Departments of the Research School

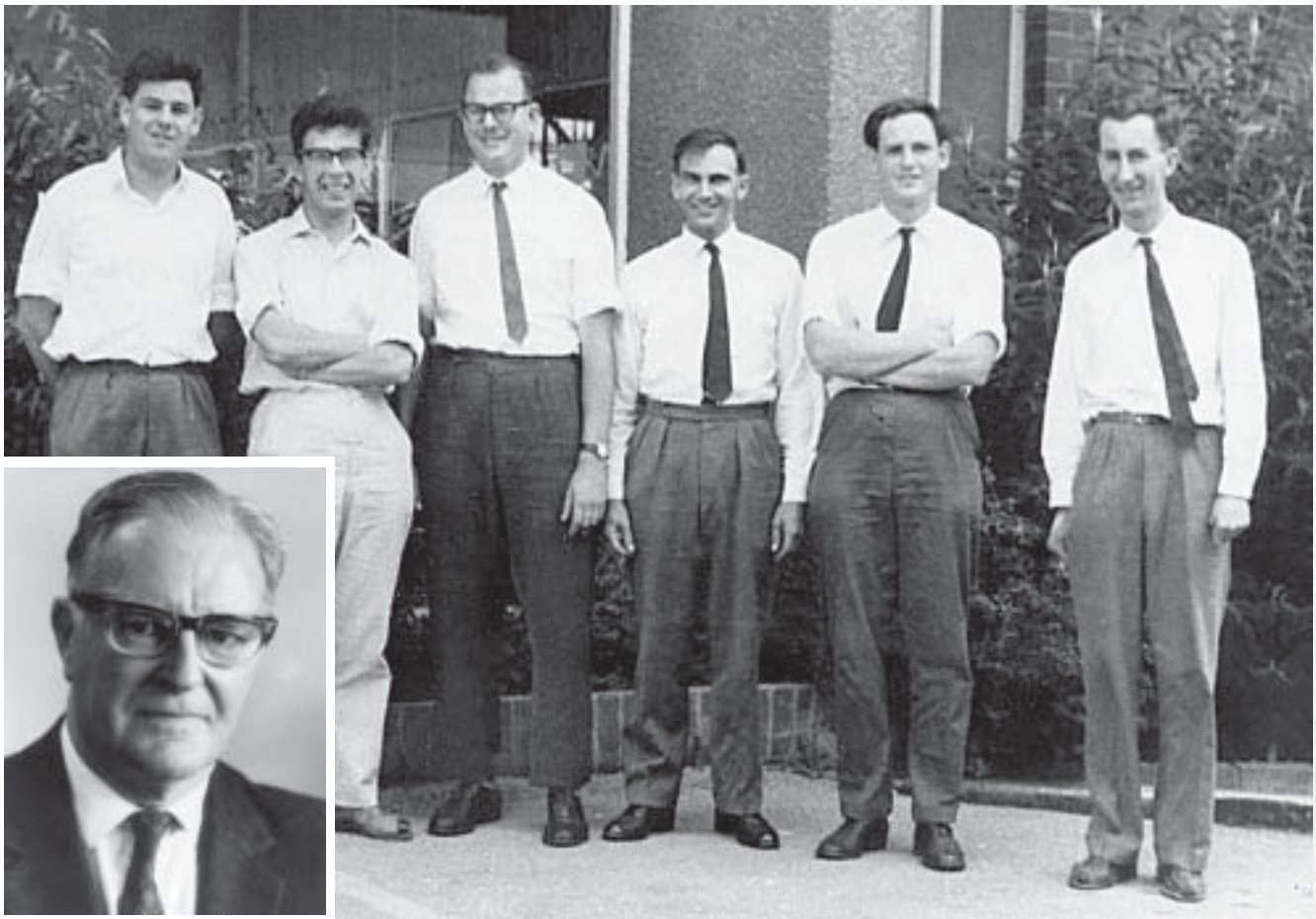
Atomic & Molecular Physics Laboratories

Although formally constituted only in 1981 as an initiative of the then Director, J.H. Carver, the three elements that form the Laboratories, namely the Diffusion Research Unit, the Electron Physics Group (known as the Electron and Ion Diffusion Unit until 1987) and the Ultraviolet Physics Unit have somewhat longer histories.

The Diffusion Research Unit was created in 1964 on Oliphant's retirement, although its first head, R. Mills, had been a member of the School within the Department of Radiochemistry since 1954. Work on various aspects of liquid state physics continued for more than 30 years, first under Mills' direction and then, from 1982, under the direction of its only other tenured staff member, L.A. Woolf.

The Electron and Ion Diffusion Unit (usually known simply as the Ion Diffusion Unit) was formed in 1961 by the then Vice-Chancellor, L.G.H. Huxley, as a separate entity of the Institute. Huxley was head of the Unit, and R.W. Crompton, M.T. Elford and J. Gascoigne, from Huxley's old department at the University of Adelaide, were the other foundation members of staff. On Huxley's retirement in 1967, the Unit became part of the Research School and Crompton assumed the headship.

In its 35 years existence, the Unit has embraced activities other than those for which it was established. In 1974, the technical expertise established to support the work on electron and ion transport led to an approach by B.W. Ninham (Head of the Department of Applied Mathematics) for the Unit to provide space and technical support to establish the experimental work on the direct measurement of surface forces under the leadership of J.N. Israelachvili.



Original staff and students of the Electron and Ion Diffusion Unit, April 1961.
Rodney Jory, Alan Rees, John Gascoigne, Bob Crompton, Malcolm Elford and John Lowke. Inset: Leonard Huxley.

There was a further broadening of the Unit's activities in 1980 when funding was provided for the establishment of a sub-group under R.O. Watts to work on experimental and theoretical molecular physics. In its short life of 7 years, the "molecular beam group" achieved remarkable successes in a highly competitive area, but the work ceased when Watts accepted an appointment in the USA. With increasing emphasis on electron beam experiments under the direction of S.J. Buckman, the Unit's work was finally consolidated into its core activity of the study of low-energy electron and ion scattering. In 1987 the Unit was given its present name and Elford became its head. Buckman took over in 1992 when Elford was appointed head of the Atomic & Molecular Physics Laboratories, and in 1993 the group was enlarged in both numbers and breadth by the arrival from Flinders University of a group working on polarized electron, crossed-beam studies under the direction of E. Weigold, who had been appointed Director of the School one year earlier.
The work and staff of the Ultraviolet Physics Unit also had its genesis at the University of Adelaide. When J.H. Carver was appointed Director of the School in 1979, the creation of a small group to work on UV spectroscopy enabled him to continue his interests in the modelling of terrestrial and planetary atmospheres and the laboratory studies that underpin such work. B.R. Lewis was appointed to lead the experimental program and became the Unit's head on Carver's retirement in 1992.

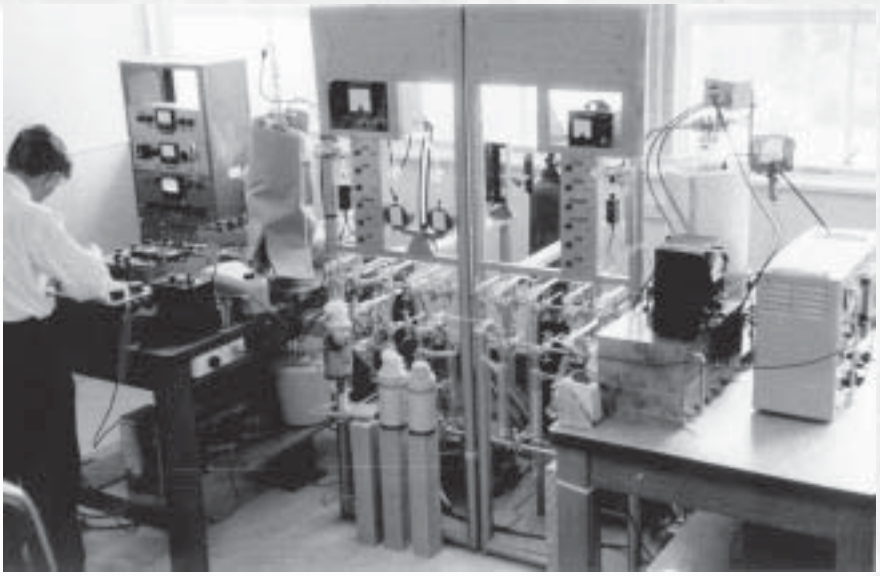
The formation of the Laboratories in 1981 gave some administrative cohesion to the work on atomic and molecular physics in the School and eventually to cooperative research programs between the groups. But the Laboratories remained a confederation rather than a monolithic structure under the direction of its heads [R.W. Crompton (1981-91), M.T. Elford (1992-5), S.J. Buckman (1996-)]; research directions have been determined by the heads of the individual groups, a few highlights of whose activities follow.

Diffusion Research Unit

The work of the Unit stemmed from studies in the mid-1950s which were concerned with diffusion of ions in electrolyte solutions, but was soon extended to molten salts and to non-electrolytes in water and non-aqueous media. Those measurements employed radioactive isotopes as labelled species to follow the progress of diffusion; the availability of such isotopes enabled accurate investigation of the

Staff and students: Atomic and Molecular Physics Laboratories (1987).

Back L to R:
Brenton Lewis, Tom Halstead, Colin Dedman, John Carver, Laurie Woolf, Steve Buckman, Stan Newman, Jack Derlacki, Julian England, Steve Gibson and John Gascoigne.
Front L to R:
Kevin Roberts, Kevin Lonsdale, Alice Duncanson, Bob Crompton, Lynette Robin, Malcolm Elford, Reg Mills and Lindsay Wilson.



Part of the laboratories of EIDU with Bob Crompton at the controls (Circa 1961).

effects of differing isotopic mass on diffusion in liquids, a subject of particular interest at that time because of the potential for nuclear energy applications.

Later, the Unit developed its own nuclear magnetic resonance (nmr) spectrometer to study diffusion at atmospheric pressure and in compressed fluids. Precise measurements made earlier in the Unit for the self diffusion of water, using tritium as a label, were later adopted internationally for the calibration of nmr diffusiometers at atmospheric pressure. Another development beginning in the late 1960s was the design and construction of diffusion cells to measure self diffusion under high pressures using isotopes that were either radioactive or differed only in nuclear mass from the parent liquid. The results were the first accurate data necessary for testing and extending theories of liquids. This work was done at about the same time that R.O. Watts, a Research Fellow in the Unit, developed an improved potential function for argon.

A shortage of literature data for the effect of pressure on the volume of liquids and solutions led to the development of a volumometer capable of measurements up to 400 MPa. The accuracy of this instrument exceeded expectations and enabled thermodynamic data for alternative refrigerants to be calculated from derivatives of the volumetric data measured with it.

During the 1970s and 1980s, the Unit began measuring diffusion data for multiply charged metal ions and water solutions to enable interpretation of neutron scattering experiments being made in the UK and Europe. This led to the development of a simple model of ionic hydration which has been extended during the 1990s to systems containing complex ions. In the last decade the earlier work on diffusion in mixtures of non-electrolytes has proved of particular value for fine-tuning the intermolecular potentials needed for computer simulation of the mass transport properties of such systems.

Electron Physics Group

The core of the research program of the original Ion Diffusion Unit was the accurate measurement of the transport properties of electrons and ions in low pressure gases (so-called 'swarm experiments') and the interpretation of these data in terms of ensemble-averaged data that could be used for a number of applications, for example, to the theory of ionospheric radiowave propagation. However, with the development in the size and speed of computers it became possible to extend the analysis of these data to provide accurate cross sections for electron-atom/molecule collisions or, in the case of ions, interaction potentials. The new levels of accuracy of the transport data and the analyses to determine cross sections from them was a stimulus to many other groups to refine transport theory, and in some cases led to explanations of new phenomena (e.g. anisotropic diffusion, diffusion and attachment cooling).

Cross sections and interaction potentials resulting from this work became the bench marks against which theoretical treatments of electron and ion scattering produced by other research groups could be tested. Benchmark transport coefficient measurements, and benchmark collision data derived from them, became hallmarks of the Group's work, and when later opportunities arose to extend the work to differential cross section measurements

using crossed-beam techniques, this tradition continued.

The brief excursion into neutral-beam studies was equally successful. Major advances were made on two fronts: the development of new theoretical methods for predicting vibrational frequencies in systems with large amplitude motions, and the use of infrared lasers with molecular beams to measure vibrational predissociation spectra of weakly bound clusters. Accompanying theoretical studies resulted in novel quantum simulation codes and a potential energy surface for water molecules which remain at the forefront of research in this area. The experimental research also reported the first rotationally resolved infrared spectra of van der Waals dimers: line widths of the transition were narrower than previously reported by a factor of about 10^4, leading to a major re-consideration of mechanisms for intramolecular vibrational energy redistribution in these weakly coupled systems.

In the last decade, the emphasis of the Group's work has swung progressively towards crossed-beam studies. Notable progress has been made in the application of single collision crossed beam studies to the measurement of absolute differential and total scattering cross sections for a broad range of atomic and molecular species. Specific emphasis is placed on critical comparison with scattering theory, in collaboration with several international theoretical groups.

In recent years the breadth of the Group's activities has been substantially increased to include (e,2e) ionization studies of atoms with spin polarised electron beams, studies of scattering from excited atoms and molecules and, in collaboration with the Laser Physics Centre, the development of an intense, cool and slow beam of excited He(2^3S) atoms to facilitate a range of scattering experiments, spectroscopic studies, atom optics development, and atomic lithography.

Ultraviolet Physics Unit

The original research program of the Ultraviolet Physics Unit comprised two related aspects: first, laboratory measurements of the interaction of vacuum ultraviolet (VUV) radiation with atoms and molecules of significance to problems in astronomy, aeronomy and the photochemistry of the terrestrial and planetary atmospheres; and second, modelling studies of the thermal and photochemical evolution of the terrestrial atmosphere.

The laboratory measurements consisted principally of photoabsorption and photodissociation cross-sections for atmospheric molecules, obtained with the aid of a scanning VUV monochromator of medium resolution. Over the years, the Unit has gained a reputation for the reliability of its cross sections and many important applications have followed; for example, the use of O_2 and H_2O cross sections in calculations of the photodestruction rate of water vapour in the terrestrial atmosphere, and the remarkable use of temperature-dependent CO_2 cross sections to explain successfully CO/CO_2-ratio anomalies in the Martian atmosphere.

The climate-modelling studies of the evolution of the terrestrial atmosphere, begun by J.H. Carver, have culminated in a model which explains successfully most of the past glaciations and, disturbingly, predicts that CO_2 control of the earth's temperature will no longer be able to compensate for a solar flux that continues to increase in the future.

In 1987, two developments occurred leading to a revitalization of the Unit's activities which has continued to the present day. First, in association with K.G.H. Baldwin of the Laser Physics Centre, the successful development of ultra-high resolution laser-based techniques for the generation of coherent VUV radiation led to a considerable enhancement of the Unit's experimental capabilities. Second, following the appointment of S.T. Gibson, comparable theoretical advances were made through the application of the coupled-channel Schrödinger equations methodology of scattering theory to the calculation of molecular photodissociation cross sections.

Although the flavour of the Unit's original research program has been retained, the new developments have led to a greater concentration on the details of the molecular dissociation processes. Advances have been made, for example, in understanding the electronic structure of O_2, the most important atmospheric molecule. In addition, there has been greatly increased involvement in collaborative experimental and theoretical studies with overseas groups, which has served to enhance the reputation of the Unit as a provider of reliable data and as a source of significant advances in the interpretation of molecular spectra.

Bob Crompton