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Alan McLeod Sargeson 1930–2008¹

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Alan Sargeson was an extraordinarily gifted inorganic chemist who consistently made important and lasting contributions to his discipline. His lifelong interests were in the area of coordination chemistry, especially in the stereochemistry and reactivity of complexes involving the transition element cobalt. Notable discoveries included the elucidation of the mechanisms of substitution reactions of cobalt complexes, and the demonstration that amino acid amides and their esters and phosphate esters incorporated in properly designed metal complexes could achieve the high rates of hydrolysis displayed by enzyme reactions. Perhaps most notable was the discovery of the ready formation of cage complexes where the metal is fully encapsulated. His impact on his field was far-reaching, his achievements were at the highest level and for over thirty years he was among the few who dominated the field.

The Early Years

Alan McLeod Sargeson, universally known as 'Sargo' (pronounced Sarjo), was born on 13 October 1930 at Armidale in northern New South Wales to Herbert Leslie Sargeson and Alice Sargeson (née McLeod). He had two older brothers, Leslie McLeod and John McLeod Sargeson. His father trained as a solicitor and, after serving as a magistrate in various parts of the state, became a Senior Stipendiary Magistrate in Sydney and one of the leaders of the judicial system in New South Wales. Alan's mother was born on a farm in Wentworth in the far west of the state.

By a twist of fate I came face to face with Herbert Sargeson presiding in a Sydney court but I did not note the magistrate's name. At that time I was a 21-year-old who had recently run his car into the back of the car in front. My flimsy defence was that my brakes failed. The magistrate, possibly trying to be helpful, asked if I had any evidence, a note from a garage for example, to support the brake failure hypothesis. I was too naïve to realize that the magistrate was possibly giving me a way out. My response, 'no', was honest but not helpful. 'Then it will be



five pounds [a considerable amount for a youth in those days], pay at the counter, next case.' A year or so later I arrived in Canberra to do a PhD with Frank Dwyer who had just recruited Alan. There, with great indignation, I told the story to a much-amused Alan Sargeson who to

¹This memoir will also appear in the 2012 volume of *Biographical Memoirs of Fellows of the Royal Society of London*, where it will include several photographs of Alan Sargeson that do not appear here.

my embarrassment informed me that it was his father who had administered the justice!

Because of Alan's father's work, the family moved when he was six months old to Cessnock and stayed there for about four years. This was followed by another four years spent at Taree near the New South Wales coast. Although this time covered the economic depression of the 1930s, the family did not suffer inordinately and Alan remembered his stay in Taree as pleasant and enjoyable. He grew up in an outdoor environment and developed all of the physical co-ordination that he was later to display. His father and mother were both excellent golfers and his father was fond of fishing. The athletic abilities of his parents were passed on to their sons who were exceptional at sports. Both parents ran a disciplined household and insisted that the children perform their assigned tasks, especially school homework.

Like most children brought up outdoors in good weather, Alan at first did not enjoy school. The outbreak of the Second World War in 1939 was not conducive to scholastic application because he was moved to five different schools in five years as his father was assigned to geographically different courts. When he was 14, they moved to Cootamundra where a teacher named Daphne Morton instilled into the young Alan a strong interest in science. As a result he began pestering his father and the local pharmacist for chemicals, with the predictable results. His final two years at high school were spent at Maitland Boys' High School in the Hunter Valley north of Sydney, now a well-known wineproducing area. The school had good teachers in Mathematics, Physics and English, and by the time he finished he had made up his mind to be a science teacher. He won a New South Wales Education Department scholarship to the Teachers' College located on the grounds of the University of Sydney. This was a common way of defraying the cost of obtaining a science degree; it was the avenue used by Frank Dwyer, Ron Nyholm and myself. The scholarship provided a stipend and paid for the university tuition. In return, the Education Department required that its scholarship holders work as schoolteachers for five years after graduation. If one did not comply, however, the penalty amounted to only a small fraction of the total outlay by the Department. Recognizing the cost-benefit advantage, many chose to pay the penalty with gratitude.

University of Sydney

Possibly because they were influenced by the economic vicissitudes of the depression, Alan's parents were pleased when he decided on taking what appeared to be a secure course; namely, completing a science degree followed by high school teaching. They were not convinced, however, that he should obtain a higher degree. Even so, they did not protest too vigorously when he informed them of his intention.

At that time the University of Sydney science course was structured and undergraduates did not have many choices in the subjects they could select for a science degree. Alan began by studying Mathematics, Physics, and Chemistry and, oddly, Geography. He dropped the last after the first year. He continued with Mathematics, Chemistry and Physics, specializing in Chemistry in the third year. The chemistry courses were dominated by instruction in organic chemistry, especially the study of natural products. As a consequence, Alan did his fourth-year Honours thesis in organic chemistry. He later commented on this decision: 'I have to say that it was a bit of a disaster. In the end I was disenchanted and so was my supervisor.' Fortunately, he had earlier completed a small inorganic project with Frank Dwyer, a distinguished inorganic chemist specializing in coordination chemistry. (Coordination chemistry is the study of chemical compounds bearing coordinate bonds. These are formed by the interaction of a metal ion and ligands that are molecules or atoms with lone-pair electrons such as NH₃. Coordination compounds of cobalt are usually octahedral in shape where six ligands are arranged symmetrically about the metal ion.) Dwyer guessed that Alan was a unique individual, and readily offered him a place as a postgraduate student. The assessment proved prescient.

Soon after the end of the Second World War the University of Sydney started conferring PhD degrees, and a variety of distinguished chemists from the USA and Britain gave lectures in the Chemistry Department during Alan's doctoral studies. These lectures and his association with Dwyer were responsible for Alan's determination to devote his life to research. His doctoral work was on the stability of acetylacetonate complexes (1-4), and the resolution of tris-oxalato metal complexes (5). His first job after completing his PhD, and the required Diploma in Education, was as a part-time evening lecturer at the newly created University of Technology in Sydney (now the University of New South Wales). All of his students worked elsewhere during the day and consequently arrived tired, some falling asleep during his less than polished lectures. Nonetheless, the students appeared satisfied; they bought him beer at the end of the course, as was the custom among Australian undergraduates for certain lecturers. This ceremonial custom was, however, reserved for lecturers who were regarded as 'good blokes', an accolade bestowed only after it was determined that the subject had displayed proper antipodean virtues. These included, behaving as a mate and not being remote. Although university jobs were rare in 1955, a post of lecturer in Physical and Inorganic Chemistry at the University of Adelaide became vacant. Alan applied and, after an interview with the head of department, he was offered the job. The only other inorganic chemist there was Bruce West who later became an inorganic chemistry professor at Monash University in Melbourne.

University of Adelaide

In Adelaide, Alan worked initially on problems similar to those he had researched with Dwyer. Included in these studies was the isolation of EDTA (ethylenediaminetetraacetate) metal complexes, the resolution of tris-(dithio-oxalato) complexes and an initial investigation of the diasteroselection of tris-1, 2-diamino propane complexes of cobalt. Perhaps his most interesting work at that time was that with Wolfgang Sasse, a graduate student of Professor Geoffrey Badger, an organic chemist. Badger at the time was a consultant to the ICI company. Sasse discovered an efficient method of producing di-pyridyl compounds from pyridine using Raney nickel. This research led to the production by ICI of the herbicides, Diquat and Paraquat. He also devised conditions for making the very popular ligand 2,2^t-dipyridyl in large quantities, which hitherto had required elaborate procedures for its formation. One of the side products of this reaction was an insoluble neutral nickel complex bearing

two pyridyl-pyrrolate ligands and a dipyridyl chelate (7). Sargeson and Sasse managed to assign correctly the structure of this complex at a time when there were few easily accessible direct methods available.

Family

In Adelaide Alan met Marietta Anders of Freeling, South Australia, the daughter of Frank Hilton Anders and Joyce Anne Anders (née Barclay). They married on 21 November 1957 in Freeling. Marietta's distant family migrated from Schleswig-Holstein over a century ago and set up a foundry in the Barossa area. This developed into the farm machinery business, E.A. Anders and Sons Farm Machinery Manufacturers and Distributors for the Barossa Valley.

Alan and Marietta had four children, Kirsten Ann, Frank Leslie Anders, William Jon McLeod and Bente Barbara Alice. Although the children turned out well, none became a chemist. At this time there are five grandchildren.

After two years in Adelaide, Alan learned that his mentor, Frank Dwyer, was to move to the John Curtin School of Medical Research at the Australian National University (ANU) in Canberra. He was to lead a unit called Biological and Inorganic Chemistry, a subject that Dwyer developed long before it became fashionable twenty years later. Dwyer was scheduled to move to the ANU in 1958 and asked Alan to help him set up the unit. The University of Adelaide gave Alan leave of absence, while the ANU provided him with a temporary fellowship. After six months, the ANU offered him a Research Fellowship that assured him of at least five years of employment, and he resigned from his post in Adelaide. At the time the decision to leave a tenured job in Adelaide for a job of uncertain duration was problematic. But as we know, it turned out well.

John Curtin School of Medical Research

While at the University of Sydney, Dwyer had speculated that the positively charged tris(ophenanthroline)metal complexes might be toxic, 'rather like protonated strychnine' he said. This rudimentary supposition turned out to be essentially correct because it was later shown that these complexes acted to inhibit cholinesterase in animals. This observation was developed further



Figure 1. The proposed hydroxide ion catalysed mechanism for the racemization of a chiral secondary nitrogen atom bound to a stable metal ion The example shown is for the $[Co(NH_3)_4(arcosinate)]^{2+}$ complex where the (four) NH₃ ligands are omitted.

when Dwyer moved to the John Curtin School in Canberra. There, in collaboration with the Melbourne-based physiologists Albert Schulman and (Roy) Douglas Wright they discovered that derivatives of these complexes were powerful bacteriostatic agents. For some time they were used to control Staphylococcus aureous infections in infants in hospitals in Melbourne. The tris(tetramethylphenanthroline)nickel and iron complexes were applied to the skin, and because of the intense red colour of the iron compound in particular, mothers had to be reassured that nothing was awry. Although the Monsanto Chemical Company showed an initial interest in these complexes, they decided not to pursue their use. Both the iron and nickel complexes are still used by various Australian chemists as topical treatments for abrasions and cold sores. Alan continued to use them for these purposes for forty years.

In addition to the bioinorganic chemistry studies, Dwyer and Alan together with the students in the group continued to pursue some important studies in coordination chemistry; these included the resolution and racemization of tris-o-phenathroline and bipyridyl complexes (Broomhead), the synthesis of polypyridyl complexes of ruthenium (Bosnich), analogous complexes of osmium (Buckingham), resolution of EDTA metal complexes (Garvan) and diastereoselection in chiral complexes using chiral ligands (McDermott). All of these students, save Garvan who was and remains a Christian Brother, went on to academic posts, a circumstance that may reflect the post-Sputnik expansion of science as much as other factors. After as few years of collaboration with Dwyer, Alan began his own programme. Perhaps the most notable achievement of this early independent work was his discovery that secondary amines bound to a kinetically inert metal centre exist in moderately stable chiral forms. The sarcosine (CH₃N(H)CH₂C(O)OH) cobalt complex, $[Co(NH_3)_4(accosinate)]^{2+}$, is chiral only by virtue of the asymmetry of the kinetically stable cobalt-bound sarcosine amino group (41).

The asymmetric nitrogen atom loses its configurational integrity by dissociation of the nitrogen-bound proton. The mechanism in aqueous solution is outlined in Figure 1, where a planar intermediate is formed after proton abstraction either by hydroxide ions or, much more slowly, by abstraction by water.

Whereas this work was interesting and the result was surprising at the time, it had much



Figure 2. Alan Sargeson operating an ionexchange column, a technique that he developed and exploited for the separation of charged coordination compound isomers.

wider implications related to the structures of multidentate polyamine complexes and in many of Alan's subsequent mechanistic studies. As a result of the stereochemical stability of the coordinated secondary nitrogen atoms, new isomers were predicted for octahedral complexes of the ligand, triethylenetetraamine (NH₂CH₂CH₂NHCH₂CH₂NHCH₂CH₂NH₂) for example. These new types of isomers were isolated and characterized by Graham Searle and Alan (58). Their isolation of the chiral trans isomer as a result of the stability of the secondary nitrogen centres occasioned considerable interest and surprise at the time (Figure 2).

Having established an independent research programme, Alan decided to spend a sabbatical year with Henry Taube, a distinguished inorganic chemist at Stanford University. This was Alan's first journey outside Australia. It was to be one of many, almost yearly, visits to the USA and Denmark during his career. Alan regarded these visits as crucial to his keeping abreast with developments in his field and he used them diligently. The visit to Stanford was scheduled for the middle of 1962, but in early 1962 Dwyer suddenly died of a heart attack. He was 51. Dwyer's passing brought into question the viability of the research unit in the medical school and it took some time to resolve the matter. Finally, Alan was put in charge of the unit and was left to deal with the immediate problems. When these were settled, he departed for Stanford in October 1963. At about this time David Buckingham, a former student of Dwyer's, was an Assistant Professor at Brown University. Alan brought Buckingham back to the research unit, and there began a most productive collaboration. The pair had complementary strengths; Alan had an unorthodox inventiveness whereas Buckingham, while not without considerable imagination, was punctilious in the analysis and execution of experiments. The pair initially continued with the work that Alan had started on chiral amine complexes. Later they developed important new chemistry.

Their studies on the base hydrolysis of cobalt complexes are notable (42). At the time there was a long-running dispute as to the mechanism of base hydrolysis of cobalt amine complexes. Thus, for example, the rapid reaction of hydroxide ions with the complex, $[Co(NH_3)_5X]^{2+}$, to give $[Co(NH_3)_5OH]^{2+}$ was envisaged to proceed by either the associative, SN^2 , or by the dissociative SN^1CB mechanisms. These are summarized below:

$$SN^{2}$$

$$[Co(NH_{3})_{5}X]^{2^{+}} + OH^{-} \longrightarrow [Co(NH_{3})_{5}OH]^{2^{+}} + X^{-}$$

$$SN^{1}CB$$

$$[Co(NH_{3})_{5}X]^{2^{+}} + OH^{-} \xleftarrow{Fast} [Co(NH_{3})_{4}(NH_{2})X]^{+} + H_{2}O$$

$$[Co(NH_{3})_{4}(NH_{2})X]^{+} \underbrace{Slow}_{Fast} [Co(NH_{3})_{4}(NH_{2})]^{2^{+}} + X^{-}$$

$$[Co(NH_{3})_{4}(NH_{2})]^{2^{+}} + H_{2}O \xleftarrow{Fast} [Co(NH_{3})_{5}OH]^{2^{+}} + H^{+}$$



Figure 3. Proposed mechanism that leads to the accelerated rate of peptide coupling.

Since the latter dissociative mechanism, unlike the associative process, has a 5-coordinate intermediate, namely $[Co(NH_3)_4(NH_2)]^{2+}$, this intermediate could in principle be captured by extraneous ions, Y⁻. It was shown that Y⁻ ions reacted very slowly with both the starting complex and the product in the absence of hydroxide. These extraneous ions, however, were captured to a small extent during base hydrolysis, providing persuasive evidence for the dissociative mechanism.

Perhaps the most notable work that came from the collaboration was the cobalt promoted amino acid ester and amide hydrolysis and the coupling to form peptides. The bisethylenediamine (NH₂CH₂CH₂NH₂) complex bearing the glycine methyl ester (Figure 3) in dry dipolar aprotic solvents was found to react rapidly with amino acid esters and peptides to form new peptide bonds (59). Thus they demonstrated that the cobalt ion could act as a protecting group for the amino group and also to act as an activating agent (Lewis acid) for the carbonyl centre of the chelated amino acid ester.

In related work (71) they showed that the complex, $[Co(NH_3)_5NH_2CH_2C(O)OC_2H_5]^{3+}$, in alkali aqueous solution rapidly produced the bidentate glycine amide complex, $[Co(NH_3)_4NH_2CH_2C(O)NH]^{2+}$ via the amido intermediate, $[Co(NH_3)_4(NH_2)NH_2CH_2C(O))C_2H_5]^{2+}$.

Whereas the putative amido intermediate has a very short lifetime, it is capable of very rapid reaction with the ester group presumably because of the anchimeric effect, the rate acceleration due to the enforced proximity of the reacting partners.

A similar transformation was observed for the reaction starting with $[Co(en)_2Br(NH_2CH_2C(O) NH_2)]^{2+}$. Displacement of the Br⁻ ligand by hydroxide ions was followed by rapid intramolecular formation of the coordinated amino acid (84). The reaction paths are illustrated in Figure 4. Generally, these intramolecular reactions were found to proceed more than 400 times faster than the corresponding intermolecular reactions.

The Research School of Chemistry

In 1967 the Australian National University completed the construction of the Research School of Chemistry and it was determined that Alan and his group should move there. He left the medical school with some regret because he had profited from the proximal interactions with biologists, but the chemistry school offered unique advantages, not least of which was its more flexible administrative structure. The Sargeson-Buckingham association continued for a few more years at the new school, but it became



Figure 4. Proposed mechanisms for the conversion of glycine amide to the two isotopomers of the coordinated glycine amino acid.

increasingly apparent that the collaboration was not sustainable because promotion required a clear differentiation of individual contributions. Whereas Alan as the senior collaborator was not at a disadvantage, it was considered important that Buckingham develop a distinctly independent area of research. The two separated their work, and after a few more years at the ANU Buckingham returned to his native New Zealand, becoming a professor at the University of Otago. At about this time Alan was fortunate to hire two exceptionally skilled co-workers, Jack Harrowfield and Greg Jackson, who had worked previously with me. Both later became professors at Australian universities.

It was generally known that ions such as Zn^{2+} and Mg^{2+} , for example, were capable of accelerating the hydrolysis of polyphosphates and of phosphate esters. Because of the lability of these metal-phosphate bonds (the complexes

are kinetically unstable) it was difficult to identify the precise steps in the mechanisms of hydrolysis. The ion Co³⁺ forms thermodynamically stable (non-labile) phosphate-cobalt (oxygen) bonds, making them well suited for the study of the mechanisms of phosphorusoxygen bond cleavage. There then began a long series of studies on phosphate ester hydrolysis using cobalt complexes, which resembled the work with amino acid esters and amides (298). Harrowfield and David Jones, a student of Professor Len Lindoy who was at James Cook University at the time, began these studies (160). Thus $[Co(NH_3)_5OP(O)_2OC_6H_4NO_2]^+$, bearing the unidentate p-nitrophenolphosphate ligand in basic aqueous solution was found to form the cyclic phosphoramido ligand accompanied by the release of p-nitrophenolate (NPO). This intramolecular cyclization is believed to occur after deprotonation of a cis disposed ammonia ligand. The estimated rate acceleration for the intramolecular displacement of (NPO) was found to be more than 10⁶ times faster than for the corresponding intermolecular reaction.

A similar intramolecular cyclization, but involving a cobalt bound hydroxyl ligand, was studied with cis-[Co(en)₂(OH)(OP(O)₂OC₆H₄ NO₂]⁺ (199). Some of the steps are outlined in Figure 5. Whereas the coordinated hydroxide ion is at least 10^7 less basic than the free hydroxide ion, the intramolecular process is at least 10^5 times faster than the corresponding intermolecular displacement of the NPO group by free hydroxide ions.

In addition to these biologically related studies Alan continued with his long-standing work on classical substitution reactions of Co³⁺ complexes. Most notable of these was the incisive and comprehensive studies with Jackson on the stereochemical course of cis-[Co(en)₂XY]ⁿ⁺ ions that undergo spontaneous and assisted aquation reactions (140). These and other studies with Jackson provided coherence to an area that was littered with poorly executed experiments and unjustified conclusions.

Perhaps Alan's most notable achievement was the high-yield synthesis of molecular cages where the metal ion is fully encapsulated. Harrowfield initiated this work. Its synthetic conception stemmed from earlier observations in the group that in basic aqueous solutions formaldehyde was capable of reacting with 253

cobalt bound amine ligands, giving in one case a macrocyclic ligand in which adjacent nitrogen atoms of two ethylenediamine ligands are linked by bis-methyleneoxo groups (126). A remarkable reaction occurs when formaldehyde and ammonia are injected slowly and separately into a basic aqueous solution of $[Co(en)_3]^{3+}$. A very high yield of $[Co(sep)]^{3+}$ (Figure 6) was obtained (134, 178).

The polycyclic cage was given the name sepulchrate (sep) for reasons not difficult to divine. Given that Alan had established that coordinated amines were capable of reaction in basic solutions with formaldehyde and that the trimethyleneamine cap in these complexes is the same as that observed in hexamethylenetetraamine that forms spontaneously from formaldehyde and ammonia, in retrospect formation of the cage complex need not have occasioned surprise. As is always the case for very clever ideas, however, they are obvious only after the event. They leave observers wondering why they had not thought of the idea.

The cage complex, [Co(sep)]³⁺, is stable indefinitely in neutral aqueous solutions and in 3 M HCl. The reduced analogue $[Co(sep)]^{2+}$ is stable in neutral and mildly basic solutions; in such solutions it is readily oxidized by oxygen to the original complex, $[Co(sep)]^{3+}$. The [Co(sep)]²⁺ion decomposes in acid solutions by a mechanism that involves protonation of the apical (cap) amines (178). The stability of the higher oxidation state complex [Co(sep)]³⁺is connected with the much lower basicity of the apical amines. The caps of the cage are diazaacetals, which in organic chemistry are known to decompose catalytically in mild aqueous acid solutions by protonation of the amine groups. The homochiral (optically active) forms of the cage [Co(sep)]3+ were isolated and it was found that, upon reduction to the $[Co(sep)]^{2+}$ complex and then on reoxidation, the chirality was completely preserved. This result indicates that the Co²⁺ ion is not released from the cage, a result that was confirmed by tracer $({}^{60}Co^{2+})$ exchange studies (178). This is a most unusual result because nearly all Co²⁺ complexes exchange the metal ion rapidly (microseconds). As well as indicating that the metal is not exchanging, the preservation of the configurational integrity shows that the six (homochiral) nitrogen atoms bound to the metal preserve their



Figure 5. Proposed mechanism for the hydrolysis of p-nitrophenol phosphate ester in basic solutions.

chiral forms despite the occurrence of nitrogen proton exchange. The deprotonated intermediate (Figure 1) cannot invert because of the constraints imposed by the cage structure. The topological chirality about the metal and amino nitrogen chiralities are complementary.

The inherent acid instability of divalent complexes of sep was circumvented with the preparation of $[Co(sar)]^{3+}$ (sar is the contraction of sarcophagine!), an analogous cage complex in which the cap nitrogen atoms were replaced by methine groups (Figure 6).

This complex was prepared in high yield by allowing $[Co(en)_3]^{3+}$ to react with formaldehyde and nitromethane in cold basic aqueous solutions (330). In the initially formed cage complex the apical carbon atoms of the cage caps bear nitro groups. Hydrogen atom replacement of these groups was achieved by standard organic procedures. As expected, the $[Co(sar)]^{3+}$



Figure 6. Molecular structures of the cage compounds $[Co(sar)]^{3+}$ and $[Co(sep)]^{3+}$.

complex was stable in strong acid solutions; its other chemistry was similar to that of the amine capped analogue $[Co(sep)]^{3+}$. Given the expected stability of the free sar ligand, considerable effort was expended in devising an efficient method of removing the metal from the extraordinarily stable complex. Eventually, several methods of achieving this removal were developed, the most widely useful being the reaction of cyanide ions with the Co²⁺ complex in boiling water. Once the free ligand or its acid salts were available, the formation of other metal complexes of sar is a trivial matter in most cases. Thus, nearly all of the first row transition metal ions, some in two oxidation states, have been encapsulated in the sar cage. All of these complexes show remarkable thermodynamic and kinetic stability and some have unusual physical properties (399). Not surprisingly, the study of cage compounds was Alan's predominant interest for the last twenty years of his working life.

The Man

Alan Sargeson will be remembered for his charm and wit. He was always approachable and was at ease with others as he was with himself. He was generous to a fault and considerate to his co-workers. It is notable that nearly all of his co-workers continued their association with Alan either personally or professionally after they had become established elsewhere. Towards the end of his life he became especially close to his family, in particular to his younger daughter Bente.

Nearly everyone who is asked about Alan recalls with amusement his storytelling at various functions, usually after dinners. It seemed that he had a repertoire of only four stories that he would tell over and over again. The number of these that he would tell at any one time depended on the endurance of the audience. It was not the content of the story that moved the audience to hilarity but the telling. The stories were characterized by continuous laughter from Alan who was clearly amused by what he was about to say next, by digressions having mysterious connections to the theme of the story, by exhortations to the audience for help or other contributions. Perhaps the most amusing of these tales was the case of a chemistry professor at the University of Sydney known for a somewhat stilted and serious demeanour. It involved a class demonstration on the action of surfactants. For this purpose a technician produced a live duck, a large, deep glass dish containing water and a bottle of detergent. These were placed on the bench before the student audience and the duck was induced to float on the water. The professor gave the usual explanation for the duck's ability to float. Then with his hand over the duck and looking down, he asked the technician to add the detergent. Much froth was generated; the duck flapped around but did not sink into the water. Thinking that pushing it down into the water would help, the professor pressed down on the duck, which sank, but as soon as the pressure was removed from the duck's back it returned to what appeared to be the same position as it had adopted before the detergent was added. Determined to get the demonstration right, the professor kept adding detergent and continued pumping the duck up and down while the audience roared with laughter. What they could see, but the professor could not, was that the duck simply dropped its legs to the bottom of the dish and used them to support itself in the water. It is uncertain whether this story is apocryphal or not. I have asked former students who had attended lectures by this professor whether this had occurred. They all said they had not seen it, but that they knew of someone who had! For Alan the story as outlined was an opportunity to digress into observations about colleagues, to intermingle observations about current events, and to talk about just about anything that happened to cross his fertile mind. In some cases he would exhaust himself and his audience

with laughter so that he could not finish the tale.

Although Alan never fully admitted it, there was an amusing aspect to his perception of the chemistry he studied. The complexes of Co³⁺ are highly coloured; they vary in colour from violet to green and display all of the colours spanning these two extremes. It was astonishing to discover that Alan was at least partly colour blind and yet he enjoyed working with cobalt complexes. He insisted he was not colour blind, only that he perceived colours differently! He certainly could detect colour changes during reaction, but what he saw was different from normal vision, as anyone will attest who was present when Alan said a compound was blue when in fact it was pink. Marietta recalls that whenever he bought or commented on her clothes they were always blue, and that if he bought her clothes that he thought were red, they were inevitably 'horrible' brown colours that had to be returned.

Alan knew what he understood well and he recognized the areas where his understanding was incomplete or insufficiently mature. He was not afraid to admit a lack of expertise and he developed extended collaborations both in Australia and elsewhere. Many of his co-workers remember taking journeys to visit various experts either to clarify an interpretation or to seek advice on how to perform an experiment. He was always meticulous in ensuring that proper recognition was given to his co-workers.

Like many scientists who have reached the peak of their profession, Alan expected others to perform their science with the same diligence, completeness and integrity that he imposed on himself. He was especially dismissive of scientists whom he saw as using publications for no other purpose than as a method of career advancement. His complete dedication to the integrity of science was perhaps Alan's defining personal characteristic.

His physical co-ordination was astonishing. I remember Alan's accidentally knocking a flask from the bench and 'catching' it with his foot. He remarked that he probably could not do it a second time. After watching him play tennis and cricket, it was clear that he was likely to be able to repeat the flask capture. Had he not chosen the laboratory, Alan almost certainly could have become an exceptional tennis and cricket player with a minimum of dedication. Even well after middle age, Alan would surprise students who had pretensions to sporting provess.

Alan was organized in his scientific work but was less so when confronted with administrative chores. He did serve one term of three years as Dean (Chairman) of the Research School of Chemistry without incident. The impression he gave was that while he was prepared to do administrative work as a duty to his colleagues, his research took precedence. As a consequence he was seldom asked to do routine committee work or to assume posts that involved administration. He was an adequate lecturer but not one whose presentation gripped his audience. At the Research School of Chemistry, research support was distributed according to past performance and not by the elaborate proposals that are required for external funding. As a result, Alan was always well funded to do his work without the distraction of having to write proposals and reports. Further, he had access to generous travel expenses that allowed him to visit other laboratories. Given his modest lecturing ability and his unembellished writing style, one wonders how he would have fared in a granting environment where paper-churning mountebanks all too often prevail.

As will be listed presently, Alan was accorded numerous honours and awards. Although he appreciated receiving these, he carried them lightly. One had to enquire to know which honours he had received. He was engagingly patriotic; the honours were a reflection of the ability of Australians to do science in Australia, he would say. Accordingly he never was tempted to move to another country despite several generous offers.

He retired at 65. He was happy to do so, he said, because it provided an opportunity for a 'young fella' to make a name for himself. As an emeritus professor he continued to come into the department and to participate appropriately in its activities. Soon after retirement his health began to decline, at first slowly but rather rapidly over the last few years of his life. In his latter years he suffered a variety of maladies that made him frail. Two weeks before he died he remarked to me, 'I'm ready to go, I've had a good innings'. 'There is no rush, old mate,' I said. On 29 December 2008, soon after enjoying a happy Christmas at home with his family, he was gone.

Major Honours and Awards

- 1975 Inaugural Award of the Royal Australian Chemical Institute for Inorganic Chemistry and Burrows Lecture
- 1978 H.G. Smith Medal, Royal Australian Chemical Institute
- 1980 American Chemical Society Award for Inorganic Chemistry
- 1980 Bailar Medal, University of Illinois, Urbana
- 1983 Nyholm Medal, The Royal Society of Chemistry, UK
- 1985 Dwyer Medal, University of New South Wales
- 1990 Doctor of Science honoris causa, University of Sydney
- 1992 Centenary Medal, The Royal Society of Chemistry, UK
- 1995 Rolf Sammet Award, Johann Wolfgang Goethe Universität, Frankfurt am Main, Germany
- 1996 Doctor of Science honoris causa, University of Copenhagen
- 1997 International Izatt-Christensen Award in Macrocyclic Chemistry. Brigham Young University, Utah, USA
- 1997 Doctor of Science honoris causa, University of Bordeaux
- 2000 Leighton Medal, Royal Australian Chemical Institute
- 2002 Mathew Flinders Lecture and Medal, Australian Academy of Science

Membership of Learned Societies

- 1972 Fellow of the Royal Australian Chemical Institute
- 1976 Fellow of the Australian Academy of Science
- 1976 Foreign Member of the Royal Danish Academy of Arts and Science
- 1983 Fellow of the Royal Society of London
- 1996 Foreign Associate, National Academy of Sciences, USA
- 1998 Foreign Honorary Member of the American Academy of Arts and Sciences
- 2002 Member of the Royal Physiographic Society, Lund, Sweden

Guest Professorships and Special Lectureships

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1967	Cornell University
1968	University of Western Ontario
1970	University of Copenhagen
1975	Burrows Lecture, Royal Australian
	Chemical Institute
1979	'West Coast Inorganic Lectures',
	USA and Canada
1980	Bailar Lecture. University of
	Illinois, USA
1983	Guest Lectures in 'Frontiers
	in Science'. Texas A & M
	University, USA
	Nyholm Lectures, Royal Society
	of Chemistry, UK
	Royal Society of Chemistry
	Lectures, Australia
	Liversidge Lecture, ANZAAS
1985	Dwyer Lecture, University of
	New South Wales
1987	College of Science Lectures
	at University of Notre Dame,
	Indiana, USA
	Phillips Distinguished Visitor Series
	Lectures at Haverford College,
	Haverford, Pennsylvania, USA
	A. D. Little Lectures at the
	Chemistry Department,
	Massachusetts Institute of
	Technology, Cambridge,
	Massachusetts, USA
	The 39th Annual Falk-Plaut Lecture
	Series at the Chemistry Department,
	Columbia University, USA
1988	Cross Lectures, University of
	Washington, Seattle, USA
	Inaugural Bert Halpern Lecture,
	University of Wollongong,
	Australia
	Earl Muetterties Lectures,
	Chemistry Department, University
	of California, Berkeley, USA

- 1990–1 Miller Research Professor, University of California, Berkeley, USA
- 1991 Dupont Lecture, Claremont Colleges, USA
- 1992 Geoffrey Coates Lecture, University of Wyoming, USA Lee Memorial Lecture, University of Chicago, USA

- 1992 The Royal Society of Chemistry Centenary Lecture, Universities of London, Glasgow, Newcastle, Dundee, Warwick, Sussex, Kent, Hull, UK
- 1993 Visiting Professor and Lecturer, Universities of Bordeaux, Brest and Rennes, France
- 1994 Sherman Fairchild Distinguished Scholar, California Institute of Technology, Pasadena, USA
- 1995 Visiting Lecturer, Universities of Frankfurt, Munich, Heidelberg, Mainz and the Max Planck Institute, Mulheim, Germany
- 1996 Inaugural Graduate Course, 'Organic Reactivity Mediated by Metal Ions', University of Copenhagen (October– November)
- 1998 Guest Professor (May–August), University of Lund, Sweden
- 1999 EPSRC Lecturer (March–April), University of Edinburgh and Newcastle-on-Tyne, UK Guest Professor (July–December), Lund University, Sweden

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