommendations published in PAC 2011, 84(4), 931-1014.