International Atomic Energy Agency

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INDC

INTERNATIONAL NUCLEAR DATA COMMITTEE

Third Meeting

of the

Atomic and Molecular Data Centre Network

Vienna, 1-3 November 1982

SUMMARY REPORT

Prepared by A. Lorenz

February 1983

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

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Table of Content

Abstract

Summary report of the Third A+M Data Centre Network Meeting convened by the IAEA at IAEA Headquarters, Vienna, Austria, 1-3 November 1982. The meeting was attended by five representatives of centres from four Member States concerned with the coordination of the international management of atomic and molecular data pertinent to controlled fusion research and technology.

A. Meeting Summary

Introduction

The Third A+M Data Centre Network (DCN) meeting was convened by the IAEA Nuclear Data Section at IAEA Headquarters, in Vienna, Austria, on 1-3 November 1982. The meeting was attended by five representatives of centres from four Member States concerned with the coordinated international management of atomic and molecular data pertinent to controlled fusion research and technology. The meeting was chaired by A. Lorenz.

The participants in this meeting are listed in Appendix 1, the Adopted Agenda is given in Appendix 2, and the papers submitted to the meeting are listed in Appendix 3. The list of Actions which resulted from this meeting is given in Appendix 4.

Summary of Conclusions and Agreements

Bibliographic Data

- The data centre representatives discussed the implication of high speed data transmission using existing data transmission networks (i.e, TYMNET, TRANSPAC, etc...)

- Having completed the internal computer system for the IAEA A+M bibliographic data base, IAEA formally offered to provide other centres with selective bibliographic retrieval services, and to make available the entire A+M bibliographic data base system to other centres upon request.

- Recognizing the need for improved literature coverage in the field of plasma-wall and other surface interaction data for the A+M Data Bulletin, the data centres encouraged the support that could be provided by the Fachinformationszentrum in the Federal Republic of Germany in this respect.

- Discussed the publication of the next CIAMDA data index, and agreed to have its publication deferred until 1985. Provisionally, IAEA agreed to provide the other data centres with a current compendium (of A+M collision data references) which would complement the CIAMDA-80 publication.

Numerical Data

- IAEA agreed to provide other data centres with an index to numerical and bibliographic A+M data available at each of the data centres in the network, and to publicize this information in the A+M Data Bulletin.

- The participating centres present at the meeting discussed the adoption of an EXFOR-type format for the exchange of data between A+M data centres, agreed to participate in the conceptional development of an EXFOR-type format for A+M data, and to investigate the adaptability of such an EXFOR transmission format within their own data centre environments.

Next Meeting

The meeting participants deemed it desirable to convene the A+M data centre network more frequently than in the past, and suggested to have the next meeting in November 1983.

B. Meeting Proceedings

1. Progress Reports

1.1. Y. Nakai (JAERI)

Progress report included as Appendix 5.

1.2. H. Tawara (IPP/Nagoya)

Progress report included as Appendix 6.

1.3. F.J. Smith (Queen's University, Belfast)

Progress report included as Appendix 7.

1.4. G. Ebel (Fachinformationszentrum, Karlsruhe)

Progress report included as Appendix 8.

1.5. J.-L. Delcroix

Progress report included as Appendix 9.

1.6. W.L. Wiese (Data Centre on Atomic Transition Probabilities, National Bureau of Standards, USA)

Progress report received by mail, reproduced in Appendix 10.

1.7. W.C. Martin (Atomic Energy Levels Data Center, National Bureau of Standards, USA)

Progress report received by mail, reproduced in Appendix 11.

1.8. J. Gallagher (JILA)

Progress report received by mail, reproduced in Appendix 12.

1.9. A. Lorenz (IAEA, A+M Data Unit)

Progress Report included in Appendix 13.

2. Bibliographic Data

2.1. Status and description of IAEA A+M Bibliographic Data Base (A+M/BDB)

The description of the A+M/BDB, as presented by D. Gremillet (IAEA), is given in Appendix 14; the "Input and Update Procedures" of this system are described in IAEA-NDS-AM 12 (internal report, available on request from the A+M Data Unit).

With the completion of the A+M/BDB system and the final clean-up of the data base itself, the A+M Data Unit informed the centres that it is prepared to extend selective retrieval services from the A+M/BDB to all data centres, and to provide the entire A+M/BDB system to the other data centres upon request. The selective retrieval service will also be extended to the atomic physics and fusion communities, which will be advertised in the IAEA Bulletin and "Nuclear Fusion" journal.

In view of their strong reliance on the IAEA A+M/BDB and its resultant Bulletin, the Belfast centre strongly supported this Agency activity, and commended the A+M/BDB as being a useful and comprehensive system.

The JAERI A+M Data Centre asked if IAEA could send them the A+M/BDB system and its description (Action # 1).

2.2. Exchange of Bibliographic Data

A certain amount of interest among the meeting participants was expressed for data transmission of bibliographic data using transmission networks, a method which already exists in certain parts of the world to complement on-line retrieval capabilities of some data banks. Even though it was questioned whether such expedient systems are justified for the transmission of A+M bibliographic data, the meeting felt that the topic should be put on the Agenda of the next network meeting, and IAEA was asked to investigate what possibilities exist at the IAEA to have data transmitted through transmission networks (Action # 2).

The currently existing connection of IAEA with external international data networks was described by Gremillet as follows:

a) TYMNET: There exists a direct connection of the American network TYMNET to the IAEA. Many places throughout the world are directly connected to TYMNET. TYMNET can also be accessed by phone.

b) The P.T.T. international telephone network can be used for connection to the IAEA. The IAEA computer actually admits up to eight simultaneous telephone entries.

c) European Space Agency (ESA) in Frascati: A connection has been established between Frascati (Italy) and the IAEA and an appropriate software, QUEST, has been written for this special purpose by the Frascati data center. QUEST has been designed for the STAIRS data base management system and therefore only the IAEA STAIRS data bases can be accessed through that line. (The A+M Data Unit, however, does not use the STAIRS data base management system).

d) IIASA: A direct connection actually exists between the IIASA and the IAEA but it may be discontinued in the near future. This connection was used in particular by the East European countries.

Note: Once connected to the IAEA, only the CICS (Customer Information Control System) can be used which only supports low-speed terminals (300 bauds = 30 caracters/s). The Time Sharing Option (TSO) cannot be accessed.

2.3. IAEA A+M Data Bulletin

The meeting took note of the information conveyed by letter to the IAEA, that the US will terminate the publication of its "Atomic Data for Fusion" Newsletter, and that the IAEA A+M Data Bulletin will be the only publication of its kind to serve the fusion community.

Although commended on its excellence and high standard, the meeting participants were concerned that the Bulletin be as complete as possible within the subject scope that it is supposed to cover. One area of concern was the coverage completeness of surface interaction data (discussed under paragraph 2.5. below), the other was the coverage completeness of atomic structure data. To check on the latter, Delcroix agreed to send IAEA a GAPHYOR retrieval on all structure references for 1980 so as to compare it with equivalent IAEA retrieval from the A+M/BDB. (See Actions 4 and 5). The results of this comparison are to be sent to the other centres for their information.

2.4. IAEA CIAMDA A+M Collision Data Index

In view of the arguments put forward by the IAEA (see Appendix 13, para. B.4.), the data centres agreed on the necessary postponement of the publication of the next issue of CIAMDA to a later date, suggested to be 1985.

In the interim, the IAEA agreed to send in January 1983 to all data centres a retrieval from the A+M/BDB of all information entered since the cut-off data of CIAMDA-80 (July 1979) until the end of 1982 (see Action # 3).

2.5. Bibliographic plasma-wall interaction data

Consideration of this topic centred primarily on the possibility to benefit from the extensive bibliographic compilation effort performed by the staff of the IPP at Garching, which is subsequently published in the Surface Physics Index by the Fachinformationszentrum (FIZ) at Karlsruhe.

In order to test the feasibility of a transfer of bibliographic plasma-wall interaction data from FIZ to IAEA on a regular basis, G. Ebel agreed to perform a trial retrieval of their data base, using a best approximation of fusion relevance criteria, and to send the retrieved data on tape to IAEA for further analysis.

In summary, the meeting made the following recommendation:

The meeting emphasized the importance for the IAEA A+M Data Bulletin to have as complete a coverage of references to plasma-wall and other surface interaction data publications as possible. One which could be of significant help to achieve this aim would be to extract the pertinent reference citations from existing bibliographic data bases such as the Surface and Vacuum Physics Index of the Max-Planck Institut fuer Plasmaphysik in Garching and the Physics Data Base of the Fachinformationszentrum Energie, Physik, Mathematik in Karlsruhe. The references thus provided would be of great benefit to assure the required completeness of the surface-interaction part of the Bulletin

In a parallel action, both Japanese centres, at JAERI and IPP/Nagoya, agreed to send their bibliograhpic surface interaction data to IAEA for inclusion in the A+M/BDB (see Action # 6).

3. Numerical Data

3.1. Exchange Format

The principal discussion on numerical A+M data, centered on the desirability to have a straightforward way to transfer data from one data centre to another without any loss of information, and have an agreed scope of information transfer.

The following five-point agreement resulted from the discussions:

(1) The data centres agreed to adapt the A+M EXFOR format for the exchange of A+M data on a voluntary basis;

(2) The data centres would analyze the dictionaries proposed in the IAEA EXFOR Manual, and those used at their own centre, and communicate their comments and suggestions to the IAEA;

(3) IAEA would review the proposals on the dictionaries, formulate a final proposal and send it out to the data centres.

(4) The data centres would investigate the adaptability of EXFOR within their data centre environment.

(5) IAEA would provide all possible assistance in the programming aspects for the implementation of the translation programmes from and into EXFOR.

3.2. Numerical A+M Data Storage Systems

The following data centres described their internal data storage and retrieval system used for numerical A+M data.

(1) JAERI A+M Data Centre

- AMSTOR data base for atomic collision data (based on the EXFOR system). (See Appendix 15).

- AMSTOR data base for atomic structure data (see Appendix 16); this centre has developed plotting programmes to produce Grotrian diagrams from this part of the data base (examples are shown in Appendix 16). A more complete example of this capability is illustrated in the JAERI-M-82-078 report "Grotrian Diagrams for Highly Ionized Titatinium TiV-TiXXII", by K. Mori (June 1982).

(2) IPP/Nagoya A+M Data Centre

- AMDIS data base for ionization and electron impact excitation (see Appendix 17). H. Tawara was asked to send a full description of the AMDIS system to all other centres (see Action 9).

(3) Queen's University, Belfast Data Centre

- The Belfast Atomic Collisions Database (description published in internal report by J.G. Hughes and F.J. Smith (June 1982), Department of Computer Science, The Queen's University of Belfast).

3.3. IAEA Coordination

With an aim to improve awareness of the existence of compiled A+M data at the various data centres, the suggestion was made that IAEA collect this information from all centres, and produce an all-inclusive inventory list (see Actions # 7 and # 8). This list, which should include information on bibliographic as well as numerical data collections, would be circulated to all centres and publicized in the A+M Data Bulletin.

3.4. Miscellaneous Data Activities

The following current activities at data centres were called to the attention of the meeting:

- Compilation of Ionization Cross-Sections for Ion-Atom and Ion-Molecule Collisions, Part 1 (Ionization cross sections for H^+, H_2^+, H_3^+, He^+ and He^{++} incident on H, H_2 and He), published in JAERI-M-9310 report by M. Sataka et al (February 1981).

- Empirical Formula of the Total Cross Section for A^{q+} + H, H_2 and He $A^{(q-1)+}$, by Y. Nakai et al. Included in this report as Appendix 18.
- Compilation of Desorption Data, by S. Nagai and Y. Nakai. Included in this report as Appendix 19.

Appendix 1

Third Meeting of the

Atomic and Molecular Data Centre Network Meeting

Vienna, 1-3 November 1982

List of Participants

Delcroix, J.L.	Laboratoire de Physice des Plasmas Universite de Paris XI (Paris-Sud) 15, Rue G. Clemenceau F-91405 Orsay Cedex
Ebel, G.	Fachinformationszentrum Energie, Physik, Mathematik GesmbH Kernforschungszentrum D-7514 Eggenstein-Leopoldshafen
Gremillet, D.	IAEA, A+M Data Unit
Hayakawa, S.	Department of Astrophysics Institute of Plasma Physics Nagoya University Chikusa-Ku, Nagoya 464, Japan
Katsonis, K.	IAEA, A+M Data Unit
Lorenz, A. (Head)	IAEA, A+M Data Unit
Nakai, Y.	Nuclear Data Centre - JAERI Tokai-Mura, Naka-Gun Ibaraki-Ken 319-11, Japan
Schmidt, J.J.	IAEA, Nuclear Data Section
Smith, F.J.	Department of Computer Science Queen's University of Belfast Belfast BT7 1NN Northern Ireland
Tawara, H.	Institute of Plasma Physics Nagoya University Chikusa-Ku, Fro-Cho Nagoya 464, Japan

Appendix 2

Third Meeting of the

Atomic and Molecular Data Centre Network Meeting

Vienna, 1-3 November 1982

Adopted Agenda

1. Introductory items

2. Review of Actions from the 1980 A+M Data Centre Network meeting

3. Reports from A+M data centres and groups

4. Report of the IAEA A+M Data Unit

5. Bibliographic Data

   5.1. Current status and description of the IAEA A+M Bibliographic Data Base
   5.2. Exchange of bibliographic data
   5.3. Status of the IAEA and US Atomic Data Bulletins
   5.4. Next publication of the CIAMDA data index
   5.5. Bibliographic index for plasma-wall interaction data
   5.6. Other data indexes

6. Numerical Data

   6.1. Recommendations of the IFRC Subcommittee regarding numerical A+M data
   6.2. IAEA activity in the coordination of atomic collision data generation and evaluation
   6.3. Other systematic efforts in the generation of numerical A+M data
   6.4. Description of the Belfast Atomic Collisions Data base
   6.5. Consideration of a common format for the storage/retrieval and exchange of numerical A+M data
   6.6. Numerical plasma-wall interaction data. IAEA "state-of-the-art" review.

7. Next meeting

Appendix 3

Third Meeting of the

Atomic and Molecular Data Centre Network Meeting

Vienna, 1-3 November 1982

List of Papers

1. Progress Report of the IAEA A+M Data Unit for the Period February 1981 - October 1982. A. Lorenz (October 1982)

2. First Research Coordination Meeting on Atomic Collision Data for Diagnostics of Magnetic Fusion Plasmas. Summary Report. K. Katsonis and A. Lorenz (October 1982)

3. Description of the IAEA Data Base For Bibliographic A+M Data. IAEA-NDS-AM 12. D. Gremillet, R.A. Langley, A. Lorenz (October 1982)

4. The IAEA A+M Bibliographic Data Base. D. Gremillet (October 1982)

5. Progress Report. Japan Atomic Energy Research Institute (JAERI). Activities on A+M Data for Fusion. Y. Nakai, T. Shirai and K. Ozawa

6. Report at the IAEA Data Centre Network Meeting. H. Tawara and Y. Itikawa

7. Survey of A+M Data Usage by Fusion Plasma Modellers. A. Lorenz

8. GAPHYOR - Progress Report

9. Empirical Formula of the Total Cross Section for $A^{q+} + H$, H_2 and $He \rightarrow A^{(q-1)+}$. Y. Nakai, T. Tabata, R. Ito, A. Kikuchi and T. Shirai

10. AMDIS (Atomic and Molecular Data Interactive System) Data Base for Cross Sections of Ionization and Excitation by Electron Impact

11. GAPHYOR On-Line Users Manual. J.L. Delcroix, D. Gremillet and G. Rouquie

Appendix 4

List of Actions

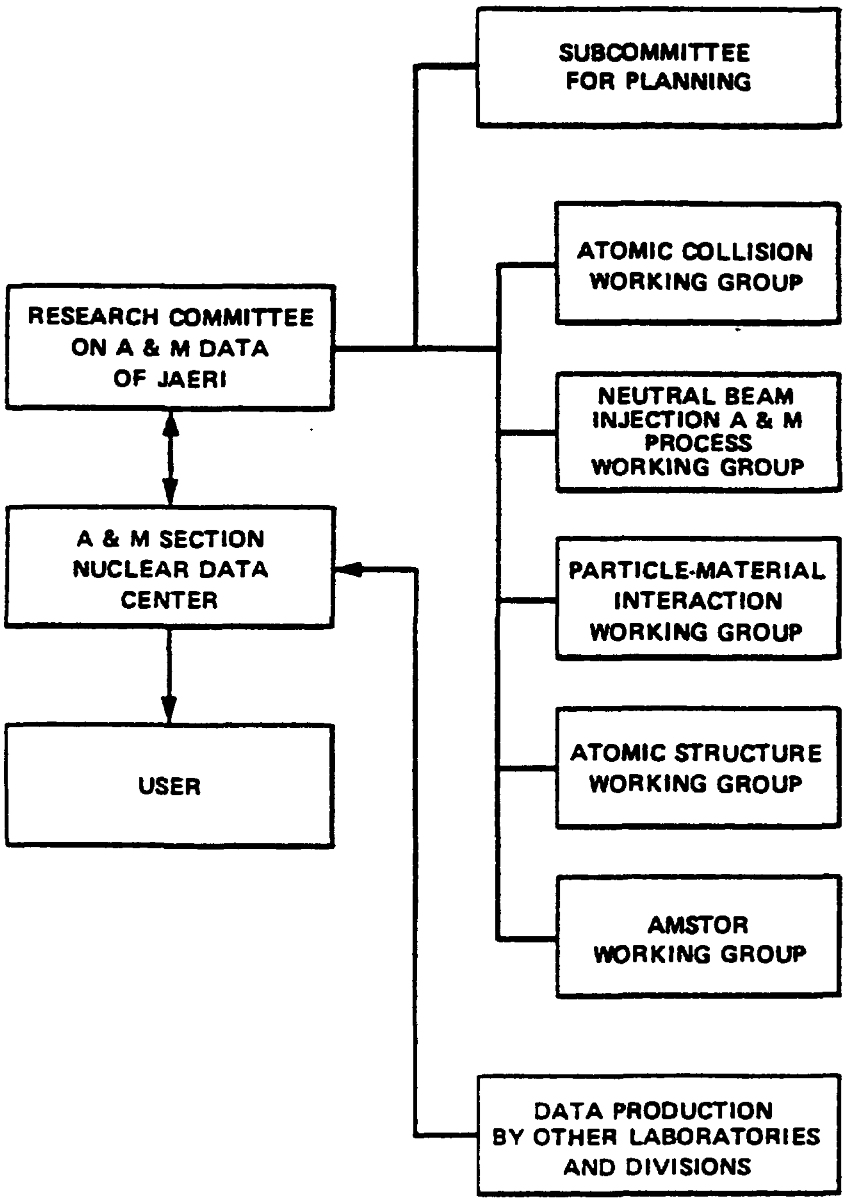
(IAEA = A+M Data Unit of the Nuclear Data Section)

1. IAEA	Send the A+M/BDB system and its description to the JAERI A+M Data Centre.
2. IAEA	Put the topic of data communication networks on the Agenda of the next meeting.
3. IAEA	Make a compendium of all information entered into the A+M/BDB since the CIAMDA-80 cut-off data, and sent copy of the compendium to all data centres.
4. Delcroix	Send a GAPHYOR retrieval for year 1980 to the A+M Data Unit.
5. Katsonis	Compare GAPHYOR retrieval received from Delcroix with equivalent retrieval from the A+M/BDB, and send results to the other centres.
6. Nakai and Tawara	Send bibliographic reference citations for surface interactions for inclusion in the Agency's A+M Data Bulletin.
7. All centres	Send IAEA a list of all numerical and bibliographic data collections available at their centre.
8. IAEA	Produce an all-inclusive inventory list of numerical and bibliographic data available at all A+M data centres, and publicize this list in the A+M Data Bulletin.
9. Tawara	Send to all data centres a full description of the AMDIS (data storage and retrieval system) system used at Nagoya.
10. Nakai	Send to Gremillet the program, input data, and the description of the AMSTOR system.

Japan Atomic Energy Research Institute(JAERI) Activities on A + M Data for Fusion

Y. Nakai, T. Shirai and K. Ozawa
JAERI, Tokai-mura, Japan

1. Organization for A + M Activities



2. Data Compilation and Evaluation

2.1. JEAMDL-1 (Evaluated A + M Data Library)

2.1.1. Atomic Collision

(1) Charge Transfer Cross Sections: (H^+, H or H^-) + (Target)

(σ_{10}, σ_{1-1}, σ_{0-1}, σ_{01}, σ_{-10}, σ_{-11})

(a) Target: H_2, N_2, O_2, CO, CO_2, H_2O, C, CH_4 etc.

(b) Target: He, Ne, Ar, Kr, Xe

(c) Target: Alkali and alkali-earth vapors

(2) Charge Transfer Cross Sections: (He Ions or Atom) + (Target)

Target: same as (1) (a),(b) and (c)

(3) Ionization Cross Sections: (H, He) + (H, H_2, He)

(4) Charge Transfer Cross Sections: (C^{q+}, O^{q+}) + (H, H_2)

(U.S.-Japan joint research on A+M data for fusion)

Formulation of empirical formula for A^{q+} + H, H_2 $\rightarrow$ $A^{(q-1)+}$

(5) Charge Transfer Cross Sections: A^{q+} + He

2.1.2. Particle-Material Interaction

(1) Elementary Processes for Hydrogen Recycling in Fusion Materials

(a) Trapping and re-emission

(b) Diffusion process

(c) Radiation effects and segregation

(2) Surface Effects on Damaged Profiling in Fusion Materials by Ion Beam Bombardment

(a) Damage profiling

(b) Void density profiling

(c) Swelling profiling

(3) Electron-Material Data

(a) Bremsstrahlung and stopping power

(b) Backscattering, penetration and energy deposition

2.1.3. Atomic Structure (Energy Levels and Transition Probabilities)

(1) Ti V - Ti XXII (1980-1981)
Wavelength tables and Grotrian diagrams: JAERI-M 82-078 (1982)

(2) Ni and Mo Data (1981-1982: compilation)

2.2. Atomic and Molecular Data Storage and Retrieval System(AMSTOR) Program

(1) Atomic Collision Data
Numerical data format is developed with reference to the exchange format(EXFOR).
see separate sheets.

(2) Particle-Material Interaction Data
At present a format for plotting numerical data is designed, but we have no appropriate format for data storage/retrieval.

(3) Atomic Structure Data
Wavelength tables and Grotrian diagrams
see separate sheets.

3. Data Production

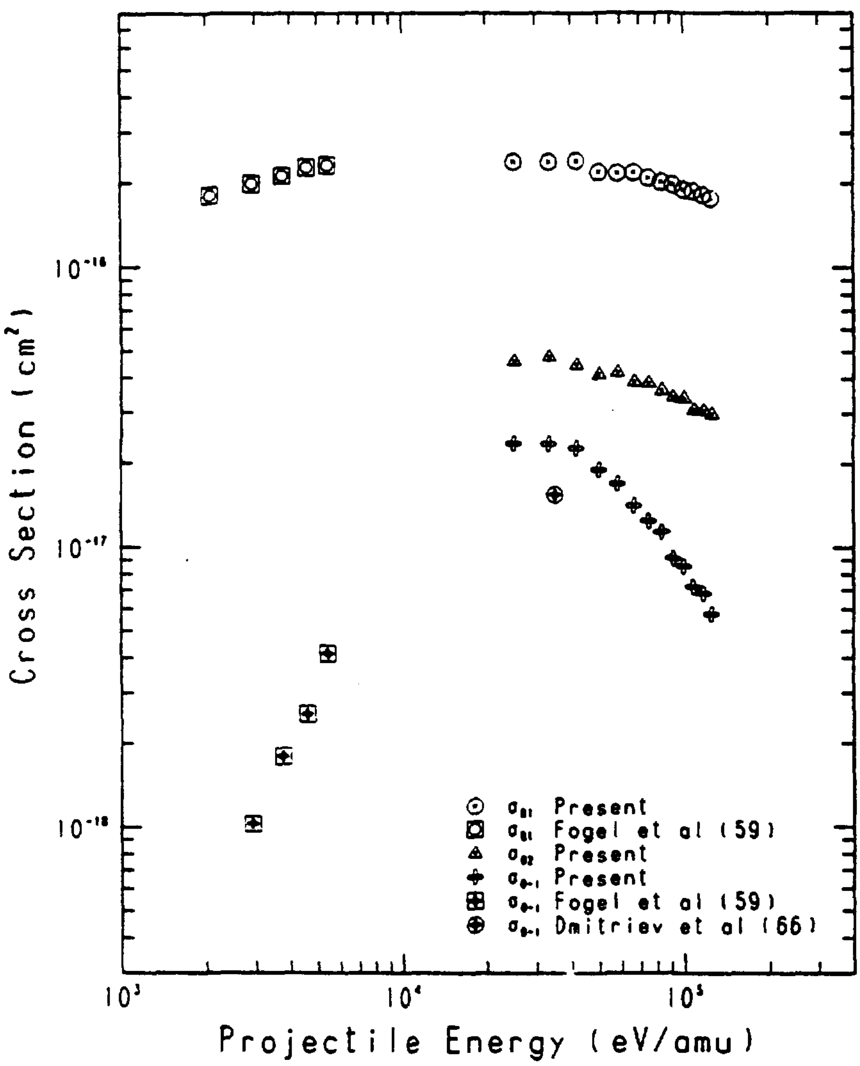
3.1. Theoretical

(1) Ion-Atom Collisions (Charge Transfer)

(2) Atom-Atom Collisions (Ionization)

3.2. Experimental

(1) Ion, Atom-Molecule Collisions (Charge Transfer)



Cross Sections for C + He - C^{+}, C^{2+} and C^{-}

(2) Inner-Shell Ionization

(3) Trapping and Detrapping of Hydrogen Isotopes in Materials

(4) Heavy Ion Collisions (Beam-Foil and Charge Transfer Experiments)

Appendix 6

Report at the IAEA Data Center Network Meeting
Vienna, 1-3 November, 1982

Data Center Activities of the Research Information Center, IPP/Nagoya

H. Tawara
Y. Itikawa

1. Compilation and evaluation of atomic data for fusion research and related fields

Most of the activities in data compilation and evaluation are supported by Working Groups which consist of scientists in and outside of IPP on collaboration basis. They survey literatures, collect numerical data and evaluate them. They make also analysis of problems to be encountered in fusion research. The results of the Working Group activities are published in a form of the Center report (mostly in IPPJ-AM series). Some of the collected numerical data are stored in a computer to form the computerized data bases.

As of October, 1982, two Working Groups are active in the field of atomic data. The members of the Working Groups are listed in Appendix I. A publication list is given in Appendix II.

(1) Working Group on Atomic Processes in Plasmas

The major activities are concerned with the following subjects:

(a) electron-ion collisions

Collection of excitation and ionization cross sections (both theoretical and experimental) is continuing to be made. Following the first bibliography (AM-7; 1978), the up-dated bibliography on excitation and ionization of ions in electron -ion collisions has been published as AM-24 (1982). Based on the data collected, a computerized data base is being produced. With the use of the Atomic and Molecular Data Interactive System (AMDIS), retrieval and display of the data can be done on an on-line basis.

Since 1981 a special subgroup has been organized to evaluate the collected data. As a first step, the evaluation of excitation cross sections of carbon and oxygen ions by electron impact were begun as one of the international collaboration programs. Then, the program has been extended along the iso-electronic sequence to H-like through N-like ions.

(b) collisions of H, H_2, He and their ions with atomic ions

The previous data compilations (AM-15; 1980: AM-20; 1981) on the processes

$$A^{q+} + H \longrightarrow A^{(q-1)+}$$

and

$$A^{q+} + H_2 \longrightarrow A^{(q-n)+}$$

are being up-dated, where A represents any ion and q and n are integers. Based on the results, a computerized data base is under planning.

(c) atomic processes in high-density plasmas

For applications to the inertial confinement fusion systems, a survey was made on atomic processes in high-density plasmas. As a conclusion of the survey, a compilation has been started on the spectroscopic data of atomic ions in high-density plasmas.

(2) Working Group on Plasma-Wall interactions

This group concentrates its effort on the analysis of problems and data compilation of elementary processes in plasma-wall interacitons.

(a) ion sputtering

The compiled data on ion-sputtering yield (AM-14; 1980) is being up-dated. The results are stored in a computer to form a data base. The empirical formula of the total yield proposed previously is now revised and its reliability is improved. The data collection is extended to include the dependence of the sputtering yield on the incident angle, energy and angular distributions of the sputtered particles, and other parameters.

(b) reflection of ions

The data compiled on backscattering coefficients of light ions (AM-18; 1981) are supplemented with the values calculated by the empirical formula derived by the Working Group. The resulting set of data of the coefficients for 36 elements is to be published in the Atomic Data and Nuclear Data Tables. Data compilations of the angular dependence and other quantities are in progress.

(c) desorption

A rather comprehensive review on desorption and related phenomena has been published as AM-22 (1982).

(d) hydrogen recycling

A simulation code is being developed to understand the interrelations of the elementary processes in hydrogen-recycling phenomena in fusion devices. Fundamental data are compiled to be input into the code.

2. Computer retrieval of literature and numerical data

Under the collaboration of the Computer Center of IPP, a computer retrieval system of literature information has been developed. This system is based on the INSPEC data base, which contains bibliographical information including abstracts taken from over 2000 journals. One can make literature searches by any word in titles, abstracts and authors. This system has also beeen adapted to the bibliographic data base on atomic and molecular processes kindly offered by the Oak Ridge National Laboratory Data Center. The ORNL data base includes the bibliographic information categorized under processes and atomic/molecular species.

As is mentioned in the previous section, the numerical data collected by the Working Groups are stored in a computer. A system (called AMDIS) has been developed to retrieve and display those data on an on-line interactive basis. At present, the computerized data bases are formed on electron-ion collision and sputtering of ions from solids.

The above data bases (bibliographic and numerical)are open to scientists in IPP and those who are participating in the collaborative research programs at IPP.

3. Promotion of collaboration between atomic physics community and fusion research community

Once or twice a year the Center organizes workshops on problems of mutual interest to both the communities. The subjects taken recently are "Charge transfer collisions in tokamak plasmas", "Elementary processes in the edge region of fusion plasmas", and "Atomic processes in high-density and high-temperature plasmas". Proceedings of each workshop have been published in Japanese.

The Institute of Plasma Physics has started a planning and preparatory study of the Reacting Plasma Project (R-project). The project aims at solving physical and technical problems expected in the fusion plasma with D-T burning. The Center supports the R-project by providing basic data and coordinating joint task groups of plasma physicists and atomic or solid state physicists. The areas concerned are plasma modelling, developments of diagnostics for alpha-particles, beam sources of negative hydrogen ions, and wall materials.

4. International cooperation

Collaboration among data centers and groups is essential to establish comprehensive data compilations and distribute them to fusion people. The Center has already contributed and will continue to contribute to the activities at IAEA through all possible means.

To promote the world-wide collaboration in the field of atomic data, the effort of each local data center is also important. Collaboration program is now starting between the U.S. and Japan data centers as a part of the U.S.-Japan collaboration programs in fusion research. In October, 1980, the U.S.-Japan Workshop on Atomic Collision Data for Fusion was held in Boulder. The activity of the evaluation of electron-ion collision data mentioned in Section 1 has been started as a conclusion of the Workshop and performed as a collaboration program of the U.S. and Japan data centers. In a continuation of the 1980 Workshop, the U.S.-Japan Workshop on Surface Data Review was held in Nagoya in December, 1981. Elementary processes in plasma-wall interaction were surveyed to establish methods of compilation and evaluation of the relevant data. Possible collaborative programs with data centers in other countries are also under discussion.

Appendix I The members of the Working Groups

(1) Working Group on Atomic Processes in Plasma

Amano, T.	Institute of Plasma Physics, Nagoya University
Arikawa, T.	Faculty of Technology Tokyo University of Agriculture and Technology
Fujita, J.	Institute of Plasma Physics, Nagoya University
Itikawa, Y.	The Institute of Space and Astronautical Science
Iwai, T.	Department of The Liberal Arts Kansai Medical University
Kagawa, T.	Nara Women's University
Kato, T.	Institute of Plasma Physics, Nagoya University
Matsuzawa, M.	The University of Electro-Communications
Mori, K.	
Nakai, Y.	Japan Atomic Energy Research Institute
Nishihara, K.	Institute of Laser Engineering Osaka University
Ohtani, S.	Institute of Plasma Physics, Nagoya University
Otsuka, M.	Institute of Plasma Physics, Nagoya University
Oyano, I.	Institute for Molecular Science
Suzuki, H.	Faculty of Science and Technology Sophia University
Tanaka, K.	Tokyo Astronomical Observatory
Takayanagi, K.	The Institute of Space and Astronautical Science
Tawara, H.	Kyushu University
Watanabe, T.	Faculty of Engineering, The University of Tokyo

(2) Working Group on Plasma-Wall Interactions

Aono, M.	National Institute for Research in Inoganic Materials
Hamada, T.	Institute of Plasma Physics, Nagoya University
Imoto, S.	Faculty of Engineering, Osaka University
Ishino, S.	Faculty of Engineering, The University of Tokyo
Itikawa, Y.	The Institute of Space and Astronautical Science
Itoh, N.	Faculty of Engineering, Nagoya University
Kamata, K.	Institute of Plasma Physics, Nagoya University
Kato, T.	Institute of Plasma Physics, Nagoya University
Kino, T.	Faculty of Science, Hiroshima University
Koma, A.	The University of Tsukuba
Koshikawa, T.	Osaka Electro-Communication University
Miyahara, A.	Institute of Plasma Physics, Nagoya University
Morita, K.	Faculty of Engineering, Nagoya University
Okada, M.	National Research Institute for Metals
Okamoto, K.	ULVAC Corporation
Ozawa, K.	Japan Atomic Energy Research Institute
Sakairi, H.	The Institute of Physical and Chemical Research
Shimizu, H.	Electrotechnical Laboratory Headquarters
Shimizu, R.	Faculty of Engineering, Osaka University
Sugisaki, M.	Faculty of Engineering, Kyushu University
Tajima, T.	Institute of Plasma Physics, Nagoya University
Tabata, T.	Radiation Center of Osaka Prefecture
Tanabe, T.	Faculty of Engineering, Osaka University
Yamaguchi, S.	Faculty of Engineering, Tohoku University
Yamamoto, S.	Japan Atomic Energy Research Institute
Yamamura, Y.	Okayama University of Science
Yamashina, T.	Faculty of Engineering, Hokkaido University
Yamawaki, M.	Faculty of Engineering, The University of Tokyo

Appendix II. LIST OF IPPJ-AM REPORTS

IPPJ-AM-1* "Cross Sections for Charge Transfer of Hydrogen Beams in Gases and Vapors in the Energy Range 10 eV - 10 keV"
H. Tawara (1977) [Published in Atomic Data and Nuclear Data Tables 22, 491 (1978)]

IPPJ-AM-2* "Ionization and Excitation of Ions by Electron Impact – Review of Empirical Formulae –"
T. Kato (1977)

IPPJ-AM-3 "Grotrian Diagrams of Highly Ionized Iron FeVIII-FeXXVI"
K. Mori, M. Otsuka and T. Kato (1977) [Published in Atomic Data and Nuclear Data Tables 23, 196 (1979)]

IPPJ-AM-4 "Atomic Processes in Hot Plasmas and X-Ray Emission"
T. Kato (1978)

IPPJ-AM-5* "Charge Transfer between a Proton and a Heavy Metal Atom"
S. Hiraide, Y. Kigoshi and M. Matsuzawa (1978)

IPPJ-AM-6* "Free-Free Transition in a Plasma – Review of Cross Sections and Spectra –"
T. Kato and H. Narumi (1978)

IPPJ-AM-7* "Bibliography on Electron Collisions with Atomic Positive Ions: 1940 Through 1977"
K. Takayanagi and T. Iwai (1978)

IPPJ-AM-8 "Semi-Empirical Cross Sections and Rate Coefficients for Excitation and Ionization by Electron Collision and Photoionization of Helium"
T. Fujimoto (1978)

IPPJ-AM-9 "Charge Changing Cross Sections for Heavy-Particle Collisions in the Energy Range from 0.1 eV to 10 MeV I. Incidence of He, Li, Be, B and Their Ions"
Kazuhiko Okuno (1978)

IPPJ-AM-10 "Charge Changing Cross Sections for Heavy-Particle Collisions in the Energy Range from 0.1 eV to 10 MeV II. Incidence of C, N, O and Their Ions"
Kazuhiko Okuno (1978)

IPPJ-AM-11 "Charge Changing Cross Sections for Heavy-Particle Collisions in the Energy Range from 0.1 eV to 10 Mev III. Incidence of F, Ne, Na and Their Ions"
Kazuhiko Okuno (1978)

IPPJ-AM-12* "Electron Impact Excitation of Positive Ions Calculated in the Coulomb-Born Approximation – A Data List and Comparative Survey –"
S. Nakazaki and T. Hashino (1979)

IPPJ-AM-13 "Atomic Processes in Fusion Plasmas – Proceedings of the Nagoya Seminar on Atomic Processes in Fusion Plasmas Sept. 5-7, 1979"
Ed. by Y. Itikawa and T. Kato (1979)

IPPJ-AM-14 "Energy Dependence of Sputtering Yields of Monatomic Solids"
N. Matsunami, Y. Yamamura, Y. Itikawa, N. Itoh, Y. Kazumata, S. Miyagawa, K. Morita and R. Shimizu (1980)

IPPJ-AM-15 "Cross Sections for Charge Transfer Collisions Involving Hydrogen Atoms"
Y. Kaneko, T. Arikawa, Y. Itikawa, T. Iwai, T. Kato, M. Matsuzawa, Y. Nakai, K. Okuno, H. Ryufuku, H. Tawara and T. Watanabe (1980)

IPPJ-AM-16 "Two-Centre Coulomb Phaseshifts and Radial Functions"
H. Nakamura and H. Takagi (1980)

IPPJ-AM-17 "Empirical Formulas for Ionization Cross Section of Atomic Ions for Electron Collisions –Critical Review with Compilation of Experimental Data–"
Y. Itikawa and T. Kato (1981)

IPPJ-AM-18 "Data on the Backscattering Coefficients of Light Ions from Solids"
T. Tabata, R. Ito, Y. Itikawa, N. Itoh and K. Morita (1981)

IPPJ-AM-19 "Recommended Values of Transport Cross Sections for Elastic Collision and Total Collision Cross Section for Electrons in Atomic and Molecular Gases"
M. Hayashi (1981)

IPPJ-AM-20 "Electron Capture and Loss Cross Sections for Collisions between Heavy Ions and Hydrogen Molecules"
Y. Kaneko, Y. Itikawa, T. Iwai, T. Kato, Y. Nakai, K. Okuno and H. Tawara (1981)

IPPJ-AM-21 "Surface Data for Fusion Devices – Proceedings of the U.S–Japan Workshop on Surface Data Review Dec. 14-18, 1981"
Ed. by N. Itoh and E.W. Thomas (1982)

IPPJ-AM-22 "Desorption and Related Phenomena Relevant to Fusion Devices"
Ed. by A. Koma (1982)

IPPJ-AM-23 "Dielectronic Recombination of Hydrogenic Ions"
T. Fujimoto, T. Kato and Y. Nakamura (1982)

IPPJ-AM-24 "Bibliography on Electron Collisions with Atomic Positive Ions: 1978 Through 1982 (Supplement to IPPJ-AM-7)"
Y. Itikawa (1982)

Available upon request to Research Information Center, Institute of Plasma Physics, Nagoya University, Nagoya 464, Japan, except for the reports noted with*.

Appendix 7

Belfast Data Centre on Atomic and Molecular Physics

The Queen's University of Belfast

Recommended Data

The Belfast data centre has put its emphasis on the production of recommended data. This is made easier in Belfast by the availability of a large group of both theoretical and experimental scientists in Atomic and Molecular Physics.

The process of producing recommended data begins with the collection of bibliographics. For this we rely primarily on the CIAMDA index and on the IAEA Bulletin. Raw data is then extracted or obtained from another data centre and input to the database. For each reaction the data from different sources are brought together and compared on graphs. These graphs and copies of the original publications are kept in a separate file for each reaction. For example, there is one file kept for the electron ionization of C^+, another for C^{++}, etc. It should be made clear that by "data" we mean both theoretical and experimental data; data obtained from empirical formula are also included. The file is then discussed with experts in both theory and experiment and finally recommended data is produced. This is then stored with the other data in the database.

Data Collections

1. Recommended Data. - So far recommended data has been produced on electron ionization of light atoms and ions, $Z \leq 8$ (Culham report CLM-R216,p.982).

2. Raw Data. - Raw data is being collected on the following with a view to obtaining recommended data:

   (a) electron ionization of heavy atoms ($Z > 8$)
   (b) electron ionization of molecules relevant to fusion (i.e., mainly molecules made up of H, C, O, He),
   (c) charge exchange of H with atomic ions.

3. Computer Data. - Data produced by large computer programs, mainly on electron excitation of atoms and ions, has been collected in a separate database at Belfast. This includes a great deal of structure with resonances over very small energy intervals. Average values, relevant to fusion, are also stored.

4. Interatomic Potentials. - Raw data on interatomic potentials has been collected for several years in Belfast. This is being brought up-to-date and authenticated for potentials involving H and H^+.

Appendix 8

Activities of the Fachinformationszentrum Energie, Physik, Mathematik in the field of numerical data documentation.

G. Ebel
Fachinformationszentrum Energie, Physik, Mathematik
Eggenstein-Leopoldshafen
Federal Republic of Germany

At the last meeting of the A+M Data Centre Network a general survey was given of the organization and the work of the Fachinformationszentrum. Therefore this report will be restricted to activities that have taken place during the last two years.

1. Bibliographic data bases in physics.

The new physics data base INKA-PHYS has been established at the Fachinformationszentrum and can be accessed online via public networks. This database started in 1979 and contains about 45o.ooo documents at the end of 1982. The annual increase is more than 1oo.ooo documents. The input work is done in cooperation with the American Institute of Physics so that references to the US physics literature are available at an very early time. The references are also printed in the abstract journal Physics Briefs, the successor of the longstanding Physikalische Berichte.

Other computerized data bases of relevance to plasma physics and fusion technology that are available at the Fachinformationszentrum, including the data base of the International Nuclear Information Systems (INIS).

In addition to these large databases the Fachinformationszentrum publishes three bibliographic indices compiled at the Max-Planck-Institut für Plasmaphysik in Garching:

- Plasma Physics Index
- Surface and Vacuum Physics Index
- Technology Index for Plasma Physics Research and Fusion Reactors

These indexes however are not offered on an online basis.

With the introduction of fees for the use of the data bases a substantial decrease in the number of retrospective searches and SDI profiles has occured. But after a short time the number of users has now increased again.

2. Numerical data bases

During the last years a number of computerized numerical data bases for physics has beer established and made available to users. These data bases are listed in the following:

- Nuclear Structure Data Bank, consisting of the following parts
  ENSDF (Evaluated Nucöear Structure Data File)
  NSR (Nuclear Structure References)
  MEDLIST (Nuclear Data for Medical Applications)

  Alle three parts are implemented under the ADABAS data base management systems and are accessible from January 1983 via public networks.

- ICSD (Inorganic Crystal Structure Data Bank)
  This databank which is built up in cooperation with the University of Bonn will contain the crystal structure data of about 3oooo inorganic substances. Up to

now, 18.000 strutures are in the data bank. The data bank is similar to the Cambridge Crystallographic Data File that contains the structure data of organic and organometallic compounds. Both databanks together will finally contain the data for all known crystal structures. The ICSD data base can be accessed online via networks or leased as a whole.

- C13 Spectral Databank
  This databank has been established in cooperation with the BASF company and contains at this time (December 1982) the C13 nuclear magnetic resonance spectra of about 36.000 organic compounds. A variety of sophisticated retrieval methods has been developped and implemented. This databank can either be leased as a whole or accessed online.

A somewhat smaller data base has been completed on the adsorption of gases on metal surfaces. It has been produced at the Technische Universität München and represents a comprehensive index of the relevant literature from 1956 to 1977 with indications of what types of data have been measured. The index has been published up to now in a printed version but will eventually be transformed to a machine retrievable data base.

Further data bases in the state of development are on electron density distribution in crystals and on properties of molecules in the gas phase.

Finally it should be mentioned that in the past most work in numerical data documentation has been done in the field of physics. This work will be extended in the future to data relevant for energy reaearch and technology. In this connection the International Energy Agency IAE has appointed the Fachinformationszentrum to act as an information centre for heat pumps.

Appendix 9

GAPHYOR (Progress Report)

J.-L. Delcroix

1. General structure now oriented by retrieval possibilities on-line:

   - 12 users can be connected simultaneously 4 days/week
   - 12 experts - 70 journals regularly searched

2. Present volume

   Jan. 82. 100 000 entries + 20 000 in error
   Nov. 82. 120 000 entries + 5 000 in error

   We have an automatic error correction program

3. Publications

Blue books	-	every 3 months
Red books	-	R (1980)
	-	H (1981)
coming	-	R+X (R+R, R+H, R+1A, ...)
	-	N
	-	1A

4. SYGAL (sygal = System Gaphyor Language)

   works in natural chemical notations: C 102/+/rv
   automatics helps ORDER -ALL - EXASS - DSASS

5. Special problems

   multiply charged ions, isoelectronic series
   new DS
   2-step process
   zero and blank

6. New manual summary (distributed: pink sheets)
   full text: published in Nov. 1982

Data Center on Atomic Transition Probabilities

Bldg. 221, Rm. A267
National Bureau of Standards
Washington, D.C. 20234
Tel. (301) 921-2071

Director: Dr. W. L. Wiese

Contacts: Dr. G. A. Martin
Mr. J. R. Fuhr

NBS Data Center on Atomic Transition Probabilities - recent work and outlook

The Data Center on Atomic Transition Probabilities at the National Bureau of Standards, Washington, D.C., has continued its critical compilation and bibliographical work on transition probabilities. An extensive critical compilation (262 pages) has been completed for the three elements Fe, Co, and Ni [1], which covers all stages of ionization on which reliable data are available. Also, a table of transition probabilities for about 5000 selected lines of all elements for which reliable data were available on an absolute scale was recently published [2]. Work is now in progress on the updating and revision of the existing NBS critical data compilations for all allowed [1,3,4] and forbidden [5] transitions in Fe-group elements. A single volume containing all these data for the Fe-group elements Sc to Ni (Vol. III of the NBS series of atomic transition probabilities) is planned for publication in the 1983-1984 period. A new supplemental bibliography has been published, covering the literature references from November 1977 through March 1980 [6]. It contains approximately 600 references in chronological order and includes listings by element, stage of ionization, and experimental or theoretical method applied, as well as an author index.

REFERENCES

[1] Fuhr, J. R., Martin, G. A., Wiese, W. L., Younger, S. M.: 1981, J. Phys. Chem. Ref. Data 10, p. 305.

[2] Wiese, W. L., Martin, G. A.: 1981, "Handbook of Chemistry and Physics," 62nd ed., edited by R. C. Weast and M. J. Astle, Chemical Rubber, Boca Raton, FL, p. E335; and, 1980, Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.) 68, Part II (U.S. Government Printing Office, Washington, D.C.).

[3] Wiese, W. L., Fuhr, J. R.: 1975, J. Phys. Chem. Ref. Data 4, p. 263.

[4] Younger, S. M., Fuhr, J. R., Martin, G. A., Wiese, W. L.: 1978, J. Phys. Chem. Ref. Data 7, p. 495.

[5] Smith, M. W., Wiese, W. L.: 1973, J. Phys. Chem. Ref. Data 2, p. 85.

[6] Miller, B. J., Fuhr, J. R., Martin, G. A.: 1980, Bibliography on Atomic Transition Probabilities (November 1977 through March 1980), Nat. Bur. Stand. (U.S.) Spec. Publ. 505, Suppl. 1, U.S. Government Printing Office, Washington, D.C.

Work in progress: G. A. Martin, W. L. Wiese, J. R. Fuhr, and S. M. Younger, "Atomic Transition Probabilities (Sc through Ni--A Critical Data Compilation)," Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), Vol. III (in preparation).

Publications List for Data Center on Atomic Transition Probabilities

1. W. L. Wiese, M. W. Smith, and B. M. Glennon
"Atomic Transition Probabilities (H through Ne--A Critical Data Compilation)," Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.) 4, Vol. I (U.S. Government Printing Office, Washington, D.C., 1966).

2. W. L. Wiese, M. W. Smith, and B. M. Miles
"Atomic Transition Probabilities (Na through Ca--A Critical Data Compilation)," Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.) 22, Vol. II (U.S. Government Printing Office, Washington, D.C., 1969).

3. B. M. Miles and W. L. Wiese
"Critically Evaluated Transition Probabilities for Ba I and II," Nat. Bur. Stand. (U.S.) Tech. Note 474 (U.S. Government Printing Office, Washington, D.C., 1969); At. Data 1, 1-17 (1969).

4. M. W. Smith and W. L. Wiese
"Graphical Presentations of Systematic Trends of Atomic Oscillator Strengths Along Isoelectronic Sequences and New Oscillator Strengths Derived by Interpolation," Astrophys. J. Suppl. Ser. 23, #196, 103-192 (1971).

5. J. R. Fuhr, W. L. Wiese, and L. J. Roszman
"Bibliography on Atomic Line Shapes and Shifts (1889 through March 1972)," Nat. Bur. Stand. (U.S.) Spec. Publ. 366 (U.S. Government Printing Office, Washington, D.C., 1972).

6. M. W. Smith, G. A. Martin, and W. L. Wiese
"Systematic Trends and Atomic Oscillator Strengths," Nucl. Instrum. Methods 110, 219-226 (1973).

Publications List for Data Center on Atomic Transition Probabilities

7. M. W. Smith and W. L. Wiese
"Atomic Transition Probabilities for Forbidden Lines of the Iron Group Elements (A Critical Data Compilation for Selected Lines)," J. Phys. Chem. Ref. Data 2, 85-120 (1973).

8. J. R. Fuhr, L. J. Roszman, and W. L. Wiese
"Bibliography on Atomic Line Shapes and Shifts (April 1972 through June 1973)," Nat. Bur. Stand. (U.S.) Spec. Publ. 366, Suppl. 1 (U.S. Government Printing Office, Washington, D.C., 1974).

9. W. L. Wiese and J. R. Fuhr
"Atomic Transition Probabilities for Scandium and Titanium (A Critical Data Compilation of Allowed Lines)," J. Phys. Chem. Ref. Data 4, 263-352 (1975).

10. J. R. Fuhr, G. A. Martin, and B. J. Specht
"Bibliography on Atomic Line Shapes and Shifts (July 1973 through May 1975)," Nat. Bur. Stand. (U.S.) Spec. Publ. 366, Suppl. 2 (U.S. Government Printing Office, Washington, D.C., 1975).

11. N. Konjevic and W. L. Wiese
"Experimental Stark Widths and Shifts for Non-Hydrogenic Spectral Lines of Ionized Atoms (A Critical Review and Tabulation of Selected Data)," J. Phys. Chem. Ref. Data 5, 259-308 (1976).

12. N. Konjevic and J. R. Roberts
"A Critical Review of the Stark Widths and Shifts of Spectral Lines from Non-Hydrogenic Atoms," J. Phys. Chem. Ref. Data 5, 209-257 (1976).

13. G. A. Martin and W. L. Wiese
"Tables of Critically Evaluated Oscillator Strengths for the Lithium Isoelectronic Sequence," J. Phys. Chem. Ref. Data 5, 537-570 (1976).

14. W. L. Wiese and S. M. Younger
"Atomic Oscillator Strengths in Fusion Plasma Research," Beam-Foil Spectroscopy, Vol. 2, pp. 951-960 (Plenum Publishing Corp., New York, N.Y., 1976).

15. G. A. Martin and W. L. Wiese
"Atomic Oscillator Strength Distributions in Spectral Series of the Lithium Isoelectronic Sequence," Phys. Rev. A 13, 699-714 (1976).

Publications List for Data Center on Atomic Transition Probabilities

16. J. R. Fuhr, B. J. Miller, and G. A. Martin
"Bibliography on Atomic Transition Probabilities (1914 through October 1977)," Nat. Bur. Stand. (U.S.) Spec. Publ. 505 (U.S. Government Printing Office, Washington, D.C., Apr. 1978).

17. S. M. Younger, J. R. Fuhr, G. A. Martin, and W. L. Wiese
"Atomic Transition Probabilities for Vanadium, Chromium, and Manganese (A Critical Data Compilation of Allowed Lines)," J. Phys. Chem. Ref. Data 7, 495-630 (1978).

18. J. R. Fuhr, B. J. Miller, and G. A. Martin
"Bibliography on Atomic Line Shapes and Shifts (June 1975 through June 1978)," Nat. Bur. Stand. (U.S.) Spec. Publ. 366, Suppl. 3 (U.S. Government Printing Office, Washington, D.C., 1978).

19. W. L. Wiese
"Atomic Transition Probabilities and Lifetimes," Progress in Atomic Spectroscopy, Part B, Ch. 25, 1101-1155 (Eds., W. Hanle and H. Kleinpoppen, Plenum Publishing Corp., 1979).

20. B. J. Miller, J. R. Fuhr, and G. A. Martin
"Bibliography on Atomic Transition Probabilities (November 1977 through March 1980," Nat. Bur. Stand. (U.S.), Spec. Publ. 505, Suppl. 1 (U.S. Government Printing Office, Washington, D.C., Aug. 1980).

21. J. R. Fuhr, G. A. Martin, W. L. Wiese, and S. M. Younger
"Atomic Transition Probabilities for Iron, Cobalt, and Nickel (A Critical Data Compilation of Allowed Lines)," J. Phys. Chem. Ref. Data 10, 305-565 (1981).

22. W. L. Wiese and G. A. Martin
"Atomic Transition Probabilities," CRC Handbook of Chemistry and Physics, 61st Edition, E349-E384 (CRC Press, Inc., Boca Raton, Fla., 1980), 62nd Edition, E335-E370 (CRC Press, Inc., Boca Raton, Fla., 1981), 63rd Edition, E334-E369 (CRC Press, Inc., Boca Raton, Fla., 1982); also in "Wavelengths and Transition Probabilities for Atoms and Atomic Ions," Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.) 68, Part II, "Transition Probabilities" (U.S. Government Printing Office, Washington, D.C., 1980).

Appendix 11

Atomic Energy Levels Data Center

Room A155, Physics Building
National Bureau of Standards
Washington, D.C. 20234 (USA) - Tel. (301) 921-2011

Director: W. C. Martin

Staff: J. Sugar
A. Albright

Critical evaluation and compilation of data on atomic energy levels and spectra. Data on levels, g values, calculated eigenvectors, wavelengths and line classifications, ionization energies. Bibliographic files also include references for Zeeman effect, Stark effect, hyperfine structure, isotope shift, and related theoretical results.

Compilations of Energy Levels and Spectral Lines - recent work and outlook

New compilations of the energy levels for all the spectra of Fe (Fe I - XXVI) [1] and Co (Co I - XXVII) [2] have been published. Although compilations of the levels for the 235 iron-group spectra (K through Ni) by the NBS AEL Data Center have been published by element during the past five years, the single-volume collection of these levels now under preparation will incorporate fairly extensive additions and revisions for many of the spectra. A compilation of the levels for Si (Si I - XIV) has been completed and should appear early in 1983 [3].

The wavelength tables in the NSRDS-NBS volume "Wavelengths and Transition Probabilities for Atoms and Atomic Ions" [4] have about 47,000 lines arranged by spectrum and also in a finding list. The stronger lines of the first five spectra (I - V) of all elements are listed, the coverage extending over all wavelength regions. The first part of these tables (lines arranged by spectrum) are included in recent editions of the "CRC Handbook of Chemistry and Physics"; a few corrections are made in the latest edition [5] (notably the inclusion of 13 Fe lines near 2600 Å, 7 of them belonging to the Fe II UV multiplet No. 1, erroneously omitted in the earlier tables).

The NBS AEL Data Center maintains a current bibliographic file covering publications on energy levels, wavelengths, line classifications, and several other categories of atomic spectroscopic data. The next in a series of bibliographies published from these files will cover the literature from June 1979, through a date not yet decided.

REFERENCES

[1] Corliss, C., and Sugar, J., [1982], J. Phys. Chem. Ref. Data 11, 135-241.

[2] Sugar, J., and Corliss, C. [1981], J. Phys. Chem. Ref. Data 10, 1097-1174.

[3] Martin, W. C., and Zalubas, R. [1983], J. Phys. Chem. Ref. Data, to be published.

[4] Reader, J., Corliss, C. H., Wiese, W. L., and Martin, G. A. [1980], "Wavelengths and Transition Probabilities for Atoms and Atomic Ions," NSRDS-NBS 68, 415 pp. Available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, U.S.A. (Price $14).

[5] Reader, J., and Corliss, C. H., Eds. [1982], "Line Spectra of the Elements," CRC Handbook of Chemistry and Physics, 63rd Edition, R. C. Weast, Ed., CRC Press, Boca Raton, FL, U.S.A.

References for Atomic Energy Levels (arranged by spectra)

* H I, D, T (1972) [13]
He I (1973) [14]
C I-VI (1970) [8]
* N I-III (1975) [18]
* N IV-VII (1971) [10]
* O I (1976) [19]
* O IV (1982) [39]
* O V (1980) [31]
* O VI-VIII (1979) [28]
Na I-XI (1981) [35]
Mg I-XII (1980) [30]
Al I-XIII (1979) [27]
* Si I (1967) [2]
* Si II-IV (1965) [1]
K I-XIX (1979) [25]
Ca I-XX (1979) [29]
Sc I-XXI (1980) [32]

Ti I-XXII (1979) [26]
V I-XXIII (1978) [24]
Cr I-XXIV (1977) [22]
Mn I-XXV (1977) [20]
Fe I-XXVI (1982) [38]
Co I-XXVII (1981) [37]
Ni I-XXVIII (1981) [36]

Rare Earths, La-Lu (Z=57-71) (1978) [23]

Older Data: AEL Vols I, II, III [9]

H - V (Z=1-23) (1949, reissued 1971)
Cr - Nb (Z=24-41) (1952, reissued 1971)
Mo - La (Z=42-57) (1958, reissued 1971)
Hf - Ac (Z=72-89) (1958, reissued 1971)

Wavelength Tables, Multiplet Tables

[3] - Ultraviolet Multiplet Tables originally issued 1950-1952.

[12] - Multiplet Tables originally issued in 1945.

[15] - Reference Wavelengths, 15 Å to 25000 Å.

[17] - Has 39,000 lines of 70 elements, mainly first and second spectra, arranged by element and in a finding list, 2000 - 9000 Å.

[34] - Has 47,000 lines, first through fifth spectra of all elements, by spectra and in a finding list, all wavelength regions.

[40] - The first part of the tables in [34], with the lines arranged by spectra, were published in the 60th (1979) and later editions of the CRC Handbook. Some corrections have been included in the 63rd edition.

Bibliographies

[4], [6], [11], [21], [33] - Cover literature since AEL I-III through June 1979.

Computer-readable Data

The data in most of the listed publications exist in computer-readable form. The details (most appropriate supplier, formats, etc.) are different for several different types of publications. Inquiries may be addressed to the AEL Data Center.

Data for the spectra preceded by an asterisk are compiled in C. E. Moore's series "Selected Tables of Atomic Spectra," which include a multiplet table for each spectrum.

The numbers in brackets in the sections below refer to the publications list at the end.

Some Publications Issued or Reprinted Since 1965

1. Moore, C. E., "Selected Tables of Atomic Spectra" (Si II-IV), Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.) 3, Sec. 1, U.S. Government Printing Office, Washington, D.C. (1965).

2. Moore, C. E., "Selected Tables of Atomic Spectra" (Si I), Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.) 3, Sec. 2, U.S. Government Printing Office, Washington, D.C. (1967).

3. Moore, C. E., "An Ultraviolet Multiplet Table", Nat. Bur. Stand. (U.S.), Circ. 488, Sec. 1 (1950) and Sec. 2 (1952); Secs. 3, 4, 5 (1962), U.S. Government Printing Office, Washington, D.C. (reprinted 1968).

4. Moore, C. E., "Bibliography on the Analyses of Optical Atomic Spectra", Nat. Bur. Stand. (U.S.), Spec. Publ. 306, Sec. 1, U.S. Government Printing Office, Washington, D.C. (1968).

5. Moore, C. E., and Merrill, P. W., "Partial Grotrian Diagrams of Astrophysical Interest", Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.) 23, U.S. Government Printing Office, Washington, D.C. (1968).

6. Moore, C. E., "Bibliography on the Analyses of Optical Atomic Spectra", Nat. Bur. Stand. (U.S.), Spec. Publ. 306, Sec. 2, Sec. 3, and Sec. 4, U.S. Government Printing Office, Washington, D.C. (1969).

7. Moore, C. E., "Ionization Potentials and Ionization Limits Derived from the Analyses of Optical Spectra", Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.) 34, U.S. Government Printing Office, Washington, D.C. (1970).

8. Moore, C. E., "Selected Tables of Atomic Spectra" (C I-VI), Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.) 3, Sec. 3, U.S. Government Printing Office, Washington, D.C. (1970).

9. Moore, C. E., "Atomic Energy Levels", Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.) 35, Vol. I, Vol. II, and Vol. III, U.S. Government Printing Office, Washington, D.C. (1971). (Reprint of NBS Circ. 467, originally issued in 1949, 1952, and 1958).

10. Moore, C. E., "Selected Tables of Atomic Spectra" (N IV-VII), Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.) 3, Sec. 4, U.S. Government Printing Office, Washington, D.C. (1971).

11. Hagan, L., and Martin, W. C., "Bibliography on Atomic Energy Levels and Spectra, July 1968 through June 1971", Nat. Bur. Stand. (U.S.), Spec. Publ. 363, U.S. Government Printing Office, Washington, D.C. (1972).

12. Moore, C. E., "A Multiplet Table of Astrophysical Interest", Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.) 40, U.S. Government Printing Office, Washington, D.C. (1972). (A reprint of Contrib. Princeton Univ. Obs. No. 20, 1945).

13. Moore, C. E., "Selected Tables of Atomic Spectra" (H I, D, T), Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.) 3, Sec. 6, U.S. Government Printing Office, Washington, D.C. (1972).

14. Martin, W. C., "Energy Levels of Neutral Helium (^{4}He I)", J. Phys. Chem. Ref. Data 2, 257-266 (1973).

15. Kaufman, V., and Edlén, B., "Reference Wavelengths from Atomic Spectra in the Range 15 Å to 25000 Å", J. Phys. Chem. Ref. Data 3, 825-895 (1974).

16. Martin, W. C., Hagan, L., Reader, J., and Sugar, J., "Ground Levels and Ionization Potentials for Lanthanide and Actinide Atoms and Ions", J. Phys. Chem. Ref. Data 3, 771-780 (1974).

17. Meggers, W. F., Corliss, C. H., and Scribner, B. F., "Tables of Spectral-Line Intensities, Part I - Arranged by Elements, Part II - Arranged by Wavelengths", Nat. Bur. Stand. (U.S.), Monogr. 145, U.S. Government Printing Office, Washington, D.C. (1975).

18. Moore, C. E., "Selected Tables of Atomic Spectra" (N I-III), Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.) 3, Sec. 5, U.S. Government Printing Office, Washington, D.C. (1975).

19. Moore, C. E., "Selected Tables of Atomic Spectra" (O I), Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.) 3, Sec. 7, U.S. Government Printing Office, Washington, D.C. (1976).

20. Corliss, C., and Sugar, J., "Energy Levels of Manganese, Mn I through Mn XXV", J. Phys. Chem. Ref. Data 6, 1253-1329 (1977).

21. Hagan, L., "Bibliography on Atomic Energy Levels and Spectra, July 1971 through June 1975", Nat. Bur. Stand. (U.S.), Spec. Publ. 363, Suppl. 1, U.S. Government Printing Office, Washington, D.C. (1977).

22. Sugar, J., and Corliss, C., "Energy Levels of Chromium, Cr I through Cr XXIV", J. Phys. Chem. Ref. Data 6, 317-383 (1977).

23. Martin, W. C., Zalubas, R., and Hagan, L., "Atomic Energy Levels--The Rare-Earth Elements", Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.) 60, U.S. Government Printing Office, Washington, D.C. (1978).

24. Sugar, J., and Corliss, C., "Energy Levels of Vanadium, V I through V XXIII", J. Phys. Chem. Ref. Data 7, 1191-1262 (1978).

25. Corliss, C. and Sugar, J., "Energy Levels of Potassium, K I through K XIX", J. Phys. Chem. Ref. Data 8, 1109-1145 (1979).

26. Corliss, C. and Sugar, J., "Energy Levels of Titanium, Ti I through Ti XXII", J. Phys. Chem. Ref. Data 8, 1-62 (1979).

27. Martin, W. C. and Zalubas, R., "Energy Levels of Aluminum, Al I through Al XIII", J. Phys. Chem. Ref. Data 8, 817-864 (1979).

28. Moore, C. E., "Selected Tables of Atomic Spectra" (O VI-VIII), Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.) 3, Sec. 8, U.S. Government Printing Office, Washington, D.C. (1979).

29. Sugar, J., and Corliss, C., "Energy Levels of Calcium, Ca I through Ca XX", J. Phys. Chem. Ref. Data 8, 865-916 (1979).

30. Martin, W. C., and Zalubas, R., "Energy Levels of Magnesium, Mg I through Mg XII", J. Phys. Chem. Ref. Data 9, 1-58 (1980).

31. Moore, C. E., "Selected Tables of Atomic Spectra" (O V), Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.) 3, Sec. 9, U.S. Government Printing Office, Washington, D. C. (1980).

32. Sugar, J., and Corliss, C., "Energy Levels of Scandium, Sc I through Sc XXI", J. Phys. Chem. Ref. Data 9, 473-511 (1980).

33. Zalubas, R., and Albright, A., "Bibliography on Atomic Energy Levels and Spectra, July 1975 through June 1979", Nat. Bur. Stand. (U.S.), Spec. Publ. 363, Suppl. 2, U.S. Government Printing Office, Washington, D.C. (1980).

34. Reader, J., Corliss, C. H., Wiese, W. L., and Martin, G. A., "Wavelengths and Transition Probabilities for Atoms and Atomic Ions, Part I. Wavelengths, Part II. Transition Probabilities", Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.) 68, U.S. Government Printing Office, Washington, D.C. (1980).

35. Martin, W. C., and Zalubas, R. "Energy Levels of Sodium, Na I through Na XI", J. Phys. Chem. Ref. Data 10, 153-195 (1981).

36. Corliss, C. and Sugar, J., "Energy Levels of Nickel, Ni I through Ni XXVIII", J. Phys. Chem. Ref. Data 10, 197-289 (1981).

37. Sugar, J., and Corliss, C., "Energy Levels of Cobalt, Co I through Co XXVII", J. Phys. Chem. Ref. Data 10, 1097-1174 (1981).

38. Corliss, C., and Sugar, J., "Energy Levels of Iron, Fe I through Fe XXVI", J. Phys. Chem. Ref. Data 11, 135-241 (1982).

39. Moore, C. E., "Selected Tables of Atomic Spectra" (O IV), Nat. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.) 3, Sec. 10, U.S. Government Printing Office, Washington, D.C. (1982).

40. Reader, J., and Corliss, C. H., Eds., "Line Spectra of the Elements," CRC Handbook of Chemistry and Physics, 63rd Edition, R. C. Weast, Ed., CRC Press, Boca Raton, FL, 1982.

Appendix 12

JOINT INSTITUTE FOR LABORATORY ASTROPHYSICS

UNIVERSITY OF COLORADO
BOULDER, COLORADO 80309

UNIVERSITY OF COLORADO

NATIONAL BUREAU OF STANDARDS

19 October 1982

JILA Atomic Collisions Cross Sections Data Center

Projects recently completed:

1. "A Compilation of Rate Coefficients for Vibrational Energy Transfer Involving the Hydrogen Halides," S. R. Leone, JCPRD (to be published), 1982.

2. "An Annotated Compilation and Appraisal of Electron Swarm Data in Electro-Negative Gases," J. W. Gallagher, E. C. Beaty, J. Dutton, and L. C. Pitchford, JCPRD (to be published), 1983.

3. "Evaluated Theoretical Cross Section Data for Charge Exchange of Multiply Charged Ions with Atoms.
   I. Hydrogen Atom-Fully Stripped Ion Systems.
   II. Hydrogen Atom-Partially Stripped Ion Systems," R. K. Janev, B. H. Bransden, J. W. Gallagher, JCPRD (submitted).

4. "Differential Cross Sections for Elastic Scattering of Electrons by Atomic Targets. I. Experimental Data for Helium and Atomic Hydrogen," J. A. Rees, E. C. Beaty, J. W. Gallagher, JCPRD (submitted).

Projects planned for the near future:

1. Tabulation of collision strengths for ions of astrophysical interest, J. M. Shull.

2. "Evaluated Theoretical Charge Transfer Cross Sections. III. Atom (Z 2)-Ion Systems," R. K. Janev and J. W. Gallagher.

3. "Differential Elastic Scattering of Electrons by Atomic Targets. II. Alkalis, Mercury, Other Metals. III. Rare Gases," J. A. Rees, E. C. Beaty, J. W. Gallagher.

4. A critical evaluation of secondary electron spectra. I. He, Y.-K. Kim.

5. Update on the review of atomic electron affinities, W. C. Lineberger.

6. Data survey and review of inelastic collision cross sections and scaling laws in the diatomic halogens, J. I. Steinfeld.

7. Review of data on proton impact ionization of gaseous targets, M. E. Rudd.

8. Review of electron impact excitation of atomic gases.

9. On-line data base for electron impact data.

Cable Address: JILA

Telephone Number: 492-7789

Appendix 13

Progress Report of the IAEA A+M Data Unit for the period February 1981 - October 1982

A. Lorenz

A. A+M Data Unit Staff

1. Staff Changes

Since the last meeting of the A+M Data IFRC Subcommittee, R.A. Langley who was the head of the A+M Data Unit from August 1980 until November 1981, returned to the ORNL in the USA at the end of 1981. Because of the need to introduce a change in the programmatic emphasis in the Nuclear Data Section, at that time, requiring a staff reorganization, A. Lorenz was appointed head of the A+M Data Unit. The other professional staff of the Unit, K. Katsonis and D. Gremillet, has remained the same during this reporting period. Two new clerical staff, K. Sheikh (data processing clerk) and E. Baumgartner (secretary), make up the complement of five in the A+M Data Unit.

2. Attendance of non-IAEA Meetings

External, non-IAEA, meetings attended and laboratories visited by the A+M Data Unit staff, are listed in Annex 1 to this report.

B. Bibliographic A+M Data

1. Status of the A+M Bibliographic Data Base (A+M/BDB)

The A+M Bibliographic Data Base (A+M/BDB) consists of a computerized file of references to publications on atomic and molecular data relevant to fusion. It includes references to atomic collision data, structure and spectra data, surface interaction data and general references pertinent to A+M data for fusion. All reference citations stored in the A+M/BDB are indexed with respect to their content, so as to allow selective retrieval from the data base and the production of special publications (e.g. Quarterly A+M Data Bulletin, CIAMDA, etc.).

The computer system of the A+M/BDB which supersedes all earlier computer programmes generated for the production of the A+M Data Bulletin and of CIAMDA, is now completed, and all bibliographic data which existed in the past in separate files (i.e. CIAMDA and Bulletin) have been cleaned up and converted to the new system. A general description of the A+M/BDB is contained in a separate report presented to this meeting, and the Input and Update Procedures of this system are described in IAEA-NDS-AM-12 (report to be published).

2. Updating of the A+M/BDB

The A+M/BDB is updated quarterly, corresponding to the production of the International Bulletin on A+M Data for Fusion. At the present time, a total of 137 journals are systematically scanned to provide the input for the update; this is supplemented by information received from correpsondents and reference citations provided by other centres.

3. Publication of the A+M Data Bulletin

The IAEA Bulletin has continued to be published regularly on a quarterly basis. This year, the Bulletin was issued in February (No. 18), June (No. 19), September (No. 20) and foreseeably in December (No. 21). It is distributed to 1105 scientists in 26 Member States and International organizations.

4. Publication of CIAMDA

The date of the next publication of CIAMDA depends on two factors,

- the status of the CIAMDA 80 sales, and
- the number of new indexation lines entered since the publication of CIAMDA 80.

In addition to the limited number of copies distributed free of charge, the Agency has sold 521 copies in 1980-1981, and 14 copies in 1982; 130 copies are still in stock. Although the total sales for this document are considered good by IAEA standards, it is questionable whether the IAEA Publications Committee will agree to a new publication with 130 copies of the old publication still in stock, unless the new product would be considerably different from the old one. With regard to this point, approximately 660 new reference citations for collision data have been entered into the system since the publication of CIAMDA 80, which is approximately 5 % of the total content of CIAMDA 80. Under these circumstances, a new CIAMDA publication is not warranted at the present time. It is suggested to re-assess the justification to publish a new CIAMDA in two years time (i.e. at the next meeting of the IFRC Subcommittee).

5. Selective Retrievals from the A+M/BDB

To supplement the information published in CIAMDA 80 and in the individual issues of the Bulletin, it is now possible, with the conversion to the A+M/BDB system, to perform selective retrievals from the complete bibliographic data base on request from individual users. Such retrievals would also serve as tests of completion made on the basis of feed-back received from the users. The retrievals could be made on all of the indexed information, including "structure and spectra", "collisions" and "surface interactions". It is proposed to inform the readers of the Bulletin of this new service in each of the future issues of the Bulletin.

C. Numerical A+M Data

1. Coordinated Research Programme on Atomic Collision Data for Diagnostics of Magnetic Fusion Plasmas (Atomic Collision Data CRP)

Following the review of the Agency's A+M Data Programme by the IFRC Subcommittee on A+M Data for Fusion in January 1981, the objectives of the CRP on Atomic Collision Data were reoriented so as to comply with the recommendations of the Subcommittee, namely "that the effort in this CRP concentrate on the calculation and evaluation of the required data". The collision processes which were to be emphasized by the CRP were those which the Subcommittee identified to have the highest priority (INDC(SEC)-77/GA), namely

- electron impact ionization
- electron excitation, and
- electron capture.

With the view to determine more specifically the data types which the CRP should cover and to establish an order of priority among the needed data, the A+M Data Unit, using the recommendations of the May 1980 IAEA Technical Committee Meeting on A+M Data for Fusion (reference: Physica Scripta 23 69 (1981) 206-209), formulated a questionnaire and conducted a survey among the fusion research community. The results of this questionnaire are summarized in the Summary Report of the first meeting of the CRP (INDC(NDS)-136/GA). The emphasis of the CRP is thus based on the initial IFRC subcommittee recommendation and on the results of the Data Priority Questionnaire.

The first meeting of the participants in the IAEA Coordinated Research Programme (CRP) on Atomic Collision Data for Diagnostics of Magnetic Fusion Plasmas was convened by the IAEA Nuclear Data Section on 21-25 June 1982 at IAEA Headquarters in Vienna. The meeting was chaired by A. Lorenz with the assistance of three co-chairmen: M.R.C. McDowell, H.B. Gilbody and G. Dunn. The Scientific Secretary of the meeting was K. Katsonis.

The CRP reviewed the overall status of electron collision data of importance to the diagnostics of magnetic fusion plasmas. In reviewing these data from the point of view of reliability and presently accepted accuracies, the CRP could identify only certain electron impact ionization data which could be recommended to be used by the fusion community at this time. The accuracy of these data could be taken to be $\pm$ 10 % (see section C.2. below).

The summary report of this meeting (INDC(NDS)-136/GA) will be distributed at the IFRC Subcommittee meeting, and is to be published in November 1982.

2. Recommended A+M Collision Data

The electron impact ionization data recommended by the Atomic Collision CRP, consists of the ionization cross sections of all species for Z = 1-8, including all ionization stages, generated by the Belfast report CLM-R 216), and for $Z > 8$, of data measured in recent cross-beam measurements. A list of these data (taken from the Summary Report of the CRP Meeting) is given in Table I.

The data for Z   8, which have been identified by the CRP as the best currently available, are proposed to be recommended data, and are not "evaluated data". The Z = 1-8 data, generated by the Belfast group are "evaluated", in the sense that these were derived from an assessment of all existing numerical data and complemented by theory.

The ionization data generated by the Belfast group, and published in the CLM-R 216, is part of the Belfast Data base on Atomic and Molecular Physics. This data base is kept up-to-date at Queen's University, Belfast, and at the Daresbury Laboratory.

3. International Numerical Data Base

As a first step in the establishment of an international base for the storage and exchange of numerical A+M collision data, the A+M Data Unit, with the cooperation of the Queen's University Computer Science Department staff, has made the Belfast system operable at the IAEA.

The data stored in this system at IAEA, consists of the evaluated Belfast data (Z = 1-8) as published in the CLM-R 216 report, which was transmitted to us from Belfast, and most of the $Z > 8$ data listed in Table I, which will be entered into this system by the A+M Data Unit.

It has been agreed with the Queen's University Computer Science Department to pursue the further development of the system itself, as well as the exchange of data which either Belfast or IAEA adds to the data base.

4. Coordinated Research Programme for the Evaluation of Atomic Data Pertinent to Plasma-wall Interaction Processes (Plasma-Surface Data CRP)

The Plasma-Surface Data CRP, conducted by R.A. Langley, was a one year project which was completed during calendar year 1981. The compendium of data for plasma-surface interaction (summarized in Annex 2) which resulted from this CRP is to be published in a special issue of the Agency's Nuclear Fusion Journal.

5. A+M Data for Fusion Plasma Modelling

A consultants' meeting on Computer Codes for Fusion Research, convened by the IAEA Physics Section in December 1979, identified the appreciable need for atomic physics data used as input to computer codes designed for the computation of fusion plasma models.

In an effort to identify these data users and what data they use, and to initiate an activity which would eventually lead to an atomic data library, providing a common data base for the calculations performed by these modelling groups, the A+M Data Unit sent a circular letter to 60 scientists, identified by the original participants in the 1979 consultants' meeting. The response was 30 %. The information sent back to us has not yet been fully analyzed; in a number of cases new names have been suggested, which will require follow-up letters to be sent.

Table I

Electron Impact Ionization Data Proposed to be Recommended

Z = 1 - 8

Evaluated cross sections of all species, from hydrogen to oxygen, including all stages of ionization, with the exception of Be^+ and C^{3+}, published by Bell et al., (Culham report CLM-R216 (1982)), are proposed to be recommended.

Z = 9 - 18

In this Z range reasonable sets of cross sections could be generated based on prediction formulae and more accurate calculations. At present, the following cross-beam measurement results (with an uncertainty of about 10%) are proposed to be recommended:

Na^+	Peart and Dolder, J. Phys. B2 1 (1968)
Mg^+	Martin, et al., J. Phys. B2 1 (1968) 537
Mg^+	Crandall et al., Phys. Rev. A 25 (1982) 143
Mg^{2+}	Peart, et al., J. Phys. B 2 (1969) 1176
Al^+	Belic, et al., Priv. Comm. (1982)
Al^{2+} Si^{3+}	Crandall, et al., Phys. Rev. A 25 (1982) 143
Ar^+ Ar^{2+} Ar^{3+} Ar^{4+}	Mueller, et al., J. Phys. B 13 (1980) 1877
Ne^+	Dolder, et al., Proc.Roy.Soc. A 274 (1963) 546
Ne^{3+}	Gregory, Dittner and Crandall, Priv. Comm. (1982)

Z = 19 - 102

For Z 19, with the exception of a few good cross-beam measurements, no recommended cross sections can be proposed. Those proposed to be recommended, having a 10% uncertainty, are

K^+	Peart and Dolder, J.Phys. B2 1 (1968) 240
Ca^+	Peart and Dolder, J.Phys. B 8 (1975) 56
Ti^{3+}	Falk, et al., Phys.Rev.Lett. 47 (1981) 494
Zn^+ Ga^+	Rogers, et al., Phys.Rev. A 25 (1982) 737
Kr^{3+}	Gregory, Dittner and Crandall, Priv. Comm. (1982)
Rb^+ Sr^+ Cs^+	Peart and Dolder, J.Phys. B 8 (1975) 56
Zr^{3+} Hf^{3+} Ta^{3+}	Falk, et al., Phys.Rev.Lett. 47 (1981) 494
Cd^+ Hg^+	Belic, et al., Priv. Comm. (1982)
Xe^+	Mueller, et al., J.Phys. B 13 (1980) 1877
Xe^{3+}	Gregory, Dittner and Crandall, Priv. Comm. (1982)
Ba^+	Peart, et al., J. Phys. B 6 (1973) 146
Tl^+	Divine, et al., Phys.Rev. A 13 (1976) 54

Annex 1

A. Meetings attended by A+M staff (Feb. 81 - Oct. 82)

- International Seminar of High-Energy Ion-Atom Collision Processes, Debrecen, Hungary, 17-19 March 1981 (K. Katsonis)
- 9th International Conference on Atomic Collisions in Solids, Lyon, France, 5-10 July 1981 (R.A. Langley)
- XII International Conference on the Physics of Electronic and Atomic Collisions (ICPEAC), Gatlinburg, Tennessee, USA, 15 July - 21 July 1981 (K. Katsonis)
- Xth European Conference on Controlled Fusion and Plasma Physics, Moscow, 14-19 September 1981, (R.A. Langley)
- Symposium on Atomic and Surface Physics (SASP), 7-13 February 1982, Maria Alm-Hintermoos, Austria (K. Katsonis)
- Winter School on Atomic Physics of Hot Plasmas with Application to Fusion Plasma Diagnostics, Les Houches, France, 1-13 March 1982 (K. Katsonis)
- European Sectional Conference on Atomic and Molecular Physics of Ionized Gases (6th ESCAMPIG), Oxford, UK, 1-3 September 1982 (K. Katsonis)

B. Laboratories visited by A+M staff (Feb. 81 - Oct. 82)

- Institute for Plasma Physics, Max-Planck Institute, Garching, FRG, 11-15 May 1981 (R.A. Langley)
- Institute of Physics, Beograd, Yugoslavia, June 1981 (R.A. Langley)
- KFA, Jülich (FRG), Hahn-Meitner Institute (West Berlin), FOM Institute, Amsterdam (The Netherlands), Culham and JET Laboratories, Oxford (UK), Fontenay-aux-Roses (France), 15 June - 2 July 1981 (R.A. Langley)
- Institute of High Temperature of the Academy of Sciences, Moscow, the Kurchatov Institute of Atomic Energy, Moscow, and the Ioffe Institute of the Academy of Sciences, Leningrad, September 1981 (R.A. Langley)
- Visit to the Laboratoire de Physique des Plasmas of the University of Paris, France, 11-13 and 16 January 1982 and to the EURATOM-CEA Association Fusion Laboratory at Fontenay-aux-Roses, France, January 1982 (K. Katsonis)
- Fusion Research Department of CEN Laboratory in Grenoble, France, 15 March 1982 (K. Katsonis)
- Culham Laboratory, JET Joint Undertaking, and Royal Holloway College, University of London, Egham Hill, UK, August 1982 (K. Katsonis)
- Institute of Physics, University of Belgrade, Yugoslavia, 28-30 September 1982 (K. Katsonis)

Annex 2

Data Compendium for Plasma-Surface Interactions

Abstract

Reviews of particle-solid processes pertinent to modelling plasma-wall interactions are presented and sets of recommended data are given. Analytic formulas are used where possible otherwise data are presented in the form of tables and graphs. The incident particles considered are e^-, H, D, T, He, C, O and self ions. The materials include the metals: aluminium, copper, molybdenum, stainless steel, titanium and tungsten and the non-metals: carbon and TiC.

Content

Appendix 14

D. Gremillet
18 October 1982

The IAEA A+M Bibliographic Data Base

I. Introduction

The Atomic and Molecular (A+M) Data Unit of the IAEA Nuclear Data Section was formed in 1977 with the objective of coordinating the compilation and evaluation of bibliographic and numerical atomic and molecular data for controlled fusion research, and of publishing and disseminating these data.

As the first step in this direction, the IAEA convened a meeting of atomic and fusion physicists at the Culham Laboratory in 1976, for the purpose of reviewing the requirements of the A+M data for fusion research. At that meeting it was recommended that the IAEA "Compile and publish international computerized indexes to the literature on atomic and molecular collision, structure and surface interaction data pertinent to fusion research". To implement this recommendation, the A+M Data Unit initiated the development of computerized systems that were designed for bibliographic data storage and for computerized production of bibliographic data indexes.

Initially two separate systems were developed: one for the production of the CIAMDA, data index, and the other for the production of the quarterly A+M Data Bulletin.

The system developed for the production of CIAMDA, was designed primarily for the merging of four separate existing data bases, and for the final publication of one homegeneous data index. This resulted in the publication of CIAMDA 80 in June 1980. The content of this data base consisted of approximately 13000 citations to references dealing with A+M collision data, which were extracted from:

- The comprehensive bibliographic file of atomic processes, compiled at the Oak Ridge National Laboratory, USA,

- The bibliographic files on electron, photon and heavy particle collisions, compiled at the Joint Institute for Laboratory Astrophysics in the U.S.A.

- The GAPHYOR bibliographic file on the properties of neutral and ionized atoms, compiled at the Laboratoire de Physique des Gaz et des Plasmas, at Orsay, France, and

- The bibliographic A+M physics data file of the Queen's University of Belfast, UK,

These were supplemented by contribution from Japan and the USSR, and with the current material compiled by the IAEA A+M Data Unit.

In parallel, another system was developed for the production of the Quarterly International Bulletin on Atomic and Molecular Data for Fusion. This data base has been periodically updated with new references compiled by the A+M Data Unit from the current literature since the beginning of this activity in 1977.

Both systems had essentially the same internal structure, but they were developed separately for two main reasons. The CIAMDA system was intended primarily for the storage of collision data only, while the scope of the A+M bulletin is wider. The bulletin file was updated on a continuous basis, through a regular procedure, while the CIAMDA data base built up from contributions outside the IAEA, in diverse formats, and major problems had to be resolved in order to convert these data from their original formats into a unique common format.

Although the two systems were operational at the time of the publication of CIAMDA, in June 1980, their storage format was complicated and over-coded, corrections were difficult to perform, and selective retrieval operations were impossible. Besides, any exchange of our data with other data centers would have been very difficult or impossible.

In order to alleviate this situation, a completely new data base system, including the logical organization and all the procedures for the management and update of the data base, was designed in February 1981 and operational in June 1981. Since then both the CIAMDA data base and the Bulletin data base were merged together forming a single data base which now offers the following advantages:

- The data in the new format are easily exchangeable with any data center,
- The files are 100% people-readable: it is possible to get them on visual display units (screens), and read them and correct them on-line,
- The logic of the whole system was revised so as to allow a greater flexibility in the data base use,
- Selective retrieval can be performed on the complete data base,

The content of the new data base has the same physics scope as the International Bulletin on Atomic and Molecular Data for Fusion. The data base presently contains 17147 citations. About 13500 of these citations are references to A+M collision data.

II. The A+M Bibliographic data base (A+M/BDB)

A. A+M/BDB Content

The new A+M/BDB consists of the complete CIAMDA data base and of the input of all Bulletins issued to-date. It is subdivided into the following subject categories:

- Structure and Spectra (spectral indentification, energy levels, ionization potentials, wavelengths, transition probabilities, oscillator strengths, lifetimes, broadening: line shapes and shifts, polorizabilities, electric moments, interatomic potentials),
- Collision (photon, electron, heavy particle),
- Surface interaction,
- Plasma diagnostics,
- Plasma composition, impurities,
- Plasma heating, cooling, fueling,
- Plasma theory, models,
- Fusion research of general interest,
- Interactions of Lasers or Multiphotons with Atoms or Molecules,
- Data, bibliographies, progress reports.

B. A+M/BDB Input and Update Procedures

The input coding rules and the update procedures of the A+M/BDB, are described in considerable detail in IAEA-NDS-AM 12, which is designed primarily as a guide for preparing the input to this data base.

C. Logical organization

The data base consists of two logically and physically separated files: a bibliographic file and a searchable file.

- The bibliographic file consists of the complete collection of reference citations. These citations contain normal bibliographic information: author(s), title, reference, and an optional abstract and/or comment. The bibliographic file is used exclusively to produce the printed output.

- The searchable file contains coded records describing the physics content of the reference citations stored in the bibliographic file, e.g., reactants, process, energies, etc. Using these coded descriptions (one in a record), this file is used to retrieve selectively from the bibliographic file.

Each "citation" in the bibliographic file is associated with one or more descriptive records in the searchable file.

This organization logically and physically separates the data selection (retrievals) from the output operation, and provides a usefull flexibility for the selective retrieval of information. For instance a retrieval operation can extract from the searchable file a subset of descriptive records. If the subset does not satisfy the given criteria, it can be further processed with new criteria. Two or more subsets can be combined, and the data can be manipulated as long as the retrieval criteria are not satisfied before any output is processed.

The system also has the capability to screen collision data with respect to given physics criteria. One such criterion was designed to apply the so-called Procrustes fusion-relevance criterion. Such criteria are coded in a special file that the system refers to at the time of the data screening. It is therefore possible to add any other physics screening by simply providing new appropriate criteria.

To summarize:

- any selection of any level of complexity, can be performed on the searchable file.

- any data can be screened on the basis of specific physics criteria. This screening removes the data that do not comply with the screening criteria.

- selection and screening can be applied in any sequence any number of times. This allows data to be manipulated as long as the proper subset of data is not obtained, and provides a very usefull flexibility in the performance of retrievals.

- The finally selected data are then printed out together with the appropriate bibliography. The complete bibliographic file is therefore consulted only once, after the retrieval is completed.

III. Retrieval capabilities

A retrieval is generally made on the basis of physics criteria (reactants, process...etc), but it can also be made on the basis of bibliographic information, such as the reference or the date of publication.

The data fields that can be retrieved on are the following:

1. Process code: process describing the collision, or surface interaction (such as "ionization" or "trapping, detrapping"), or subdivision of the structure and spectra general category (such as "interatomic potentials"), or general categories such as plasma diagnostics...etc. A complete list of existing process codes, which can be used for retrievals, is given in Annex I.

2. Data generation method: experimental data, theoretical data,...

3. Energy range: it is possible to select either on the lowest or highest energy boundary, or both,

4. Reactant identification for structure and spectra, and collision data:

   - particle, molecule, element or range of elements,
   - ionization state (Na^+ can be distinguished from Na or Na^{+2}...etc)
   - excitation state (H can be distinguished from H*, H^{+*}), and
   - homonuclear and isoelectronic sequences can be retrieved for any element (or series of them)

   All these retrieval capabilities are separately available for both "reactants" in case of collisions or interatomic potentials.

5. Surface interactions. This indexation is described by three "components": the incoming particles (up to 4), the definition of the surfaces (up to 5) and the outgoing particles (up to 4).

   a) The system can retrieve separately on each of the 5 surfaces which can be simple element symbols chemical notations for materials (Al203), or conventional material identifications (SS304).

   b) The retrieval can also be made on any of the four incoming or the four outgoing particles, in which case it is possible to specify:

      -the particle, molecule or element (no atomic sequences)
      -the ionization state (no homonuclear sequences)
      -the excitation state

6. Additionally it is also possible to retrieve on the following reference subfields:

-journals, reports, books, or thesis
-journal names or country and/or a laboratory or institute
-volume number or report numbers (eventually page)
-year of publication

The retrievals can be performed on any of these subfields or on any combination of them. It is possible to fix values, or a range of values, or to exclude values. For instance a retrieval can select all reactions involving as projectile or as target, any one element, any atom in a given Z-range, an entire Z-range or an element in an isoelectronic sequence. Or the retrieval can reject all reactions for a given element or molecule. Subfields that are not assigned values by the retrieval criteria will have any possible value in the retrieved data.

Any retrieval procedure can be made of up to 10 different retrieval criteria. Each retrieval criterion can be made of up to 10 different sub-criteria; in that case a descriptive record will be selected out if, and only if, it satisfies the 10 sub-criteria simultaneously.

If n retrieval criteria are processed in the same run, the selected records can be kept in n separate subsets or can be combined, leading to q subsets ($q < n$). This last case is equivalent to a logical OR between the retrievals. For instance, to retrieve all references dealing with Be and C, pertaining to charge transfer, published in the UK before 1980 would require only one retrieval run, made of a only one retrieval criterion.

ANNEX I

Process Dictionary

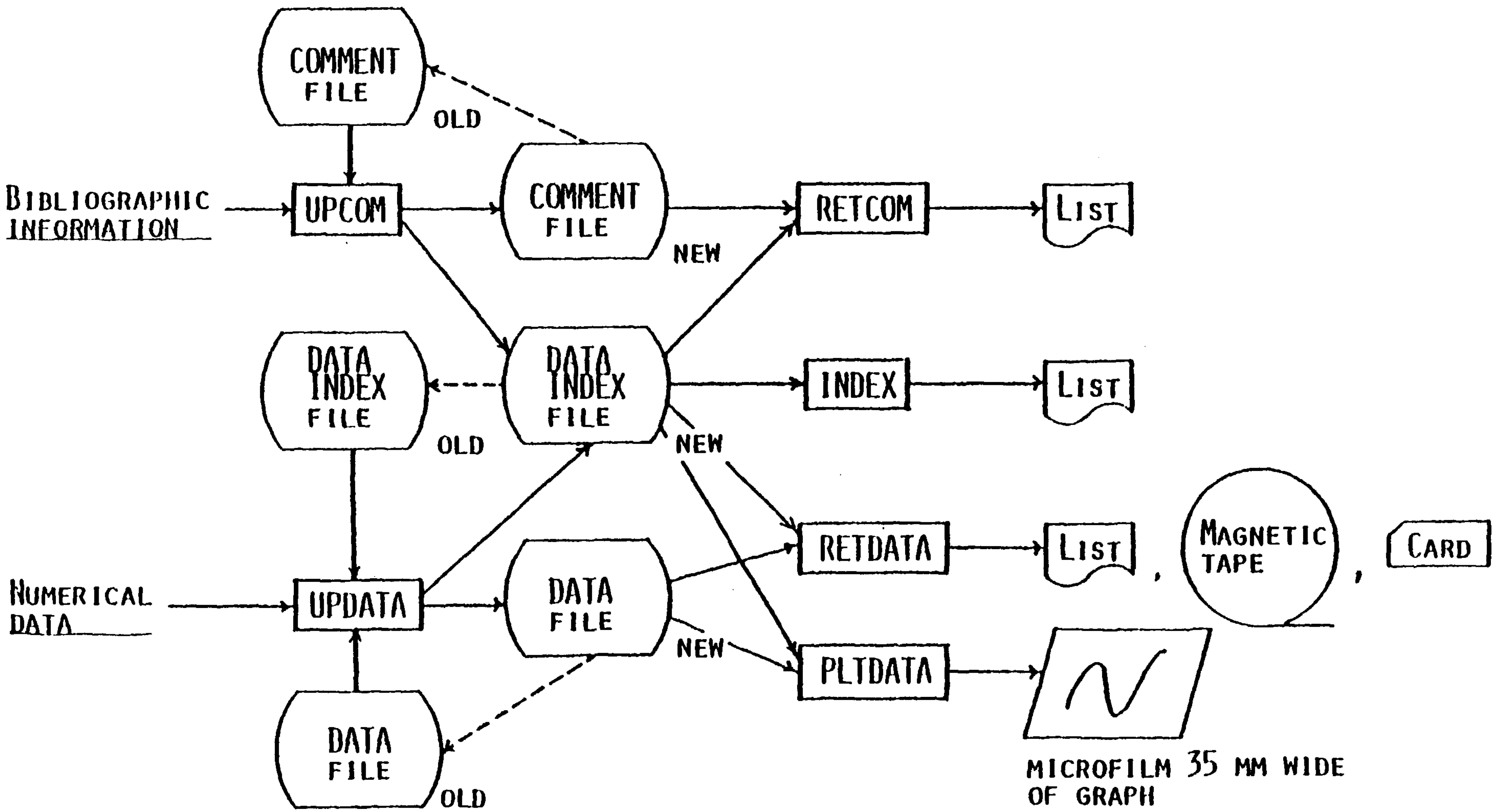
Category	Code	Description
Structure + Spectra	S	Spectral Identification, Energy Levels Ionization Potentials, Wavelengths
	T	Transition Probabilities, Oscillator Strengths, Lifetimes
	B	Broadening: Line Shapes and Shifts
	P	Polarizabilities, Electric Moments
	I	Interatomic Potentials
Collisions		
Photons	PA	Total Absorption plus Scattering
	PE	Elastic Scattering
	PF	Free-Free Transitions
	PZ	Photoionization
	PD	Photodissociation
	PT	Photodetachment
	PM	Multiphoton Absorption
	PX	Photoexcitation
	PU	Fluorescence
Electrons	ES	Total Scattering
	EE	Elastic Scattering
	EX	Excitation
	ED	De-excitation
	EZ	Ionization
	ER	Recombination
	EA	Attachment
	ET	Detachment
	EC	Dissociation
	EB	Bremsstrahlung
Heavy Particles	HS	Total Scattering
	HE	Elastic Scattering
	HF	Charge Transfer
	HX	Excitation
	HD	De-excitation
	HZ	Ionization
	HI	Interchange Reaction
	HA	Association
	HC	Dissociation
	HT	Detachment
	HR	Recombination
	HL	Inelastic Energy Losses

Surface	SD	Surface Damage
	BF	Blistering and Flaking
	RS	Erosion
	SP	Sputtering
	AR	Arcing
	CR	Chemical Reactions
	TD	Trapping and Detrapping
	AD	Adsorption and Absorption
	RC	Recombination
	AC	Accomodation
	DE	Desorption
	RF	Reflection
	BS	Backscattering
	RE	Reemission
	SM	Secondary Emission
	SE	Secondary Electron Emission
General	GSS	Structure, Spectra
	GPC	Photon Collisions
	GEC	Electron Collisions
	GHC	Heavy Particle Collisions
	GSI	Surface Interactions
	GPD	Plasma Diagnostics
	GPI	Plasma Composition, Impurities
	GPH	Plasma Heating, Cooling and Fueling
	GPT	Plasma Theory, Models
	GDB	Data, Bibliographies, Progress Reports
	GFR	Fusion Research of General Interest
	GIL	Interaction of Lasers or Multiphotons with Atoms or Molecules

ATOMIC AND MOLECULAR DATA

STORAGE AND RETRIEVAL SYSTEM (AMSTOR)

ATOMIC COLLISION DATA



Appendix 15

NUMERICAL DATA FORMAT

```
ENTRY              1001     810323
BIB
TITLE      IONIZATION AND ELECTRON CAPTURE FOR HELIUM IONS
           INCIDENT ON NOBLE AND DIATOMIC GASES
           BETWEEN 10 AND 150 KEV
AUTHOR     F.J. DE HEER, J. SCHUTTEN, AND H. MOUSTAFA
REFERENCE  J,PHY,32,1793,(1960)
REACTION  1HE+ + HE, CP , HE + HE+ 'CAPTURE'
          2HE+ + NE, CP , HE + NE+
          3HE+ + AR, CP , HE + AR+
          4HE+ + KR, CP , HE + KR+
          5HE+ + H2, CP , HE + H2+
          6HE+ + N2, CP , HE + N2+
          7HE+ + O2, CP , HE + O2+
QUANTITY   SIG,HE+
EXP-METHOD C  'CONDENSER METHOD'
STATUS     TABLE
INDEX
ENDBIB
COMMON
DATA-ERR1  DATA-ERR2
PER-CENT   PER-CENT
         5.         6.
ENDCOMMON
DATA
EI         DATA      1DATA      2DATA      3DATA      4DATA      5
EV         CMSQ       CMSQ       CMSQ       CMSQ       CMSQ
DATA      6DATA      7
CMSQ       CMSQ
    10.E+03   58.3E-17   65.0E-17   68.8E-17   77.5E-17   12.3E-17
   61.2E-17
    15.E+03   52.9E-17   66.0E-17   72.5E-17   81.6E-17   17.0E-17
   62.1E-17   84.9E-17
    20.E+03   47.0E-17   62.5E-17   75.1E-17   81.8E-17   20.5E-17
   66.7E-17   85.4E-17
```

```
    25.E+03    43.2E-17   58.1E-17   73.5E-17   81.0E-17   23.1E-17
    67.3E-17   81.2E-17
    30.E+03    40.0E-17   52.8E-17   75.2E-17   80.7E-17   25.5E-17
    68.5E-17   74.0E-17
    35.E+03    39.4E-17   50.8E-17   74.1E-17   82.4E-17   27.0E-17
    68.0E-17   68.0E-17
    40.E+03    34.4E-17   45.5E-17   71.3E-17   81.6E-17   26.3E-17
    68.7E-17   65.7E-17
    50.E+03    30.9E-17   40.0E-17   65.2E-17   74.3E-17   28.0E-17
    66.8E-17   62.6E-17
    60.E+03    28.3E-17   35.9E-17   60.0E-17   72.0E-17   30.0E-17
    64.2E-17   58.1E-17
    70.E+03    26.1E-17   33.1E-17   57.0E-17   67.1E-17   30.0E-17
    63.8E-17   54.6E-17
    80.E+03    23.7E-17   29.3E-17   54.1E-17   64.3E-17   29.2E-17
    58.0E-17   51.6E-17
    90.E+03    22.4E-17   27.4E-17   50.1E-17   61.7E-17   28.2E-17
    55.1E-17   48.4E-17
   100.E+03    21.0E-17   25.9E-17   46.9E-17   56.1E-17   26.6E-17
    52.0E-17   45.0E-17
   110.E+03    19.7E-17   24.5E-17   45.4E-17   57.7E-17   24.3E-17
    44.7E-17   42.6E-17
   120.E+03    18.6E-17   23.5E-17   42.6E-17   50.0E-17   22.9E-17
    42.9E-17   38.6E-17
   130.E+03    16.3E-17   21.0E-17   41.0E-17   45.6E-17   21.7E-17
    39.5E-17   35.5E-17
   140.E+03    15.9E-17   20.2E-17   40.0E-17   45.0E-17   19.7E-17
    36.4E-17   32.4E-17
ENDDATA
BIB
REACTION   1HE+ + HE, ION ,HE+ + HE+ + E 'IONIZATION'
           2HE+ + NE, ION ,HE+ + NE+ + E
           3HE+ + AR, ION ,HE+ + AR+ + E
           4HE+ + KR, ION ,HE+ + KR+ + E
           5HE+ + H2, ION ,HE+ + H2+ + E
           6HE+ + N2, ION ,HE+ + N2+ + E
```

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          7HE+ + O2, ION ,HE+ + O2+ + E
ENDBIB
COMMON
DATA-ERR1  DATA-ERR2
PER-CENT   PER-CENT
         5.         6.
ENDCOMMON
DATA
EI          DATA       1DATA      2DATA      3DATA      4DATA      5
EV          CMSQ        CMSQ       CMSQ       CMSQ       CMSQ
DATA       6DATA       7
CMSQ        CMSQ
    10.E+03   6.88E-17   7.59E-17   36.6E-17   39.7E-17   4.98E-17
   39.7E-17   38.0E-17
    15.E+03   6.60E-17   10.6E-17   46.0E-17   49.6E-17   5.45E-17
   49.6E-17   44.0E-17
    20.E+03   6.67E-17   11.6E-17   49.5E-17   58.5E-17   5.83E-17
   58.5E-17   50.0E-17
    25.E+03   6.54E-17   12.7E-17   52.5E-17   64.3E-17   6.90E-17
   64.3E-17   54.0E-17
    30.E+03   6.10E-17   13.8E-17   56.6E-17   69.4E-17   7.87E-17
   69.4E-17   55.5E-17
    35.E+03   6.31E-17   14.6E-17   59.5E-17   74.3E-17   9.10E-17
   74.3E-17   58.5E-17
    40.E+03   6.47E-17   15.3E-17   66.8E-17   81.3E-17   9.85E-17
   81.3E-17   60.4E-17
    50.E+03   7.11E-17   18.5E-17   70.0E-17   85.0E-17   12.1E-17
   85.0E-17   64.2E-17
    60.E+03   8.14E-17   19.6E-17   73.0E-17   92.5E-17   14.9E-17
   92.5E-17   67.3E-17
    70.E+03   8.50E-17   21.3E-17   77.0E-17   102.E-17   17.1E-17
   102.E-17   68.5E-17
    80.E+03   8.80E-17   23.0E-17   81.0E-17   102.E-17   19.5E-17
   102.E-17   71.8E-17
    90.E+03   9.30E-17   24.4E-17   85.0E-17   113.E-17   21.0E-17
   113.E-17   75.6E-17
```

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   100.E+03   9.42E-17   25.4E-17   89.4E-17   112.E-17   22.2E-17
   112.E-17   78.8E-17
   110.E+03   10.7E-17   28.1E-17   92.8E-17   114.E-17   23.4E-17
   114.E-17   81.2E-17
   120.E+03   11.9E-17   28.7E-17   95.0E-17   113.E-17   25.2E-17
   113.E-17   86.7E-17
   130.E+03   13.2E-17   29.3E-17   97.0E-17   118.E-17   27.8E-17
   119.E-17   87.4E-17
   140.E+03   13.1E-17   30.2E-17   100.E-17   122.E-17   27.9E-17
   122.E-17   88.3E-17
ENDDATA
ENDENTRY
ENTRY                1002      810320
BIB
TITLE      ELECTRON SCATTERING FROM ATOMIC HYDROGEN III. ABSOLUTE
           DIFFERENTIAL CROSS SECTIONS FOR ELASTIC SCATTERING OF
           ELECTRONS OF ENERGIES FROM 20 TO 680 EV
AUTHOR     J.F. WILLIAMS
REFERENCE  J,JP/B,8,2191,(1975)
REACTION   E + H(1S),EL,E + H(1S)
EXP-METHOD CB
QUANTITY   SIG/DA,E
STATUS     TABLE
ENDBIB
COMMON
EI         1EI        2EI        3EI        4EI        5EI        6
EV          EV         EV         EV         EV         EV
EI         7EI        8
EV          EV
       12.        20.        30.        50.       100.       200.
      400.       680.
ENDCOMMON
DATA
ANG         DATA      1DATA-ERR  1DATA      2DATA-ERR  2DATA      3
ADEG        AU/STR     AU/STR     AU/STR     AU/STR     AU/STR
DATA-ERR   3DATA      4DATA-ERR  4DATA      5DATA-ERR  5DATA      6
```

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ENTRY              1001     810323                                        100100000001
BIB                   8         16                                        100100100001
TITLE      IONIZATION AND ELECTRON CAPTURE FOR HELIUM IONS                100100100002
           INCIDENT ON NOBLE AND DIATOMIC GASES                           100100100003
           BETWEEN 10 AND 150 KEV                                         100100100004
AUTHOR     F.J. DE HEER, J. SCHUTTEN, AND H. MOUSTAFA                     100100100005
REFERENCE  J,PHY,32,1793,(1960)                                           100100100006
REACTION  1HE+ + HE, CP , HE + HE+ 'CAPTURE'                              100100100007
          2HE+ + NE, CP , HE + NE+                                        100100100008
          3HE+ + AR, CP , HE + AR+                                        100100100009
          4HE+ + KR, CP , HE + KR+                                        100100100010
          5HE+ + H2, CP , HE + H2+                                        100100100011
          6HE+ + N2, CP , HE + N2+                                        100100100012
          7HE+ + O2, CP , HE + O2+                                        100100100013
QUANTITY   SIG,HE+                                                        100100100014
EXP-METHOD C  'CONDENSER METHOD'                                          100100100015
STATUS     TABLE                                                          100100100016
INDEX                                                                     100100100017
ENDBIB               16                                                   100100100018
COMMON                2          3                                        100100100019
DATA-ERR1  DATA-ERR2                                                      100100100020
PER-CENT   PER-CENT                                                       100100100021
         5.         6.                                                    100100100022
ENDCOMMON             3                                                   100100100023
DATA                  8         34                                        100100100024
EI         DATA       1DATA      2DATA      3DATA      4DATA      5 100100100025
EV         CMSQ        CMSQ       CMSQ       CMSQ       CMSQ        100100100026
DATA      6DATA       7                                                   100100100027
CMSQ       CMSQ                                                           100100100028
    10.E+03   58.3E-17   65.0E-17   68.8E-17   77.5E-17   12.3E-17 100100100029
   61.2E-17                                                        100100100030
    15.E+03   52.9E-17   66.0E-17   72.5E-17   81.6E-17   17.0E-17 100100100031
   62.1E-17   84.9E-17                                             100100100032
    20.E+03   47.0E-17   62.5E-17   75.1E-17   81.8E-17   20.5E-17 100100100033
   66.7E-17   85.4E-17                                             100100100034
```

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  25.E+03   43.2E-17   58.1E-17   73.5E-17   81.0E-17   23.1E-17 100100100035
 67.3E-17   81.2E-17                                              100100100036
  30.E+03   40.0E-17   52.8E-17   75.2E-17   80.7E-17   25.5E-17 100100100037
 68.5E-17   74.0E-17                                              100100100038
  35.E+03   39.4E-17   50.8E-17   74.1E-17   82.4E-17   27.0E-17 100100100039
 68.0E-17   68.0E-17                                              100100100040
  40.E+03   34.4E-17   45.5E-17   71.3E-17   81.6E-17   26.3E-17 100100100041
 68.7E-17   65.7E-17                                              100100100042
  50.E+03   30.9E-17   40.0E-17   65.2E-17   74.3E-17   28.0E-17 100100100043
 66.8E-17   62.6E-17                                              100100100044
  60.E+03   28.3E-17   35.9E-17   60.0E-17   72.0E-17   30.0E-17 100100100045
 64.2E-17   58.1E-17                                              100100100046
  70.E+03   26.1E-17   33.1E-17   57.0E-17   67.1E-17   30.0E-17 100100100047
 63.8E-17   54.6E-17                                              100100100048
  80.E+03   23.7E-17   29.3E-17   54.1E-17   64.3E-17   29.2E-17 100100100049
 58.0E-17   51.6E-17                                              100100100050
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 55.1E-17   48.4E-17                                              100100100052
 100.E+03   21.0E-17   25.9E-17   46.9E-17   56.1E-17   26.6E-17 100100100053
 52.0E-17   45.0E-17                                              100100100054
 110.E+03   19.7E-17   24.5E-17   45.4E-17   57.7E-17   24.3E-17 100100100055
 44.7E-17   42.6E-17                                              100100100056
 120.E+03   18.6E-17   23.5E-17   42.6E-17   50.0E-17   22.9E-17 100100100057
 42.9E-17   38.6E-17                                              100100100058
 130.E+03   16.3E-17   21.0E-17   41.0E-17   45.6E-17   21.7E-17 100100100059
 39.5E-17   35.5E-17                                              100100100060
 140.E+03   15.9E-17   20.2E-17   40.0E-17   45.0E-17   19.7E-17 100100100061
 36.4E-17   32.4E-17                                              100100100062
ENDDATA           38                                              100100199999
BIB                1          7                                   100100200001
REACTION  1HE+ + HE, ION ,HE+ + HE+ + E 'IONIZATION'              100100200002
          2HE+ + NE, ION ,HE+ + NE+ + E                           100100200003
          3HE+ + AR, ION ,HE+ + AR+ + E                           100100200004
          4HE+ + KR, ION ,HE+ + KR+ + E                           100100200005
          5HE+ + H2, ION ,HE+ + H2+ + E                           100100200006
          6HE+ + N2, ION ,HE+ + N2+ + E                           100100200007
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          7HE+ + O2, ION ,HE+ + O2+ + E                                     100100200008
ENDBIB               7                                                      100100200009
COMMON               2          3                                           100100200010
DATA-ERR1  DATA-ERR2                                                        100100200011
PER-CENT   PER-CENT                                                         100100200012
         5.         6.                                                      100100200013
ENDCOMMON            3                                                      100100200014
DATA                 8         34                                           100100200015
EI         DATA      1DATA      2DATA      3DATA      4DATA      5          100100200016
EV         CMSQ       CMSQ       CMSQ       CMSQ       CMSQ                 100100200017
DATA      6DATA      7                                                      100100200018
CMSQ       CMSQ                                                             100100200019
    10.E+03   6.88E-17   7.59E-17   36.6E-17   39.7E-17   4.98E-17 100100200020
   39.7E-17   38.0E-17                                             100100200021
    15.E+03   6.60E-17   10.6E-17   46.0E-17   49.6E-17   5.45E-17 100100200022
   49.6E-17   44.0E-17                                             100100200023
    20.E+03   6.67E-17   11.6E-17   49.5E-17   58.5E-17   5.83E-17 100100200024
   58.5E-17   50.0E-17                                             100100200025
    25.E+03   6.54E-17   12.7E-17   52.5E-17   64.3E-17   6.90E-17 100100200026
   64.3E-17   54.0E-17                                             100100200027
    30.E+03   6.10E-17   13.8E-17   56.6E-17   69.4E-17   7.87E-17 100100200028
   69.4E-17   55.5E-17                                             100100200029
    35.E+03   6.31E-17   14.6E-17   59.5E-17   74.3E-17   9.10E-17 100100200030
   74.3E-17   58.5E-17                                             100100200031
    40.E+03   6.47E-17   15.3E-17   66.8E-17   81.3E-17   9.85E-17 100100200032
   81.3E-17   60.4E-17                                             100100200033
    50.E+03   7.11E-17   18.5E-17   70.0E-17   85.0E-17   12.1E-17 100100200034
   85.0E-17   64.2E-17                                             100100200035
    60.E+03   8.14E-17   19.6E-17   73.0E-17   92.5E-17   14.9E-17 100100200036
   92.5E-17   67.3E-17                                             100100200037
    70.E+03   8.50E-17   21.3E-17   77.0E-17   102.E-17   17.1E-17 100100200038
   102.E-17   68.5E-17                                             100100200039
    80.E+03   8.80E-17   23.0E-17   81.0E-17   102.E-17   19.5E-17 100100200040
   102.E-17   71.8E-17                                             100100200041
    90.E+03   9.30E-17   24.4E-17   85.0E-17   113.E-17   21.0E-17 100100200042
   113.E-17   75.6E-17                                             100100200043
```

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   100.E+03   9.42E-17   25.4E-17   89.4E-17   112.E-17   22.2E-17 100100200044
   112.E-17   78.8E-17                                              100100200045
   110.E+03   10.7E-17   28.1E-17   92.8E-17   114.E-17   23.4E-17 100100200046
   114.E-17   81.2E-17                                              100100200047
   120.E+03   11.9E-17   28.7E-17   95.0E-17   113.E-17   25.2E-17 100100200048
   113.E-17   86.7E-17                                              100100200049
   130.E+03   13.2E-17   29.3E-17   97.0E-17   118.E-17   27.8E-17 100100200050
   119.E-17   87.4E-17                                              100100200051
   140.E+03   13.1E-17   30.2E-17   100.E-17   122.E-17   27.9E-17 100100200052
   122.E-17   88.3E-17                                              100100200053
ENDDATA             38                                              100100299999
ENDENTRY                                                            100199999999
ENTRY             1002     810320                                   100200000001
BIB                  7          9                                   100200100001
TITLE      ELECTRON SCATTERING FROM ATOMIC HYDROGEN III. ABSOLUTE   100200100002
           DIFFERENTIAL CROSS SECTIONS FOR ELASTIC SCATTERING OF    100200100003
           ELECTRONS OF ENERGIES FROM 20 TO 680 EV                  100200100004
AUTHOR     J.F. WILLIAMS                                            100200100005
REFERENCE  J,JP/B,8,2191,(1975)                                     100200100006
REACTION   E + H(1S),EL,E + H(1S)                                   100200100007
EXP-METHOD CB                                                       100200100008
QUANTITY   SIG/DA,E                                                 100200100009
STATUS     TABLE                                                    100200100010
ENDBIB               9                                              100200100011
COMMON               8          6                                   100200100012
EI        1EI        2EI        3EI        4EI        5EI         6 100200100013
EV         EV         EV         EV         EV         EV           100200100014
EI        7EI        8                                              100200100015
EV         EV                                                       100200100016
       12.        20.        30.        50.       100.       200.   100200100017
      400.       680.                                               100200100018
ENDCOMMON            6                                              100200100019
DATA                17         48                                   100200100020
ANG        DATA      1DATA-ERR  1DATA      2DATA-ERR  2DATA       3 100200100021
ADEG       AU/STR     AU/STR     AU/STR     AU/STR     AU/STR       100200100022
DATA-ERR  3DATA      4DATA-ERR  4DATA      5DATA-ERR  5DATA       6 100200100023
```

MASTERFILE FORMAT

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ENTRY              1001     810323                                          100100000001
BIB                                                                         100100100001
TITLE      IONIZATION AND ELECTRON CAPTURE FOR HELIUM IONS                  100100100002
TITLE      INCIDENT ON NOBLE AND DIATOMIC GASES                             100100100003
TITLE      BETWEEN 10 AND 150 KEV                                           100100100004
AUTHOR     F.J. DE HEER, J. SCHUTTEN, AND H. MOUSTAFA                       100100100005
STANDARD                                                                    100100100006
FACILITY                                                                    100100100007
ANALYSIS                                                                    100100100008
DETECTOR                                                                    100100100009
I-SOURCE                                                                    100100100010
STATUS     TABLE                                                            100100100011
CORRECTION                                                                  100100100012
ERR-ANALYS                                                                  100100100013
FLAG                                                                        100100100014
COMMENT                                                                     100100100015
EXP-METHOD C      'CONDENSER METHOD'                                        100100100016
INDEX                                                                       100100100017
REACTION  1HE+ + HE, CP , HE + HE+ 'CAPTURE'                                100100100018
REACTION*  1CP                                                              100100100019
           2  HE+                                        wA       w         100100100020
           3  HE                                         wA       w         100100100021
           4  HE                                         wA       w         100100100022
           5  HE+                                        wA       w         100100100023
           6                                                                100100100024
REFERENCE  J,PHY,32,1793,(1960)                                             100100100025
REFERENCE* JPHY 32  17931960                                                100100100026
QUANTITY   SIG,HE+                                                          100100100027
QUANTITY*  SIG       HE+                                                    100100100028
ENDBIB                                                                      100100100029
DATA                         17                                             100100100030
EI         DATA       DATA-ERR1  DATA-ERR2                                  100100100031
EV         CMSQ       PER-CENT   PER-CENT                                   100100100032
    10.E+03   58.3E-17         5.         6.                                100100100033
    15.E+03   52.9E-17         5.         6.                                100100100034
```

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    20.E+03   47.0E-17          5.          6.                         100100100035
    25.E+03   43.2E-17          5.          6.                         100100100036
    30.E+03   40.0E-17          5.          6.                         100100100037
    35.E+03   39.4E-17          5.          6.                         100100100038
    40.E+03   34.4E-17          5.          6.                         100100100039
    50.E+03   30.9E-17          5.          6.                         100100100040
    60.E+03   28.3E-17          5.          6.                         100100100041
    70.E+03   26.1E-17          5.          6.                         100100100042
    80.E+03   23.7E-17          5.          6.                         100100100043
    90.E+03   22.4E-17          5.          6.                         100100100044
   100.E+03   21.0E-17          5.          6.                         100100100045
   110.E+03   19.7E-17          5.          6.                         100100100046
   120.E+03   18.6E-17          5.          6.                         100100100047
   130.E+03   16.3E-17          5.          6.                         100100100048
   140.E+03   15.9E-17          5.          6.                         100100100049
ENDDATA                                                                100100199999
BIB                                                                    100100200001
TITLE      IONIZATION AND ELECTRON CAPTURE FOR HELIUM IONS             100100200002
TITLE      INCIDENT ON NOBLE AND DIATOMIC GASES                        100100200003
TITLE      BETWEEN 10 AND 150 KEV                                      100100200004
AUTHOR     F.J. DE HEER, J. SCHUTTEN, AND H. MOUSTAFA                  100100200005
STANDARD                                                               100100200006
FACILITY                                                               100100200007
ANALYSIS                                                               100100200008
DETECTOR                                                               100100200009
I-SOURCE                                                               100100200010
STATUS     TABLE                                                       100100200011
CORRECTION                                                             100100200012
ERR-ANALYS                                                             100100200013
FLAG                                                                   100100200014
COMMENT                                                                100100200015
EXP-METHOD C      'CONDENSER METHOD'                                   100100200016
INDEX                                                                  100100200017
REACTION  2HE+ + NE, CP , HE + NE+                                     100100200018
REACTION*  1CP                                                         100100200019
           2  HE+                                    wA       w        100100200020
```

```
           3  NE                                             RA       R       100100200021
           4  HE                                             wA       w       100100200022
           5  NE+                                            RA       R       100100200023
           6                                                                  100100200024
REFERENCE  J,PHY,32,1793,(1960)                                               100100200025
REFERENCE* JPHY 32  17931960                                                  100100200026
QUANTITY   SIG,HE+                                                            100100200027
QUANTITY*  SIG       HE+                                                      100100200028
ENDBIB                                                                        100100200029
DATA                                    17                                    100100200030
EI         DATA       DATA-ERR1  DATA-ERR2                                    100100200031
EV         CMSQ       PER-CENT   PER-CENT                                     100100200032
    10.E+03   65.0E-17        5.         6.                                   100100200033
    15.E+03   66.0E-17        5.         6.                                   100100200034
    20.E+03   62.5E-17        5.         6.                                   100100200035
    25.E+03   58.1E-17        5.         6.                                   100100200036
    30.E+03   52.8E-17        5.         6.                                   100100200037
    35.E+03   50.8E-17        5.         6.                                   100100200038
    40.E+03   45.5E-17        5.         6.                                   100100200039
    50.E+03   40.0E-17        5.         6.                                   100100200040
    60.E+03   35.9E-17        5.         6.                                   100100200041
    70.E+03   33.1E-17        5.         6.                                   100100200042
    80.E+03   29.3E-17        5.         6.                                   100100200043
    90.E+03   27.4E-17        5.         6.                                   100100200044
   100.E+03   25.9E-17        5.         6.                                   100100200045
   110.E+03   24.5E-17        5.         6.                                   100100200046
   120.E+03   23.5E-17        5.         6.                                   100100200047
   130.E+03   21.0E-17        5.         6.                                   100100200048
   140.E+03   20.2E-17        5.         6.                                   100100200049
ENDDATA                                                                       100100299999
BIB                                                                           100100300001
TITLE      IONIZATION AND ELECTRON CAPTURE FOR HELIUM IONS                    100100300002
TITLE      INCIDENT ON NOBLE AND DIATOMIC GASES                               100100300003
TITLE      BETWEEN 10 AND 150 KEV                                             100100300004
AUTHOR     F.J. DE HEER, J. SCHUTTEN, AND H. MOUSTAFA                         100100300005
STANDARD                                                                      100100300006
```

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FACILITY                                                                   100100300007
ANALYSIS                                                                   100100300008
DETECTOR                                                                   100100300009
I-SOURCE                                                                   100100300010
STATUS  '  TABLE                                                           100100300011
CORRECTION                                                                 100100300012
ERR-ANALYS                                                                 100100300013
FLAG                                                                       100100300014
COMMENT                                                                    100100300015
EXP-METHOD C      'CONDENSER METHOD'                                       100100300016
INDEX                                                                      100100300017
REACTION  3HE+ + AR, CP , HE + AR+                                         100100300018
REACTION*  1CP                                                             100100300019
           2  HE+                                       wA       w         100100300020
           3  AR                                       2 A      2          100100300021
           4  HE                                        wA       w         100100300022
           5  AR+                                      2 A      2          100100300023
           6                                                               100100300024
REFERENCE  J,PHY,32,1793,(1960)                                            100100300025
REFERENCE* JPHY 32  17931960                                               100100300026
QUANTITY   SIG,HE+                                                         100100300027
QUANTITY*  SIG       HE+                                                   100100300028
ENDBIB                                                                     100100300029
DATA                           17                                          100100300030
EI         DATA       DATA-ERR1  DATA-ERR2                                 100100300031
EV         CMSQ       PER-CENT   PER-CENT                                  100100300032
    10.E+03   68.8E-17         5.         6.                               100100300033
    15.E+03   72.5E-17         5.         6.                               100100300034
    20.E+03   75.1E-17         5.         6.                               100100300035
    25.E+03   73.5E-17         5.         6.                               100100300036
    30.E+03   75.2E-17         5.         6.                               100100300037
    35.E+03   74.1E-17         5.         6.                               100100300038
    40.E+03   71.3E-17         5.         6.                               100100300039
    50.E+03   65.2E-17         5.         6.                               100100300040
    60.E+03   60.0E-17         5.         6.                               100100300041
    70.E+03   57.0E-17         5.         6.                               100100300042
```

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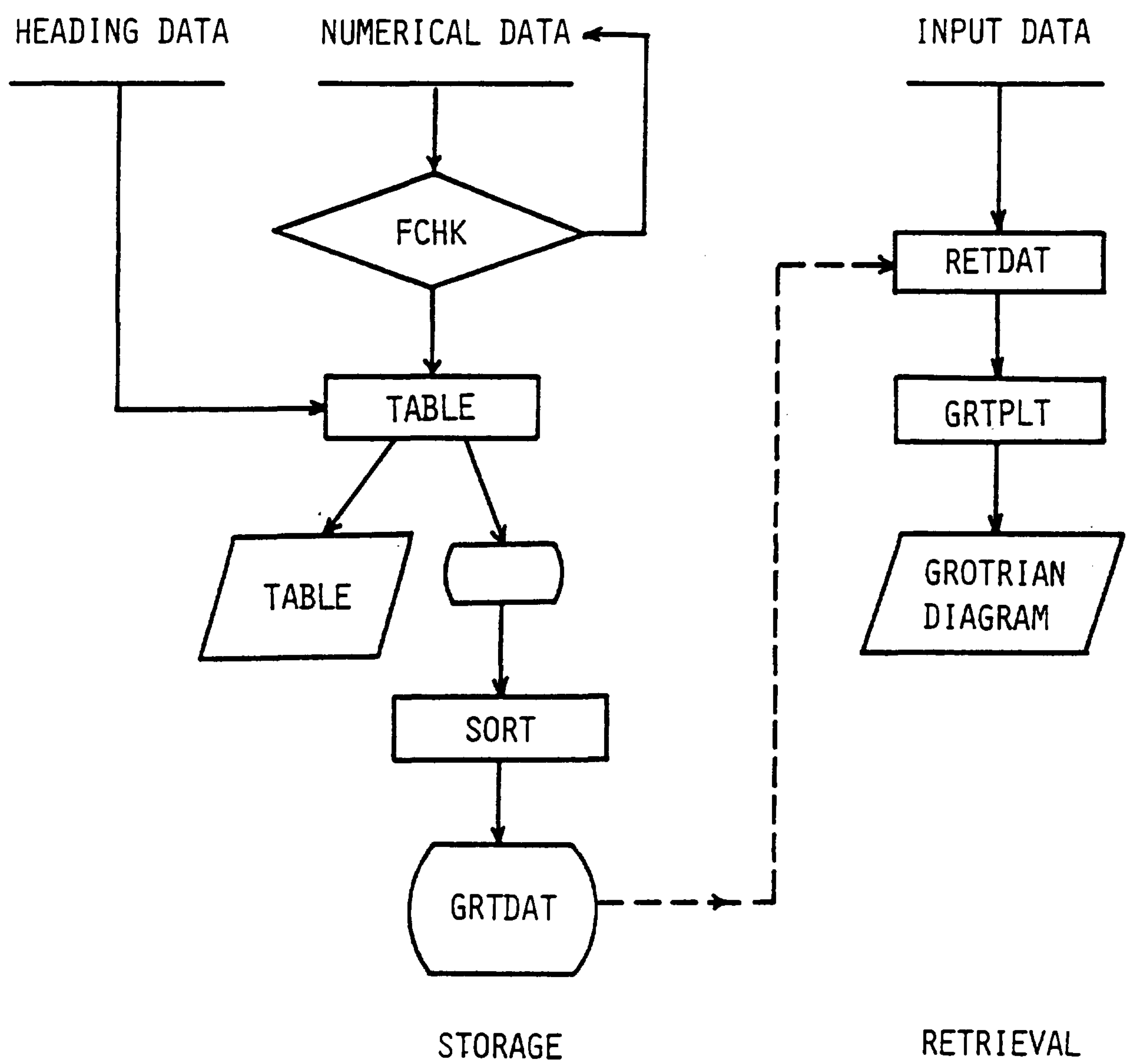
   80.E+03   54.1E-17          5.          6.                        100100300043
   90.E+03   50.1E-17          5.          6.                        100100300044
  100.E+03   46.9E-17          5.          6.                        100100300045
  110.E+03   45.4E-17          5.          6.                        100100300046
  120.E+03   42.6E-17          5.          6.                        100100300047
  130.E+03   41.0E-17          5.          6.                        100100300048
  140.E+03   40.0E-17          5.          6.                        100100300049
ENDDATA                                                              100100399999
```

Appendix 16

ATOMIC AND MOLECULAR DATA
STORAGE AND RETRIEVAL SYSTEM (AMSTOR)

ATOMIC STRUCTURE DATA



```
----*----1----*----2----*----3----*----4----*----5----*----6----*----7-R--*----8
NO.1     MODULE NAME TI5                 BLOCKS     6
                    LEVEL      12        DATE       81.10.28   TIME       11.05.57

              ***** APPOINTED MODULE INFORMATION *****

                    LEVEL      12        DATE       82.10.12   TIME       11.26.43


800900CM!'-1'       (99.300E£V)                                                    00000010     8
252.958      0          395321      900  3.63-1   1.26+11 C 20,49,67,82!>J,99,     00000100     5
                                                            101!>C,113!*           00000200     6
3S!23P!6 !1£S#0                        3P!5(!2£P!XO)3D !1£P!XO#1                   00000300     3
363.145      0          275372      1                       20,49,82!>J,101!>C     00000400     6
3S!23P!6 !1£S#0                        3P!5(!2£P!XO)3D !3£P!XO#1                   00000600     3
323.365      0          309252      85   1.9-3    4.0+7   E 20,49!>C,82!>J,101,    00000700     5
                                                            ,113!*                 00000800     5
3S!23P!6 !1£S#0                        3P!5(!2£P!XO)3D !3£D!XO#1                   00000900     3
225.347      0          443753      400  3.3-1    1.4+10  E 82!>J,101!>C,113!*     00001000     5
3S!23P!6 !1£S#0                        3P!5(!2£P!XO)4S !1£P!XO#1                   00001100     3
228.909      0          436850      250  9.7-2    4.1+9   E 82!>J,101!>C,113!*     00001200     5
3S!23P!6 !1£S#0                        3P!5(!2£P!XO)4S !3£P!XO#1                   00001300     3
162.984      0          613558      20                      82!>J,85,101!>C        00001400     5
3S!23P!6 !1£S#0                        3P!5(!2£P!XO)5S !1£P!XO#1                   00001500     7
164.446      0          608101      35                      82!>J,85,101!>C        00001600     5
3S!23P!6 !1£S#0                        3P!5(!2£P!XO)5S !3£P!XO#1                   00001700     7
146.897      0          680748      3                       82!>J,101!>C           00001800     5
3S!23P!6 !1£S#0                        3P!5(!2£P!XO)6S !3£P!XO#1                   00001900     7
145.79       0          685940      1                       82!>J,101!>C           00002000     5
3S!23P!6 !1£S#0                        3P!5(!2£P!XO)6S !1£P!XO#1                   00002100     7
144.551      0          691797      6                       79,82!>J,101!>C        00002200     5
3S!23P!6 !1£S#0                        3S3P!64P !1£P!XO#1                          00002300     3
145.354      0          687976      6                       79!>J                  00002400     5
3S!23P!6 !1£S#0                        3S3P!64P !3£P!XO#1                          00002500     3
120.824      0          827650      12                      79!>J                  00002600     5
3S!23P!6 !1£S#0                        3S3P!65P !1£P!XO#1                          00002700     3
121.138      0          825505      2                       79!>J                  00002800     5
3S!23P!6 !1£S#0                        3S3P!65P !3£P!XO#1                          00002900     3
112.495      0          888928      10                      79!>J                  00003000     5
3S!23P!6 !1£S#0                        3S3P!66P !1£P!XO#1                          00003100     3
112.896      0          885771      0                       79!>J                  00003200     5
3S!23P!6 !1£S#0                        3S3P!66P !3£P!XO#1                          00003300     3
108.443      0          922143      6                       79!>J                  00003400     5
3S!23P!6 !1£S#0                        3S3P!67P !1£P!XO#1                          00003500     3
108.611      0          920717      0                       79!>J                  00003600     5
3S!23P!6 !1£S#0                        3S3P!67P !3£P!XO#1                          00003700     3
106.154      0          942028      3                       79!>J                  00003800     5
3S!23P!6 !1£S#0                        3S3P!68P !1£P!XO#1                          00003900     3
106.308      0          940663      0                       79!>J                  00004000     5
3S!23P!6 !1£S#0                        3S3P!68P !3£P!XO#1                          00004100     3
104.711      0          955100      0.8                     79!>J                  00004200     5
3S!23P!6 !1£S#0                        3S3P!69P !1£P!XO#1                          00004300     3
104.732      0          954818      0.5                     79!>J                  00004400     5
3S!23P!6 !1£S#0                        3S3P!69P !3£P!XO#1                          00004500     3
103.733      0          964013      0.8                     79!>J                  00004600     5
3S!23P!6 !1£S#0                        3S3P!610P !1£P!XO#1                         00004700     3
103.754      0          963818      0.8                     79!>J                  00004800     5
3S!23P!6 !1£S#0                        3S3P!610P !3£P!XO#1                         00004900     3
103.059      0          970318      0                       79!>J                  00005000     5
```

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----*----1----*----2----*----3----*----4----*----5----*----6----*----7-R--*----8
3S!23P!6 !1£S#0                          3S3P!611P !1£P!X0#1                       00005100    12
557.115      309433      488929      00                          101!>J            00005200     5
3D !3£D!X0#2                             3S3P!63D !3£D#1                           00005300     7
556.562      309252      488929      0                           101!>J            00005400     5
#1                                       #1                                        00005500
549.083      309433      491559      6                           101!>J            00005600     5
#2                                       #2                                        00005700
548.533      309252      491559      4                           101!>J            00005800     5
#1                                       #2                                        00005900
546.062      309433      492567      5                           101!>J            00006000     5
#2                                       #3                                        00006100
543.103      307429      491559      7                           101!>J            00006200     5
#3                                       #2                                        00006300
504.665      290779      488929      12                          101!>J            00006400     5
3D !3£F!X0#2                             3S3P!63D !3£D#1                           00006500     7
498.050      290779      491559                                  101               00006600     5
#2                                       #2                                        00006700
493.783      289050      491559      6                           101!>J            00006800     5
#3                                       #2                                        00006900
491.358      289050      492567      1                           101!>J            00007000     5
#3                                       #3                                        00007100
487.115      287277      492567      4                           101!>J            00007200     5
#4                                       #3                                        00007300
468.257      275372      488929      3                           101!>J            00007400     5
3D !3£P!X0#1                             3S3P!63D !3£D#1                           00007500     7
466.749      277311      491559      1                           101!>J            00007600     5
#2                                       #2                                        00007700
466.224      274440      488929      4                           101!>J            00007800     5
#0                                       #1                                        00007900
464.562      277311      492567      5                           101!>J            00008000     5
#2                                       #3                                        00008100
462.565      275372      491559      3                           101!>J            00008200     5
#1                                       #2                                        00008300     3
513.374      311434      506225      8                           101!>J            00008400     5
3D !1£F!X0#3                             3S3P!63D !1£D#2                           00008500     7
501.631      306875      506225      2                           101!>J            00008600     9
3D !1£D!X0#2                             3S3P!63D !1£D#2                           00008700     9
507.683      309252      506225      6                           101!>J            00010000     9
3D !3£D!X0#1                             3S3P!63D !1£D#2                           00010100    11
503.031      307429      506225      3                           101!>J            00010200     5
#3                                       #2                                        00010300
464.143      290779      506225      00                          101!>J            00010400     5
3D !3£F#2                                3S3P!63D !1£D#2                           00010500     7
901.692      395321      506225      1                           101!>J            00011000     5
3D !1£P!X0#1                             3S3P!63D !1£D#2                           00011100    11
984.530      395321      496891      0                           101!>J            00011200     5
3D !1£P!X0#1                             4P !1£P#1                                 00011300     9
834.315      395321      514609      3                           101!>J            00011400     5
3D !1£P!X0#1                             4P !1£S#0                                 00011500     9
534.297      306875      494036      0                           101!>J            00011600     7
3D !3£F!X0#2                             4P !1£D#2                                 00011700     9
```

HIGHEST SEVERITY CODE=00

STATISTICS: HIGHEST SEVERITY CODE=00

Ti V (Ar-Sequence) IP=800900 cm^{-1} (99·300 eV)

λ (A)	Configuration		Energy level (cm^{-1})		Int	f/Type	A (s^{-1})	Acc	Reference
252·958	$3s^23p^6\ ^1S_0$	$3p^5(^2P^\circ)3d\ ^1P^\circ_1$	0	395321	900	3·63−1	1·26+11	C	20, 49, 67, 82$^{\Delta}$, 99, 101°, 113*
363·145	$3s^23p^6\ ^1S_0$	$3p^5(^2P^\circ)3d\ ^3P^\circ_1$	0	275372	1				20, 49, 82$^{\Delta}$, 101°
323·365	$3s^23p^6\ ^1S_0$	$3p^5(^2P^\circ)3d\ ^3D^\circ_1$	0	309252	85	1·9−3	4·0+7	E	20, 49°, 82$^{\Delta}$, 101., 113*
225·347	$3s^23p^6\ ^1S_0$	$3p^5(^2P^\circ)4s\ ^1P^\circ_1$	0	443753	400	3·3−1	1·4+10	E	82$^{\Delta}$, 101°, 113*
228·909	$3s^23p^6\ ^1S_0$	$3p^5(^2P^\circ)4s\ ^3P^\circ_1$	0	436850	250	9·7−2	4·1+9	E	82$^{\Delta}$, 101°, 113*
162·984	$3s^23p^6\ ^1S_0$	$3p^5(^2P^\circ)5s\ ^1P^\circ_1$	0	613558	20				82$^{\Delta}$, 85, 101°
164·446	$3s^23p^6\ ^1S_0$	$3p^5(^2P^\circ)5s\ ^3P^\circ_1$	0	608101	35				82$^{\Delta}$, 85, 101°
146·897	$3s^23p^6\ ^1S_0$	$3p^5(^2P^\circ)6s\ ^3P^\circ_1$	0	680748	3				82$^{\Delta}$, 101°
145·79	$3s^23p^6\ ^1S_0$	$3p^5(^2P^\circ)6s\ ^1P^\circ_1$	0	685940	1				82$^{\Delta}$, 101°
144·551	$3s^23p^6\ ^1S_0$	$3s3p^64p\ ^1P^\circ_1$	0	691797	6				79, 82$^{\Delta}$, 101°
145·354	$3s^23p^6\ ^1S_0$	$3s3p^64p\ ^3P^\circ_1$	0	687976	6				79$^{\Delta}$
120·824	$3s^23p^6\ ^1S_0$	$3s3p^65p\ ^1P^\circ_1$	0	827650	12				79$^{\Delta}$
121·138	$3s^23p^6\ ^1S_0$	$3s3p^65p\ ^3P^\circ_1$	0	825505	2				79$^{\Delta}$
112·495	$3s^23p^6\ ^1S_0$	$3s3p^66p\ ^1P^\circ_1$	0	888928	10				79$^{\Delta}$

TABLE

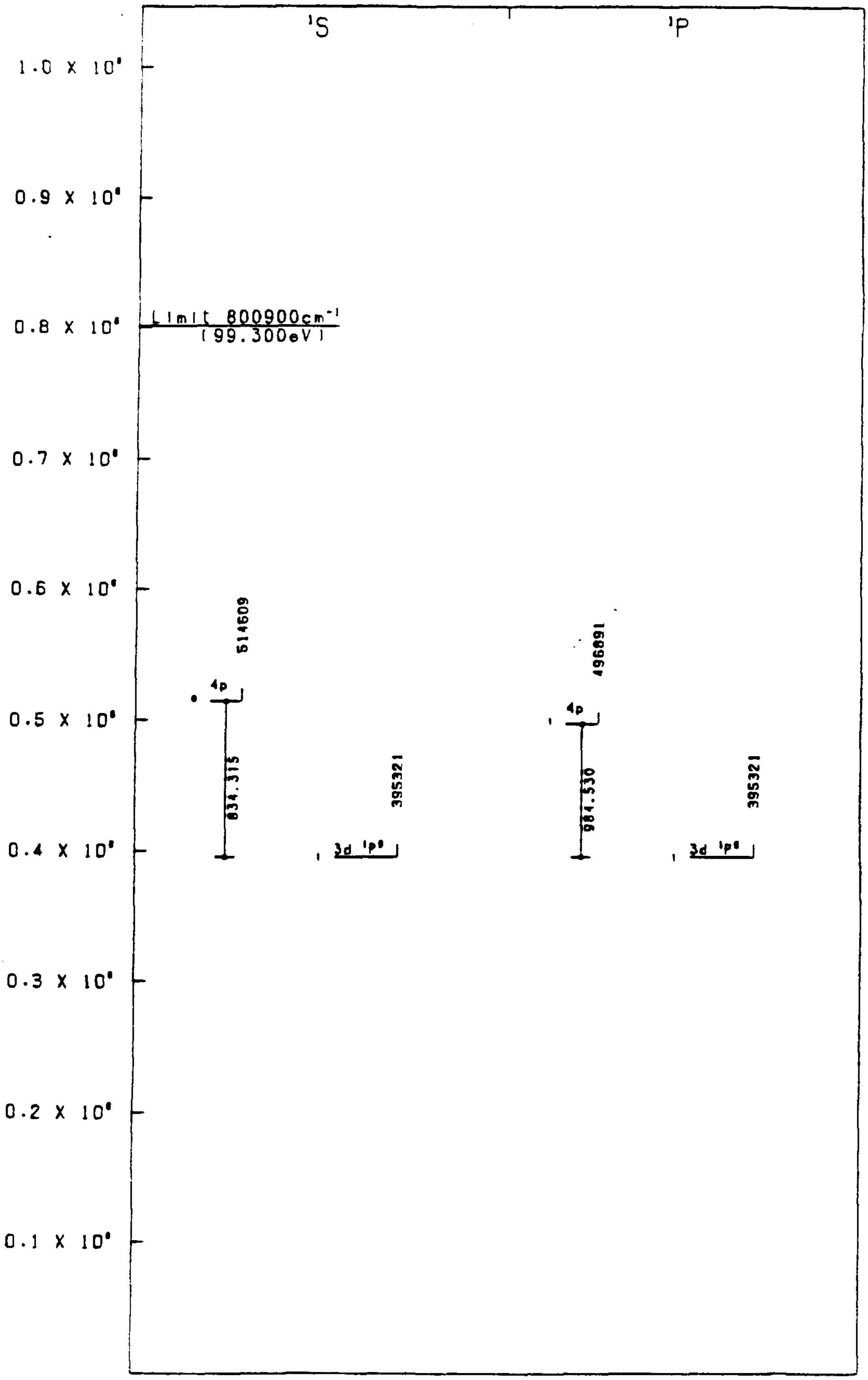
Ti V (Ar-Sequence)   IP=800900 cm^{-1} (99·300 eV)

λ (A)	Configuration		Energy level (cm^{-1})		Int	f/Type	A (s^{-1}) Acc	Reference
112·896	$3s^23p^6\ ^1S_0$	$3s3p^66p\ ^3P^o_1$	0	885771	0			79$^{\Delta}$
108·443	$3s^23p^6\ ^1S_0$	$3s3p^67p\ ^1P^o_1$	0	922143	6			79$^{\Delta}$
108·611	$3s^23p^6\ ^1S_0$	$3s3p^67p\ ^3P^o_1$	0	920717	0			79$^{\Delta}$
106·154	$3s^23p^6\ ^1S_0$	$3s3p^68p\ ^1P^o_1$	0	942028	3			79$^{\Delta}$
106·308	$3s^23p^6\ ^1S_0$	$3s3p^68p\ ^3P^o_1$	0	940663	0			79$^{\Delta}$
104·711	$3s^23p^6\ ^1S_0$	$3s3p^69p\ ^1P^o_1$	0	955100	0·8			79$^{\Delta}$
104·732	$3s^23p^6\ ^1S_0$	$3s3p^69p\ ^3P^o_1$	0	954818	0·5			79$^{\Delta}$
103·733	$3s^23p^6\ ^1S_0$	$3s3p^610p\ ^1P^o_1$	0	964013	0·8			79$^{\Delta}$
103·754	$3s^23p^6\ ^1S_0$	$3s3p^610p\ ^3P^o_1$	0	963818	0·8			79$^{\Delta}$
103·059	$3s^23p^6\ ^1S_0$	$3s3p^611p\ ^1P^o_1$	0	970318	0			79$^{\Delta}$
557·115	$3d\ ^3D^o_2$	$3s3p^63d\ ^3D_1$	309433	488929	00			101$^{\Delta}$
556·562	1	1	309252	488929	0			101$^{\Delta}$
549·083	2	2	309433	491559	6			101$^{\Delta}$
548·533	1	2	309252	491559	4			101$^{\Delta}$
546·062	2	3	309433	492567	5			101$^{\Delta}$
543·103	3	2	307429	491559	7			101$^{\Delta}$
504·665	$3d\ ^3F^o_2$	$3s3p^63d\ ^3D_1$	290779	488929	12			101$^{\Delta}$
498·050	2	2	290779	491559				101
493·783	3	2	289050	491559	6			101$^{\Delta}$

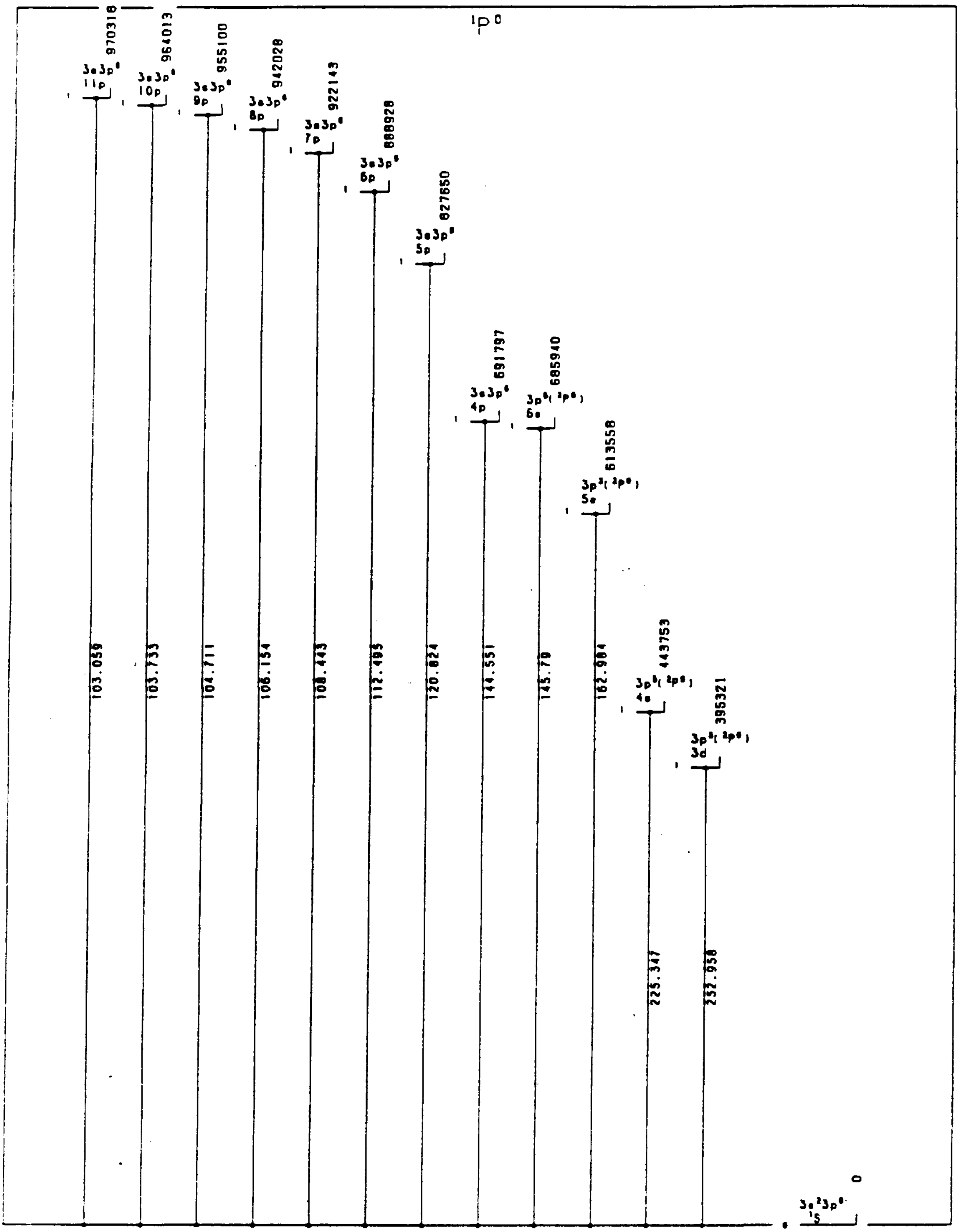
Ti V (Ar–Sequence)   IP = 800900 cm^{-1} (99·300 eV)

λ (Å)	Configuration		Energy level (cm^{-1})		Int	f/Type	A (s^{-1})	Acc	Reference
491·358	$_3$	$_3$	289050	492567	1				101[Δ]
487·115	$_4$	$_3$	287277	492567	4				101[Δ]
468·257	3d $^3P^o_1$	$3s3p^63d$ $^3D_1$	275372	488929	3				101[Δ]
466·749	$_2$	$_2$	277311	491559	1				101[Δ]
466·224	$_0$	$_1$	274440	488929	4				101[Δ]
464·562	$_2$	$_3$	277311	492567	5				101[Δ]
462·565	$_1$	$_2$	275372	491559	3				101[Δ]
513·374	3d $^1F^o_3$	$3s3p^63d$ $^1D_2$	311434	506225	8				101[Δ]
501·631	3d $^1D^o_2$	$3s3p^63d$ $^1D_2$	306875	506225	2				101[Δ]
507·683	3d $^3D^o_1$	$3s3p^63d$ $^1D_2$	309252	506225	6				101[Δ]
503·031	$_3$	$_2$	307429	506225	3				101[Δ]
464·143	3d $^3F_2$	$3s3p^63d$ $^1D_2$	290779	506225	00				101[Δ]
901·692	3d $^1P^o_1$	$3s3p^63d$ $^1D_2$	395321	506225	1				101[Δ]
984·530	3d $^1P^o_1$	4p $^1P_1$	395321	496891	0				101[Δ]
834·315	3d $^1P^o_1$	4p $^1S_0$	395321	514609	3				101[Δ]
534·297	3d $^3F^o_2$	4p $^1D_2$	306875	494036	0				101[Δ]

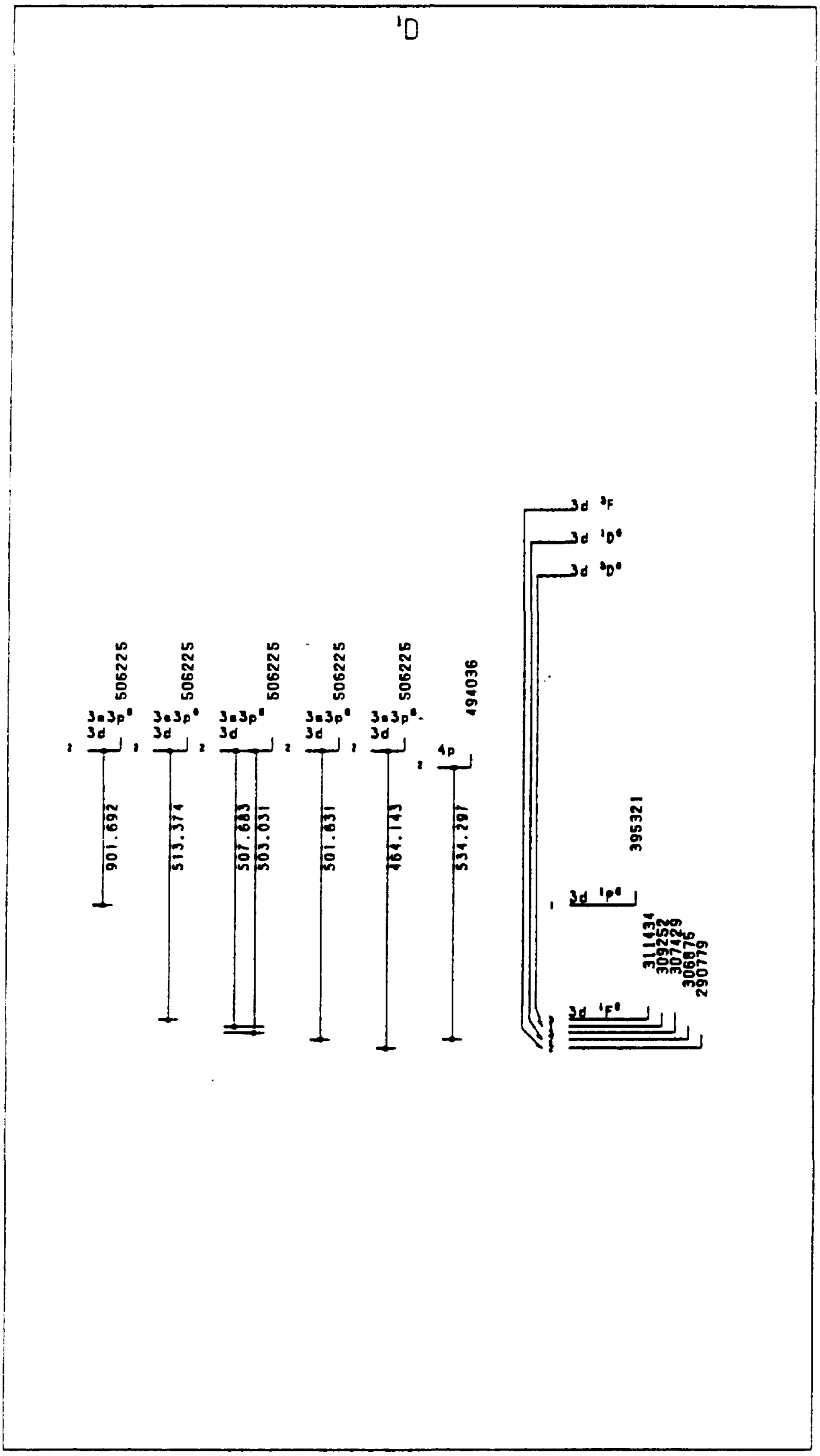
GROTRIAN DIAGRAM



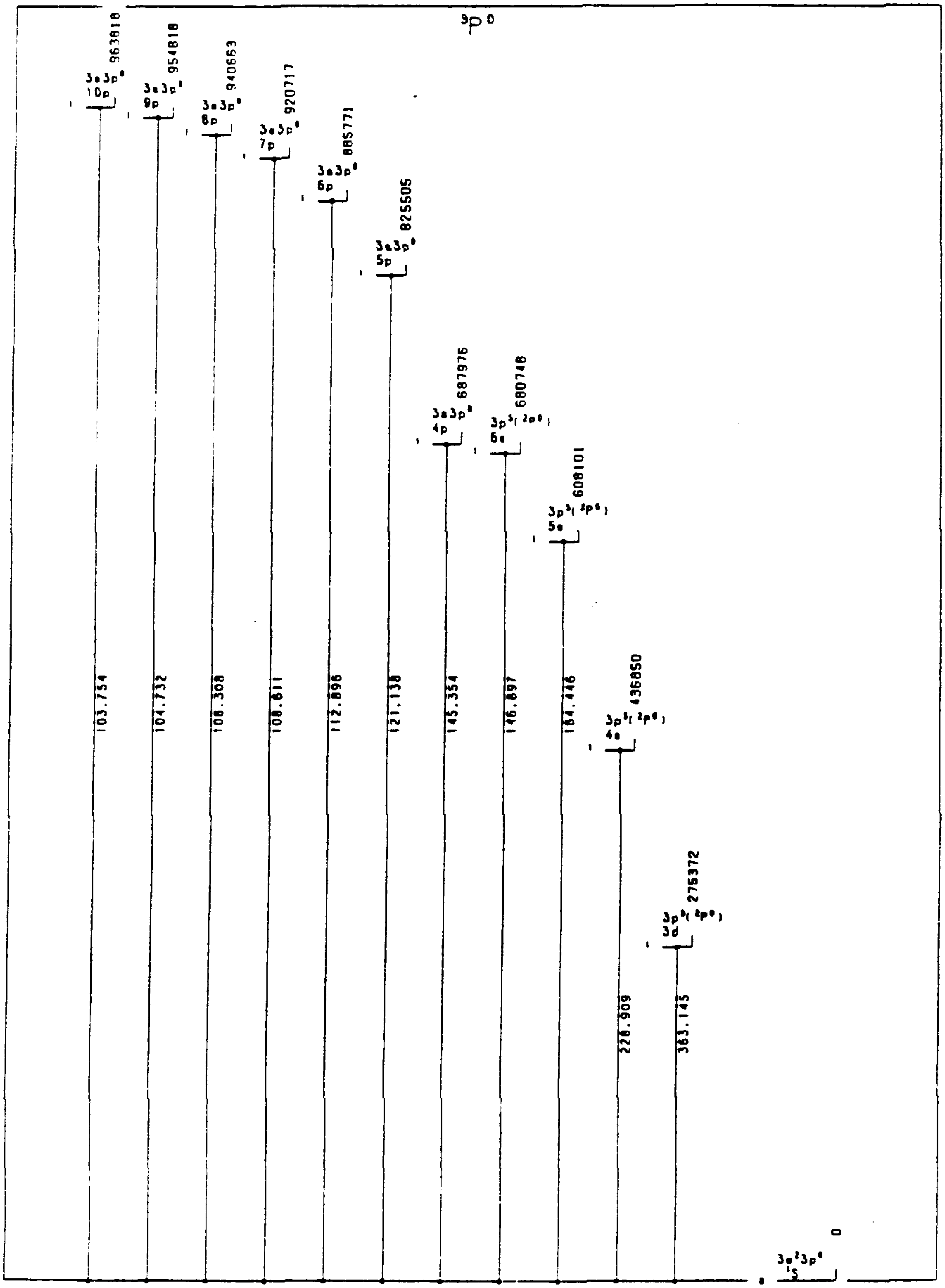
Ti V(Ar-Sequence)



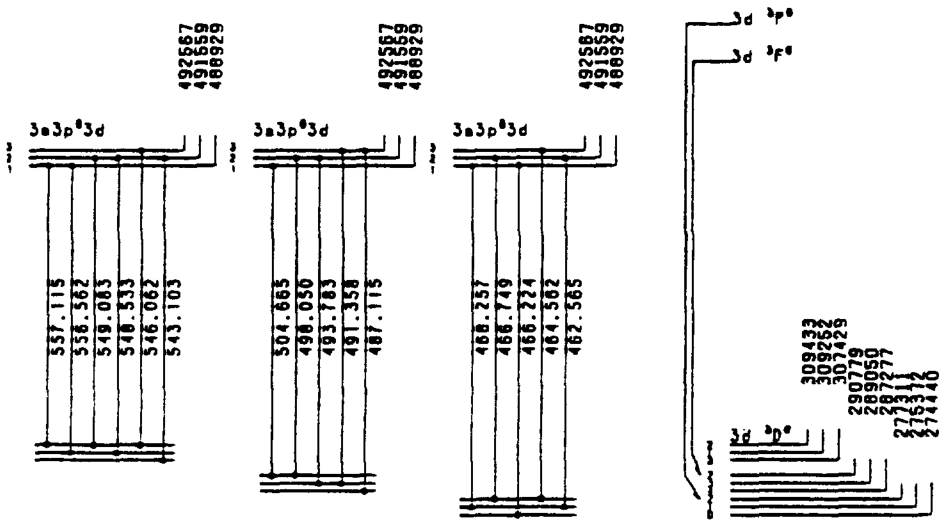
1P0
3s3p6 11p 970318
3s3p6 10p 964013
3s3p6 9p 955100
3s3p6 8p 942028
3s3p6 7p 922143
3s3p6 6p 888928
3s3p6 5p 827650
3s3p6 4p 691797
3p5(2P0) 6s 685940
3p5(2P0) 5s 613558
3p5(2P0) 4s 443753
3p5(2P0) 3d 395321
103.059
103.733
104.711
106.154
108.443
112.495
120.824
144.551
145.79
162.984
225.347
252.958
3s23p6 1S 0

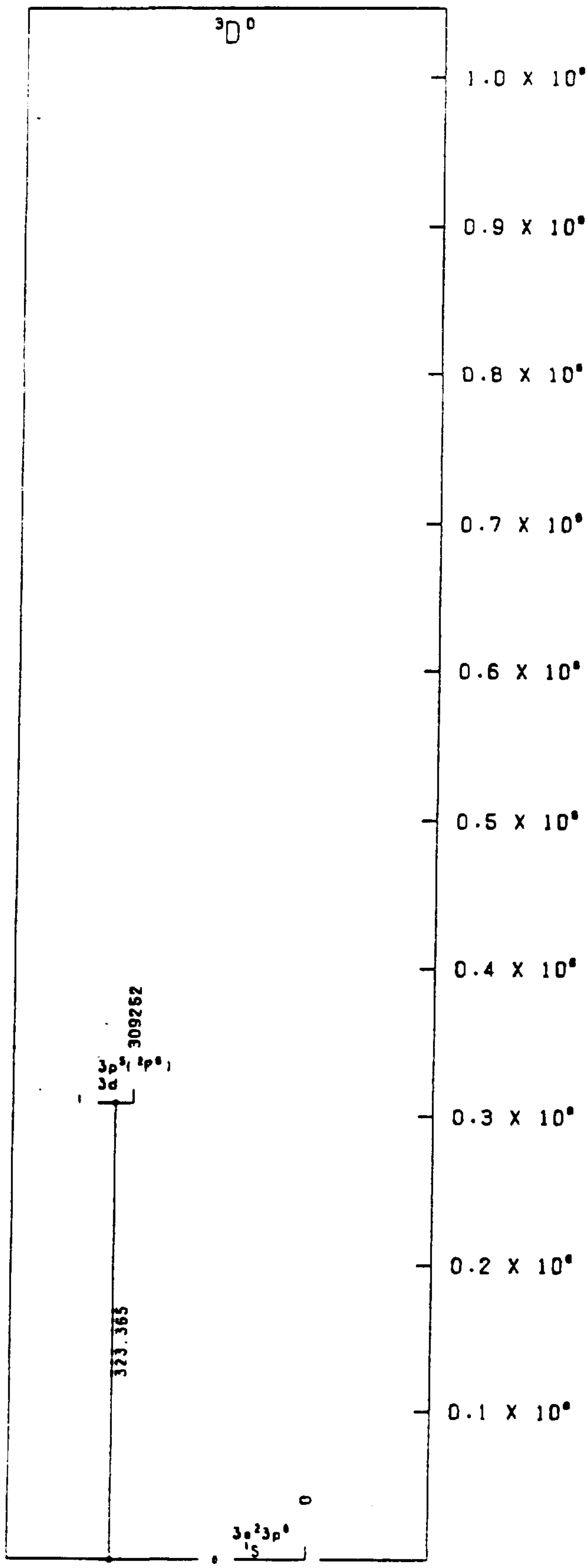


1D
506225
506225
506225
506225
506225
494036
4p
901.692
513.374
507.683
503.031
501.831
464.143
534.297
395321
311434
309252
307429
306876
290779


1P0
3s3p6 10p 963818
3s3p6 9p 954818
3s3p6 8p 940663
3s3p6 7p 920717
3s3p6 6p 885771
3s3p6 5p 825505
3s3p6 4p 687976
3p5(2P0) 6s 680748
3p5(2P0) 5s 608101
3p5(2P0) 4s 436850
3p5(2P0) 3d 275372
3s23p6 1S 0
103.754
104.732
106.308
108.611
112.896
121.138
145.354
146.897
164.446
228.909
363.145

^3D


3s3p⁶3d
492567
491559
488929
557.115
556.562
549.083
548.533
546.062
543.103
504.665
498.050
493.783
491.358
487.115
468.257
466.749
466.224
464.582
462.565
3d ³P°
3d ³F°
3d ³D°
309433
309252
307429
290779
289050
287277
277311
275312
274440


$^3D^0$
1.0 X 10⁶
0.9 X 10⁶
0.8 X 10⁶
0.7 X 10⁶
0.6 X 10⁶
0.5 X 10⁶
0.4 X 10⁶
0.3 X 10⁶
0.2 X 10⁶
0.1 X 10⁶
309262
$3p^5(^2P^0)$
3d
323.365
0
$3s^23p^6$
^1S

AMDIS(Atomic and Molecular Data Interactive System)

Database for cross sections of ionization and excitation by electron impact.

1. Contents

number	element
22	AL
49	AR
19	B
12	BA
44	BE
331	C
56	CA
1	CS
15	F
431	FE
2	H
52	HE
4	HG
6	K
27	KR
50	LI
27	MG
29	MO
123	N
8	NA
175	NE
336	O
4	P
4	RB
23	SC
97	SI
4	SN
4	SR
1	TL
2	V
1	XE

Ionization		
Experiment		57
Theory		244
		301
Excitation		
Experiment		30
Theory	DW	784
	CC	204
	CB	454
	others	186
		1658
Total		1959

2. Example of retrieval

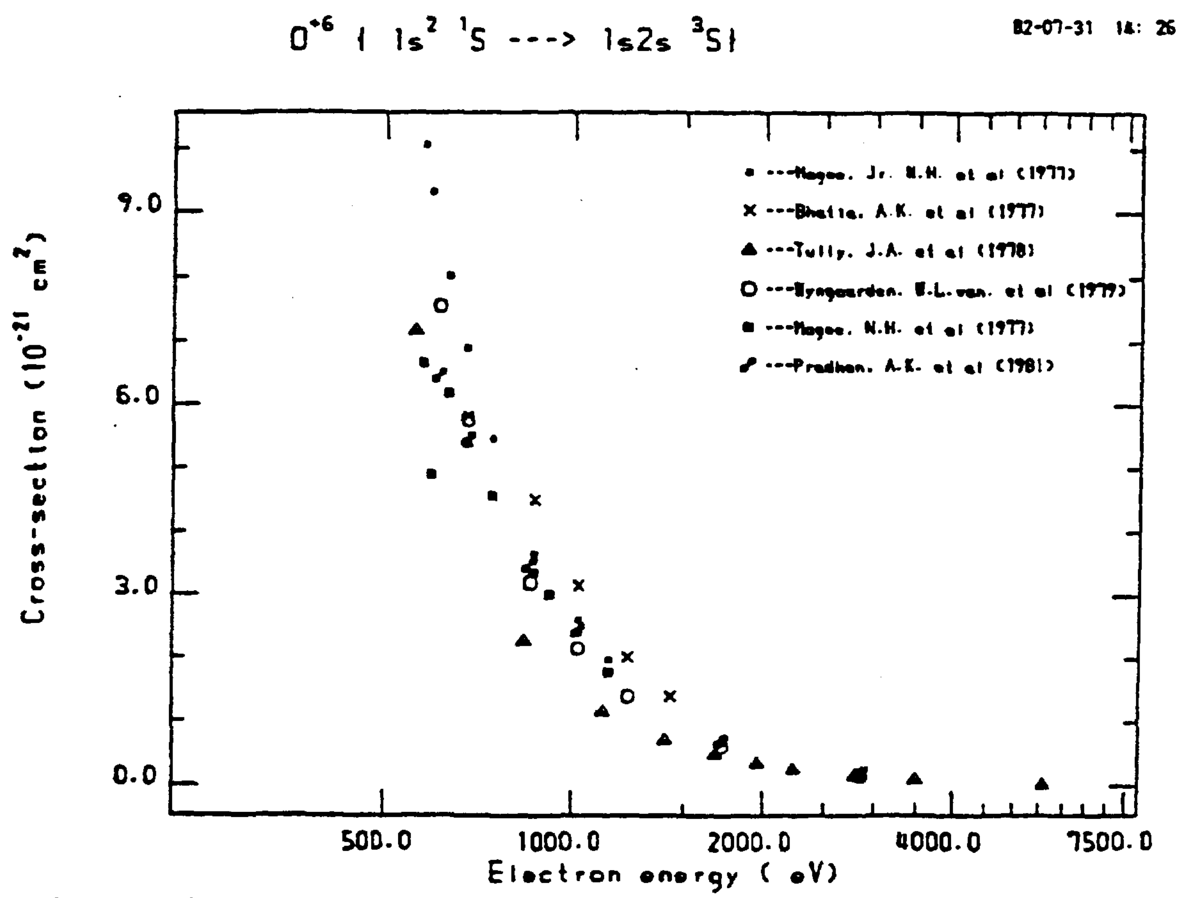
```
FAIRS
+FCA000I FAIRS-I (V02/L06B)
FAIRS> RS
RS> SEL AMDIS
RS> SEA EL HAS O AND PR HAS EXC
+FRS100I 317 RECORD(S) FOUND
RS> AND IS HAS 6
+FRS100I 105 RECORD(S) FOUND
RS> AND IN HAS 1S AND FI HAS 1S2S
+FRS100I 24 RECORD(S) FOUND
RS> AND FI HAS 3
+FRS100I 10 RECORD(S) FOUND
```

3. Examples of outputs

82-07-31 14: 26

Figure Caption

Data NO.	Process	<T>heory or <E>xperiment	Transition	Author (Date)
1---•	Excitation	T	O^{+6} ($1s^2\ ^1S$ ---> $1s2s\ ^3S$)	Magee. Jr. N.H. et al (1977)
2---x	•	•	•	Bhatia. A.K. et al (1977)
3---▲	•	•	•	Tully. J.A. et al (1978)
4---O	•	•	•	Wyngaarden. W.L. van. et al (1979)
5---▪	•	•	•	Magee. N.H. et al (1977)
6---ℯ	•	•	•	Pradhan. A.K. et al (1981)



key in 1..I=1(END),2(DISPLAY),3(XOSEI),4(COPY)(I1)= ?

4. Data on electron impact ionization of ions

Fig.no.	Processes
1.	$He^{+} + e \longrightarrow He^{2+} + 2e$
2.	$Li^{+} + e \longrightarrow Li^{2+} + 2e$
3.	$B^{3+} + e \longrightarrow B^{4+} + 2e$
4.	$C^{+} + e \longrightarrow C^{2+} + 2e$
5.	$C^{2+} + e \longrightarrow C^{3+} + 2e$
6.	$C^{3+} + e \longrightarrow C^{4+} + 2e$
7.	$C^{4+} + e \longrightarrow C^{5+} + 2e$
8.	$N^{+} + e \longrightarrow N^{2+} + 2e$
9.	$N^{2+} + e \longrightarrow N^{3+} + 2e$
10.	$N^{3+} + e \longrightarrow N^{4+} + 2e$
11.	$N^{4+} + e \longrightarrow N^{5+} + 2e$
12.	$N^{5+} + e \longrightarrow N^{6+} + 2e$
13.	$O^{+} + e \longrightarrow O^{2+} + 2e$
14.	$O^{2+} + e \longrightarrow O^{3+} + 2e$
15.	$O^{3+} + e \longrightarrow O^{4+} + 2e$
16.	$O^{4+} + e \longrightarrow O^{5+} + 2e$
17.	$O^{5+} + e \longrightarrow O^{6+} + 2e$
18.	$Ne^{+} + e \longrightarrow Ne^{2+} + 2e$
19.	$Na^{+} + e \longrightarrow Na^{2+} + 2e$
20.	$Mg^{+} + e \longrightarrow Mg^{2+} + 2e$
21.	$Mg^{2+} + e \longrightarrow Mg^{3+} + 2e$
22.	$Ar^{+} + e \longrightarrow Ar^{2+} + 2e$
23.	$Ar^{2+} + e \longrightarrow Ar^{3+} + 2e$
24.	$Ar^{3+} + e \longrightarrow Ar^{4+} + 2e$
25.	$Ar^{4+} + e \longrightarrow Ar^{5+} + 2e$
26.	$Ar^{5+} + e \longrightarrow Ar^{6+} + 2e$
27.	$K^{+} + e \longrightarrow K^{2+} + 2e$

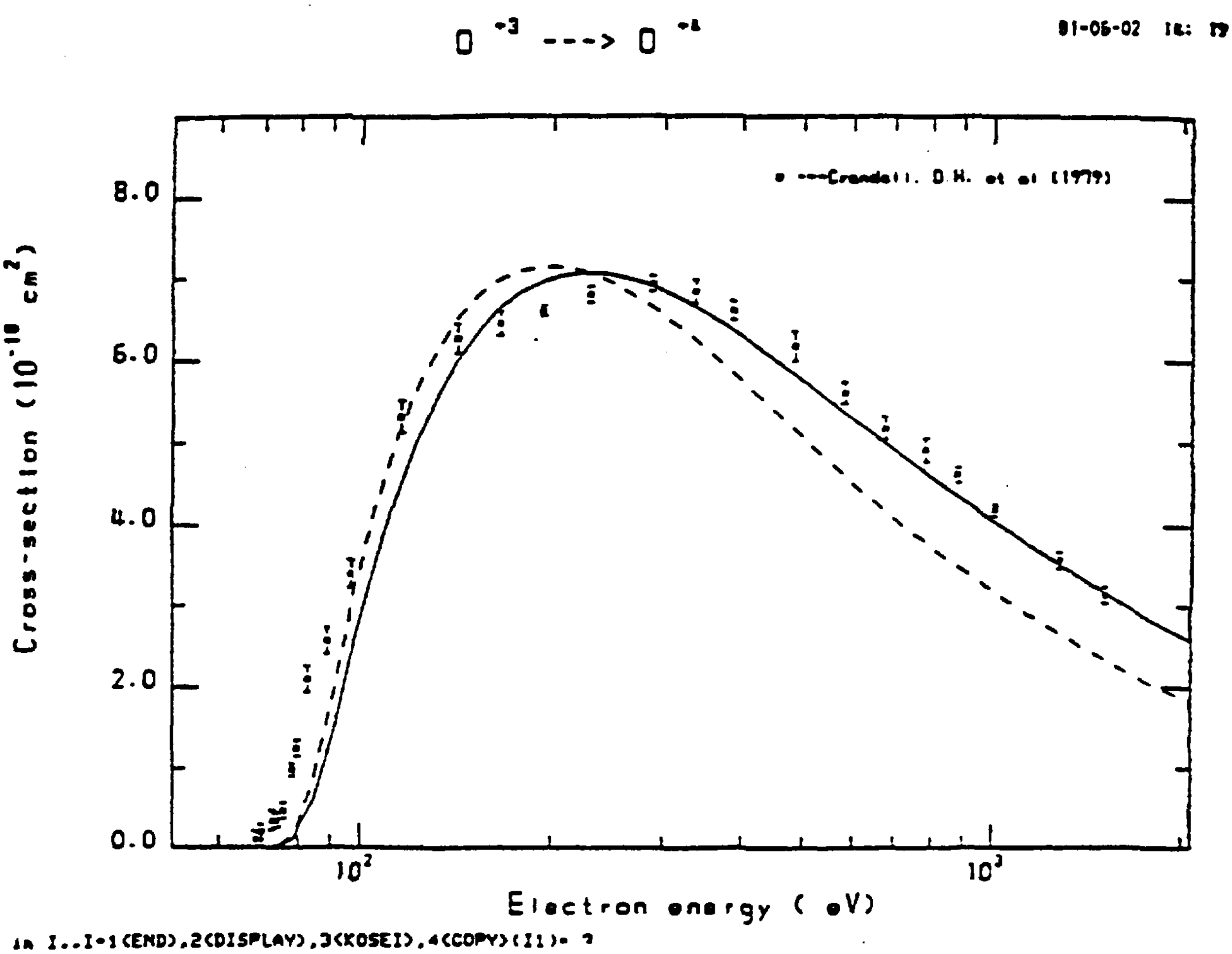


Fig. 15

5. Data on electron transfer of multiply charged ions in H_2

Charge Transfer Fig. No.	Processes
1.	$Li^{+} + H_2 \longrightarrow Li$
2.	$Li^{2+} + H_2 \longrightarrow Li^{+}$
3.	$Li^{3+} + H_2 \longrightarrow Li^{2+}$
4.	$B^{+} + H_2 \longrightarrow B$
5.	$B^{2+} + H_2 \longrightarrow B^{+}$
6.	$B^{3+} + H_2 \longrightarrow B^{+}$
7.	$B^{3+} + H_2 \longrightarrow B^{2+}$
8.	$B^{4+} + H_2 \longrightarrow B^{2+}$
9.	$B^{4+} + H_2 \longrightarrow B^{3+}$
10.	$B^{5+} + H_2 \longrightarrow B^{4+}$
11.	$C^{+} + H_2 \longrightarrow C$
12.	$C^{2+} + H_2 \longrightarrow C^{+}$
13.	$C^{3+} + H_2 \longrightarrow C^{2+}$
14.	$C^{4+} + H_2 \longrightarrow C^{2+}$
15.	$C^{4+} + H_2 \longrightarrow C^{3+}$
16.	$C^{5+} + H_2 \longrightarrow C^{4+}$
17.	$C^{6+} + H_2 \longrightarrow C^{5+}$
18.	$N^{+} + H_2 \longrightarrow N$
19.	$N^{2+} + H_2 \longrightarrow N^{+}$
20.	$N^{3+} + H_2 \longrightarrow N^{2+}$
21.	$N^{4+} + H_2 \longrightarrow N^{3+}$
22.	$N^{5+} + H_2 \longrightarrow N^{3+}$
23.	$N^{5+} + H_2 \longrightarrow N^{4+}$
24.	$O^{+} + H_2 \longrightarrow O$
25.	$O^{2+} + H_2 \longrightarrow O$
26.	$O^{2+} + H_2 \longrightarrow O^{+}$
27.	$O^{3+} + H_2 \longrightarrow O^{2+}$
28.	$O^{4+} + H_2 \longrightarrow O^{3+}$
29.	$O^{5+} + H_2 \longrightarrow O^{3+}$
30.	$O^{5+} + H_2 \longrightarrow O^{4+}$
31.	$O^{6+} + H_2 \longrightarrow O^{4+}$
32.	$O^{6+} + H_2 \longrightarrow O^{5+}$
33.	$F^{+} + H_2 \longrightarrow F$
34.	$F^{9+} + H_2 \longrightarrow F^{8+}$
35.	$Ne^{+} + H_2 \longrightarrow Ne$
36.	$Ne^{2+} + H_2 \longrightarrow Ne^{+}$
37.	$Ne^{3+} + H_2 \longrightarrow Ne^{2+}$
38.	$Mg^{2+} + H_2 \longrightarrow Mg^{+}$
39.	$Si^{2+} + H_2 \longrightarrow Si^{+}$
40.	$Si^{3+} + H_2 \longrightarrow Si^{2+}$
41.	$Si^{4+} + H_2 \longrightarrow Si^{3+}$
42.	$Si^{5+} + H_2 \longrightarrow Si^{4+}$
43.	$Si^{6+} + H_2 \longrightarrow Si^{5+}$
44.	$Si^{7+} + H_2 \longrightarrow Si^{6+}$
45.	$Si^{8+} + H_2 \longrightarrow Si^{7+}$
46.	$Si^{9+} + H_2 \longrightarrow Si^{8+}$
47.	$Si^{11+} + H_2 \longrightarrow Si^{10+}$
48.	$Cl^{3+} + H_2 \longrightarrow Cl^{2+}$
49.	$Cl^{4+} + H_2 \longrightarrow Cl^{3+}$
50.	$K^{+} + H_2 \longrightarrow K$
51.	$Ar^{+} + H_2 \longrightarrow Ar$
52.	$Ar^{2+} + H_2 \longrightarrow Ar^{+}$
53.	$Ar^{3+} + H_2 \longrightarrow Ar^{+}$
54.	$Ar^{3+} + H_2 \longrightarrow Ar^{2+}$
55.	$Ar^{4+} + H_2 \longrightarrow Ar^{2+}$
56.	$Ar^{4+} + H_2 \longrightarrow Ar^{3+}$
57.	$Ar^{5+} + H_2 \longrightarrow Ar^{4+}$
58.	$Ar^{6+} + H_2 \longrightarrow Ar^{5+}$
59.	$Ar^{7+} + H_2 \longrightarrow Ar^{6+}$
60.	$Ar^{8+} + H_2 \longrightarrow Ar^{7+}$
61.	$Ar^{9+} + H_2 \longrightarrow Ar^{8+}$
62.	$Ti^{2+} + H_2 \longrightarrow Ti$
63.	$Ti^{2+} + H_2 \longrightarrow Ti^{+}$
64.	$Fe^{4+} + H_2 \longrightarrow Fe^{3+}$
65.	$Fe^{5+} + H_2 \longrightarrow Fe^{4+}$
66.	$Fe^{6+} + H_2 \longrightarrow Fe^{5+}$
67.	$Fe^{7+} + H_2 \longrightarrow Fe^{6+}$
68.	$Fe^{8+} + H_2 \longrightarrow Fe^{7+}$
69.	$Fe^{9+} + H_2 \longrightarrow Fe^{8+}$
70.	$Fe^{10+} + H_2 \longrightarrow Fe^{9+}$
71.	$Fe^{11+} + H_2 \longrightarrow Fe^{10+}$

Fig. No.	Processes
72.	$Fe^{12+} + H_2 \longrightarrow Fe^{11+}$
73.	$Fe^{13+} + H_2 \longrightarrow Fe^{12+}$
74.	$Fe^{14+} + H_2 \longrightarrow Fe^{13+}$
75.	$Fe^{15+} + H_2 \longrightarrow Fe^{14+}$
76.	$Fe^{16+} + H_2 \longrightarrow Fe^{15+}$
77.	$Fe^{18+} + H_2 \longrightarrow Fe^{17+}$
78.	$Fe^{20+} + H_2 \longrightarrow Fe^{19+}$
79.	$Fe^{21+} + H_2 \longrightarrow Fe^{20+}$
80.	$Fe^{22+} + H_2 \longrightarrow Fe^{21+}$
81.	$Fe^{23+} + H_2 \longrightarrow Fe^{22+}$
82.	$Fe^{24+} + H_2 \longrightarrow Fe^{23+}$
83.	$Fe^{25+} + H_2 \longrightarrow Fe^{24+}$
84.	$Zn^{2+} + H_2 \longrightarrow Zn^{+}$
85.	$Br^{3+} + H_2 \longrightarrow Br^{2+}$
86.	$Br^{4+} + H_2 \longrightarrow Br^{3+}$
87.	$Br^{5+} + H_2 \longrightarrow Br^{4+}$
88.	$Br^{6+} + H_2 \longrightarrow Br^{4+}$
89.	$Br^{6+} + H_2 \longrightarrow Br^{5+}$
90.	$Br^{7+} + H_2 \longrightarrow Br^{5+}$
91.	$Br^{7+} + H_2 \longrightarrow Br^{6+}$
92.	$Br^{8+} + H_2 \longrightarrow Br^{6+}$
93.	$Br^{8+} + H_2 \longrightarrow Br^{7+}$
94.	$Br^{9+} + H_2 \longrightarrow Br^{8+}$
95.	$Br^{10+} + H_2 \longrightarrow Br^{9+}$
96.	$Br^{11+} + H_2 \longrightarrow Br^{10+}$
97.	$Br^{12+} \quad H_2 \longrightarrow Br^{11+}$
98.	$Kr^{2+} + H_2 \longrightarrow Kr^{+}$
99.	$Mo^{4+} + H_2 \longrightarrow Mo^{3+}$
100.	$Mo^{5+} + H_2 \longrightarrow Mo^{4+}$
101.	$Mo^{6+} + H_2 \longrightarrow Mo^{5+}$
102.	$Mo^{7+} + H_2 \longrightarrow Mo^{6+}$
103.	$Mo^{8+} + H_2 \longrightarrow Mo^{7+}$
104.	$Mo^{9+} + H_2 \longrightarrow Mo^{8+}$
105.	$Mo^{10+} + H_2 \longrightarrow Mo^{9+}$
106.	$Mo^{11+} + H_2 \longrightarrow Mo^{10+}$
107.	$Mo^{12+} + H_2 \longrightarrow Mo^{11+}$
108.	$Mo^{13+} + H_2 \longrightarrow Mo^{12+}$
109.	$Mo^{14+} + H_2 \longrightarrow Mo^{13+}$
110.	$Mo^{15+} + H_2 \longrightarrow Mo^{14+}$
111.	$Mo^{16+} + H_2 \longrightarrow Mo^{15+}$
112.	$Mo^{17+} + H_2 \longrightarrow Mo^{16+}$
113.	$Mo^{18+} + H_2 \longrightarrow Mo^{17+}$
114.	$Cd^{2+} + H_2 \longrightarrow Cd^{+}$
115.	$I^{2+} + H_2 \longrightarrow I$
116.	$I^{2+} + H_2 \longrightarrow I^{+}$
117.	$I^{3+} + H_2 \longrightarrow I^{+}$
118.	$I^{3+} + H_2 \longrightarrow I^{2+}$
119.	$I^{4+} + H_2 \longrightarrow I^{2+}$
120.	$I^{4+} + H_2 \longrightarrow I^{3+}$
121.	$I^{5+} + H_2 \longrightarrow I^{3+}$
122.	$I^{5+} + H_2 \longrightarrow I^{4+}$
123.	$I^{6+} + H_2 \longrightarrow I^{4+}$
124.	$I^{6+} + H_2 \longrightarrow I^{5+}$
125.	$I^{7+} + H_2 \longrightarrow I^{5+}$
126.	$I^{7+} + H_2 \longrightarrow I^{6+}$
127.	$I^{8+} + H_2 \longrightarrow I^{6+}$
128.	$I^{8+} + H_2 \longrightarrow I^{7+}$
129.	$I^{9+} + H_2 \longrightarrow I^{7+}$
130.	$I^{9+} + H_2 \longrightarrow I^{8+}$
131.	$I^{10+} + H_2 \longrightarrow I^{8+}$
132.	$I^{10+} + H_2 \longrightarrow I^{9+}$
133.	$I^{11+} + H_2 \longrightarrow I^{10+}$
134.	$I^{12+} + H_2 \longrightarrow I^{11+}$
135.	$I^{13+} + H_2 \longrightarrow I^{12+}$
136.	$I^{14+} + H_2 \longrightarrow I^{13+}$
137.	$I^{15+} + H_2 \longrightarrow I^{14+}$
138.	$I^{16+} + H_2 \longrightarrow I^{15+}$
139.	$I^{17+} + H_2 \longrightarrow I^{16+}$
140.	$I^{18+} + H_2 \longrightarrow I^{17+}$
141.	$Xe^{2+} + H_2 \longrightarrow Xe^{+}$
142.	$Xe^{3+} + H_2 \longrightarrow Xe^{2+}$
143.	$Xe^{4+} + H_2 \longrightarrow Xe^{3+}$
144.	$Xe^{5+} + H_2 \longrightarrow Xe^{4+}$
145.	$Xe^{6+} + H_2 \longrightarrow Xe^{5+}$
146.	$Xe^{7+} + H_2 \longrightarrow Xe^{6+}$

Fig. No.	Processes
147.	$Xe^{8+} + H_2 \longrightarrow Xe^{7+}$
148.	$Xe^{9+} + H_2 \longrightarrow Xe^{8+}$
149.	$Xe^{10+} + H_2 \longrightarrow Xe^{9+}$
150.	$Xe^{11+} + H_2 \longrightarrow Xe^{10+}$
151.	$Xe^{12+} + H_2 \longrightarrow Xe^{11+}$
152.	$Ba^{2+} + H_2 \longrightarrow Ba^{+}$
153.	$Ta^{3+} + H_2 \longrightarrow Ta^{2+}$
154.	$Ta^{4+} + H_2 \longrightarrow Ta^{3+}$
155.	$Ta^{5+} + H_2 \longrightarrow Ta^{4+}$
156.	$Ta^{6+} + H_2 \longrightarrow Ta^{5+}$
157.	$Ta^{7+} + H_2 \longrightarrow Ta^{6+}$
158.	$Ta^{8+} + H_2 \longrightarrow Ta^{7+}$
159.	$Ta^{9+} + H_2 \longrightarrow Ta^{8+}$
160.	$Ta^{10+} + H_2 \longrightarrow Ta^{9+}$
161.	$Ta^{11+} + H_2 \longrightarrow Ta^{10+}$
162.	$Ta^{12+} + H_2 \longrightarrow Ta^{11+}$
163.	$Ta^{13+} + H_2 \longrightarrow Ta^{12+}$
164.	$Ta^{14+} + H_2 \longrightarrow Ta^{13+}$
165.	$Ta^{15+} + H_2 \longrightarrow Ta^{14+}$
166.	$Ta^{16+} + H_2 \longrightarrow Ta^{15+}$
167.	$Ta^{17+} + H_2 \longrightarrow Ta^{16+}$
168.	$Ta^{18+} + H_2 \longrightarrow Ta^{17+}$
169.	$Ta^{19+} + H_2 \longrightarrow Ta^{18+}$
170.	$W^{4+} + H_2 \longrightarrow W^{3+}$
171.	$W^{5+} + H_2 \longrightarrow W^{4+}$

Fig. No.	Processes
172.	$W^{6+} + H_2 \longrightarrow W^{5+}$
173.	$W^{7+} + H_2 \longrightarrow W^{6+}$
174.	$W^{8+} + H_2 \longrightarrow W^{7+}$
175.	$W^{9+} + H_2 \longrightarrow W^{8+}$
176.	$W^{10+} + H_2 \longrightarrow W^{9+}$
177.	$W^{11+} + H_2 \longrightarrow W^{10+}$
178.	$W^{12+} + H_2 \longrightarrow W^{11+}$
179.	$W^{13+} + H_2 \longrightarrow W^{12+}$
180.	$W^{14+} + H_2 \longrightarrow W^{13+}$
181.	$W^{15+} + H_2 \longrightarrow W^{14+}$
182.	$Au^{5+} + H_2 \longrightarrow Au^{4+}$
183.	$Au^{6+} + H_2 \longrightarrow Au^{5+}$
184.	$Au^{7+} + H_2 \longrightarrow Au^{6+}$
185.	$Au^{8+} + H_2 \longrightarrow Au^{7+}$
186.	$Au^{9+} + H_2 \longrightarrow Au^{8+}$
187.	$Au^{10+} + H_2 \longrightarrow Au^{9+}$
188.	$Au^{11+} + H_2 \longrightarrow Au^{10+}$
189.	$Au^{12+} + H_2 \longrightarrow Au^{11+}$
190.	$Au^{13+} + H_2 \longrightarrow Au^{12+}$
191.	$Au^{14+} + H_2 \longrightarrow Au^{13+}$
192.	$Au^{15+} + H_2 \longrightarrow Au^{14+}$
193.	$Au^{16+} + H_2 \longrightarrow Au^{15+}$

Ionization

Fig. No.	Processes
A1.	$Li^{+} + H_2 \longrightarrow Li^{2+}$
A2.	$Li^{2+} + H_2 \longrightarrow Li^{3+}$
A3.	$B^{+} + H_2 \longrightarrow B^{2+}$
A4.	$B^{2+} + H_2 \longrightarrow B^{3+}$
A5.	$C^{+} + H_2 \longrightarrow C^{2+}$
A6.	$C^{2+} + H_2 \longrightarrow C^{3+}$
A7.	$C^{3+} + H_2 \longrightarrow C^{4+}$
A8.	$C^{4+} + H_2 \longrightarrow C^{5+}$
A9.	$N^{4+} + H_2 \longrightarrow N^{5+}$
A10.	$O^{2+} + H_2 \longrightarrow O^{3+}$
A11.	$Si^{3+} + H_2 \longrightarrow Si^{4+}$
A12	$Si^{4+} + H_2 \longrightarrow Si^{5+}$
A13.	$Cl^{2+} + H_2 \longrightarrow Cl^{3+}$
A14.	$Cl^{3+} + H_2 \longrightarrow Cl^{4+}$
A15.	$K^{+} + H_2 \longrightarrow K^{2+}$
A16.	$Fe^{20+} + H_2 \longrightarrow Fe^{21+}$
A17.	$Fe^{21+} + H_2 \longrightarrow Fe^{22+}$
A18.	$Fe^{22+} + H_2 \longrightarrow Fe^{23+}$
A19.	$Fe^{23+} + H_2 \longrightarrow Fe^{24+}$
A20.	$Fe^{24+} + H_2 \longrightarrow Fe^{25+}$
A21.	$Fe^{25+} + H_2 \longrightarrow Fe^{26+}$
A22.	$Br^{3+} + H_2 \longrightarrow Br^{4+}$
A23.	$Br^{4+} + H_2 \longrightarrow Br^{5+}$
A24.	$Br^{4+} + H_2 \longrightarrow Br^{6+}$

Fig. No.	Processes
A25.	$Br^{4+} + H_2 \longrightarrow Br^{7+}$
A26.	$Br^{4+} + H_2 \longrightarrow Br^{8+}$
A27.	$Br^{5+} + H_2 \longrightarrow Br^{6+}$
A28.	$Br^{5+} + H_2 \longrightarrow Br^{7+}$
A29.	$Br^{6+} + H_2 \longrightarrow Br^{7+}$
A30.	$Br^{6+} + H_2 \longrightarrow Br^{8+}$
A31.	$Br^{7+} + H_2 \longrightarrow Br^{8+}$
A32.	$Br^{7+} + H_2 \longrightarrow Br^{9+}$
A33.	$Br^{8+} + H_2 \longrightarrow Br^{9+}$
A34.	$Br^{8+} + H_2 \longrightarrow Br^{10+}$
A35.	$Br^{9+} + H_2 \longrightarrow Br^{10+}$
A36.	$Br^{10+} + H_2 \longrightarrow Br^{11+}$
A37.	$Br^{11+} + H_2 \longrightarrow Br^{12+}$
A38.	$I^{2+} + H_2 \longrightarrow I^{3+}$
A39.	$I^{2+} + H_2 \longrightarrow I^{4+}$
A40.	$I^{2+} + H_2 \longrightarrow I^{5+}$
A41.	$I^{3+} + H_2 \longrightarrow I^{4+}$
A42.	$I^{3+} + H_2 \longrightarrow I^{5+}$
A43.	$I^{3+} + H_2 \longrightarrow I^{6+}$
A44.	$I^{4+} + H_2 \longrightarrow I^{5+}$
A45.	$I^{4+} + H_2 \longrightarrow I^{6+}$
A46.	$I^{4+} + H_2 \longrightarrow I^{7+}$
A47.	$I^{5+} + H_2 \longrightarrow I^{6+}$
A48.	$I^{5+} + H_2 \longrightarrow I^{7+}$
A49.	$I^{5+} + H_2 \longrightarrow I^{8+}$
A50.	$I^{6+} + H_2 \longrightarrow I^{7+}$
A51.	$I^{6+} + H_2 \longrightarrow I^{8+}$
A52.	$I^{6+} + H_2 \longrightarrow I^{9+}$
A53.	$I^{7+} + H_2 \longrightarrow I^{8+}$
A54.	$I^{7+} + H_2 \longrightarrow I^{9+}$
A55.	$I^{8+} + H_2 \longrightarrow I^{9+}$
A56.	$I^{8+} + H_2 \longrightarrow I^{10+}$
A57.	$I^{9+} + H_2 \longrightarrow I^{10+}$
A58.	$I^{9+} + H_2 \longrightarrow I^{11+}$
A59.	$I^{10+} + H_2 \longrightarrow I^{11+}$

5. Data on electron transfer of multiply charged ions in atomic hydrogen

Charge Transfer

Fig. No.	Processes
1.	$\underline{H}^+ + H \longrightarrow \underline{H}$
	$\underline{H}^+ + H \longrightarrow \underline{H} + H^+$
	$\underline{D}^+ + D \longrightarrow \underline{D} + D^+$
2.	$\underline{H}^+ + H \longrightarrow \underline{H}(2s) + H^+$
	$\underline{D}^+ + H \longrightarrow \underline{D}(2s) + H^+$
3.	$\underline{H}^+ + H \longrightarrow \underline{H}(2p) + H^+$
	$\underline{D}^+ + H \longrightarrow \underline{D}(2p) + H^+$
4.	$^4He^{2+} + H \longrightarrow He^+$
	$^3He^{2+} + H \longrightarrow He^+$
5.	$^3He^{2+} + H \longrightarrow He^+(2s)$
	$^4He^{2+} + H \longrightarrow He^+(2s)$
6.	$^4He^+ + H \longrightarrow He$
7.	$^7Li^+ + H \longrightarrow Li$
8.	$^7Li^{2+} + H \longrightarrow Li^+$
9.	$^7Li^{3+} + H \longrightarrow Li^{2+}$
10.	$^{11}B^+ + H \longrightarrow B$
11.	$^{11}B^{2+} + H \longrightarrow B^+$
	$B^{2+} + H \longrightarrow B^+$
12.	$^{11}B^{3+} + H \longrightarrow B^{2+}$
	$B^{3+} + H \longrightarrow B^{2+}$
13.	$B^{4+} + H \longrightarrow B^{3+}$
14.	$B^{5+} + H \longrightarrow B^{4+}$
	$^{11}B^{5+} + H \longrightarrow B^{4+}$
15.	$C^+ + H \longrightarrow C^0$
16.	$C^{2+} + H \longrightarrow C^+$
17.	$C^{3+} + H \longrightarrow C^{2+}$
18.	$C^{4+} + H \longrightarrow C^{3+}$
19.	$C^{5+} + H \longrightarrow C^{4+}$
20.	$C^{6+} + H \longrightarrow C^{5+}$
21.	$N^+ + H \longrightarrow N^0$
22.	$N^{2+} + H \longrightarrow N^+$
23.	$N^{3+} + H \longrightarrow N^{2+}$
24.	$N^{4+} + H \longrightarrow N^{3+}$
25.	$N^{5+} + H \longrightarrow N^{4+}$
26.	$N^{7+} + H \longrightarrow N^{6+}$
27.	$O^+ + H \longrightarrow O^0$
28.	$O^{2+} + H \longrightarrow O^+$
29.	$O^{3+} + H \longrightarrow O^{2+}$
30.	$O^{4+} + H \longrightarrow O^{3+}$
31.	$O^{5+} + H \longrightarrow O^{4+}$
32.	$O^{6+} + H \longrightarrow O^{5+}$
33.	$O^{7+} + H \longrightarrow O^{6+}$
34.	$O^{8+} + H \longrightarrow O^{7+}$

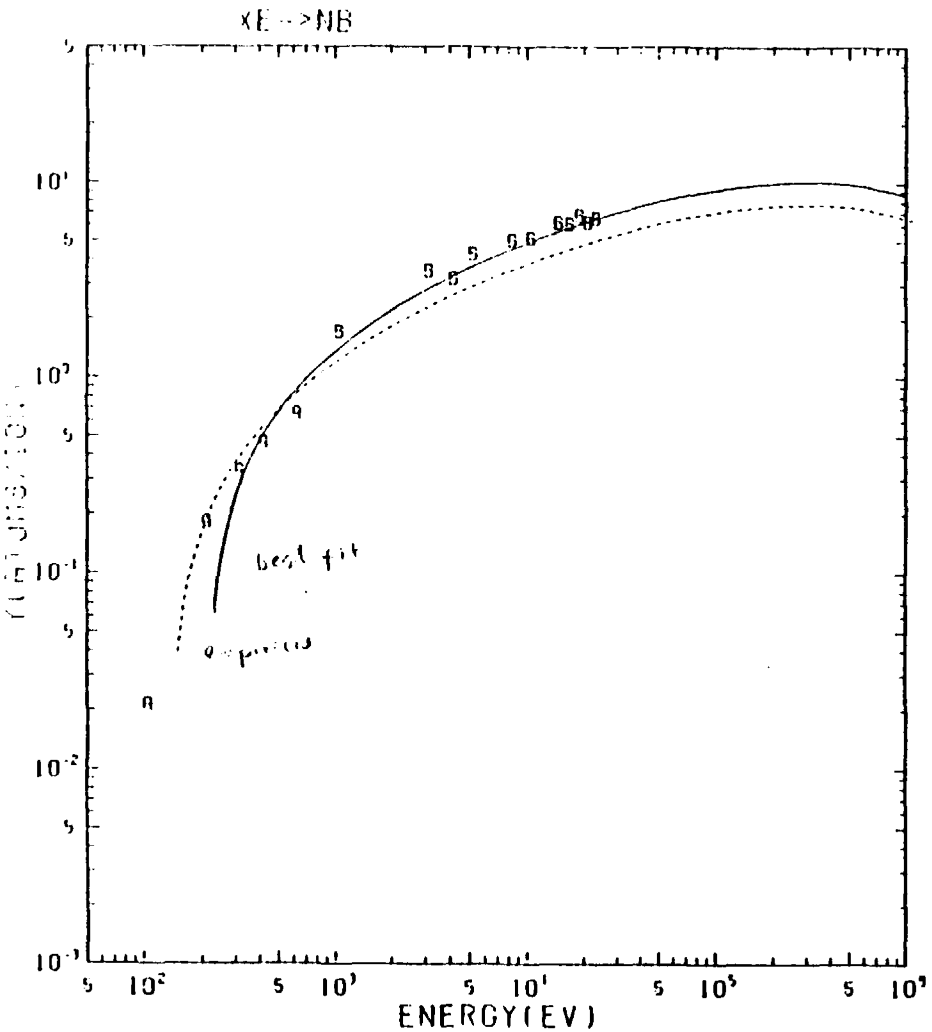
Fig. No.	Processes
35.	$Mg^{2+} + H \longrightarrow Mg^+$
36.	$Si^{2+} + H \longrightarrow Si^+$
37.	$Si^{3+} + H \longrightarrow Si^{2+}$
38.	$Si^{4+} + H \longrightarrow Si^{3+}$
39.	$Si^{5+} + H \longrightarrow Si^{4+}$
40	$Si^{6+} + H \longrightarrow Si^{5+}$
41.	$Si^{7+} + H \longrightarrow Si^{6+}$
42.	$Si^{8+} + H \longrightarrow Si^{7+}$
43.	$Si^{9+} + H \longrightarrow Si^{8+}$
44.	$Ar^{2+} + H \longrightarrow Ar^+$
45.	$Ar^{3+} + H \longrightarrow Ar^{2+}$
46.	$Ar^{4+} + H \longrightarrow Ar^{3+}$
47.	$Ar^{5+} + H \longrightarrow Ar^{4+}$
48.	$Ar^{6+} + H \longrightarrow Ar^{5+}$
49.	$Ar^{7+} + H \longrightarrow Ar^{6+}$
50.	$Ar^{8+} + H \longrightarrow Ar^{7+}$
51.	$Ar^{9+} + H \longrightarrow Ar^{8+}$
52.	$Ti^{2+} + H \longrightarrow Ti^+$
53.	$Fe^{4+} + H \longrightarrow Fe^{3+}$
54.	$Fe^{5+} + H \longrightarrow Fe^{4+}$
55.	$Fe^{6+} + H \longrightarrow Fe^{5+}$
56.	$Fe^{7+} + H \longrightarrow Fe^{6+}$
57.	$Fe^{8+} + H \longrightarrow Fe^{7+}$
58.	$Fe^{9+} + H \longrightarrow Fe^{8+}$
59.	$Fe^{10+} + H \longrightarrow Fe^{9+}$
60.	$Fe^{11+} + H \longrightarrow Fe^{10+}$
61.	$Fe^{12+} + H \longrightarrow Fe^{11+}$
62.	$Fe^{13+} + H \longrightarrow Fe^{12+}$
63.	$Fe^{14+} + H \longrightarrow Fe^{13+}$
64.	$Fe^{15+} + H \longrightarrow Fe^{14+}$
65.	$Zn^{2+} + H \longrightarrow Zn^+$
66.	$Kr^{2+} + H \longrightarrow Kr^+$
67.	$Mo^{4+} + H \longrightarrow Mo^{3+}$
68.	$Mo^{5+} + H \longrightarrow Mo^{4+}$
69.	$Mo^{6+} + H \longrightarrow Mo^{5+}$
70.	$Mo^{7+} + H \longrightarrow Mo^{6+}$
71.	$Mo^{8+} + H \longrightarrow Mo^{7+}$
72.	$Mo^{9+} + H \longrightarrow Mo^{8+}$
73.	$Mo^{10+} + H \longrightarrow Mo^{9+}$
74.	$Mo^{11+} + H \longrightarrow Mo^{10+}$
75.	$Mo^{12+} + H \longrightarrow Mo^{11+}$
76.	$Mo^{13+} + H \longrightarrow Mo^{12+}$

Fig. No.	Processes
77.	$Mo^{14+} + H \longrightarrow Mo^{13+}$
78.	$Mo^{15+} + H \longrightarrow Mo^{14+}$
79.	$Mo^{16+} + H \longrightarrow Mo^{15+}$
80.	$Mo^{17+} + H \longrightarrow Mo^{16+}$
81.	$Mo^{18+} + H \longrightarrow Mo^{17+}$
82.	$Cd^{2+} + H \longrightarrow Cd^{+}$
83.	$Xe^{2+} + H \longrightarrow Xe^{+}$
84.	$Xe^{3+} + H \longrightarrow Xe^{2+}$
85.	$Xe^{4+} + H \longrightarrow Xe^{3+}$
86.	$Xe^{5+} + H \longrightarrow Xe^{4+}$
87.	$Xe^{6+} + H \longrightarrow Xe^{5+}$
88.	$Xe^{7+} + H \longrightarrow Xe^{6+}$
89.	$Xe^{8+} + H \longrightarrow Xe^{7+}$
90.	$Xe^{9+} + H \longrightarrow Xe^{8+}$
91.	$Xe^{10+} + H \longrightarrow Xe^{9+}$
92.	$Xe^{11+} + H \longrightarrow Xe^{10+}$
93.	$Xe^{12+} + H \longrightarrow Xe^{11+}$
94.	$Ba^{+} + H \longrightarrow Ba^{+}$
95.	$Ta^{3+} + H \longrightarrow Ta^{2+}$
96.	$Ta^{4+} + H \longrightarrow Ta^{3+}$
97.	$Ta^{5+} + H \longrightarrow Ta^{4+}$
98.	$Ta^{6+} + H \longrightarrow Ta^{5+}$
99.	$Ta^{7+} + H \longrightarrow Ta^{6+}$
100.	$Ta^{8+} + H \longrightarrow Ta^{7+}$
101.	$Ta^{9+} + H \longrightarrow Ta^{8+}$
102.	$Ta^{10+} + H \longrightarrow Ta^{9+}$
103.	$Ta^{11+} + H \longrightarrow Ta^{10+}$
104.	$Ta^{12+} + H \longrightarrow Ta^{11+}$
105.	$Ta^{13+} + H \longrightarrow Ta^{12+}$
106.	$Ta^{14+} + H \longrightarrow Ta^{13+}$
107.	$Ta^{15+} + H \longrightarrow Ta^{14+}$
108.	$Ta^{16+} + H \longrightarrow Ta^{15+}$
109.	$Ta^{17+} + H \longrightarrow Ta^{16+}$
110.	$Ta^{18+} + H \longrightarrow Ta^{17+}$
111.	$Ta^{19+} + H \longrightarrow Ta^{18+}$
112.	$W^{4+} + H \longrightarrow W^{3+}$
113.	$W^{5+} + H \longrightarrow W^{4+}$
114.	$W^{6+} + H \longrightarrow W^{5+}$
115.	$W^{7+} + H \longrightarrow W^{6+}$
116.	$W^{8+} + H \longrightarrow W^{7+}$
117.	$W^{9+} + H \longrightarrow W^{8+}$
118.	$W^{10+} + H \longrightarrow W^{9+}$
119.	$W^{11+} + H \longrightarrow W^{10+}$
120.	$W^{12+} + H \longrightarrow W^{11+}$
121.	$W^{13+} + H \longrightarrow W^{12+}$
122.	$W^{14+} + H \longrightarrow W^{13+}$

Fig. No.	Processes
123.	$W^{15+} + H \longrightarrow W^{14+}$
124.	$Au^{5+} + H \longrightarrow Au^{4+}$
125.	$Au^{6+} + H \longrightarrow Au^{5+}$
126.	$Au^{7+} + H \longrightarrow Au^{6+}$
127.	$Au^{8+} + H \longrightarrow Au^{7+}$
128.	$Au^{9+} + H \longrightarrow Au^{8+}$
129.	$Au^{10+} + H \longrightarrow Au^{9+}$
130.	$Au^{11+} + H \longrightarrow Au^{10+}$
131.	$Au^{12+} + H \longrightarrow Au^{11+}$
132.	$Au^{13+} + H \longrightarrow Au^{12+}$
133.	$Au^{14+} + H \longrightarrow Au^{13+}$
134.	$Au^{15+} + H \longrightarrow Au^{14+}$
135.	$Au^{16+} + H \longrightarrow Au^{15+}$

Fig. No.	Processes
A1.	$\underline{H}^+ + H \longrightarrow \underline{H}^+ + H(2p)$
	$\underline{D}^+ + H \longrightarrow \underline{D}^+ + H(2p)$
A2.	$\underline{H}^+ + H \longrightarrow \underline{H}^+ + H(2s)$
A3.	$\underline{H}^+ + H \longrightarrow \underline{H}^+ + H(n=2)$
A4.	$\underline{H}^+ + H \longrightarrow \underline{H}^+ + H(n=3)$
A5.	$\underline{H}^+ + H \longrightarrow \underline{H}^+ + H(n=4)$
A6.	$\underline{H}^+ + H \longrightarrow \underline{H}^+ + H^+ + e$
A7.	$\underline{H} + H \longrightarrow \underline{H}^+$
A8.	$\underline{H} + H \longrightarrow \underline{H}(2s)$
	$\underline{H}(1s) + H(1s) \longrightarrow \underline{H}(2s)$
A9.	$\underline{H} + H \longrightarrow \underline{H}(2p)$
A10.	$\underline{H} + H \longrightarrow \underline{H}^- + H^+$
A11.	$\underline{H}^- + H \longrightarrow \underline{H}$
	$\underline{H}^- + H \longrightarrow \underline{H} + H^-$
A12.	$\underline{H}^- + H \longrightarrow \underline{H}^+$
A13.	$^4He^+ + H \longrightarrow He^{2+}$
A14.	$^4He^+ + H \longrightarrow He^+ + H(2p)$
A15.	$^3He^+ + H \longrightarrow He^+(2s)$
A16.	$^4He + H \longrightarrow He^+$
A17.	$^4He^- + H \longrightarrow He$
A18.	$C^+ + H \longrightarrow C^{2+}$
A19.	$C^{2+} + H \longrightarrow C^{3+}$
A20.	$C^{3+} + H \longrightarrow C^{4+}$

7. Data on sputtering yields by ion impact



XE->NB
A ROSENBLEG.WEHNER (1962)
B KOSHKIN.RYSOV.SHKARBAN (1963)

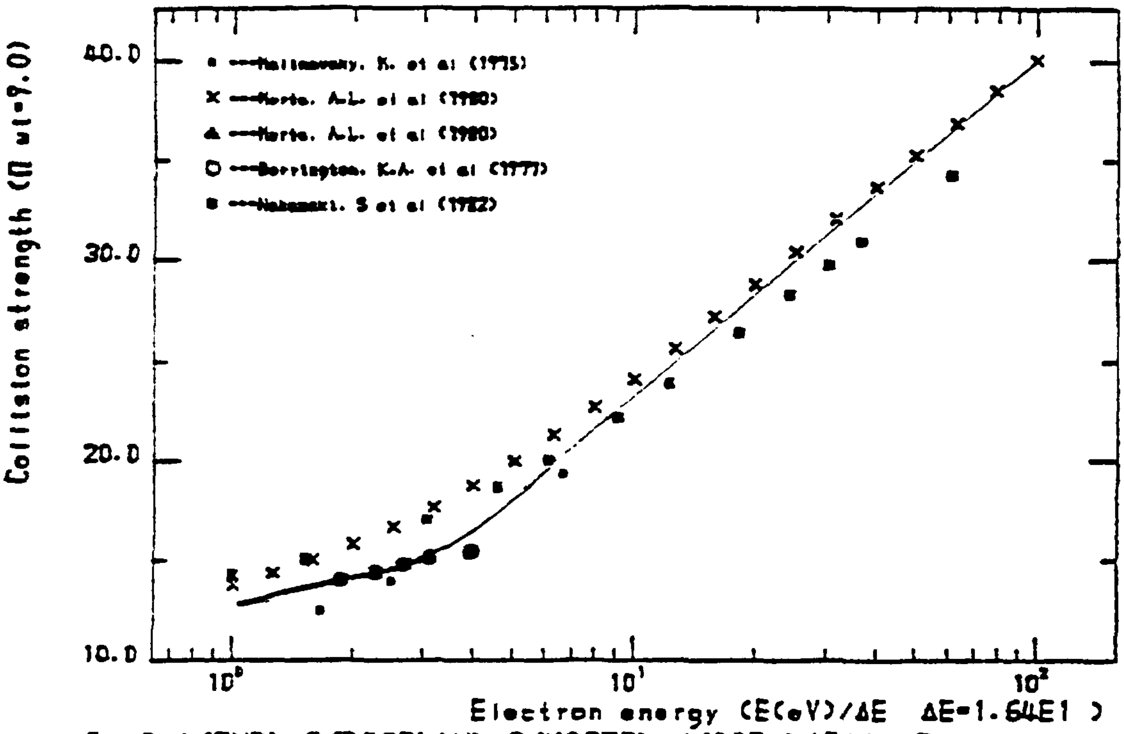
Table I Ion-target combinations in the present data compilation

Target \ Ion		H 1	D 1	He 2	Li 3	N 7	O 8	Ne 10	Ar 18	Zn 30	Kr 36	Xe 54	Cs 55	Gd 64	Hg 80	Pb 82	+
Be	4			*				*	*		*	*					
B	5			x													
C	6	x	*	*					*		*	*			*		
Al	13			*				*	*		*	*			*		*
Si	14			*				*	*		*	*				*	
Ti	22	x		*				*	*		*	*			*		
V	23			*				*	*		*	*			*		
Cr	24			*				*	*		*	*			*		x
Mn	25										x	x					
Fe	26			*		*		*	*		*	*	*		*	*	
Co	27			*				*	*		*	*			*		*
Ni	28	*	*	*			*	*	*		*	*			*		*
Cu	29		*	*		*		*	*	x	*	*	*		*	*	*
Zn	30								x								x
Ge	32			*				*	*		*	*			*		
Zr	40			*	*			*	*		*	*			*		
Nb	41	x	*	*	*			*	*		*	*	*		*		*
Mo	42	*	*	*				*	*		*	*	*		*	*	
Ru	44							*	*		*	*					
Rh	45			*				*	*		*	*			*		
Pd	46			*				*	*		*	*			*		
Ag	47	*	*	x				*	*	x	*	*		x	*		*
Cd	48								x								
In	49														x		
Sn	50							x	*		x	x					*
Hf	72			x				*	*		*	*			*		
Ta	73			x				*	*		*	*			*		
W	74			*				*	*		*	*	*		*	x	
Re	75							*	*		*	*			*		
Os	76			*				*	*		*	*					
Ir	77			*				*	*		*	*			*		
Pt	78			*				*	*		*	*			*		
Au	79	*	*	*		*		*	*		*	*			*		*
Pb	82			x													
Th	90							*	*		*	*					
U	92							*	*		*	*			*		

		Na 11	Si 14	P 15	S 16	Cl 17	K 19	Ni 28	Cd 48	Tl 81
Cu	29	x	x	x	x	x	x	x	x	x

+ Self-sputtering

O^{4+} (2s2p ^3P ---> $2p^2$ ^3P) 82-10-22 18:25



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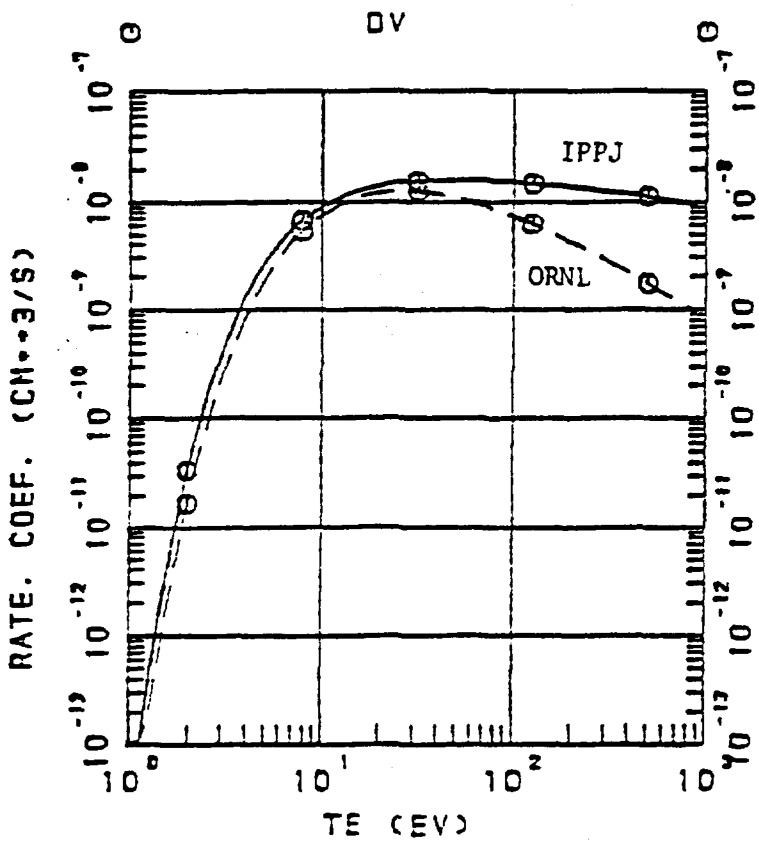

⊙ 2-4

	IPPJ		ORNL
A	9.2626+00	A	2.858E-01
B	-1.148E+01	B	5.972E+01
C	2.369E+01	C	-5.471E+01
D	0.0	D	0.0
E	6.710E+00	E	0.0
F	0.0	F	0.0
Y	1.630E+01	Y	1.630E+01

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Empirical Formula of the Total Cross Section for $A^{q+} + H$, H_2 and $He \rightarrow A^{(q-1)+}$

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[*] Radiation Center of Osaka Prefecture

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1. Formulation Procedure for $A^{q+} + H \rightarrow A^{(q-1)+}$

$$\sigma_{q,q-1} = \sigma_{10}\, q^{p} \tag{1}$$

q dependence: See Fig. 1[1)]

Ryufuku-Watanabe's scaled universal curve[2)]

$$\sigma_{q,q-1} = q^{b_1}\, \tilde{\sigma},\quad E = q^{b_2}\, \tilde{E} \tag{2}$$

$$\tilde{\sigma} = k\, \tilde{E}^{n} \tag{3}$$

$$\sigma_{q,q-1} = k\, E^{n}\, q^{(-b_2 n + b_1)} \tag{4}$$

$$\sigma_{10} = k\, E^{n} \quad \text{when } q = 1 \tag{5}$$

$$\therefore \sigma_{q,q-1} = \sigma_{10}\, q^{(-b_2 n + b_1)}. \tag{6}$$

$n(E)$: obtained from slopes of log-log plot of $\sigma_{10}(E)$ curve.

Fig. 2: Experimental data of σ_{10} for various projectiles.[3)]

Fig. 3: σ_{10} for H^+ and A^+ $(Z>8)$[3)]

Empirical formura for $\sigma_{10}(E)$

$$\sigma_{10}(E) = \sigma_0[(\frac{E}{a_1})^{a_2}(1+(\frac{E}{a_3})^{a_4} + (\frac{E}{a_5})^{a_6})]^{-1} \tag{7}$$

for $\sigma_{q,q-1}(E)$

$$\sigma_{q,q-1} = \sigma_{10}\, q^{\,b_2[a_2 + \frac{a_4(\frac{E}{a_3})^{a_4} + a_6(\frac{E}{a_5})^{a_6}}{1+(\frac{E}{a_3})^{a_4} + (\frac{E}{a_5})^{a_6}}] + b_1} \tag{8}$$

Fig. 4: Energy dependence of exponent

Fig. 5-7: Comparison with experimental data[3] for q = 5, 10 and 15

2. Emperical Formula for $A^{q+} + H_2$ and He $\rightarrow A^{(q-1)+}$

$$(\sigma_{q,q-1}(E))_{H_2,He} = (\sigma_{q,q-1}(E))_H / c_{H_2,He} \tag{9}$$

$$E_{H_2,He} = E_H / c_{H_2,He} \tag{10}$$

Fig. 8-10: $A^{q+} + H_2 \rightarrow A^{(q-1)+}$ (q = 5, 10 and 15) with experimental data[4]

Fig. 11-13: $A^{q+} + He \rightarrow A^{(q-1)+}$ (q = 5, 10 and 15) with experimental data[5]

References

1) F.W. Meyer et al.: Phys. Rev. A19 515 (1979)

2) H. Ryufuku and T. Watanabe: Phys. Rev. A20 1828 (1979)

3) Y. Kaneko et al.: IPPJ-AM-15, Nagoya (1980)

4) Y. Kaneko et al.: IPPJ-AM-20, Nagoya (1981)

5) Y. Nakai et al.: under compilation

Fig. 1. Charge Dependence

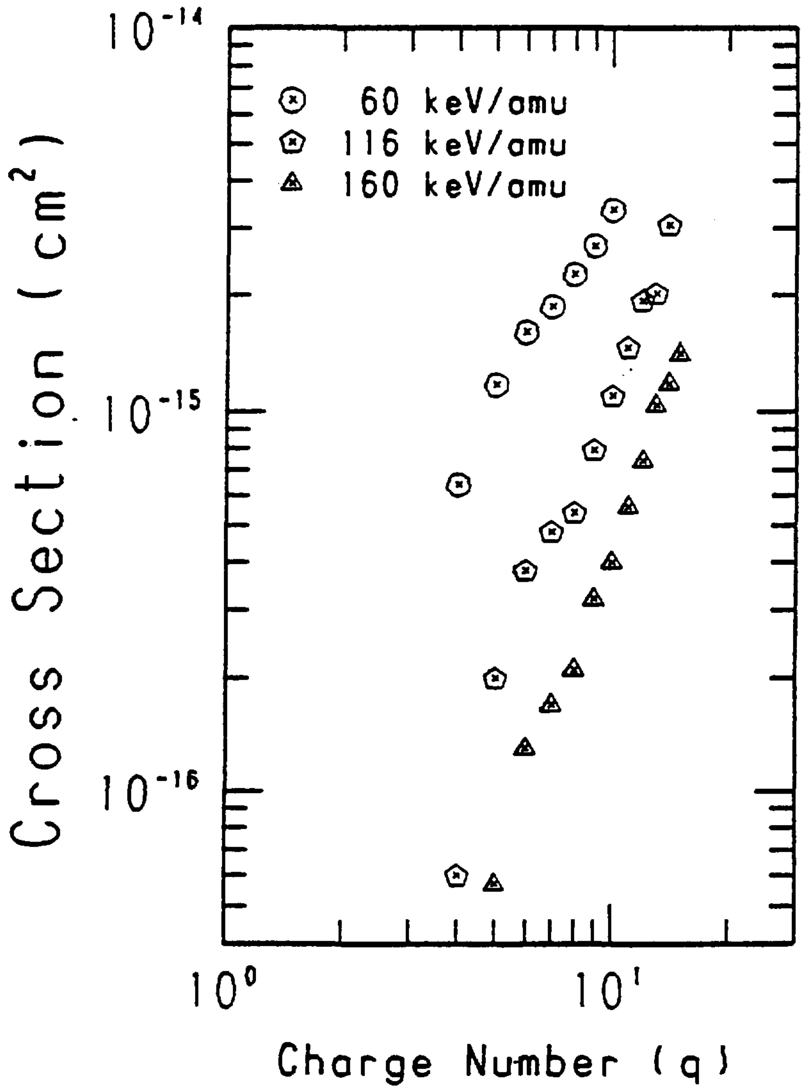


FIG. 2

$A^+ + H \rightarrow A \quad (\sigma_{10})$

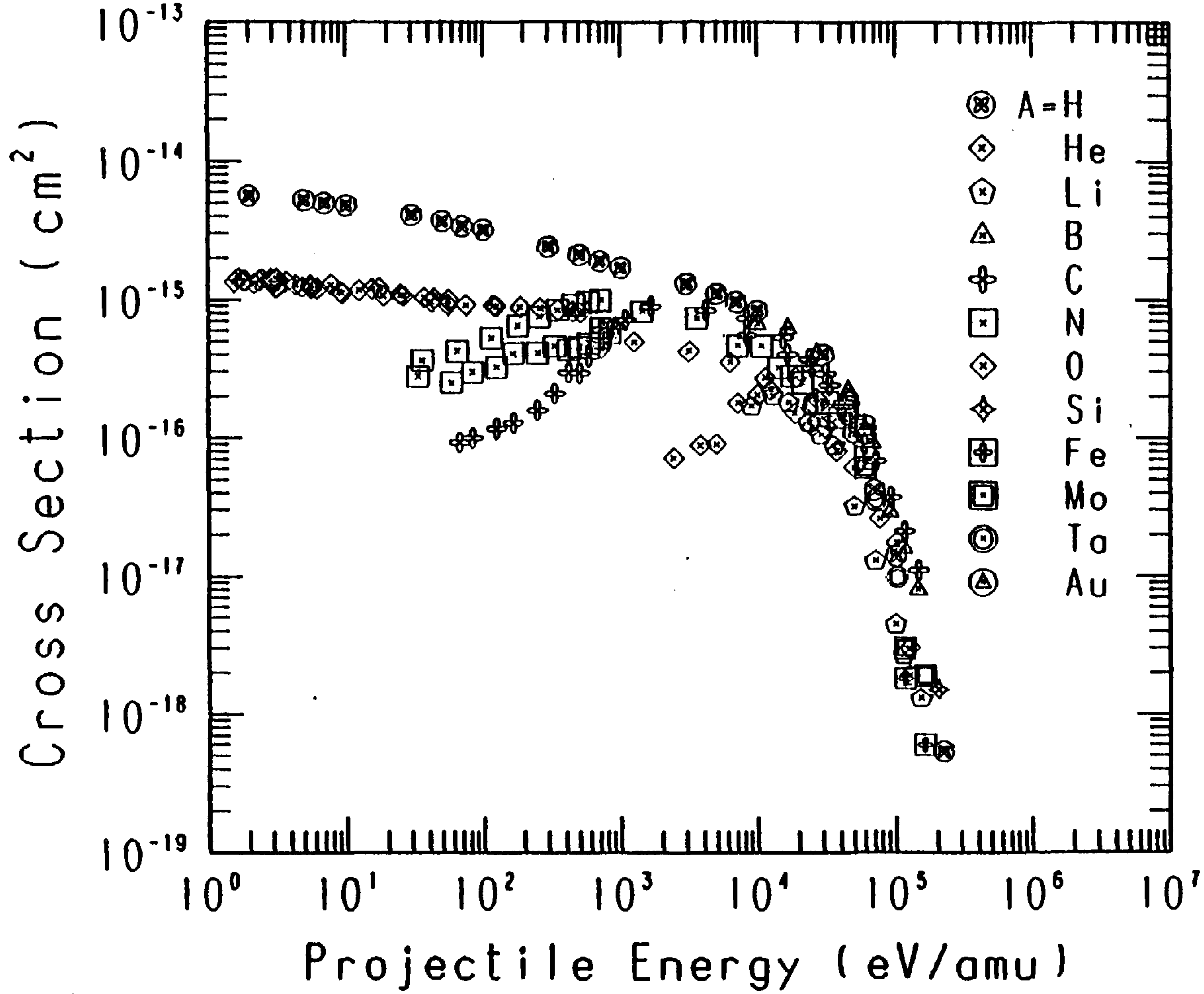


FIG. 3 σ_{10} FOR H^+ AND A^+ $(Z \geq 8)$

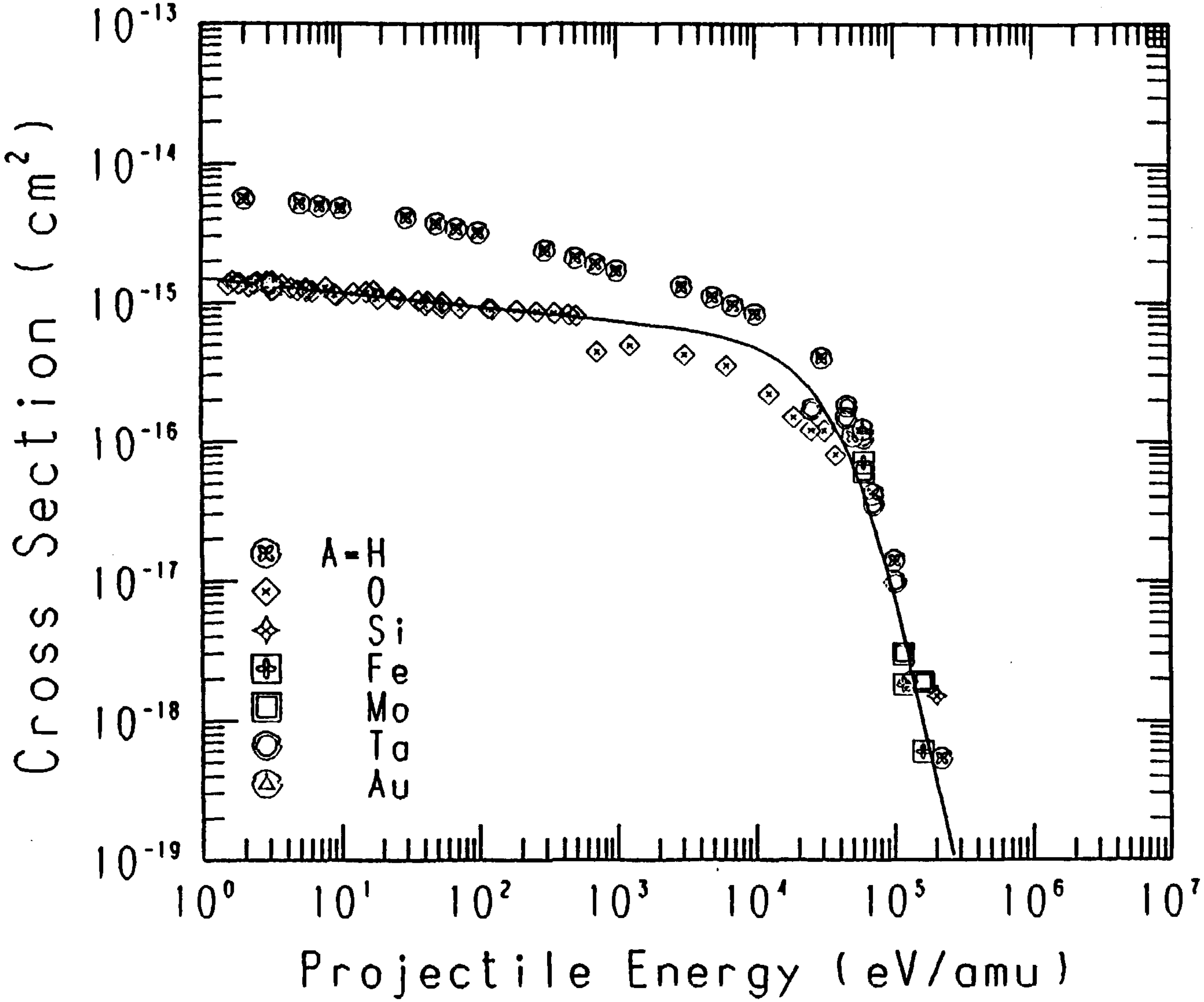


FIG. 4

Energy Dependence of Exponent

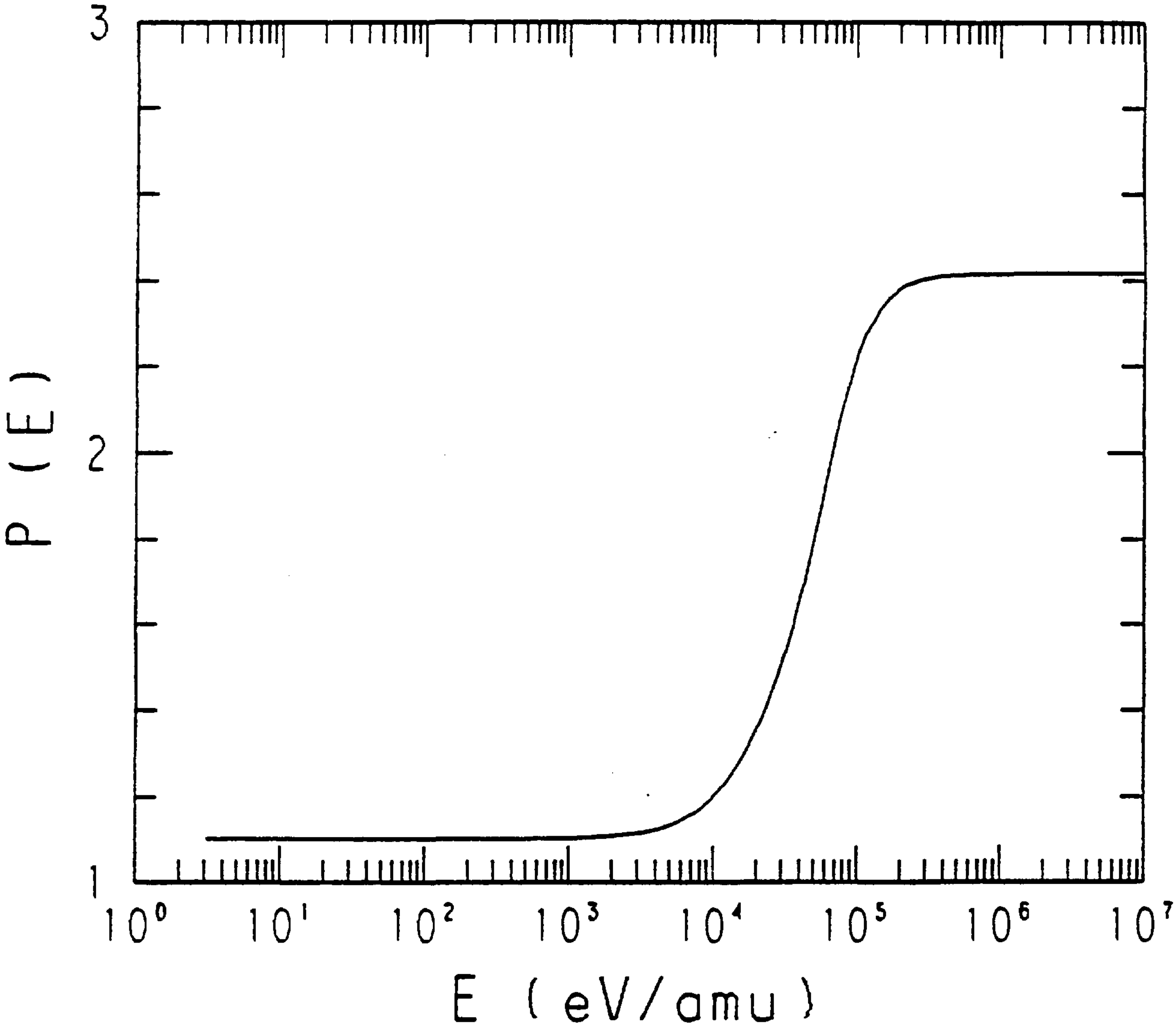


FIG. 5

$A^{5+} + H \rightarrow A^{4+} \quad (\sigma_{54})$

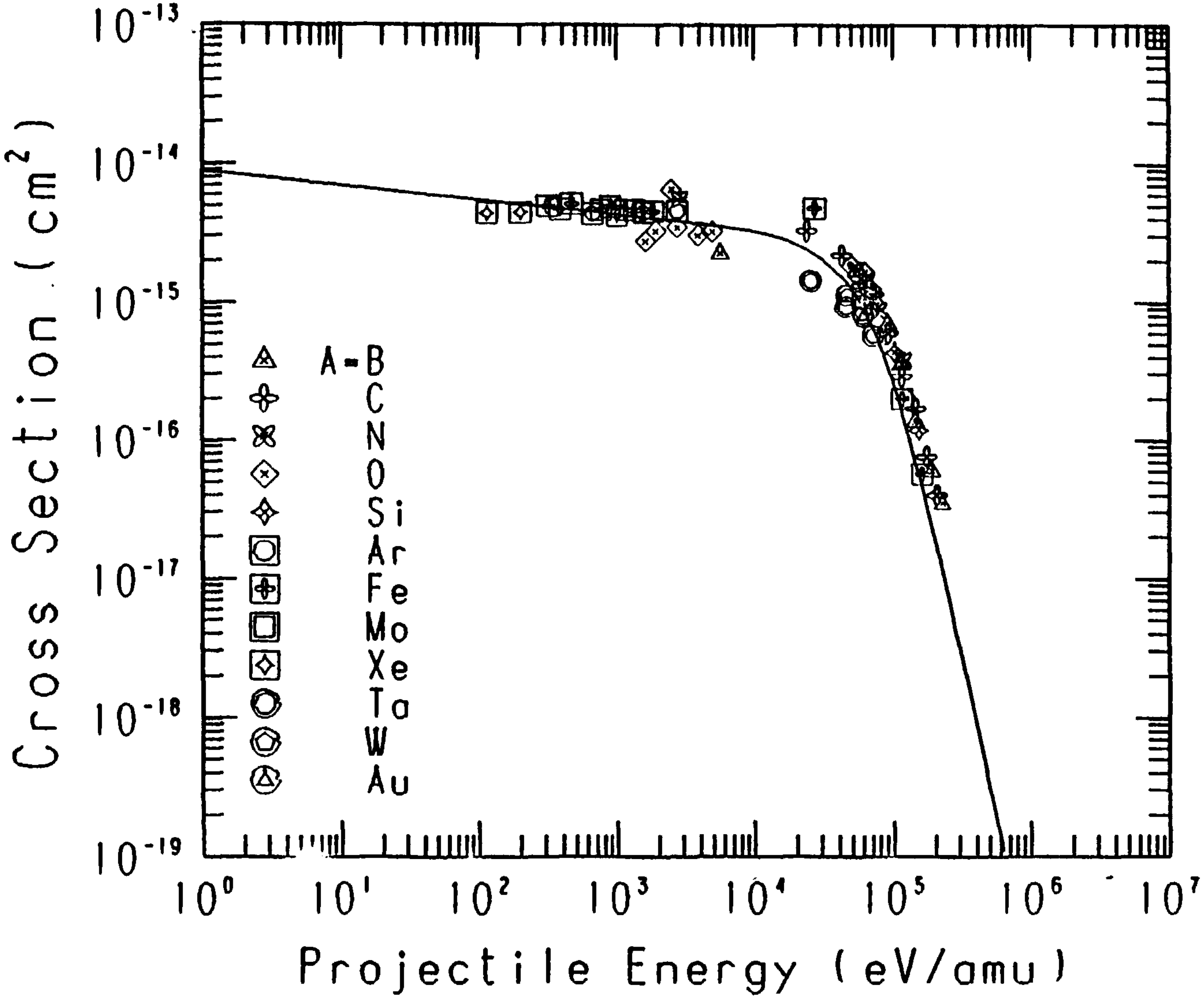


FIG. 6

$A^{10+} + H \rightarrow A^{9+} \quad (\sigma_{10-9})$

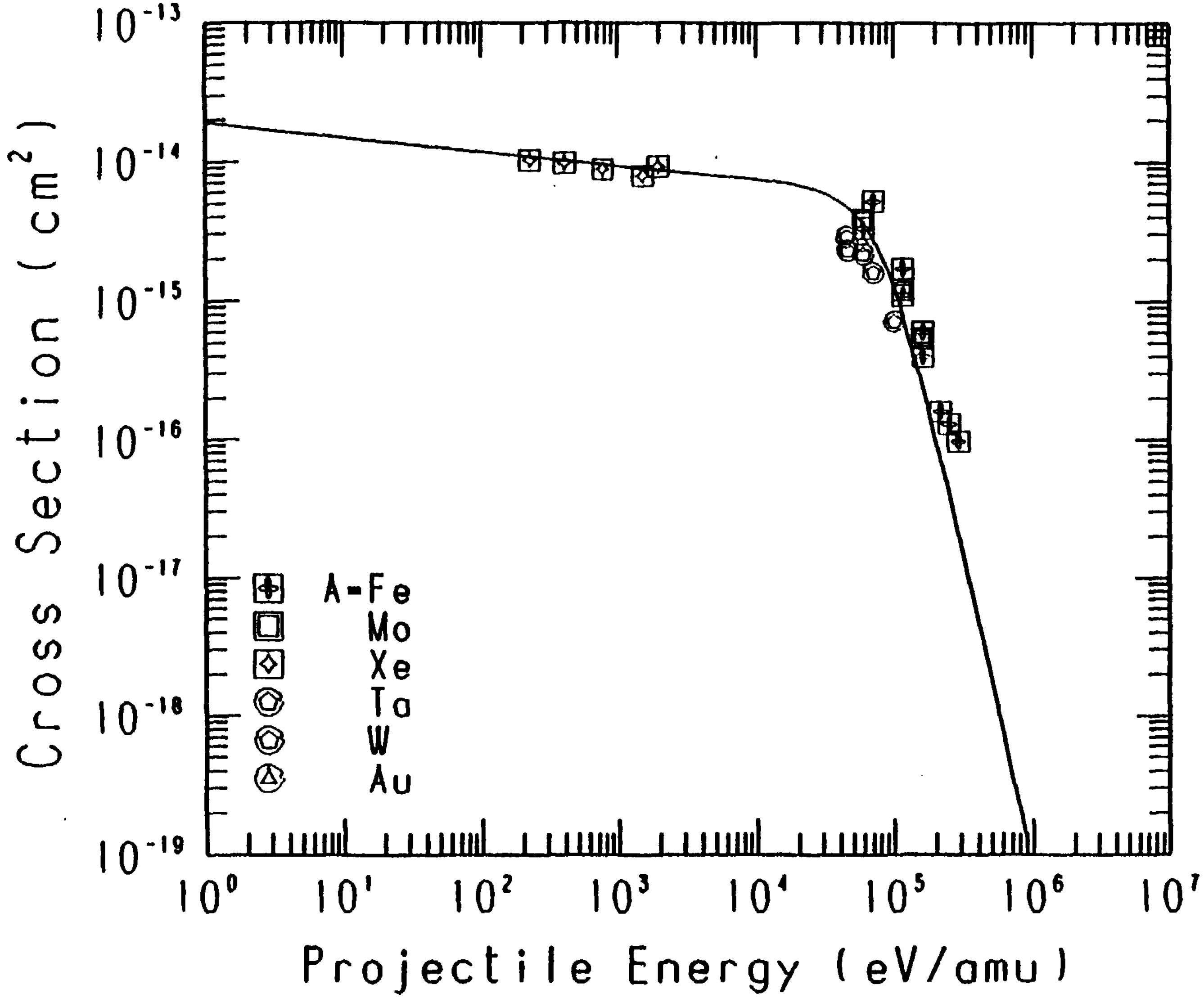


FIG. 7

$A^{15+} + H \rightarrow A^{14+} \quad (\sigma_{15-14})$

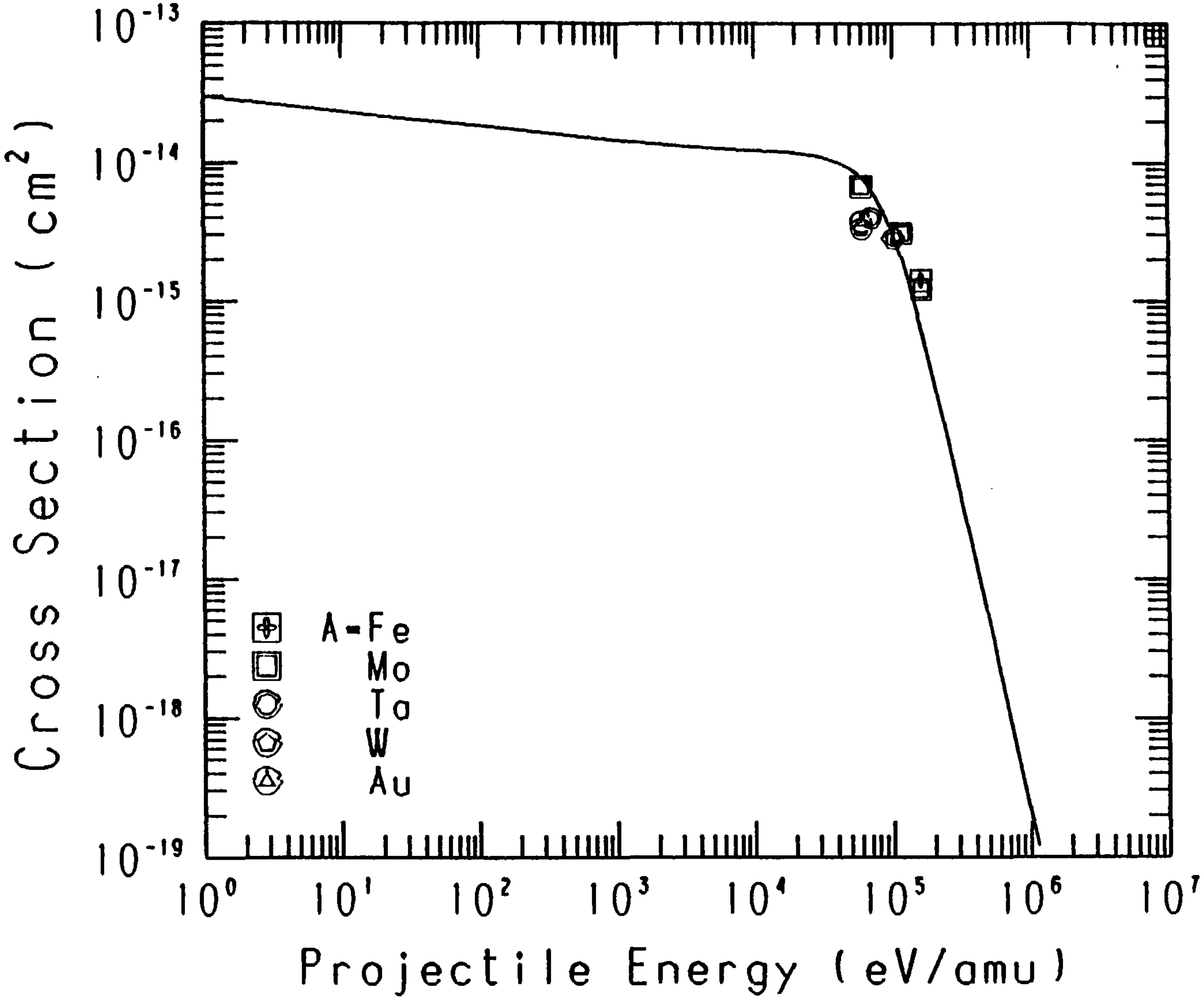


FIG. 8

$A^{5+} + H_2 \rightarrow A^{4+} \quad (\sigma_{54})$

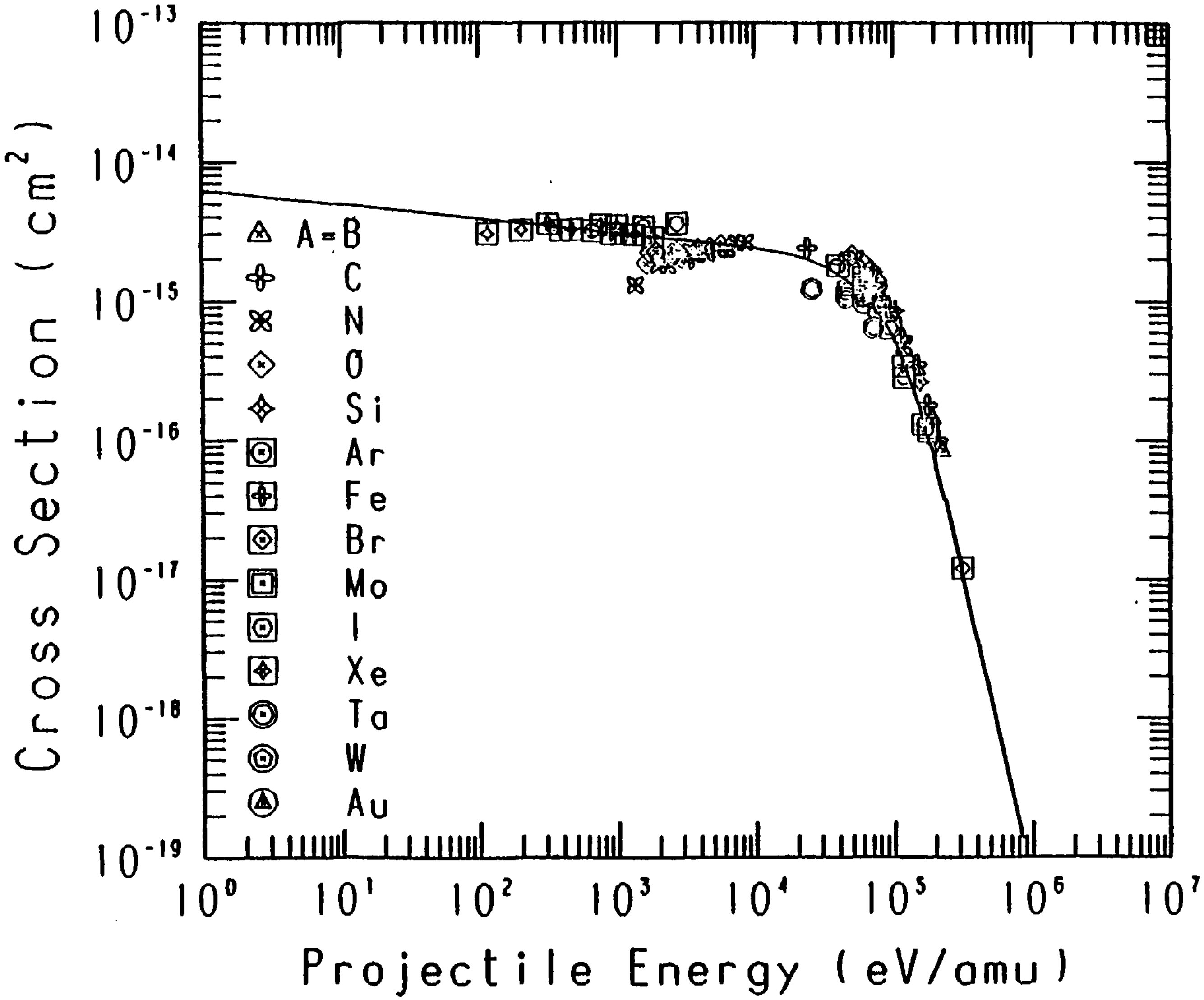


FIG. 9

$A^{10+} + H_2 \rightarrow A^{9+}$ (σ_{10-9})

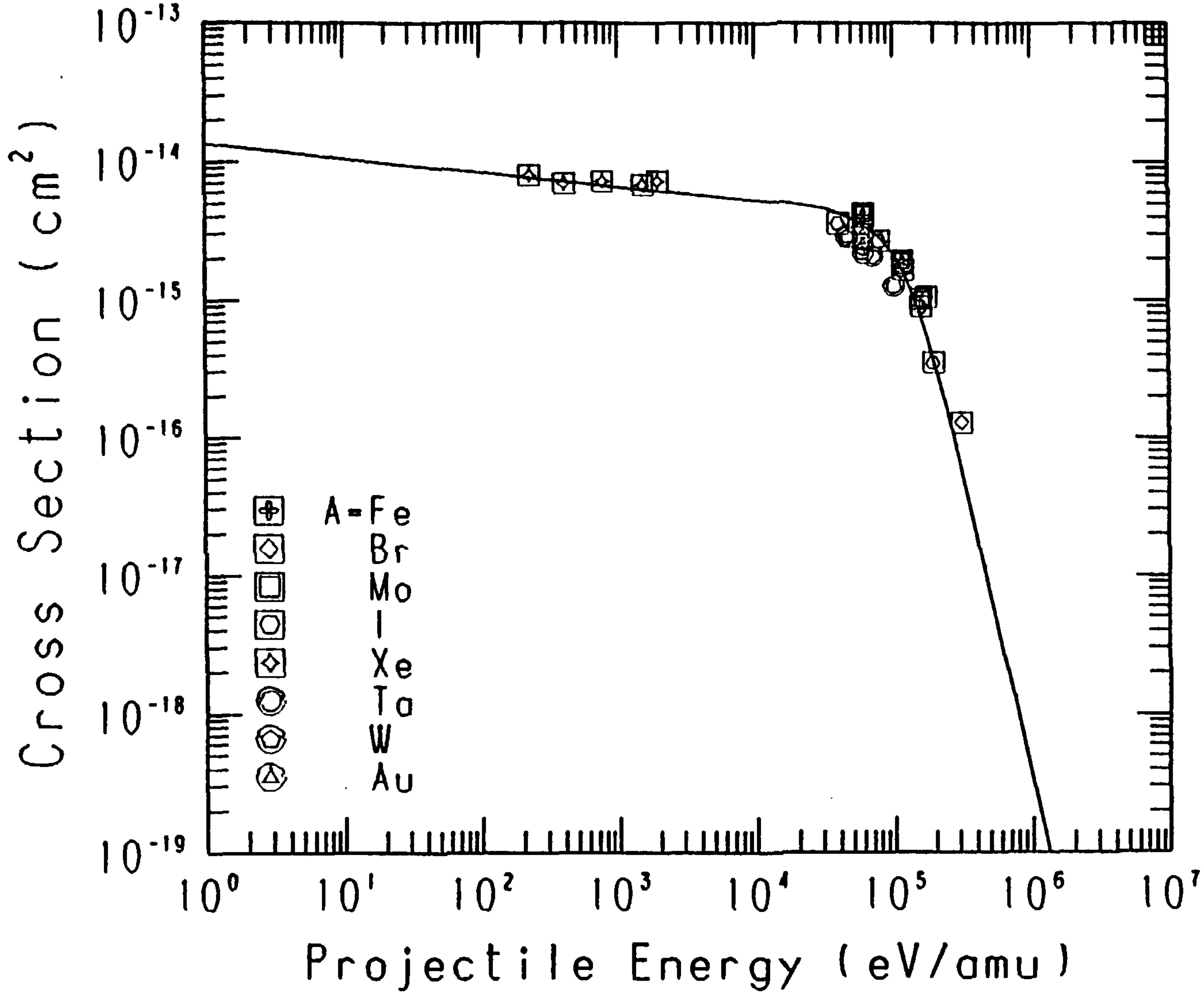


FIG.10

$A^{15+} + H_2 \rightarrow A^{14+}$ (σ_{15-14})

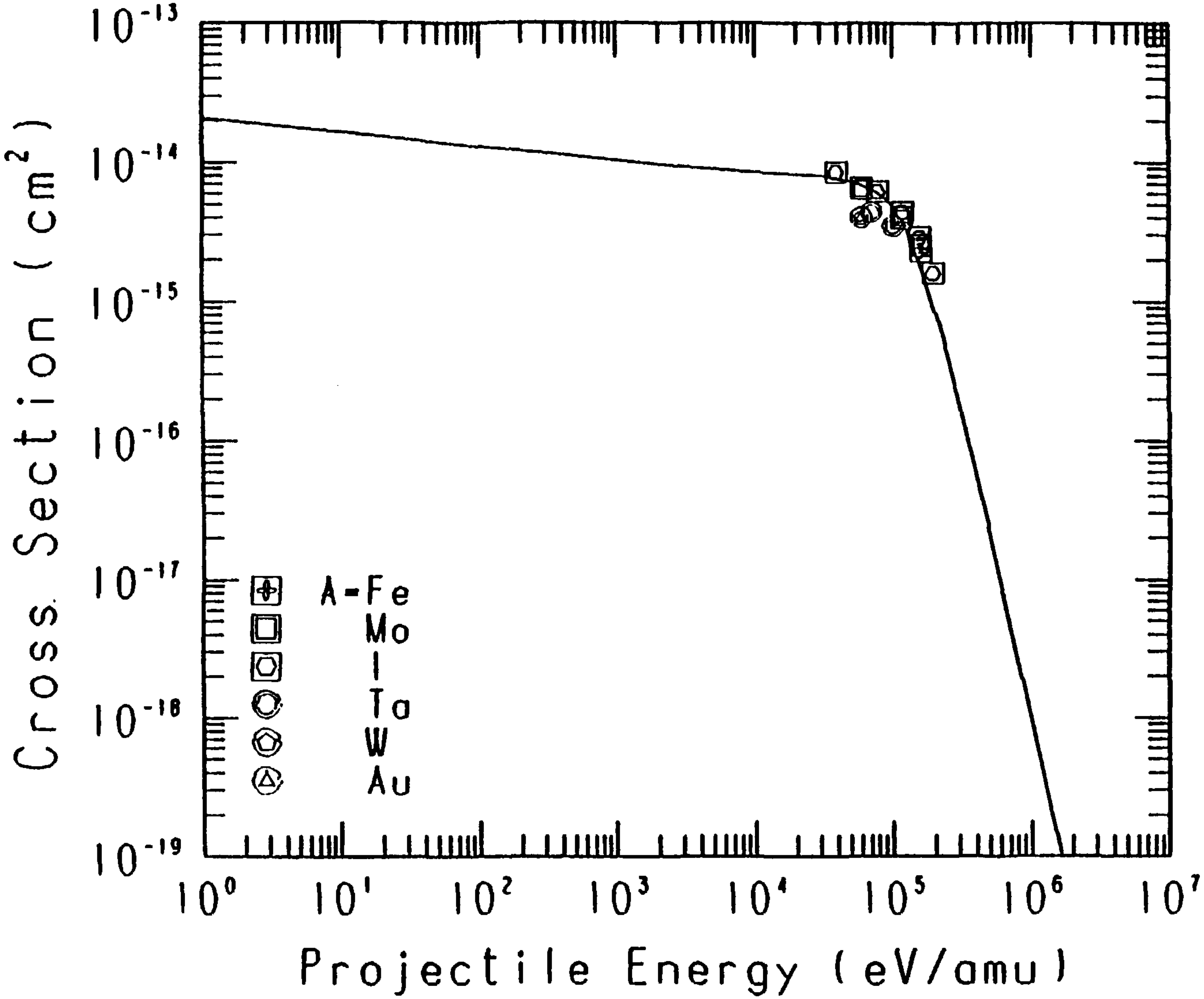


FIG.11 $A^{5+} + He \rightarrow A^{4+}$ (σ_{54})

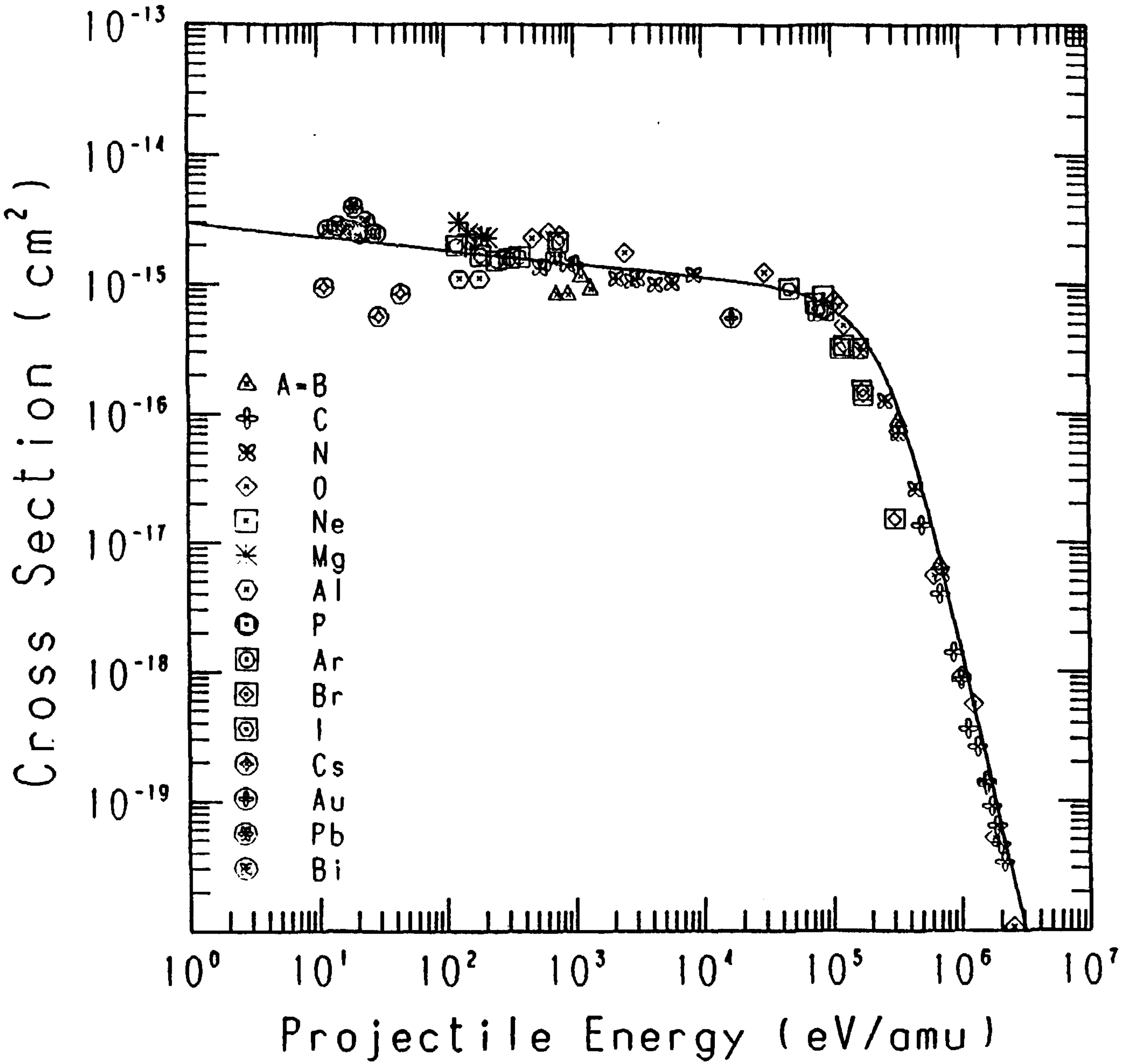


FIG.12 $A^{10+} + He \rightarrow A^{9+}$ (σ_{10-9})

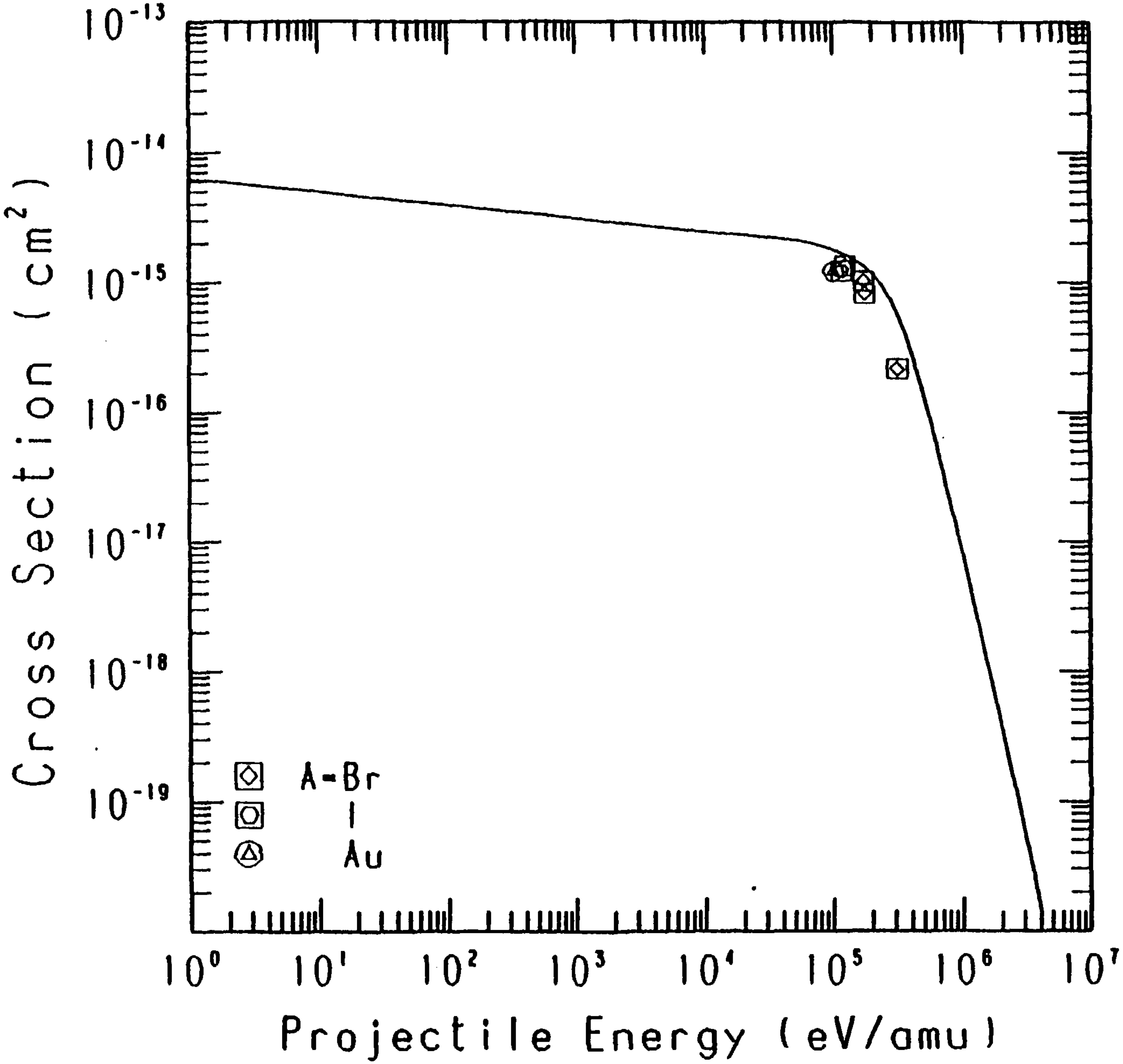
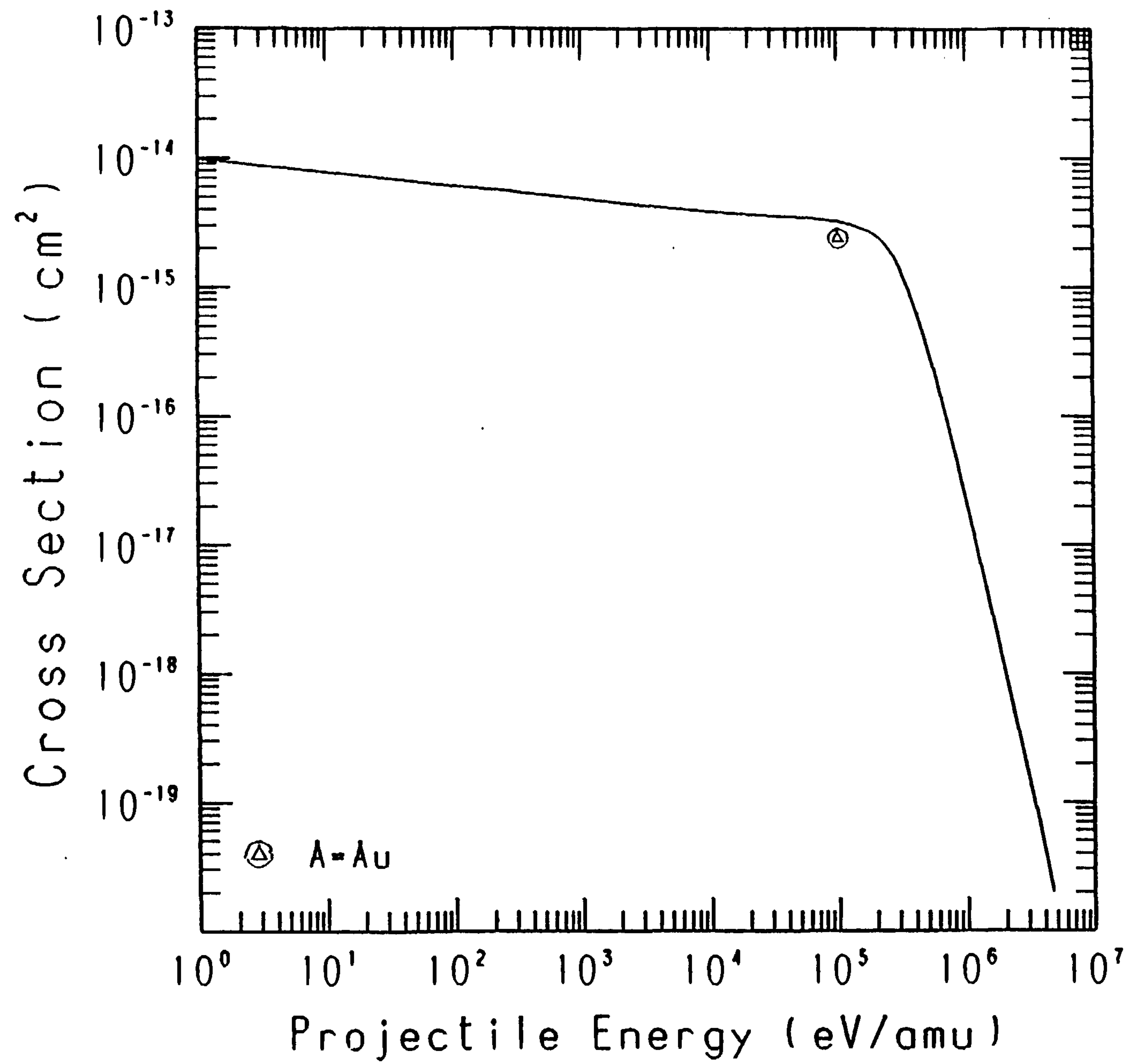


FIG.13 $A^{15+} + He \rightarrow A^{14+}$ (σ_{15-14})



Appendix 19

Compilation of Desorption Data

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When energetic photons, electrons, or ions impinge on gases adsorbed on solid surfaces, the adsorbed gases undergo desorption from surfaces as neutrals and ions, as well as other processes such as chemical reactions. Such desorption of adsorbed gases play important roles in the plasma-material interactions through impurity introduction to the plasma and participation in fuel gas recycling.

A survey of literatures has been made on Photon Stimulated Desorption (PSD), Electron Stimulated Desorption (ESD), and Ion Impact Desorption (IID), with attention being paid to the desorption cross section. Numerous reports (more than 270 papers) concerning ESD have been published until the end of 1981, while the number of papers on IID is limited (about 40 papers). PSD has not been studied so extensively as ESD, but several reports published recently reveal that the PSD cross sections for some systems are almost identical with the ESD cross sections. Generally, IID cross sections are in the range of $10^{-16} \sim 10^{-14}$ cm^2 whereas ESD cross sections lie in the vicinity of 10^{-18} cm^2. Data of the desorption cross section are compiled and stored in the computer system of JAERI. Examples of computer output of the stored data are shown in Figures 1 and 2. Figure 1 shows the ESD cross section of O_2 from tungsten surface as a function of energy of incident electrons. Figure 2 shows the data of IID of CO from Ni surface as a function of incident ion energy.

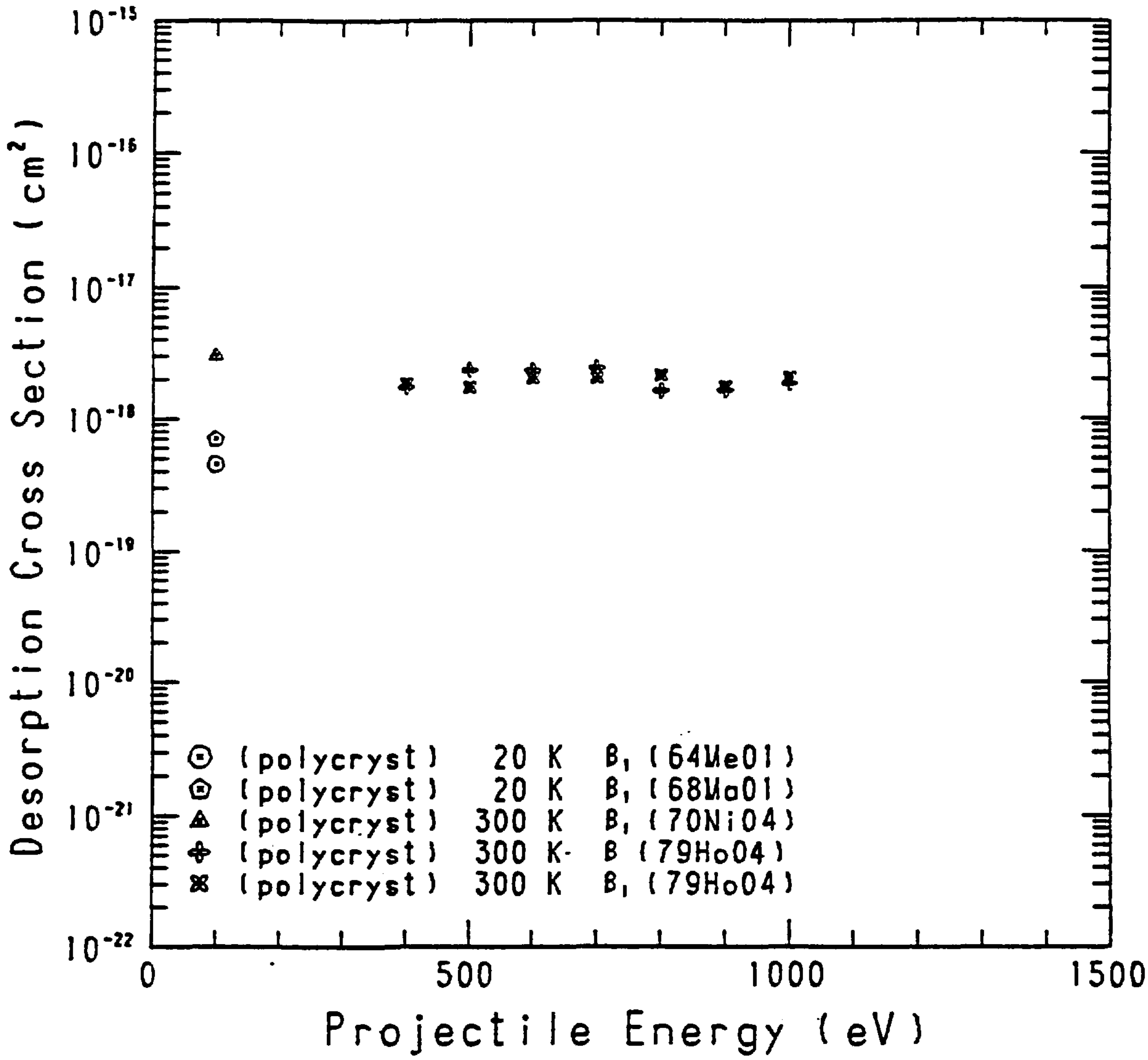

Figure 1. Electron stimulated desorption cross section of O_2 from W surface as a function of electron energy.

References:

64Me01; D. Menzel and D. Gomer, J. Chem. Phys., 41, 3311(1964).

68Ma01; T. E. Madey and J. T. Yates, Jr., Surf. Sci., 11, 327(1968).

70Ni04; M. Nishijima and F. M. Propst, Phys. Rev, B2, 2368(1970).

79Ho04; J. L. Hock, J. H. Craig, Jr. and D. Lichtman, surf. Sci., 85, 101(1979).

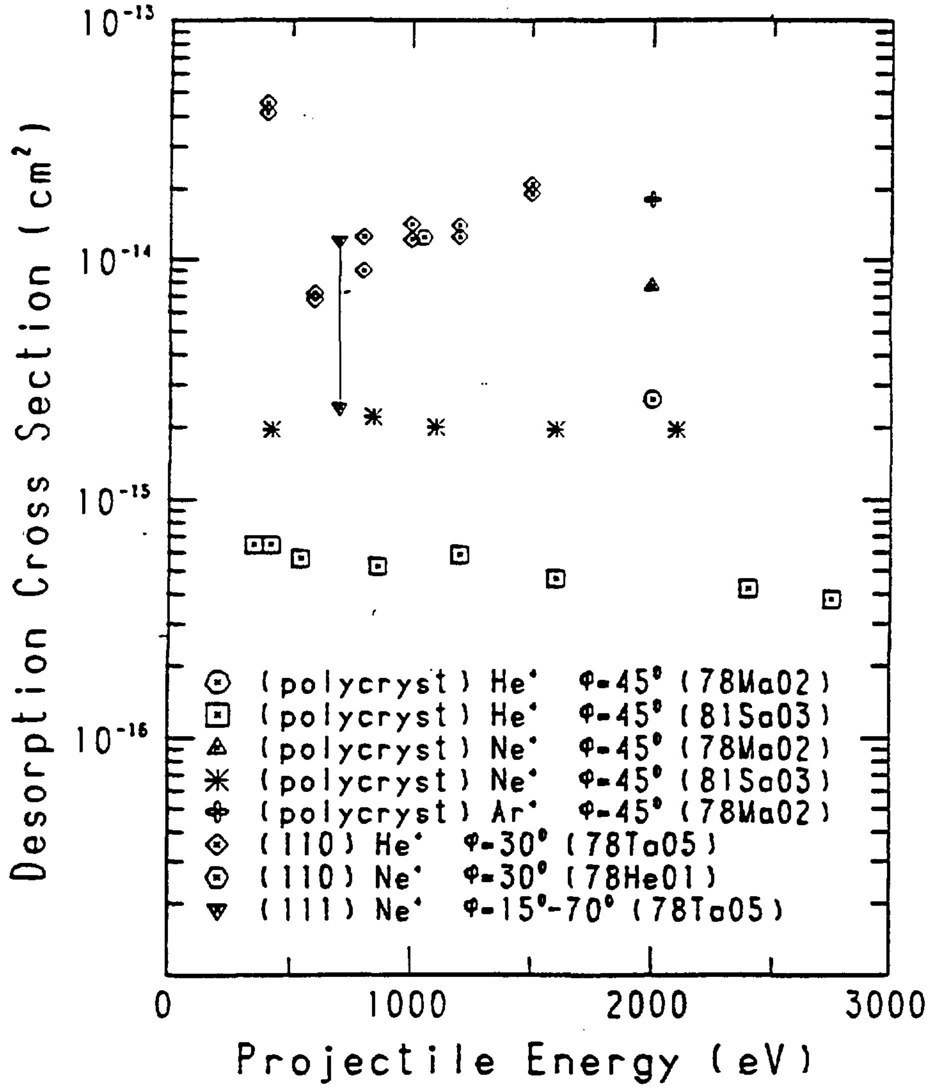

Figure 2. Ion impact desorption cross section of CO from Ni surface as a function of primary ion energy.

References:

78Ma02; R. J. MacDonald, E. Taglauer and W. Heiland, Appl. Phys. Lett., 33, 576(1978).

81Sa03; A. Sagara, K. Akaishi, K. Kamada and A. Miyahara, Proc. 2nd Topical Meeting on Fusion Reactor Materials, Seattle, 1981.

78Ta05; E. Taglauer, U. Beitat and W. Heiland, Nucl. Instr. Meth., 149, 605(1978).

78He01; W. Heiland and E. Taglauer, Symp. Atomic and Surface Phys., Tirol, p9(1978).