

COMMISSION 14. Atomic & Molecular Data

PRESIDENT: Sveneric Johansson

VICE-PRESIDENT: Steven R. Federman

SECRETARY: Glenn M. Wahlgren

**ORGANIZING COMMITTEE: Saul J. Adelman, Emile Biémont,
Steve R. Federman, Sveneric Johansson, Jim Lawler, Michael
Mickelson, Donald Morton, Tanya Ryabchikova, Peter L. Smith,
Chantal Stehle, Glenn M. Wahlgren**

Abstract. This triennial report from Comm. 14 covers the topics Atomic Spectra and Wavelength Standards, Atomic Transition Probabilities, Collision Processes, and Line Broadening.

Commission 14 belongs to Division XII of the IAU. The rôle of Commission 14 is to inform the astronomical community of new developments in the diverse fields of research and measurement that involve atoms, molecules and solid state particles. Conversely, it endeavours to sensitize the research communities active in those fields to the specific needs of astronomy, especially concerning basic data and modeling tools. More generally, Commission 14 tries to foster long term relations and collaborations between the two communities and, when necessary, to alert funding authorities to the specific needs of ground and space based astronomy for specific atomic and molecular data.

This report is one of the main contributions of Commission 14 to the astronomical community. It comprises Sections prepared by four of the eight Working Groups of Commission 14. It is also available on the Commission 14 website.

1. WORKING GROUP ON ATOMIC SPECTRA AND WAVELENGTH STANDARDS

(GROUPE DE TRAVAIL SUR LES SPECTRES ET LONGUEURS D'ONDE ATOMIQUES)

CHAIR: S. Johansson

CO_CHAIR: G. Nave

1.1. *Energy Level Analyses, Wavelengths and Line Classifications*

The references cited in this section are mostly papers on original laboratory research; compilations and data bases are covered in another section. The references, ordered by atomic number and spectrum, are given in parentheses following the spectral notations. They are designated by the first letter of the first author's last name and a serial number; these designations precede the full citations in the reference list at the end of the report.

H I, **D I** (K1), **H I** (K6) hfs, **Li I** (D2), **Li I** (W1) hfs, **B II** (M1,R1), **Ne I** (S4), **Ne III** (K5), **Ca I** (M4) hfs, **Sc I** (B2) hfs, **Ti I** (L3), **Ti IV** (R2), **V I** (L1) hfs, **Mn I** (B1, L2) hfs, **Mn II** (B5) hfs, **Cr II** (S5), **Ni VII** (K7), **Sr II** (B3) hfs, **Y I** (N2) hfs,

Nb I (B4) hfs, **Mo II** (N1), **Cs II** (S6), **Sm I** (O1) hfs, **Sm II** (M5) hfs, **Bi II** (D3), **Pt I,II** (N3, S5), **Ta I** (M2), **Ta I** (J1) hfs, **Ta II** (E1,M3,Z1) hfs, **Ta III** (A1).

The references for elements heavier than Ni ($Z > 28$) are limited to the first three or four spectra only, these data being of interest for solar and stellar spectroscopy. The references of the lighter elements are also incomplete, the selection being limited to those of highest astrophysical interest. The quality of astrophysical spectra sometimes requires that hyperfine structure (hfs) is considered in the analysis. We have therefore included some experimental data on hfs.

Current work in term analyses of high-resolution laboratory spectra (energy levels, wavelengths) of the lowest ionization stages of astrophysical significance is ongoing at Lund, Sweden (transition elements and rare earth elements), London, UK (iron group elements), NIST, USA (heavy elements, rare earths), Troitsk, Russia (heavy elements), Antigonish, Canada (higher ionization states, heavy elements) and Meudon & Orsay, France (transition groups, theory). A number of laboratories are involved in measurements of hfs.

1.2. *Wavelength Standards*

Based on the refined energy levels of **H & D** (K1) accurate wavelengths have been derived for these H isotopes (see Reader, 2004). Banerjee, Das, & Natarajan (2004) present frequency measurements with an accuracy of 0.7 mÅ of the resonance lines of **K I**, which can be used to test calibration lines. Nave & Sansonetti (2004) give reference wavelengths of **Fe I**, **Ge I** & **Pt I** lines in a region around 1935 Å. A similar work on **U I** & **Th I** in a limited wavelength region (6040-7550 Å) is published by Degraffenreid & Sansonetti (2002,D1). Accurate wavelengths for ground state lines in **Ti II**, **Cr II**, **Mn II**, **Fe II** & **Ni II** have been measured in a single spectrum from a composite hollow-cathode lamp (Aldenius, Johansson & Murphy 2005). Fourier Transform Spectrometry has been used at NIST to measure calibration wavelengths of monoisotopic mercury, ^{198}Hg (Salit et al 2004; Zeza et al 2005)

1.3. *Larger Compilations, Reviews, Conference Proceedings*

A number of compilations on wavelengths and energy levels have been published or submitted by the spectroscopy group at NIST:

Be II (K3), **Ne I** (S2), **Ga I-XXXI** (S9), **KrI-XXXVI** (S3), **RbI-XXXVII** (S8), **XeI-LIV** (S1), **BaI-II** (C1), **WI-II** (K4), and special compilations of X-ray data for the Chandra Observatory: **NeV-VIII** (P4), **MgV-X** (P3), **SiVI-XII** (P2), **S VII-XIV** (P1). Ionization energies for tungsten (W^{2+} to W^{7+}) are compiled by Kramida & Reader (2005). Morton (2003) has continued with a third compilation on *Atomic Data for Resonance Absorption Lines*, which concerns wavelengths longward of the Lyman Limit for H-Ga.

A number of papers on atomic spectroscopic data are included in proceedings of the *Eighth International Colloquium on Atomic Spectra and Oscillator Strengths for Astrophysical and Laboratory Plasmas*, held in Madison, WI, USA, August 2004. Invited papers are published in the Physica Scripta T Series (Lawler, Wahlgren & Wiese 2005). A few papers on astrophysical data needs are included in the proceedings from the third and fourth international conferences, *ICAMDATA*, held at Gatlinburg, Tn, USA, in April 2002 (Shultz, Krstic & Ownby 2002), and at Toki, Japan in October 2004 (Kato, Kato & Funaba 2005), respectively. The proceedings contain review papers as well as descriptions of atomic and molecular databases. Proceedings from the EGAS (European group of Atomic Spectroscopy) conferences appear in the Physica Scripta T-series: 31st EGAS T86 (2000) and 32nd EGAS T95 (2001).

1.4. Atomic Spectroscopic Data on the Internet

A comprehensive bibliographic database on atomic spectroscopy with a search engine on various atomic parameters is available at the Institute of Spectroscopy, Troitsk, at the URL address: <http://das101.isan.troitsk.ru/bibl.htm>.

The database DREAM is devoted to the rare-earth elements in the low ionization stages. It contains presently data for over 60 000 transitions, many of them of astrophysical interest. More details can be found on the Web site: <http://www.umh.ac.be/astro/dream/shtml>. The database has been described recently in Biémont & Quinet (2005). A set of databases (R4) are available at NIST at following URL addresses:

<http://physics.nist.gov/Handbook>

This handbook by Sansonetti & Martin (S7) includes about 10000 wavelengths for the strongest lines of all elements H-Es for neutral and singly-ionized atoms, with ionization energies, transition probabilities, line classifications, isotope information and references. URL: <http://physics.nist.gov/ASD>

The Atomic Spectra Database (R3) version 3.0 is fully revised since last report with new Web interface. Many new data, corrected errors, online generation of Grotrian diagrams, Saha/LTE spectra and direct access to references. Versions 2.0 and 1.3 are archived and will not be updated.

<http://physics.nist.gov/Chandra>.

This X-ray database for the Chandra Observatory (P5) contains Wavelengths, energy levels and transition probabilities for lines between 20 Å and 170 Å for Ne, Mg, Si and S ions

<http://physics.nist.gov/IonEnergy>

The database (M6) gives Ground Levels and Ionization Energies for the Neutral Atoms of 9 elements.

<http://physics.nist.gov/HDEL>

Theoretical values of energy levels of H and D for quantum numbers $n=1$ to 200.

An Atomic Energy Levels and Spectra Bibliographic Database is in preparation. It contains about 8500 references between July 1968-December 2000 on atomic energy levels and spectra. It will be merged with the transition probability and line broadening bibliographic databases.

References

- Aldenius, M., Johansson, S. & Murphy, M. 2006, *Mon. Not. R. Astr. Soc.* in press
- A1 Azarov, V. I., Tchang-Brillet, W.-Ü. L., Wyart, J.-F., Meijer, F. G. 2003, *Physica Scripta* 67, 190
- Banerjee, A., Das, D. & Natarajan, V. 2004 *J. Opt. Soc. Am. B* 21, 79
- Biémont, E., Quinet, P. 2005, *J. Electr. Spectr. Rel. Phen.* 144-147, 23-25
- B3 Barwood, G.P., Gao, K., Gill, P., Huang, G. & Klein, H.A. 2003 *Phys. Rev. A* 67, 013402
- B2 Basar, G., Basar, G., Acar, F.G., Ozturk, I.K. & Kroger, S. 2004 *Physica Scripta* 69, 189
- B1 Blackwell-Whitehead, R.J., Pickering, J.C., Pearse, O., & Nave, G. 2005 *Ap. J. Suppl.* 157, 402
- B5 Blackwell-Whitehead, R.J., Toner, A., Hibbert, A., Webb, J., & Ivarsson, S. 2005 *Mon. Not. R. Astron. Soc.* 364, 705
- B4 Bouzed, A., Kröger, S., Zimmerman, D., Kronfeldt, H.-D. & Guthöhrlein, G.H., 2003 *Eur. J. Phys. D* 23, 57
- C1 Curry, J.J. 2004 *J. Phys. Chem. Ref. Data* 33, 725
- D1 DeGraffenreid, W. & Sansonetti, C.J. 2002 *J. Opt. Soc. Am. B* 19, 1711
- D2 DeGraffenreid, W. & Sansonetti, C.J. 2003 *Phys. Rev. A* 67, 012509
- D3 Dolk, L., Litzén, U. & Wahlgren, G.M. 2002 *Astron. Astrophys.* 388, 692

- E1 Eriksson, M., Litzén, U., Wahlgren, G.M. & Leckrone, D.S. 2002 *Physica Scripta* 65, 480
- J1 Jaritz, N., Guthöhrlein, G.H., Windholz, L., Messnarz, D., Engleman, R., Pickering, J.C., & Jäger, H. 2004, *Physica Scripta* 69, 441
- Kato, T., Kato, D., & Funaba, H. 2005 *AIP Conference Proceedings* 771
- K6 Kolachevsky, N., Fischer, M., Karshenboim, S.G. & Hänsch, T. 2004 *Phys.Rev.Lett.* 92, 033003
- K1 Kotochigova, S., Mohr, P.J., & Taylor, B.N. 2002 *Can.J.Phys.* 80, 1373
- K2 Kotochigova, S., Mohr, P.J., & Taylor B.N. 2004 *The Energy Levels of Hydrogen and Deuterium* (NIST, Gaithersburg, MD, USA)
- K3 Kramida, A.E. 2005 *Physica Scripta*, 72, 309
- K4 Kramida, A.E. 2006 *J.Phys.Chem.Ref.Data*, in press
- K5 Kramida, A.E., Nave, G. 2006 *Eur.J.Phys.D*, 37, 1
- Kramida, A.E. & Reader, J. 2006 *At.Data Nucl.Data tables*, in press
- K7 Kildiyarova R.R., Churilov S.S., Joshi Y.N., Ryabtsev A.N. 2005 *J.Opt.Soc.Am.B* 22, 884
- Lawler, J. E., Wahlgren, G. M., Wiese, W. L.: editors, *Physica Scripta* T119 (2005)
- L1 Lefèbvre, P.-H., Garnir, H.-P. & Biémont, E. 2002 *Physica Scripta* 66, 363
- L2 Lefèbvre, P.-H., Garnir, H.-P. & Biémont, E. 2003 *Astron.Astrophys.* 404, 1153
- L3 Litzén, U. 2005 *Physica Scripta*, 71, 471
- M5 Masterman, D., Rosner, S.D., Scholl, T.J., Sharikova, A., Holt, R.A. 2003 *Can.J.Phys.* 81, 1389
- M1 Martinson I., Awaya Y., Ekberg J.O., Kink I., Mannervik S., Ryabtsev A.N. 2003 *J.Phys.B* 36, 419
- M2 Messnarz, D., Jaritz, N., Arcimowics, B., Zilio, V.O., Engleman, R., Pickering, J.C., Jäger, H., Guthöhrlein, G.H., & Windholz, L. 2003 *Physica Scripta* 68, 170
- M3 Messnarz, D. & Guthöhrlein, G.H. 2003 *Physica Scripta* 67, 59
- M6 Martin, W.C. et al. 2003 *Ground Levels and Ionization Energies for the Neutral Atoms* (NIST, Gaithersburg, MD, USA)
- M4 Mortensen, A., Lindballe, J.J.T., Jense, I.S., Staunum, P. & Voigt, D. 2004 *Phys.Rev.A* 69, 042502
- Morton, D.C. 2003 *ApJ. Suppl* 149, 205
- N3 Nave, G. & Sansonetti, C.J. 2004 *J.Opt.Soc.Am.B* 21, 442
- N1 Nilsson, H., Pickering, J. C. 2003 *Physica Scripta* 67, 223
- N2 Nakada, H., Jin, W.G., Minowa, T., Katsuragawa, H. & Uematsu, H. 2004 *Jap.J.Appl.Phys* 43, A6423
- O1 Oh, M.K., Choi, W., Jeon, J.H., Lee, M., Choi, Y., Park, S., Lee, J.H. & An, K. 2004 *Spectrochim. Acta B* 59, 1919
- P1 Podobedova, L.I., Musgrove, A., Kelleher, D.E., Reader, J., & Wiese, W.L. 2003 *J.Phys.Chem.Ref.Data* 32, 1367
- P2 Podobedova, L.I., Kelleher, D.E., Reader, J., & Wiese, W.L. 2004 *J.Phys.Chem.Ref.Data* 33, 471
- P3 Podobedova, L.I., Kelleher, D.E., Reader, J., & Wiese, W.L. 2004 *J.Phys.Chem.Ref.Data* 33, 495
- P4 Podobedova, L.I., Kelleher, D.E., Reader, J., & Wiese, W.L. 2004 *J.Phys.Chem.Ref.Data* 35, 525
- Podobedova, L., Musgrove, A., Kelleher, D., Reader, J. & Wiese, W. 2003, *Spectral Data for the Chandra X-ray Observatory, Version 1.0* (NIST, Gaithersburg, MD, USA).
- Reader, J. 2004 *Appl. Spectrosc.* 58, 12
- R1 Ryabtsev A.N., Kink I., Awaya Y., Ekberg J.O., Mannervik S., Ölme A., Martinson I. 2005 *Physica Scripta* 71, 489
- R2 Ryabtsev A.N., Churilov S.S., Kononov E.Ya. 2005 *Optics & Spectr.* 98, 519
- R3 Ralchenko, Yu, Jou, F.-C., Kelleher, D.E., Kramida, A.E., Musgrove, A., Reader, J., Wiese, W.L. & Olsen, K. 2005 *Atomic Spectra Database Version 3.0.2* (NIST, Gaithersburg, MD, USA)
- R4 Ralchenko, et al. 2006 *J. Plasma & Fusion Research*, in press.
- Salit, M.L., Sansonetti, C. J., Veza, D, & Travis, J.C. 2004 *J.Opt.Soc.Am.B* 21, 1543

- S1 Saloman, E.B. 2004 *J.Phys.Chem.Ref.Data* 33, 765
S2 Saloman, E.B. & Sansonetti, C.J. 2004 *J.Phys.Chem.Ref.Data* 33, 1113
S3 Saloman, E.B. 2005 *J.Phys.Chem.Ref.Data*, submitted
S4 Sansonetti, C.J., Blackwell, M.M., & Saloman, E.B. 2004 *J.Res.NIST* 109, 371
S5 Sansonetti, C.J., Kerber, F., Reader, J., & Rosa, M.R. 2004 *Ap.J.Suppl.Ser.* 153, 555
S6 Sansonetti, C.J. & Andrew, K.L. 2005 *Physica Scripta* 71, 362
S7 Sansonetti, J.E., & Martin, W.C. 2005 *Phys. Chem. Ref. Data*, 34, 1559
S8 Sansonetti, J.E. 2006 *Phys.Chem.Ref.Data*, in press
Shultz, D.R., Krstić, P. S., & Ownby, F. 2002 *AIP Conference Proceedings* 636
S9 Shirai, T., Reader, J., Kramida, A.E., Sugar, J. 2006, *J.Phys.Chem.Ref.Data*, submitted
W1 Walls, J., Ashby, R., Clarke, J.J., Lu, B. & Van Wijngaerden, W.A. 2003 *Eur.Phys.J.D* 22, 159
Veza, D, Salit, M.L., Sansonetti, C. J., , & Travis, J.C. 2006 *J.Phys.B*, 38, 3739
Z1 Zilio, V. & Pickering, J.C. 2002 *Mon.Not.R.Astr.Soc.* 334, 48

2. WORKING GROUP ON ATOMIC TRANSITION PROBABILITIES

(*GROUPE DE TRAVAIL POUR PROBABILITES DE TRANSITION ATOMIQUES*)

CHAIR: G. M. Wahlgren

CO-CHAIR: J. R. Fuhr

Members of the astronomy and physics communities continue to produce new data on transition probabilities and oscillator strengths that are crucial to spectral analysis of astronomical objects. The techniques include laboratory experiment, *ab initio* calculations and direct inference from stellar spectra. In addition to creating new data, progress continues in providing easily accessible data sets.

The attached bibliography for the period 2002 - 2005 consists of 182 references. Of these, 145 publications involve quantum mechanical calculations, many as the sole technique. The reference list of ions is represented by 96 elements and a wide range of ionic states. The distribution among ions states is not equitable, but reflects two groupings: the lowest three ions and the highest ionization states.

The distribution by spectrum also reflects the techniques employed. Studies of high-ionization states are invariably of a theoretical nature, while those for the lowest ionization states include all of the experimental analyses reported. Among the experimental works, the techniques involve study of emission lines and the recording of atomic lifetimes, usually by the method of laser-induced fluorescence. The maturity of this technique is now providing benefits to many applications. The application of absorption spectroscopy appears currently to be a rare occurrence.

It is also apparent that work on atomic data is generally motivated by the needs of astronomical-based projects, and not to enhance the overall knowledge of atomic parameters. Of continued interest have been elements from the iron group, the lanthanides, and even heavier stable elements. The experimental work conducted in support of these programs is limited to the neutral and two lowest ions by available instrumentation and light sources, often being hollow-cathode designs.

The following major compilations of transition probability data have been published

during the latest 3-year period:

(a) The MCHF/MCDHF Collection on the Web has been established by C. Froese Fischer et al.: http://www.vuse.vanderbilt.edu/~cff/mchf_collection/. It contains a large number of transitions for Li-like through Ar-like ions of various chemical elements, principally the lighter elements through atomic number $Z = 30$. The data include various types of electric-dipole forbidden lines and are obtained from sophisticated multi-configuration Hartree Fock (MCHF) or, for the heavier, more highly ionized species, from multi-configuration Dirac Hartree Fock (MCDHF) calculations. The tabulations provide data for fine-structure transitions and include other important spectroscopic data for each line, and are structured similar to the NIST tables. Another large compilation was recently published: Breit-Pauli energy levels, lifetimes, and transition probabilities for the beryllium-like to neon-like sequences, C. F. Fischer and G. Tachiev, *At. Data Nucl. Data Tables* 87, 1-184 (2004).

(b) Transition probabilities for the resonance lines of selected elements have been compiled by Morton: Atomic data for resonance absorption lines. III. Wavelengths longward of the Lyman limit for the elements hydrogen to gallium, D. C. Morton, *Astrophys. J., Suppl. Ser.* 149, 205-238 (2003); Erratum: 151, 403 (2004).

(c) NIST Atomic Transition Probabilities, J. R. Fuhr and W. L. Wiese, in *CRC Handbook of Chemistry and Physics*, 86th Edition, 10-93-10-155 (Edited by D. R. Lide, CRC Press, Boca Raton, FL, 2005)

The use of electronic databases continues to grow as more data and bibliographies are made available in this medium. Several of the most useful databases active during this reporting period include:

(a) Version 7.0 of the NIST Atomic Transition Probability Bibliographic Database now contains 6570 references, dating from 1914 through June 2002. For this version, 454 bibliographic entries have been added.

(b) The availability of transition probability and oscillator strength data computed under the TOPbase and Opacity Projects is accessible at <http://vizier.u-strasbg.fr/topbase/topbase.html> for astrophysically abundant ions ($Z \leq 26$). The OPserver at this site allows opacity calculations for arbitrary chemical mixtures.

(c) The D.R.E.A.M. database (Database on Rare Earths at Mons University) continued to have data added for wavelengths, energy levels, oscillator strengths and radiative lifetimes for neutral, singly and doubly-ionized rare earth elements. These data reflect input from calculations, lifetime measurements, and experimental branching fractions.

Discussions around the availability of data, along with the presentation of techniques, continued through the proceedings of the 8th International Colloquium on Atomic Spectra and Oscillator Strengths (ASOS8) [105]. Several review articles present techniques in determining experimental oscillator strengths, including the laser-induced fluorescence, electron-beam ion-traps, and storage rings.

The main body of this report is a bibliography of selected recent literature references, which contain new transition probability data of astrophysical interest produced during

the last three-year period. Thus, this new selected bibliography continues where the last working group left off. As in the previous reports, the bibliographical material is ordered with respect to element and stage of ionization. One table provides an overview of the bibliographical data by spectrum. We were selective in our choice of these references, i.e., all papers had to contain a significant amount of numerical data, normally for more than ten spectral lines. The references are identified by a running number, which refers to the general reference list given in this report. In the general reference list, the literature is ordered alphabetically according to the first author, and each reference contains one or more code letters indicating the method applied by the authors. These code letters are defined as follows:

THEORETICAL METHODS:

~ Q quantum mechanical calculations

EXPERIMENTAL METHODS:

~ A measurements in absorption (absorption tube, etc.)

~ E measurements in emission (arc, hollow cathode, etc.)

~ L lifetime measurements (laser-induced fluorescence, beam-laser and beam-foil spectroscopy, etc.)

~ M miscellaneous experimental methods (for example, Stark effect, astrophysical measurements, etc.)

OTHER:

~ CP data compilations

~ CM comments

~ F forbidden transitions (not electric dipole)

~ R relative values only

Table 1. Important Literature References

| | | |
|---------------------------|------------------------|----------------------------|
| Ac LXXVII: 139 | Ar XV: 115, 121 | Bi LXXI: 139 |
| Ac LXXXII: 174 | Ar XVI: 112, 115, 121 | Bi LXXXVI: 174 |
| | Ar XVII: 115, 121, 140 | |
| Ag XXXV: 139 | | Bk LXXXV: 139 |
| Ag XL: 174 | As XXI: 139 | |
| | As XXVI: 174 | Br XXIII: 139 |
| Al I: 18 | | Br XXVIII: 174 |
| Al II: 177 | At LXXIII: 139 | |
| Al VI: 99 | At LXXVIII: 174 | C I: 44, 73, 167, 168, 176 |
| | | C II: 50 |
| Am LXXXIII: 139 | Au LXVII: 139 | C III: 74 |
| | Au LXXII: 174 | C IV: 6 |
| Ar I: 14, 85 | | C V: 140 |
| Ar V: 157 | B II: 74 | |
| Ar VI: 77, 139 | | Ca I: 18, 44, 68 |
| Ar VII: 67 | Ba I: 52 | Ca VII: 102 |
| Ar XI: 99, 115, 121, 174 | Ba II: 52 | Ca VIII: 101, 139 |
| Ar XII: 66, 115, 121 | Ba XLIV: 139 | Ca IX: 94, 150 |
| Ar XIII: 1, 106, 115, 121 | Ba XLIX: 174 | Ca XIII: 99, 174 |
| Ar XIV: 1, 115, 121 | | Ca XIX: 95 |

Table 1. Important Literature References (cont.)

| | | |
|------------------------------|---|----------------|
| Cd I: 160 | Cu XVII: 139 | Ga XIX: 139 |
| Cd II: 111, 160 | Cu XXII: 99, 174 | Ga XXIV: 174 |
| Cd XXXVI: 139 | | |
| Cd XLI: 174 | Dy III: 175 | Gd I: 159 |
| | Dy LIV: 139 | Gd II: 159 |
| Ce I: 163 | Dy LIX: 174 | Gd III: 34 |
| Ce II: 163 | | Gd LII: 139 |
| Ce III: 35 | Er I: 164 | Gd LVII: 174 |
| Ce XLVI: 139 | Er II: 158 | |
| Ce LI: 174 | Er LVI: 139 | Ge XX: 139 |
| | Er LXI: 174 | Ge XXV: 174 |
| Cf LXXXVI: 139 | | |
| | Es LXXXVII: 139 | Hf LX: 139 |
| Cl I: 19 | | Hf LXV: 174 |
| Cl II: 19, 58, 141, 147, 149 | Eu III: 133 | |
| Cl III: 19, 141 | Eu LI: 139 | Hg LXVIII: 139 |
| Cl IV: 19 | Eu LVI: 174 | Hg LXXIII: 174 |
| Cl V: 19, 47, 139 | | |
| Cl VI: 19, 67, 123 | Fe I: 44 | Ho I: 122 |
| Cl VII: 19 | Fe II: 13, 49, 82, 89, 126, 128, 138, 142 | Ho II: 104 |
| Cl VIII: 19 | Fe III: 126 | Ho LV: 139 |
| Cl IX: 19 | Fe IV: 70, 118, 126 | Ho LX: 174 |
| Cl X: 19, 41, 99, 174 | Fe V: 126 | |
| Cl XI: 19 | Fe VI: 126 | I XLI: 139 |
| Cl XII: 19 | Fe VII: 126, 170 | I XLVI: 174 |
| Cl XIII: 19 | Fe VIII: 126, 171, 172 | |
| Cl XIV: 19 | Fe IX: 126, 171 | In II: 125 |
| Cl XV: 19 | Fe X: 2, 59, 153 | In XXXVII: 139 |
| Cl XVI: 19 | Fe XI: 8, 27, 153 | In XLII: 174 |
| | Fe XII: 38, 153 | |
| Cm LXXXIV: 139 | Fe XIII: 4, 153, 156, 157, 166 | Ir I: 87 |
| | Fe XIV: 15, 75, 139 | Ir II: 86 |
| Co XV: 139 | Fe XV: 96 | Ir LXV: 139 |
| Co XVII: 136, 137 | Fe XVI: 96, 135, 137 | Ir LXX: 174 |
| Co XX: 99, 174 | Fe XVII: 3, 9, 24, 120, 181 | |
| | Fe XVIII: 92 | K I: 146 |
| Cr I: 18, 44 | Fe XIX: 91, 99, 174 | K VII: 139 |
| Cr II: 18 | Fe XX: 90, 119, 127 | K VIII: 37, 56 |
| Cr VIII: 114 | Fe XXI: 127 | K XII: 99, 174 |
| Cr XII: 139 | Fe XXII: 127 | K XIV: 7 |
| Cr XVII: 99, 174 | Fe XXIII: 127 | |
| Cr XIX: 7 | Fe XXIV: 71, 112, 127 | Kr I: 14 |
| | Fe XXV: 127 | Kr XXIII: 157 |
| Cs XLIII: 139 | | Kr XXIV: 139 |
| Cs XLVIII: 174 | Fm LXXXVIII: 139 | Kr XXIX: 174 |
| | | |
| Cu II: 65 | Fr LXXV: 139 | La I: 31 |
| Cu XIV: 152 | Fr LXXX: 174 | La II: 62, 138 |

Table 1. Important Literature References (cont.)

| | | |
|---------------------|-----------------------------|----------------------------|
| La XLV: 139 | Ne V: 129 | Pm LIV: 174 |
| La L: 174 | Ne VI: 129 | |
| | Ne VII: 129, 173 | Po LXXII: 139 |
| Lu I: 53 | Ne VIII: 129 | Po LXXXVII: 174 |
| Lu LIX: 139 | Ne IX: 140 | |
| Lu LXIV: 174 | | Pr I: 30 |
| | Ni I: 18, 88 | Pr II: 33, 144 |
| Mg I: 18 | Ni IV: 113 | Pr XLVII: 139 |
| Mg II: 46, 108, 109 | Ni XII: 145 | Pr LII: 174 |
| Mg V: 99, 130 | Ni XIII: 10, 152 | |
| Mg VI: 130 | Ni XIV: 10 | Pt I: 60 |
| Mg VII: 130 | Ni XV: 10 | Pt LXVI: 139 |
| Mg VIII: 130 | Ni XVI: 10, 75, 139 | Pt LXXI: 174 |
| Mg IX: 130 | Ni XVII: 57 | |
| Mg X: 130 | Ni XVIII: 134, 137 | Pu LXXXII: 139 |
| Mg XI: 165 | Ni XXI: 26, 99, 174 | |
| | Ni XXV: 154 | Ra LXXXVI: 139 |
| Mn I: 39 | | Ra LXXXI: 174 |
| Mn II: 151 | Np LXXXI: 139 | |
| Mn XIII: 139 | | Rb XXV: 139 |
| Mn XVIII: 99, 174 | O I: 73, 176, 180 | Rb XXX: 174 |
| Mn XX: 7 | O II: 180 | |
| | O III: 180 | Re LXIII: 139 |
| Mo II: 124 | O IV: 50, 97, 116, 169, 180 | Re LXVIII: 174 |
| Mo XXX: 139 | O V: 16, 117, 180 | |
| Mo XXXV: 174 | O VI: 5, 180 | Rh XXXIII: 139 |
| | O VII: 140 | Rh XXXVIII: 174 |
| N I: 179 | | |
| N III: 50, 64 | Os I: 87 | Rn I: 14 |
| N IV: 16, 64 | Os II: 86 | Rn LXXXIV: 139 |
| N V: 64 | Os LXIV: 139 | Rn LXXXIX: 174 |
| N VI: 140 | Os LXIX: 174 | |
| | | Ru XXXII: 139 |
| Na I: 146 | P II: 148 | Ru XXXVII: 174 |
| Na III: 83 | P III: 78, 139 | |
| Na IV: 99 | P IV: 67, 79 | S II: 84 |
| | P VIII: 99, 174 | S IV: 139 |
| Nb XXIX: 139 | | S V: 67 |
| Nb XXXIV: 174 | Pa LXXIX: 139 | S VII: 42 |
| | Pa LXXXIV: 174 | S VIII: 132 |
| Nd I: 30 | | S IX: 23, 43, 99, 132, 174 |
| Nd II: 61, 143, 161 | Pb LXX: 139 | S X: 21, 43, 93, 132 |
| Nd XLVIII: 139 | Pb LXXV: 174 | S XI: 103, 132 |
| Nd LIII: 174 | | S XII: 132 |
| | Pd XXXIV: 139 | S XIII: 132 |
| Ne I: 14 | Pd XXXIX: 174 | S XIV: 132 |
| Ne II: 178 | | S XV: 95 |
| Ne III: 25, 100 | Pm XLIX: 139 | |

Table 1. Important Literature References (cont.)

| | | |
|--------------------------|-----------------|-------------------|
| Sb XXXIX: 139 | Sr XXXI: 174 | V XI: 139 |
| Sb XLIV: 174 | | V XVI: 99, 174 |
| | Ta III: 12 | V XVIII: 7 |
| Sc IX: 139 | Ta LXI: 139 | |
| Sc XIV: 99, 174 | Ta LXXVI: 174 | W LXII: 139 |
| Sc XVI: 7 | | W LXVII: 174 |
| | Tb LIII: 139 | |
| Se XXII: 139 | Tb LVIII: 174 | Xe I: 14, 54, 55 |
| Se XXVII: 174 | | Xe II: 182 |
| | Tc XXXI: 139 | Xe V: 28 |
| Si I: 18, 44, 51, 69 | Tc XXXVI: 174 | Xe VI: 29 |
| Si II: 45 | | Xe VIII: 72 |
| Si III: 63 | Te XL: 139 | Xe XLII: 139 |
| Si V: 17 | Te XLV: 174 | Xe XLVII: 174 |
| Si VI: 131 | | |
| Si VII: 20, 99, 131, 174 | Th LXXVIII: 139 | Y XXVII: 139 |
| Si VIII: 22, 131 | Th LXXXIII: 174 | Y XXXII: 174 |
| Si IX: 131 | | |
| Si X: 131, 155 | Ti I: 44 | Yb I: 107 |
| Si XI: 131 | Ti II: 81 | Yb II: 36 |
| Si XII: 131 | Ti X: 76, 139 | Yb LVIII: 139 |
| Si XIII: 140 | Ti XI: 56 | Yb LXIII: 174 |
| | Ti XV: 99, 174 | |
| Sm II: 143, 162 | Ti XVII: 7 | Zn I: 18, 40, 98 |
| Sm III: 32 | | Zn II: 40, 80 |
| Sm L: 139 | Tl LXIX: 139 | Zn XVIII: 139 |
| Sm LV: 174 | Tl LXXIV: 174 | Zn XXIII: 99, 174 |
| | | Zr III: 110 |
| Sn II: 11, 48 | Tm LVII: 139 | Zr XXVIII: 139 |
| Sn XXXVIII: 139 | Tm LXII: 174 | Zr XXXIII: 174 |
| Sn XLIII: 174 | | |
| | U LXXX: 139 | |
| Sr XXVI: 139 | U LXXXV: 174 | |

References

1. Aggarwal, K. M., Keenan, F. P., Nakazaki, S., A&A 436, 1141-1150 (2005) Q, QF
2. Aggarwal, K. M., Keenan, F. P., A&A 427, 763-767 (2004) Q, QF
3. Aggarwal, K. M., Keenan, F. P., Kisielius, R., A&A 420, 783-788 (2004) Q, QF
4. Aggarwal, K. M., Keenan, F. P., A&A 418, 371-385 (2004) Q
5. Aggarwal, K. M., Keenan, F. P., Phys. Scr. 70, 222-234 (2004) Q
6. Aggarwal, K. M., Keenan, F. P., Phys. Scr. 69, 385-397 (2004) Q
7. Aggarwal, K. M., Keenan, F. P., Msezane, A. Z., A&A 401, 377-383 (2003) Q
8. Aggarwal, K. M., Keenan, F. P., MNRAS 338, 412-424 (2003) Q
9. Aggarwal, K. M., Keenan, F. P., Msezane, A. Z., ApJS 144, 169-210 (2003) Q
10. Aggarwal, K. M., Keenan, F. P., Msezane, A. Z., At. Data Nucl. Data Tables 85, 453-494 (2003) Q
11. Alonso-Medina, A., Colón, C., Rivero, C., Phys. Scr. 71, 154-158 (2005) Q
12. Azarov, V. I., Tchchang-Brillet, W.-Ü. L., Wyart, J.-F., Meijer, F. G., Phys. Scr. 67,

- 190-207 (2003) Q
13. Beck, D. R., Phys. Scr. 71, 447-452 (2005) Q
 14. Beck, D. R., Phys. Rev. A 66, 034502 (2002) QF
 15. Beiersdorfer, P., Träbert, E., Pinnington, E. H., ApJ 587, 836-840 (2003) LF
 16. Bell, K. L., Phys. Scr. T100, 64 (2002) Q
 17. Ben Nessib, N., Elabidi, H., Cornille, M., Dubau, J., Phys. Scr. 72, 23-30 (2005) Q
 18. Bensby, T., Feltzing, S., Lundström, I., A&A 410, 527-551 (2003) M
 19. Berrington, K. A., Nakazaki, S., At. Data Nucl. Data Tables 82, 1 (2002) Q
 20. Bhatia, A. K., Landi, E., ApJ 585, 587-597 (2003) Q, QF
 21. Bhatia, A. K., Landi, E., ApJS 147, 409-419 (2003) Q, QF
 22. Bhatia, A. K., Landi, E., At. Data Nucl. Data Tables 85, 317-376 (2003) Q, QF
 23. Bhatia, A. K., Landi, E., At. Data Nucl. Data Tables 85, 169-253 (2003) Q, QF
 24. Bhatia, A. K., Doschek, G. A., At. Data Nucl. Data Tables 85, 1-45 (2003) Q, QF
 25. Bhatia, A. K., Thomas, R. J., Landi, E., At. Data Nucl. Data Tables 83, 113-152 (2003) Q, QF
 26. Bhatia, A. K., Landi, E., Mason, H. E., At. Data Nucl. Data Tables 83, 71-112 (2003) Q, QF
 27. Bhatia, A. K., Doschek, G. A., Eissner, W., At. Data Nucl. Data Tables 82, 211-255 (2002) Q, QF
 28. Biémont, E., Quinet, P., Zeippen, C. J., Phys. Scr. 71, 163-169 (2005) Q
 29. Biémont, E., Buchard, V., Garnir, H.-P., Lefèbvre, P.-H., Quinet, P., Eur. Phys. J. D 33, 181-191 (2005) L, Q
 30. Biémont, E., Quinet, P., Svanberg, S., Xu, H. L., J. Phys. B 37, 1381-1389 (2004) L
 31. Biémont, E., Quinet, P., Svanberg, S., Xu, H. L., Eur. Phys. J. D 30, 157-162 (2004) L, Q
 32. Biémont, E., Garnir, H. P., Litzén, U., Nielsen, K., Quinet, P., Svanberg, S., Wahlgren, G. M., Zhang, Z. G., A&A 399, 343-349 (2003) E, L, Q
 33. Biémont, E., Lefèbvre, P.-H., Quinet, P., Svanberg, S., Xu, H. L., Eur. Phys. J. D 27, 33-41 (2003) L, Q
 34. Biémont, E., Kohonen, G., Quinet, P., A&A 393, 717-720 (2002) Q
 35. Biémont, E., Quinet, P., Ryabchikova, T. A., MNRAS 336, 1155-1160 (2002) Q
 36. Biémont, E., Quinet, P., Dai, Z., Zhankui, J., Zhiguo, Z., Xu, H., Svanberg, S., J. Phys. B 35, 4743-4749 (2002) L, Q
 37. Biémont, E., Dumont, P.-D., Garnir, H. P., Palmeri, P., Quinet, P., Eur. Phys. J. D 20, 199-204 (2002) Q
 38. Biémont, E., Palmeri, P., Quinet, P., Träbert, E., Zeippen, C. J., Eur. Phys. J. D 20, 37-44 (2002) Q, QF
 39. Blackwell-Whitehead, R. J., Xu, H. L., Pickering, J. C., Nave, G., Lundberg, H., MNRAS 361, 1281-1286 (2005) E, L
 40. Blagoev, K. B., Malcheva, G., Penchev, V., Biémont, E., Xu, H. L., Persson, A., Svanberg, S., Phys. Scr. 69, 433-440 (2004) L, Q
 41. Bogdanovich, P., Karpušienė, R., Martinson, I., Phys. Scr. 67, 44-51 (2003) Q
 42. Borges, F. O., Cavalcanti, G. H., Trigueiros, A. G., Jupén, C., JQSRT 83, 751-763 (2004) Q
 43. Borges, F. O., Cavalcanti, G. H., Trigueiros, A. G., JQSRT 78, 119-129 (2003) Q
 44. Borrero, J. M., Bellot Rubio, L. R., Barklem, P. S., del Toro Iniesta, J. C., A&A 404, 749-762 (2003) M
 45. Cavalcanti, G. H., Borges, F. O., Mania, A. J., Orloski, R. V., Trigueiros, A. G., JQSRT 90, 291-308 (2005) Q
 46. Charro, E., Martín, I., ApJ 585, 1191-1196 (2003) QF

47. Choudhury, K. B., Deb, N. C., Roy, K., Msezane, A. Z., *Eur. Phys. J. D* 27, 103-107 (2003) Q
48. Colón, C., Alonso-Medina, A., *A&A* 422, 1109-1111 (2004) Q
49. Corrége, G., Hibbert, A., *ApJ* 627, L157-L159 (2005) Q
50. Corrége, G., Hibbert, A., *At. Data Nucl. Data Tables* 86, 19-34 (2004) Q
51. Coutinho, L. H., Trigueiros, A. G., *JQSRT* 75, 357 (2002) Q
52. Curry, J. J., *J. Phys. Chem. Ref. Data* 33, 725-746 (2004) CP
53. Dai, Z., Zhankui, J., Xu, H., Zhiguo, Z., Svanberg, S., Bimont, E., Lefèbvre, P. H., Quinet, P., *J. Phys. B* 36, 479-487 (2003) L, Q
54. Das, M. B., Karmakar, S., *Phys. Scr.* 71, 170-171 (2005) L
55. Das, M. B., Karmakar, S., *Eur. Phys. J. D* 32, 285-288 (2005) L
56. Das, R., Deb, N. C., Roy, K., Msezane, A. Z., *A&A* 416, 375-381 (2004) Q
57. Das, R., Deb, N. C., Roy, K., Msezane, A. Z., *Phys. Scr.* 67, 401-406 (2003) Q
58. Deb, N. C., Crothers, D. S. F., Felfli, Z., Msezane, A. Z., *J. Phys. B* 36, p. L47-L55 (2003) Q
59. Del Zanna, G., Berrington, K. A., Mason, H. E., *A&A* 422, 731-749 (2004) CM, CMF, Q, QF
60. Den Hartog, E. A., Herd, M. T., Lawler, J. E., Sneden, C., Cowan, J. J., Beers, T. C., *ApJ* 619, 639-655 (2005) E, L
61. Den Hartog, E. A., Lawler, J. E., Sneden, C., Cowan, J. J., *ApJS* 148, 543-566 (2003) E, L
62. Derkach, A., Ilyinsky, L., Mannervik, S., Norlin, L.-O., Rostohar, D., Royen, P., Schef, P., Biémont, E., *Phys. Rev. A* 65, 062508 (2002) LF, QF
63. Djeniže, S., Dimitrijević, M. S., Srećković, A., Bukvić, S., *A&A* 396, 331-336 (2002) ER, Q
64. Djeniže, S., Srećković, A., Bukvić, S., *Eur. Phys. J. D* 20, 11-16 (2002) E
65. Dong, C. Z., Fritzsche, S., *Phys. Rev. A* 72, 012507 (2005) Q
66. Eissner, W., Landi, E., Bhatia, A. K., *At. Data Nucl. Data Tables* 89, 139-194 (2005) Q, QF
67. Fan, J., Zheng, N. W., *Chem. Phys. Lett.* 400, 273-278 (2004) Q
68. Fischer, C. F., Tachiev, G., *Phys. Rev. A* 68, 012507 (2003) Q
69. Froese Fischer, C., *Phys. Rev. A* 71, 042506 (2005) Q, QF
70. Froese Fischer, C., Rubin, R. H., *MNRAS* 355, 461-474 (2004); Erratum: 355, 1400 (2004) QF
71. Galavís, M. E., Bautista, M. A., Mendoza, C., *Rev. Mex. Fis.* 49(3), 63-66 (2003) (Span.) Q
72. Gallardo, M., Raineri, M., Giuliani, M., Lagorio, C., Padilla, S., Sarmiento, R., Reyna Almandos, J. G., *JQSRT* 95, 365-372 (2005) Q
73. Golly, A., Jazgara, A., Wujec, T., *Phys. Scr.* 67, 485-490 (2003) E
74. Gou, B.-C., Wang, F., *Phys. Rev. A* 69, 042513 (2004) Q
75. Gupta, G. P., Msezane, A. Z., *At. Data Nucl. Data Tables* 89, 1-44 (2005) Q
76. Gupta, G. P., Msezane, A. Z., *Phys. Scr.* 70, 235-240 (2004) Q
77. Gupta, G. P., Msezane, A. Z., *Phys. Scr.* 69, 273-282 (2004) Q
78. Gupta, G. P., Msezane, A. Z., *Phys. Scr.* 66, 354-362 (2002) Q
79. Gupta, G. P., Msezane, A. Z., *Phys. Scr.* 66, 43-50 (2002) Q
80. Harrison, S. A., Hibbert, A., *MNRAS* 340, 1279-1286 (2003) Q
81. Hartman, H., Schef, P., Lundin, P., Ellmann, A., Johansson, S., Lundberg, H., Mannervik, S., Norlin, L.-O., Rostohar, D., Royen, P., *MNRAS* 361, 206-210 (2005) LF, MF
82. Hartman, H., Derkach, A., Donnelly, M. P., Gull, T., Hibbert, A., Johansson, S., Lundberg, H., Mannervik, S., Norlin, L.-O., Rostohar, D., Royen, P., Schef, P., *A&A* 397,

- 1143-1149 (2003) MF, QF
83. Hibbert, A., *J. Phys. B* 36, 4703-4715 (2003) CM, Q
84. Irimia, A., Froese Fischer, C., *Phys. Scr.* 71, 172-184 (2005) Q, QF
85. Irimia, A., Fischer, C. F., *J. Phys. B* 37, 1659-1672 (2004) Q
86. Ivarsson, S., Wahlgren, G. M., Dai, Z., Lundberg, H., Leckrone, D. S., *A&A* 425, 353-360 (2004) E, L
87. Ivarsson, S., Andersen, J., Nordström, B., Dai, X., Johansson, S., Lundberg, H., Nilsson, H., Hill, V., Lundqvist, M., Wyart, J. F., *A&A* 409, 1141-1149 (2003) E, L
88. Johansson, S., Litzén, U., Lundberg, H., Zhang, Z., *ApJ* 584, p. L107-L110 (2003) E, L
89. Johansson, S., Derkatch, A., Donnelly, M. P., Hartman, H., Hibbert, A., Karlsson, H., Kock, M., Li, Z. S., Leckrone, D. S., Litzén, U., Lundberg, H., Mannervik, S., Norlin, L.-O., Nilsson, H., Pickering, J., Raassen, T., Rostohar, D., Royen, P., Schmitt, A., Johanning, M., Sikström, C. M., Smith, P. L., Svanberg, S., Wahlgren, G. M., *Phys. Scr. T100*, 71 (2002) CM
90. Jonauskas, V., Bogdanovich, P., Keenan, F. P., Foord, M. E., Heeter, R. F., Rose, S. J., Ferland, G. J., Kisielius, R., van Hoof, P. A. M., Norrington, P. H., *A&A* 433, 745-750 (2005) Q, QF
91. Jonauskas, V., Keenan, F. P., Foord, M. E., Heeter, R. F., Rose, S. J., Ferland, G. J., Kisielius, R., van Hoof, P. A. M., Norrington, P. H., *A&A* 424, 363-369 (2004) Q, QF
92. Jonauskas, V., Keenan, F. P., Foord, M. E., Heeter, R. F., Rose, S. J., van Hoof, P. A. M., Ferland, G. J., Aggarwal, K. M., Kisielius, R., Norrington, P. H., *A&A* 416, 383-389 (2004) Q, QF
93. Karpuškienė, R., Bogdanovich, P., Udriš, A., *At. Data Nucl. Data Tables* 89, 45-76 (2005) Q
94. Karpuškienė, R., Bogdanovich, P., Udriš, A., *J. Phys. B* 37, 2067-2086 (2004) Q
95. Kingston, A. E., Norrington, P. H., Boone, A. W., *J. Phys. B* 35, 4077-4100 (2002) Q, QF
96. Kisielius, R., Hibbert, A., Ferland, G. J., Foord, M. E., Rose, S. J., van Hoof, P. A. M., Keenan, F. P., *MNRAS* 344, 696-706 (2003) Q
97. Koc, K., *J. Phys. B* 37, 3821-3835 (2004) Q
98. Kubkowska, M. K., Szcześniak, T. M., Grycuk, T., *Acta Phys. Pol. A* 105, 317-328 (2004) A
99. Landi, E., *A&A* 434, 365-376 (2005) Q, QF
100. Landi, E., Bhatia, A. K., *At. Data Nucl. Data Tables* 89, 195-265 (2005) Q, QF
101. Landi, E., Storey, P. J., Zeippen, C. J., *ApJ* 607, 640-652 (2004) Q, QF
102. Landi, E., Bhatia, A. K., *ApJ* 589, 1075-1084 (2003) Q, QF
103. Landi, E., Bhatia, A. K., *ApJS* 149, 251-263 (2003) Q, QF
104. Lawler, J. E., Sneden, C., Cowan, J. J., *ApJ* 604, 850-860 (2004) E
105. Lawler, J. E., Wahlgren, G. M., Wiese, W. L.: editors, *Phys. Scr. T119*, 82 pp. (2005)
106. Liang, G.-Y., Dong, G.-X., Zeng, J.-L., *At. Data Nucl. Data Tables* 88, 83-161 (2004) Q, QF
107. Liu, X.-W., Wang, Z.-W., *Phys. Rev. A* 40, 1838-1842 (1989) Q
108. Majumder, S., Gopakumar, G., Chaudhuri, R. K., Das, B. P., Merlitz, H., Mahapatra, U. S., Mukherjee, D., *Eur. Phys. J. D* 28, 3-9 (2004) QF
109. Majumder, S., Merlitz, H., Gopakumar, G., Das, B. P., Mahapatra, U. S., Mukherjee, D., *ApJ* 574, 513-517 (2002) Q
110. Mayo, R., Ortiz, M., Campos, J., *JQSRT* 94, 109-116 (2005) E
111. Mayo, R., Ortiz, M., Campos, J., Blagoev, K., Malcheva, G., *Phys. Scr.* 72, 142-147 (2005) E, Q

112. McKeown, K., Aggarwal, K. M., Keenan, F. P., Rose, S. J., Phys. Scr. 70, 295-303 (2004) Q, QF
113. Meléndez, M., Bautista, M. A., A&A 436, 1123-1130 (2005) QF
114. Mohan, M., Singh, A. K., Jha, A. K. S., Singh, N., Pramana 65, 75-84 (2005) Q
115. Mulye, Y. G., Natarajan, L., Phys. Scr. 69, 24-29 (2004) Q
116. Murakami, I., Safronova, U. I., Vasilyev, A. A., Kato, T., At. Data Nucl. Data Tables 90, 1-74 (2005) Q
117. Murakami, I., Safronova, U. I., Kato, T., Can. J. Phys. 80, 1525-1542 (2002) Q
118. Nahar, S. N., Pradhan, A. K., A&A 437, 345-354 (2005) Q
119. Nahar, S. N., A&A 413, 779-787 (2004) Q, QF
120. Nahar, S. N., Eissner, W., Chen, G.-X., Pradhan, A. K., A&A 408, 789-801 (2003) Q, QF
121. Natarajan, L., J. Phys. B 35, 3179-3190 (2002) Q
122. Nave, G., JOSAS B 20, 2193-2202 (2003) E
123. Neerja, Gupta, G. P., Tripathi, A. N., Msezane, A. Z., At. Data Nucl. Data Tables 84, 85-97 (2003); Erratum: 85, 495 (2003) Q
124. Nilsson, H., Pickering, J. C., Phys. Scr. 67, 223-233 (2003) Q
125. Özdemir, L., Boya, G., JQSRT 91, 111-120 (2005) Q
126. Palmeri, P., Mendoza, C., Kallman, T. R., Bautista, M. A., Meléndez, M., A&A 410, 359-364 (2003) Q
127. Palmeri, P., Mendoza, C., Kallman, T. R., Bautista, M. A., A&A 403, 1175-1184 (2003) Q, QF
128. Pickering, J. C., Donnelly, M. P., Nilsson, H., Hibbert, A., Johansson, S., A&A 396, 715-722 (2002) E, Q
129. Podobedova, L. I., Fuhr, J. R., Reader, J., Wiese, W. L., J. Phys. Chem. Ref. Data 33, 525-540 (2004) CP
130. Podobedova, L. I., Kelleher, D. E., Reader, J., Wiese, W. L., J. Phys. Chem. Ref. Data 33, 495-524 (2004) CP
131. Podobedova, L. I., Kelleher, D. E., Reader, J., Wiese, W. L., J. Phys. Chem. Ref. Data 33, 471-494 (2004) CP
132. Podobedova, L. I., Musgrove, A., Kelleher, D. E., Reader, J., Wiese, W. L., J. Phys. Chem. Ref. Data 32, 1367-1386 (2003) CP
133. Quinet, P., Biémont, E., MNRAS 340, 463-467 (2003) Q
134. Ray, H., AS&S 283, 415-436 (2003) QF
135. Ray, H., ApJ 579, 914-919 (2002) QF
136. Ray, H., A&A 391, 1173-1184 (2002) QF
137. Ray, H., J. Phys. B 35, p. L299-L307 (2002) QF
138. Rostohar, D., Derkach, A., Hartman, H., Norlin, L.-O., Royen, P., Schef, P., Man-nervik, S., Hyperfine Interact. 146-147, 151-159 (2003) LF
139. Safronova, U. I., Sataka, M., Albritton, J. R., Johnson, W. R., Safronova, M. S., At. Data Nucl. Data Tables 84, 1-83 (2003) Q
140. Savukov, I. M., Johnson, W. R., Safronova, U. I., At. Data Nucl. Data Tables 85, 83-167 (2003) Q, QF
141. Schectman, R. M., Federman, S. R., Brown, M., Cheng, S., Fritts, M. C., Irving, R. E., Gibson, N. D., ApJ 621, 1159-1162 (2005) E, L
142. Schnabel, R., Schultz-Johanning, M., Kock, M., A&A 414, 1169-1176 (2004) E, L
143. Scholl, T. J., Holt, R. A., Masterman, D., Rivest, R. C., Rosner, S. D., Sharikova, A., Can. J. Phys. 80, 1621-1629 (2002) L
144. Scholl, T. J., Holt, R. A., Masterman, D., Rivest, R. C., Rosner, S. D., Sharikova, A., Can. J. Phys. 80, 713-722 (2002) L

145. Singh, N., Singh, A. K., Mohan, M., *Can. J. Phys.* 81, 861-867 (2003) Q
146. Stone, P. M., Kim, Y.-K., *J. Res. NIST* 109, 505-515 (2004) Q
147. Tayal, S. S., *A&A* 426, 717-720 (2004) Q
148. Tayal, S. S., *ApJS* 146, 459-465 (2003) Q
149. Tayal, S. S., *J. Phys. B* 36, 3239-3249 (2003) Q
150. Tayal, V., Gupta, G. P., Msezane, A. Z., *Phys. Scr.* 71, 627-637 (2005) Q
151. Toner, A., Hibbert, A., *MNRAS* 361, 673-678 (2005) Q
152. Träbert, E., Saathoff, G., Wolf, A., *Eur. Phys. J. D* 30, 297-302 (2004) LF
153. Träbert, E., *Hyperfine Interact.* 146-147, 269-273 (2003) LF
154. Tully, J. A., Chidichimo, M. C., *J. Phys. B* 37, 689-701 (2004) Q
155. Vilkas, M. J., Ishikawa, Y., Träbert, E., *Phys. Scr.* 72, 181-199 (2005) Q
156. Vilkas, M. J., Ishikawa, Y., *Phys. Rev. A* 69, 062503 (2004) Q, QF
157. Vilkas, M. J., Ishikawa, Y., *J. Phys. B* 36, 4641-4650 (2003) QF
158. Xu, H., Jiang, Z., Zhang, Z., Dai, Z., Svanberg, S., Quinet, P., Biémont, E., *J. Phys. B* 36, 1771-1781 (2003) L, Q
159. Xu, H., Jiang, Z., Svanberg, S., *J. Phys. B* 36, 411-417 (2003) L
160. Xu, H. L., Persson, A., Svanberg, S., Blagoev, K., Malcheva, G., Pentchev, V., Biémont, E., Campos, J., Ortiz, M., Mayo, R., *Phys. Rev. A* 70, 042508 (2004) E, L, Q
161. Xu, H. L., Svanberg, S., Cowan, R. D., Lefèbvre, P.-H., Quinet, P., Biémont, E., *MNRAS* 346, 433-440 (2003) L, Q
162. Xu, H. L., Svanberg, S., Quinet, P., Garnir, H. P., Biémont, E., *J. Phys. B* 36, 4773-4787 (2003) L, Q
163. Xu, H. L., Persson, A., Svanberg, S., *Eur. Phys. J. D* 23, 233-236 (2003) L
164. Xu, H.-L., Jiang, Z.-K., Svanberg, S., *Phys. Scr.* 67, 64-67 (2003) L
165. Yamamoto, N., Kato, T., Rosmej, F. B., *JQSRT* 96, 343-361 (2005) Q
166. Young, P. R., *A&A* 417, 785-792 (2004) Q, QF
167. Zatsarinny, O., Bartschat, K., Bandurina, L., Gedeon, V., *Phys. Rev. A* 71, 042702 (2005) Q
168. Zatsarinny, O., Froese Fischer, C., *J. Phys. B* 35, 4669-4683 (2002) Q
169. Zeng, J., Yuan, J., *J. Phys. B* 35, 3041-3054 (2002) Q
170. Zeng, J.-L., Liang, G. Y., Zhao, G., Shi, J. R., *MNRAS* 357, 440-448 (2005) Q
171. Zeng, J.-L., Dong, G.-X., Zhao, G., Yuan, J.-M., *J. Phys. B* 37, 2529-2542 (2004) Q
172. Zeng, J.-L., Jin, F.-T., Zhao, G., Yuan, J.-M., *J. Phys. B* 36, 3457-3465 (2003) Q
173. Jiaolong Zeng, Jianmin Yuan, *Phys. Rev. A* 66, 022715 (2002) Q
174. Zhang, H. L., Sampson, D. H., *At. Data Nucl. Data Tables* 82, 357-389 (2002) Q
175. Zhang, Z. G., Svanberg, S., Palmeri, P., Quinet, P., Biémont, E., *MNRAS* 334, 1 (2002) L, Q
176. Zheng, N., Wang, T., *ApJS* 143, 231-240 (2002) Q
177. Zheng, N. W., Fan, J., Ma, D. X., Wang, T., *J. Phys. Soc. Jpn.* 72, 3091-3096 (2003) Q
178. Zheng, N. W., Wang, T., *Spectrochim. Acta, Part B* 58, 1319-1324 (2003) Q
179. Zheng, N. W., Wang, T., *Chem. Phys.* 282, 31-36 (2002) Q
180. Zheng, N. W., Wang, T., Zhou, T., Ma, D. X., *J. Phys. Soc. Jpn.* 71, 1672 (2002) Q
181. Zhong, J.-Y., Zhang, J., Zhao, G., Lu, X., *Chin. Astron. Astrophys.* 28, 264-272 (2004) Q
182. Zielińska, S., Bratasz, L., Dzierżega, K., *Phys. Scr.* 66, 454-457 (2002) E

3. WORKING GROUP ON Collision Processes

(*GROUPE DE TRAVAIL POUR Collision Processes*)

PRESIDENT: D.R. Schultz and P.C. Stancil

Since the last working group report in 2002, very active research continues that spans the vast range of atomic and molecular collision processes of interest in astrophysics. Given the large volume and scope of the pertinent published literature and the limited space available here, rather than seeking to comprehensively review this progress, we have attempted to identify works and some compilations of particular importance. In addition, access to an on-line bibliographic database that can be searched by collision reaction category, reactants, authors, and dates is made available by the Oak Ridge National Laboratory Controlled Fusion Atomic Data Center (CFADC 2005). Since a very high level of overlap exists between the atomic and molecular data needs of plasma science relevant to fusion energy and to astrophysics, this database, containing entries from 1978 to present, should be quite useful for those seeking such information. In addition, categorized bibliographies based largely on the bibliographic data compilation of the ORNL CFADC have been published in hardcopy by the International Atomic Energy Agency (CIAMDA 1998).

Here we organize our report summarizing new work on relevant collision processes including electron impact on atoms, ions, molecules, and molecular ions; ion-atom and atom-atom collisions; ion-, atom-, and molecule-molecule collisions; and reactive scattering and chemistry.

3.1. *Electron Collisions with Atoms, Ions, Molecules, and Molecular Ions*

Collisions of electrons with atoms, ions, molecules, and molecular ions are the major excitation mechanism in a wide range of astrophysical environments. In addition, they largely drive ionization and recombination, contribute to molecular fragmentation and formation, and influence transport. In the following sections we summarize recent work of interest for electron collisions with astrophysically relevant species regarding elastic scattering, excitation, dissociation, ionization, recombination, and electron detachment from negative ion since the time of the last Commission report (Schultz & Stancil 2002).

3.2. *Electron-Atom Scattering*

New references for elastic scattering from atoms are as follows: H (Papp & Hu 2002, James, Childers & Khakoo 2004, Witthoef, Loch & Pindzola 2004, Jablonski, Salvat & Powell 2004), noble gases (Garcia et al. 2002 - Ne, Ar, Kr, Xe; Baek & Grosswendt 2003 - He, Ne, Ar; Demesie et al. 2003 - Xe; Blanco & Garcia 2003 - He, Ne, Ar, Kr, Xe, Date, Ishimaru & Shimozuma 2003 - Xe; Salvat 2003 - He, Ne, Ar, Kr, Xe; McEachran & Stauffer 2003 - Kr; Ariyasinghe & Goains 2004 - Kr, Xe; Cho et al. 2004b - Kr; Milosavljevic, Sevic & Marinkovic 2004 - Kr), O (Plummer, Noble & Le Dourneuf 2004), Mg (Al-Mulla & Joensson 2002, Bartschat & Sadeghpour 2003, Bartschat et al. 2004), Al (Jablonski, Salvat & Powell 2004), Ca (Bartschat & Sadeghpour 2003), Ni (Jablonski, Salvat & Powell 2004), and Zn (Sienkiewicz et al. 2002).

Excitation of atoms are covered in new references: H (Sweeney et al. 2001, Kim 2001, James et al. 2002, Sweeney, Grafe & Shyn 2004, James, Childers. & Khakoo 2004, Witthoef, Loch. & Pindzola 2004), He (Kim 2001, Dogan & Crowe 2002, Mityureva, Smirnov & Ponomarenko 2002, Bartschat & Andersen 2003, Baek & Grosswendt 2003, Harries, Hammond & Murray 2003, Merabet et al. 2003b, Kheifets 2004), Li (Kim 2001, Griffin et al. 2001, Witthoef et al. 2003), Be (Kim 2001, Ballance et al. 2003b), C (Srivastava,

McEachran & Stauffer 2002, Kim & Desclaux 2002, Zatsarinny & Fischer 2002), N (Kim & Desclaux 2002), O (Zatsarinny & Tayal 2002a, Kim & Desclaux 2002, Tayal 2002, Johnson et al. 2003a, Johnson et al. 2003b, Plummer, Noble & Le Dourneuf 2004), Ne (Boffard et al. 2001, Khakoo et al. 2002, Stewart et al. 2002, Meneses et al. 2002, Baek & Grosswendt 2003, Zatsarinny & Bartschat 2004a, Ballance & Griffin 2004), Mg (Fursa & Bray 2001, Kim 2001, Kai et al. 2004), Si (Srivastava, McEachran. & Stauffer 2002), S (Zatsarinny & Tayal 2002b), Ar (Stewart et al. 2002, Baek & Grosswendt 2003, Weber, Boffard & Lin 2003, Madison et al. 2004, Zatsarinny & Bartschat 2004b), Ca (Kim 2001, Muktavat, Srivastava & Stauffer 2002), Kr (Stewart et al. 2002, Yuan et al. 2002, Tsurubuchi Kobayashi & Hyodo 2003, Li et al. 2003, Yu et al. 2003, Cho et al. 2004b), and Xe (Kanik, Johnson & James 2001, Boechat-Roberty et al. 2002, Yu et al. 2003, Date, Ishimaru & Shimozuma 2003, Bartschat, Dasgupta & Madison 2004).

New publications on ionization include: H (Deb & Crothers 2002, Lepp, Stancil & Dalgarno 2002, Isaacs et al. 2001, Szluniska, Van Reeth & Laricchia 2002, Bartlett, Stelbovics & Bray 2003, Childers et al. 2003, Bartlett & Stelbovics 2004, Chen et al. 2004, Childers et al. 2004), He (Lepp, Stancil & Dalgarno 2002, Dogan & Crowe 2002, Denifl et al. 2002, Keller 2003, Bray, Fursa & Stelbovics 2003, Fursa & Bray 2003, Merabet et al. 2003a, Defrance, Kereselidze & Machavariani 2003, Merabet et al. 2003b, Kheifets & Bray 2004, Sorokin et al. 2004, Kheifets 2004, Pindzola et al. 2004, Uddin et al. 2004b), noble gases (Rejoub, Lindsay & Stebbings 2002 - He, Ne, Ar, Kr, Xe; Kobayashi et al. 2002 - Ne, Ar, Kr, Xe; Bartlett & Stelbovics 2002 - Ne, Ar, Kr, Xe; Gstir et al. 2002 - Ne, Ar, Xe; Szluniska, Van Reeth & Laricchia 2002 - He, Ne, Ar, Kr, Xe; Gstir et al. 2003 - He, Ne, Ar, Kr, Xe; Erwin & Kunc 2003 - Ar, Kr, Xe, Rn), Li (Huang et al. 2002, Ghosh & Sinha 2003), C (Kim & Desclaux 2002, Szluniska, Van Reeth & Laricchia 2002, Alfaz Uddin & Basak 2003a), N (Kim & Desclaux 2002, Szluniska, Van Reeth & Laricchia 2002, Alfaz Uddin & Basak 2003a), O (Kim & Desclaux 2002, Szluniska, Van Reeth & Laricchia 2002, Joshipura, Antony & Vinodkumar 2002, Alfaz Uddin & Basak 2003a), Mg (Kampp et al. 2002, Jha & Roy 2002), Si (Bartlett & Stelbovics 2002), P (Bartlett & Stelbovics 2002), S (Bartlett & Stelbovics 2002), Ar (Biava et al. 2002, Stano et al. 2003, Cooper & van Boeyen 2004), Ca (Alfaz Uddin & Basak 2003b), Ti (Alfaz Uddin & Basak 2003b), Cr (Alfaz Uddin & Basak 2003a), Mn (Llovet, Merlet & Salvat 2002, Alfaz Uddin & Basak 2003a), Fe (Llovet, Merlet & Salvat 2002, Alfaz Uddin & Basak 2003a), Kr (Denifl et al. 2002, Loch et al. 2002), Xe (Date, Ishimaru & Shimozuma 2003), and series of atoms (Santos, Parente & Kim 2003 - C, N, O, Ne, Mg, Al, Si, P, S, Ar, Ti, Cr, Fe, Co, Ni, Kr).

Negative ion formation (i.e. $e + A \rightarrow A^-$) has been studied for: H (Ghosh, Nath & Sinha 2003, Grujic 2003, Fritioff et al. 2004), Li (Le Padellec et al. 2002), and S (Fritioff et al. 2003).

3.3. Electron-Ion Scattering

New elastic data exists for He^+ (Bhatia 2002).

New work for excitation of atomic ions include: He^+ (Kim 2002, Witthoeft, Pindzola & Colgan 2003), He-like (Whiteford et al. 2001 - Ar, Fe; Zhang & Sampson 2002 - O, Fe), Li^+ (Ballance et al. 2003a), Li-like (Whiteford et al. 2002 - Ar, Fe; Starobinets et al. 2003 - Be, B), Be-isonuclear (Ballance et al. 2003b - Be^{+3+}), C^{2+} (Mitnik et al. 2003), C^{3+} (Aggarwal & Keenan 2004a), O^{2+} (Niimura, Smith & Chutjian 2002), O^{3+} (Smith et al. 2003), O^{6+} (Delahaye & Pradhan 2002), O^{7+} (Berrington & Ballance 2002), Ne^{2+} (McLaughlin, Daw & Bell 2002), Ne^{8+} (Bautista 2003), Ne-like (Brown, Beiersdorfer & Widmann 2001 - Fe, Co, Ni, Kr), Mg^+ (Kim 2002), Mg-like (Kai, Srivastava & Nakazaki 2004 - S, Ar, Ca), Al^{2+} (Dunn et al. 2002, Bannister et al. 2002, Smith et al. 2003),

Si⁶⁺ (Bhatia & Landi 2003), Si²⁺ (Janzen et al. 2003, Smith et al. 2003), P²⁺ (Gupta & Msezane 2002), Ar⁶⁺ (Smith et al. 2003), Ar⁷⁺ (Smith et al. 2003), Ca⁶⁺ (Landi & Bhatia 2003), Ca⁷⁺ (Landi, Storey & Zeippen 2004), Ca¹⁴⁺ (Aggarwal & Keenan 2002, Aggarwal & Keenan 2003b), Ti²⁺ (Popovic et al. 2002), Fe⁺ (Burke et al. 2002, Ramsbottom et al. 2002, Ramsbottom et al. 2004), Fe²⁺ (McLaughlin et al. 2002), Fe⁴⁺ (Woeste et al. 2002), Fe⁸⁺ (Storey, Zeippen & Le Dourneuf 2002), Fe¹⁰⁺ (Aggarwal & Keenan 2003a), Fe¹²⁺ (Aggarwal & Keenan 2004b, Aggarwal & Keenan 2005), Fe¹⁴⁺ (Aggarwal, Keenan & Msezane 2003), Fe¹⁶⁺ (Chen, Pradhan & Eissner 2003), Fe²¹⁺ (Gu 2004), Fe²³⁺ (Pindzola 2002, Bautista et al. 2003), Fe²⁵⁺ (Ballance, Badnell & Berrington 2002), Fe-isonuclear (Bautista et al. 2004 - Fe¹⁶⁻²²⁺), Ni⁺ (Bautista 2004), Ni⁴⁺ (Burke et al. 2002), Ni²⁴⁺ (Chidichimo, Badnell & Tully 2003), Zn⁺ (Kim 2002), and Xe²⁶⁺ (Badnell et al. 2004).

Ionization and detachment have been studied for: H⁻ (Ghosh, Nath & Sinha 2003), H-like ions (Watanabe et al. 2003 - Fe, Mo; Alfaz Uddin et al. 2003 - He, Li, B, C, N, O, Ne, Fe; Bartlett & Stelbovics 2004 - Li, Be), He⁺ (Lepp, Stancil & Dalgarno 2002), He-like ions (Kuo & Huang 2001 - Li, B, C, N, Fe; Uddin et al. 2004b - Li, B, C, N, O, Ne, Fe), Li⁺ (Lepp, Stancil & Dalgarno 2002), Li²⁺ (Lepp, Stancil & Dalgarno 2002, Colgan, Pindzola & Robicieux 2002), Li-like ions (Uddin et al. 2004a - C, N, O, Ne), Be ions (Colgan et al. 2003b - Be⁺³⁺), Be-like ions (Chang et al. 2004 - B, C, N, O, Ne, Al, Ar, Fe), C⁺ (Jha 2002), N⁺ (Jha 2002), O⁺ (Jha 2002), O⁴⁺ (Uddin et al. 2004a), O ions (Loch et al. 2003 - O⁺⁴⁺), Ne⁺ (Jha 2002), Ne⁶⁺ (Uddin et al. 2004a), Mg⁺ (Becker et al. 2004), Al ions (Aichele et al. 2001 - Al³⁻⁷⁺), Ar ions (Zhang et al. 2002 - Ar⁴⁻¹¹⁺), Ti³⁺ (van Zoest et al. 2004), Ti¹¹⁺ (Qi et al. 2002a), Cr¹³⁺ (Qi et al. 2002b), and Kr ions (Khoulid et al. 2001 - Kr¹²⁻¹⁸⁺; Loch et al. 2002 - Kr⁺³⁵⁺; Beigman, Defrance & Vainshtein 2003a - Kr¹⁰⁻¹⁸⁺; Beigman, Defrance & Vainshtein 2003b - Kr^{10-12,17,18+}).

Another important process is recombination for which a number of new works have appeared: He ions (Lepp, Stancil & Dalgarno 2002 - He⁺²⁺), He-like ions (Zhang & Sampson 2002 - O, Fe; O'Rourke et al. 2003 - Ti, Fe; Behar et al. 2004 - Ar, Fe), Li ions (Lepp, Stancil & Dalgarno 2002 - Li⁺³⁺; Colgan, Pindzola & Badnell 2004 - Be, B, C, N, O, Ne, Mg, Al, Si, P, S, Ar, Ti, Cr, Fe, Ni, Kr, Xe and others), Be⁺ (Mohamed et al. 2002, Schuch 2003), Be-like ions (Colgan et al. 2003a - B, C, O, N, Ne, Mg, Al, Si, P, S, Ar, Ca, Ti, Cr, Fe, Ni, Kr, Xe and others; Schnell et al. 2003 - F, Fe), B-like ions (Altun et al. 2004 - C, N, O, Ne, Mg, Al, Si, P, S, Ar, Ca, Ti, Cr, Fe, Ni, Kr, Xe and others), C³⁺ (Bureyeva et al. 2002b), C-like (Zatsarinny et al. 2004a - N, O, Ne, Mg, Al, Si, P, S, Ar, Ca, Ti, Cr, Fe, Co, Ni, Kr, Xe and others), N²⁺ (Kisielius & Storey 2002), N-like ions (Mitnik & Badnell 2004 - O, Ne, Mg, Al, Si, P, S, Ar, Ca, Ti, Cr, Fe, Ni, Kr, Xe and others), O⁵⁺ (Boehm et al. 2003, Murakami, Safronova & Kato 2002), O ions (Badnell et al. 2003 - O⁴⁻⁵⁺), O-like ions (Chen 2002 - Mg, S, Si, Fe; Zatsarinny et al. 2003 - Ne, Mg, Al, Si, P, S, Ar, Ca, Ti, Cr, Fe, Co, Ni, Kr, Xe and others), Ne-like ions (Zatsarinny et al. 2004b - Mg, Al, Si, P, S, Ar, Ca, Ti, Cr, Fe, Co, Ni, Kr, Xe and others), Na⁸⁺ (Nikolic et al. 2004), Mg⁺ (Bureyeva et al. 2002b), Mg⁸⁺ (Schippers et al. 2004), Mg ions (Gu 2003a - Mg⁴⁻¹²⁺; Gu 2003b - Mg²⁻¹¹⁺), Si¹⁴⁺ (Heerlein, Zwicknagel & Toepffer 2002), Si ions (Gu 2003a - Si⁶⁻¹⁴⁺; Gu 2003b - Si⁴⁻¹³⁺), S ions (Gu 2003a - S⁸⁻¹⁶⁺; Gu 2003b - S⁶⁻¹⁵⁺), Ar ions (Gu 2003a - Ar¹⁰⁻¹⁸⁺; Gu 2003b - Ar⁸⁻¹⁷⁺), Ca ions (Gu 2003a - Ca¹²⁻²⁰⁺; Gu 2003b - Ca¹⁰⁻¹⁹⁺), Ti²⁰⁺ (O'Rourke et al. 2004), Fe¹⁷⁺ (Gorczyca, Badnell & Savin 2002, Zhang, Nahar & Pradhan 2001), Fe¹⁸⁺ (Savin et al. 2002), Fe²³⁺ (Pindzola 2002), Fe ions (Gu 2003a - Fe¹⁸⁻²⁶⁺; Gu 2003b - Fe¹⁶⁻²⁵⁺; Gu 2003c - Fe¹⁶⁻²³⁺; Dasgupta & Whitney 2004 - Fe²⁴⁻²⁵⁺), Ni¹⁷⁺ (Fogle et al. 2003a, Fogle et al. 2003b), Ni ions (Gu 2003a - Ni²⁰⁻²⁸⁺; Gu 2003b - Ni¹⁸⁻²⁷⁺; Dasgupta &

Whitney 2004 - Ni^{26-27+}), Zn^{27+} (Bureyeva et al. 2002a, Bureyeva et al. 2002b), Kr^{34+} (Madzunkov et al. 2002), and Xe^{27+} (Yan, Li & Yao 2003).

3.4. Electron-Molecule Scattering

For molecules, new elastic scattering references have appeared as follows: H_2 (Lee & Mazon 2002), H_2O (Cho et al. 2004a, Faure, Gorfinkiel & Tennyson 2004), LiH (Antony et al. 2004), CH (Baluja & Msezane 2001), CH_4 (Ariyasinghe & Powers 2002, Ariyasinghe, Wijeratne & Palihawadana 2004), C_2H_2 (Ariyasinghe & Powers 2002), C_2H_4 (Ariyasinghe & Powers 2002, Panajotovic et al. 2003, Szmytkowski, Kwitnewski & Ptasinska-Denga 2003, Brescansin et al. 2004, Trevisan, Orel & Rescigno 2003), C_2H_6 (Ariyasinghe & Powers 2002, Maia & Bettega 2003), C_3H_4 (Nakano et al. 2002, Lopes & Bettega 2003), C_3H_6 (Curik & Gianturco 2002), C_4H_6 (Szmytkowski & Kwitnewski 2003, Lopes et al. 2004), C_6H_6 (Makochekanwa, Sueoka & Kimura 2003, Kimura, Makochekanwa & Sueoka 2004, Makochekanwa, Sueoka & Kimura 2004), CO (Blanco & Garcia 2003), CO_2 (Gianturco & Stoecklin 2001, Allan, M. 2002, Blanco & Garcia 2003), CS_2 (Allan, M. 2003), NO (Zhang et al. 2004), N_2 (Blanco & Garcia 2003), N_2O (Lee et al. 2002a, Akther et al. 2002, Allan & Skalicky 2003), O_2 (Garcia, Blanco & Williard 2001, Linert, Zubek & Zubek 2004), O_3 (de Pablos et al. 2002), OH (Sobrinho, Lozano & Lee 2004), OCS (Bettega, Lima & Ferreira 2004), SiH (Lee et al. 2002b), SiH_4 (Ariyasinghe, Wijerathna & Powers 2003), Si_2H_6 (Maia & Bettega 2003), PH_2 (Bettega & Lima 2004), PH_3 (Ariyasinghe, Wijerathna & Powers 2003, Szmytkowski et al. 2004), and SH (Baluja & Msezane 2002).

Regarding excitation, new references include: H_2 (Lee & Mazon 2002, Pigarov 2002, Celiberto, Capitelli & Laricchiuta 2002, Machado et al. 2001, Trevisan & Tennyson 2001, Wrkich et al. 2002, Curik & Carsky 2003, Harries, Hammond & Murray 2003, Liu et al. 2003, Horacek et al. 2004, da Costa, da Paixao & Lima 2004, Laricchiuta, Celiberto & Janev 2004), H_2O (Allan & Moreira 2002, Curik & Carsky 2003, Itikawa 2004, Faure, Gorfinkiel & Tennyson 2004), LiH (Antony et al. 2004), CH (Baluja & Msezane 2001), CH_4 (Nishimura & Gianturco 2002, Itikawa 2004, Joshipura et al. 2004), C_2H_4 (Panajotovic et al. 2003, Szmytkowski, Kwitnewski & Ptasinska-Denga 2003), C_2H_6 (Merz & Linder 2003a, Itikawa 2004), C_3H_4 (Nakano et al. 2002), C_4H_6 (Szmytkowski & Kwitnewski 2003), C_6H_6 (Makochekanwa, Sueoka & Kimura 2003), $\text{CH}_3\text{CH}_2\text{CH}_3$ (Merz & Linder 2003b), hydrocarbons (Janev & Reiter 2003 - CH , CH_2 , CH_3 , CH_4 , C_2H , C_2H_2 , C_2H_3 , C_2H_4 , C_2H_5 , C_2H_6 , C_3H , C_3H_2 , C_3H_3 , C_3H_4 , C_3H_5 , C_3H_6 , C_3H_7 , C_3H_8), CS_2 (Allan 2003, Michelin et al. 2003, Kroin et al. 2003), CO (Poparic, Vicic & Belic 2001, Kroin, Michelin & Lee 2001, Michelin et al. 2003), CO_2 (Rescigno et al. 2002, Green et al. 2002a, Rocha & Bielschowsky 2002, Allan 2002, McCurdy et al. 2003, Michelin et al. 2003, Kroin et al. 2003, Itikawa 2004, Vanroose et al. 2004), N_2 (Poparic, Vicic & Belic 2002, Feng, Sun & Morrison 2003), NO (Schappe, Edgell & Urban 2002), N_2O (Akther et al. 2002, Allan & Skalicky 2003), O_2 (Johnson & Kanik 2001, Green et al. 2002b, Terrell, Hansen & Ajello 2004), O_3 (de Pablos et al. 2002), OCS (Michelin et al. 2003, Kroin et al. 2003), SiH_4 (Ariyasinghe, Wijerathna & Powers 2003, Joshipura et al. 2004), PH_3 (Ariyasinghe, Wijerathna & Powers 2003), and SH (Baluja & Msezane 2002).

New work for dissociative processes consist of the following: H_2 (Harb, Kedzierski & McConkey. 2000, Trevisan & Tennyson 2001, Krasheninnikov 2002, Pigarov 2002, Celiberto, Capitelli & Laricchiuta 2002, Fabrikant, Wadehra & Xu 2002, Horacek et al. 2004, Laricchiuta, Celiberto & Janev 2004), H_2O (Haxton et al. 2004), CH_4 (Luna et al. 2003), C_2H_4 (Szmytkowski, Kwitnewski & Ptasinska-Denga 2003), C_4H_6 (Szmytkowski & Kwitnewski 2003), C_6H_6 (Makochekanwa, Sueoka & Kimura 2003), CH_3OH (Skalicky & Allan 2004), hydrocarbons (Janev & Reiter 2003 - CH , CH_2 , CH_3 , CH_4 , C_2H , C_2H_2 ,

C_2H_3 , C_2H_4 , C_2H_5 , C_2H_6 , C_3H , C_3H_2 , C_3H_3 , C_3H_4 , C_3H_5 , C_3H_6 , C_3H_7 , C_3H_8), CS_2 (Kedzierski 2002), NO (Allan 2004), N_2O (Allan & Skalicky 2003), and O_3 (de Pablos et al. 2002).

Research on molecular ionization have been performed on: H_2 (Hanel et al. 2002, Pigarov 2002, Celiberto, Capitelli & Laricchiuta 2002, Houamer et al. 2003, Mansouri et al. 2004, Liu & Shemansky 2004), H_2O (Champion, Hanssen & Hervieux 2002a, Hanel et al. 2002, Champion, Hanssen & Hervieux 2002b, Vinodkumar et al. 2003 - crystalline ice; Champion, Hanssen & Hervieux 2004), H_2S (Lindsay, Rejoub & Stebbings 2003), B_2H_6 (Basner, Schmidt & Becker 2003), CH_4 (Stano et al. 2003, Luna et al. 2003, Joshipura et al. 2004, Champion, Hanssen & Hervieux 2004), C_2H_4 (Szmytkowski, Kwitnewski & Ptasinska-Denga 2003), C_6H_6 (Hanel et al. 2002, Makochekanwa, Sueoka & Kimura 2003), $CH_3COCOCH_3$ (Takahashi et al. 2003), hydrocarbons (Janev & Reiter 2003 - CH , CH_2 , CH_3 , CH_4 , C_2H , C_2H_2 , C_2H_3 , C_2H_4 , C_2H_5 , C_2H_6 , C_3H , C_3H_2 , C_3H_3 , C_3H_4 , C_3H_5 , C_3H_6 , C_3H_7 , C_3H_8), CO (Hudson, Vallance & Harland 2004), CO_2 (Hudson, Vallance & Harland 2004), CS_2 (Lindsay, Rejoub & Stebbings 2003, Hudson, Vallance & Harland 2004), NH_3 (Champion, Hanssen & Hervieux 2004), N_2O (Lindsay, Rejoub & Stebbings 2003), NO_2 (Jiao, DeJoseph & Garscadden 2002), O_2 (Johnson & Kanik 2001, Joshipura, Antony & Vinodkumar 2002), O_3 (Joshipura, Antony & Vinodkumar 2002), O_4 (Joshipura, Antony & Vinodkumar 2002), OCS (Hudson, Vallance & Harland 2004), $OHCCO$ (Takahashi et al. 2003), SiH_3 (Ariyasinghe, Wijerathna & Powers 2003), SiH_4 (Joshipura et al. 2004), and PH_3 (Ariyasinghe, Wijerathna & Powers 2003).

Andersen, Herber & Zajfman (2004) have studied negative ion formation from C_2 .

3.5. *Electron-Molecular-Ion Scattering*

New elastic scattering results exist for H_3^+ and H_3O^+ (Faure & Tennyson 2002a).

For excitation, studies have been conducted for: H_2^+ (Pigarov 2002), H_3^+ (Faure & Tennyson 2002a, Faure & Tennyson 2002b, Gorfinkiel & Tennyson 2004), H_3O^+ (Faure & Tennyson 2002a, Faure & Tennyson 2002b), and hydrocarbon ions (Janev & Reiter 2003 - CH^+ , CH_2^+ , CH_3^+ , CH_4^+ , C_2H^+ , $C_2H_2^+$, $C_2H_3^+$, $C_2H_4^+$, $C_2H_5^+$, $C_2H_6^+$, C_3H^+ , $C_3H_2^+$, $C_3H_3^+$, $C_3H_4^+$, $C_3H_5^+$, $C_3H_6^+$, $C_3H_7^+$, $C_3H_8^+$).

References on dissociative processes have appeared for: H_2^+ (Neau et al. 2002, Krasheninnikov 2002, Pigarov 2002, Takagi 2002, Strasser et al. 2002b, Florescu et al. 2003, Al-Khalili et al. 2003, Abdellahi El Ghazaly et al. 2004), H_3^+ (Krasheninnikov 2002, Glosik et al. 2001, Strasser et al. 2002a, McCall et al. 2004, Royal, Larson & Orel 2004, Gorfinkiel & Tennyson 2004, Kalhori et al. 2004), HeH^+ (Royal, Larson & Orel 2004, Takagi 2004), H_2O^+ (Thomas et al. 2002), CH^+ (Bannister et al. 2003), CH_4^+ (Janev 2002), $C_2H_2^+$ (Derkatch, Minaev & Larsson 2003), $C_2H_4^+$ (Janev 2002), ${}_2H_6^+$ (Janev 2002), $C_3H_8^+$ (Janev 2002), CO_2^+ (Bahati et al. 2001a, Seiersen et al. 2003), N_2^+ (Bahati, E. M. et al. 2001b), and SO_2^+ (Geppert et al. 2004).

New reports of results for ionization include: H_2^+ (Serov et al. 2002), H_3^+ (Gorfinkiel & Tennyson 2004), hydrocarbon ions (Janev & Reiter 2003 - CH^+ , CH_2^+ , CH_3^+ , CH_4^+ , C_2H^+ , $C_2H_2^+$, $C_2H_3^+$, $C_2H_4^+$, $C_2H_5^+$, $C_2H_6^+$, C_3H^+ , $C_3H_2^+$, $C_3H_3^+$, $C_3H_4^+$, $C_3H_5^+$, $C_3H_6^+$, $C_3H_7^+$, $C_3H_8^+$), CO_2^+ (Bahati et al. 2001a, Deutsch et al. 2002), and N_2^+ (Deutsch et al. 2002, Bahati et al. 2001b).

Finally, recombination of electrons with molecular ions have been studied for: H_2^+ (Neau et al. 2002, Krasheninnikov 2002, Pigarov 2002, Takagi 2002, Florescu et al. 2003, Ngassam et al. 2003, Al-Khalili et al. 2003), H_3^+ (Glosik et al. 2001, Strasser et al. 2002a, Strasser et al. 2002b, Kokoouline & Greene 2003a, 2003b, McCall et al. 2004, Royal, Larson & Orel 2004), H_2O^+ (Thomas et al. 2002), HeH^+ (Royal, Larson & Orel 2004, Takagi 2004), hydrocarbon molecular ions (Janev 2002 - CH_4^+ , $C_2H_4^+$, $C_2H_6^+$, $C_3H_8^+$;

Derkatch, Minaev & Larsson 2003 - $C_2H_2^+$, CO_2^+ (Seiersen et al. 2003), NH_4^+ (Ojekull et al. 2004), N_2H^+ (Geppert et al. 2004a), and SO_2^+ (Geppert et al. 2004b).

3.6. Ion-Atom and Atom-Atom Collisions

Charge transfer plays an important role in a variety of environments and therefore has seen a substantial amount of activity over the report period. Studies for collisions on H include: H^+ (Cabrera-Trujillo et al. 2002a, Celiberto et al. 2002, Killian et al. 2004, Krstić et al. 2004), He^{2+} (Le et al. 2004), Li^{+-3+} (Purkait 2003), Li^{3+} and Ne^{10+} (Errea et al. 2004b), B^{2+} (Turner et al. 2003), C^{4+} (Liu et al. 2003), $C^{4,5+}$, $N^{5,6+}$, and $O^{6,7+}$ (Kearns et al. 2003), N^+ (Lin et al. 2005), N^{2+} (Barragan et al. 2004), N^{4+} (Cabrera-Trujillo et al. 2002c), N^{5+} (Kearns et al. 2002), O^+ (Spirko et al. 2003), O^{2+} (Cabello et al. 2003), O^{3+} (Wang et al. 2003), O^{8+} and Ar^{8+} (Edgu-Fry et al. 2004, Lee et al. 2004), Ne^{2+} (Mroczkowski et al. 2003), Ne^{3+} (Rejoub et al. 2004), and Ne^{4+} (Havener et al. 2004). Collisions of neutral species with protons include: He^* (Chibisov et al. 2002), N (Lin et al. 2005), Na (Watanabe et al. 2002, Le et al. 2003), S (Zhao et al. 2005a), Ar (Kirschner et al. 2004), and K (Watanabe et al. 2002, Hayakawa et al. 2004).

Neutral helium is also an important target for which studies have considered the incident ions: H^+ (Minami et al. 2004), $Be^{3,4+}$ (Shimakura et al. 2003), C^{2+} (Gao & Kwong 2003), C^{2-6+} , N^{2-6+} , O^{2-6+} (Ishii et al. 2004), O^+ (Lindsay & Stebbings 2003, Zhao et al. 2005b), O^{5+} (Sobocinski et al. 2003), O^{6+} and Ne^{8+} (Bordenave-Montesquieu et al. 2003), O^{7+} (Shevelko et al. 2004), Ne^{2+} (Imai et al. 2003), Ne^{4+} (Kamber et al. 2003), Ne^{10+} (Rigazio et al. 2002, Ali et al. 2005), S^{2+} (Zhao et al. 2005c), S^{4+} (Wang et al. 2002), Ar^{9+} (Bliman et al. 2002), and Fe^{5-13+} (Čadež et al. 2003). The reverse process through radiative charge transfer has been considered for $O + He^+$ (Zhao et al. 2004). Some relevant symmetric charge transfer studies were done for $N^+ + N$ and $O^+ + O$ (Eletskii et al. 2004) On-line databases of charge transfer data include the National Institute for Fusion Science (NIFS) Charge Transfer Database Chart (2005) and the ORNL/UGA Charge Transfer Database for Astrophysics (2005) sites.

Elastic scattering and spin exchange have been studied for $H^+ + H$ by Krstić et al. (2004) and Glassgold et al. (2005) while Zygelman et al. (2003) reported new spin-exchange calculations for $H + H$. Chung & Dalgarno (2002) studied diffusion of H in He and He in H.

Molecules can be formed by collisions of atoms through radiative association. Bennett et al. (2003) studied the role of quasi-bound states in the formation of LiH. Atom collisions can also result in changes in internal energy and recent work includes: Li with H (Belyaev & Barklem 2003), He^* with He (Vrinceanu & Sadeghpour 2002), and C and S with He (Le Picard et al. 2002).

3.7. Ion-, Atom-, and Molecule-Molecule Collisions

In photoionized environments, multiply charged ions may coexist with neutral molecules. Examples include x-ray ionized regions and solar wind interactions with cometary gas. In these environments charge transfer plays an important role. Recent studies of ion-molecule charge transfer include H^+ (Cabrera-Trujillo et al. 2002b, Savin et al. 2004), H^+ and D^+ (Kuskabe et al. 2004), He^{2+} (Errea et al. 2003), C^{2+} (Gao & Kwong 2003), C^{4+} (Konnai et al. 2003), C^{4-5+} , N^{5-6+} , and O^{6-7+} (Kearns et al. 2003), N^{5+} (Kerns et al. 2002, Errea et al. 2004a), O^+ (Pichl et al. 2003), O^{3+} (Wang et al. 2004), O^{6+} (Bordenave-Montesquieu et al. 2003), O^{8+} and Ar^{8+} (Edgu-Fry et al. 2004), S^{2+} (Chen et al. 2003), and Fe^{3+} (Gao et al. 2003) with H_2 ; C^{2+} (Gao & Kwong 2003), C^{3-4+} (Gao & Kwong 2002), and S^{2+} (Chen et al. 2003) with CO; H^+ (Cabrera-Trujillo et al. 2002d),

C^{2+} (Gao & Kwong 2003), S^{2+} (Chen et al. 2003), and Fe^{3+} (Gae et al. 2003) with N_2 ; He^{2+} with H_2O and CO_2 (Abu-Haija et al. 2003); and H^+ with CH_2 (Suno et al. 2004).

For applications to x-ray emission from comets a number of investigations have considered a range of highly charged ions on various molecular targets including $Ne^{+,3,5,7,9+}$ with H_2O (Pesic et al. 2004); Ne^{10+} with H_2 , H_2O , and CO_2 (Rigazio et al. 2002); and Ne^{10+} with CO and CO_2 (Ali et al. 2005). Also, see Krasnopolsky et al. (2004) for a review of cometary x-ray relevant collision data.

In some environments, advances in modeling require vibrationally-resolved charge transfer and dissociation data. Such data are generally not available, but some studies have been performed for $H^+ + H_2$ and $H + H_2^+$ (Krstić & Janev 2003), $O^{3+} + H_2$ (Wang et al. 2004), and $O^{3+} + HD$ (Stancil et al. 2004).

In low ionization environments, excited rovibrational states of molecules are formed through collisional excitation by atom and molecule impact. Investigations have been performed for excitation of H_2 by H (Mielke et al. 2003), by He (Lee et al. 2005), by H_2 (Ceballos et al. 2002, Lin & Guo 2002), and by Li^+ (Roeggen et al. 2002); CO by H (Yang et al. 2005a), by He (Krems, et al. 2002, Carty et al. 2004, Smith et al. 2004, Yang et al. 2005b), and by H^+ (Kumar & Kumar 2004); N_2 by He (Stoecklin et al. 2002); F_2 by He (Stoecklin et al. 2003); SiO by H (Palov et al. 2002); CaH by He (Krems et al. 2003); H_2O by H_2 (Dubernet & Grosjean 2002, Grosjean et al. 2003, Weisenfeld et al. 2003); N_2 by N_2 (Ramos et al. 2002); N_2 by CO (Cacciatore et al. 2004); CO by CO (Billings et al. 2003); and CH_3OH by He (Flower and Davis 2004). A useful online database of rovibrational collisional excitation data, BASECOL, can be found at: <http://amdpo.obspm.fr/basecol/>.

Elastic scattering data for vibrationally-excited molecules have been presented by Krstić & Schultz (2003) for $H^+ + H_2$ and $H + H_2^+$ collisions. An online database can be found at: <http://cfadc.phy.ornl.gov/elastic/homeph2.html>.

3.8. Reactive Scattering and Chemistry

Due to space limitations, we cannot review the many advances in reactive scattering and chemical processes relevant to astrophysics. However, some noteworthy and relevant studies include OH formation in $O + H_2$ collisions (Baunstein et al. 2004, Balakrishnan 2004, Sultanov & Balakrishnan 2004), CO_2 formation in $OH + CO$ collisions (Valero & Kroes 2004), OH formation in $H + H_2O$ collisions (Zhang et al. 2002), and H_2 formation in $LiH + H$ collisions (Kim et al. 2003).

Acknowledgements

DRS acknowledges support from the DOE Office of Fusion Energy Sciences to Oak Ridge National Laboratory which is managed by UT-Battelle, LLC under contract No. DE-AC0500OR22725. The work of PCS was partially supported by NASA grant NAG5-11453. We thank Ms. Fay Ownby for assistance with preparing this manuscript.

D.R. Schultz and P.C. Stancil
Chairpersons of the Working Group

References

- Abdellahi El Ghazaly, M. O. et al. 2004 *J. Phys. B* 37, 2467
- Abu-Haija, O. et al. 2003, *Nucl. Inst. Meth. B*, 205, 634
- Aggarwal, K. M. & Keenan, F. P. 2002 *Phys. Scr.* 65, 383
- Aggarwal, K. M. & Keenan, F. P. 2003a *Astron. Astrophys.* 399, 799
- Aggarwal, K. M. & Keenan, F. P. 2003b *Astron. Astrophys.* 407, 769

- Aggarwal, K. M., Keenan, F. P. & Msezane, A. Z. 2003 *Astron. Astrophys.* 410, 349
Aggarwal, K. M. & Keenan, F. P. 2004a *Phys. Scr.* 69, 385
Aggarwal, K. M. & Keenan, F. P. 2004b *Astron. Astrophys.* 418, 371
Aggarwal, K. M. & Keenan, F. P. 2005 *Astron. Astrophys.* 429, 1117
Aichele, K. et al. 2001 *J. Phys. B* 34, 4113
Akther, P. et al. 2002 *J. Phys. B* 35, L481
Al-Khalili, A. et al. 2003 *Phys. Rev. A* 68, 042702
Al-Mulla, S.Y.Y. & Joensson, L. 2002 *Phys. Scr.* 65, 387
Al-Khalili, A. et al. 2003 *Phys. Rev. A* 68, 042702
Alfaz Uddin, M. & Basak, A. K. 2003a *Phys. Scr.* 67, 37
Alfaz Uddin, M. & Basak, A. K. 2003b *Phys. Scr.* 67, 112
Alfaz Uddin, M. et al. 2003 *Phys. Scr.* 68, 192
Ali, R. et al. 2005, *Astrophys. J.*, 629, L125
Allan, M. & Moreira, O. 2002 *J. Phys. B* 35, L37
Allan, M. 2002 *J. Phys. B* 35, L387
Allan, M. 2003 *J. Phys. B* 36, 2489
Allan, M. & Skalicky, T. 2003 *J. Phys. B* 36, 3397
Allan, M. 2004 *J. Phys. B* 37, L359
Altun, Z. et al. 2004 *Astron. Astrophys.* 420, 775
Andersen, L. H., Herber, O. & Zajfman, D. 2004 *J. Phys. B* 37, R57
Antony, B. K. et al. 2004 *J. Phys. B* 37, 1689
Ariyasinghe, W. M. & Powers, D. 2002 *Phys. Rev. A* 66, 052716
Ariyasinghe, W. M., Wijerathna, T. & Powers, D. 2003 *Phys. Rev. A* 68, 032708
Ariyasinghe, W. M. et al. 2004 *Nucl. Inst. Meth. B* 217, 389
Ariyasinghe, W. M. & Goains, C. 2004 *Phys. Rev. A* 70, 052709
Badnell, N. R. et al. 2003 *Astron. Astrophys.* 406, 1151
Badnell, N. R. et al. 2004 *J. Phys. B* 37, 4589
Baek, W. Y. & Grosswendt, B. 2003 *J. Phys. B* 36, 731
Bahati, E. M. et al. 2001a *J. Phys. B* 34, 1757
Bahati, E. M. et al. 2001b *J. Phys. B* 34, 2963
Balakrishnan, N. 2004, *J. Chem. Phys.*, 121, 6346
Ballance, C. P., Badnell, N. R. & Berrington, K. A. 2002 *J. Phys. B* 35, 1095
Ballance, C. P. et al. 2003a *J. Phys. B* 36, 235
Ballance, C. P. et al. 2003b *Phys. Rev. A* 68, 062705
Ballance, C. P. & Griffin, D. C. 2004 *J. Phys. B* 37, 2943
Baluja, K. L. & Msezane, A. Z. 2001 *J. Phys. B* 34, 3057
Baluja, K. L. & Msezane, A. Z. 2002 *J. Phys. B* 35, 437
Bannister, M. E. et al. 2002 *Phys. Rev. A* 66, 032707
Bannister, M. E. et al. 2003 *Phys. Rev. A* 68, 042714
Barragan, P. 2004, *Phys. Rev. A*, 70, 022707
Bartlett, P. L. & Stelbovics, A. T. 2002 *Phys. Rev. A* 66, 012707
Bartlett, P. L., Stelbovics, A. T. & Bray, I. 2003 *Phys. Rev. A* 68, 030701(R)
Bartlett, P. L. & Stelbovics, A. T. 2004 *Phys. Rev. A* 69, 040701
Bartschat, K. & Sadeghpour, H. R. 2003 *J. Phys. B* 36, L9
Bartschat, K. & Andersen, N. 2003 *J. Phys. B* 36, 163
Bartschat, K. et al. 2004 *J. Phys. B* 37, 2617
Bartschat, K., Dasgupta, A. & Madison, D. H. 2004 *Phys. Rev. A* 69, 062706
Basner, R., Schmidt, M. & Becker, K. 2003 *J. Chem. Phys.* 118, 2153
Baunstein, M. et al. 2004, *J. Chem. Phys.*, 120, 4316
Bautista, M. A. 2003 *J. Phys. B* 36, 1503

- Bautista, M. A. et al. 2003 *Astron. Astrophys.* 403, 339
Bautista, M. A. et al. 2004 *Astron. Astrophys.* 418, 1171
Bautista, M. A. 2004 *Astron. Astrophys.* 420, 763
Becker, C. et al. 2004 *J. Phys. B* 37, 1503
Behar, E. et al. 2004 *Phys. Rev. A* 69, 022704
Beigman, I., Defrance, P. & Vainshtein, L. 2003a *J. Phys. B* 36, 2019
Beigman, I., Defrance, P. & Vainshtein, L. 2003b *Nucl. Inst. Meth. B* 205, 427
Belyeav, A. K. & Barklem, P. S. 2003, *Phys. Rev. A*, 68, 062703
Bennett, O. J. et al. 2003, *Mon. Not. Roy. Astron. Soc.*, 341, 361
Berrington, K. A. & Ballance, C. P. 2002 *J. Phys. B* 35, 2275
Bettega, M.H.F. & Lima, M.A.P. 2004 *J. Phys. B* 37, 3859
Bettega, M.H.F., Lima, M.A.P. & Ferreira, L. G. 2004 *Phys. Rev. A* 70, 062711
Bhatia, A. K. 2002 *Phys. Rev. A* 66, 064702
Bhatia, A. K. & Landi, E. 2003 *Astrophys. J.*, Pt. 1 585, 587
Biava, D. A. et al. 2002 *J. Phys. B* 35, 293
Billings, G. D. 2003, *J. Phys. B.*, 36, 1175
Blanco, F. & Garcia, G. 2003 *Phys. Rev. A* 67, 022701
Bliman, S. et al. 2002, *Phys. Rev. A*, 66, 052707
Boechat-Roberty, H. M. et al. 2002 *J. Phys. B* 35, 1409
Boehm, S. et al. 2003 *Astron. Astrophys.* 405, 1157
Boffard, J. B. et al. 2001 *Phys. Rev. A* 64, 032708
Bordenave-Montesquieu, D. et al. 2003, *J. Phys. B*, 36, 65
Bray, I., Fursa, D. V. & Stelbovics, A. T. 2003 *J. Phys. B* 36, 2211
Brescansin, L. M. et al. 2004 *J. Phys. B* 37, 471
Brown, G. V., Beiersdorfer, P. & Widmann, K. 2001 *Phys. Rev. A* 63, 032719
Bureyeva, L. A. et al. 2002a *J. Phys. B* 35, 2505
Bureyeva, L. A. et al. 2002b *Phys. Rev. A* 65, 032702
Burke, P. G. et al. 2002 *Phys. Scr.* T100, 55
Cabello, C. M. et al. 2003, *J. Phys. B*, 36, 307
Cabrera-Trujillo, R. et al. 2002a, *J. Chem. Phys.*, 116, 2783
Cabrera-Trujillo, R. et al. 2002b, *Phys. Rev. A*, 65, 024901
Cabrera-Trujillo, R. et al. 2002c, *Phys. Rev. A*, 66, 022706
Cabrera-Trujillo, R. et al. 2002d, *Phys. Rev. A*, 66, 042712
Cacciatore, M. et al. 2004, *J. Phys. B*, 37, 3379
Čadež, I. et al. 2003, *J. Phys. B*, 36, 3303
Carty, D. et al. 2004, *J. Chem. Phys.*, 121, 4671
Ceballos, A. et al. 2002, *J. Phys. Chem. Ref. Data*, 31, 371
Celiberto, R., Capitelli, M. & Laricchiuta, A. 2002 *Phys. Scr.* T96, 32
CFADC 2002, www-cfadc.phy.ornl.gov
Champion, C., Hanssen, J. & Hervieux, P. A. 2002a *J. Chem. Phys.* 117, 197
Champion, C., Hanssen, J. & Hervieux, P. A. 2002b *Phys. Rev. A* 65, 022710
Champion, C., Hanssen, J. & Hervieux, P.-A. 2004 *J. Chem. Phys.* 121, 9423
Chang, J.-C. et al. 2004 *Phys. Rev. A* 69, 052713
Chen, D. et al. 2003, *Phys. Rev. A*, 68, 052703
Chen, G.-X., Pradhan, A. K. & Eissner, W. 2003 *J. Phys. B* 36, 453
Chen, M. H. 2002 *Phys. Rev. A* 66, 052715
Chen, Z. et al. 2004 *J. Phys. B* 37, 981
Chibisov, M. I. et al. 2002, *J. Phys. B*, 35, 5081
Chidichimo, M. C., Badnell, N. R. & Tully, J. A. 2003 *Astron. Astrophys.* 401, 1177
Childers, J. G. et al. 2003 *Phys. Rev. A* 68, 030702(R)

- Childers, J. G. et al. 2004 Phys. Rev. A 69, 022709
Cho, H. et al. 2004a J. Phys. B 37, 625
Cho, H. et al. 2004b J. Phys. B 37, 4639
Chung, H.-K. & Dalgarno, A. 2002, Phys. Rev. A, 66, 012712
CIAMDA 98, 1998, Computer Index to Atomic and Molecular Collision Data (Vienna: International Atomic Energy Agency)
Colgan, J., Pindzola, M. S. & Robicheaux, F. 2002 Phys. Rev. A 66, 012718
Colgan, J. et al. 2003a Astron. Astrophys. 412, 597
Colgan, J. et al. 2003b Phys. Rev. A 68, 032712
Colgan, J., Pindzola, M. S. & Badnell, N. R. 2004 Astron. Astrophys. 417, 1183
Cooper, J. W. & van Boeyen, R. W. 2004 J. Phys. B 37, L77
Curik, R. & Gianturco, F. A. 2002 J. Phys. B 35, 717
Curik, R. & Carsky, P. 2003 J. Phys. B 36, 2165
da Costa, R. F., da Paixao, F. J. & Lima, M.A.P. 2004 J. Phys. B 37, L129
Dasgupta, A. & Whitney, K. G. 2004 Phys. Rev. A 69, 022702
Date, H., Ishimaru, Y. & Shimozuma, M. 2003 Nucl. Inst. Meth. B 207, 373
de Pablos, J. L. et al. 2002 J. Phys. B 35, 865
Deb, N. C. & Crothers, D.S.F. 2002 Phys. Rev. A 65, 052721
Defrance, P. et al. 2003 Nucl. Inst. Meth. B 205, 405
Delahaye, F. & Pradhan, A. K. 2002 J. Phys. B 35, 3377
Demesie, A. M. et al. 2003 J. Phys. B 36, 665
Denifl, S. et al. 2002 J. Phys. B 35, 4685
Derkatch, A. M., Minaev, B. & Larsson, M. 2003 Phys. Scr. 67, 407
Deutsch, H. et al. 2002 J. Phys. B 35, L65
Dogan, M. & Crowe, A. 2002 J. Phys. B 35, 2773
Dubernet, M.-L. & Grosjean, A. 2002, Astron. Astrophys., 390, 793
Dunn, G. H. et al. 2002 Phys. Rev. A 66, 032706
Edgu-Fry, E. et al. 2004, Phys. Rev. A, 69, 052714
Eletskii, A. V. et al. 2004, Phys. Rev. A, 69, 042718
Errea, L. F. et al. 2003, J. Phys. B, 36, L135
Errea, L. F. et al. 2004a, Phys. Rev. A, 69, 012705
Errea, L. F. et al. 2004b, Phys. Rev. A, 70, 052713
Erwin, D. A. & Kunc, J. A. 2003 J. Phys. B 36, 4605
Fabrikant, I. I., Wadehra, J. M. & Xu, Y. 2002 Phys. Scr. T96, 45
Faure, A. & Tennyson, J. 2002a J. Phys. B 35, 1865
Faure, A. & Tennyson, J. 2002b J. Phys. B 35, 3945
Faure, A., Gorfinkiel, J. D. & Tennyson, J. 2004 J. Phys. B 37, 801
Feng, H., Sun, W. & Morrison, M. A. 2003 Phys. Rev. A 68, 062709
Florescu, A. I. et al. 2003 J. Phys. B 36, 1205
Flower, D. R. & Davis, S. L. 2004, J. Phys. B, 37, 165
Fogle, M. et al. 2003a Astron. Astrophys. 409, 781
Fogle, M. et al. 2003b J. Phys. B 36, 2563
Fritioff, K. et al. 2003 Euro. Phys. J: D 27, 23
Fritioff, K. et al. 2004 Phys. Rev. A 69, 042707
Fursa, D. V. & Bray, I. 2001 Phys. Rev. A 63, 032708
Fursa, D. V. & Bray, I. 2003 J. Phys. B 36, 1663
Gao, K. et al. 2003, Phys. Rev. A, 67, 022702
Gao, H. & Kwong, V. H. S. 2003, Phys. Rev. A, 68, 052704
Gao, H. & Kwong, V. H. S. 2004, Phys. Rev. A, 69, 052715
Garcia, G., Blanco, F. & Williard, A. 2001 Chem. Phys. Lett. 335, 227

- Garcia, G. et al. 2002 *J. Phys. B* 35, 4657
Geppert, W. D. et al. 2004a *Astrophys. J.*, Pt. 1 609, 459
Geppert, W. D. et al. 2004b *Astrophys. J.*, Pt. 1 610, 1228
Ghosh, D. & Sinha, C. 2003 *J. Phys. B* 36, 675
Ghosh, D., Nath, B. & Sinha, C. 2003 *J. Phys. B* 36, 1479
Gianturco, F. A. & Stoecklin, T. 2001 *J. Phys. B* 34, 1695
Glassgold, A. E. et al. 2005, *Astrophys. J.*, 621, 808
Glosik, J. et al. 2001 *J. Phys. B* 34, L485
Gorczyca, T. W., Badnell, N. R. & Savin, D. W. 2002 *Phys. Rev. A* 65, 062707
Gorfinkiel, J. D. & Tennyson, J. 2004 *J. Phys. B* 37, L343
Green, M. A. et al. 2002a *J. Phys. B* 35, 567
Green, M. A. et al. 2002b *J. Phys. B* 35, 3793
Griffin, D. C. et al. 2001 *Phys. Rev. A* 64, 032718
Grosjean, A. et al. 2003, *Astron. Astrophys.*, 408, 1197
Grujic, P. V. 2003 *Phys. Scr.* 68, C90
Gstir, B. et al. 2002 *J. Phys. B* 35, 2993
Gstir, B. et al. 2003 *Nucl. Inst. Meth. B* 205, 413
Gu, M. F. 2003a *Astrophys. J.*, Pt. 1 589, 1085
Gu, M. F. 2003b *Astrophys. J.*, Pt. 1 590, 1131
Gu, M. F. 2003c *Astrophys. J.*, Pt. 1 593, 1249
Gu, M. F. 2004 *Phys. Rev. A* 70, 062704
Gupta, G. P. & Msezane, A. Z. 2002 *Phys. Scr.* 66, 354
Hanel, G. et al. 2002 *J. Chem. Phys.* 116, 2456
Harb, T., Kedzierski, W. & McConkey, J. W. 2000 *J. Chem. Phys.* 115, 5507
Harries, J. R., Hammond, P. & Murray, A. J. 2003 *J. Phys. B* 36, 2579
Havener, C. C. et al. 2004, *Phys. Rev. A*, 71, 034702
Haxton, D. J. et al. 2004 *Phys. Rev. A* 69, 062714
Hayakawa, S. et al. 2004, *Phys. Rev. A*, 70, 022708
Heerlein, C., Zwicknagel, G. & Toepffer, C. 2002 *Phys. Rev. Lett.* 89, 083202
Horacek, J. et al. 2004 *Phys. Rev. A* 70, 052712
Houamer, S. et al. 2003 *J. Phys. B* 36, 3009
Huang, M.-T. et al. 2002 *Phys. Rev. A* 66, 012715
Hudson, J. E., Vallance, C. & Harland, P. W. 2004 *J. Phys. B* 37, 445
Imai, T. W. et al. 2003, *Phys. Rev. A*, 68, 012716
Isaacs, W. A. et al. 2001 *Phys. Rev. A* 63, 030704
Ishii, K. et al. 2004, *Phys. Rev. A*, 70, 042716
Itikawa, Y. 2004 *J. Phys. B* 37, R1
Jablonski, A., Salvat, F. & Powell, C. J. 2004 *J. Phys. Chem. Ref. Data* 33, 409
James, G. K. et al. 2002 *Phys. Rev. A* 66, 042710
James, K. E., Childers, J. G. & Khakoo, M. A. 2004 *Phys. Rev. A* 69, 022710
Janev, R. K. 2002 *Phys. Scr.* T96, 94
Janev, R. K. & Reiter, D. 2003 *J. Nucl. Mater.* 313-316, 1202
Janzen, P. H. et al. 2003 *Phys. Rev. A* 67, 052702
Jha, L. K. 2002 *Phys. Scr.* 66, 228
Jha, L. K. & Roy, B. N. 2002 *Euro. Phys. J: D* 20, 5
Jiao, C. Q., DeJoseph, C. A. & Garscadden, A. 2002 *J. Chem. Phys.* 117, 161
Johnson, P. V. & Kanik, I. 2001 *J. Phys. B* 34, 3041
Johnson, P. V. et al. 2003a *J. Phys. B* 36, 3203
Johnson, P. V. et al. 2003b *J. Phys. B* 36, 4289
Joshiyura, K. N., Antony, B. K. & Vinodkumar, M. 2002 *J. Phys. B* 35, 4211

- Joshiyura, K. N. et al. 2004 Phys. Rev. A 69, 022705
Kai, T. et al. 2004 J. Phys. Soc. Japan 73, 885
Kai, T., Srivastava, R. & Nakazaki, S. 2004 Phys. Rev. A 70, 062705
Kalhori, S. et al. 2004 Phys. Rev. A 69, 022713
Kamber, E. Y. et al. 2003, Nucl. Inst. Meth. B, 205, 577
Kampp, M. et al. 2002 J. Phys. B 35, 2325
Kanik, I., Johnson, P. V. & James, G. K. 2001 J. Phys. B 34, 1685
Kearns, D. M. et al. 2002, J. Phys. B. 35, 4335
Kearns, D. M. et al. 2003, J. Phys. B. 36, 3653
Kedzierski, W. 2002 J. Phys. B 35, 4401
Keller, S. 2003 J. Phys. B 36, 755
Khakoo, M. A. et al. 2002 Phys. Rev. A 65, 062711
Kheifets, A. S. 2004 Phys. Rev. A 69, 032712
Kheifets, A. S. & Bray, I. 2004 Phys. Rev. A 69, 050701
Khouilid, M. et al. 2001 J. Phys. B 34, 1727
Killian, B. J. et al. 2004, J. Phys. B, 37, 4733
Kim, K. H. et al. 2003 J. Chem. Phys., 119, 4689
Kim, Y.-K. 2001 Phys. Rev. A 64, 032713
Kim, Y.-K. & Desclaux, J.-P. 2002 Phys. Rev. A 66, 0127080
Kim, Y.-K. 2002 Phys. Rev. A 65, 022705
Kimura, M., Makochekanwa, C. & Sueoka, O. 2004 J. Phys. B 37, 1461
Kirschner, T. et al. 2004, Phys. Rev. A, 69, 012708
Kisielius, R. & Storey, P. J. 2002 Astron. Astrophys. 387, 1135
Kobayashi, A. et al. 2002 J. Phys. B 35, 2087
Kokoouline, V. & Greene, C. H. 2003a Phys. Rev. A 68, 012703
Kokoouline, V. & Greene, C. H. 2003b Phys. Rev. Lett. 90, 133201
Konnai, A. et al. 2003, Nucl. Inst. Meth. B, 205, 586
Krasheninnikov, S. I. 2002 Phys. Scr. T96, 7
Krasnopolsky, V. et al. 2004, Space Sci. Reviews, 113, 271
Krems, R. V. et al. 2002, J. Chem. Phys., 116, 4517
Krems, R. V. et al. 2003, Phys. Rev. A, 67, 060703
Kroin, T., Michelin, S. E. & Lee, M.-T. 2001 J. Phys. B 34, 1829
Kroin, T. et al. 2003 Phys. Rev. A 68, 012701
Krstić, P. S. 2002, Phys. Rev. A, 66, 042717
Krstić, P. S. & Schultz, D. R. 2003, J. Phys. B, 36, 385
Krstić, P. S. & Janev, R. K. 2003, Phys. Rev. A, 67, 022708
Krstić, P. S. 2004, J. Phys. B, 37, L217
Krstić, P. S. et al. 2004, Phys. Rev. A, 70, 042711
Kumar, T. J. D. & Kumar, S. 2004, J. Chem. Phys., 121, 191
Kuo, T.-Y. & Huang, K.-N. 2001 Phys. Rev. A 64, 032710
Kusakabe, T. et al. 2004, Phys. Rev. A, 70, 052710
Landi, E. & Bhatia, A. K. 2003 Astrophys. J., Pt. 1 589, 1075
Landi, E., Storey, P. J. & Zeippen, C. J. 2004 Astrophys. J., Pt. 1 607, 640
Laricchiuta, A., Celiberto, R. & Janev, R. K. 2004 Phys. Rev. A 69, 022706
Le, A.-T. et al. 2003, Phys. Rev. A, 68, 012705
Le, A.-T. et al. 2004, Phys. Rev. A, 69, 062703
Le Padellec, A. et al. 2002 J. Phys. B 35, 3669
Le Picard, S. D. et al. 2002, J. Chem. Phys., 117, 10109
Lee, M.-T. et al. 2002a Phys. Rev. A 65, 062702
Lee, M.-T. et al. 2002b Phys. Rev. A 66, 062703

- Lee, M.-T. & Mazon, K. T. 2002 *Phys. Rev. A* 65, 042720
Lee, T.-G. et al. 2004, *Phys. Rev. A*, 70, 012702
Lee, T.-G. et al. 2005, *J. Chem. Phys.*, 122, 024307
Lepp, S., Stancil, P. C. & Dalgarno, A. 2002 *J. Phys. B* 35, R57
Li, W.-B. et al. 2003 *Phys. Rev. A* 67, 062708
Lin, C.-Y. et al. 2005, *Phys. Rev. A*, 71, 062708
Lin, S. Y. & Guo, H. 2002, *J. Chem. Phys.*, 117, 5183
Lindsay, B. G., Rejoub, R. & Stebbings, R. F. 2003 *J. Chem. Phys.* 118, 5894
Lindsay, B. G. & Stebbings, R. F. 2003, *Phys. Rev. A*, 67, 022715
Linert, I., Zubek, M. & Zubek, M. 2004 *J. Phys. B* 37, 4681
Liu, C.-N. et al. 2003, *Phys. Rev. A*, 68, 062702
Liu, X. et al. 2003 *J. Phys. B* 36, 173
Liu, X. & Shemansky, D. E. 2004 *Astrophys. J.*, Pt. 1 614, 1132
Llovet, X., Merlet, C. & Salvat, F. 2002 *J. Phys. B* 35, 973
Loch, S. D. et al. 2002 *Phys. Rev. A* 66, 052708
Loch, S. D. et al. 2003 *Phys. Rev. A* 67, 042714
Lopes, A. R. & Bettega, M.H.F. 2003 *Phys. Rev. A* 67, 032711
Lopes, A. R. et al. 2004 *Phys. Rev. A* 69, 014702
Luna, H. et al. 2003 *J. Phys. B* 36, 4717
Machado, A. M. et al. 2001 *Phys. Rev. A* 63, 032707
Madison, D. H. et al. 2004 *J. Phys. B* 37, 1073
Madzunkov, S. et al. 2002 *Phys. Rev. A* 65, 032505
Maia, C.A.S. & Bettega, M.H.F. 2003 *Phys. Rev. A* 67, 042710
Makochekanwa, C., Sueoka, O. & Kimura, M. 2003 *Phys. Rev. A* 68, 032707
Makochekanwa, C., Sueoka, O. & Kimura, M. 2004 *J. Phys. B* 37, 1841
Mandy, M. E. et al. 2004, *J. Chem. Phys.*, 120, 5585
Mansouri, A. et al. 2004 *J. Phys. B* 37, 1203
Maté, B. et al. 2005, *J. Chem. Phys.*, 122, 064313
McCall, B. J. et al. 2004 *Phys. Rev. A* 70, 052716
McCurdy, C. W. et al. 2003 *Phys. Rev. A* 67, 042708
McEachran, R. P. & Stauffer, A. D. 2003 *J. Phys. B* 36, 3977
McLaughlin, B. M., Daw, A. & Bell, K. L. 2002 *J. Phys. B* 35, 283
McLaughlin, B. M. et al. 2002 *J. Phys. B* 35, 2755
Meneses, G. D. et al. 2002 *J. Phys. B* 35, 3119
Merabet, H. et al. 2003a *J. Phys. B* 36, 3383
Merabet, H. et al. 2003b *Nucl. Inst. Meth. B* 205, 399
Merz, R. & Linder, F. 2003a *J. Phys. B* 36, 1143
Merz, R. & Linder, F. 2003b *J. Phys. B* 36, 2921
Michelin, S. E. et al. 2003 *J. Phys. B* 36, 1525
Mielke, S. L. 2003, *Phys. Rev. Lett.*, 91, 063201
Milosavljevic, A. R., Sevic, D. & Marinkovic, B. P. 2004 *J. Phys. B* 37, 4861
Minami, T. et al. 2004, *J. Phys. B*, 37, 4025
Mitnik, D. M. et al. 2003 *J. Phys. B* 36, 717
Mitnik, D. M. & Badnell, N. R. 2004 *Astron. Astrophys.* 425, 1153
Mityureva, A. A., Smirnov, V. V. & Ponomarenko, G. A. 2002 *Opt. Spectrosc.* 92, 325
Mohamed, T. et al. 2002 *Phys. Rev. A* 66, 022719
Mroczkowski, T. et al. 2003, *Phys. Rev. A*, 68, 032721
Muktavat, K., Srivastava, R. & Stauffer, A. D. 2002 *J. Phys. B* 35, 4797
Murakami, I., Safronova, U. I. & Kato, T. 2002 *Can. J. Phys.* 80, 1525
Nakano, Y. et al. 2002 *Phys. Rev. A* 66, 032714

National Institute for Fusion Science (NIFS) Charge Transfer Database Chart (2005);

amdata.nifs.ac.jp

- Neau, A. et al. 2002 Phys. Rev. A 65, 044701
Ngassam, V. et al. 2003 Phys. Rev. A 68, 032704
Niimura, M., Smith, S. J. & Chutjian, A. 2002 Astrophys. J., Pt. 1 565, 645
Nikolic, D. et al. 2004 Phys. Rev. A 70, 062723
Nishimura, T. & Gianturco, F. A. 2002 J. Phys. B 35, 2873
O'Rourke, B. E. et al. 2003 Nucl. Inst. Meth. B 205, 378
O'Rourke, B. E. et al. 2004 J. Phys. B 37, 2343
Ojekull, J. et al. 2004 J. Chem. Phys. 120, 7391
ORNL/UGA Charge Transfer Database for Astrophysics (2005); cfadc.phy.ornl.gov/astro/ps/data/
Palov, A. P. et al. 2002, J. Chem. Phys., 116, 1388
Panajotovic, R. et al. 2003 J. Phys. B 36, 1615
Papp, Z. & Hu, C.-Y. 2002 Phys. Rev. A 66, 052714
Pestic, Z. D. et al. 2004, J. Phys. B, 37, 1405
Pichl, L. et al. 2003, J. Chem. Phys., 118, 4872
Pigarov, A. Yu. 2002 Phys. Scr. T96, 16
Pindzola, M. S. 2002 Phys. Rev. A 65, 014701
Pindzola, M. S. et al. 2004 Phys. Rev. A 70, 032705
Plummer, M., Noble, C. J. & Le Dourneuf, M. 2004 J. Phys. B 37, 2979
Poparic, G., Vicic, M. & Belic, D. S. 2001 J. Phys. B 34, 381
Poparic, G. B., Vicic, M. D. & Belic, D. S. 2002 Phys. Rev. A 66, 022711
Popovic, D. B. et al. 2002 Phys. Rev. A 65, 034704
Purkait, M. et al. 2003, Nucl. Inst. Meth. B, 207, 101
Qi, J. B. et al. 2002a J. Phys. B 35, 829
Qi, J. B. et al. 2002b Phys. Rev. A 65, 032720
Ramos, A. et al. 2002, Phys. Rev. A, 66, 022702
Ramsbottom, C. A. et al. 2002 J. Phys. B 35, 3451
Ramsbottom, C. A. et al. 2004 J. Phys. B 37, 3609
Rejoub, R., Lindsay, B. G. & Stebbings, R. F. 2002 Phys. Rev. A 65, 042713
Rejoub, R. et al. 2004, Phys. Rev. A, 69, 052704
Rescigno, T. N. et al. 2002 Phys. Rev. A 65, 032716
Rigazio, M. et al. 2002, Phys. Rev. A, 66, 064701
Rocha, A. B. & Bielschowsky, C. E. 2002 Phys. Rev. A 66, 052720
Roegen, I. et al. 2002, J. Phys. B, 35, 1707
Royal, J., Larson, A. & Orel, A. E. 2004 J. Phys. B 37, 3075
Salvat, F. 2003 Phys. Rev. A 68, 012708
Santos, J. P., Parente, F. & Kim, Y.-K. 2003 J. Phys. B 36, 4211
Savin, D. W. et al. 2002 Astrophys. J., Pt. 1 576, 1098
Savin, D. W. et al. 2004, Astrophys. J., 606, L157; 607, L147
Schappe, R. S., Edgell, R. J. & Urban, E. 2002 Phys. Rev. A 65, 042701
Schippers, S. et al. 2004 Astron. Astrophys. 421, 1185
Schnell, M. et al. 2003 Nucl. Inst. Meth. B 205, 367
Schuch, R. 2003 Phys. Scr. T104, 181
Schultz, D. R., & Stancil, P. C. 2002 Reports on Astronomy XXVA, 1001-2002
Seiersen, K. et al. 2003 Phys. Rev. A 68, 022708
Serov, V. V. et al. 2002 Phys. Rev. A 65, 062708
Shevelko, V. P. et al. 2004, J. Phys. B, 37, 201
Shimakura, N. et al. 2003, Nucl. Inst. Meth. B, 205, 596
Sienkiewicz, J. E. et al. 2002 Phys. Lett. A, 293, 183

- Skalicky, T. & Allan, M. 2004 *J. Phys. B* 37, 4849
Smith, A.C.H. et al. 2003 *Nucl. Inst. Meth. B* 205, 421
Smith, S. J. et al. 2003 *Phys. Rev. A* 68, 062708
Smith, T. C. et al. 2004, *J. Chem. Phys.*, 120, 2285
Sobocinski, P. et al. 2003, *J. Phys. B*, 36, 1283
Sobrinho, A.M.C., Lozano, N.B.H. & Lee, M.-T. 2004 *Phys. Rev. A* 70, 032717
Sorokin, A. A. et al. 2004 *J. Phys. B* 37, 3215
Spinko, J. A. et al. 2003, *J. Phys. B*, 36, 1645
Srivastava, R., McEachran, R. P. & Stauffer, A. D. 2002 *Can. J. Phys.* 80, 687
Stancil, P. C. et al. 2004, *Faraday Discuss.*, 127, 73
Stano, M. et al. 2003 *J. Phys. B* 36, 261
Starobinets, A. et al. 2003 *Phys. Scr.* 67, 500
Stewart, M. D. et al. 2002 *Phys. Rev. A* 65, 032704
Stoecklin, T. et al. 2002, *Phys. Rev. A*, 66, 042703
Stoecklin, T. et al. 2003, *Phys. Rev. A*, 68, 032716
Storey, P. J., Zeippen, C. J. & Le Dourneuf, M. 2002 *Astron. Astrophys.* 394, 753
Strasser, D. et al. 2002a *Phys. Rev. A* 65, 010702
Strasser, D. et al. 2002b *Phys. Rev. A* 66, 032719
Sultanov, R. A. & Balakrishnan, N. 2004, *J. Chem. Phys.*, 121, 11038
Suno, H. et al. 2004, *Phys. Rev. A*, 70, 032703
Sweeney, C. J., Grafe, A. & Shyn, T. W. 2001 *Phys. Rev. A* 64, 032704
Sweeney, C. J., Grafe, A. & Shyn, T. W. 2004 *Phys. Rev. A* 69, 052709
Szluniska, M., Van Reeth, P. & Laricchia, G. 2002 *J. Phys. B* 35, 4059
Szymtkowski, C. & Kwitnewski, S. 2003 *J. Phys. B* 36, 2129
Szymtkowski, C., Kwitnewski, S. & Ptasinska-Denga, E. 2003 *Phys. Rev. A* 68, 032715
Szymtkowski, C. et al. 2004 *J. Phys. B* 37, 1833
Takagi, H. 2002 *Phys. Scr.* T96, 52
Takagi, H. 2004 *Phys. Rev. A* 70, 022709
Takahashi, M. et al. 2003 *J. Phys. B* 36, 2539
Tayal, S. S. 2002 *Phys. Rev. A* 66, 030701
Terrell, C. A., Hansen, D. L. & Ajello, J. M. 2004 *J. Phys. B* 37, 1931
Thomas, R. et al. 2002 *Phys. Rev. A* 66, 032715
Trevisan, C. S. & Tennyson, J. 2001 *J. Phys. B* 34, 2935
Trevisan, C. S., Orel, A. E. & Rescigno, T. N. 2003 *Phys. Rev. A* 68, 062707
Tsurubuchi, S., Kobayashi, H. & Hyodo, M. 2003 *J. Phys. B* 36, 2629
Turner, A. R. et al. 2003, *Phys. Rev. A*, 68, 012704
Uddin, M. A. et al. 2004a *J. Phys. B* 37, 1909
Uddin, M. A. et al. 2004b *Phys. Rev. A* 70, 032706
Valero, R. & Kroes, G.-J. 2004, *Phys. Rev. A*, 70, 0407011
van Zoest, T. et al. 2004 *J. Phys. B* 37, 4387
Vanroose, W. et al. 2004 *Phys. Rev. Lett.* 92, 053201
Vinodkumar, M. et al. 2003 *Nucl. Inst. Meth. B* 212, 63
Vrinceanu, D. & Sadeghpour, H. R. 2002, *Phys. Rev. A*, 65, 062712
Wang, J. G. et al. 2002, *J. Phys. B*, 35, 3137
Wang, J. G. et al. 2003, *Phys. Rev. A*, 67, 012710
Wang, J. G. et al. 2004, *Phys. Rev. A*, 69, 062702
Watanabe, A. et al. 2002, *Phys. Rev. A*, 66, 044701
Watanabe, H. et al. 2003 *Nucl. Inst. Meth. B* 205, 417
Weber, T., Boffard, J. B. & Lin, C. C. 2003 *Phys. Rev. A* 68, 032719
Whiteford, A. D. et al. 2001 *J. Phys. B* 34, 3179

- Whiteford, A. D. et al. 2002 J. Phys. B 35, 3729
Wiesenfeld, L. et al. 2003, J. Phys. B, 36, 1319
Witthoef, M. C., Pindzola, M. S. & Colgan, J. 2003 Phys. Rev. A 67, 032713
Witthoef, M. et al. 2003 Phys. Rev. A 68, 022711
Witthoef, M. C., Loch, S. D. & Pindzola, M. S. 2004 Phys. Rev. A 70, 022711
Woeste, G. et al. 2002 J. Phys. B 35, 4847
Wrkich, J. et al. 2002 J. Phys. B 35, 4695
Yan, J., Li, Y.-M. & Yao, J.-H. 2003 Nucl. Inst. Meth. B 205, 382
Yang, B.H. et al. 2005a, J. Chem. Phys, 123, 094308
Yang, B.H. et al. 2005b, J. Chem. Phys, 123, 134326
Yu, D. H. et al. 2003 Phys. Rev. A 67, 032707
Yuan, Z.-S. et al. 2002 Phys. Rev. A 66, 062701
Zatsarinny, O. & Tayal, S. S. 2002a J. Phys. B 35, 241
Zatsarinny, O. & Tayal, S. S. 2002b J. Phys. B 35, 2493
Zatsarinny, O. & Fischer, C. F. 2002 J. Phys. B 35, 4669
Zatsarinny, O. et al. 2003 Astron. Astrophys. 412, 587
Zatsarinny, O. et al. 2004a Astron. Astrophys. 417, 1173
Zatsarinny, O. et al. 2004b Astron. Astrophys. 426, 699
Zatsarinny, O. & Bartschat, K. 2004a J. Phys. B 37, 2173
Zatsarinny, O. & Bartschat, K. 2004b J. Phys. B 37, 4693
Zhang, D. H. et al. 2002, Phys. Rev. Lett., 89, 283293
Zhang, H. L., Nahar, S. N. & Pradhan, A. K. 2001 Phys. Rev. A 64, 032719
Zhang, H. L. et al. 2002 J. Phys. B 35, 3829
Zhang, H. L. & Sampson, D. H. 2002 Phys. Rev. A 66, 042704
Zhang, Z. et al. 2004 Phys. Rev. A 69, 062711
Zhao, L. B. et al. 2004, Astrophys. J., 615, 1063
Zhao, L. B. et al. 2005a, Phys. Rev. A, 71, R060701
Zhao, L. B. et al. 2005b, Phys. Rev. A, 71, 062713
Zhao, L. B. et al. 2005c, Phys. Rev. A, 72, 032719
Zygelman, B. et al. 2003, Phys. Rev. A, 67, 042715

4. WORKING GROUP ON LINE BROADENING *(GROUPE DE TRAVAIL POUR LES PROFILS DE RAIES)* **PRESIDENTS: N.F. ALLARD AND G. PEACH**

Two conferences held in 2004 and 2005 have been devoted to the subject of Spectral Line Shapes. The 17th International Conference on Spectral Line Shapes (ICSLS) was held at the Université Pierre et Marie Curie in Paris (France) in 2004; the proceedings have been published by the Editions Frontier group and include a special section on astrophysical applications. The 5th Serbian Conference on Spectral Line Shapes in Astrophysics (SCSLSA) was held in Vršac in 2005 and the proceedings have been published in *Memorie della Supplementi degli Società Astronomica Italiana* (Mem. S.A.It.).

In the following report, we select experimental and theoretical work that may be of interest for astrophysics.

4.1. Stark broadening

The Critical Review of Selected Data on Experimental Stark Widths and Shifts for Spectral Lines of Neutral and Ionized Atoms for the period 1989-2000, see Konjević et al

(2002), contains tables where measured values are listed and compared with semi-classical calculations. The Bibliography of Line Shapes and Shifts contains more recent data, see section 3 on Databases. There are also several papers on Stark broadening and plasma-induced line shifts among the articles published as a tribute to Charles Hooper under the collective title Radiative Properties of Hot Dense Matter (Lee 2003). An overview of the role of the plasma microfield in the Stark broadening of spectral lines has been presented by Demura (2004) and Demura and Gilles (2004). These articles contain many useful references.

A short review of the French-Serbian collaboration on theoretical calculations of Stark broadening of spectral line shapes for non-hydrogenic atoms within the framework of the semi-classical approach has been presented by Dimitrijević and Sahal-Bréchet (2004).

Developments in line broadening theory

Alexiou and Poquérusse (2005) and Poquérusse and Alexiou (2005) have extended standard semi-classical impact theory for hydrogen and hydrogenic ions to include penetrating collisions. Alexiou and Lee (2005) have tested this theory against full quantum mechanical calculations for hydrogen and have found that the difference between the two is much reduced. Bouguettaia et al (2005) have rederived results for Lyman- α using a path integral formalism that treats the electron and proton perturbers on the same basis.

Elabidi et al (2004b) have obtained a new quantum-mechanical formula for the electron impact width and shift of isolated lines using intermediate coupling and a quantum kinetic theory approach to the line broadening of isolated lines with stationary non-equilibrium level populations has been developed by Iglesias (2005).

Isolated lines

The term ‘isolated lines’ means lines between atomic levels that are sufficiently separated from the other atomic levels to enable the Stark effect to be treated within perturbation theory (second-order Stark effect). The line broadening and shift is dominated in this case by the interaction with the plasma electrons. Recent theoretical results have been obtained for lines of Ag I (Dimitrijević and Sahal-Bréchet 2003), Be III (Dimitrijević et al 2003), O II and C II (Mahmoudi et al 2004a, 2004b, 2005), Tl II (Milovanović 2005) and Cu III and Zn III (Simić et al 2005).

Stark broadening of lines of He I, Mg I and Ar I for a perturber density of 10^{16} cm^{-3} and for temperatures between 2,500 K and 50,000 K have been investigated by Zmerli et al (2005). Theoretical results have also been obtained for lines of Ne I (Milosavljević and Djeniže 2002b), (Milosavljević et al 2004), Ar I (Valognes et al 2004, 2005) and Kr I (Milosavljević et al 2003), (Milosavljević 2005). Calculations of line widths for Ar I (Ben Nessib and Sahal-Bréchet 2004) are compared with the experimental values of Milosavljević and Djeniže (2003a, 2003b, 2003c) and Nikolić et al (2004). Cadwell and Hüwel (2004) have determined Stark-broadening parameters for 12 Ar I lines from time-resolved emission spectra with an estimated accuracy of 20%.

Stark broadening parameters for Cd I have been calculated by (Simić 2005) for 11 singlets and 13 triplets in the ultraviolet and visible spectral region and 24 triplets in the infrared, for temperatures between 2,500 K and 50,000 K, and for a perturber density of 10^{16} cm^{-3} . Moreover line widths have been obtained within the modified semi-empirical approach for 10 F III multiplets, for temperatures 10,000 K – 300,000 K and for a perturber density of 10^{17} cm^{-3} . Dimitrijević et al (2005) have used the impact approximation to calculate line widths and shifts for the $4p^7 \text{ P}^0\text{-}4d^7 \text{ D}$ transitions in Cr I broadened by electrons, protons and ionized helium.

Most of these results have been obtained by using semi-classical theory which provides a powerful tool for the rapid calculation of line widths and shifts.

Quantum-mechanical Stark broadening calculations for lines of Ne VII and Ne VIII which are in intermediate coupling have been carried out by Elabidi et al (2004a, 2005). Hydrogen-like and helium-like ions of C, Si and Ar have been studied by Stambulchik and Maron (2005) using a numerical simulation of the plasma particle motion and find that ion dynamics is very important for these cases.

Hydrogen lines

The occupation probability method (OPM) is normally applied to the matching of discrete and continuous radiative spectra in dense hydrogenic plasmas (Vitel et al 2004). An alternative method that removes the matching problem has been developed by D'yachkov (2004) and the results obtained are in good agreement with experimental data.

The Stark broadening of the Radio Recombination Lines (RRLs) of Hydrogen observed from galactic H II regions is controlled by inelastic collisions with charged particles. Gavrilenko and Oks (2004) have presented a method of calculating both the cross sections of such collisions and the Stark broadening of RRLs based on the classical-trajectory Monte Carlo approach.

For lines of hydrogen in the visible and ultraviolet, measurements of widths and shifts for the Balmer α and β lines in a laser-induced plasma have been made by Parigger et al (2003, 2004). Stark widths and shifts of the H α line measured in a flash tube plasma have been compared with theoretical results by Griem and Halenka (2004) and Flih et al (2003, 2004). Also a theoretical study of the Lyman γ line profile of atomic hydrogen perturbed by collisions with protons is reported by Allard et al (2004).

Spectroscopic diagnostics of warm dense matter are presented by Astapenko et al (2004).

Neutral Helium lines

Stark broadening calculations for the spectral line of neutral helium at 6678Å formed in a non-ideal plasma have been performed by Ben Chaoucha et al (2004). Stark line profiles for He I lines emitted by dense plasmas have also been calculated by Gigosos et al (2004) and Ozmar et al (2004) and compared to the experimental results of Milosavljević and Djenize (2003d). Calculations have also been carried out for lines of He I by Milosavljević and Djenize (2002a), Li and You (2002) and Bardet et al (2003).

4.2. Broadening by neutral atoms and molecules

A collection of papers concerning the status of the molecular spectroscopic database, HITRAN 2000, has been published by Rothman et al (2003) and this has recently been updated for the current version HITRAN 2004 by Rothman et al (2005). These reviews contain papers specific to line broadening and shift phenomena in molecules.

An overview of state-of-the-art simulations of cool stellar atmospheres using the code PHOENIX was presented by Hauschildt and Baron (2005) and Homeier (2005) at the SCSLSA meeting. Molecules are the dominant opacity source and the resonance lines of Na and K have line wings that are particularly strong features of these spectra. The main difficulty is the lack of much realistic experimental or theoretical data for collision broadening by the dominant perturbers in these atmospheres, H₂ and He. The assumption of Van der Waals broadening gives at best only crude estimates for the line broadening parameters.

Developments in lineshape theory

Beaud and Knopp (2003) have developed a method of scaling rotationally inelastic collisions with an effective angular momentum parameter and applying it to collision-induced intra-molecular rotational energy transfer. Excellent agreement with experiment has been achieved for the CO–CO, N₂–N₂ and N₂–He systems. Wang (2004) has produced a refined version of the non-perturbative pressure-broadening theory of Neilson and Gordon and has obtained good agreement for CO lines in the fundamental band broadened by Ar.

Broadening of atomic lines

Some theoretical work has been published in the period 2002-2005 and the transitions with the perturbing atoms or molecules are listed below.

Li far-wing profile of the 2s-2p resonance line broadened by He (Zhu et al 2005).

Na far-wing line profiles for the 3s-3p resonance line broadened by He, Ar and Xe Chung et al (2002).

Na and K full line profiles including far line wings of the resonance lines broadened by H and H₂ (Allard et al 2003).

Na and K far-wing line profiles of the resonance lines broadened by H₂ and He (Burrows and Volobuyev 2003).

Na line broadening and mixing in the 3p-3d transition broadened by H (Sanchez-Fortún Stoker and Dickinson (2003).

Na line widths for the 3s-3p and 3d-4p transitions broadened by He (Peach et al 2005).

Broadening and shift of molecular lines

Much more experimental data has been published since the last report was prepared. The molecules are listed below with their perturbing atomic or molecular species.

D₂ collision-induced absorption in the fundamental band in D₂–N₂ and D₂–O₂ mixtures (Varghese et al 2004).

HCN lines in the 2ν₂ region broadened and shifted by HCN and air (Devi et al 2004).

HNO₃ millimeter-wave transitions broadened by N₂ and O₂ (Colmont et al 2003).

H₂O lines in the 26000–13000 cm⁻¹ region broadened by H₂O and N₂ (Coheur et al 2002).

H₂O 183 GHz line broadened and shifted by N₂, O₂ and air (Tretyakov 2003).

H₂O self-broadened pure rotational lines (Podobedov et al 2004).

H₂O lines in the ν₂ band broadened by air (Wagner et al 2005).

H₂O lines in the 1.39μm region broadened by N₂, O₂ and air (Durry et al 2005).

H₂S lines in the ν₂ band broadened and shifted by H₂, D₂, N₂, O₂ and CO₂ (Kissel et al 2002).

HCl $J = 1 - 0$ rotational transition broadened and shifted by N₂, O₂ and Ar (Morino and Yamada 2005).

CH₄ two lines of the 2ν₃ band broadened by N₂, O₂, He and Ar (Dufour et al 2003).

CO $J = 5 - 4$ transition at 576 GHz broadened and shifted by CO, N₂ and O₂ (Markov et al 2002) and by He, Ne, Ar, Kr and Xe (Yamada and Abe 2003).

CO $R(7)$ and $R(7)$ transitions in the fundamental band broadened by Ar (Mantz et al 2003).

CO second overtone band broadened and shifted by CO and air (Sung and Varanasi 2004).

CO₂ lines in the 1.6μm region broadened by N₂ and O₂ (Pouchet et al 2004).

CO₂ and OCO self-broadened lines near 2.04mm (Le Barbu et al 2005).

CF₄ lines in the ν₄ band broadened by He, N₂ and Ar (Domanskaya et al 2004).

CF₃CFH₂ rotational lines broadened by CF₃CFH₂, N₂ and O₂ (Cazzoli et al 2004).
NH₃ 134 rovibrational transitions in the ν_4 and $2\nu_2$ bands broadened by H₂ and N₂ (Nouri et al 2004).
N₂O millimeter lines broadened by N₂ and O₂ (Rohart et al 2003).
O₂ 60-GHz band and single line at 118.75 GHz broadened by N₂, O₂, He, Ne, Ar, H₂O, CO and CO₂ (Golubiatnikov et al 2003).
O₂ single line at 118.75 GHz broadened and shifted by O₂ and air (Tretyakov et al 2004).
O₂A-band broadened by He, Ne, Ar, Kr and Xe (Pope et al 2004).
O₂-O₂ collision-induced resonances at 477nm and 577nm (Sneep et al 2005).
O₃ submillimeter-wave lines broadened by N₂, O₂ and air (Yamada and Amano 2005).
O₃ millimeter-wave lines broadened by N₂, O₂ and air (Colmont et al 2005).
PH₃ ν_2 and ν_4 bands broadened by H₂, He and Ar (Bouanich et al 2004), (Salem et al 2004, 2005).

Theoretical results obtained during the period 2002-2005 are listed below.

H₂O effects of vibration on lines broadened and shifted by N₂ (Gamache and Hartmann 2004).
H₂O 11 vibrational bands in the range 3.2-17.76 μ m broadened by N₂, O₂ and air (Gamache 2005).
CH₃D lines in the ν_2 band broadened by He (Féjard et al 2003).
CO lines in the fundamental and first two overtone bands broadened and shifted by H₂ (Bouanich and Predoi-Cross 2005).

4.3. Databases

A 'virtual observatory' has been developed for astronomers to give immediate access to data archives, databases, reference surveys and information services anywhere in the world, see:

cdsarc.u-strasbg.fr,

and the latest version of the database High resolution Transmission, HITRAN 2004, can be found at:

<http://www.hitran.com>.

The current version of the database Gestion et Etude des Informations Spectroscopiques Atmosphériques (GEISA-03) is at:

<http://ara.lmd.polytechnique.fr>,

and the Spherical Top data System (STDS), for spherical top molecules is at:

<http://www.u-bourgogne.fr/LPUB/sTDS.html>.

The National Institute for Standards and Technology (NIST) maintains a database at:

<http://www.physics.nist.gov/PhysRefData>,

which contains the Bibliography on Atomic Line Shapes and Shifts up to 1999 and the database at the Observatoire de Paris,

<http://amrel.obspm.fr/balss>,

contains the Bibliography up to 2003. The Vienna Atomic Line Database (VALD) can be found at:

<http://www.astro.univie.ac.at/~vald>,

and the Belgrade database at:

<http://www.aob.bg.yu/BELDATA>.

N.F. Allard and G. Peach
Chairpersons of the Working Group

References

- Alexiou S. and Lee, R.W., 2005, *J. Quant. Spectrosc. Radiat. Transfer*, in press.
- Alexiou S. and Poquérusse, A., 2005, *Phys. Rev. E*, 72, 046404.
- Allard, N.F., Allard, F., Hauschildt, P.H., Kielkopf, J.F. and Machin, L., 2003, *A&A*, 411, L473.
- Allard N.F., Kielkopf J.F., Hébrard G., Peek J. 2004, *Eur. Phys. J. D*, 29, 7.
- Astapenko, V., Bureyeva, L., and Lisitsa, V., 2004, in *Spectral Line Shapes, Proceedings of the 17th ICSLS*, ed. E. Dalimier, Editions Frontier Group, Paris, p 129.
- Bardet, J.P., Valognes, J.C. and Vitel, Y., 2003, *J. Quant. Spectrosc. Radiat. Transfer*, 76, 45.
- Beaud, P. and Knopp, G., 2003, *Chem. Phys. Lett.*, 371, 194.
- Ben Chaouacha, H. and Ben Nessib, N. and Sahal-Bréchet, S., 2004, *A&A*, 419, 771.
- Ben Nessib, N. and Sahal-Bréchet, S., 2004, in *Spectral Line Shapes, Proceedings of the 17th ICSLS*, ed. E. Dalimier, Editions Frontier Group, Paris, p 385.
- Bouanich, J.-P. and Predoi-Cross, A., 2005, *J. Mol. Struct.* 742, 183.
- Bouanich, J.-P., Salem, J., Aroui, H., Walrand, J. and Blanquet, G., 2004, *J. Quant. Spectrosc. Radiat. Transfer*, 84, 195.
- Bouguettaia, H., Chihi, Is., Chenini, K., Meftah, M.T., Khelfaoui, F. and Stamm, R., 2005, *J. Quant. Spectrosc. Radiat. Transfer*, 94, 335.
- Burrows, A. and Volobuyev, M., 2003, *ApJ*, 583, 985.
- Cadwell, L. and Hüwel, L., 2004, *J. Quant. Spectrosc. Radiat. Transfer*, 83, 579.
- Cazzoli, G., Puzzarini, C. and Dore, L., 2004, *J. Quant. Spectrosc. Radiat. Transfer*, 83, 699.
- Chung, H.-K., Shurgalin, M. and Babb, J.F., 2002, in *Spectral Line Shapes*, vol 12, ed. C.A. Back, 211.
- Coheur, P.-F., Fally, S., Carleer, M., Clerbaux, C., Colin, R., Jenouvrier, A., Mérianne, M.-F., Hermans, C. and Vandaele, A.C., 2002, *J. Quant. Spectrosc. Radiat. Transfer*, 74, 493.
- Colmont, J.-M., Bakri, B., Rohart, F. and Włodarczak, G., 2003, *J. Mol. Spectrosc.*, 220, 52.
- Colmont, J.-M., Bakri, B., Rohart, F., Włodarczak, G., Demaison, J., Cazzoli, G., Dore, L. and Puzzarini, C., 2005, *J. Mol. Spectrosc.*, 231, 171.
- Demura, A.V., 2004, in *Encyclopedia of Low Temperature Plasmas*, volume II, Thermodynamics of Plasmas, ed. I. Iosilevski, and A. Starostin, Fizmatlit (in Russian).
- Demura, A.V. and Gilles, D., 2004, in *Spectral Line Shapes, Proceedings of the 17th ICSLS*, ed. E. Dalimier, Editions Frontier Group, Paris, p 121.
- Devi, V.M., Benner, D.C., Smith, M.A.H., Rinsland, C.P., Sharpe, S.W. and Sams, R.L., 2004, *J. Quant. Spectrosc. Radiat. Transfer*, 87, 339.
- Dimitrijević, M.S., Dačić, M., Cvetković, Z. and Sahal-Bréchet, S., 2003, *A&A*, 400, 791.
- Dimitrijević, M.S., and Sahal-Bréchet, S., 2003, *Atomic Data and Nuclear Data Tables*, 85, 269.

- Dimitrijević, M.S., and Sahal-Bréchet, S., 2004, in *Spectral Line Shapes*, Proceedings of the 17th ICSLS, ed. E. Dalimier, Editions Frontier Group, Paris, p 397.
- Dimitrijević, M.S., Ryabchikova, T., Popović, L.C., Shulyak, D. and Tsymbal, V., 2005, *A&A*, in press.
- Domanskaya, A.V., Tonkov, M.V. and Boissoles, J., 2004, *J. Quant. Spectrosc. Radiat. Transfer*, 86, 425.
- Dufour, G., Hurtmans, D., Henry, A., Valentin, A. and Lepère, M., 2003, *J. Mol. Spectrosc.*, 221, 80.
- Durry, G., Zeninari, V., Parvitte, B., Le Barbu, T., Lefevre, F., Ovarlez, J. and Gamache, R.R., 2005, *J. Quant. Spectrosc. Radiat. Transfer*, 94, 387.
- D'yachkov, L., 2004, in *Spectral Line Shapes*, Proceedings of the 17th ICSLS, ed. E. Dalimier, Editions Frontier Group, Paris, p 113.
- Elabidi, H., Ben Nessib, N., Cornille, M., Dubau, J., and Sahal-Bréchet, S., 2004a, in *Spectral Line Shapes*, Proceedings of the 17th ICSLS, ed. E. Dalimier, Editions Frontier Group, Paris, p 430.
- Elabidi, H., Ben Nessib, N. and Sahal-Bréchet, S., 2004b, *J. Phys. B: At. Mol. Opt. Phys.*, 37, 63.
- Elabidi, H., Ben Nessib, N. and Dimitrijević, M.S., 2005, *Proceedings of the 5th Serbian Conference on Spectral Line Shapes in Astrophysics*, Mem. S.A.It. 7, 213.
- Féjard, L., Gabard, T. and Champion, J.-P., 2003, *J. Mol. Spectrosc.*, 219, 88.
- Flih, S.A., Oks, E. and Vitel, Y., 2003, *J. Phys. B: At. Mol. Opt. Phys.*, 36, 283.
- Flih, S.A., Oks, E. and Vitel, Y., 2004, in *Spectral Line Shapes*, Proceedings of the 17th ICSLS, ed. E. Dalimier, Editions Frontier Group, Paris, p 445.
- Gamache, R.R., 2005, *J. Mol. Spectrosc.*, 229, 9.
- Gamache, R.R. and Hartmann, J.-M., 2004, *J. Quant. Spectrosc. Radiat. Transfer*, 83, 119.
- Gavrilenko, V.P. and Oks, E., 2004, in *Spectral Line Shapes*, Proceedings of the 17th ICSLS, ed. E. Dalimier, Editions Frontier Group, Paris, p 105.
- Gigosos, M.A., González, M.A., Talin, B. and Calisti, A., 2004, in *Spectral Line Shapes*, Proceedings of the 17th ICSLS, ed. E. Dalimier, Editions Frontier Group, Paris, p 451.
- Golubiatnikov, G.Yu., Koshelev, M.A. and Krupnov, A.F., 2003, *J. Mol. Spectrosc.*, 222, 191.
- Griem, H.R. and Halenka, J., 2004, in *Spectral Line Shapes*, Proceedings of the 17th ICSLS, ed. E. Dalimier, Editions Frontier Group, Paris, p 442.
- Hauschildt, P.H. and Baron, E., 2005, *Proceedings of the 5th Serbian Conference on Spectral Line Shapes in Astrophysics*, Mem. S.A.It. 7, 137.
- Homeier, D., 2005, *Proceedings of the 5th Serbian Conference on Spectral Line Shapes in Astrophysics*, Mem. S.A.It. 7, 157.
- Iglesias, C.A., 2005, *High Energy Density Physics*, in press.
- Kissel, A., Sumpf, B., Kronfeldt, H.-D., Tikhomirov, B.A. and Ponomarev, Yu.N., 2002, *J. Mol. Spectrosc.*, 216, 345.
- Konjević, N., Lesage, A., Fuhr, J.R. and Wiese, W.L., 2002, *J. Phys. Chem. Ref. Data*, 31, 819.
- Le Barbu, T., Zéninari, V., Parvitte, B., Courtois, D. and Durry, G., 2005, *J. Quant. Spectrosc. Radiat. Transfer*, in press.
- Lee, R.W. (ed.), 2003, *Radiative Properties of Dense Matter*, *J. Quant. Spectrosc. Radiat. Transfer*, 81, 1 (special issue).
- Li H. and You J., 2002, *Chinese Astron. & Astrophys.*, 26, 293.
- Mahmoudi, W., Ben Nessib, N. and Dimitrijević, M.S., 2004a, *A&A*, 434, 773.
- Mahmoudi, W., Ben Nessib, N., Dimitrijević, M.S. and Sahal-Bréchet, S., 2005, Pro-

ceedings of the 5th Serbian Conference on Spectral Line Shapes in Astrophysics, Mem. S.A.It. 7, 217.

Mahmoudi, W., Ben Nessib, N. and Sahal-Bréchet, S., 2004b, *Phys. Scripta*, 70, 142.

Mantz, A.W., Thibault, F., Cacheiro, J.L., Fernandez, B., Pedersen, T.B., Koch, H., Valentin, A., Claveau, C., Henry, A. and Hurtmans, D., 2003, *J. Mol. Spectrosc.*, 222, 131.

Markov, V.N., Golubiatnikov, G.Yu., Savin, V.A., Sergeev, D.A., Guarnieri, A. and Mäder, H., 2002, *J. Mol. Spectrosc.*, 212,1.

Milosavljević, V., 2005, Proceedings of the 5th Serbian Conference on Spectral Line Shapes in Astrophysics, Mem. S.A.It. 7, 191.

Milosavljević, V. and Djeniže, S., 2002a, *New Astronomy*, 7, 543.

Milosavljević, V. and Djeniže, S., 2002b, *Phys. Lett. A*, 305, 70.

Milosavljević, V. and Djeniže, S., 2003a, *A&A*, 393, 721.

Milosavljević, V. and Djeniže, S., 2003b, *A&A*, 398, 1179.

Milosavljević, V. and Djeniže, S., 2003c, *A&A*, 405, 397.

Milosavljević, V. and Djeniže, S., 2003d, *Eur. Phys. J. D.*, 23, 385.

Milosavljević, V., Djeniže, S. and Dimitrijević, M.S., 2003, *Phys. Rev. E.*, 68, 016402.

Milosavljević, V., Djeniže, S. and Dimitrijević, M.S., 2004, *J. Phys. B: At. Mol. Opt. Phys.*, 37, 2713.

Milovanović, N., 2005, Proceedings of the 5th Serbian Conference on Spectral Line Shapes in Astrophysics, Mem. S.A.It. 7, 129.

Morino, I. and Yamada, K.M.T., 2005, *J. Mol. Spectrosc.*, 233, 77.

Nikolić, D., Djurović, S., Mijatović, Z., Kobilarov, R., Vujičić, B. and Ćirišan, M., 2004, *J. Quant. Spectrosc. Radiat. Transfer*, 86, 285.

Nouri, S., Orphal, J., Aroui, H. and Hartmann, J.-M., 2004, *J. Mol. Spectrosc.*, 227, 60.

Ozmar, B., Wierling, A., Günter, S. and Röpke, G., 2004, in *Spectral Line Shapes*, Proceedings of the 17th ICSLS, ed. E. Dalimier, Editions Frontier Group, Paris, p 150.

Parigger, C.G., Plemmons, D.H. and Oks, E., 2003, *Appl. Opt.*, 42, 5992.

Parigger, C.G., *Spectral Line Shapes*, 2004, in *Spectral Line Shapes*, Proceedings of the 17th ICSLS, ed. E. Dalimier, Editions Frontier Group, Paris, p 97.

Peach, G., Mullamphy, D.F.T., Venturi, V. and Whittingham, I.B., Proceedings of the 5th Serbian Conference on Spectral Line Shapes in Astrophysics, Mem. S.A.It. 7, 145.

Podobedov, V.B., Plusquellic, D.F. and Fraser, G.T., 2004, *J. Quant. Spectrosc. Radiat. Transfer*, 87, 377.

Pope, R.S., Wolf, P.J. and Perram, G.P., 2004, *J. Mol. Spectrosc.*, 223, 205.

Poquérousse, A. and Alexiou, S., 2005, *J. Quant. Spectrosc. Radiat. Transfer*, in press.

Pouchet, I., Zéninari, V., Parvitte, B. and Durry, G., 2004, *J. Quant. Spectrosc. Radiat. Transfer*, 83, 619.

Rohart, F., Colmont, J.-M., Włodarczak, G. and Bouanich, J.-P., 2003, *J. Mol. Spectrosc.*, 222, 159.

Rothman, L.S., Chance, K. and Goldman, A. (ed.), 2003, *J. Quant. Spectrosc. Radiat. Transfer*, 82, 1 (HITRAN special issue).

Rothman, L.S., Jacquemart, D., Barbe, A., Benner, D.C., Birk, B., Brown, L.R., Carleer, M.R. et al, 2005, *J. Quant. Spectrosc. Radiat. Transfer*, 96, 139.

Salem, J., Bouanich, J.-P., Walrand, J., Aroui, H. and Blanquet, G., 2004, *J. Mol. Spectrosc.*, 228, 23.

Salem, J., Bouanich, J.-P., Walrand, J., Aroui, H. and Blanquet, G., 2005, *J. Mol. Spectrosc.*, 232, 247.

- Sanchez-Fortún Stoker, J. and Dickinson, A.S., 2003, *J. Phys. B: At. Mol. Opt. Phys.*, **36**, 1309.
- Simić, Z., 2005, Proceedings of the 5th Serbian Conference on Spectral Line Shapes in Astrophysics, *Mem. S.A.It.* **7**, 119.
- Simić, Z., Popović, L.C., Dimitrijević, M.S. and Dacić, M.D., 2005, Proceedings of the 5th Serbian Conference on Spectral Line Shapes in Astrophysics, *Mem. S.A.It.* **7**, 237.
- Sneep, M., Ityakov, I., Aben, I., Linnartz, H. and Ubachs, W., 2005, *J. Quant. Spectrosc. Radiat. Transfer*, in press.
- Stambulchik, E. and Maron, Y., 2005, *J. Quant. Spectrosc. Radiat. Transfer*, in press.
- Sung, K. and Varanasi, P., 2004, *J. Quant. Spectrosc. Radiat. Transfer*, **83**, 445.
- Tretyakov, M.Yu., Golubiatnikov, G.Yu., Parshin, V.V., Koshelev, M.A., Myasnikova, S.E., Krupnov, A.F. and Rosenkranz, P.W., 2004, *J. Mol. Spectrosc.*, **223**, 31.
- Tretyakov, M.Yu., Parshin, V.V., Koshelev, M.A., Shanin, V.N., Myasnikova, S.E. and Krupnov, A.F., 2003, *J. Mol. Spectrosc.*, **218**, 239.
- Valognes, J.C., Bardet, J.P., Flih, S.A. and Vitel, Y., 2004, *J. Quant. Spectrosc. Radiat. Transfer*, **87**, 221.
- Valognes, J.C., Bardet, J.P., Vitel, Y. and Flih, S.A., 2005, *J. Quant. Spectrosc. Radiat. Transfer*, **95**, 113.
- Varghese, G., Stamp, C. and Paddi Reddy, S.P.S., 2004, *J. Quant. Spectrosc. Radiat. Transfer*, **87**, 387.
- Vitel, Y., Gavrilova, T.V., D'yachkov, L.G. and Kurilenkov, Yu.K., 2004, *J. Quant. Spectrosc. Radiat. Transfer*, **83**, 387.
- Wagner, G., Birk, M., Gamache, R.R. and Hartmann, J.-M., 2005, *J. Quant. Spectrosc. Radiat. Transfer*, **92**, 211.
- Wang, W.F., 2004, *J. Quant. Spectrosc. Radiat. Transfer*, **86**, 437.
- Yamada, K.M.T. and Abe, H., 2003, *J. Mol. Spectrosc.*, **217**, 87.
- Yamada, M.M. and Amano, T., 2005, *J. Quant. Spectrosc. Radiat. Transfer*, **95**, 221.
- Zhu, C., Babb, J.F. and Dalgarno, A., 2005, *Phys. Rev. A*, **71**, 052710.
- Zmerli, B., Ben Nessib, N. and Dimitrijević, M.S., 2005, Proceedings of the 5th Serbian Conference on Spectral Line Shapes in Astrophysics, *Mem. S.A.It.* **7**, 243.