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1st IAEA Research Co-ordination Meeting on

"RADIATIVE COOLING RATES OF FUSION PLASMA IMPURITIES"

10-11 November 1994, Vienna, Austria

SUMMARY REPORT

Prepared by R.K. Janev

January 1995

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**IAEA NUCLEAR DATA SECTION, WAGRAMERSTRASSE 5, A-1400 VIENNA**



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## **Abstract**

A brief proceedings and a summary of the conclusions of the 1st Research Co-ordination Meeting of the IAEA Co-ordinated Research Programme (CRP) on "Radiative Cooling Rates of Fusion Plasma Impurities", are provided. The meeting was held on November 10 and 11, 1994, at the IAEA Headquarters in Vienna, Austria, and was attended by all CRP participants, except one. The plan of the co-operative effort to be performed within the CRP by September 1996 is outlined.



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## 1. INTRODUCTION

The first Research Co-ordination Meeting (RCM) of the participants in the IAEA Co-ordinated Research Programme (CRP) on "Radiative Cooling Rates of Fusion Plasma Impurities" was convened on November 10 and 11, 1994, at the IAEA Headquarters in Vienna, Austria. The Meeting was attended by the principal scientific investigators of the projects included in this CRP, except for Dr K. Katsonis (Orsay, France), who was not able to attend Dr. J. Abdallah from the research group of Dr. R.E.H. Clark (Los Alamos, USA) and Prof. E.W. Thomas (School of Physics, Georgia Institute of Technology, Atlanta, USA) also participated in the work of the meeting. Additionally, the meeting was attended by the professional staff of the IAEA Atomic and Molecular (A+M) Data Unit. The List of Meeting Participants is given in Appendix 1.

The objectives of the first RCM on "Radiative Cooling Rates of Fusion Plasma Impurities" were to review the work performed by the CRP participants in the preceding period, to adjust the CRP objectives in view of the recent developments in the A+M data needs for fusion (in particular those related to ITER EDA), to discuss and agree on the methods of work co-ordination within the CRP and define the content and format of the final product of this co-ordinated joint effort.

## 2 BRIEF MEETING PROCEEDINGS

After the welcoming address and some introductory remarks by the Scientific Secretary, the work of the Meeting proceeded according to the adopted Meeting Agenda (see Appendix 2).

The first session of the meeting was devoted to an analysis of the computational codes for calculation of plasma impurity radiation, interfacing of radiative emission data to fusion experiments (Prof. H.P. Summers), and to the presentation of the results on plasma impurity line radiation modelling (Dr. R. Marchand) and radiative plasma power losses due to a number of common plasma impurities (Dr. R.E.H. Clark)

The second session of the meeting included presentations related to the atomic data required in the plasma radiative power loss calculations. Dr. J. Abdallah described the set of Los Alamos atomic physics codes currently used to provide the database for plasma radiation calculations, Dr. T. Kato presented results on the radiation loss and line spectra from carbon

and iron ions in finite density plasmas, Dr. K. Berrington provided an exhaustive information on the recently obtained relevant collisional data from the IRON project, while Dr. V. Abramov presented the status of the collisional database for vanadium ions. In the same session Prof S.C. Mukherjee described a method for calculation of charge exchange and ionization cross sections in (high energy) collisions of fully stripped ions with hydrogen atoms.

During the third session, the meeting participants discussed the type and format of atomic data input to the radiative cooling computational codes, the optimum physics content of the codes for ensuring sufficiently high levels of modeling accuracy and predictive capability, the type and format of the code output, format interconversion of existing atomic databases (ADAS, ALADDIN, etc) and their interfacing with the radiative cooling computational codes.

During the last, fourth session of the meeting, the CRP objectives were analyzed in the light of the most urgent fusion programme needs (in particular, the radiative cooling of the ITER divertor plasma) and specific impurities (Be and Ne) were selected as the immediate focus of the CRP activities. The question of the format of final CRP results on radiative cooling rates was also addressed. The forms of work co-ordination for achievement of adopted CRP objectives for the period of next eighteen months were discussed, including adoption of a plan of action. A summary of the conclusions reached and adopted regarding the Agenda items discussed during the last two meeting sessions is given in the next Section.

### 3. MEETING CONCLUSIONS AND PLAN OF CO-ORDINATED WORK

#### A. General Approach

1. The concept of establishing recommended radiative cooling rates for selected fusion plasma impurities should be based on the collisional-radiative (CR) model with inclusion of charge exchange effects. The required fundamental collision data, therefore, include excitation, ionization, recombination and charge exchange processes, involving, in principle, all individual impurity ion states.
2. The CR based radiative cooling rate calculations should, as minimum, include all the collisional and radiative processes involving the ground, metastable, resonant and other discrete states, found to be important in a specific ion. Use of scaling relationships to create an infinite-level interaction (or collision) matrix should also be considered where appropriate.

- 3 The CR model based codes should be designed to produce the CR ionization and recombination coefficients, radiative cooling and electron energy loss/gain rates (including the separated parts due to excitation and recombination), and other supplementary data if additionally required by fusion users.
4. It is desirable to format the produced data in forms convenient also for use in plasma simulation models and experimental plasma spectroscopy.
5. The radiative power loss calculations for plasma impurities should be performed for the range of plasma ( $T_e$ ) temperatures 0.5 eV - 30 keV, plasma densities ( $n_e$ ) in the range  $10^{12} - 10^{16} \text{ cm}^{-3}$  and neutral hydrogen concentrations  $n_H = (10^{-3} - 10^{-5}) n_e$ .

#### **B. Plan of Co-ordinated Work for 1995-1996**

1. In view of their importance for ITER EDA, Be and Ne are selected as impurities on which the CRP work will concentrate during 1995-1996
2. **Beryllium**
  - a) The required atomic database for Be will be collected and prepared for use in the CR cooling codes by the Belfast and Los Alamos groups (electron impact processes) and by the IAEA (charge exchange processes)
  - b) The calculations of the CR coefficients and radiation power electron energy loss functions will be performed by the JET and Los Alamos groups.
  - c) Time frame. end of 1995
3. **Neon**
  - a) Database establishment:
    - Electron-impact processes: Belfast - Nagoya collaboration, Los Alamos group, Lebedev - Kurchatov Institutes collaboration
    - Charge exchange processes: Orsay, Calcutta, IAEA
  - b) Calculations of CR coefficients and functions: JET, Los Alamos, Univ. of Quebec.
  - c) Time frame: September 1996.



## **APPENDICES**



**Appendix 1**

**1st IAEA Research Co-ordination Meeting on "Radiative Cooling Rates of Fusion Plasma Impurities"**

**November 10-11, 1994, IAEA Headquarters, Vienna, Austria**

**List of Meeting Participants**

- |                                   |   |
|-----------------------------------|---|
| Dr. R. Marchand                   | INRS - ENERGIE, Universite de Quebec, Inst. National de la Recherche Scientifique, 1650 Montee Sainte-Julie, Case Postale 1020, Varennes Quebec J3X 152, CANADA |
| Prof. S.C. Mukherjee              | Dept. of Theoretical Physics, IACS - Indian Association for the Cultivation of Science, Jadavpur, Calcutta 700 032, West Bengal, INDIA                          |
| Dr. T. Kato                       | Data and Planning Centre, National Institute for Fusion Science, Nagoya 464 (41), JAPAN   |
| Dr. V.A. Abramov                  | Scientific Research Centre "Kurchatov Institute", Ploshchad I V Kurchatova, Moscow D-182, 123182, RUSSIA  |
| Dr. K. Berrington                 | The Queen's University of Belfast, Department of Applied Mathematics and Theoretical Physics, Belfast BT7 1NN, Northern Ireland, UNITED KINGDOM                 |
| Prof. H. Summers                  | University of Strathclyde, Department of Physics and Applied Physics, 107 Rottenrow, Glasgow G4 0NG, UNITED KINGDOM   |
| Dr. J. Abdallah Jr.<br>(Observer) | Los Alamos National Laboratory, MS B212, T-4, Alamos, New Mexico 87545, USA   |
| Dr. R.E.H. Clark                  | Los Alamos National Laboratory, Radiation Transport Group, Los Alamos, New Mexico 87545, USA  |
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Appendix 2

**1st IAEA RCM on "Radiative Cooling Rates of Fusion Plasma Impurities"**

**November 10-11, 1994, IAEA Headquarters, Vienna, Austria**

**MEETING AGENDA**

Thursday, November 10, 1994

**Meeting Room: C07-V**

09:30            **Opening Address**  
**Adoption of Agenda**

Session 1:        **Modelling and Calculations of Radiative Cooling Rates**

**Chairman:**    V.A. Abramov

10:00 - 10:45: **Summers:**    **Interfacing radiative emission data to fusion experiments**

10:45 - 11:30: **Marchand.**    **Modelling impurity line radiation from tokamak plasmas.**

11:30 - 11:45:        Coffee Break

11:45 - 12:30: **Clark:**        **Calculated radiative power loss using the Los Alamos set of atomic physics codes**

12:30 - 14:00        Lunch

Session 2:        **Atomic Data for Radiative Cooling Rate Calculations**

**Chairman:**    R.E.H. Clark

14:00 - 14:45: **Abdallah:**    **The Los Alamos atomic physics codes**

14:45 - 15:30: **Kato:**        **Radiation loss and line spectra from carbon and iron ions in finite density plasmas**

15:30 - 15:45:        Coffee Break

15:45 - 16:30: **Berrington:**    **Recent collisional calculations on ions of the iron group**

16:30 - 17:15: **Abramov:**    **Status of atomic data for vanadium ions needed for the CR-model**

17:15 - 18:00: **Mukherjee:**    **Charge transfer and ionization in stripped ion-atom collisions**

Friday, November 11, 1994

Session 3.      Coupling of Atomic Physics Data Bases with Radiative Cooling Rate Computational Codes and Data Needs

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Chairman:    H.P. Summers

- 09.30 - 10:30.    -    Analysis of physics and structural features of cooling rate computational codes,  
                          -    Interfacing atomic databases with the codes  
                          -    Data preparation formats

10:30 - 11:00:    Coffee Break

- 11:00 - 12:30:    -    Spectroscopic and collision data needs for selected (ITER relevant) impurities,  
                          possible contribution of the present CRP

12:30 - 14:00:    Lunch

Session 4:      CRP Work Co-ordination and Meeting Conclusions

Chairman    R.K. Janev

- 14:00 - 15:30:    -    Reformulation of CRP objectives and methods of their accomplishment,  
                          -    Definition of the end CRP product

15.30 - 16:00.    Coffee Break

- 16 00 - 17:30.    -    Formulation and adoption of Meeting conclusions and plan of actions

**Adjourn of the meeting**