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Procedures for Evaluation of Atomic, Molecular and Plasma-Material Interaction Data for Fusion

Summary Report of an IAEA Consultants' Meeting

National Institute for Fusion Science, Toki, Japan

7–9 February 2012

Prepared by

Hyun-Kyung Chung

May 2012

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Abstract

This report summarizes the proceedings of the IAEA Consultants' Meeting on "Procedures for Evaluation of Atomic, Molecular and Plasma-Material Interaction Data for Fusion" on 7-9 February 2012. Fourteen participants from 8 Institutes of 3 Member States attended the three-day meeting held at the National Institute for Fusion Science, Toki in Japan. The report includes discussions on data evaluation activities, meeting conclusions and recommendations and the abstracts of presentations presented in the meeting.

May 2012

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1. Introduction

The IAEA Consultants' Meeting (CM) on "Procedures for Evaluation of Atomic, Molecular and Plasma-Material Interaction Data for Fusion" was held at the National Institute for Fusion Science (NIFS), Toki in Japan from 7th to 9th February 2012. The objective was to discuss data evaluation activities of atomic, molecular and plasma-material interaction data for fusion.

At the 21st meeting of the A+M Data Centres Network (DCN) on Technical Aspects of Atomic and Molecular Data Processing and Exchange in September, 2011, the need for internationally accepted and recommended data for the design of fusion experiments and power plants in the pursuit of energy use of nuclear fusion was emphasized. Recommendations were made that there should be more IAEA technical meetings and workshops on this subject and the IAEA/DCN should identify their roles in data activities to meet the needs of ITER research and other fusion applications. It was suggested that efforts should be made to establish international standards for A+M/PSI fusion data evaluation.

This meeting was the first meeting of a series that the IAEA A+M Data Unit intend to organize to address these issues. In order to allow more participants actively engaged in the data evaluation to attend it was agreed to hold the meeting at NIFS in Japan. The Agency is grateful to NIFS and to Prof Izumi Murakami for their willingness to host this meeting.

Fourteen participants attended the meeting from the Member States Japan, Korea and China: Prof I. Murakami, Prof D. Kato, Prof T. Kato, Prof Y. Itikawa, Dr X. Ding (NIFS, Japan), Dr T. Nakano (JAEA, Japan), Dr M. Imai (Kyoto University, Japan), Prof F. Koike (Kitasato University, Japan), Dr J. Yoon, Dr M. Song (NFRI, Republic of Korea), Prof H. Cho (Chung-Nam University, Republic of Korea), Dr C. Kim, Dr J. Choi (KRISS, Republic of Korea) and Dr J. Yan (IAPCM, China).

The Agency was represented by Dr Hyun-Kyung Chung as the scientific secretary of the meeting. Prof Murakami of NIFS was the Local Organizer. The full list of participants is available in Appendix 1.

Prof A. Komori, the Director General of NIFS opened the meeting, which was followed by the welcome address by the Local Organizer Prof Murakami and the Scientific Secretary Dr Hyun-Kyung Chung (Physicist, A+M Data Unit, Nuclear Data Section). Participants introduced themselves and the agenda was adopted (see Appendix 2).

The following topics were presented and discussed in the meeting:

- Current Data Evaluation Activities of the Data Centres
- Data Evaluation Methods
- Definition of Measurement and its Uncertainties
- Coordination of Data Evaluation Activities and Data Evaluators' Network
- IAEA Standard Data Library for Fusion Applications

2. Proceedings of the Meeting

The meeting proceeded with presentations on the current data evaluation activities and on data evaluation methods. The presentations at the meeting are available on the A+M Data Unit web site http://www-amdis.iaea.org/DCN/Evaluation/CM1/ via the link to Agenda and Meeting Presentations. The presentations were followed by discussions on data evaluation activities.

2.1 Data Evaluation Activities of the Data Centres

The first session began with a presentation to review the Meeting objectives, which was followed by presentations from data centres and data evaluators. The presentations are summarized here and the abstracts are attached in the Appendix 3.

Review of Meeting Objectives
H. Chung, IAEA

The roles and activities of IAEA Nuclear Data Section (NDS) Atomic and Molecular (A+M) Data Unit were introduced as well as the unit's short-term and long-term goals regarding the data evaluation activities.

The Nuclear Fusion programs at IAEA are carried out by the Physics Section and the Nuclear Data Section. The IAEA role was deeply imprinted during the INTOR Experimental Power Reactor design (a collaboration of EC, Japan, USA and USSR) and it was highlighted on the formal agreement of seven members for the construction of ITER. The A+M data unit was formed in 1977 with the objectives to review progress and achievements of A+M/PSI data for Fusion programmes and to stimulate international cooperation in measurement, compilation and evaluation of A+M/PSI data for fusion. The unit achieves these goals by coordinating projects on data activities, organizing meetings and maintaining databases. The overview of these activities can be found in the web page http://www-amdis.iaea.org.

The need for internationally accepted and recommended data sets has long been expressed by users doing data-intensive simulations, such as edge physics modelling of fusion reactors. As plasma chemistry plays a critical role in the transport of particles and energy in the colder and denser regions the edge transport code runtime increases exponentially as the reactor size increases. If a typical runtime for a small tokamak such as TEXTOR is 1 day, the same physics simulation will take 3 months for the ITER size reactor. In order for the A+M/PSI data to be helpful and effective, data users suggest that the data should be verified by experts, robust and comprehensive. In addition, the data set should be maintained with a version control so that any confusion by use of different versions can be avoided and any effect due to different data on the final results may be traced. A recommended and internationally agreed library will meet the data requirements set by the users.

The establishment of an evaluated data library for A+M/PSI data can only be achieved with the consensus and the commitment of the community, including data users, producers and evaluators. The establishment of such an evaluated standard library is a long-term goal of the IAEA A+M data unit around which its future activities will be coordinated. In pursuit of this goal this meeting is organized to discuss the coordination of data centres and data evaluators as well as the technical details of data evaluation methods.

Data evaluation activities at NIFS
I. Murakami, NIFS, Japan

Dr Murakami summarized activities at NIFS for nearly 40 years on retrievable data bases, reports, organization of working groups and international collaboration. The evaluation procedure carried out at NIFS includes three steps: 1) collect data and compare them using data base, 2) select good data and 3) fit with proper formula with correct asymptotic behaviour.

The NIFS AM/PWI Numerical Database (http://dbshino.nifs.ac.jp) contains almost 500,000 data for processes of electron impact collisions, charge exchange and heavy particle collisions as well as sputtering yields and reflection coefficients. Data evaluation has been carried out by working groups or by collaboration, and the evaluated AM/PWI data sets have been compiled and published. The evaluated data has been fitted by an empirical formula.

Data Evaluation Activities at JAEA
T. Nakano, JAEA, Japan

JAEA hosts a Japanese Evaluated A&M Data Library (JEAMDL) of evaluated and compiled data sets mainly by Dr T. Shirai and Dr H. Kubo. Dr T. Nakano reported on the survey of T. Shirai's evaluation work: 1) for experimental data evaluation, the consistency between the data sets is important and the systematic measurement is preferred, 2) for theoretical data evaluation, the level of sophistication of calculations such as number of states and the degree of agreement with experimental data sets are important.

Summary for the JAEA-Kyoto University Co-operative Research Program
M. Imai, Kyoto, Japan

Dr Imai of Kyoto University reported on the co-operative research project on charge exchange and electron capture cross-section data between JAEA (JAERI)-Kyoto University of more than 25 years. It started in 1983 with the compilation of data derived experimentally, and continued with experimental data production.

Absolute cross-sections have been produced since 1988 on the fusion relevant electron capture processes: C^{q+} (q = 1,2,3), Cr^{q+} (q = 1,2), Ni^{q+} (q = 1,2), Fe^{q+} (q = 1), Be^{q+} (q = 1,2), B^{q+} (q = 1,2), and W^{q+} (q = 1,2) projectile ions colliding with He, Ne, Ar, Kr, H_2, CO, CO_2, N_2, CH_4, C_2H_6, and C_3H_8 targets at 5-32 keV. The data for C, Be, B, Fe, and Ni ions had been published in two papers, J. Phys. Soc. Jpn. **64**, 3255-3264 (1995) and J. Plasma Fusion Res. Series **7**, 323-326 (2006).

Charge changing cross-sections are compiled for 1186 collision systems from 374 collected papers. An electronic database (http://toshi3.nucleng.kyoto-u.ac.jp:5560/isqlplus/) under development contains 1766 cross-sections from 486 collision systems with author information for 145.

Data Production and Evaluation at CRAAMD
J. Yan, IAPCM, China

CRAAMD (China Research Association of Atomic and Molecular Data) was founded in 1987 by physicists to promote atomic and molecular physics and to produce and evaluate the data in China. Dr Yan described the online database CAMBD (http://www.camdb.ac.cn/e/) maintained by the IAPCM and recent CRAAMD activities on data collection, production and evaluation.

Collisional data evaluation is noted to be difficult with many problems. Large-scale data sets are needed for a wide energy range and yet most available data sets are from calculations. As there are many experimental and theoretical methods to produce collisional data sets, large discrepancies exist with very few benchmark data. In addition, some part of collisional physics is not yet well understood. Therefore, collaboration on data evaluation should address these issues: 1) ranges for which data sets should be evaluated, 2) whether data should be produced if not available, 3) standard procedures of evaluation, 4) establishment of benchmark results and 5) organizational matters.

National System of Standard Reference Data in Korea
C. Kim, KRISS, Republic of Korea

Dr Kim presented an overview of the National Standard Reference Data System (NSRD) in Korea as well as the evaluation criteria and procedures to develop Standard Reference Data (SRD). As the economy, industry and technology of Korea grew rapidly in the past few decades the demand for scientific data grew exponentially and the needs for reliability and accuracy assessment of available data grew as well. The lack of information on reliability and accuracy of data in use was found to result in a significant increase in the cost of research and development (R&D), a duplication of efforts and a delay in the industrial development based on scientific and technological advances.

The National Center for Standard Reference Data (NCSRD) of the Korea Research Institute of Standards and Science (KRISS) was established by the Korean government to establish and maintain a national system for evaluation of data quality produced by R&D institutes and universities. Its functions include: 1) survey on the national demand of SRD, 2) establishment of strategic plans for the development of SRD program, 3) fostering data centres, 4) support and operation of the Steering Committee, 5) operation of Technical Committees for each sector, 6) registration and distribution of SRD, 7) establishment and maintenance of SRD Database, 8) collection and dissemination of scientific and technical data, and 9) international cooperation in the area of reference data. The responsibilities of data centres and committees were presented.

The guidelines for the establishment and distribution of SRD were presented. The technical evaluation of a data set is carried out by 7 criteria before it becomes a certified SRD: 1) description of the measurand, 2) measurement methods, 3) traceability, 4) uncertainty, 5) reproducibility, 6) consistency, and 7) review by experts. Each criterion was explained with examples. The procedures to develop SRD consist largely two parts: 1) a data set is produced, collected, processed and compiled by data centres before evaluated by expert groups and 2) the data is evaluated by a series of reviews, first by the data centre, secondly by technical committee (of each topic), notified on the web for a review by third-party experts, finally reviewed by the steering committee before the SRD registration.

Dr Kim advised participants to develop international guidelines of quality system for data producing organizations, and asked for an international cooperation to standardize data evaluation methods.

Data evaluation activities at National Fusion Research Institute
J.S. Yoon, NFRI, Republic of Korea

Dr Yoon described data evaluation activities at NFRI in three parts: 1) external collaboration with specialists, 2) development of Standard Reference Data (SRD) in collaboration with KRISS, 3) evaluation of reaction rate coefficients for low temperature plasma simulations.

It was emphasized that data collection without quality judgement is not useful and that only better data should replace existing ones. The quality assessment is crucial for users and such evaluation must be done by experienced scientists. Evaluation was done on three principles: 1) how well the data generation is described, 2) whether the data follows the known physical laws and 3) how the data compare with other measurements or calculations.

Data survey and evaluation by specialists are mostly based on their experience. Therefore a more systematic data evaluation process was developed with the support of National Standard Reference Data project as described by Dr Kim (KRISS). There are three classes of SRD: 1) qualified SRD, which satisfies minimum technical requirement of SRD, 2) validated SRD, which is consistent with other measurements, 3) certified SRD, which is critically reviewed by relevant scientists for its reliability and accuracy. The minimum technical requirements include a clear description of measurand: 1) rationale of measurement methods and theoretical calculation, 2) uncertainty estimate, 3) traceability of measuring equipment to the national measurement standards, 4) control of variables which may impact on measurement results, 5) description of measurement errors and its accuracy and 6) description of measurement methods and procedures for reproducibility by the third parties.

Approximately 415 SRD data have been obtained during the period 2008-2011. A few full sets of recommended cross-sections for plasma simulations are available.

2.2 Evaluation Methods and Evaluated Data

Evaluation of Cross-Section Data – A Personal Experience -
Y. Itikawa, Japan

Prof Itikawa shared his personal experience in evaluating measured cross-sections of electron collisions with molecules. A data evaluation should consider the following elements: 1) quoted uncertainty, 2) agreement among data obtained by different authors or methods, 3) how the absolute values were determined, 4) physics involved and 5) consistency between related quantities.

First the quoted uncertainties of data should be considered for evaluation. While the cited error is likely to be the statistical error, the systematic error should be considered as well. It may be estimated by checking the agreement among data obtained by different groups of authors or methods. Absolute values are often normalized by another source and the reliability of the source should be checked. An asymptotic feature or threshold laws from theory can be applied to check the measured data and a scaling law may be inferred. The consistency between related, but different quantities should be examined, for example, the consistency between the sum of partial ionization cross-sections and the total ionization cross-section, or that between the sum of cross-section for individual processes and the total scattering cross-section. Finally the reliability of author's data should be judged by the author's other work.

He recommended evaluating the "evaluated data set", as an example, by setting up model experiments. Also recommended is a network of evaluators so that evaluators, scientists engaged in data evaluation, can be easily found and trained.

Evaluation of the electron impact excitation of $1s^2\,{}^1S \rightarrow 1s^1 2p^1\,{}^1P$ of Helium
M. Y. Song, NFRI, Republic of Korea

Dr Song demonstrated the new evaluation procedure developed in NFRI based on the Standard Reference Data Evaluation Process. A well-known electron impact cross-section of helium was evaluated based on this procedure and compared with previous evaluated data.

The evaluation procedure consists of three parts: 1) collection and determination of *valid data* sets based on the minimum technical requirements as presented by Dr Yoon, 2) determination of *candidate data* by comparison of valid data sets with graph tests, accuracy tests, consistency tests and uncertainty tests, 3) determination of *validated, certified or qualified data* by expert review.

The collected 29 data sets were classified based on methods (measurement methods or calculation methods, calibration or normalization), uncertainties and producers. Valid data sets were selected based on the minimum technical requirements. A graph test was done by plotting all valid data sets together and the accuracy test was done by using the original data. Consistencies were tested and the uncertainty of each data item was identified. A candidate data set was determined by an average method and the uncertainty of candidate data was determined. The candidate data set is in a very good agreement with previously evaluated data sets.

Measurement and Uncertainty – Basic concept and its application
J. O. Choi, KRISS, Republic of Korea

Dr Choi presented the concepts of measurement, traceability and uncertainty based on VIM3 (Vocabulary in Metrology 3 ed., BIPM (Bureau International des Poids et Mesures) 2007) and GUM (Guide to the uncertainty in measurement, ISO 1993).

Based on VIM3 the basic terminologies are defined: 1) Quantity: a property of a phenomenon, body, or substance, to which a number can be assigned *with respect to a reference*, 2) Value: the number and reference together expressing magnitude of a quantity, 3) Measurand: quantity intended to be measured, 4) Measurement: process of experimentally obtaining one or more quantity values that can reasonably be attributed to a quantity and 5) Measurement result: information about the set of quantity values being attributed to a measurand.

The measurement result means essentially a value and its uncertainty. The uncertainty in value should be evaluated by combining the uncertainties in the standard and in the measurement procedure based on the GUM. It means that there should be a reference or a predefined standard for any measurement to be valid. Therefore, first a standard (or a reference) should be established with prescribed methods and procedures and then the measurement result can claim "metrological traceability" which is the property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty.

Based on GUM, 5 steps for the evaluation of measurement uncertainties were introduced: 1) modelling the measurement, 2) identifying uncertain components for each input quantity, 3) evaluating standard uncertainty (type A and B), 4) combining standard uncertainties of input quantities and 5) expanded uncertainty. Type A and B uncertainties were described. In addition to the basics in uncertainty evaluation, the determination of the uncertainty in multiple measurements based on the GUM's principle was explained.

Finally, the difference between uncertainty and error, which are often used without a distinction in physics community, was explained in detail. The objective of a measurement is to determine the value of the measurand (GUM, 1993). Traditionally, an error was defined as the difference between the measurement result and the true value (value consistent with the definition of a given particular quantity) and the uncertainty was a measure of the possible error. This is called *a true value approach*. However, based on GUM and VIM, in the so-called *the uncertainty approach* the uncertainty is defined as the parameter that characterizes the dispersion of the quantity value that is being attributed to a measurand based on the information used. In this case, the true value is meaningless since it will not be known or it does not exist to begin with. Therefore an error is defined to be the difference between the measured value and the reference value (or assigned value). In this approach, the focus is on the observed (or estimated) variability of the value, not the value itself, and hence there is no need of mentioning an error in a measurement.

3. Discussion on Data Evaluation Activities

This Consultants' meeting follows the 21st DCN meeting recommendations that there should be more IAEA technical meetings and workshops on data evaluation activities and the IAEA/DCN should identify their role in data recommendation, evaluation and specification of standards to meet the needs of ITER. It was suggested that the international standards of A+M/PSI for fusion data evaluation should be considered.

In this meeting, participants discussed the current status and the future coordination of data evaluation activities in the community. The specific topics for discussion were the methods of data evaluation, the procedures of establishing a data library with evaluated data sets, the role of data evaluators' network and the scope of the IAEA-NFRI technical meeting on data evaluation.

3.1 Discussion on Data Evaluation Methods

Uncertainty Approach

Data evaluation activities for most processes, apart from radiative transitions, have been carried out rather individually often driven by specific applications of interest to the evaluator. It was obvious that there was a critical need to first define terminologies used in evaluation procedures in order for the evaluation work to be a community effort.

The International Vocabulary of Metrology (VIM3 Vocabulary in Metrology 3rd BIPM 2007) was developed to define a common language and terminology in metrology, which has been endorsed by many international organizations including the IAEA. Compliant to the VIM3 definition, a quantity is the property of a phenomenon, body or substance, to which a number can be assigned with respect to a reference and a measurand is the quantity intended to be measured. Measurement is defined to be a process of experimentally obtaining one or more quantity values that can reasonably be attributed to a measurand and uncertainty is defined to be a parameter that characterizes the dispersion of the quantity value that is being attributed to a measurand, based on the information used.

It was emphasized that there is a difference between an uncertainty and an error. In the traditional approach where the "true" value is assumed to exist, the error may be defined to characterize the range of values where the true value lies. However, the new approach, or the uncertainty approach does not assume that there exists a "true" value to start with. Therefore, the focus is on the observed (or estimated) variability of the value and hence there is no need of mentioning an error according to the Guidelines of Uncertainty Measurement (GUM). The concept of uncertainty has changed accordingly. In 1980s, an uncertainty was a measure of the possible error in the estimated value of the measurand as provided by the results of a measurement. In 1990s, it was an estimate characterizing the range of values with which the true value of a measurand lies (VIM1). In 2007, it was a parameter associated with the result of a measurement that characterizes the dispersion of the values that could reasonably be attributed to the measurand (VIM2). However, since 2008 an uncertainty is defined as a parameter that characterizes the dispersion of the quantity value that is attributed to a measurand, based on the information used (VIM3).

The AM/PSI data sets are sparse with only a limited number of measurements and diverse with theoretical data of various accuracies. Considering that it will be almost impossible to find a true value for most of processes of interest, participants acknowledged the value of the uncertainty approach and agreed to consider the evaluation process based on VIM3 and GUM. Compliant to the VIM3 definition: ***an evaluation is to assess the quality of available data sets, that is, to calculate the uncertainty with agreed guidelines, while a recommended data is a consensus value with agreed guidelines by experts or an authority***. In this approach, "measurements" can refer to both physical laboratory experiments and theoretical estimates as long as the proper uncertainties are defined for the "measurements" based on the GUM. Adopting the uncertainty approach, it is feasible to evaluate and recommend data sets for currently available AM/PSI data from predominantly theoretical methods and hence conceivable to establish a standard data library for fusion applications.

Data Evaluation System – Infrastructure

As identified in the most recent DCN meeting, availability of a centralized database of compiled data sets for community use is essential for coordinated data evaluation activities. Dr Yoon (NFRI) introduced the Data Evaluation System developed at NFRI which may provide an e-infrastructure for collaboration and coordination of data evaluators in the community. The Data Evaluation System consists of a series of on-line tools to integrate comprehensive databases of numerical and bibliographical data, graph packages for data comparison, and the reviews by experts. This system can give remote access to experts to carry out data evaluation in a streamlined fashion, which is documented in a centralized location. The procedure was demonstrated for the evaluation of helium collisional cross-sections as presented by Dr Song (NFRI) earlier.

This system, still in its development stage, already offers a great opportunity for effective coordination in data evaluation activities and synergistic collaboration among data evaluators. Remote access makes it possible to invite wider groups of experts for data evaluation, not limited by regions or by time constraints. Due to its streamlined nature the entire process of data evaluation from data compilation through data selection to final evaluation is clearly documented and easily reviewed. Most importantly, the documentation of experts' comments will be a valuable source of expert knowledge, sometimes more valuable information than the reviewed articles themselves, and it will facilitate the knowledge transfer from experienced data evaluators and the training of the younger generation.

Currently the system contains published data sets mostly on the electron collisional processes and it works best if multiple sets exist. If there are too few data, recommendation of a unique set is difficult; however, it will be still valuable that the expert can give a general remark on the quality of the data sets and provide some confidence to the user of data.

For heavy particle collisions or plasma-material interaction data there are several parameters to check for the consistency of measurements, for example angle dependence and incident particle velocity distributions. The extension of the system should be considered for such complex processes. Finally, there should be a process for regular updates of the database to include unpublished data sets in addition to the new data sets.

Qualifications of Experts

The first step for any data evaluation is the compilation of data sets. Supposedly, the Data Evaluation System proposed by NFRI will provide the compiled data sets and there are two very important requirements to proceed: Experts and Guidelines of Evaluation Procedures.

The role of an expert and the role of data centres were discussed: an expert is to review the compiled data sets, select the candidate data sets based on their quality and uncertainty, and propose an evaluated data set, possibly for recommendation. Experts should be identified for each category of processes. On the other hand, the role of data centres is important for establishing the recommended data library. Data centres may serve as an editorial board to designate experts and to approve recommended data sets for the library.

The qualification of experts was an important topic for discussion. It was suggested that a modeller doing spectroscopic analysis would be a good candidate in general. Evaluation of measured data sets with well-defined uncertainties is tractable if there are a sufficient number of data sets available. However, data sets are sparse, experimental or theoretical, for most processes of interest. In the worst case (and unfortunately in most cases) when only theoretical data sets are available there is hardly any uncertainty information that is critical to evaluation. If the uncertainty of theoretical data can be addressed a data producer will be more likely to be a better candidate. Experts should be selected for each category of processes. Most importantly, experts should have the deep understanding of data production and evaluation. Therefore, retired scientists or senior scientists should be considered as reviewers.

While the needs for evaluated data are great, the numbers of evaluated data and experts are too few and many experienced evaluators are retiring. In order to promote and sustain evaluation activities more systematic approaches are needed. Younger generation evaluators should be recruited and trained with guidance from senior evaluators. Publication of the work is very important to reward the evaluators for their hard work. It was urged that IAEA should take an initiative to convince communities of the importance of the evaluation work and to encourage young scientists.

Guidelines of Data Evaluation Procedures

While the data evaluation procedure has relied heavily on knowledge of the individual evaluator, the new uncertainty approach for evaluation is based on the assessment of uncertainties of measurements with agreed guidelines. Therefore, it is of primary importance to establish the guidelines of data evaluation procedures.

An agreement on the guidelines of uncertainties and evaluation procedures should be reached by the wider community of A+M/PSI data producers. Meetings of experts were suggested for technical discussion to establish the guidelines. Both the general guidelines and the specific ones for each process should be established. Existing guidelines in data centres or personal knowledge of expert evaluators in the community should be utilized as the first draft. The guidelines should be reviewed and updated regularly, and the IAEA A+M Data Unit was asked to take the responsibility for this. Indeed, the agreement from the international research community will be difficult without the assurance of IAEA on the value and the continuity of the collaboration.

Currently, one of the most urgent problems is the lack of uncertainty estimates for theoretical data. Uncertainties are rarely given in the publication of theoretical data, and at best by a comparison with measurements. However, the new uncertainty approach based on the GUM brings some light to this complicated problem. For a physical measurement, the uncertainty is estimated with uncertainty components in the course of a measurement such as previous measurement data, experience with the behaviours and properties of relevant materials and instrument, manufacturer's specifications, or data provided in calibration and other certificates and so on, which are all evaluated with respect to references. Similarly, the uncertainty of theoretical data is estimated by identifying and assessing the uncertainty components of theoretical data production or theoretical "measurement" which should be evaluated with their own theoretical references.

A couple of uncertainty components for a theoretical "measurement" were identified: the first validation should be done on the theoretical methods which should be assigned with uncertainty estimates. Secondly, the individual implementation of the method should be examined for certainty estimates by defining every "numerical" procedure or assumptions in the course of implementation. While it is clear that technical discussions should be left for experts in the field of each process, a few suggestions were made in estimating the uncertainty of each procedure: sensitivity studies, comparison with internationally agreed standards (or references) such as a simple system for benchmark, or code comparison workshops to measure differences among different methods. A meeting of code producers, such as the IAEA meeting of code centre network (CCN) was suggested for technical discussions on this subject.

Evaluation towards Recommendation

As mentioned above, recommended data is a consensus value with agreed guidelines by experts or an authority after the data are evaluated. Therefore, evaluation may not lead to a unique recommended set for a given process and rather the recommendation should be better made on the basis of applications. For example, spectroscopic analysis often requires a full set of all possible processes to influence the spectra and a "consistent" set with lower quality data works better than a "composite" set with a few high quality data and the rest of lower quality data. Therefore the recommended data library should be constructed with a consideration of applications and then data users should play a role in determining which data sets should be evaluated.

Normally, the recommended value is used for applications and its uncertainty is less of importance. In the uncertainty approach, however, the measurement is considered to exist within the ranges defined by the uncertainties and the given value is less of importance. Therefore, a data user can adopt any value within the ranges in a confidence limit. For applications where the convergence of modelling depends on A+M/PSI data, it will be possible for modellers to vary the data within the ranges.

3.2 Discussion on Data Evaluators Network

It was obvious that there is a great need to collaborate with many scientists in the field of A+M/PSI data in order to carry out the evaluation and recommendation of data sets for fusion applications. They should perform tasks as experts to review compiled data sets for evaluation and the authority group to recommend the evaluated data sets. In order to facilitate this collaborative development, a data evaluators' network was proposed to consist of not only the data centres but also their collaborators. The preliminary terms of reference discussed in the meeting are listed below.

Roles and Responsibilities of Data Evaluators Network

Experts will be engaged in the coordinated data evaluation projects with the following tasks:

- write down the guidelines for evaluation of AM/PSI data
- evaluate/update old evaluated data according to the guidelines
- find a way to expand the community and each specialty group
- hand down the knowledge to train a younger generation
- serve on a technical committee for evaluation

- serve on an advisory board to recommend evaluated data sets for the standard data library
- document and review available “evaluated” data for publication in technical journals
- identify urgent data needs

Membership of Data Evaluators Network

- Data centres should be in the network and may play an editorial role.
- Collaborators of data centres may be invited to the network to perform the tasks of experts for evaluation as well as the member for the advisory board.
- Senior (and/or retired) experts should be actively invited for knowledge transfer to a younger generation and supported financially in a sustainable manner.
- It is important for an evaluator to have an objective view. Therefore, it is desirable to have data evaluators different from data producers.
- Code producers who participate in the establishment of guidelines/uncertainty for theoretical data evaluation should be included.
- Spectroscopic analysts may be a good candidate if he/she can serve as an evaluator.

Meetings of Data Evaluators Network

- Hold meetings to recruit and train new evaluators, and expand the community.
- Hold a technical committee meeting for data evaluation,
    - review the status of evaluated data for fusion relevant applications.
- Hold an editorial board meeting from the technical committee,
    - recommend data for data library.

The preliminary terms of reference of a data evaluators’ network lay the foundation to reach a broader consensus and agreement from the community. The terms of reference will be further discussed and finalized in the IAEA future meetings.

3.3 Organization of a joint IAEA-NFRI Technical Meeting on Data Evaluation

Immediately after the DCN meeting in September 2011, meetings were proposed to organize data evaluation activities in the community. NFRI has organized data evaluation activities with a group of scientists on collisional processes from Asia and the Pacific region and had a plan to host the 8th international symposium on standard reference data. The symposium provides a great opportunity to reach out to data evaluators and hence an IAEA technical meeting (TM) on data evaluation activities was planned to be held in Korea in conjunction with the symposium. The organization of the joint TM was discussed in this meeting.

The main objective of the TM is to build the community of data evaluators and establish the general guidelines of data evaluation methods for fusion relevant A+M/PMI data. Therefore the meeting will consist of invited presentations, contributed presentations and technical sessions for discussion. A few invitations will be made to presentations on evaluation methods from existing databases of evaluated data in other communities such as astrophysics or chemistry.

The topics for contributed presentations will be limited to data sets of ***collisional processes*** of atoms, molecules and heavy particles, and plasma-material interaction. Abstracts will be reviewed and accepted for contributed presentations by the scientific advisory committee. Currently, data evaluation on atomic structures and radiative transition probabilities is in a good shape thanks to the dedicated efforts at NIST (National Institute of Standards and Technology, USA) and therefore the evaluation of atomic spectroscopy and radiative transition data will be deferred to future meetings.

More preparation is required for technical discussion sessions on general guidelines of data evaluation. It is suggested that a draft based on current knowledge and expertise from experts should be prepared before the meeting with the APAN network and data centres, which should be revised and adopted at the meeting by experts.

The scope of the meeting is defined to attract primarily evaluators who can participate in the data evaluators' network and its coordinated activities. Potential participants for the meeting were collected from institutes to produce evaluated data and individual researchers (Expert groups) of evaluators and producers.

4. Meeting Conclusions and Recommendations

Recommendations on the Future Data Evaluation Activities

The 1st IAEA Consultants' meeting on data evaluation was held at NIFS in Japan so that more participants from the Asia region, currently most active in this field, could participate in the discussion of coordinating data evaluation activities in the community. The meeting was very productive and the framework was discussed on the coordination and collaboration of data centres and researchers to establish the evaluated data library. Participants made the following recommendations regarding the coordination of data evaluators' network activities.

- The IAEA should play an important role to draw consensus from the international community of data producers, users and evaluators.
- Guidelines for data evaluation should be established, reviewed and updated regularly.
- Regular IAEA TM/CMs should be organized to review the guidelines in coordination with the data centre network.
- Community Meetings such as ICAMDATA, APIP or regional meetings (APAN, China-Japan) should be pursued as a place to exchange information and hold committee meetings.
- The proposals on ITER-related activities should consider including data evaluation activities.

The IAEA Standard Library for Fusion Relevant AM/PMI Data

An establishment of the IAEA standard library of fusion relevant AM/PMI data was discussed. The motivation is as follows:

- There are constant requests from data users to validate and improve the reliability of A+M/PMI data for fusion relevant applications.
- There should be a list of essential AM/PMI data from plasma modellers to be reviewed by experts, which in turn, may motivate data producers to investigate the topics urgently needed but not available or reliable (by documenting the missing data sets).
- The library provides a practical mechanism through which the collaboration of data producers, data evaluators and data users is effectively coordinated.
- The library will increase the visibility of data activities to plasma communities and encourage new research where needed.
- The interdisciplinary collaboration will create an opportunity to train and educate young researchers internationally, especially from developing countries, and transfer knowledge.

Establishing the standard data library requires a coordinated effort from data producers, users and evaluators. In outline their roles and the procedures involved are as follows:

- Establishment of a list of AM/PMI data required for fusion relevant applications by data users.
- Data production by data producers.
- Data compilation of data centres or compilers.

- Establishment of universal numerical and bibliographical databases for reviews.
- Establishment of general and specific guidelines for data evaluation by evaluators.
- Evaluation of the specific AM/PMI data sets by expert groups.
- Review by the Technical Committee and editorial boards (data evaluator network) for standard data.
- Publication of the standard data library.

It was proposed to reformulate the IAEA code centre network (CCN) which had its 2nd meeting in 2010. The CCN represents a group of code producers who provide theoretical data sets for fusion applications. In the last meeting, it was proposed to extend the network not only to the code producers, but also experimentalists and plasma modellers involved in fusion applications. This will increase the interaction among data users and producers, and lead to understanding the needs of both sides. This fits perfectly well in the framework of the IAEA evaluated / standard data library. In addition, the code producers may play a critical role in establishing uncertainties of theoretical data. Already there were discussions on the uncertainties of theoretical data and the needs of code comparisons in the CCN meetings. More discussions will follow on the reformulation of the CCN.

As a preliminary step, it was proposed to collect the evaluated data sets currently available by data centres and databases. Some are readily available online and others are documented in reports. Participants documented the data sources and these will be collected on the IAEA web page in the future. Relevant data sources mentioned in the discussion are NIFS, JAEA, IAEA, CHIANTI, UMAST, EIRENE, ORNL and several groups (ADAS, Queen's University at Belfast, JILA, CRAAMD, NASA JPL, VAMDC) will be contacted for any available evaluated data.

The IAEA technical meeting will be held in Daejeon, Korea jointly organized with NFRI, 4-7 September 2012 in conjunction with the 8th International Symposium on Standard Reference Data. A forum on various aspects of data evaluation activities will be discussed in the meeting. The next IAEA meeting in the series is proposed to be held in China, possibly in July 2013 before or after the 28th International Conference on Photonic, Electronic and Atomic Collision (ICPEAC). It will be discussed in the course of the IAEA-NFRI meeting.

A Consultants' Meeting on "Development of a Recommended Library for A+M/PMI data" is planned in June 2012 at the IAEA Headquarters in Vienna to address the overall issues of the IAEA Standard Data Library.

A Tentative Roadmap to the Establishment of Internationally Agreed Standard Data Library for AM/PSI Data Relevant to Fusion Applications

Phase 1: Establishment of infrastructure for evaluated data library

- IAEA Atomic and Molecular Unit: Development of database to host the standard data library
    - It is understood that the IAEA A+M data unit will host two databases: 1) the internationally agreed standard (recommended) data library and 2) the evaluated data library.
    - The standard data library is the final goal which gives a single recommended data set as the best data of the given process at the time of determination.
    - The evaluation data library is the intermediate database where evaluated data sets are collected before standardization (recommendation) and there may be more than one evaluated data set for the given process. The version of data sets can be traced through the evaluated data library.
    - The data format and the maintenance of databases should be determined as the first step.

    - The unit should make efforts to emphasize the importance of data evaluation activities to the member states for more support at the government level.
- Data Centers: Compilation of relevant data for evaluation
    - It was suggested that there should be a unified database available for evaluators.
    - A meeting should be organized to discuss the location of the database, the coordination of data collection, the decision of data format for this data storage.
- Data Centers and Evaluators: Establishment of data evaluators' network
    - Data evaluator's network should be established to coordinate effectively evaluation activities in the community level.
    - The network will train younger generation and facilitate the knowledge transfer from seasoned evaluators.
- Data Evaluators: Guidelines of evaluation methods
    - Evaluation methods should be agreed among data evaluators and standardized.
    - Meetings should be organized for evaluators to discuss the guidelines of evaluation methods for each category of processes.
- Data Producers: Guidelines of uncertainty estimates
    - There is a need of internationally agreed standards for theoretical data uncertainties.
    - Meetings should be organized to draw a consensus among data producers and to find the methods to determine the uncertainties.
- Data Users: Priority list of critical data needs
    - There are a variety of A&M/PSI data sets required for fusion applications.
    - A users' network of intensity data applications should be established to provide and update the priority list of critical data needs for fusion applications.

Phase 2: Establishment of evaluated data library

- IAEA: Establishment / maintenance of databases to host the evaluated data library
    - IAEA will host the database to contain the evaluated data sets in coordination with data centers and evaluators.
    - IAEA will organize meetings for evaluation activities
- Data Centers: Coordination of data evaluators' network activities
    - The designated committee of the network will work with evaluators to assign an evaluation task to the corresponding expert.
    - The committee will collect evaluated data sets in the evaluation data library and will publish the volume of evaluated data sets.
- Data Evaluators: Evaluation of data sets
    - Designated evaluators will evaluate data sets and maintain/improve the guidelines of evaluation methods
    - Evaluators will review the previously evaluated data sets on regular basis
- Data Producers: Guidelines of scaling laws / fit expressions
    - Evaluated data sets need to be extended to ranges where no data sets are available.
    - Data producers, especially of theoretical data will be able to provide the scaling laws or physically consistent fit expressions.
- Data Users: Development of data format compatible to applications
    - Evaluated data sets will be used for modeling and the common data format will make it easier to transfer data sets from the evaluated library to the modeling code.

Phase 3: Establishment and maintenance of standard data library

- IAEA: Establishment / maintenance of databases to host the standard data library
    - IAEA will host the database to contain the standard data sets in coordination with data centers and evaluators.
    - IAEA will organize meetings for evaluation activities

- Data Evaluators and Data Centers: Coordination of Technical Committees
    - Data centers and evaluators will work together to form technical committees to recommend the evaluated data as the internationally agreed standard data.
- Data Producers: Feedback on data sets (production of missing data, data improvement)
    - The standard data library will provide an overview of the quality of the data required for fusion and data producers may provide a feedback on data sets.
- Data Users: Feedback on data sets
    - Data users will update the data lists required for plasma applications and may give the feedback about the quality of the standard data sets after applications to modeling work.

Appendix 1

IAEA Consultants' Meeting on Procedures for Evaluation of Atomic, Molecular and Plasma-Material Interaction Data for Fusion

7-9 February 2012, National Institute for Fusion Science, Toki, Japan
Scientific Secretary**:** Hyun-Kyung Chung

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IAEA Consultants' Meeting on Procedures for Evaluation of Atomic, Molecular and Plasma-Material Interaction Data for Fusion

7-9 February 2012, National Institute for Fusion Science, Toki, Japan
Local organizer: Izumi Murakami — Scientific Secretary**:** Hyun-Kyung Chung

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Agenda

Tuesday, 7 February — **Meeting Room: A1-402**

10:00 – 10:15	NIFS Director General Prof A. Komori: Welcome
	H. Chung and I. Murakami: Introduction of Participants and Adoption of Agenda
10:15 – 11:00	H. Chung (IAEA): Review of Meeting Objectives
Session 1:	Data Evaluation Activities of the Data Centres
Chairman:	D. Kato
11:00 – 11:45	I. Murakami (NIFS): Data Evaluation Activities at NIFS
11:45 – 13:15	*Lunch*
13:15 – 14:00	T. Nakano (JAEA): Data Evaluation Activities at JAEA
14:00 – 14:45	M. Imai (Kyoto): Summary for the JAEA-KU Cooperative Research Program
14:45 – 15:00	*Coffee break*
15:00 – 15:45	J. Yan (IAPCM): Data Production and Evaluation at CRAAMD
15:45 – 16:30	C. Kim (KRISS): National System of Standard Reference Data in Korea
16:30 – 17:00	J. Yoon (NFRI): Data Evaluation Activities at NFRI

Wednesday, 8 February

Session 2:	Evaluation Methods and Evaluated Data
Chairman:	I. Murakami
09:00 – 09:45	Y. Itikawa (JAXA): Evaluation of Cross Section Data – a personal experience
09:45 – 10:30	M. Song (NFRI): Data Evaluation of Helium
10:30 – 10:45	*Coffee break*
10:45 – 13:00	J. Choi (KRISS): Concept and Definition of Measurement and its Uncertainty Based on GUM
13:00 – 14:00	*Lunch*

Session 3: Data Evaluation Methods and Data Uncertainties

Chairman: J. Yoon

14:00 – 14:30 J. Yoon (NFRI): Data Evaluation System

14:30 – 17:00 Discussion on Data Evaluation

- Data Evaluation Methods
- Data Uncertainties
- Technical framework and scope of the NFRI-IAEA Technical Meeting on Data Evaluation (September 2012)

Thursday, 9 February

Session 4: Data Evaluation Activities

Chairman: Y. Itikawa

09:00 – 10:30 Review on Data Evaluation Methods and Formulation of Future Activities

10:30 – 10:45 *Coffee break*

Session 5: Recommendation to IAEA on Data Evaluation Activities

Chairman: H. Chung

10:45 – 12:00 Status of Atomic, Molecular, Plasma-Surface Interaction Data Evaluation

- Lists of Institutes and Researchers
- Evaluated Data Sets for Fusion Applications

12:00 – 13:30 *Lunch*

13:30 – 15:00 Discussion on Data Evaluators Network

15:00 – 15:15 *Coffee break*

15:15 – 17:00 Formulation of Meeting Conclusions and Recommendations (Round-Table)

17:00 – ***Adjourn of the Meeting***

Abstracts of Presentations

The abstracts are given below for the meeting presentations available at http://www-amdis.iaea.org/DCN/Evaluation.

Review of Meeting Objectives

H. Chung
International Atomic Energy Agency, Vienna, Austria

The IAEA A+M Data Unit is devoted to the development of databases for atomic, molecular and plasma-material interaction (A+M/PMI) properties that are relevant for fusion energy research. The unit organizes coordinated research projects (CRP) and technical meetings (TM) to promote international collaboration among scientists on data activities. In particular, the series of TMs of the international data centre network (DCN) have played an important role in connecting data producers of the A+M/PSI physics community with data users of the plasma physics community for more than 30 years.

Data evaluation has always been an important topic in the IAEA meetings including the DCN meetings. Since the beginning of the A+M data unit, data users from plasma modelling community have expressed the need for a “standard” or “recommended” data library for important fusion relevant data. However, data evaluation was not actively pursued due to many difficulties involved in the evaluation procedures. Finally, in the 21st meeting of DCN in September 2011, several data centres expressed an interest in working together towards data evaluation, which led to the first IAEA CM at NIFS (Japan, February 2012), the second IAEA meeting (TM) at NFRI (Korea, September 2012) with the third IAEA meeting (TM) planned for China (2013).

The long-term goals of this effort are: 1) the establishment of a standard data library for users of data for fusion and other plasma applications, 2) the continuous support to the data evaluation community and 3) the synergistic collaboration among data producers, evaluators and users. With these goals in mind, the IAEA proposes these topics to be discussed in the meeting.

Summary for the JAEA-KU Cooperative Research Program

M. Imai
Kyoto University, Kyoto, Japan

Makoto Imai of Kyoto University in Japan is an expert on ion-atom collision processes. His laboratory in Kyoto University issued a cooperative research program for compilation and production of charge exchange cross sections between 1983 and 2008 and Makoto Imai has been in charge of the program from 1995. He presented a summary for that cooperative research program as well as efforts after 2009, which they have continued as a standalone activity.

He presented the compilation of charge exchange, i.e., electron capture and loss cross sections, derived experimentally for as many as 1186 collision systems from 374 papers published between 1983 and 2008. Also shown were his own efforts for developing an electric version of the compiled cross section database, which distributes part of the compiled data in the present status, although it does not have user-friendly web-interfaces.

His laboratory has measured electron capture cross sections for C^{q+} (q = 1,2,3), Cr^{q+} (q = 1,2), Ni^{q+} (q = 1,2), Fe^{q+} (q = 1), Be^{q+} (q = 1,2), B^{q+} (q = 1,2), and W^{q+} (q = 1,2) projectile ions colliding with He, Ne, Ar, Kr, H_2, CO, CO_2, N_2, CH_4, C_2H_6, and C_3H_8 targets at 5-32 keV and that data for C, Be, B, Fe, and Ni ions had been published in two papers, J. Phys. Soc. Jpn. **64**, 3255-3264 (1995) and J. Plasma Fusion Res. Series **7**, 323-326 (2006).

He showed that the recent data for W projectiles were in preparation for publication, and compared the electron capture cross section at 10 keV from Ar and H_2 targets with the only existing data in the literature at 8.5 MeV and at 40 keV, making use of the general energy dependence for electron capture cross section, as an example for data evaluation for those scarce data. He claimed that making full use of such empirical and semi-empirical formulae in evaluating cross sections for heavy-particle collisions should be effective.

National System of Standard Reference Data in Korea

C.-G. Kim
National Center for Standard Reference Data, Korea Research Institute of Standards and Science, Daejeon, South Korea

National Center for Standard Reference Data (NCSRD) was established in 2006 by law, based on the Fundamental Act for National Standard. The motivation of establishment was caused by the demand from the industry for data with a guaranteed quality. As is well known, Korean industry has grown very fast during the last 50 years. They begin to realize that data with a high quality is very essential in good design and manufacturing of high quality products. At the same time, the standard of living has increased in parallel with the development of industry. People begin to be concerned about health diagnosis, food products, and environment. This concern about quality of life naturally leads to an interest on the reference data related with health and the environment.

To satisfy these demands from the industry as well as from the people, the Korean government decided to establish a national system for the evaluation of data quality produced by the R&D institutes and universities. NCSRD coordinates all the national activities regarding evaluation and dissemination of scientific data by law. The primary goal of the NCSRD is to develop and disseminate standard reference data which are critically evaluated for their reliability by experts for use in technical problem-solving, research and development. NCSRD consist of a steering committee (SC), spectral technical committees (TCs) and data centres. Right now there are 22 data centres designated by the Minister of Knowledge and Economics (MKE) and 24 technical committees for data evaluation.

The Steering Committee acts as the top decision-making body of the SRD program. The members of the SC consist of 11 experts from universities, research institutes and industries. Technical committees in each area serve as an expert group to deal with data-related matters such as evaluation of the reliability of the collected or measured data, development of detailed data evaluation guidelines in each area, etc. The detailed data evaluation guideline should be followed by the basic criteria of evaluation stated on ‘the Guidelines for the Establishment and Distribution of Standard Reference Data’ in 2006 by MKE. The members of each TC consist of professors (2), research scientists (2), experts employed at industrial sectors (2) and experts on uncertainty (1).

Data Centres are formally designated by MKE on the recommendation of the SC. To be designated, they should be equipped with technical and managerial capabilities (ISO Guide 17025 or equivalent, traceability, uncertainty evaluation, etc.) to collect, produce and evaluate scientific data. Their major role is to develop SRD in their files according as the detailed data evaluation guideline.

According to the report from Microsoft Research, science is now entering to the 4th stage of development and it is data intensive science. This means that the quality of data would become more and more important as the paradigm in R&D is changing. In other words, it is getting important to provide highly qualified data to industry as well as to the people for a better quality of life and products.

For worldwide use of SRD, the developing of an international guideline of data evaluation and SRD through international collaboration will be necessary.

> *ISO Guide 99 VIM (International Vocabulary of Metrology)*
> *Reference Data:*
> Data related to a property of a phenomenon, body or substance, or to a system of components of known composition or structure, obtained from an identified source, critically evaluated and verified for accuracy
> *Standard Reference Data (SRD):*
> Reference Data issued by a recognized authority

Evaluation of Cross Section Data - A personal experience –

Y. Itikawa

Through the reviews and compilations of cross section data for electron-molecule collisions [1], data evaluation has been attempted. Particular points taken into account in the evaluation are the following:
(1) Quoted uncertainty
(2) Agreement among the data obtained by different authors / methods
(3) How the absolute values were determined
(4) Physics involved
(5) Consistency between related but different quantities
In the talk, each point has been explained in details with examples.

[1] Data reviews were published in: For N2, JPCRD 35, 31 (2006); O2, JPCRD 38, 1 (2009); H2, JPCRD 37, 913 (2008); CO2, JPCRD 31, 749 (2002); H2O, JPCRD 34, 1 (2005) where JPCRD is J. Phys. Chem. Ref. Data.

Evaluation of the electron impact excitation of $1s^2\,{}^1S \rightarrow 1s^1 2p^1\,{}^1P$ of Helium

M. Y. Song
National Fusion Research Institute, Republic of Korea

Collision processes involving helium by electron impact are fundamental to the investigation of few electron interactions in atoms and molecules. Knowledge of such collision processes is important not only for the understanding of the collision dynamics but also for laboratory and astrophysical plasma and fusion plasma. There are huge amounts of cross section data of helium by electron impact excitation. Evaluation of helium data had already been done by de Heer et al. and Yu. Ralchenko et al, but they didn't include uncertainty of the recommended data. We would like to decide appropriate evaluation methods through the available electron impact processes. This work will be started to understand the previous evaluation studies. First step to start, we collected published collision data until 2010 using NIFS database, KISTI database, and AMBDASD Bibliography. Then we reviewed these articles and evaluated the electron impact excitation cross sections for the transition $1s^2\,{}^1S$-$1s^1 2p^1\,{}^1P$ Helium atoms and calculated the uncertainty. Finally we compared our evaluated data with the previous evaluated data.

[1] de Heer et. al, Suppl. Nuclear Fusion, **3** (1992) p19
[2] Yu. Ralchenko et. al, At. Data Nucl. Data Tables **94** (2008) 603

Measurement and Uncertainty- Concept and its application -

Jong Oh Choi
Korea Research Institute of Standards and Science

Based on VIM3 (Vocabulary in metrology 3 ed. BIPM 2007) and GUM (Guide to the uncertainty in measurement, ISO 1993), the concepts of measurement, traceability and uncertainty are discussed. Based on GUM endorsed by IAEA, uncertainty evaluation is emphasized for the publication of the recommended data of the plasma properties. It is shown that there are currently two different views on the concept of measurements. Uncertainty approach and error approach on the concept of measurement are discussed. Based on the discussion, the documentation based on uncertainty approach is recommended for publication of the IAEA standard procedures. The difference between uncertainty and error, which tends to be confusing for physicists, is explained and discussed. A brief example of uncertainty evaluation and its application to multiple measurements are presented. The uncertainty evaluation for multiple measurements based on the GUM is shown. For the publication of reference data on plasma properties as IAEA standards, the importance of uncertainty evaluation is well emphasized for the participants and is expected to be reflected in future works.

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