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Rendez-vous: Istanbul

1981 is General Conference Year — the fifth in the history of the EPS — and a year in which we hold the General Meeting of our members.

The General Conference has become recognized as a major event in physics. As the title "Trends in Physics" indicates, the Programme Committee has attempted to arrange a review of significant recent developments over the whole field, presented at a level which is comprehensible to all physicists. Such reviews are increasingly useful as the continuous expansion of our subject forces us into an undesirable, but frequently also unavoidable specialization. In this issue of *Europhysics News*, representatives of the EPS Divisions offer us a foretaste of some of the exciting topics in physics which will be presented at the Conference.

Perhaps the most important aspect of the General Conference is the opportunity which it affords for informal contacts between physicists from all over Europe, and indeed also from many non-European countries. The concern which we feel that science should be used for the enlightenment and benefit of all mankind is reflected in the discussions and workshops on the relationship between physics, education and society which are included in the programme.

The General Meeting is also a special occasion. It provides the only opportunity for our members to exchange views on the EPS, its status, aspirations and development. Accordingly, the agenda will be arranged so that the reports of the officers of the Society will be kept as brief as possible, in order that the members should have an adequate opportunity to express their views.

I wish you all a peaceful and prosperous 1981 and look forward to seeing you in Istanbul in September.

A.R. Mackintosh
President of EPS

TRENDS IN PHYSICS

Some personal views of the current lead points in physics presented by senior members of the EPS Divisions with special reference to the: 5th General Conference, Istanbul, 7-11 Sept. 1981

Atoms in Highly Ionized States

H.W. Drawin, Fontenay aux Roses

Highly ionized atoms play a fundamental role in both astrophysical and laboratory plasmas, especially in fusion-oriented plasmas, and in other branches of plasma applications. Atoms, neutral and ionized, have a direct influence on the thermodynamic state of a plasma and, thus, on its emission properties.

Under most laboratory and many astrophysical conditions, the plasma's state deviates from local thermodynamic equilibrium (L.T.E.), the deviation in general increasing with temperature and decreasing with particle density. As the latter is mostly fixed (within limits), the changes of temperature are the more significant. In order to describe the thermodynamic non-equilibrium state locally and temporally, and especially the spectral dependence of the local instantaneous emission coefficient, recourse is made to models whose input depends directly on atomic properties (such as Einstein coefficients, oscillator strengths, cross-sections, ...) together with more specific data for special purposes. Owing to the peculiar properties of high-temperature plasmas, it is only possible to interpret some measurements through the use of such models.

In the solar corona, for example, where the temperature is of the order of $kT \approx 100$ to 200 eV, one finds up to 14 times ionized iron atoms. Tokamaks, laser-produced and low-inductance spark plasmas on the other hand, now reach temperatures of the order of keV and, thus, permit the ionization of atoms to much higher charge states: in Tokamaks, spectral lines of Fe XXV and Mo XXXII have been observed. Information on many new atomic states is thus needed for plasma diagnostics and plasma modelling. At the same time, these new types of high-temperature plasma, open to physicists a new field, as the observed spectra can be used for testing theoretical structure and collision data, and for stimulating new research work in the fields of atomic

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physics proper and of the atomic physics of highly ionized plasmas in general.

EPS Symposium on Atoms in Highly Ionized States

Because the physics of highly ionized atoms plays an outstanding role not only in fusion research, but also in astrophysics, in the development of X-ray lasers and in our general understanding of the evolution of the plasma state under various physical conditions, and because of the progress that has been made during the past years, EPS decided to organize during the Fifth General Conference in Istanbul a Symposium on *Atoms In Highly Ionized States* with emphasis on the importance of atomic physics in high-temperature plasma research in the largest sense. In the following, a brief review of the proposed programme of invited lectures (selected by an International Programme Committee) is given in connection with recent progress and developments in the various fields.

Edlén Seminar on Level Structure and Radiative Transitions

A necessary pre-requisite for the spectroscopic diagnosis of a plasma is a knowledge of the wavelengths associated with the various ionization stages of an element. At present there is a definite lack of reliable wavelength data for highly ionized atoms, which may be demonstrated by the following example. Tungsten spectra observed between 40 Å and 70 Å on the ORMAK Tokamak were attributed to transitions in W XXXI to W XXXV. From the relative line intensities, relative concentrations of the tungsten species W^{30+} to W^{34+} were deduced. Recent calculations however, have led to the result that the ORMAK spectra should rather originate from W XXVIII which belongs to the AgI isoelectronic sequence. This has important consequences for the thermodynamics of the plasma.

The first afternoon of the Symposium will be organized as a seminar in celebration of Professor B. Edlén's 75th birthday. Edlén, who will give a talk on *Forbidden Transitions and Their Application in Astrophysical and Laboratory Plasmas* has made important contributions to our knowledge of the level structure of highly ionized atoms. His first papers on spark spectra appeared in 1933, while in 1941, he identified all the important spectral lines emitted by the solar corona as transitions originating from metastable levels of the ground state configurations of highly ionized atoms. To this day, Edlén has continued to analyze spectra of highly ionized atoms and recently he deduced level structures of many configurations and provided critical compilations of energy levels of Fe IV, Li I-, Na I-, Be I-, O I- and F I-like systems. His semi-empirical formulae predict wavelengths of ions which have not yet been observed. He discovered important inconsistencies in the wavelengths attributed to the sp ^1P - s^2 ^1S transition of Be I-like iron by different Tokamak groups. Three years ago, Edlén identified new solar coronal lines belonging to Ni XI and Ni XII. His "Handbuchartikel"[1]) is well-known to spectroscopists.

In the same Seminar will be discussed the problem of identifying the ionization stages of highly ionized atoms from their far UV and soft X-ray spectra. The example of tungsten has already been mentioned above and the same problem occurs in X-ray astrophysics. The reason for the difficulty of classifying transitions from the observed spectra lies in the fact that the ground state configurations of the ions possess many equivalent electrons leading to numerous lines which are often difficult to resolve experimentally. The result is that bands are observed, the structures of which need to be evaluated as a function of element and charge state.

Cross-Sections for Fusion and Astrophysical Plasmas

The ideal fusion plasma would consist of hydrogen isotope ions and electrons only, well-separated from material walls by suitably tailored magnetic field configurations. In practice, high-energy plasma particles leak through the confining field, strike the walls and liberate material. Thus, wall atoms such as iron and molybdenum diffuse into the plasma where they are ionized and excited. Excitation and ionization is accompanied by radiative decay and radiative plus dielectronic recombination. This leads to unwanted radiation losses in addition to the always present bremsstrahlung radiation, which has to be compensated by additional power injection in order to maintain the temperature at a high level. Thus, knowledge and control of impurity concentrations is an important problem in magnetically confined fusion plasmas. Also the means for exhausting the ash (helium produced in the D-T reaction) is still unresolved. Many collision processes must thus be considered in order to understand the physical properties and behaviour of such plasmas. A modern introduction to the problems may be found in reference 2.

In both astrophysical and fusion plasmas, electronic excitation, dielectronic recombination and charge exchange collisions have an important influence on the charge distribution. There exist still large uncertainties in the relevant cross-sections and rate coefficients. Two lectures have, therefore been scheduled in which these important problems will be treated.

Both electronic excitation and dielectronic recombination in highly ionized plasmas are, in principle, based on the same physical mechanism: dielectronic recombination is the consequence of an excitation process accompanied by the capture of the exciting electron with subsequent radiative decay. This leads in the spectra to so-called dielectronic satellites to resonance lines, which contribute to the energy losses by radiation. They can, on the other hand, be used for plasma physical diagnostics. In addition to dielectronic satellites one observes satellites originating from inner-shell excitation and inner-shell ionization processes. For a recent review of dielectronic recombination see reference 3.

Charge exchange processes can have a non-negligible influence on the charge state distribution in plasmas. This was first recognized by Chamberlain in 1956 in the case of the relative abundance of hydrogen and oxygen ions due to the accidental resonant charge exchange between O^+ and H. As the relevant cross-sections were not known at that time, he scaled the known H^+ - H cross-sections to O^+ - H and applied the reaction to a supernova remnant. It was only in 1971 that the process was applied to diffuse interstellar regions and it is only very recently that the importance of charge transfer for the calculation of ionization equilibria has been fully recognized, both for astrophysical and for fusion plasmas. The reason for this effect is that the charge exchange cross-sections between neutral and ionized atoms increase with the ion charge, and lead to excited states which contribute to the radiation losses. At present very few experimental data exist; our knowledge is mainly based on theoretical calculations.

Highly Ionized Atoms in Dense Plasmas

Spark and laser-produced plasmas are hot and dense and show strong spatial and temporal variations. In order to understand what is going on in such plasmas as a function of space and time one needs models which account for both the radiation and collision processes. One way to tackle the problems is to establish rate equations and to link their solutions to the observed spectral emission and vice versa. Besides spatial and temporal relaxation phenomena of non L.T.E. states which essentially affect the relative concentrations of the various ion charge states, there occur non-equilibrium effects in the population of levels within multiplets of a given ion. With the charge state increasing, spin-orbit coupling leads to relatively large fine-structure splittings, followed by increasing deviations from the equilibrium population of the sublevels. For instance, for the intensity ratio of the fine-structure components of the Ly α resonance doublet of hydrogen-like ions one has found values of 0.7 - 1.7 in laser-produced plasmas, depending on the experimental conditions and the ion-charge state Z. Refined studies have shown that the fine-structure populations depend in a complicated manner on the various population mechanisms and also that ion-ion collisions must be taken into account in order to explain the observed features. Further, radiative absorption and hydrodynamic effects may contribute to the observed deviations from the equilibrium populations. As these effects are of a general nature, they will be covered in a talk entitled *Rate Equations for Dense Plasmas and Their Applications.*

Highly-ionized species emit lines in the region of weak X-rays. Population inversion would therefore lead to light amplification in this wavelength region, which would provide an alternative to the free-electron laser for which a synchrotron is needed. Recent studies in this field will also be reviewed.

In laser-compressed plasmas, electron densities of the order of $10^{24}cm^{-3}$ have been obtained. The spectral lines of high-Z impurities (added for reasons of diagnostics) are broadened by the Stark effect, and a line shift occurs depending on the ion charge state and the electron density. A measurement of the shift and width or, if possible, the whole profile allows in principle the determination of the electron density. In addition to the electric microfields there can exist self-generated magnetic fields of the order of 10^2 to 10^3 T which also influence the line profiles. And finally the line profiles may be influenced by collective plasma oscillations. Reliable theoretical calculations of the profiles are necessary for diagnostic applications. This new field of application of line broadening will be reviewed and we shall hear how Stark and Zeeman effects may also influence other relevant plasma data such as dielectronic recombination coefficients and opacities.

References

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Atomic and Molecular Collision Physics

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For many decades, spectroscopic methods dominated research in atomic and molecular physics, quite overshadowing scattering experiments which, in contrast, held the stage in nuclear and particle physics. As a result, our knowledge of bound atomic and molecular systems developed much faster than that of unbound systems and important questions such as those relating to interatomic potentials or molecular reaction mechanisms remained without a final or proper physical answer. Only in the mid sixties did experimentalists learn how to master the severe problems inherent in low energy scattering phenomena, while the theoreticians, in their turn, developed the physical concepts necessary for understanding and computing the physical processes involved. The word "collision" — frequently used in this domain instead of "scattering" — underlines the complex character of these many body encounters. Since then, the field of atomic and molecular collisions has grown and spread at a prodigious rate.

In the following we pick out three characteristic topics around which discussions at Istanbul will revolve:

i) collisions of heavy atoms at very high energies
ii) lasers involved in low energy collisions
iii) the role of theory in atomic and molecular collision physics.

Collisions of Heavy Atoms at High Energies

This field was born when heavy ions could be accelerated to energies of several MeV per nucleon. At these energies, not only the colliding nuclei exhibit quite new and interesting features but also the electron clouds. Many of them may be understood in the picture of a quasi-molecule transforming into a quasi-atom by (more or less adiabatic) merging of the two electron shells around a common centre of charge $Z_1 + Z_2$ for some 10^{-20} s. *Europhysics News* reported on these new phenomena in an article by F.W. Saris and Yu. S. Gordeev (vol. 11 (1980) N° 1/2). We shall confine ourselves to those related to the very highest charges and energies.

When we enlarge in a gedanken experiment the central charge of an atom beyond $Z = 137$, strange things happen to the innermost electrons according to Dirac's theory: their spatial wave function shrinks tremendously with a corresponding increase in the high momentum components; the binding energy equals the electron rest mass around $Z \approx 150$ and reaches even the fermi niveau of the negative energy continuum at $Z \approx 173$ (calculated for a charge of nuclear dimensions rather than a point charge). Neither the electron self energy nor the vacuum polarisation are expected to prevent this "diving". Obviously, such atoms would be most desirable objects for investigating fundamental effects of quantum electrodynamics. Although they do not exist in nature, one may create them in a heavy ion collision for the short lifetime of a quasi-atom. At the