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PHOTOIONISATION OF ATOMS AND IONS : AN EXTENDED BIBLIOGRAPHY FOR 1986-1990

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RESUME : Une liste de plus de 900 publications parues en 1986-90 sur les transitions lié-libre induites par impact photonique dans les systèmes atomiques est présentée. Ce travail étend la bibliographie 1970-87 de Butler *et al* (1988) sur la photoionisation des atomes et des ions dans deux directions. D'une part, elle élargit le domaine d'investigation systématique à l'ionisation simple et multiple, directe et résonnante, impliquant des couches externes ou internes, induite par un seul ou un grand nombre de photons, en présence ou non de champs statiques externes. D'autre part, elle affine l'indexation des références obtenues qui sont classées simultanément par espèce, type de processus et de travail.

ABSTRACT : A list of over 900 references published during the period 1986-90 on bound-free transitions induced by photon-impact in atomic systems is presented. This work extends the 1970-87 bibliography of Butler *et al* (1988) on the photoionisation of atoms and ions in two directions. On one hand, it enlarges the domain of systematic investigation to simple and multiple ionisation, direct and resonant, implying outer and inner shells, induced by a single or a large number of photons, with or without the presence of external static fields. On the other hand, it refines the indexation of the selected references by species, type of process and of work.

1. PRESENTATION OF THE BIBLIOGRAPHY

The study of photon interactions with atoms and molecules is a rapidly expanding field of research, due to the development of versatile experimental tools (synchrotron radiation, lasers) and powerful computational techniques (*R*-matrix methods, Many Body Perturbation Theory, Random Phase Approximation with Exchange, Local Density Functional Approximation, ...), which allow to explore species and processes of increasing complexity.

It becomes timely to gather the outcome of such studies in order to make them available to related research fields, such as the modelling of radiative transfer in plasmas. The International Opacity Project on the *ab initio* calculation of the stellar envelope opacities (Seaton, 1988 and many contributions of the present issue) is such an integrated program, which requires the collaboration of a large number of researchers to produce radiative data, to evaluate them and introduce them in adequate equations of state in order to model the evolution of the stellar envelopes. This astrophysical project has largely promoted the activity of the International Atomic Data Workshops (Daresbury 1985, Oxford 1987, Meudon 1989), in the framework of which the present series of bibliographies on the photoionisation of atoms and ions has been undertaken (Le Dourneuf & Zeippen 1986; Butler *et al* 1988, later on referred as BLZ).

This third bibliography aims at providing an extended selection of the data published during the 1986-90 period for all types of bound-free transitions induced by one or more photons in atomic systems. Because of an increasing activity in several areas (autoionizing states, Auger spectra, multiple ionization, multiphoton processes, photoionisation in the presence of static fields), an attempt has therefore been made to fill some gaps in our previous list for 1986-87. Note however that the references of 1986 and 1987 which were already included in our previous bibliography (BLZ) have been discarded from the present list, so that the reader should systematically refer to BLZ to get a complete list for these two years. The compilation is based on a systematic investigation of the Physical Abstract Section on "Photon interaction with atoms", in parallel to that of the many journals more rapidly available at the Observatory of

Paris (as mentioned in section 2). In addition, the analysis of the references has been deepened. The list of references (section 3) is still presented in alphabetical order with the full titles. But, concise comments on three topics are added. The first one concerns the type of publication, qualified as a review (R), mainly experimental (E), theoretical (T), or a mixture of both (Exp & theory = M). The second one qualifies the process under study by the association of up to three keys : OU for transitions involving outer shells, IN for those involving inner shells (inner valence shells being sometimes qualified by the association of both keys), AI when emphasis is put on autoionizing states and resonant processes, MI when multiple ionization is investigated, SF for photoionization in the presence of static fields, FP for processes induced by a few photons, MP for processes involving many photons. The third comment concerns the species for which specific data is given. The index based on this analysis and presented in section 4 can therefore be very detailed : it is presented by species gathered in isoelectronic or isonuclear sequences, and for each species according to the keys classifying the processes and the type of data contained in each reference. The bibliography is stored in a database created using the R:BASE system V by MICRORIM, which facilitates regular updates and allows various modes of selection and presentation to be made.

This bibliography cannot be guaranteed as exhaustive or bugless, but every effort has been made to include a maximum of relevant references and to check them. In particular, efforts have been made to include as many references published in 1990 as possible before the printing of the Proceedings. Because of the difficulties specific to compilations and classifications, the present work should be considered as complementary to similar efforts made, for example, in the International Bulletin on Atomic and Molecular Data For Fusion edited by J.J. Smith for the International Atomic Energy Agency and in the Multiphoton Bibliography edited by S.J. Smith, J.H. Eberly and J.W. Gallagher for NIST.

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2. KEYS TO JOURNAL ABBREVIATIONS

The 909 references which are analyzed in the following bibliography are extracted from about 80 different journals or conference proceedings. The abbreviations of their titles used in the following list of papers are given below, together with a label (*) to indicate those for which the author had easy local access. While most of the 750 corresponding references have been checked individually, the indexing of the remaining ones, which could not be accessed directly, is based exclusively on Physical Abstracts, and may be less accurate.

AA*	Astron. Astrophys. (Springer, Berlin)
AAMP*	Adv. At. Mol. Phys. (Academic Press)
ADNDT*	At. Data Nucl. Data Tables (USA)
ADW2*	Atomic Data Workshop: Assessment of data for photoionization and photoexcitation and for electron impact excitation of atomic ions (Daresbury National Laboratory, UK)
AIPCP*	AIP Conf. Proc. (USA)
APB	Applied Phys. B : Photophys. Laser. Chem. (West Germany)
APPA	Acta Phys. Pol. A (Poland)
APS	Acta Phys. Sin. (China)
ASI*	Astrophys. Space Sci. (Netherlands)
AtP	Atomic Physics (Proceedings of the International Atomic Physics Conference)
BASUPS	Bull. Acad. Sci. USSR Phys. Ser. (USA)
BICRKU	Bull. Inst. Chem. Res. Kyoto. Univ. (Japan)
CAMP*	Comments. At. Mol. Phys. (GB)
ChJP	Chin. J. Phys. (Taiwan)
ChP	Chin. Phys. (USA)
ChPL	Chin. Phys. Lett. (China)
CJP*	Can. J. Phys. (Canada)
CoP	Contemp. Phys. (USA)
CP*	Chem. Phys. (Holland)
CPL*	Chem. Phys. Lett. (Holland)
ChPL	Chin. Phys. Lett. (China)
CPR*	Comput. Phys. Rep. (Holland)
EL*	Europhys. Lett. (Switzerland)
IEEEETPS	IEEE Trans. Plasma Sci. (USA)
IJQCQCS	Int. J. Quant. Chem. : Quant. Chem. Sympos. (USA)
JCICS	J. Chem. Inf. Comput. Sci. (USA)
JCP*	J. Chem. Phys. (USA)
JESRP*	J. Electron. Spect. Relat. Phenom. (Holland)
JJAP2L	Jap. J. Applied Phys. 2 Lett. (Japan)
JKPS	J. Korean Phys. Soc. (South Korea)
JMO	J. Mod. Opt. (UK)
JOSAB*	J. Opt. Soc. Am. B (USA)
JP*	J. Physique (Paris)
JPA*	J. Phys. A (UK)
JPB*	J. Phys. B (UK)
JPCh	J. Phys. Chem. (USA)
JPCo*	J. Physique Coll. (Paris)
JPD	J. Phys. D (Applied Phys.) (UK)
JPSJ*	J. Phys. Soc. Japan (Japan)
JQSRT*	J. Quant. Spectrosc. Radiat. Transfer (UK)
JSLR	J. Sov. Laser. Res. (USA)
JVSTA	J. Vac. Sci. Technol. A Vac. Surf. Films (USA)
MP	"Multiphoton processes", Proceedings of the 4th International Conference on Multiphoton Processes, Boulder (1987), Cambridge University Press 1988
MUPB	Moscow Univ. Phys. Bull. (USA)
NATO1	"Fundamental Processes in Atomic Collisions Physics", Plenum Press 1985 (NATO ASI, Santa Flavia Italy)
NATO2	"Giant Resonances in Atoms, Molecules and Solids" (Plenum Press, New York, 1987)
NCD	Nuovo Cimento D (Italy)
NIMPR	Nucl. Instrum. Methods : Phys. Res. (Netherlands)
OC*	Opt. Commun. (Netherlands)
OL	Opt. Lett. (USA)
OS*	Opt. Spectroscopy (USA)
PA	Physica A (Netherlands)
PB	Phys. Bl. (West Germany)
PLA	Phys. Lett. A (Netherlands)
PQE	Prog. Quant. Electronics (UK)
PRA*	Phys. Rev. A (USA)

Pramana	Pramana (India)
PRL*	Phys. Rev. Lett. (USA)
PRp*	Phys. Rep. (Netherland)
PS*	Phys. Scr. (Sweden)
PSI*	Planet. Space Sci. (UK)
PSPIE	Proc. SPIE Int. Soc. Opt. Eng. (USA)
RBF	Rev. Bras. Fis. (Brazil)
RNC	Riv. Nuovo Cimento (Italy)
RPP*	Rep. Prog. Phys. (UK)
SAE	Sov. At. Energ. (USA)
SJNP	Sov. J. Nucl. Phys. (USA)
SJQE	Sov. J. Quant. Electronics (USA)
SPC	Sov. Phys. Collect. (USA)
SPIG86	"Physics of Ionized Gases", SPIG'86 Belgrade 1986
SPIG88	"Physics of Ionized Gases", SPIG'88, Sarajevo, 1988 (Commack, NY USA - Nova Science 1989)
SPJETP*	Sov. Phys. JETP (USA)
SPJETPL*	Sov. Phys. JETP Lett. (USA)
SPTP	Sov. Phys. Tech. Phys. (USA)
SPU	Sov. Phys. Usp. (USA)
STPL	Sov. Tech. Phys. Lett. (USA)
THEOCHEM	Theochem (Holland)
UFZ	Ukr. Fiz. Zh. (URSS)
ZPD*	Z. Phys. D (Germany)

3. BIBLIOGRAPHY

In the following list, ordered alphabetically and chronologically, the full references are followed by a few *comments*, indicating the major philosophy of the publication (*Theory, Experiment, Review*), up to three *keys* characterizing the processes under study (OU an/or IN specifying processes involving mainly outer and/or inner shells —inner valence shells being sometimes indexed by both—, AI, MI, SF, FP, MP indicating special emphasis respectively on autoionizing states, multiple ionization, presence of external static fields, processes involving a few or many —large or unspecified— photons) and the list of *species* on which special data is given (*General* means that no specific species is involved or could be identified because the author of the bibliography has no easy access to the reference). In some cases this indexation is obvious from the title, in other cases it gives additional information, and in all cases it indicates the keys which have been used for the index in section 4, so that the reader can easily take care of any omission or mistake in the analysis of the references.

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- [873] A.A. Wills, A.A. Cafolla, A. Svensson and J. Comer. Resonance structure in the neon photoelectron satellites. JPB, 23:2013-28, 1990. *Exp - Keys : OU - Species : Ne.*
- [874] B.G. Wilson, C. Iglesias and F. Rogers. Near-threshold photoabsorption cross sections for nonhydrogenic ions. PRA, 38:4633-8, 1988. *Theory - Keys : OU - General.*
- [875] P. Winkler. A unified many-body theory of dielectronic recombination and autoionization. IJQCQCS, 19:201-16, 1986. *Th. review - Keys : AI - General.*

- [876] D. Wintgen and H. Friedrich. Photoabsorption calculations for the magnetised hydrogen atom in the quasi-Landau region. JPB, 19:L99-104, 1986. *Theory - Keys : SF - Species : H.*
- [877] B. Wolff, H. Rottke, D. Feldmann and K.H. Welge. Multiphoton-ionization of hydrogen atoms in intense laser fields. ZPD, 10:35-43, 1988. *Exp - Keys : MP - Species : H.*
- [878] H.Y. Wong, A.R.P. Rau and C.H. Greene. Negative-ion photodetachment in an electric field. PRA, 37:2393-403, 1988. *Theory - Keys : SF - Species : S⁻.*
- [879] B.R. Wu, S. Zhang, J.W. Zhong, J.Z. Qiu, S.F. Hu, J. Lu and J.Z. Sun. Measurement of the $(5p_{3/2}ns)_1$ and $(5p_{3/2}nd)_3$ autoionizing levels of strontium by the multistep excitation technique. ChP, 8:71-7, 1988. *Exp - Keys : AI - Species : Sr.*
- [880] I.J. Wu and H. Xie. Theoretical calculation of two-photon excitation of Hg atom. APS, 35:556-60, 1986. *Theory - Keys : FP - Species : Hg.*
- [881] L. Wu and J. Xi. The autoionisation widths of He I below the $N=3$ He⁺ threshold. JPB, 23:727-35, 1990. *Theory - Keys : AI - Species : He.*
- [882] Y.J. Wu and J.M. Li. Non-relativistic self-consistent-field calculation of two-photon transitions in atomic inner shells for Xe. JPB, 21:1509-1517, 1988. *Theory - Keys : FP IN - Species : Xe.*
- [883] Y.J. Wu and J.M. Li. Correlation interaction in atomic inner shell photoelectric effect. APS, 38:1056-61, 1989. *Theory - Keys : IN - Species : Ne⁺, Ne.*
- [884] F.J. Wuilleumier, D.L. Ederer and J.L. Picqué. Photoionization and collisional ionization of excited atoms using synchrotron and laser radiations. AAMP, 23:198-286, 1987. *Review - Keys : OU IN AI - Species : He, Li, Ne, Na, K, Xe, Cs, Ba.*
- [885] X. Xing, D. Charalambidis and C. Fotakis. Influence of space charge on photoelectron angular distributions and energy spectra in resonance multiphoton ionization. OC, 79:181-6, 1990. *Exp - Keys : MP - Species : Xe.*
- [886] J.Q. Xu. New interpretation of the Ag L-series X-ray spectrum. ZPD, 13:25-7, 1989. *Exp & theory - Keys : IN - Species : Ag.*
- [887] A. Yagishita, S. Aksela, T. Prescher, M. Meyer, M. Richter, E. von Raven and B. Sonntag. Decay channels of the 4p resonances in atomic Sr. JPB, 21:945-53, 1988. *Exp - Keys : IN AI - Species : Sr.*
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- [889] D. Yao and M.H. Nayfeh. Photoionization spectrum of H in strong DC electric fields. PRA, 35:2508-17, 1987. *Theory - Keys : SF - Species : H.*
- [890] D. Yao and M.H. Nayfeh. $m=1$ photoionization spectrum of hydrogen in strong DC electric fields. PRA, 36:4072-5, 1987. *Exp - Keys : SF - Species : H.*
- [891] G.H. Yao and Z.Z. Xu. Coherent effects in intense laser-field induced autoionization. APS, 37:1760-6, 1988. *Exp - Keys : AI MP - General.*
- [892] G.H. Yao and Z.Z. Xu. Peak-switching of the photoelectron spectrum. APS, 38:864-8, 1989. *Exp - Keys : MP - General.*
- [893] G.H. Yao and Z.Z. Xu. Ejection of energetic photoelectrons in laser-induced autoionisation : effects of high-order ionisation processes. JPB, 22:211-21, 1989. *Theory - Keys : AI MP - General.*
- [894] G.H. Yao, W. Yu, Z.Z. Xu and R.Q. Chen. Above-threshold ionization by a smooth laser pulse. APS, 39:35-9, 1990. *Theory - Keys : MP - General.*
- [895] T.S. Yih, H.H. Wu, H.T. Chan, C.C. Chu and B.J. Pong. Measurement of the photoabsorption cross-section of magnesium vapor in the VUV range. ChJP, 27:136-9, 1989. *Exp - Keys : OU - Species : Mg.*
- [896] K. Yoshino, A.S.C. Cheung, J.R. Esmond, W.H. Parkinson, D.E. Freeman, S.L. Guberman, A. Jenouvrier, B. Coquart and M.F. Merienne. Improved absorption cross-sections of oxygen in the wavelength region 205-240 nm of the Herzberg continuum. PSI, 36:1469-75, 1988. *Exp - Keys : OU - Species : O.*

- [897] W. Yu and Z.Z. Xu. Model study for the time evolution of above-threshold ionization. JPB, 22:L427-31, 1989. *Theory - Keys : MP - General.*
- [898] Y. Yu and M.J. Seaton. Atomic data for opacity calculations. IV. Photoionization cross sections for C II. JPB, 20:6409-29, 1987. *Theory - Keys : OU - Species : C⁺.*
- [899] S.A. Zapryagaev, B.A. Zon and Y.A. Nefedov. Photoionization of doubly excited atomic states. OS, 63:422-6, 1988. *Theory - Keys : OU - Species : Mg, Ca, Sr.*
- [900] J. Zhang and T.A. King. Photoionisation in the Tl anti-Stokes Raman laser. JPB, 23:1587-94, 1990. *Exp Keys : OU - Species : Tl.*
- [901] Y. Zhu, R.R. Jones, W. Sandner, T.F. Gallagher, P. Camus, P. Pillet and J. Boulmer. Multiphoton double ionisation of Ba from 280 to 700 nm. JPB, 22:585-99, 1989. *Exp - Keys : MP MI - Species : Ba.*
- [902] Y. Zhu, E.Y. Xu and T.F. Gallagher. Energy and angular distributions of autoionization electrons and channel interaction effects for the Sr 5pns $J=1$ autoionizing series. PRA, 36:3751-67, 1987. *Exp - Keys : OU AI - Species : Sr.*
- [903] V.A. Zilitis. Photoionization cross sections for ions of the potassium isoelectronic series calculated by the Dirac-Fock method. OS, 65:588-90, 1988. *Theory - Keys : OU - Species : K seq with $20 \leq Z \leq 28$ (Ca⁺, Sc²⁺, Ti³⁺, Cr⁵⁺, Fe⁷⁺, Ni⁹⁺).*
- [904] P. Zimmerer, N. Grun and W. Scheid. Trajectory method for time-dependent Thomas-Fermi equations and application to Ar atoms in laser fields. PLA, 134A:57-61, 1988. *Theory - Keys : MP - Species : Ar.*
- [905] P. Zimmermann. Study of multicharged photoions using synchrotron radiation. CAMP, 23:45-53, 1989. *Review - Keys : IN MI - Species : La, Ce, Gd, Dy.*
- [906] M. Zubek and G.C. King. Photoionisation studies of autoionising states of helium between 69 and 77 eV. JPB, 22:3411-21, 1989. *Exp - Keys : AI - Species : He.*
- [907] M. Zubek, G.C. King, P.M. Rutter, and F.H. Read. Threshold photoionisation studies in helium and nitrogen. SPIG86, -0-111-13, 1986. *Exp - Keys : OU - Species : He, N.*
- [908] A.D. Zyurikov, V.S. Letokhov, V.I. Mishin, and V.N. Fedoseev. Laser resonance photoionization spectroscopy of excited and autoionization atomic states of rare-earth elements. I. Europium. OS, 63:572-8, 1988. *Exp - Keys : OU AI - Species : Eu.*
- [909] A.D. Zyurikov, V.I. Mishin, and V.N. Fedoseev. Laser resonance photoionization spectroscopy of excited and autoionization atomic states of rare-earths. III. Neodymium. OS, 64:287-8, 1988. *Exp - Keys : OU AI - Species : Nd.*

4. INDEX BY SPECIES, TYPES OF PROCESSES AND RELATED

The index of the bibliography is made by species, grouped into isoelectronic or isonuclear sequences, by the keys defining the processes (multiple keys being used as in the previous paragraph to emphasize several aspects of the work or some ambiguity in the classification : inner valence shells being sometimes simultaneously classified in OU and IN) and by the type of publication (T for a paper describing a calculation, E for an experiment, M for a 'mixture' or experimental and theoretical analysis, R for a review). Finally, it should be noticed that most of the papers relevant to the H sequence are general papers, concerning the development of new approaches, tested on H rather than on a model problem.

Reviews, general studies

OU 023T 030R 059T 109T 159E 185T 202R 206R 210T 229R 253T 304T 366T 408T 451T 465T 492T 538R 561R
 562R 564R 583E 606T 695E 696T 697T 755R 772T 786R 797R 855T 866R 874T
 IN 059T 176T 228R 229R 318T 320T 342E 389T 437T 442T 443T 495T 612T 628R 639R 770T 786R 866R
 AI 106T 138T 139T 147T 189T 203T 303T 334T 366T 495T 518R 530T 535T 550T 705T 812T 875T 891E 893E
 MI 130R 131T 147T 216T 518R 628R

SF 122T 230T 705T
 FP 207T 231T 335T 430E 530T 649T 694E
 MP 006R 013T 036T 073T 075T 082T 083R 094T 096R 111T 122T 123T 130R 131T 133R 138T 139T 147T 149T
 171T 172T 187R 188T 196T 197T 205E 216T 217T 219R 220T 224T 254R 255R 267T 271T 276T 287T 290T
 298T 299R 300R 301T 302T 306T 307T 308T 309R 310T 311T 318T 334T 340E 342E 345T 348T 351T 362T
 364T 365T 372T 414T 415T 416T 418T 442T 443T 444T 467T 469R 483T 490T 496E 510T 511T 517R 518R
 519R 525R 532R 535T 588T 595T 596R 603E 607T 615R 617T 647T 648T 653T 673T 679T 680T 681R 693T
 707T 709T 711T 712T 719T 726T 754T 768R 775R 776T 777T 790R 801T 804T 805T 812T 815R 839T 851T
 862T 891E 892E 893E 894T 897T

H-sequence ($N=1$ with $1s$ ground configuration)

H OU 043T 045T 646T 708T
 SF 017T 126T 468T 477M 478T 720E 863T 876T 889T 890E
 FP 072E 110T 274T 316T 373T 454T 646T 654R 829T
 MP 015M 016E 078T 079T 080T 081T 114T 115T 124T 132E 145T 173T 213T 221T 259T 268T 270T 273E 291T
 305T 312R 313E 329E 331T 332T 344T 346T 347T 363T 419T 433T 452T 453T 470E 482E 512T 516R 526T
 527T 528T 529T 536T 578E 589T 633T 656T 657T 674T 675T 682T 683T 684T 685T 686T 702T 714M 715T
 721E 727T 803T 813T 824T 825T 826T 827T 830T 861T 877E
 Li²⁺ MP 327E
 Be³⁺ OU 635R
 Na¹⁰⁺ MP 327E

He-sequence ($N=2$ with $1s^2$ ground configuration)

Many Z OU 315T ($Z=2-14, 16, 18-20, 24-26, 28, 36$)
 756T ($Z=2-10, 12-14, 16, 18, 20, 26$)
 IN 097E ($Z=16, 18, 19, 21-24, 26, 36$)
 571T
 AI 101T 349R 571T
 183T ($Z=1, 2, 6, 7, 8$)
 449T ($Z=10, 12, 18, 20, 22, 24, 26, 28$)
 552T ($Z=2-6, 8$)
 773T ($Z=2-10$)
 859T ($Z=6, 8, 10, 12, 26$)
 MI 146T
 MP 146T
 H⁻ OU 044T 143T 354T 424T 634T 729T
 AI 141T 183T 324T 378E 393T 629T 630T
 SF 194E 277T 278T 279T 280T 296T 297T 353T 704T 798E
 FP 046T 227T
 MP 095T 223T 226T 269T 286T 289T 336T 609T 611T 809E
 He OU 047E 068E 142T 323T 371T 386T 387E 458R 466E 531T 708T 728T 740T 749T 793R 858T 860T 884R
 907E
 IN 591T 784R 789T 884R
 AI 107T 183T 212T 323T 324T 338T 368E 371T 386T 392T 394E 457T 479E 551T 552T 566T 597T 629T 631T
 637T 773T 858T 860T 881T 884R 906E
 MI 056T 466E 480E 509E 767E 789T
 FP 056T 368E 456E
 MP 077E 134E 193T 330T 475E 493T 502T 543R 616E 828T 831T 847M
 Li⁺ OU 144T 395T 531T 749T
 AI 551T 552T 629T 773T
 Be²⁺ OU 635R
 AI 551T 552T 773T
 B³⁺ OU 635R
 AI 551T 552T 773T
 C⁴⁺ OU 410E 635R
 IN 409E 411E
 AI 183T 552T 566T 773T 859T
 N⁵⁺ AI 183T 565T 566T 650T 651M 773T

O ⁶⁺	AI	055T 183T 552T 566T 773T 859T
F ⁷⁺	AI	773T
Ne ⁸⁺	AI	449T 773T 859T
Mg ¹⁰⁺	AI	859T
Si ¹²⁺	IN	450T
	AI	450T
Ar ¹⁶⁺	IN	441E 450T
	AI	450T
Fe ²⁴⁺	OU	738T
	AI	859T
Ni ²⁶⁺	OU	769T
Xe ⁵²⁺	OU	738T
Ba ⁵⁴⁺	AI	394E

Li-sequence ($N=3$ with [He]2s ground configuration)

Many Z	OU	659T and 756T ($Z=3-10$)
	IN	571T
	AI	243T ($Z=3-18$)
		242T and 245T ($Z=3-10$)
		244T ($Z=2-6$)
		571T
He ⁻	OU	661E 662E 663E 735T 818E 819E
	AI	150T 629T
	MI	232T
Li	OU	086R 089R 236E 395T 582E 708T 743R 793R 884R
	IN	040T 086R 540T 557E 743R 884R
	AI	086R 089R 412T 413T 743R 884R
	SF	865T
	MP	674T
Be ⁺	OU	635R 659T
B ²⁺	OU	635R 659T
C ³⁺	OU	635R 659T
	IN	168E 411E
N ⁴⁺	OU	659T
	IN	168E
O ⁵⁺	OU	659T
	IN	168E
F ⁶⁺	OU	659T
Ne ⁷⁺	OU	659T
	AI	170E

Be-sequence ($N=4$ with [He]2s² ground configuration)

Many Z	OU	835T and 836T ($Z=4-14, 16, 18, 20, 26$)
Li ⁻	OU	156T 161T 602T
	AI	629T
	MI	633T
	SF	632T
	MP	632T 633T
Be	OU	089R 635R
	IN	084T 191T 486E 487T 734T
	AI	084T 089R 352R 580T 637T
B ⁺	OU	635R 834T
	AI	190T 834T
C ²⁺	OU	635R 671T
	IN	411E
	AI	192T 841T
N ³⁺	AI	841T
O ⁴⁺	AI	841T

Ne ⁶⁺	AI	841T
	IN	627T
Ar ¹⁴⁺	AI	112E
Ti ¹⁸⁺	AI	112E
Xe ⁵⁰⁺	AI	841T

B-sequence ($N=5$ with [He] $2s^22p$ ground configuration)

Many Z	IN	179T ($Z=6-10, 12, 14, 16, 18, 20, 22, 26, 28, 36, 42, 47, 54$)
		180T ($Z=6-26$)
B	IN	191T
C ⁺	OU	898T

C-sequence ($N=6$ with [He] $2s^22p^2$ ground configuration)

Many Z	OU	175T ($Z=6-26$)
		545T and 687T ($Z=6-14, 16, 18, 20, 26$)
B ⁻	OU	661E
C	IN	411E 645R
O ²⁺	OU	546T
Ne ⁴⁺	AI	448T
Xe ⁴⁸⁺	OU	175T

N-sequence ($N=7$ with [He] $2s^22p^3$ ground configuration)

N	OU	559T 623T 748R 817T 907E
	IN	645R
	MI	744E 745E
O ⁺	OU	069T
Ne ³⁺	AI	448T

O-sequence ($N=8$ with [He] $2s^22p^4$ ground configuration)

O	OU	035E 099T 100T 148T 748R 757T 843E 845E 896E
	IN	645R
	MI	742E 744E 745E
	FP	070E 262T
Ne ²⁺	AI	448T 497T
La ⁴⁹⁺	IN	181E

F-sequence ($N=9$ with [He] $2s^22p^5$ ground configuration)

O ⁻	OU	376E 806E
	SF	485E
F	OU	844E
	AI	048T
Ne ⁺	IN	883T
La ⁴⁸⁺	IN	181E

Ne-sequence ($N=10$ with [He] $2s^22p^6$ ground configuration)

Many Z	AI	178T
F ⁻	OU	500E 840E
	FP	119E 225R 652T
	MP	218T 222T 343T 500E 523E
Ne	OU	086R 089R 092E 152E 387E 406M 743R 748R 763E 793R 873E 884R
	IN	007R 010E 011E 033T 086R 092E 160T 195T 250T 544T 645R 743R 766R 784R 789T 802T 883T 884R
	AI	086R 089R 700T 743R 802T 884R
	MI	742E 744E 745E 789T
	MP	475E 616E
Mg ²⁺	IN	627T

Ar⁸⁺ IN 627T
Ba⁴⁶⁺ OU 769T

Na-sequence ($N=11$ with [Ne]3s ground configuration)

Many Z IN 177T ($Z=18, 22, 26$)
AI 178T
Na OU 067T 162E 233R 236E 581E 608T 736T 737T 884R
IN 234E 235E 246T 247T 258E 672T 716E 802T 884R
AI 108T 162E 672T 791R 802T 884R
FP 020T 067T 233R 234E 339E 484E 791R
MP 038E 326E 791R 888E
Mg⁺ AI 317E
Al²⁺ AI 317E 605T
Si³⁺ AI 605T
Se²³⁺ OU 636E

Mg-sequence ($N=12$ with [Ne]3s² ground configuration)

Na⁻ OU 029T
AI 322T
MP 343T
Mg OU 021T 165T 166T 398E 598T 599T 601T 774T 895E 899T
IN 084T 380E 627T 645R
AI 021T 084T 166T 239E 352R 637T
FP 600T
MP 240E 397E 462E 810T
Al⁺ OU 256T
Ar⁶⁺ IN 627T

Al-sequence ($N=13$ with [Ne]3s²3p ground configuration)

Al OU 822T
IN 049E 645R
AI 548T
MI 049E
MP 548T

Si-sequence ($N=14$ with [Ne]3s²3p² ground configuration)

Many Z OU 687T ($Z=14, 16, 18, 20, 26$)
Si OU 356T 579T
IN 645R

P-sequence ($N=15$ with [Ne]3s²3p³ ground configuration)

Si⁻ OU 029T
P OU 579T
IN 701E

S-sequence ($N=16$ with [Ne]3s²3p⁴ ground configuration)

S OU 579T 814T
IN 645R 701E
AI 321T 814T

Cl-sequence ($N=17$ with [Ne]3s²3p⁵ ground configuration)

S⁻ SF 878T
FP 563E

Cl OU 155E 458R 723E 743R 748R
 IN 701E 743R
 AI 723E 743R

Ar-sequence ($N=18$ with $[\text{Ne}]3s^23p^6$ ground configuration)

Cl⁻ FP 093T 121E 272T 420T
 MP 076E 218T 222T 343T 522E 523E 821E
 Ar OU 024R 086R 088E 089R 092E 369E 577E 730T 743R 746E 747E 748R 760E 762R 793R 870T 871E
 IN 007R 010E 033T 086R 092E 158E 184T 208T 209T 250T 263E 285E 295E 367E 369E 381E 388E 435T 524T
 539M 627T 641T 645R 724T 733T 743R 753T 784R 802T 833T 846T 856E
 AI 086R 089R 352R 743R 760E 762R 802T
 MI 130R 184T 263E 508E
 FP 573E 652T 664M
 MP 130R 174E 330T 391E 473E 534E 543R 667M 713R 796R 904T
 K⁺ OU 560T 626T
 AI 214T

K-sequence ($N=19$ with $[\text{Ar}]4s$ neutral ground configuration)

Many Z OU 903T ($Z=20, 21, 22, 24, 26, 28$)
 AI 725E
 K OU 560T 731T 792E 884R
 IN 403E 701E 884R
 AI 884R
 FP 403E 783E
 MP 799E
 Ca⁺ OU 587T
 Fe⁷⁺ OU 756T

Ca-sequence ($N=20$ with $[\text{Ar}]4s^2$ neutral ground configuration)

K⁻ MI 058T
 Ca OU 054E 360E 458R 463T 464T 584E 837E 899T
 IN 084T 182T 204E 586M 645R 688E 701E 864E
 AI 084T 352R 355T 360E 463T 464T 521E 586M 604E 637T 692E
 SF 692E
 FP 018M 703R
 MP 461E
 Fe⁶⁺ OU 756T

Sc-sequence ($N=21$ with $[\text{Ar}]4s^23d$ neutral ground configuration)

Ca⁻ OU 662E
 AI 377E
 Sc OU 333R
 IN 585R 765R
 MI 765R

Ti-sequence ($N=22$ with $[\text{Ar}]4s^23d^2$ neutral ground configuration)

Ti IN 585R 658E 765R
 MI 765R

V-sequence ($N=23$ with $[\text{Ar}]4s^23d^3$ neutral ground configuration)

V IN 585R
 FP 750E

Cr-sequence ($N=24$ with $[\text{Ar}]4s^3d^5$ neutral ground configuration)

Cr OU 063E 064E 265T
 IN 211E 585R 765R
 MI 765R
 Mn⁺ IN 211E

Mn-sequence ($N=25$ with $[\text{Ar}]4s^23d^5$ neutral ground configuration)

Mn OU 024R 028T 333R 421E 458R
 IN 211E 481E 585R 765R
 MI 765R

Fe-sequence ($N=26$ with $[\text{Ar}]4s^23d^6$ neutral ground configuration)

Fe OU 057R
 IN 034T 585R 645R 765R
 MI 765R

Co-sequence ($N=27$ with $[\text{Ar}]4s^23d^7$ neutral ground configuration)

Co IN 585R 765R
 MI 765R

Ni-sequence ($N=28$ with $[\text{Ar}]4s^23d^8$ neutral ground configuration)

Ni IN 007R 585R 658E 765R 869E
 MI 765R 869E

Cu-sequence ($N=29$ with $[\text{Ar}]4s3d^{10}$ neutral ground configuration)

Many Z AI 725E
 Cu IN 034T 569E 570M 585R 765R
 AI 060E
 MI 765R
 Zn⁺ OU 660E
 AI 215T
 Gd³⁵⁺ IN 741T

Zn-sequence ($N=30$ with $[\text{Ar}]4s^23d^{10}$ neutral ground configuration)

Cu⁻ OU 764T
 Zn OU 002T 567T 771R
 IN 575E 585R 765R 778T
 AI 167E
 MI 765R
 Ga⁺ OU 660E

Ga-sequence ($N=31$ with $[\text{Ar}]4s^23d^{10}4p$ neutral ground configuration)

Ga OU 151E
 AI 151E 488E

Ge-sequence ($N=32$ with $[\text{Ar}]4s^23d^{10}4p^2$ neutral ground configuration)

Ge AI 352R

Se-sequence ($N=34$ with $[\text{Ar}]4s^23d^{10}4p^4$ neutral ground configuration)

Se OU 432E
 IN 432E

Br-sequence ($N=35$ with $[\text{Ar}]4s^23d^{10}4p^5$ neutral ground configuration)

Se⁻ FP 563E
 Br OU 743R
 IN 743R
 AI 743R

Kr-sequence ($N=36$ with $[\text{Ar}]4s^23d^{10}4p^6$ neutral ground configuration)

Br⁻ FP 119E
 MP 120M 218T 222T
 Kr OU 089R 370E 553E 743R 747E 748R 785E
 IN 007R 009T 010E 032T 157E 158E 294E 370E 383E 384E 388E 434T 435T 436T 447E 592T 620E 640E 641T
 665E 722T 743R 779T 780T 856E
 AI 089R 252E 352R 592T 743R 838E 857E
 MI 130R 382E 620E
 FP 252E 573E 590E
 MP 077E 130R 135R 136T 391E 473E 474E 520E 666E 667M

Rb-sequence ($N=37$ with $[\text{Kr}]5s$ neutral ground configuration)

Rb OU 771R
 IN 008E 012M 472E
 AI 407E 795E
 MI 472E
 MP 014T

Sr-sequence ($N=38$ with $[\text{Kr}]5s^2$ neutral ground configuration)

Rb⁻ SF 357T
 Sr OU 052T 053T 899T 902E
 IN 472E 641T 887E
 AI 241T 402E 476E 515E 676T 692E 879E 887E 902E
 MI 153M 472E 501R
 SF 692E
 FP 379E 515E 655E
 MP 153M 501R 669R

Y-sequence ($N=39$ with $[\text{Kr}]5s^24d$ neutral ground configuration)

Y OU 333R
 IN 423E

Mo-sequence ($N=42$ with $[\text{Kr}]5s4d^5$ neutral ground configuration)

Mo IN 610T 678T
 FP 610T

Pd-sequence ($N=46$ with $[\text{Kr}]4d^{10}$ neutral ground configuration)

Pd OU 782T
 IN 007R 678T

Ag-sequence ($N=47$ with $[\text{Kr}]5s4d^{10}$ neutral ground configuration)

Ag OU 001E 037E 198R
 IN 007R 455E 568E 610T 794E 886M
 AI 061E
 MI 001E
 FP 061E 610T

Cd-sequence ($N=48$ with [Kr]5s²4d¹⁰ neutral ground configuration)

Ag⁻ OU 029T
 Cd OU 458R 567T 771R
 IN 007R 575E
 AI 422E

In-sequence ($N=49$ with [Kr]5s²4d¹⁰5p neutral ground configuration)

In OU 062E 619E
 IN 568E
 AI 062E 488E 619E

Sn-sequence ($N=50$ with [Kr]5s²4d¹⁰5p² neutral ground configuration)

Sn AI 352R

Sb-sequence ($N=51$ with [Kr]5s²4d¹⁰5p³ neutral ground configuration)

Sb IN 572E

Te-sequence ($N=52$ with [Kr]5s²4d¹⁰5p⁴ neutral ground configuration)

Te IN 431E 568E

I-sequence ($N=53$ with [Kr]5s²4d¹⁰5p⁵ neutral ground configuration)

Te⁻ MI 816T
 I OU 823M
 IN 200T 625E

Xe-sequence ($N=54$ with [Kr]5s²4d¹⁰5p⁶ neutral ground configuration)

I⁻ OU 024R 029T
 FP 119E 506T
 MP 218T 222T
 Xe OU 024R 027T 057R 090E 199R 201R 370E 458R 499T 514T 638E 747E 748R 761E 808T 832T 872E 884R
 IN 010E 022T 027T 032T 039T 041T 042E 087E 090E 091E 127E 158E 199R 370E 383E 385E 388E 434T 435T
 436T 445E 446E 471E 593T 610T 622E 641T 642T 643M 644E 722T 766R 781T 808T 846T 856E 882T 884R
 AI 042E 352R 516R 788T 884R
 MI 027T 130R 382E 501R 504T 505T 516R 537R 614M 689E
 FP 066M 417T 489E 504T 505T 573E 590E 610T 882T
 MP 003E 004E 005R 077E 118R 130R 135R 136T 137E 169E 213T 288T 319R 361T 391E 404E 405E 473E 474E
 494T 501R 503E 516R 537R 666E 667M 668E 669R 670R 710T 713R 796R 808T 811T 848R 867R 885E
 Cs⁺ OU 199R
 IN 199R
 Ba²⁺ OU 199R 375E
 IN 199R 722T
 La³⁺ OU 026T 199R 375E
 IN 199R

Cs-sequence ($N=55$ with [Xe]6s neutral ground configuration)

Many Z OU 050T 513T ($Z=55-65$)
 Cs OU 024R 025T 050T 057R 237E 251T 264T 333R 341T 624T 732T 771R 884R
 IN 568E 576E 622E 884R
 AI 791R 884R
 MI 621E
 FP 399E 549E 791R
 MP 791R
 Ba⁺ OU 050T 547R

IN 722T
 AI 350E
 La²⁺ OU 025T 026T 050T
 IN 284E

Ba-sequence ($N=56$ with [Xe]6s² neutral ground configuration)

Ba OU 027T 051T 074T 117E 233R 333R 337E 358T 374E 390E 428E 440E 498T 717E 752E 771R 884R
 IN 027T 085R 116E 542T 568E 622E 698T 699T 722T 849T 884R
 AI 102M 103E 104E 105E 113T 154E 163E 238E 248E 249E 293E 325R 352R 425E 426E 427E 428E 676T 677T
 691E 751R 752E 791R 850E 884R
 MI 027T 328E 429E 621E 901E
 SF 427E 751R
 FP 233R 293E 440E 459E 655E 791R 800E
 MP 292E 328E 427E 429E 791R 852E 901E
 La⁺ OU 026T
 IN 284E
 Ce²⁺ IN 284E
 Pr³⁺ FP 787T

La-sequence ($N=57$ with [Xe]6s²5d neutral ground configuration)

La OU 024R 026T 374E 717E
 IN 282T 585R 842E 905R
 AI 842E
 MI 905R
 Ce⁺ IN 284E
 Pr²⁺ IN 284E
 Nd³⁺ FP 787T

Ce-sequence ($N=58$ with [Xe]6s²4f5d neutral ground configuration)

Ce OU 374E 717E
 IN 042E 281E 282T 905R
 AI 042E
 MI 281E 905R
 Pr⁺ IN 284E
 Nd²⁺ IN 284E

Pr-sequence ($N=59$ with [Xe]6s²4f³ neutral ground configuration)

Pr IN 282T
 Nd⁺ IN 284E

Nd-sequence ($N=60$ with [Xe]6s²4f⁴ neutral ground configuration)

Nd OU 909E
 IN 282T
 AI 909E
 Sm²⁺ IN 284E
 Eu³⁺ FP 787T

Pm-sequence ($N=61$ with [Xe]6s²4f⁵ neutral ground configuration)

Sm⁺ IN 284E
 Eu²⁺ IN 284E
 Gd³⁺ FP 787T

Sm-sequence ($N=62$ with $[\text{Xe}]6s^24f^6$ neutral ground configuration)

Sm OU 718E
 IN 042E 622E
 AI 042E 401E
 Eu⁺ IN 284E
 Tb³⁺ FP 787T

Eu-sequence ($N=63$ with $[\text{Xe}]6s^24f^7$ neutral ground configuration)

Eu OU 024R 031T 458R 718E 908E
 IN 622E
 AI 908E

Gd-sequence ($N=64$ with $[\text{Xe}]6s^24f^75d$ neutral ground configuration)

Gd OU 201R 333R 594E 718E
 IN 042E 282T 283E 905R
 AI 042E 594E
 MI 905R
 FP 594E

Tb-sequence ($N=65$ with $[\text{Xe}]6s^24f^9$ neutral ground configuration)

Tb IN 281E 282T 283E
 MI 281E

Dy-sequence ($N=66$ with $[\text{Xe}]6s^24f^{10}$ neutral ground configuration)

Dy IN 282T 283E 905R
 MI 905R
 Tm³⁺ FP 787T

Ho-sequence ($N=64$ with $[\text{Xe}]6s^24f^{11}$ neutral ground configuration)

Ho IN 283E 678T

Er-sequence ($N=68$ with $[\text{Xe}]6s^24f^{12}$ neutral ground configuration)

Er IN 042E 283E
 AI 042E

Tm-sequence ($N=69$ with $[\text{Xe}]6s^24f^{13}$ neutral ground configuration)

Tm IN 140E 275T 283E
 AI 853E 854T
 MI 275T

Yb-sequence ($N=70$ with $[\text{Xe}]6s^24f^{14}$ neutral ground configuration)

Yb OU 086R 164T 460E 807E
 IN 042E 086R 281E 283E 622E
 AI 042E 086R
 MI 128E 281E
 FP 460E
 MP 128E

Hf-sequence ($N=72$ with $[\text{Xe}]6s^24f^{14}5d^2$ neutral ground configuration)

Hf IN 868E

Ta-sequence ($N=73$ with $[\text{Xe}]6s^24f^{14}5d^3$ neutral ground configuration)

Ta IN 868E

W-sequence ($N=74$ with $[\text{Xe}]6s^24f^{14}5d^4$ neutral ground configuration)

W IN 739E 868E

Re-sequence ($N=75$ with $[\text{Xe}]6s^24f^{14}5d^5$ neutral ground configuration)

Re IN 085R 868E

Os-sequence ($N=76$ with $[\text{Xe}]6s^24f^{14}5d^6$ neutral ground configuration)

Os IN 868E

Ir-sequence ($N=77$ with $[\text{Xe}]6s^24f^{14}5d^7$ neutral ground configuration)

Ir IN 868E

Pt-sequence ($N=78$ with $[\text{Xe}]6s4f^{14}5d^9$ neutral ground configuration)

Pt IN 658E 868E

Au-sequence ($N=79$ with $[\text{Xe}]6s4f^{14}5d^{10}$ neutral ground configuration)

Au OU 098E 198R
IN 507E 556E 658E 868E
FP 098E

Hg-sequence ($N=80$ with $[\text{Xe}]6s^24f^{14}5d^{10}$ neutral ground configuration)

Hg OU 396E 567T 574E 743R 758E 759E 771R
IN 261E 743R 759E 868E
AI 186M 743R 759E
MI 690E
FP 880T

Tl-sequence ($N=81$ with $[\text{Xe}]6s^24f^{14}5d^{10}6p$ neutral ground configuration)

Tl OU 129E 201R 333R 900E
IN 868E

Pb-sequence ($N=82$ with $[\text{Xe}]6s^24f^{14}5d^{10}6p^2$ neutral ground configuration)

Pb OU 201R 618E 743R
IN 438E 439E 556E 743R 868E
AI 488E 743R
MP 260E

At-sequence ($N=85$ with $[\text{Xe}]6s^24f^{14}5d^{10}6p^5$ neutral ground configuration)

At OU 314T

Rn-sequence ($N=86$ with $[\text{Xe}]6s^24f^{14}5d^{10}6p^6$ neutral ground configuration)

Rn OU 057R 314T

Fr-sequence ($N=87$ with $[\text{Rn}]7s$ neutral ground configuration)

Fr OU 314T

Th'-sequence ($N=90$ with $[\text{Rn}]7s^26d^2$ neutral ground configuration)

Th OU 201R 333R
 IN 556E

U-sequence ($N=92$ with $[\text{Rn}]7s^25f^36d$ neutral ground configuration)

U OU 019E 793R
 IN 439E 556E
 AI 558E 706E
 FP 065E 359E 400E 554E 555E 558E

Isonuclear sequences

Many Z IN 071T ($Z=01-26$)
 257R ($Z=44-99$)
 613T ($Z=02-36$)
 645R ($Z=06-08, 10, 12-14, 16, 18, 20, 26$)

Ne ions OU 266T 491T

Ar ions OU 266T 533R

Ca ions OU 199R 793R

 IN 199R

Fe ions OU 199R 266T 541T 820T

 IN 199R

Kr ions OU 533R

Xe ions OU 533R 820T

U ions OU 266T