which was endorsed by Mr. R. Fort, who, while in general supporting Mr. Willey's views, argued that fundamental research should properly be the responsibility of the universities. Like Mr. Willey, he echoed some criticism of the British national organization of research which has been recently voiced in *Nature*, but thought that the four research councils provided a good mechanism for determining research priorities and that this pattern could be more widely applied.

In his reply for the Government, Mr. H. Nicholls, Parliamentary Secretary to the Ministry of Works, after reviewing briefly the general pattern of Government support for civil science, pointed out that in the past two years the expenditure of the Department of Scientific and Industrial Research has increased by 23 per cent, of the Medical Research Council by 34 per cent, of the Agricultural Research Council by 20 per cent, and of the Nature Conservancy by 25 per cent. He then announced that the Government has decided to repeat the experiment of financing the Department of Scientific and Industrial Research on a five-year basis. In the first quinquennium ending on March 31, 1959, total expenditure would be about £36 million; for the next quinquennium a total of £61 million is envisaged, reaching £14 million for 1967-68, excluding the contribution to the European Organization for Nuclear Research. Paying tribute to the work of the research associations, Mr. Nicholls said that the thirty-nine research associations and ten smaller organizations in the scheme employ a staff of 4,500, of whom 1,500 are of graduate status, and the 20,000 member firms cover about 50 per cent of manufacturing industry. To their expenditure of about £7 million in 1957-58 the Department of Scientific and Industrial Research contributed about £1.75 million in grants, and for the next quinquennium this will be increased to more than £2 million.

In regard to the universities, Mr. Nicholls agreed that we should look to them mainly for fundamental research and he stressed the value of the increase of

postgraduate awards by about 10 per cent in the next five years. By 1963-64, 3,800 students will be receiving grants for training and research from the Department of Scientific and Industrial Research compared with 1,900 this year, and the amount available for research in universities and similar institutions will also be increased three-fold or four-fold in the next five years. In the current year university building projects to the value of £12 million are being started; for the years 1960-63 this will rise to £15 million a year, and technical college building projects to the value of £15 million a year had been in hand since the end of 1956. He had every reason to believe that the target output of 20,000 scientists and engineers a year set for the late 1960's will be achieved.

In conclusion, Mr. Nicholls said that he understood the decision of the Council for Scientific and Industrial Research with regard to the Microbiological Group at the National Chemical Laboratory was taken entirely on scientific merits and without any Ministerial intervention, which would have been entirely contrary to the spirit of the Act. The Lord President was satisfied that the Council had given extremely careful thought to the matter before giving its decision. Mr. John Hynd later referred to the outstanding £130,000 in the capital cost of constructing the Jodrell Bank radio telescope. Mr. Nicholls, in reply, pointed out that the House itself had welcomed the assurance that no voted money should be spent on covering this outstanding item. Later, in a written answer, he added that the Department of Scientific and Industrial Research had already provided £350,000 towards the cost of construction, and had funds at its disposal for financing research of special timeliness and promise. Any applications from the University of Manchester for grants for future research involving the use of the radio telescope would be considered on their merits, and one such grant of £15,200 had recently been offered.

A RADAR SIMULATOR SYSTEM

DURING the Second World War the training of Royal Air Force radar operators was greatly facilitated by the use of apparatus which enabled aircraft echoes to be simulated on the screen of the cathode-ray oscillograph in the radar receiver. Much ingenuity was applied to devising techniques whereby such artificial echoes could be produced and applied to the radar in such a way as to simulate the movement of a real target. By the use of the training equipment which resulted, the need to produce real echoes by flying aircraft was obviated, with consequent savings in fuel, wear and tear of aircraft and elimination of the difficulties of organization and administration.

From these war-time beginnings subsequent development of radar trainers has been considerable, as was shown by the demonstration recently given at the Farnborough works of Solartron Electronic Group, Ltd., of an elaborate installation for simulating air defence exercises and providing realistic instruction in the radar control of the interception of bomber aircraft by fighters. The equipment has been developed under the auspices of the North Atlantic Treaty Organization for use by the Italian Army.

The installation includes seven desk consoles each containing circuits for generating pulses which, when applied to the display oscillograph of a radar receiver, appear as normal aircraft echoes. Each console can simulate two aircraft. Means are provided in the consoles for moving an 'aircraft' along any desired track at speeds which may be varied between its stalling and maximum speeds. Controls are also provided for rate of turn and rate of climb, again in accordance with the capabilities of the aircraft being simulated.

All 'echoes' are displayed on a central plan position indicator from which the general state of the exercise may be studied.

The echo signals, which may be designated as originating from friendly or enemy aircraft as desired, are also displayed on the plan position indicators of a radar receiver. In so doing, the apparatus takes into account the horizontal and vertical radiation patterns, including side lobes, of the aerials of the radar being simulated. These plan position displays enable interception techniques to be practised by a controller who telephones instructions to the operator of the desk console simulating the fighter, who varies

the course of the fighters so as to bring about interception of the bombers. Bomber control may be carried out if required by a controller at another plan position indicator.

An interesting adjunct to the equipment is the simulation of electronic radar counter-measures both by parachuted noise jammers and by the dropping of strips of metal foil ('window'). In both cases means are provided in the equipment to take into account the effect of the prevailing wind on the drift of the jammers.

In the design of this versatile installation, the likelihood of future changes in the performance of aircraft and radar, and of air defence procedure in general, have been borne in mind, and the necessary modifications and additions to the installation to deal with such changes are readily made.

Equipment similar in principle to that demonstrated may be used for simulating marine exercises in which both radar and asdic are used, and it may also be used for training in civil air-traffic controls.

A. F. WILKINS

CHEMISTRY AND QUANTUM CHEMISTRY

IN the course of the past twenty-five years the language of quantum mechanics has invaded almost every branch of chemistry. Often this has been at a very qualitative level involving only such basic concepts as those of stationary states and energy-levels. Many of the most useful ideas, however, are ones which do not belong to accurate quantum mechanics but arose first in certain approximate calculations and have since been developed by using them to explain experimental facts. These range from the idea of a crystal potential which is used to make qualitative predictions about molecular complexes, to ideas such as hybridization and resonance which are used qualitatively to describe the structure and reactivities of molecules. Unfortunately, it is becoming very clear that most of these ideas need careful re-examination both to establish their quantum mechanical status and to show how they can be refined or modified to explain the more extensive and more accurate experimental results now available.

It was very appropriate, therefore, that this problem of the correspondence between the concepts of chemistry and those of quantum chemistry should have been the subject of a panel meeting held at Valldalen, in the Swedish mountains, during August 26-30 and organized by Dr. P. O. Löwdin, director of the Quantum Chemistry Group in Uppsala. The audience consisted primarily of experimentalists who had spent the previous month there at the summer school on quantum chemistry, and the panel included both chemists and quantum chemists. The meetings were pleasantly informal, and, since the number of prepared contributions was deliberately kept small, there was ample time to discuss fundamental problems.

The theory of molecular structure based on the overlapping of hybrid atomic orbitals which are concentrated in the bond directions was one topic discussed, and in particular the idea of assigning a constant atomic radius to each kind of hybrid. Experimental methods of determining molecular structure using micro-waves, electron diffraction and X-rays were reviewed by Prof. B. Bak (Copenhagen), Prof. K. Hedberg (Oregon), Prof. O. Bastiansen (Trondheim) and Dr. I. Lindqvist (Uppsala), and they reported that the accuracy and flexibility of these methods had recently increased considerably. The results were shown by Prof. Bak and Dr. I. Hjalmarsson (Stockholm) to imply that the approximation of a constant radius for each hybrid is often accurate to 0.001 Å. Furthermore, as Prof. L. Pauling (Pasadena) showed, the rotational barriers

can be predicted by including in the hybrids small amounts of higher angular terms, and the experimental confirmation of these predictions was discussed by Prof. L. Pierce (Notre Dame). On the other hand, Dr. Löwdin pointed out that the principle of maximum overlapping is quantitatively inaccurate even on an approximate theory and that the accurate theory does not even give any unique hybrids. In consequence, it is difficult to believe that the hybrids have any physical reality. Prof. R. S. Mulliken (Chicago) agreed that there is still no basic theoretical reason why covalent radii should be so constant.

There was general agreement on the artificial nature of the distinction often made between ionic and covalent binding. Both Dr. S. Lundqvist (Uppsala) and Prof. H. Shull (Indiana) pointed out that ionic wave-functions can sometimes give covalent properties and be almost identical with corresponding covalent wave-functions. This led naturally to a discussion of the method of 'atoms in molecules' which uses such wave-functions. Dr. R. Puncz (Haifa) showed that, when the method is applied literally to hydrogen, the results are rather poor, but Dr. H. Preuss (Göttingen) defended the method in a modified form. It seems clear that the unmodified free atoms or ions do not provide the best units for describing the compound.

The concept of hyperconjugation is also in some difficulties. This type of delocalization of the electrons plays an important part in the excited states and ionized states of many molecules and in transition complexes, but it is not so clear that it is important in molecular ground-states. The concept was strongly defended by Prof. Mulliken, and he claimed that there is sufficient experimental evidence to substantiate it even for the ground-state. The concept of conjugation also has recently been attacked, but Prof. Mulliken thought this was because the simple Hückel theory sometimes exaggerated its effects, for example, in butadiene, whereas more recent theories give much better agreement with experiment. Dr. R. McWeeny (Keele) argued that the study of diamagnetic susceptibility and proton magnetic resonance gives very strong evidence for conjugation, although Prof. Bak and Mr. R. A. Hoffman (Uppsala) pointed out that some proton magnetic resonance effects in conjugated molecules are not yet understood. Dr. S. Sunner (Lund) talked about difficulties in understanding resonance and strain energies and suggested that these are often due to the use of unrelated or inappropriate reference states.

A point which emerged clearly from the discussion is the growing tension between the so-called semi-