Chemistry in Action

THE NEW ZEALAND INSTITUTE OF CHEMISTRY (INCORP.)

1931

PER LIBRAM ET LIBRUM

Message from President . . .

The New Zealand Institute of Chemistry represents nearly 600 scientists engaged in a wide variety of chemical pursuits, such as advising and directing industry, research, and teaching in schools and Universities.

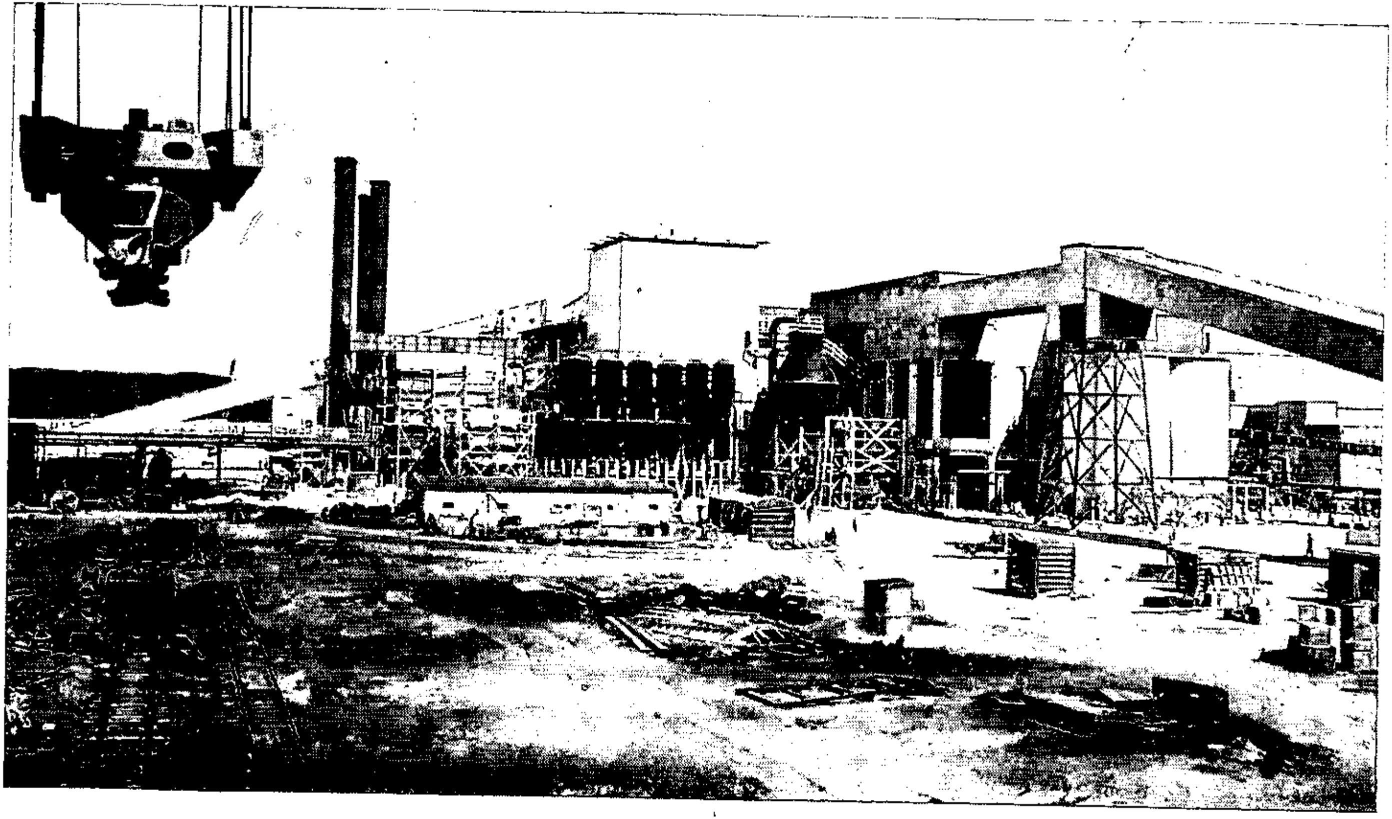
For some time its members have felt that pupils leaving school should be told about the scope of work undertaken in this country by scientists working in the field of Chemistry.

This booklet, which comes with the compliments of the New Zealand Institute of Chemistry, contains talks given to sixth form pupils in the Canterbury area by three of our members who are authorities in the widely-different fields of nuclear chemistry, chemical engineering, and agriculture.

It is sincerely hoped that these talks will help to inspire pupils leaving school to take up professional careers in chemistry, for a wide variety of interesting and responsible positions will be open to them in the future.

C R Barnicoat.

President.



Industrial development means more chemists needed urgently.

A fine example of the type of new chemical industry springing up in this country — a view of a section of the Tasman Pulp and Paper Company's works at Kawerau.

LIVING CHEMISTRY

By T. W. WALKER,
Professor of Soil Science, Canterbury Agricultural College, Lincoln.

Perhaps Chemistry seems dull to some of you at school, and it is my task to show you how fascinating Chemistry can be, at least in my sphere of interest, which is to do with living things — soils, plants and animals. You know, some chemists (they call themselves pure chemists!) may look down their noses at people like me. One of my lecturers at the Royal College of Science, who is now a well known Professor at Cambridge, was absolutely disgusted when I decided to specialise in Agricultural Chemistry after graduating in Chemistry, but I have never regretted it. I have found the chemistry of living things so enthralling that my job is my hobby and if a man can say that, I believe he should be truly happy. Fancy being paid to do something you would rather be doing than anything else on earth!

Living chemistry covers a wide range of topics. You might be interested in what makes plants and animals grow, what they are made of, how cells grow and multiply, what makes a boy's voice break, what makes a girl develop a beautiful figure, what makes me fall in love, what are those strange things we call viruses which can be crystallised like many other materials and yet grow and multiply in the right environment, why do people get goitre or cancer, how did life originate, will man ever create living organisms? A biochemist, because that is what we call a chemist who works with living things, may be interested in these and many other matters which touch our daily lives at many points.

Now I am going to narrow this field and talk about soils, plants and animals, not only because they are the things I work with, but because the economic well-being of this country depends on them. I want to try and give you a picture of what we know about these things and what we do not know, so that some of you, who imagine yourselves as budding Rutherfords, decide to become budding biochemists.

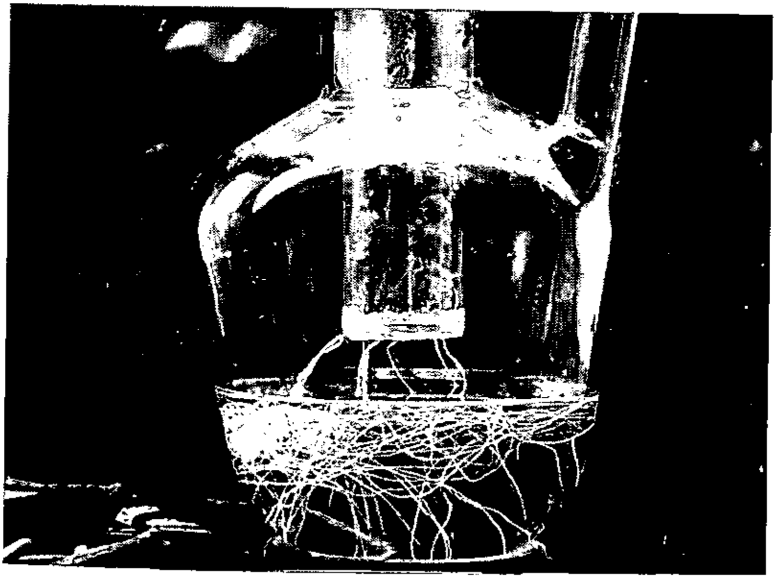
You all know something about soil. You make mud-pies with it when you are young, you get your shoes dirty trying to find a secluded spot when you are courting, and one day you will be buried in it. A handful of soil, unless it contains a worm or grass-grub, or some creepy-crawly thing, looks dead and inert, but it teems with life. There are literally millions of microbes in a teaspoon of soil; without their work plants would not grow and without plants there would be no animals. These microbes do many varied jobs. Some of them can take nitrogen gas from the air and convert it into protein; some are busy decomposing proteins and turning the nitrogen back into nitrogen gases. Some are busy breaking down dead roots and leaves and the dead bodies of creatures into simple inorganic compounds such as ammonia, nitrate, sulphate and phosphate, and then plants will use these again to make more protein and carbohydrates and vitamins and so on.

Clearly a problem in clover nutrition! The author and an associate compare a healthy and a poorly nourished clover plant.

Oh yes! Soils are certainly alive. Do you know, some old farmer once told me soils were like new-born babes: you had to keep their face clean, their bottom dry and their belly well filled! In his particular area, cropping was important and rainfall was high, and what he meant was that you had to carry out proper crop rotations to keep down weeds, pests and diseases to a minimum, you had to drain the soils and you had to apply plenty of fertilisers and lime and manure.

What is it that plants get from soil which enables them to grow; why do plants grow well on some soils and not on others? Let us take a plant and analyse it. We find it consists chiefly of water — about 80 per cent. The rest of it, which we call dry matter, contains proteins, carbohydrates, waxes, fats, oils, pigments, vitamins and many different elements. We can find as many as 50 different elements in plants and it is some of these elements, which plants get from soil which enable them to grow and manufacture their proteins and other things; they make up only 1 or 2 per cent. of the fresh plant. Now plants will take up all kinds of elements from the soil if they are there, even if they do not need them, such as gold and silver, and poisonous things like arsenic and selenium. This is fortunate in some ways because plants will take up cobalt and iodine and fluorine and sodium from soil, which as far as we know, the plants do not need, but animals do, and animals eating those plants get the benefit. Now which elements must plants get if they are to grow? In addition to carbon, hydrogen and oxygen which they get from air and water, they need nitrogen, phosphorus, sulphur, calcium, magnesium, potassium and the so-called trace elements, iron, manganese, copper, zinc, boron, molybdenum, chlorine and perhaps vanadium. Perhaps others may be added to the list in time, but if so, they will be needed in extremely small amounts. Molybdenum for instance, which was only added to the list in recent years, is needed in such small amounts that 5000 tons of hay would contain only about 1 lb. of molybdenum, whereas it might contain about 100 tons of nitrogen, 10 tons of phosphorus and sulphur, 50 tons of calcium, 20 tons of magnesium and 75 tons of potassium.

Now here is the point: If a soil is short of any one of the essential elements needed by plants, or sometimes if there is too much of one of them or certain other metals, then the plants will not grow well. (Can you see a relationship with animals here? Some of us eat too little and fail to grow well, others of us eat too much and become gross and cumbersome and prone to disease). What I have just said is not quite true fortunately for New Zealand. There are certain plants known as legumes (and some other plants and bacteria) which, if they have all the essential plant foods but nitrogen, can fix nitrogen gas from the air and manufacture it into proteins and the like. Actually it is not the legumes themselves that fix the nitrogen; they have a gentleman's agreement with some little bacteria that live in nodules on the roots. It is these bacteria that fix the nitrogen from the air in return for sugars, etc., that they get from the plant. Can you see why clovers are so important in New Zealand? Plants need more nitrogen than any other plant food, and the amount needed to grow a productive pasture that will feed a dairy cow or 6 to 8 sheep per acre for a year is about 400 to 500 lb. of nitrogen. Now the soil microbes that live in the soil organic matter and break down the complex protein nitrogen into ammonia and nitrate (which are almost the only forms of nitrogen that grasses and other non-legumes can use) can only produce about 100 lb. of nitrogen per acre per year in these forms, even on the most fertile soils. This is 300 to 400 lb. less than we need for our high-producing pastures. This is where our clover comes in, because if we give it all the necessary plant foods but nitrogen, then under our best climatic conditions clovers can easily fix this amount of nitrogen from the air. Here then is the secret of our high producing pastures, here is the main source of our wealth, our high standard of living; and it all depends on those little microbes living in harmony in the roots of their host plant — the clover. We have to find out which, if any, of the essential plant foods other than nitrogen are deficient in a soil; it might be phosphorus or sulphur or potassium or calcium or molybdenum or boron or copper or any other I named. We have to apply the missing or deficient element. Then, if our clover plant has these nodules on its roots, and if the microbes in them are efficient (some are lazy!), the clovers will grow well, a lot of nitrogen will be fixed from the air and we can get our highly productive pasture. There's a thrilling job for some of you. I know of few more satisfying experiences than to be asked by a farmer why his pastures or crops are so poor, to be able to diagnose the cause of the trouble, recommend a suitable treatment and watch " the desert rejoice and blossom as the rose". We can do this by analysing the soil or plant, or sometimes merely by looking at the plant. Plants are also like us; if they are short

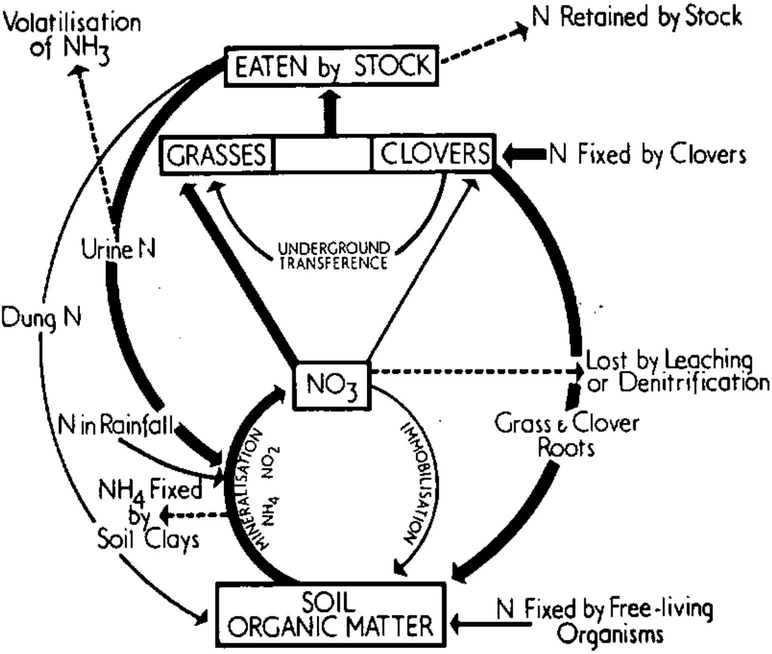


The oldest nitrogen-fixation process! Clover plants being grown under sterile conditions in order to study their nitrogen metabolism.

of an essential food they show specific symptoms of the deficiency, and with experience one can diagnose the cause, just as a doctor may examine symptoms of disease in human beings.

In New Zealand we find that the major deficiencies limiting clover growth and pasture production are phosphorus, sulphur, potassium and lime or molybdenum, but others may be responsible and there is still much to learn.

Supposing we can take any soil and find out just what we have to apply to make clovers grow well. We are at the stage where this is nearly always possible, but our troubles are by no means over. Animals must eat the pastures we grow and just because a plant is well grown, there is no guarantee that animals will thrive on it and we know very much less about just what grazing animals need from pastures than we do about what the pasture plants need from the soil. An animal is a more complex organism than a plant and heaven knows that is complicated enough. To take the simplest cases, we know that animals need cobalt, iodine, fluorine and sodium and that plants do not, or if they do, they need so little that there may be much less of them in the plant than the animal needs. It is possible therefore to have what looks like a perfect pasture and still get cobalt or iodine deficiency in animals, and there are many areas in New Zealand where stock



suffer from cobalt deficiency, and one only has to apply a few ounces of cobalt sulphate to the acre to cure the trouble. We now know why cobalt is necessary; it is an essential constituent of Vitamin B_{12}, needed by animals, and in the case of ruminating animals like cows and sheep, certain micro-organisms in the rumen can synthesise Vitamin B_{12} from the cobalt in the herbage. Without enough cobalt the animals just fail to thrive and give rise to what was called "bush sickness" or "Morton Mains" disease before we knew what caused it.

No doubt about the response of clover to sulphur fertilizers! Research workers compare the gypsum treated strip, on which they are standing, with untreated areas on either side.

Another disorder in stock, which is being sorted out, is copper deficiency. Now this can be caused by a low copper content in the herbage (here again plants will thrive when they contain much less copper than animals need), or because even if the copper content is reasonable, a high molybdenum content may cause copper deficiency in the animals and there are many other factors associated with it too, which are not yet well understood. And there are other stock troubles such as facial eczema, ill-thrift, and many others about which we are still very much in the dark. While many problems associated with making soils more productive have been solved, much more effort must now be expended in solving some of the associated animal disorders.

For this task we need especially biochemists, who have graduated in chemistry, studied biochemistry and plant and animal physiology. It requires a long period of training, just as long as, if not longer than, taking a medical degree. But what important tasks there are in this sphere, particularly for New Zealanders. I have been emphasising some practical aspects of biochemistry as applied to our major industry of agriculture, but there are equally important aspects of a more fundamental nature which could engage your life interest.

You young people of New Zealand live in a wonderful country, which I do not doubt you want to serve to your utmost capacity. For as far as one can see ahead, agriculture, and in particular the grazed pasture and fundamentally the clover, will be of supreme importance in the economy of this country. I have given you a very brief outline of the situation and tried to indicate where soil, plant and animal chemists can make a real contribution. We need some of the best brains in this country in agriculture, whether as extension officers in the Department of Agriculture who need to have done chemistry to at least Stage I, or graduates in chemistry, who are prepared to study and carry out research on soils and plants and animals. The personal reward of a satisfying vocation is guaranteed. The unravelling of the marvellous secrets of nature is the challenge and, in itself, a sufficient reward. As stated by some philosopher in Britain many years ago, " the man who can make two blades of grass grow where one grew before is of more value to mankind than all the politicians." On our shoulders is placed the heavy burden of growing more and more food for an ever-increasing world population. Let us accept the challenge.

"FROM FLASK TO FURNACE"

BY S. R. SIEMON.
Professor of Chemical Engineering, University of Canterbury, Christchurch.

I am delivering this lecture not because I am a chemist or because I am a professional lecturer, or for any other reason except that when a fifth former at the Brisbane Grammar School in the State of Queensland there fell into my hands (on the 2nd February, 1932 to be exact), a book called "Creative Chemistry." It was a second hand book, even then 9 years old. It cost me the large sum of 3/6, not a decent week's pocket money for you young people, but it certainly was not a second-rate book for it has held me in its grip ever since. It told the story of chemical developments commonplace to you — synthetic ammonia, coal tar dyes, synthetic perfumes, rayon, synthetic plastics, oil, new metals like aluminium, carborundum; all those products that were thrillingly new at the beginning of this century. These spectacular new developments caused it to be said that if the 19th century was the century of the mechanical engineer, the 20th century was the century of the chemist.

Now half-way through the century we are able to see how true that is. We can barely touch a thing around us without contacting the products of "creative chemistry." Our foods are coloured by them, flavoured by them. Our tables are covered by melamine resins, our houses painted with synthetic lake colours, our gardens made fertile with synthetic manures; we wear nylon, terylene, orlon, p.v.c. soles on our shoes, use synthetic toothbrushes, wash-up with synthetic detergents, walk on p.v.c. floors; even our roads are paved often as not with gas-works tar or petroleum tar from refinery processes. We drink out of polythene tumblers. Electro-chemistry supplies our silver-plated spoons, our chrome-plated motorcars, the acetylene that welds our bridges and the synthetic rubies for our watches.

Those of you who have listened to our Prime Minister speaking on recent Sunday evenings will have been struck by the list of basic requirements which we take for granted in New Zealand, viz., food, clothing, shelter. In South-East Asia, you remember, he said that even the first was not yet adequately supplied on the average. Professor Walker has told you something of the part played by the chemist in the production of food. I shall extend his story and in addition say something about clothing and shelter, transport (which is auxiliary to supplying these basic needs), and also touch on another need that will no doubt be amplified by Mr. Rafter, the intellectual need (or curiosity) for knowledge about how the physical world works.

I hope you will excuse me if I tell you of the chemist's contribution to these human needs in the form of stories. I realise that you have grown out of the adventure story stage, but when you reach the "old fogey" stage like myself you will probably like to tell stories. They will start something like this — "When I was your age . . . . " or "When I was in America . . . . "

Margarine and Butter

Every day we have on this planet of ours an extra 70,000 mouths to feed. Most of these 70,000 children are born to people too poor to feed themselves adequately let alone the extra children. Now this earth of ours is a desert island with no visible imports except meteorites and no exports at all. So, in spite of our rocketeers, there appears little hope of help from outside. Fortunately we have one invisible import which we do not earn and over which we have little control, viz., light from the sun. We need this sun ourselves, but we take little advantage of it, neither do the other animals.

Among the needs of animals is edible fat for fuel and insulation. When we can afford it we like to eat more and more fat. The higher the income of people the more fat they eat.

Fat consumption per capita in countries with average income

under $100 (£30)	7.9 lb.
$100-300 (£30-£100)	16.2 lb.
$300-500 (£100-£200)	29.1 lb.
over $500 (more than £200)	42.7 lb.

In Europe the per capita consumption of edible fat doubled between 1850 and 1950 as the standard of living rose. When we can we prefer to eat butter, but animals are inefficient using perhaps only 25% of their vegetable food, and hence butter is expensive compared with vegetable fats and oils. Even by 1870 the increased wealth of Western Europe had caused pressure for more butter while at the same time a slower increase in farm productivity caused an increase in the price in the growing industrial cities. This gap was closed by the chemists who first of all about 1870 found a way to emulsify animal fats with water to give a spreadable material, and then in 1900 found how to raise the melting point of liquid oils by hydrogenation to give solid fats which could be used. Previously to this only coconut oil and palm kernal oil could be so used and they had notable disadvantages, viz., getting brittle in cold weather, and going rancid rapidly. This last advance enabled the brilliant sunshine of the tropics to be used, since the rapid growth of plants there produces cheap oils of palms, coconuts and whales (in the sea of course) and other oil seeds. The oil palm, by the way, grows under conditions too hot and wet even for rice.

The use of margarine has expanded enormously so that it is now (per capita) in —

United Kingdom	16.7 lb.	margarine	for	every	16.8 lb.	butter
United States	6.1 lb.	„	„	„	10.9 lb.	„
Germany	16.4 lb.	„	„	„	13.3 lb.	„
Netherlands	37.4 lb.	„	„	„	5.7 lb.	„

The palm oil so used releases valuable land for the production of other food, especially animal protein, so margarine really is not a substitute for butter any longer but fulfils a real social need itself.

Transport — Petroleum

Nowadays practically all the energy required to carry people and things comes from petroleum, indeed about half of all energy developed comes from this source.

The chemist is an economical soul, and no better example of this can be obtained than the petroleum industry.

In a petroleum refinery crude oil of any old composition goes in, and out come a variety of products. In between, the useful molecules are sorted out, and the others are carefully changed in nature to enable them to be useful. A refinery is a sort of reformatory where organic molecules are turned into useful citizens. and also the really bad ones are eliminated.

After separation of fractions of crude oil according to their various by-products there follows the reformatory part. The good boys go to plants where they are " sweetened up " by having the dirty spots washed off by chemical treatment. The bad boys (heavy unwanted fractions) are given harsher treatment in units called " catalytic crackers " which actually take them apart and rearrange them into useful citizens at temperatures of up to 500°C. Some of the good boys — petrol volatile enough but not good enough for modern cars goes to the " platformer " where it is improved by a platinum catalyst to give good operation in an automobile engine.

Today a gallon of oil develops twice as much power in modern cars as it did 25 years ago. Much of this change is due to improved engine design, but the engine changes necessary were known 20 years ago. Their use had to await the development of fuels suitable. Earlier petrol would not behave. If it was compressed firmly in an engine it got bad-tempered and went off with a rough " bang " instead of a smooth " whoosh." Now we have available hydrocarbons so changed in structure as to behave themselves when compressed to an extent not before possible.

When the economical chemist has finished with the molecules there is not much left that is not usable petrol, or kerosene, or lubricating oil. What is left is *either* intractable sticky stuff that may be used as heavy residual fuel oil (boilers) or bitumen (for roads) according to the type of oil *or* gas. Much of the gas has the type of molecule that has a spare pair of arms ready to grab anything attractive nearby. So give it chlorine, bromine, water, or even another of its pals, and it will produce a variety of solvents, plastics, etc.

Ethyl (Lead Tetra Ethyl)

One way of making a bad boy behave is to give him a good companion, preferably one of the opposite sex. Then he will take to brushing his hair, cleaning his shoes and saving his half-crowns.

In the early part of this century an American engineer, Charles F. Kettering (who invented the self-starter for cars) asked a certain Dr. Thomas Midgley to try to find such a companion for petrol hydrocarbons to make them better behaved. In 1921 Midgley discovered lead tetra-ethyl. He found that a very little of this produced a large improvement. There were some difficulties, especially deposition of PbO and he had to devise ways of getting over this, viz., the addition of $C_2H_4Br_2$, or $C_2H_4Cl_2$. The production of tetra ethyl lead is now a major industry. Its raw materials are: Salt Brine, Hydrogen Chloride, Ethylene, Sulphuric Acid, Lead, Bromine.

$$\text{Salt Brine} \rightarrow \text{Dry Salt} \rightarrow \left\{ \begin{array}{l} \text{Sodium Metal} \\ \text{Chlorine} \rightarrow \text{Hydrogen Chloride.} \end{array} \right.$$

Liquid Sodium + Liquid Lead → Alloy bars

Ethylene + Hydrogen Chloride → Ethyl Chloride

Alloy bars + Ethyl Chloride → Lead Tetraethyl + Salt
(in an autoclave)

Add to Lead Tetraethyl some Ethylene Dibromide and dye. The resulting liquid is used at the rate of 3ml. per gallon of motor spirit and 4.6 ml. per gallon of aviation spirit.

Creative Chemistry in New Zealand

Let me assure you that not even most of chemical industry is producing organic chemicals. Historically it was inorganic, and the so-called " heavy " chemicals are inorganic.

If we think of the development of chemical industry we must think first of inorganic compounds. The basic raw materials of chemical industry are salt, air, sulphur, and carbon. All of these except sulphur we have in New Zealand. From salt come alkali, chlorine and their various derivatives. From the air comes nitrogen fertilizers and all the things oxygen can give. From sulphur comes sulphuric acid and superphosphate and all the chemicals sulphuric acid can be used to make. From carbon come the organic chemicals in millions.

New Zealand possesses already a large fertilizer industry — a quarter of the size of that of the U.S.S.R., i.e. per capita 10 times as large. It also has a salt production industry. The production of sulphuric acid is one of the indexes of industrial prosperity and sulphuric acid is produced in New Zealand in very large quantities indeed for the super-phosphate industry (10 million tons per annum, value £10 million). The use of phosphates has been the greatest single contributor to the increase in agricultural production in the past half century. This is based on imported sulphur but could perhaps use local products (nitric acid — triple phosphate).

We have a salt industry at Lake Grassmere, present output 10,000 tons per annum, potential output 40,0000 tons from the present plant, ultimately 100,000 tons. New Zealand imports 50,000 tons, landed value £550,000. From this industry could come potash, magnesia, bromine, alkali, chlorine.

Calcium carbide is a particularly interesting case of the chemist making something he wants starting with simple materials. Admittedly the technique is rather like Charles Lamb's story of Roast Pig — burning down the house to roast the pig — but it works and the ultimate products are organic compounds which occur in nature (made by the green leaf without all this fuss) or compounds entirely new and unknown in nature.

This reaction is of special interest to New Zealand because of the simple raw materials readily available and because of the immense quantities of potential hydro-electricity.

In the corner of one of our laboratories stands a rusty iron box about 18 inches cube with a hood over it. Inside this shell is a layer, one brick deep, of insulative bricks. Everytime I pass it I take off my hat to the ceramic chemists who have developed these bricks—hot face 1800°F. Inside the centre of this furnace currents of about 200 amperes at a few volts generate a temperature of 2000°C. At this temperature the reaction between coke and lime $CaO + 3C \rightarrow CaC_2 + CO$ takes place.

This has been built and is being used by my colleague, Dr. T. Hagyard, to test whether New Zealand raw materials are suitable for CaC_2 manufacture on the large scale. The impurities of interest are Mg, P and S.

With water calcium carbide gives acetylene.

$$CaC_2 + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2$$

C_2H_2 is a reactive material. Burnt with oxygen it gives very high temperatures (7900°F. or 4390°C.).

It combines with water to give acetaldehyde

$$C_2H_2 + H_2O \rightarrow C_2H_4O$$

which can be oxidised to acetic acid

$$C_2H_4O + O \rightarrow C_2H_4O_2$$

It combines with hydrochloric acid to give vinyl chloride (p.v.c.)

$$C_2H_2 + HCl \rightarrow C_2H_3Cl$$

and with acetic acid to give vinylacetate (p.v.a.)

$$C_2H_2 + HOAc \rightarrow C_2H_3OAc$$

CaC_2 with nitrogen gives calcium cyanamide.

$$CaC_2 + N_2 \rightarrow CaCN_2$$

New Zealand imports CaC_2 (1700 tons per annum) for acetylene. Dr. Hagyard estimates that this could be made in New Zealand at a price much less than the imported price. $CaCN_2$ is imported to the extent of 1000 tons per annum and p.v.c. 2500 tons per annum. Dr. Hagyard has shown that a plant to produce all three would have a capital cost of about £1 million and would produce products valued at £600,000 per annum from —

Coal	6500	tons per annum
Limestone	9400	,, ,, ,,
Salt	3000	,, ,, ,,
Air	350	,, ,, ,,

When the quality of New Zealand raw materials is proved, the next step will be to find a suitable site for operation, calculate the costs and see whether the product can really be made at a profit. Then we should start up a small continuous furnace and assess the operating difficulties. At that stage a complete plant would be fully feasible.

Other likely industries for New Zealand are gasification of coal on the large scale and utilisation of ironsands. You may well see these flourishing in the near future.

Employment of Chemists in New Zealand.

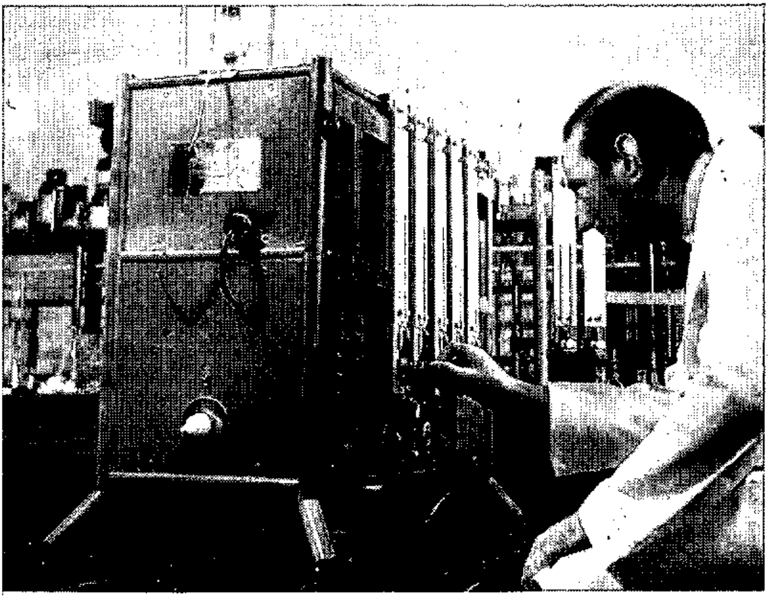
About one-third are in industry — in process control, management and research. Those industries cover fertilizer, wood products, tanning, rubber, paint, textiles, petroleum products. An increasing number are employed on research. The expenditure is at a rate of £300,000 per annum. About one-fifth are in teaching either university or post primary, many of them doing research as well. About a quarter are in Government Departments mainly on research and analytical work.

The total research expenditure in New Zealand is two and a-half to three million pounds or 0.25% of the national production. In other countries a higher proportion of the national production is spent on research (cf., U.K. 1.3%, U.S.A. 0.58%, Canada 0.52%), so it will probably increase in New Zealand.

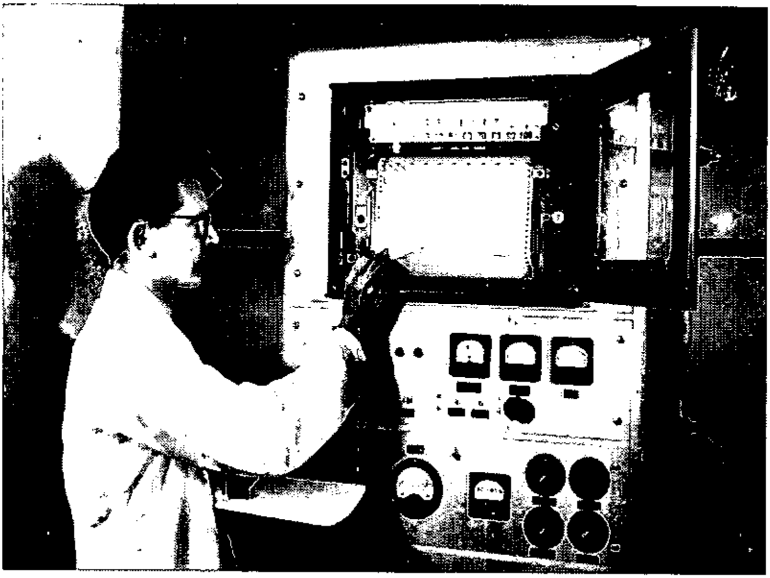
Facilities for research are improving rapidly and the drudgery is practically gone from testing and analytical work due to modern instruments.

In a big organisation like Du Pont Experiment Laboratories, each research chemist will have the part time help of a large team of men and women (24 at Du Pont) from typiste to glassblower, fitter to librarian. The time is approaching when such diversified assistance will be available to our research workers. For those of you who contemplate entering such employment in New Zealand the future looks to me exciting indeed.

Chemists and technicians carry out process control analyses under ideal conditions in a modern industrial laboratory.



The basic tool of biochemical research, a Warburg apparatus — used for studying respiration in plant and animal tissues — is adjusted prior to an experiment.



Under centrifugal forces as high as half a million times gravity, proteins yield their secrets to the ultracentrifuge, an apparatus designed for the separation of large molecules by sedimentation. Here a chemist examines a recorder trace at the end of a run.

Exacting but interesting and stimulating work. A technician in a research laboratory uses a micro-combustion furnace to determine the nitrogen present in an organic compound.

"THE NEW CHEMISTRY"

BY T. A. RAFTER

Director, Division of Nuclear Science, D.S.I.R., Wellington.

I intend to place before you, in this age of H-bombs, earth satellites and Trans-Antarctic crossings, the dependence of all progress, whether in war or in peace, upon the ability of men to study the properties of elements and the compounds that they form — compounds, many of which have never existed previously on earth and may be the keys to your prosperity and to mine. Only by the ingenuity of the chemist, can tomorrow's people be fed and clothed. It is in the " New Chemistry " that our future lies, for there are no more green pastures to discover, we have only about a hundred elements and man's abilities. In your chemistry classes, you have studied the preparation, properties and uses of the elements and compounds of hydrogen, carbon, nitrogen, oxygen, sulphur . . . to mention just a few. Maybe it is all a little confusing, but if you persevere in your learning and never let an unusual observation slip by, then someday you may find satisfaction in knowing that because of your effort, a little more has been written in the Book of Knowledge, and as a scientist you will have shared in the Divine command to " Go and subdue the earth."

I cannot hope to thrill you with chemistry of the new man-made elements, the transuranic elements, or to cover the vast fields opening up with the recovery of the new metals of this Atomic Age: titanium, zirconium, hafnium, tantalum, to mention a few. I propose, however, to confine my remarks to the chemistry of the first few elements. In accordance with the Periodic Classification we may write down the symbols in this order:—

			H				
He	Li	Be	B	C	N	O	F
Ne	Na	Mg	Al	Si	P	S	Cl

Hydrogen

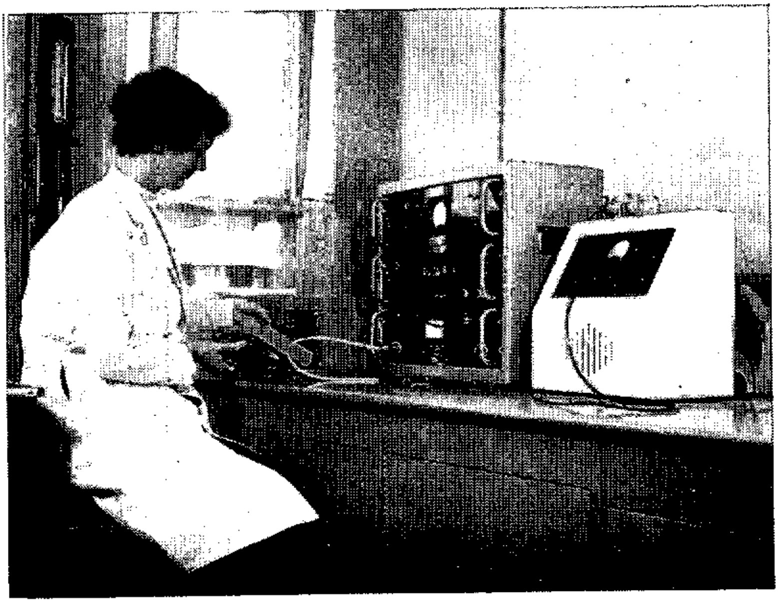
Hydrogen has an atomic weight of 1.008. When I was at college I used to feel that the chemist was being ridiculously accurate when he quoted atomic weight to three or four decimal places. Now, of course, you know that an atomic weight of 1.008 means that hydrogen is really made up of two species of mass 1 and mass 2, the average weight being actually measured. Hydrogen of mass 2 is called deuterium, discovered by Professor Urey in 1931. Deuterium occurs in natural water, but to obtain 1 ml. of D_2O it is necessary to electrolyse 100 gallons of water. This heavy water (D_2O) is not very expensive, £25,000 per ton. Its importance today is its use as a moderator in an atomic pile, i.e. it slows down the fast neutrons, given off when uranium undergoes fission, to such an energy level that they can be absorbed into the U^{238} nucleus forming plutonium and into U^{235} causing fission. The New Zealand Government was interested in the possibilities of recovering deuterium, using cheap geothermal steam. When water evaporates, the lighter molecule H_2O, distils off in a greater abundance than the heavier one HDO, so that the residual water becomes richer in deuterium. By a series of fractional distillation columns, it was planned to enrich the water to about 40% D_2O, then concentrate still further by electrolysis.

Now D_2O is very much like H_2O. It boils at 101.4°, and has a density of 1.106. If you are studying from Holmyard's Higher School Chemistry, you will read that "Chemically, D_2O is closely similar to H_2O though slight differences in the biological effects of the two liquids have been reported." Two of my assistants did not believe this statement, so they attempted to germinate seeds in D_2O instead of H_2O. The seeds germinated in H_2O but not in D_2O. If germination was started in H_2O and the seedling transferred to D_2O growth stopped, but restarted if put back into natural water. They found that D_2O was not toxic to the seed, but hindered its development. How, we do not know. What is peculiar about the D_2O molecule that blocks development in plants? Maybe if you could explain this scientific problem you would have one of the keys to the new chemistry of life processes.

We call deuterium an isotope of hydrogen . There is a third isotope called tritium which exists in rain-water to the extent of 1 molecule in every million, million, million molecules. This is such a small amount that the total world inventory is only 30 kilograms. Now tritium is radioactive with a half-life of 12.5 years. The radioactive elements that we thought existed prior to 1947 were those long-lived radionucleides: uranium, thorium, and potassium and their radioactive daughters, e.g. radium, ionium. These long-life radio-elements were synthesised at the creation of the universe, 4-5 billion years ago. Radio-tritium that was also created at the same time has long since died away. The radiotritium we find in our rainwater is actually created by cosmic ray particles on nitrogen thousands of feet above the Earth. We write the equation like this —

$$N^{14} + \text{neutron} \rightarrow H^3 + C^{12}$$

Recently the amount of tritium in rainwater has been increasing, due to the explosion of H-bombs. I shall explain about this later. Now tritium is radioactive and although it occurs in water in such incredibly small amounts, with a suitable counter it is possible to determine the activity of the water and hence its age. This gives us a method of tracing the movement of water across continents, telling, for example, whether or not water coming up geothermal bores is older than 50 years. Even more important is the fact that radioactive hydrogen will enable us to study the pathway of hydrogen through biological systems.



How "hot" is it? A sample is placed in the lead "castle," which contains the Geiger-Muller detecting tube, for a determination of the amount of radio-activity present.

Helium

The second element in this classification is helium, atomic weight 4.002. This is one of the "inert gases," which have stable structures and no valency electrons. The presence of helium in the sun was discovered by Sir Norman Lockyer in 1868, and Sir William Ramsay was subsequently able to extract it from a mineral called cleveite.

Unfortunately I cannot spend much time on this group of elements. But let us go back to the atomic weight 4.002. You know that hydrogen is built up of one proton and one electron, and helium of two protons, two neutrons and two electrons. The mass of the proton is 1.00732, the neutron 1.00866, the electron 0.0006 mass units. If you add up the masses for 2 protons, 2 neutrons and

2 electrons you will find the answer to be 4.03316 mass units. Now possibly the significance of atomic weight can be seen. The atomic weight of helium, 4.002, is less than it should be by 0.03116 mass units. It is the conversion of this amount of mass into heat, that supplies the energy of the sun.

Here then, is the germ of the idea that has lead to the recent announcement of Zeta, a machine capable of building up heavier elements from lighter elements with the consequent release of energy. To fuse lighter elements into heavier ones, temperatures of the order of 100 million degrees are required. It was announced, in January of this year, that United States scientists had succeeded in producing, in a plasma of deuterium gas, temperatures as high as six million degrees and had maintained these temperatures for a few millionths of a second. Between a million and 100 million neutrons were produced per pulse. High temperatures and longer containment times are necessary before thermonuclear power becomes a possibility on earth. It has, however, yet to be definitely established that these neutrons are produced by thermal fusion. The British team was able to isolate the gas from the walls for periods of 2-5 thousandths of a second. It will be necessary to isolate the hot gases for several seconds before thermal fusion becomes an economic possibility.

Before I leave the inert gases there are other interesting facts about these elements. Helium is produced by the decay of uranium and thorium minerals. This helium has been discovered in natural gas in the United States. You may ask, where has this helium come from? It could have been occluded in the cosmic dust particles during the creation of the earth, but it could also have arisen from the decay of radioactive minerals, uranium and thorium that emit the helium nuclei. One method of estimation of the earth's age is by the extraction of helium from radioactive minerals. By knowing how many atoms of helium are formed each year, and the amount extracted from the rocks, the age can be calculated. Another inert gas argon, can be used for age estimation or geochronology as we call it.

Lithium

Our third element is lithium. In accordance with the rules of the Periodic Table, we know that lithium of structure 2:1 should lose an electron to form a positive ion. Hydrogen should gain an electron to form the hydride ion H^-. These two ions give the hydride LiH. Likewise, lithium and deuterium should form LiD, and with tritium lithium should give LiT. Now all this looks just simple chemistry. Yet do you know that it must have cost the Americans hundreds of thousands of pounds, because they did not realise that they could use these simple chemicals in the construction of the first hydrogen bombs.

The atom bomb produces temperatures high enough to fuse the light atoms together and, as I explained above, releases a tremendous amount of energy. It would be easier to build up tritium into helium than hydrogen, but tritium exists in such small amounts in nature that in America they constructed a special plant to manufacture tritium by the nuclear reaction

$$\mathrm{Li}^{6} + \text{neutron} \rightarrow \mathrm{H}^{3} + \mathrm{He}^{4}$$

Tritium like hydrogen is a gas of very low boiling point, so, to keep liquid tritium around the atom bomb, refrigeration was necessary. It must have been a fairly bulky bomb. The Russians, however, knew a little more chemistry and, instead of the expensive tritium, simply formed LiT, which is a solid.

The actual mechanism of the H-bomb is still classified, but the nuclear reaction could be

$$_{1}\mathrm{H}^{3} + {}_{1}\mathrm{H}^{2} \rightarrow {}_{2}\mathrm{He}^{4} + {}_{0}n^{1} + \text{heat}$$

This reaction could be set off by the heat of the atomic bomb. Sufficient heat would be further developed to fuse two deuterium molecules together

$$_{1}\mathrm{H}^{2} + {}_{1}\mathrm{H}^{2} \rightarrow {}_{2}\mathrm{He}^{4} + \text{heat.}$$

Prior to World War II, the production of Li was about 450 tons per annum. In 1955 it had risen to 7,000 tons, while at the present time it is possibly treble that amount. Lithium, like sodium, forms with fats a lithium stearate that is an important component of multi-purpose greases, particularly low temperature greases. Compounds of the metal have application in metal refining, air conditioning, the ceramic industry and the manufacture of drugs and vitamins. Compounds of lithium are important catalysts and are used in organic synthesis. Dispersed lithium metal is the catalyst used in the polymerisation of isoprene to natural rubber. Lithium exists in sea-water to the extent of 0.1 p.p.m. Japan has attempted to recover Li from hot spring waters, while in New Zealand we are at present investigating the possibility of recovering it from the geothermal bore waters which contain about 15 p.p.m. of lithium. If LiCl could be extracted from a recovery plant handling 4 million lb. per hour of geothermal water, we should obtain 1,300 tons LiCl per year, the value of which would be £1,450,000.

Beryllium

Beryllium is not a particularly exciting element at the moment. Soluble compounds of beryllium are as a rule very dangerous to health. Dermatitis and acute pneumonitis may be contracted when mists, dusts and fumes of these compounds are inhaled. A more serious hazard has appeared since 1943 in the fluorescent-lamp industry, in which beryllium-zinc-silicate is used.

Beryllium forms alloys, particularly with copper. These beryllium-copper alloys are characterised by high electrical and thermal conductivity and are now finding many uses in industry.

Boron

Boron looks a harmless enough element. You are familiar with boron in borax, $Na_2B_4O_7$, 10 H_2O, or as boracic acid! You may remember the " borax bead " tests, and boracic acid has uses in medicine. I well remember that when I was going through University, boron formed some odd hydrides, in which the valency of boron seemed to be four not three and, if I can remember rightly, another explanation was the existence of a singlet- linkage between boron and hydrogen.

Years later, whilst working on the analysis of New Zealand coal ashes, we could not get our results to add up to 100%. The analyst I was working with was rather perturbed as he could usually get between 99.5 and 100% whereas in this instance, we were 3% out. This meant that we had to look for some unusual element, and finally we identified boron. I was later able to show that our Waikato coals have a considerable percentage of boron as a soluble sodium borate. I think it comes from volcanic gases.

Now, if we look at boron, we see it is followed by carbon. The carbon hydrides, methane, ethane, propane and the unsaturated hydrocarbons, ethylene, acetylene, etc., are important fuels —particularly aviation fuels. These fuels have served us well, up to this jet and missile age. Boron is lighter than carbon, and, as the weight of the fuel load is now critical, the lighter the fuel — the better the chance of winning the race.

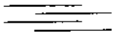
Liquid hydrogen with its high heat of combustion is the best fuel but it would, however, require refrigeration. Beryllium, in nearly all of its compounds, is extremely toxic and is in short supply, so a " new chemistry " began to spring up around the boranes (these compounds of boron and hydrogen). In 1947, the Americans started combustion studies on the uses of boranes in rocket motors, ramjets and air-breathing machines. Today, what are called HEF fuels have been developed by chemists as liquid propellants. The most interesting are pentaborane B_5H_{11} and decaborane B_4H_{10}. It was reported last year, that pentaborane, B_5H_{11}, was approximately 60% more efficient as a fuel than J.P.—4, a commonly used hydrocarbon. The work was commenced as recently as 1952.

Diborane, B_2H_6, the simplest of all the boranes can be prepared by the reaction of lithium hydride LiH with boron trifluoride BF_3. The diborane, being a gas, is easily removed, and by simple heating it can be converted to pentaborane and decaborane. These fuels are believed to meet the requirements of future high sped missiles and aircraft.

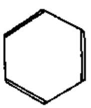
Carbon

Carbon is such a familiar element that you may think I can exclude it and get on, maybe, to something more exciting. You are going to be disappointed, for at the moment we are more interested in the possibilities of " new chemistry " in carbon than in any other element in the Periodic Table.

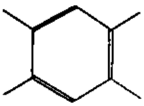
Carbon has always been a fascinating substance. In the Stone Age, it was the carbon in wood and the ability of the Stone-Age man to set it alight with flint, that started the long road of progress up to to-day. Charcoal for the reduction of iron ore ushered in the Iron-Age, and as wood supplies rapidly dwindled and threatened our development, it was another form of carbon, coke made from coal, that saved the day for the Steel Age. Then, just a few years ago, it was very high purity graphite that enabled Professor Fermi to build the first atomic reactor — to maintain controlled nuclear fusion and so give us, today, nuclear power. High purity graphite is used as the moderator in atomic reactors.

Carbon is the hub element of organic chemistry and the modern organic chemist can almost tailor-make an organic molecule for any requirement. You may have wondered how it was possible to drive tractors across the Antarctic continent without the fuel freezing up. Fuels are mostly straight chain hydrocarbons, that we can represent like this  and which freeze into a solid block which would make motoring impossible at temperatures below zero. The organic chemist overcame this difficulty in a novel way.

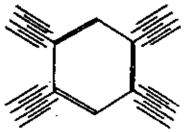
Benzene has this structure —



It is possible to add side chains to this structure by adding, say, methyl chloride in the presence of $AlCl_3$ forming toluene. Well, a number of arms can be put around the benzene molecule like this:



When a small percentage of such a chemical is added to the fuel, and freezing takes place, the crystals form around the arms of these nuclei, like this:



with the result that instead of forming one solid mass, just a slush or slurry is formed. When the engine is turned on, the heat generated melts the slurry and the engine can turn over.

The atomic weight of carbon is 12.01. You will realise now that carbon is made up of isotopes, the principal ones of which are C^{12} (98.9%) and C^{13} (1.1%). It is possible to manufacture a short-lived carbon isotope C^{11}, but it has recently been discovered that nature manufactures another long-lived isotope C^{14}, whose half-life is 5,568 years. This radioactive carbon is manufactured like tritium, that I mentioned earlier, by cosmic-ray neutrons on nitrogen shortly after these rays strike the atmosphere. Radioactive carbon dioxide is formed; this is taken in by plants which are then eaten by animals, so that all living matter becomes radioactive. When plants and animals die, they can no longer assimilate carbon into their structure, so that the radiocarbon in them at death slowly decays away. In 5,568 years, the plant or animal remains have only half the activity they had at death. We have developed a method that will tell us the age of carbonaceous material back to 45,000 years.

In the December issue of "Life" magazine, I read that a young American anthropologist discovered in a cave in Iraq the remains of a Neanderthal man, killed at the beginning of the last Ice Age, about 45,000 years ago. He was said to be about 38 years old, 5 feet 3 inches tall, short-necked, barrel-chested, large-nosed and had lost two teeth. If we could get hold of some of his bones we could tell within a few hundred years how long ago the cave, in which he sat cooking a wild boar, crumbled and killed him. Such precious remains will most likely not be given to me to burn to carbon dioxide so that we can count the radioactivity remaining. But we have dated many specimens for New Zealand or overseas scientists.

One specimen was sent in by the famous explorer, Sir Douglas Mawson. These remains constituted part of the last supper of a Diprotodon which died bogged at Lake Callabonna in South Australia. The Diprotodon was a giant herbivorous marsupial about the size of a rhinoceros. These animals were evidently trapped in a bog more than 40,000 years ago. We also examined teeth from the lower jaw of another animal from a different locality. This animal died 6,700 years ago.

When our New Zealand geologists recently returned from Antarctica they brought home the remains of a baby penguin and asked us if we could tell how long it had been dead. It didn't have a particularly attractive odour, so we put it back in the freezer for the week-end and on Monday digested it up with chromic acid to convert its carbon to CO_2. On Tuesday we knew that it had died 1,250 years ago. We have since received a similar request from the Australian team.

Now, I should like to tell you about a recent observation we have made, which we call the "Atom Bomb Effect." About 1954, I wanted to determine how the C^{14} activity of the air and the sea differed from that in the plants. You are told at school that the isotopes of elements are chemically identical. Well, to a point this is true, but when we consider rates of chemical reactions and biochemical reactions we find that the isotopes have different reaction rates. It might interest you to know that the C^{14} age of the fat of animals is 200 years older than the bones of the same animal. In the biochemical processes of building up fat and bone more of the heavier isotope C^{14} goes into the bone than into the fat. Likewise when carbon dioxide dissolves in the sea we get the equilibrium reaction

$$C^{14}O_2 + C^{12}O_3^{=} \rightleftharpoons C^{14}O_3^{=} + C^{12}O_2$$

in which it can be shown theoretically that more C^{14} will exist in the carbonate ion, than in the carbon dioxide. In 1954, we removed the CO_2 out of 25,000 litres of air and found the activity to be $+ 2.72\%$ enriched in C^{14} with respect to our wood standard. Fortunately, the collection train was kept going and as the months went by a steady increase in the activity became apparent, until at the present time the air is enriched $+ 12\%$ with respect to our standard. Our method is sensitive to about $\frac{1}{4}\%$ and this increase we believe to be due to the testing of atomic weapons. Fortunately in 1954 we also removed the bicarbonate from 80 gallon samples of sea water and today we can detect an increase in the surface waters of the oceans. From such information, we can calculate the rate of movement of air masses across the equator, the rate of exchange of atmospheric carbon dioxide with ocean carbonate, and we hope also to be able to estimate the size of the mixing and deep ocean reservoirs, and the turnover times for the oceans themselves.

We now want to persuade the Air Force, when they have a plane available, to take us up into the stratosphere so that we can collect carbon dioxide out of the stratosphere. If we can do this we may be able to calculate the rate of exchange between the stratosphere and the troposphere. This, as you may have read in the papers, is important to know, because at the present time a lot of the debris from H-Bomb explosions is up in the stratosphere and we want to know how long it will remain there.

Nitrogen

In our work we use ammonium nitrate. The only difference between this ammonium nitrate and the sample from which you prepare nitrous oxide at school, is that this ammonium nitrate cost £100 per gram of nitrogen. The nitrogen in the ammonium radicle is not N^{14}, but 61.0 Atom % excess N^{15}, i.e. it is enriched in the heavier isotope of nitrogen. Nitrogen is a valuable fertiliser as urea, KNO_3, NH_4, NO_3 or $(NH_4)_2\ SO_4$. Professor Walker, by using this compound and with the aid of our mass spectrometer, was able to show how grasses under certain conditions changed their ability to fix nitrogen.

Now nitrogen is a fairly inert element, we are told; it is an essential fertiliser and yet in the atmosphere, 4/5 of which is nitrogen, it is apparently of little use to us, (apart from the fact that we could not live in pure oxygen), except for those plants having nitrogen-fixing bacteria on their root systems, e.g. lupins. For a hundred years scientists have attempted to explain whether or not higher plants have the ability to assimilate nitrogen directly out of the atmosphere rather than through some bacterial system. Nitrogen has no radioactive isotope which would enable us to trace nitrogen from the air into the plant using radioactive methods. However, just as you can enrich water in deuterium, so you can enrich the ammonium radicle in N^{15} by an exchange reaction like this

$$\underset{(gas)}{N^{15}H_3} + \underset{(soln)}{N^{14}H_4^+} \rightleftharpoons \underset{(gas)}{N^{14}H_3} + \underset{(soln)}{N^{15}H_4^+}$$

Using a mass spectrometer it is possible to estimate the N^{15}/N^{14} ratio, and if this has changed from the normal ratio we can say that nitrogen has entered from the enriched fertiliser we may have applied to the plant. From enriched ammonium nitrate I made heavy nitrogen gas by oxidation with sodium hypobromite

(NaBrO). With this nitrogen we mixed oxygen to make a synthetic atmosphere, and then had to construct some sample holder that would enable us to remove the existing atmosphere over the plants and replace it by our synthetic mixture. This we did by modifying the principle of the common laboratory desiccator. Several plants were chosen, to grow for several days in this new atmosphere. These plants were: the common hedge plant Coprosma, small pine seedlings, several grasses such as rye-grass and cocksfoot, and a small native plant called Epilobium, that grows in abundance on land which is slowly reverting to native bush. The plants are then removed from the synthetic atmosphere; they are digested in concentrated sulphuric acid to oxidise the plant nitrogen to ammonia that we convert back again to nitrogen gas for mass spectrometer examination. .

From these experiments it has been shown that the pine seedlings and the Epilobium had somehow fixed nitrogen from the atmosphere. In fact they were enriched several hundred times over the normal N^{15} abundance in plant material. The first experiments, of course, can never be taken as conclusive, so you have to repeat over and over again the same experiment and then, what is even more difficult, you have to try to reason out by what mechanism nitrogen from the air becomes fixed in the plant material.

In this problem we are facing the same problem that Louis Pasteur had; we must be sure that what we are working with is completely sterile. Bacteria are very small organisms, but they can do a terrific amount of work given the right conditions. To grow a plant in completely sterile conditions or to start off by sterilising a particular branch or leaf of the plant is difficult technically. We have recently attempted to grow the roots separately in an enriched nitrogen atmosphere, as well as the shoots, to determine whether or not it is a root fixing or shoot fixing mechanism. The problem is not yet solved, but Dr. Cone reported last year that " Nitrogen fixation is of general occurrence in the foliage of trees, pioneer shrubs and various weeds; the process goes on in the young shoots, perhaps also in flowers and fruit and is generally associated with pigments other than the green of CO_2 fixation. The element nitrogen must be much less inert than has been assumed to be the case, and it must circulate rapidly through vegetation and soils."

If this can be substantiated then we must look upon the fact that our atmosphere is not as inert as we have previously believed it to be, for if we can cultivate pioneer plants which have this ability to assimilate nitrogen from the air, the problems of reafforestation and of converting waste lands into productive lands will all the sooner be realised with the "New Chemistry of Nitrogen."

Oxygen

I have told you of two methods that we now have available to age past geological and archaeological events. Time and temperature are both important factors. The earth has been going through warm and cold cycles, approximately every 43,000 years, for the last 1,000,000 years. We have only to raise the average temperature of the earth by a few degrees for the ice-caps to melt, causing the sea-level to rise hundreds of feet.

Take an ordinary sea-shell. Now, apart from being an ornament, and knowing that it is almost pure calcium carbonate, it may not seem to you to be very interesting. In any museum, you can see fossil shells obtained from geological formations, millions of years old. We can now tell the temperature of the sea in which the shell-fish lived and also whether it died during winter or summer. A very delicate method of measuring temperature has been discovered by considering variations in the O^{18}/O^{16} ratio in the carbonate of shells. The method was developed by Dr. Urey of Chicago, who was able to show that the oxygen isotopes in the shell, laid down in summer, differed from the ratio in winter.

In the sea, the minute shell-fish, when they die, fall to the bottom of the ocean and there build up the ocean oozes that accumulate over millions of years. Today we can take ocean bore cores, sort out these micro-shells and determine the temperature of the ocean they lived in, and, in the top of the core, their C^{14} age. It has been shown that the temperature of the equatorial waters over the last million years has gone through a series of temperature cycles with an amplitude of about 6°C. The temperature cycles correspond with Ice Ages and the rise and fall of the ocean. There have been fifteen cycles in about 600,000 years. In more recent time, there has been a continuous temperature increase from about 16,500 years, B.C. to about 6,000 years B.C. followed by a small temperature decrease. Our geologists have been able to show that 10,000 years ago, sea-level was some 200ft. lower than at present. Using the radiocarbon method and the oxygen isotopes for temperature measurements, chemists and physicists have given to geologists powerful tools for probing into the secrets of the past.

Your text-books tell you that oxygen is the most abundant element in the earth's crust, that it forms 89% by weight of water and occurs in the air (21% by volume and 23% by weight). Have you ever asked yourself where the water of the seas and the oxygen in the atmosphere came from? Such problems are at present being studied by geochemists. The common assumption is that the earth and its atmosphere have always been as they are now. Chemists are attempting to study how the earth originated and how the primitive earth developed into the present earth.

Fluorine

Fluorine has been getting much publicity lately in the new attack on tooth decay by the addition of trace amounts of fluoride to our water supplies. Fluorine exists in the mineral fluorapatite CaF_2 Ca_3 $(PO_4)_2$ and it is the ability of fluorine to replace phosphate in the enamel and so be able to attack bacteria, that leads to its use in modern dentistry. While I am on this subject, it was just this sort of chemistry that led to the hoax of the Piltdown man. When bones are buried, as water seeps through the burial grounds, the fluorine in the water can replace the phosphate and the older the bones, the greater the fluoride/phosphate ratio. This is now a recognised method of dating bones. When the Piltdown Man's bones were subjected to this test, the ratio pointed to someone having planted the remains, which were of recent origin.

In your chemistry laboratories you may have been shown how fluorine etches glass and have been warned never to play with hydrofluoric acid. One of the most painful nights I have ever spent was when a little hydrofluoric acid got under my fingernail. Fluorine is the most powerful non-metal and if it falls on skin it can cause terrible sores. The antidote is to inject lime to precipitate the insoluble CaF_2. Fluorine, being so dangerous to handle, had little commercial use. However, it sprang into prominence during during the last World War. The atomic weight of fluorine is 17.00 and it has only one isotope. This was a considerable advantage when the Americans attempted to separate U^{235} from U^{238}. U^{235} exists to the extent of 1 part in 140 in natural uranium. It is the more radioactive nucleus and could be separated from the more stable U^{238} by gaseous diffusion of the fluorides $U^{235}F_6$ and $U^{238}F_6$ in accordance with Dalton's Law of Diffusion. You can imagine the difficulties encountered in handling such a corrosive gas!

Fluorine, being such a powerful non-metal, has interested chemists because of the possibilities of new carbon-fluorine compounds like those of carbon-hydrogen chemistry. Already well over 1,000 different molecular species have been made. Straight chain compounds up to at least 20 carbon have been made; ring compounds combined with the well-known functional groups are possible.

The C-F bond is much stronger than the C-H bond. The presence of fluorine also tightens the C-C bonds from 80 k.cal. in C_2H_6, to 124 k.cal. in perfluorethane C_2F_6. Fluorine is the most powerful electro-negative element, i.e. it has the highest power of any elements to attract electrons to it. This makes the CF_3 and C_2F_5 groups acidic.

You know that methane burns readily, yet CF_4 is decomposed only above 1650°C. in the presence of water vapour and oxygen, and can be used as a gas coolant. We are interested in putting geiger tubes down the hot bores at Wairakei. The temperature down these bores is as high as 300°C. and the gases are very corrosive due to H_2S, HF and HCl. The covering material for the copper wire, which is to transmit back to us the pulses from the rocks through which the bore passes, must be very resistant to corrosion. A fluorinated polymer called TEFLON $(-C_2F_4-)n$, which only starts to peel around 300-400°C., has recently been produced and may enable us to carry out this investigation. This same material has a very low coefficient of friction and was used on the runners of sledges in the Antarctic.

Fluorine, which itself is so corrosive, when built into compounds forms new materials which are resistant to the strongest oxidising agents and even to sodium and lithium at high temperatures. Furthermore they are non-toxic, unlike CCl_4 or benzene. On account of their chemical and thermal stability new insulating oils are now available.

You have heard the statement that oil and water do not mix. This old proverb can now be brought up to date by saying that oil, water and inert fluorochemicals do not mix. Inert carbon-fluorine compounds can be used as repellants to both oil and grease. This is a new phenomenon. It is now possible to treat textiles, paper and other surfaces to impart stain resistance against both water-born and oil-borne agents at the same time. Carbon-fluorine compounds have extremely low surface tension and, in amounts of 0.1% or less, they produce great reductions of the surface tension of hydrocarbons and other organic liquids. This effect is wholly new in science and industry. Evaporation rates of benzene and other liquids can be reduced to a fraction of their normal rates because of the crowding of the relatively non-volatile fluorochemical molecules into the surface. Fire hazards can thus be reduced. Another unusual property of these compounds is their low refractive index so that it is now possible to build practically transparent rubber.

I have mentioned a few of the startling properties and uses of compounds never seen or known before. I have mentioned before the ability of the fluoride ion to prevent tooth decay. You know the formula for acetic acid — CH_3COOH; now replace one hydrogen atom by fluorine and you have CH_2F $COOH$, the sodium salt of which is the most toxic rodenticide known. Discovered during the war, it was used for rodent control around military installations. Curiously enough it occurs in the root of a South African plant, "Giftblaar" used by the Africans for rodent control.

Now I have used up my time telling you of the possibilities of nine of the ninety-two elements. I do hope that I have been able to awaken in you a keener interest in chemistry, with all its potentialities. There is sufficient raw material, and man today has the ingenuity, to solve all our material problems. However, before plenty is available to all peoples of all nations, man must first control his own freewill to direct his energies, not just toward materialistic gain, but to the furtherance of the three Virtues:—FAITH, in the brotherhood of nations, HOPE, in the ultimate attainment of peace, and CHARITY, in the realisation that knowledge should be universal, and not subjected to the barriers of country or creed.

ABOUT THE SPEAKERS

PROFESSOR T. W. WALKER, B.Sc., Ph.D., D.I.C.

Graduated with honours in chemistry from the University of London, where he was awarded his doctorate for a thesis on "The Influence of Soil Type on the Growth of Plants." He spent two years at Rothamstead Experimental Station with a Salters Fellowship working on the physical and chemical properties of soils.

He was appointed Provincial Chemist (West Midlands) for the National Agricultural Advisory Service and in 1951 came to Canterbury Agricultural College as Professor of Soil

Science. His New Zealand research work has been in connection with legumes with particular reference to sulphur and nitrogen cycles.

He has proved to be a popular and provocative speaker much sought after by the farming community. He left New Zealand in June of this year to take up the Chair of Agriculture at King's College, Newcastle, University of Durham.

PROFESSOR S. R. SIEMON,

B.Sc., M.App.Sc., A.M.I.Chem.E. A.R.A.C.I., A.N.Z.I.C., A.M.N.Z.I.E.

Is a graduate in applied science of the University of Brisbane. He came to Canterbury College in 1944 as lecturer in applied Chemistry and established the Department of Chemical Engineering. In 1952 he was appointed lecturer in charge of the department and in 1957 he was appointed to the Chair of Chemical Engineering at the University of Canterbury.

In 1951-52 he spent three months in the United States as a travelling fellow of the Carnegie Corporation and he then worked at Cambridge as Dominion travelling fellow of the Nuffield Foundation. Professor Siemon is particularly interested in the development of New Zealand's industrial processes, especially those utilising local raw materials.

Mr. T. A. RAFTER, O.B.E., M.Sc., A.N.Z.I.C.

After graduating from Victoria University College Mr. Rafter spent four years as a secondary school teacher. In 1940 he joined the staff of the Dominion Laboratory where he worked in various fields of inorganic analysis. During the war years he studied the methods of analysis of uranium minerals co-operating with British and American scientists on the method of estimation of uranium and thorium. A series of papers was written on the decomposition of uranium minerals and on these the British Government took out two patents.

In 1948 Mr. Rafter was selected by the Government to visit America and later Britain, to study radioactive isotopes with a view to introducing these new methods of research into New Zealand's problems. On his return he established the isotope section of the Dominion Laboratory at Gracefield where his work on radioactive carbon dating, a technique which he pioneered, was done. Mr. Rafter is now Director of the newly created Division of Nuclear Sciences, D.S.I.R. The O.B.E. was conferred on him in the recent Birthday Honours.

The articles in this booklet are reprinted from the Journal of the New Zealand Institute of Chemistry, Volume 22, June, 1958.

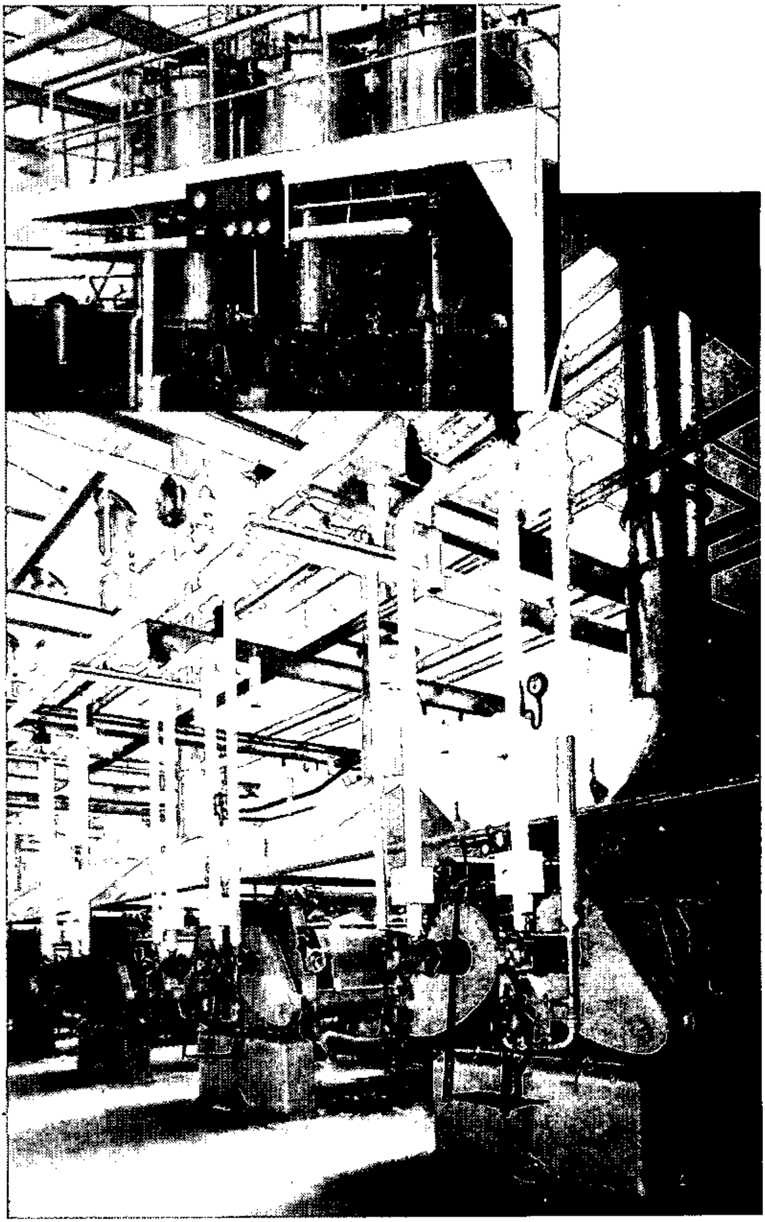
The cover design is by Mrs. R. A. S. Waters, Palmerston North.

Acknowledgment is made to Messrs. Glaxo Laboratories (N.Z.), Ltd., Palmerston North, the Plant Chemistry Division, D.S.I.R., Palmerston North, and staff of Canterbury College, Christchurch, for permission to reproduce a number of the photographs used in the booklet.

Published by the New Zealand Institute of Chemistry, G.P.O. Box 250, Wellington.

Edited by W. A. McGillivray, 178 Fitzherbert Avenue, Palmerston North.

Printed by Stylex Print Ltd., 98 Taonui Street, Palmerston North.



Despite the phenomenal growth of secondary industries, agriculture and the processing of agricultural products is still the main employer of chemists in New Zealand. The efficient operation and control of the equipment used in these processes, such as the modern triple-effect evaporator (inset) and milk drying plant shown here, demands an increasing degree of chemical and technological skill.