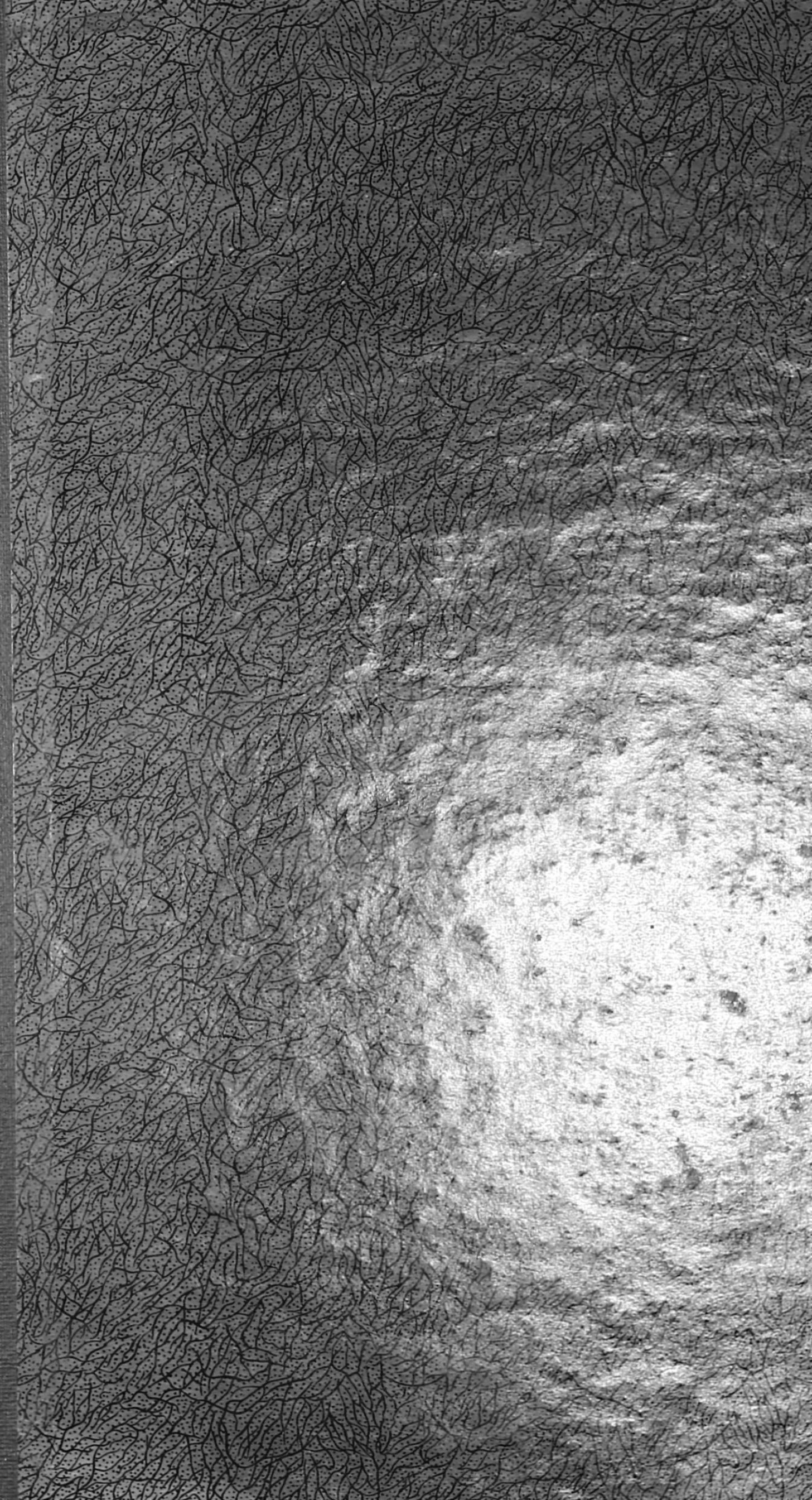


N.C.L. RESEARCH PROGRAMME 1966-67.



RESEARCH PROGRAMME

1966-67

सत्यापित / VERIFIED  
1992



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S P O N S O R E D      P R O J E C T S

1. Investigation of the synthesis and properties of the new type glycol mono alkyl ethers for the control of water evaporation to extend the industrial utilization of cottonseed oil (1964)  
U.S. Department of Agriculture - PL-480.

Object:

To synthesise new type of glycol mono alkyl ethers from the alcohols which are obtained from cottonseed oil. To study the physical properties of the above compounds for evaluating them as water evaporation retardants.

Present state of development:

Preparation of fatty alcohols from cottonseed oil by high pressure hydrogenation has been continued and extended to corresponding acids and their esters. Experiments on evaporimeter have also been continued to evaluate the efficacies of the above cetostearyl alcohol mixtures. Measurements on surface viscosity and specific resistance to evaporation has been continued. Surface thermodynamical properties are also being studied of the lower homologues of the alkoxy ethanols.

Proposed plan of work:

The project will be continued on the following lines.  
(i) Preparation of the long chain alcohols and alkoxy ethanols in the form of mixtures. (ii) Purification of the above compounds to obtain V.P.C. grade purity for measurement of various physical properties. (iii) Physical properties such as surface viscosity, pressure-area isotherms, specific resistance to evaporation, surface potential measurements etc. will be investigated. (iv) Structural studies by X-ray and electron diffraction will also be continued.

Approximate date of completion:

January 1969.

2. Fabrication of electron diffraction equipment (1965)

Object:

To design and fabricate electron diffraction equipment and associated accessories. To install and assist outside parties in connection with high tension unit and training of personnel in this field.

Present state of development:

Technical know-how for the fabrication of this highly costly equipment which is required by many research organisations has been developed. One unit has already been fabricated for NCL use and one each for Atomic Energy Establishment, Bombay and National Metallurgical Laboratory, Jamshedpur.

Proposed plan of work:

Fabrication of electron diffraction cameras will be undertaken for (i) Gauhati University, and (ii) Fertilizer Corporation of India, Sindri, who have already sent advance money towards the cost of the equipment. Three more parties including Defence Science Laboratory, Delhi, have approached the NCL for obtaining the above equipment.

3. Chemical and thermodynamic properties of refractory materials at high temperatures (1964)  
National Bureau of Standards, Washington, D.C. PL-480.

Present state of development:

Refractory sulphides such as  $\text{La}_2\text{S}_3$ ,  $\text{Ce}_2\text{S}_3$  and  $\text{MnS}$  have been synthesized by reacting their respective pure oxides with carbon disulphide vapour at  $600^\circ$ . Preliminary experiments on their vaporization behaviour have shown that even up to  $1200^\circ$ , the system has negligible vapour pressures.

Proposed plan of work:

Vaporization studies will be carried out at still higher temperatures ( $1200-1800^\circ$ ) in a tube furnace having

molybdenum-disilicide heating elements. Furnaces to study refractory systems at about 2200° will also be set up employing graphite heating elements. Synthesis of a few refractory nitrides (viz. silicon nitride, cerium nitride etc.) will also be attempted in a small gasfired zirconia crucible furnace capable of giving temperatures of the order of 2500°.

The system of anhydrous manganese chloride will be studied at several temperatures (800 - 1200°) and the data will be employed for the determination of heat of vaporization of  $MnCl_2$ .

Chemical and thermal properties of aluminium oxichloride, obtained by reacting stoichiometric amounts of  $Fe_2O_3(s)$  and  $Al_2Cl_6(g)$  will be investigated.

Approximate date of completion:

May 1969.

4. Chlorination of ilmenite for the production of titanium tetrachloride (1965)

Object:

To utilise Indian ilmenite for the preparation of titanium tetrachloride which is used as seed material in the manufacture of titanium dioxide pigment

Present state of development:

The chlorination of upgraded ilmenite containing 90% titanium dioxide has been studied on 1 kg./hour of titanium tetrachloride in the pilot plant worked out earlier.

Proposed plan of work:

A bench-scale unit (capacity 2 kg.  $TiCl_4$ /hour) will be set up involving three steps.

- i. Beneficiation of ilmenite (high temperature reduction roast) to produce  $TiO_2$  enriched material (containing about 90%  $TiO_2$ ).

- ii. Utilization of by-product iron chloride produced in the beneficiation step.
- iii. Chlorination of the mixture of  $TiO_2$ -rich material + carbon at about  $750^\circ$ .

The data obtained on the bench-scale unit will be employed to set up a pilot plant unit for the production of titanium tetrachloride (10 kg./hour to be increased to 20 kg./hr.)

Work on the hydrolysis of titanium tetrachloride to produce pigment grade rutile titania will also be undertaken.

Approximate date of completion:

31st March 1968.

5. Investigation of the effect of heat on Tung oil and derivatives of tung oil and the characterization and identification of compounds resulting from heat treatment to extend the utilization of tung oil (1963)  
U.S. Department of Agriculture, Washington - PL-480.

Object:

To study the effect of heat on tung oil,  $\alpha$ - and  $\beta$ -eleostearates.

Present state of development:

Work carried out in the previous year has led to the development of a new catalytic method for the thermal cyclisation of  $\alpha$ - and  $\beta$ -eleosterates.

Proposed plan of work:

The work will be directed to the application of the above catalytic method to tung oil itself and other suitably constituted fatty esters. Work on the structure elucidation of the main product of cyclisation of  $\alpha$ - and  $\beta$ -eleostearates will be carried out.

Approximate date of completion:

31st July 1968.

6. Composite drug research scheme (1965)  
Ministry of Health, Govt. of India

Object:

To study the chemistry of following Indian medicinal plants: (i) Boerhavia diffusa, (ii) Calotropis gigantea, (iii) Moringa pterygosperme, (iv) Asparagus racemosus, (v) Argymoni mexicena, and (vi) Caesalpinia bonducella.

Present state of development:

Work carried out so far has led to the isolation of certain extracts of Boerhavia diffusa with pronounced diuretic properties.

Proposed plan of work:

Efforts will be directed towards the isolation of the active compound having the above mentioned diuretic properties. Detailed investigation on other plants will be carried out.

The project is likely to be continued.

7. Pine oil from Indian turpentine oil (1965)

Object:

To find out different constituents present in the pine oil and their characterization and standardization.

Present state of development:

Commercial oil samples received from the party has been fractionated. The major portion of the oil has been characterized as  $\triangle^3$ -carene.

Proposed plan of work:

Detailed work on the above lines will be carried out.

8. Utilization of  $\Delta^3$ -carene (1966)

Object:

Utilization of  $\Delta^3$ -carene obtained as the major component of Indian turpentine oil.

It has been clear for many years now that any utilization of Indian turpentine oil (ex-Pinus longifolia) as a source for pinene-based industrial products can be economical only if suitable outlets for the utilization of its major components can be discovered. The problem is sponsored by a firm which annually produces as much as 4000 tons of carenes.

Proposed plan of work:

Attempts will be made to convert  $\Delta^3$ -carene into oxygenated derivatives. Besides this, the possibility of converting carene into menthol will also be investigated.

9. Utilization of longifolene (1966)

Object:

Utilization of longifolene obtained as another major component of Indian turpentine oil.

Proposed plan of work:

Attempts will be made to convert longifolene into its oxygenated derivatives. Besides this, work on the air oxidation of longifolene will also be investigated.

It may be mentioned that our work on the chemistry of longifolene has already encouraged a foreign party to import few tons of crude longifolene for experimental purposes.

10. Constitution of lac (1961)  
Indian Lac Cess Committee, Ranchi

Object:

To study the structure of the lac resin and its components.

Present state of development:

Work carried out so far has led to the following results: (i) Nature of total acids produced on base hydrolysis has been established. (ii) Structure of jalaric acid, a major building block, has been settled and a method for its quantitative estimation standardized. (iii) A more or less homogenous fraction of the hard resin has been prepared.

Proposed plan of work:

Further work will be directed to the systematic structure determination of the resin and a headway in this direction has already been made.

The project is likely to be continued.

11. Extraction of emetine and cephalin from Ipicac roots (1966)

Efforts will be made to work out the know-how for the extraction of emetine and cephalin (pharmaceutical grade) from the Ipicac roots supplied by the sponsor, on laboratory scale.

Work is undertaken for one year in the first instance.

12. Synthesis of cyclamates (1966)

Efforts will be made to synthesize Na and Ca cyclamates which find good market as sweetening agents.

Work is undertaken for one year in the first instance.

13. Preparation of carbimazole and sorbide nitrate (1966)

Synthesis of these fine chemicals used in medicine, will be developed for the party on laboratory scale (carbimazole 2-3 kg./batch and isosorbide nitrate 4 kg./batch).

The scheme is undertaken for one year in the first instance.

14. Chemistry of lac dye (1957)  
Indian Lac Cess Committee, Ranchi

There are possibilities of lac dye having an export market as a food colour. However, further work will be necessary before more definite statements can be made.

The project is to terminate on 14th July 1966 and an application has been made for three years' extension which will be considered shortly by the Indian Lac Cess Committee.

15. Reactive dyes (1963)

Several new dyes have been prepared and sent to the sponsor for evaluation.

The project has been terminated on 31st December 1965, but it may be extended for a further period.

16. Vanillin and ethylvanillin (1966)

The technical preparation of vanillin and ethylvanillin will be studied on laboratory scale, from o-anisidine and o-phenetidine. The scheme is sponsored for one year in the first instance.

17. Nonylphenol (1966)

The technical preparation of nonylphenol will be studied on laboratory scale. The scheme is sponsored for one year in the first instance.

18. Research on commercial uses of Punjab costus roots (1963)  
Government of Punjab

Object:

To find out ways for profitable utilization of costus roots grown in different areas of Punjab State.

Present state of development:

The method of extraction of perfumery-grade oil from the Punjab costus roots has been standardized. The lactones of costus root oil have been converted into a series of derivatives and are examined for their possible use in medicine.

Proposed plan of work:

Efforts will be made to develop a practical method for the conversion of dehydrocostus lactones to guaiazulene and related products. The azulenes are now finding increasing uses as anti-inflammatory agents. A maximum yield of about 8% azulene from lactone has been achieved by the NCL as against 1% yield recorded in the literature.

Approximate date of completion:

The scheme is to be terminated by 31st March 1966, but extension for one more year is expected.

19. Improvements in the process for the manufacture of l-menthol from dementholised peppermint oil (1965)

Object:

The sponsor is the manufacturer of l-menthol from imported dementholised peppermint oil. They are using a foreign know-how which is complicated and is not working satisfactorily. Aim is to simplify the process so as to improve the yield of l-menthol and bring down the cost of production.

Present state of development:

Large number of samples of various fractions obtained from the manufacturer's plant have been analysed by VPC and the maximum possible theoretical yield of l-menthol has been ascertained.

Proposed plan of work:

On the basis of the above findings, work has now been taken up to simplify the procedure. Experience obtained earlier on

the synthesis of l-menthol from citronellal will be helpful in this investigation as some of the later stages in both the processes will be nearly identical.

Approximate date of completion:

Scheme is sanctioned up to June 1966, which is likely to be extended.

20. Isolation of sandalwood oil by solvent extraction (1966)  
In collaboration with CFTRI, Mysore

Object:

Dr. Krishnan of CFTRI has started investigation to develop a solvent extraction procedure for the isolation of sandalwood oil in consultation with Government Sandalwood Oil Factory, Mysore. In certain chemical aspects of the problem, NCL is assisting Dr. Krishnan.

Present state of development :

About 3 kg. of a particular fraction of the oil has been supplied by CFTRI.

Proposed plan of work:

Detailed chemical examination of the sample will be carried out. Similar examinations will be conducted on different fractions of the oil which will be supplied by CFTRI.

21. Calcium hypophosphite (1964)

Object:

To develop process know-how for the production of pharmaceutical-grade calcium hypophosphite on pilot plant scale.

Present state of development:

Bench scale experiments have been completed (1/2 kg.phosphorous/batch) to optimise the conditions of reaction to obtain a maximum yield of calcium hypophosphite.

Proposed plan of work:

A pilot plant has been set up to process 1.5 kg. phosphorous per batch and to convert the phosphine to phosphoric acid. Pilot runs will be taken to collect necessary data for the design of a plant producing 30 kg/day of calcium hypophosphite for the sponsor.

22. Industrial chemicals from diketene

Starting from diketene, a variety of industrially important chemicals can be manufactured. These include acetoacetylides including naphthol AS-G, acetoacetic estic, acetoacetic-diethylamide, acetoacetamide and pyrazdones etc.

The work will be undertaken for one year in the first instance.

23. Investigation of fermentation problem

A pharmaceutical firm has <sup>ed</sup> sponsored a scheme to investigate the causes of spoilage of some of their pharmaceutical preparations obtained by fermentation. NCL will be suggesting them suitable preventative measures.

24. Manufacture of aminotriazole

The technical process for the production of aminotriazole will be developed. Chemical engineering designs for a plant of 100 tons/per annum will be supplied.

The scheme is undertaken for one year in the first instance.

PROJECTS LIKELY TO BE SPONSORED

1. Utilisation of wool wax

Lanolin which is obtainable from wool wax is imported to the extent of about Rs.2 crores per annum.

A woolen mill in Bombay having their combing plant at Dehra Dun alone produce about 150 tons/year of wool wax.

Work on the utilisation of wool wax is proposed.

2. Calcium levulinate and esters of p-hydroxybenzoic acid

A technical preparation will be developed.

3. Dimethylamine

This is an important chemical for which the anticipated demand is 4000 to 5000 tons/year. Preliminary work on the vapour phase process has already been carried out, but considerable work has still to be done to finalise the process on the bench scale. In addition, details have to be worked out on the separation of the amines which constitutes the most difficult step in the whole process.

The work will involve (i) the development of the process on a bench scale; (ii) study of separation techniques, and (iii) operation of a small pilot plant of about 5 kg/hour capacity. A larger pilot plant of about 20-30 kg/hour capacity can then be set up, if necessary.

PILOT PLANT PROJECTS

## Fine chemicals project

### Date of starting:

1st April 1964

### Object:

Fine chemicals project is to make available research chemicals that are so badly needed by scientific workers throughout the country and which are unavailable at short notice.

### Summary of previous work:

During the last year, the activities of the FCP have been stepped up and about 300 chemicals have been manufactured against orders. About 25 new items have been added to the list.

### Proposed work:

It is anticipated that the production of at least 6 products will be undertaken on pilot plant scale during 1966-67. These include items needed for defence such as sorbic acid, (30 kg/month) and dithranol (2 kg/month); import substitutes such as phenoxyacetic acid (1-1½ ton/month), malonic acid (200 kg/month), silica gel (200 kg/month), alumina (200 kg/month) and semi-carbazide hydrochloride (25 kg/month). The production of few other items such as thionyl chloride, para-toluene sulphonic acid and ethyl orthoformate may have to be scaled up.

The FCP has undertaken, in collaboration with Dr.J.L. Bose, the synthesis of special carbohydrate derivatives for a research institute in USA.

Besides the pilot plant scale synthesis of few items listed above, FCP will carry out routine synthesis of at least 250 items on 500 g. to 1 kg. scale and about 100 items on 1 g. to 200 g. scale.

Staff:

Scientist C	...	one
Senior Scientific Assistants		ten
Junior Scientific Assistants		twelve
Senior Laboratory Assistants		eight
Junior Laboratory Assistants		ten
Mechanic/fitter	...	two
Junior Stenographer	...	one
Lower Division Clerk	...	one
Junior Storekeeper	...	one
Junior Accountant	...	one
Stores Clerk	...	one

Expenditure:

Staff	...	Rs.3,31,293/-
Equipments	...	Rs.3,27,000/-
Contingencies	...	Rs. 45,000/-
Raw materials	...	Rs.2,55,000/-

1. Raney Alloy

Date of starting:

1st April 1966

Object:

To standardize conditions for large scale manufacture of alloy.

Summary of previous work:

Know-how for the preparation of Raney alloy has been developed at <sup>the</sup> scale of 6 kg/charge. The product was sent for trials to M/s Industrial Perfumes Ltd., Bombay, who have reported its suitability for hydrogenation.

Proposed work:

Adequate trials will be taken to standardize the product for quality, uniformity, powderability and grain size etc. Since induction furnace is not available, melting of alloy will be carried in crucible furnace as used by moulders.

Staff:

Junior Scientific Assistants	one
Senior Scientific Assistant (Chem.Engg.)	two
Moulder . . . . .	one
Attendant . . . . .	one

Expenditure:

Staff . . .	Rs.10,000
Equipments . . .	Rs. 5,000
Contingencies	Rs. 3,000
Raw materials	Rs.10,000

2. Vitamin B<sub>6</sub>

Date of starting:

1st April 1966

Object:

To prepare vitamin B<sub>6</sub> on pilot plant scale for standardizing the conditions established in the earlier work.

Summary of previous work:

The process for the preparation of vitamin B<sub>6</sub> has been earlier worked out on laboratory scale as well as on bench scale in Organic Chemistry Division.

Proposed work:

A pilot plant of suitable scale for the production of vitamin B<sub>6</sub> will be set up for demonstration to those interested in commercial exploitation of the process. The process consists of ten main steps of synthesis. About three batches of the full process will be demonstrated to a firm at their cost.

Staff:

Scientists B (Chem.Engg.)...	two
Senior Scientific Assistants	two
Attendants ' ... ..	two

Expenditure:

Expenditure is likely to be borne by an industrial firm.

3. Dissolving pulp

Date of starting:

August 1958

Object:

Investigation of indigenous cellulosic raw materials for dissolving pulp production.

Summary of previous work:

Prehydrolysis sulphate pulping of D.strictus and B.arundinecea species gave pulps of acceptable reactivity and chemical composition. Acid prehydrolysis sulphate pulp viscose solutions when spun gave rayon filament yarn of good physical property. The yield of bleached pulps was not satisfactory. A two-stage alkaline pulping process was therefore developed which yielded more bleached pulp than prehydrolysis sulphate process. The findings were confirmed on pilot plant scale with recycling of black liquor.

Comparative study of different processes for pulping Melocanna bamboo species of Assam confirmed that acid prehydrolysis sulphate and two-stage alkali pulping processes, are suitable for this species.

Acid prehydrolysis sulphate process gives pulps of good chemical composition with high ash content in case of mix-hard woods and first year growth bamboo of Maharashtra State.

Pilot plant trials on groundnut shells by water prehydrolysis sulphate process gave unbleached pulp yield of 30-32%. As these pulps could not be converted to sheet form due to small fibre length, processing of above pulps was carried out in wet conditions.

Proposed work:

(i) Continuation of work on bamboo as per recommendations of cellulose Ad-Hoc Committee by T.S.alkali process and study of hard-woods under optimum conditions of bamboo. (ii) Investigation of eucalyptus hybrid for Tyre-cord and cellulose acetate grade pulps. (iii) Purifications of pulps - study of complex forming agents like diethyl triamine pentaacetic acid and n-hydroxy ethyl ethylene diamine triacetic acid. (iv) Study of prehydrolysis-sulphate method with addition of sodium borohydride.

Staff:

Scientists B and A (one each)	two
Senior Scientific Assistants	two
Junior Scientific Assistants	five
Mechanic	one

Expenditure:

Staff	...	Rs. 72,000/-
Raw materials		Rs. 5,000/-
Contingencies		Rs. 4,000/-

Approximate date of completion:

31st March 1968

4. Chlorination and hydrochlorination of ethylene

Date of starting:

March 1963

Object:

To develop processes for hexachloroethane, trichloroethylene, tetrachloroethane and ethyl chloride.

Summary of previous work:

Work has been completed on the development of a process for hexachloroethane. The process has been given over to a firm in Gujarat, and complete chemical engineering designs are under preparation.

Proposed work:

The work will be extended to tetrachloroethylene and to tetrachloroethane (which will then be converted to trichloroethylene). All the three compounds are required by Defence.

Staff:

Senior Scientific Assistant	one
Junior Scientific Assistant	one
Senior Laboratory Assistants	two
Junior Laboratory Assistant	one

Expenditure:

Staff	...	Rs.17,900/-
Equipment	...	Rs.10,000/-
Raw materials		Rs. 5,000/-
Contingencies		Rs. 3,000/-

Approximate date of completion:

March 1967.

5. Aniline

Date of starting:

March 1963.

Object:

To design and operate a pilot plant for the vapour phase hydrogenation of nitrobenzene to aniline.

Summary of previous work:

A pilot plant using an adiabatic reactor system (6-7 kg/hour) has been set up and operated. Another pilot plant (3 kg/hour) employing a different type of reactor has also been set up at the suggestion of the <sup>Advisory Panel for</sup> Process Development and it has been found to operate satisfactorily.

Proposed work:

Continuous runs will be carried out on both the pilot plants and all the necessary engineering data will be collected. Work on catalyst life will be continued.

Hydrogenation of o-nitrotoluene to o-toluidine will also be carried out in this pilot plant. The kinetics of this reaction has already been worked out.

Staff:

Senior Scientific Assistant	...	one
Junior Laboratory Assistants	...	two
Mechanic	...	one

Expenditure:

Staff	...	Rs.11,900/-
Equipment	...	Rs.10,000/-
Raw materials		Rs.20,000/-
Contingencies		Rs. 3,000/-

Approximate date of completion:

March 1967.

6. Phthalates and other plasticizers

Date of starting:

1st April 1966

Summary of previous work:

Work has been completed on a batch process for dibutyl and dioctyl phthalates. Chemical engineering designs have also been prepared and are being handed <sup>over</sup> to a firm of project engineers.

Proposed work:

Although the capacity of the proposed phthalates plant of HOC is 10,000 tons per year, it is understood that the total requirement of the country is far in excess of this quantity. It is therefore proposed to carry out further investigations on the production of phthalates with the object of developing a continuous process for dioctyl (and dibutyl) phthalates. This will involve (i) a complete study of the reaction in a

distillation column consisting of one or more bubble plates; and (ii) setting up of a small pilot plant of about 10 kg/hr capacity based on the data collected under (i).

Although this information should be adequate to design a continuous plant of 8000 to 10,000 tons/year capacity, it may be necessary to put up a larger pilot plant of 25-30 kg/hr capacity to demonstrate the process. This part of the work can be taken up during 1967-68.

It is also proposed to study the manufacturing processes of plasticizers from sebacic and adipic acids.

Staff:

Scientists B	...	two
Senior Scientific Assistant	...	one

Expenditure:

Staff	...	Rs.12,590/=
Equipment	...	Rs.15,000/-
Raw materials		Rs.35,000/-
Contingencies		Rs. 2,000/-

Approximate date of completion:

31st March 1968.

7. Carbonation of phenols.

Date of starting:

1963

Object:

To develop a process for BON acid and to extend it to the carbonation of phenol to salicylic acid.

Summary of previous work:

Process conditions for the production of BON acid have been optimised, and reproducible results have been obtained in a

small pilot plant capable of producing 1.5-2.0 kg. BON acid. A plausible mechanism for the reaction based on mass transfer has been proposed.

Proposed work:

The process will be tested on a bigger pilot plant of 5-6 kg. BON acid per batch. This plant has been fully assembled. Methods will be worked out for making the process more economical.

The available experimental assemblies (bench scale unit and the two pilot plants) will be used for studying the carbonation of phenol to salicylic acid. The reaction model proposed for BON acid will be examined for this reaction.

A continuous reactor assembly for the carbonation of phenols will be developed.

Staff:

Senior Scientific Assistants	one
Senior Laboratory Assistant	one
Junior Laboratory assistant	one
Turner-cum-fitter	one

Expenditure:

Staff	...	Rs.11,800/-
Equipment	...	Rs. 5,000/-
Raw materials		Rs. 3,000/-

Approximate date of completion:

March 1967 in the first instance.

8. Design cell for industrial projects

Date of starting:

April 1966

Object:

In accordance to the recommendations of the Advisory Panel for Process Development, it is proposed to organize an adequately staffed design cell, conducting exclusively design work on projects completed so far, and on projects which will be completed hereafter. The chemical engineering designs so prepared may further be supplied to project engineers. The team of the design workers will pursue the project till the plant is erected.

Proposed work:

Chemical engineering designs for various sponsored projects and for NCL projects such as vitamin B<sub>6</sub>, benzoic acid, dimethylaniline, monoethylaniline, dimethylamine etc. will be undertaken in the first instance.

Staff:

Scientist C	one
Scientists B	three
Sr. Draughtsman	one

Expenditure:

Budget provisions for the expenditure of the above project will be made at a later stage.

A P P L I E D      P . R O J E C T S  
with  
T I M E      T A R G E T  
(1 to 2 years)

### 1. Thermoelectric semiconductors

To develop different types of thermoelectric semiconductors having application in refrigeration and power generation.

Preparation of  $\text{Bi}_2\text{Te}_3$ ,  $\text{PbTe}$  and  $\text{Bi}_2\text{Te}_3\text{-Bi}_2\text{Se}_3$  doped with magnetic and non-magnetic impurities will be undertaken. Semi-conducting devices using above materials will be designed.

### 2. Photoelectric cells

To develop suitable photoelectric cells and study their characteristics with a view to replace similar imported materials.

It is wellknown that chalcogenides of cadmium and thallium in thin film form are generally used for the manufacture of photoelectric cells. The actual know-how such as mode of preparation, pretreatment and sensitisation etc. is not known. During the last few years, investigations on the structures and physics of thin films have been carried out in great details with special reference to their semiconducting and other properties.

Photoelectric cells will be prepared from sulphides, selenides and tellurides of cadmium lead and thallium. Their characteristics with respect to ultra-violet, visible and infra-red light sensitivity by altering the modes of preparation heat treatment and other variables, will be studied.

### 3. Ferrites

To develop soft ferrites of high Bs.

Ferrites are used as components in radio, television, telecommunication and computer microwave equipments and many other domestic and defence appliances. The present requirement in the country is estimated as 150-200 tons per year, worth Rs.60-80 million and is expected to grow up rapidly. For different applications different types of ferrites are used and they differ in composition and methods of preparation.

Complete processes for (i) soft ferrite of high  $\mu Q$  and (ii) hard ferrite of high BH have already been worked out and are ready for commercial exploitation.

Work will be carried out on soft ferrite compositions of high Bs-type and is expected to be completed by the end of the year.

#### 4. Phosphors for tube lamps

Calcium halophosphate for tube lamps have been prepared on a laboratory scale. The product is tested for colour, spectral distribution and intensity by irradiating under a U.V. lamp. Various proportions of activators and co-activators have been prepared under different firing conditions. The method of preparation and the composition has been standardized and brightness comparable to imported samples have been obtained. The preparation was conducted only on 10 gm. scale.

It is proposed to scale up the preparation to about 1 kg/batch.

#### 5. Chromatographic adsorbents

Standardization of processes for the preparation and activation of chromatographic adsorbents.

Large scale preparations of chromatographic silica gel and alumina have been standardized and handed over to FCP.

Conditions for the preparation of chromatographic grade calcium sulphate, calcium carbonate, calcium oxide, calcium phosphate, calcium hydrogen phosphate, magnesium oxide, magnesium carbonate and bone-meal have been standardized. Activation studies of these materials will be continued, and usefulness of these materials in TLC will be investigated.

6.  $\omega$ -Chloroacetophenone

Based on the results of laboratory scale experiments, the H.E. Factory, Kirkee, has already started large scale experiments. It is proposed to work out a suitable standard for the product and also to develop a suitable stabiliser. Assistance will be rendered to H.E. Factory to work out the method on large scale.

7. Diethyl m-toluamide

The product previously prepared on small scale, is being evaluated by the Armed Forces Medical College, Poona. The party will now require a regular supply of this material and various compositions prepared from them.

An important step in the preparation of the compound is the catalytic oxidation of m-xylene to m-toluic acid. While preparing the product for the above tests, this reaction will be investigated in detail.

8. Sorbic acid

The acid catalysed conversion of the ketene crotonaldehyde polyester into sorbic acid will be investigated in detail. This work will be carried out in collaboration with M/s Sirsilk Ltd., Kagaznagar (A.P.), who will make available ketene from their plant.

9. Apomorphine

Apomorphine is an acid catalysed rearrangement product of morphine and has applications in pharmacy. A systematic investigation of this problem will be worked out.

10. Products of opium alkaloid industry

In order to utilize by-products available from opium alkaloid industry, it is proposed to undertake (i) conversion of thebaine to codeine and (ii) utilization of opium marc.

Some preliminary work has already been carried out and it is found that the opium marc contains considerable quantities of narcotine and cyclo-laudenol. The conversion of cyclo-laudenol into steroidal hormone analogues will be continued.

Attempts will be made to get this project sponsored.

11. § -Methazone

§ -Methazone (16-§ -methyl-9- $\alpha$  -fluoro prednisolone) is a costly drug (approx. value Rs.10 lakhs for 5 kg.) and last year a number of commercial firms approached Govt. of India for its import.

The raw material for the synthesis of the above drug is available in the country. The work will be undertaken if sponsored by industry.

12. Cellulose caprate

Cellulose caprate is the main ingredient of optical cement compositions of exceptional quality. There is a demand for this product in defence department. The process for the preparation of cellulose caprate of the desired degree of substitution has been worked out on a laboratory scale.

Attempts will be made to prepare larger batches of cellulose caprate and prepare actual cement composition for testing and performance trials etc.

13. Modifications of indigenous gums for use as substitutes for gum arabic

This work is undertaken at the instance of the Indian Posts and Telegraphs Department and attempts are being made to

substitute imported gum arabic by modifying easily available indigenous gums such as Karaya, Ghatti and Jeol.

Modified samples of the above gums have been tested in the laboratory and then sent for actual trials to the Posts and Telegraphs Department. Large quantities of these modified gums will be prepared and sent to P & T Department for testing at various centres in the country.

Attempts will be made to modify readily available other gums of less commercial value for different adhesive uses. Enquiries will be initiated and contacts will be made with gum industry in the country to ascertain the exact requirements of different types of modified gums.

#### 14. Synthesis of glycosides

It has been found that a research institute in United States is in need of different galactosides, fucosides, thiogalactosides and thiofucosides which are required for studies in genetics. There is a possible market for these compounds from similar institutes in other countries.

It is proposed to undertake preparation of these glycosides and locate indigenous sources of D-galactose and D-fucose. Preparation of raw  $\alpha$ -anomers of these glycosides is also in view. The sale of these compounds to foreign countries will be effected through FCP.

#### 15. Utilization of groundnut shells

The object of this project is to prepare from groundnut shells (i) dissolving grade pulp, (ii) carboxymethyl cellulose, and (iii) vanillin from groundnut shell lignin.

A modified method has been developed to prepare CMC from moist groundnut shell pulp. Different methods of oxidation of groundnut shell lignin to vanillin have been tried with limited success.

More samples of dissolving grade pulp and CMC from groundnut shell will be prepared and sent to industry for testing and evaluation. Attempts will be made to modify the samples accordingly.

Groundnut shells will be pulped by the sulphite method and the lignosulphonic acid available will be tried for oxidation to vanillin by alternative procedures. The pulp obtained will be processed for the preparation of CMC.

16. Reactive dyes

Attempts will be made to develop technical processes for the manufacture of reactive dyes based on cyanuric chloride.

17. Dioxazine dyes

Attempts will be made to develop technical processes for the commercial manufacture of dioxazine dyes and pigments.

18. Synthesis of carbohydrate derivatives

Preparation of D-glucosamine hydrochloride from carb and prawn shells and diethylaminoethylcellulose having required degree of substitution has been standardized for FCP.

Methods of preparation of 2-deoxyribose, d-arabinose and acetobromoglucose will be standardized for which orders are received in FCP. Number of other carbohydrate derivatives will be prepared as and when required by FCP.

19. Synthesis of menthol from citronellal

A method for the preparation of l-menthol from (+)citronellal available from Java citronella oil has been developed and standardized. Attempts are being made by CIMPO to cultivate citronella grass and Eucalyptus citriodora, oil from which contains a high percentage of (+)citronellal, thus substituting Java

citronella oil. As a result of this, a party who has sponsored the scheme on l-menthol from dementholised peppermint oil, is showing interest in the commercial exploitation of the process mentioned above.

(±)Citronellal is at present produced in the country by hydrogenation of citral ex-lemongrass oil. (±)Citronellal thus obtained can be used for the synthesis of (±)menthol which may find some market in the country.

It is proposed to standardize the method of conversion of (±)citronellal ex-lemongrass oil to (±)menthol. Attempts will be made to get this project sponsored.

## 20. Preparation of perfumery chemicals for sale

Practical processes for the syntheses of the following macrocyclic perfumery chemicals have already been developed and standardized:

civetone, exaltone, exaltolide, isoambrettolide, dihydroambrettolide, muscone and ambrettolide.

There is some demand for the above chemicals in India, and there is also a possibility of developing an export market for these chemicals.

It is proposed to prepare the following chemicals during the current year for their supply against possible demands (i) exaltone - 5 kg. (ii) exaltolide - 5 kg. (iii) nonoic aldehyde - 15 kg. The total market value of the above chemicals will be of the order of Rs.35,000/-.

Preparation of other perfumery chemicals such as neo-lavandulol, ionones, dihydrojasmane, civetone and peach aldehyde etc. will be carried out according to demands.

## 21. Extraction of costus root oil for sale

Costus root oil extracted by the process developed earlier in this laboratory has found favour with leading perfumery houses abroad and is proving a steady foreign exchange earner for

the laboratory. Last year, 13 kg. of the oil has earned approximately Rs.21,000/- in foreign exchange.

It is found necessary to keep a stock of at least 50 kg of the oil to meet the expected demand for which extraction of about 3500 kg. of roots will be executed.

22. Chemicals from castor oil

Cracking of castor oil and castor soap yields many chemicals including heptaldehyde, undecylenic acid, octanol, sibacic acid etc. These have been used as raw materials for the synthesis of a large number of perfumery chemicals. Undecylenic acid was used for the synthesis of isojasmone and peach aldehyde and macrocyclic musks. Octanone was also used for the synthesis of dihydrojasmone.

This work will be undertaken if sponsored by industry.

23. Maintenance of the stock culture for bacterial diastase

A process has already been released for the manufacture of bacterial diastase to a firm in Bombay. Stock cultures of the bacterial diastase project are regularly maintained under different conditions for testing etc. The same will be continued during the year.

24. Substitutes for starch/dextrine in foundry chemicals

Foundries in India are at present using starch, in the dextrinized form in binders for sand core mixture to impart necessary green strength to their cores and moulds. Substitutes based on indigenous gums will be developed for their use along with other binders.

25. Starch phosphate

Starch phosphate esters find number of uses such as thickeners in canned foods, binders in pharmaceutical products, flocculants, and in textile printing etc. It is proposed to

develop and standardize preparations of different starch phosphates from indigenous starches.

26. Can sealing compositions

The latex base can sealing composition developed earlier in the NCL is being produced by the licensee since 1961. This product is suitable for the cans used in food industry.

There is a growing demand for can sealing compositions used in packaging mineral oil, lubricating oil etc. in suitable cans. It is proposed to develop the above type of can sealing composition, the requirement of which is at present met by imports.

This item has been recommended by the Working Group at Research & Industry Get-to-gether held recently at New Delhi.

27. Styrene DVB-base cation exchange resin

A good progress has been made in improving the attrition characteristics of the above type of resin, developed earlier. The modified resin is found comparable to similar imported product.

It is proposed to standardize the new technique and prepare the resin in large batches.

28. Cation exchange resin for pharmaceutical industry

It is proposed to develop weakly acidic cation exchange resins which find use in antibiotics and pharmaceutical industries. The present demand is met by imports. The project has been recommended by the Working Group of the Research & Industry Get-to-gether held recently at New Delhi.

29. Expandable polystyrene

Some progress has been made in standardizing the conditions of polymerisation leading to free-flowing expandable polystyrene beads.

Large scale batches of the polymer beads will be prepared. It is also proposed to fabricate foam sheets of larger dimensions.

30. Surface coatings from styrenated alkyds

Necessary modifications will be made in the formulation of surface coating based on styrenated alkyds keeping in view the reports of the actual trials made by outside parties. Approved formulations will be prepared in large batches to collect technical and economic data for the release of the process to industry.

31. Linseed oil emulsion surface coatings

Preliminary experiments for the above, particularly for indoor masonry work, are promising. It is proposed to standardize the preparation of vacuum bodied linseed oil and prepare suitable emulsions of the required coating characteristics.

32. Polymerisation of Indian turpentine oil

Preliminary experiments on polymerisation of Indian turpentine oil fractions with Ziegler-type catalysts have given encouraging results. Solid and resinous polymeric products have been obtained from the oil and from  $\Delta^3$ -carene.

It is proposed to undertake a systematic study of the polymerisation reactions involved and of the properties of the polymers.

33. Polyurethane base propellants

Polyurethane base formulation consisting of castor oil has been developed for making composite propellants. Attempts will be made to modify the above formulation to suit the requirements of ERDL, Kirkee.

34. Polyurethane base coating composition for nylon fabric

Work will be continued in collaboration with SASMIRA, Bombay, and formulation suitable for application on the fabric will be developed.

35. Polyurethane base rollers for typewriters

Preliminary trials to prepare typewriter rollers of the desired hardness are encouraging. Work will be continued.

36. Rubber base adhesives

Oil and fuel resistant sealants and cements based on synthetic rubber and/or resins are being developed for Hindustan Aeronautics Ltd., Bangalore.

37. Sorbitol and vitamin C

A process for the preparation of sorbitol by hydrogenation of glucose by use of nickel catalyst prepared from Raney alloy, is being finalised. Necessary work towards this will be undertaken and the process will be demonstrated to HAL, Pimpri, for its inclusion in the vitamin C project.

Necessary help was rendered to HAL, Pimpri, in carrying out large pilot plant trials (15 kg. vitamin C/batch) starting from sorbitol. NCL shall be assisting HAL, Pimpri, in preparing a project report for a commercial unit of 125 T vit.C/year capacity. Work on any particular aspect of vitamin C process will be undertaken, if desired by HAL.

38. Instrumentation

i) ESR spectrometer: An Electron Spin Resonance spectrometer with a wide line NMR attachment developed earlier, will be fabricated into a prototype model suitable for production.

ii) IR spectrophotometer: The above equipment will be developed and fabricated using indigenous components and materials.

iii) VPC simpler model: Development of simplified model for industrial quality control will be undertaken. The prototype of a more sophisticated model has been completed and has undergone satisfactory trials.

iv) New detectors for VPC: Thermal conductivity detectors giving very high sensitivity and stability have already been developed and are in production for use in the chromatograph already developed. Research on detectors for VPC will be undertaken.

39. Design and construction of an ultrasonic interferometer

Development of precise sound propagation and detection techniques are of great interest to the Navy in connection with under-water communication and detection problems. A precision ultrasonic interferometer has been developed. Calibration of this instrument with water has given excellent agreement with recently reported results.

A time proportional electronic thermostatic control for regulation of temperature within  $0.001^{\circ}$  using a thermistor as temperature sensitive element in a bridge circuit of the above instrument will be developed.

A P P L I E D      B A S I C      R E S E A R C H

### 1. Semiconductors

Studies on the structural, electrical and magnetic problems of selected semiconductor compositions will be continued. Basic data will be collected and potential compositions evolved will be applied for making solid state devices.

Semiconductors and p-n junction devices incorporating homo- and heterojunction will also be prepared by epitaxial methods and studied.

### 2. Ferroelectrics and related materials

Electrical resistances, electro-mechanical coupling coefficients and non-linear dielectric properties of perovskite-type ferroelectrics and also of materials doped with rare earth will be studied. The basic data thus obtained will help to select potential composition for fabricating solid state devices such as transducers and posistors.

Studies on single crystals of ferroelectric and anti-ferroelectric substances doped with transition metal ions by optical absorption and electron paramagnetic resonance techniques will be continued.

Work will be continued on the study of the ferroelectric system  $\text{Pb}(\text{La}_{\frac{1}{2}}\text{V}_{\frac{1}{2}})_x(1-x)\text{O}_3$  where  $\phi = \text{Ti}$  and  $\text{Zr}$ , along with others. An instrument for undistorted display of ferroelectric hysteresis loops for correct measurement of spontaneous polarization will be fabricated.

### 3. Photoconductors

The study of the photoconductive properties of sulphides, selenites and tellurides of Pb, Cd and Zn will be continued. It is proposed to extend the nature and scope of preparative conditions and measurements of semiconductors of the above type by introducing refined techniques of detection and measurement. Instead of steady state conditions, measurements will be

conducted with chopped irradiation and A.C. detection of low level photoconductive signals. The possibility of promoting barriers in photoconducting materials by co-evaporation of lead chalcogenides and oxides will be explored. The effect of annealing and ageing vacuum deposited films under various conditions will also be studied.

#### 4. Catalysis

The following work is proposed: (i) basic work on several physical and chemical properties of potential catalyst materials; (ii) development of new catalyst systems, and catalytic reactions, and (iii) to obtain the know-how for the preparation of existing catalysts.

With the above in view, study on surface properties and physical and chemical adsorption characteristics of some transition metals and compounds will be undertaken. Optimum preparative conditions for some industrial catalysts will be developed, and their surface activities will be studied.

#### 5. Effect of radiation on materials

##### i) Chemical effects of nuclear transformation

Studies would be continued on the heat and radiation annealing of radiation damage in neutron irradiated geometric isomers, cis- and trans-  $\text{Cr} \left[ (\text{NH}_2\text{CH}_2\text{CH}_2\text{NH}_2)_2 \right] \text{Cl}_2 \text{Cl}$  in order to throw light on the stereospecificity of post-irradiation annealing reactions.

The chemical effects of electron capture decay of  $\text{Ce}^{57}$  would be studied in cobalt compounds of varying dielectric constant.

##### ii) Radiolytic oxidation of naphthalene

Work done during the last year on radiolytic oxidation of naphthalene in aqueous tetrahydrofuran solution showed that the formation of naphthol takes place in low yield. Preliminary work

on the vapour phase high temperature radiolysis of naphthalene and water, indicated that the formation of naphthol takes place through a possible chain reaction. Investigations will be taken up to determine the optimum conditions for the production of naphthols with high 'G' values.

#### 6. Ferrites

New fluorine containing lithium ferrites and Cu, Mn, Co, Ni substituted ferrite compositions will be synthesized and their physical properties will be studied.

#### 7. Laser materials

New laser materials will be synthesized and their optical properties studied. Effect of temperature, radiation and magnetic field on tunnel current in Metal-Insulator-Metal cells will be studied.

#### 8. Chemical and thermodynamic properties of technologically important materials

Accurate thermodynamic data of substances over a broad temperature range is in demand from basic and applied research workers in the solid state field. This is of fundamental importance in developing and explaining theoretical equations and elucidation of solid state properties.

Studies on the heat capacity and heat of phase transition of some ferroelectrics and semiconductors in the temperature range 77-600°K will be continued. A low temperature and high temperature calorimeter has been constructed and calibrated for the purpose.

#### 9. Metal organic compounds

##### i) Organo-titanium

Work on synthetic organo-titanium chemistry will continue. Methods have been evolved to synthesize new heterotitanoxanes of

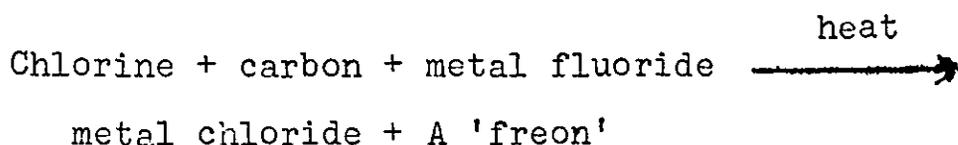
sulphur and phosphorus, and organotitanium polymers and their adducts. Proposed study will include new syntheses, study of probable structure and physical properties.

ii) Organo-silicon

Work on the synthesis of organo-silicon compounds will be initiated. In the first year, the study will be generally on the preparative techniques for organo-silicon halides and ~~xx~~ silicones of applied interest. Compounds of this category find use in defence and other industries for surface treatment of glass and various other purposes.

10. Freon

It is proposed to investigate reactions of the following type:



11. Conversion of camphene into camphor

The process now being used for the manufacture of camphor involves formation of isobornyl formate. Some data is available in literature on the direct oxidation of camphene to camphor and a direct hydration of camphene to isoborneol. It is proposed to investigate the above two reactions.

12. Studies in indigenous gums

Work has been commenced on the study of the structural aspects of "Ain" gum (*Termenalia tomentosa*) with a view to find its proper utilization.

It is intended to continue this type of work on other indigenous gums which are available in appreciable quantities.

13. Application of NMR spectroscopy in the identification of industrial products such as pesticides, surface active agents etc.

In accordance to the import substitution efforts that are being made in the country, NMR spectroscopy has been applied to determine the chemical constitutions of some imported products which are not at present manufactured in the country.

It is proposed to make systematic catalogues of spectra of different classes of compounds on which information is desired.

14. Syntheses of some biologically active indole alkaloids following the possible paths of biogenesis

The main objective of the work will be to device synthetic methods of possible economic importance for biologically active indole alkaloids present in plants of apocyanaceous family following the possible paths of biogenesis.

15. New vat dyes in dibenzanthrone series

It is proposed to carry out the Sandmeyer reaction on the tetrazotised diamine and cyclise the dichloro derivative with titanium tetrachloride or  $AlCl_3 - NaCl$  melt. The resulting dichloro dibenzanthrone compound would be a vat dye with interesting properties.

It is proposed to convert the diamine into the dihydroxy compound via the diazonium salt and methylate and alkali fuse the methyl ether into a dibenzanthrone derivative.

16. New dyes for synthetic fibres

Various factors which influence the dyeing and fastness properties of disperse dyes for synthetic fibres will be studied. The synthesis of new dyes for hydrophobic fibres like (Dacron, terylene, orlon) will be undertaken.

17. Chemicals from pinene

Large quantities of important perfumery chemicals such as geraniol, citronellal, linalol, citral etc. are now being produced in foreign countries by using pinene as the basic raw material.

It is proposed to undertake systematic investigation for converting the pinenes to acyclic hydrocarbons which are subsequently transformed to the oxygenated bodies by series of reactions.

A leading manufacturer of perfumery chemicals in the country is showing interest in the work and it is likely that after some preliminary investigations the project may be sponsored.

18. Studies in Indian essential oils

Complete chemical examination of South Indian vetiver oil will be undertaken.

At the instance of Botanical Survey of India, and ISI, chemical examination of some minor essential oils will be undertaken.

Instead of extracting costus root oil using petroleum ether as a solvent, it is proposed to extract costus roots with alcoholic solvents. The oil thus extracted may contain highly oxygenated bodies of potential medicinal value. It is proposed to isolate these constituents and undertake their chemical examination.

19. Studies in Indian medicinal plants

i) Nardostachys jatamansi (Valerianaceae)

Several furano and pyrano coumarins, one of which is jatamansin has been isolated from the oil. Jatamansin has been converted by synthetic reactions to dihydrosamidin and visnadin. These products are being examined for their medicinal properties.

The work will be extended to isolate and characterise other constituents present in jatamansin root.

ii) Valerian root oil (Valerianaceae)

Valerian root is known for its medicinal properties. Sesquiterpenes such as  $\beta$ -bergamotene and hydroxyvaleranone have been isolated and characterized. The solvent extracted concrete contains also a large amount of non-volatile solid material. It is proposed to examine this solid material for its constituents.

iii) Zingiberaceae family

Members of this family are widely used as spices. They also find use in medicine. Some of the constituents of turmeric oil (*Curcuma longa* Linn) have been isolated and characterized. Work will be extended to study other constituents of the oil as well to other species of the family.

iv) Ellatoria cardamom

The raw material will be received from Government of Sikkim. Work on investigation of the constituents will be undertaken on its arrival.

v) Cyperaceae family

Systematic examination of the oil of cyperus scariosus has already been undertaken. This work will be elaborated and extended to other species of the family.

vi) Compositae family

Many plants of this family are wellknown for their medicinal properties. Examination of Artemisia vulgaris oil has been undertaken as a joint project with the Calcutta University. A new pentacyclic triterpene has been isolated from the oil. Structure elucidation of this new alcohol will be undertaken. Examination of the roots of Inula racemosa has led to the isolation of alantolactone, isoalantolactone and related products.

Examination of the other members of this family will also be undertaken.

vii) Podophyllum emodi Wall

The dried rhizomes of the plant contain podophyllotoxin which exhibits tumor-damaging activity. Reactions of podophyllotoxin will be studied and investigations on the other constituents of the rhizomes will be undertaken.

viii) Bitters of neem oil

The chemical constitution of nimbin which is the principal crystalline constituent of neem bitters, has already been studied and elucidated. It is proposed to undertake work on other constituents of neem bitters. It is also proposed to investigate and find if the heartwood of the neem tree and that of the allied trees contain similar constituents.

20. Microbiological oxidation of hydrocarbons

Industrially important amino acids and vitamins have been successfully produced in some foreign countries using high yielding strains of bacteria.

Exploratory work on the isolation of cultures which can grow on kerosene has been undertaken and three cultures which are capable of rapid growth have been selected for further study.

The object of the present investigation is to study the utilization of these cultures and their mutants for the production of industrially useful chemicals with special reference to amino acids and organic acids and vitamins.

In collaboration with NCIM group, selection, production and biochemical study of bacterial mutants which can produce useful products of the above type, is proposed.

21. Grafting of cellulose

Preliminary experiments for grafting of cellulose with acrylonitrile and acryl amide using ceric ion redox system, have been carried out. Systematic work to standardize the grafting

procedure has been initiated and these studies will be continued. The acrylonitrile grafted cellulose is expected to be resistant to micro-organisms and acrylamide grafted cellulose on further reaction with formaldehyde will impart anticrease characteristics to cellulose.

## 22. Kinetics and reactor design

i) Experimental work on the determination of the mechanism of catalytic vapour phase reactions will be continued. This will include:

a) Dehydration of butanol, pentanol and hexanol over Indian bauxite. Experimental rates will be determined with the object of establishing and correlating the variation of adsorption and kinetic constants in a homologous series.

b) Oxidation of aromatic hydrocarbons (benzene and toluene). A plausible theory is being proposed for these oxidation reactions; experimental verification of this theory will be undertaken. The mechanism of oxidation will be examined for different catalyst compositions in order to establish any possible changes in mechanism with the proportion of catalyst ingredients.

c) Mechanism of the vapour phase condensation of aniline with methyl and ethyl alcohols over Indian bauxite. The study on the ethylation of aniline will largely be limited to monoethylation, while for methylation the experimental work will cover the formation of mono and diethylanilines.

d) Mechanism of the catalytic chlorination of ethylene to different chlorinated ethanes. The programmes of work will include a study of internal diffusion in the catalyst (active carbon).

e) Kinetics of the vapour phase catalytic hydrogenation of p-nitrotoluene to p-toluidine using the same catalyst developed for aniline.

ii) Experimental studies will be continued on the liquid phase hydrogenation of anacordol (from cashewnut shell liquid) to tetrahydroanacordol in a vibratory reactor.

iii) A new film theory has been proposed for the simultaneous adsorption of two gases in a liquid and subsequent reaction using the system ethylene-chlorine- ethylene dichloride. It is proposed to verify this theory using other systems.

iv) A new MI reactor has been set up and oxidation of benzene is being studied in this reactor system. It is believed that this reactor will be optimal for reactions of this type. Experiments will be carried out to verify the optimality criterion.

v) A mass transfer model has been developed for the carbonation of beta-naphthol to BON acid. This model will be extended to the carbonation of phenols in general.

vi) An experimental assembly has been set up for the continuous alkali fusion of 2-aminoanthraquinone to indanthrone. Experimental work will be carried out on this continuous unit with the object of obtaining engineering data for scale-up.

### 23. Amination of benzene

It is possible to produce aniline by the direct amination of benzene over a suitable catalyst. According to the available literature, this process is carried out at pressures of 30-40 atmospheres. It is proposed to carry out this reaction in the vapour phase over a solid catalyst under atmospheric pressure.

It is also reported that aniline can be produced by direct reaction of benzene with ammonia in the presence of radiation. Exploratory studies would be undertaken to find the conditions of amination of benzene and other hydrocarbons in the presence of gamma radiation.

24. Maintenance of NCIM

The culture collection consists of yeasts, bacteria and fungi of importance for research and industry which are supplied to industrial concerns, universities and other research institutions. The maintenance and testing of the cultures and studies on their biochemical performance and on the methods of preservation of the cultures will be continued.

B A S I C      R E S E A R C H

1. Theoretical research in solid state

i) Exchange interaction in magnetic solids

In the last few years indirect exchange processes in magnetic compounds have been studied. In the present and future work, emphasis will be on the mixing of electronic states and their effect on the spin coupling in compounds, metals and alloys.

ii) Phonon-Magnon interaction

The basic mechanisms of interaction between spin and ferromagnetic types of systems have been completed, and expressions for relaxation times of equilibration obtained. These are being employed for the study of transport properties of these systems, making use of advanced mathematical techniques. Interaction of spin waves with neutrons and optical phonons will be undertaken.

iii) Super-conductivity in metals and intermetallic compounds

Pressure dependance of the transition temperature ( $T_c$ ) of various super-conductors has been successfully explained.

The effect of magnetic element impurities on the transition temperature of super-conducting systems is being undertaken.

This work will be extended on hard super-conductors having great technical importance.

iv) Mobility in semi-conductors

Mobility in lead chalcogenides (PbS group) and their solid solutions has been studied. The results explained long standing problems.

The mobility of these systems in presence of magnetic field will be studied.

v) Vibronic interaction and phase transformation in solids

Earlier, origin of ferroelectricity was correlated with electron vibration coupling. The role of vibronic interaction and anharmonic terms in lattice dynamics will be studied in relation to the phase transformation in some solids.

vi) Electronic states of organic molecules and complexes

The energy levels, wave functions and electronic densities of quinone type compounds have been studied by electron gas model. Other complicated molecules with different functional groups will be studied in relation to their optical properties.

vii) The state of atoms in the presence of crystals and radiation fields

The energy levels of atoms in crystals, their interaction with oscillating crystal field and external radiation field will be studied. These will be related to the laser action of such materials.

viii) Magnetic break-down in solids

The behaviour of matter in the presence of very high magnetic field will be studied to elucidate the electron trajectories and the criteria of magnetic break-down under various conditions.

ix) Localised states of impurities in metals and alloys

The nature of localised states in various metals and alloys containing impurities will be explored.

2. Physics and chemistry of solids

i) x-Ray crystal structure studies

Basic data on crystal and molecular structure determination and service to various other projects of the laboratory and also service to universities and industrial research laboratories in special cases.

ii) Spectro-chemical studies

Basic studies on molecular structure determination and service to various other projects of the laboratory and also service to university and industrial research laboratories in special cases.

iii) Thin films

In thin film state, the properties of materials are often different from that of bulk state. In view of the above, fundamental studies on physical properties and semiconducting properties of thin films and their detailed structure have been undertaken.

Structure: Fundamental studies on surface structure, crystal growth process, phase transition intensity variation due to dynamical and kinematical modes of scattering of electrons, crystal defects with special reference to dislocations, stacking faults and other imperfections, will be carried out by electron microscope, electron diffraction, and optical microscope.

Physics of thin films: Studies on semiconducting properties especially with thermoelectric power, Hall coefficient, energy band gap, photovoltaic effects, optical properties of thin films of selenide, telluride and of some alloys would be continued with a view to understand their semiconducting behaviour and ultimately to use them in semiconducting devices.

Oxidation of metals: Studies on oxidation mechanism of thin metal films by a thermogravimetric, electron diffraction, electron microscope methods would be taken up with a view to understand the kinetics of the crystal growth process.

3. Nuclear and radiation chemistry

i) Mossbauer effect

In continuation of work on spinel-type compounds, Mossbauer spectra studies will be undertaken on mixed oxide systems

where cations have a possibility of occupying more than one possible site and have variable valency.

Work on the application of Mossbauer effect in elucidation of molecular structures of metal-organic compounds of iron will be continued.

ii) Diffusion in solid state and high temperature solid gas reactions

As a part of long range programme, on studies on diffusion of fission products in aluminium, it is proposed to extend these studies to the impurity diffusion of Sb and Sn in aluminium.

Studies on the kinetics of high temperature oxidation of some rare earth metals and alloys of silver will be continued.

iii) Thermodynamic properties of coordination compounds

Thermodynamic studies on the interaction of the divalent ions of the six transition metals, Mn, Fe, Co, Ni, Cu and Zn with the amino acids, serine and threonine in aqueous solution are in progress. Studies will be undertaken on the thermodynamics of interaction of histidine and cysteine with the above metal ions.

4. Solution chemistry

i) Measurement of adiabatic compressibility and apparent molal properties of some solutions

It is presumed that the molecular characteristics influencing the flexibility of the polymer molecule will be related to the compressibility data obtained by sound velocity measurements. It is proposed to investigate the above in case of polymer molecules with different flexibility such as carboxymethyl cellulose and polyacrylic acid.

ii) Degradation of long chain molecules by ultrasonics

Work on the degradation of butyl rubber in different solvents, changing different parameters will be continued.

iii) Light scattering and flow properties of macromolecules

Selected polymeric systems in solution will be investigated along with similar service work required by others.

5. Coordination compounds and synthetic inorganic chemistry

i) Coordination compounds

A study of the quasi-aromaticity of metal chelates, which may lead to new synthetic routes and novel reactions and may furnish useful results of both academic and applied interest has been undertaken. Earlier work on acetylacetonates, salicylaloxime and nitroacetylacetonates will be extended to other chelated  $\beta$ -dicarbonyls. In the case of salicylaloxime, the study will be of special reference to colour isomerism.

ii) Coordination polymers

Preparative techniques of inorganic coordination polymers and their properties are being studied. Bis-(8-hydroxy-5-quinolyl) methane and titanium gave a number of reaction products. Structures and thermal behaviours of these are being studied. Similar reactions with tetravalent tin will be undertaken.

iii) Infrared spectral studies of Werner-type compounds

Infrared spectra of some Werner-type complexes, e.g. metal amines and cis-trans isomers are being studied. Studies of metal complexes will be made in NaCl and CsBr prism regions to find metal ligand stretching vibrations, difference in cis- and trans-spectra and the effect of coordination on the symmetry of groups inside or outside the coordination sphere. These studies will be conducted with specially purified compounds.

## 6. Physico-analytical chemistry

In addition to the analytical services for various materials related to different NCL projects, following work will be undertaken:

i) Analytical applications of metal-poly-phosphates will be investigated further.

### ii) The molybdate dimethylglyoxime reaction

Reaction between the  $\alpha$ -dioximes and stannous chloride in presence of molybdate and/or per rhenate will be studied in detail to throw light on reaction mechanism. Work on dimethyl glyoxime-molybdate-stannous chloride will be completed in the first instance.

### iii) Direct reduction of insoluble vat dyes at the dropping mercury electrode

The phenomena of the reduction of solid insoluble dyes at d.m.e. will be further investigated.

## 7. Fluorine chemistry

Studies on ~~OR~~<sub>3</sub> substituted 'cupferron' compounds will be continued. Attempts will be made to condense benzotrichloride with other aromatic compounds. Previously reported work on bromo- and chloro-compounds will be completed.

In collaboration with 'high temperature chemistry' group, properties of  $K_2MnF_6$  and similar compounds will be studied. Attempts to prepare new complex inorganic fluorides will be made.

## 8. Natural organic products

### i) Oleoresins and resinoids

The oleoresins from Dipterocarpus pilosus and Hardwickia pinnata have been completely studied. Work on Boswellia serrata (Salai gum) has been initiated. Work on acidic components has been completed and attention will now be diverted

towards the neutral components. Salai gum is a regular product of Madhya Pradesh forests and its annual potential has been estimated between 3,500 to 4,000 quintals/p.a. Work has been initiated at the request of Madhya Pradesh Government.

ii) Wood extractives

Work on Cedrela toona has been completed.

Hardwickia binnata is an important timber of Maharashtra forests. At the request of Forest Utilization Officer, Poona, work will be undertaken.

iii) Modification of natural products

Work carried out so far under oleoresins, resinoids and wood extractives has led to the location of rich sources for several hitherto rare compounds. Since these raw materials are cheap and easily available, utilization of them after suitable modifications, etc. will be explored. In the first instance, modification of  $\beta$ -Himachalene will be undertaken.

iv) Hamycin

Work carried out last year in collaboration with the research department of HAL, has led to the separation of hamycin into three distinct factors. The active fraction behaves in a fashion very similar to trichomycin. It is proposed to pursue further this work.

v) Natural colouring matters

Anthraquinone pigments: Work on the synthesis of naturally occurring anthraquinone pigments will be continued.

Pigments of Garcinia morella and Garcinia hanburryi: The structures of morellin and several other pigments isolated from the seed coat and gamboge of G.morella have been elucidated, but there are aspects of their chemistry which remain to be clarified. Further, new pigments are also being isolated. Based

the structure for morellin the structure of gambogic acid has been proved by Yates and subsequently by Ollis. Some of the reactions of gambogic acid and chromatographic analysis to search for additional pigments will be investigated.

Pigments of Artocarpus species: Examination of the pigments of various artocarpus species will be carried out from the point of view of chemotaxonomy. This problem can be incorporated ultimately as part of a PL-480 project, but its approval has met with unexpected difficulties and may be considerably delayed.

Work on the synthesis of naturally occurring flavones, isoflavones and 2,2-dimethylchromenes will be continued.

9. Synthetic studies in organic chemistry

i) 4-(o-hydroxyphenyl)-cinnolines

A synthetic route has been developed for the preparation of these hitherto unknown cinnolines and samples have been sent to CDRI, Lucknow for screening for therapeutic value. Steric effect of various substituents on the two aromatic rings on cyclization of 2,3,4-triketo-chroman-2-arylhydrozones by this method is being studied.

ii) Meerwein arylation of 4-hydroxycoumarins

The effect of blocking the hydroxyl group in 4-position on the Meerwein arylation of 4-hydroxycoumarin is now being studied. The possible use of the new 4-hydroxy-phenyl-glyoxal monoxime monohydrates in quantitative estimations of certain metals is being explored.

iii) Chemistry of 3-acyl-4-methyl- and 4-acylmethyl coumarins

Some of the earlier trends in the synthesis of 3-acyl coumarins have been contradicted in recent years. It is therefore proposed to develop a general method of synthesis of

3-acyl-4-methyl coumarins to confirm the structure of the product developed earlier. Study of the properties of these compounds is also in view. A comparative study will be made with the isomeric 4-acylmethyl coumarins synthesized by the method developed earlier.

iv) Chemistry of synthetic dyes

Study of constitution of commercial dyes, partly in connection with a new edition of the 'chemistry of synthetic dyes' will be undertaken. Special attention will be paid to azoic coupling components, reactive dyes, dyes for polyester fibres and anthraquinonoid vat dyes. Related synthetic work will also be undertaken. A study of NMR spectra in connection with constitutional problems concerning synthetic dyes, such as chelation in azo dyes, azophenol-quinone hydrazone tautomerism, and the behaviour of polycyclic quinones towards reductive methylation and reductive acetylation will be continued.

v) Synthesis of cationoid dyes

It is proposed to synthesise cationoid dyes in which the charge is functionally capable of moving from one hetero-element such as nitrogen or sulphur to the other within the same heterocyclic polynuclear system. (See figure on page 54). The cationoid cyclic cyanines may be expected to be more stable than open chain polymethine cyanine dyes.

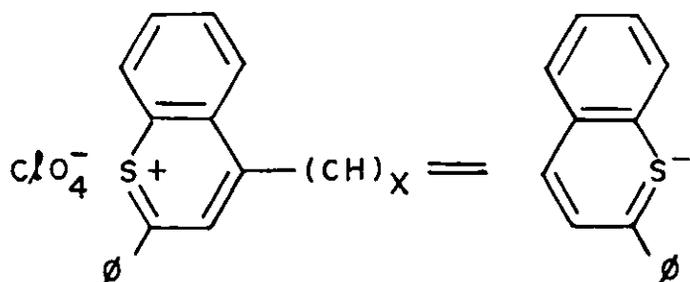
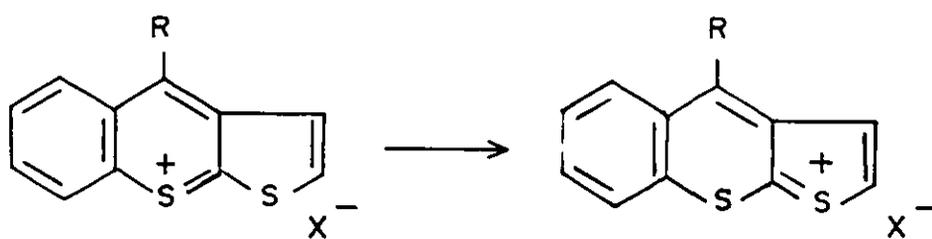
The synthesis of carbocyanine dyes in which the hetero element nitrogen is replaced by sulphur is also proposed. (See figure on page 54). With  $x = 1, 3, 5, 7$  and  $9$  methine chains will be synthesized and the absorption characteristics determined and correlated.

The synthesis of several such oxacyanines are also in view.

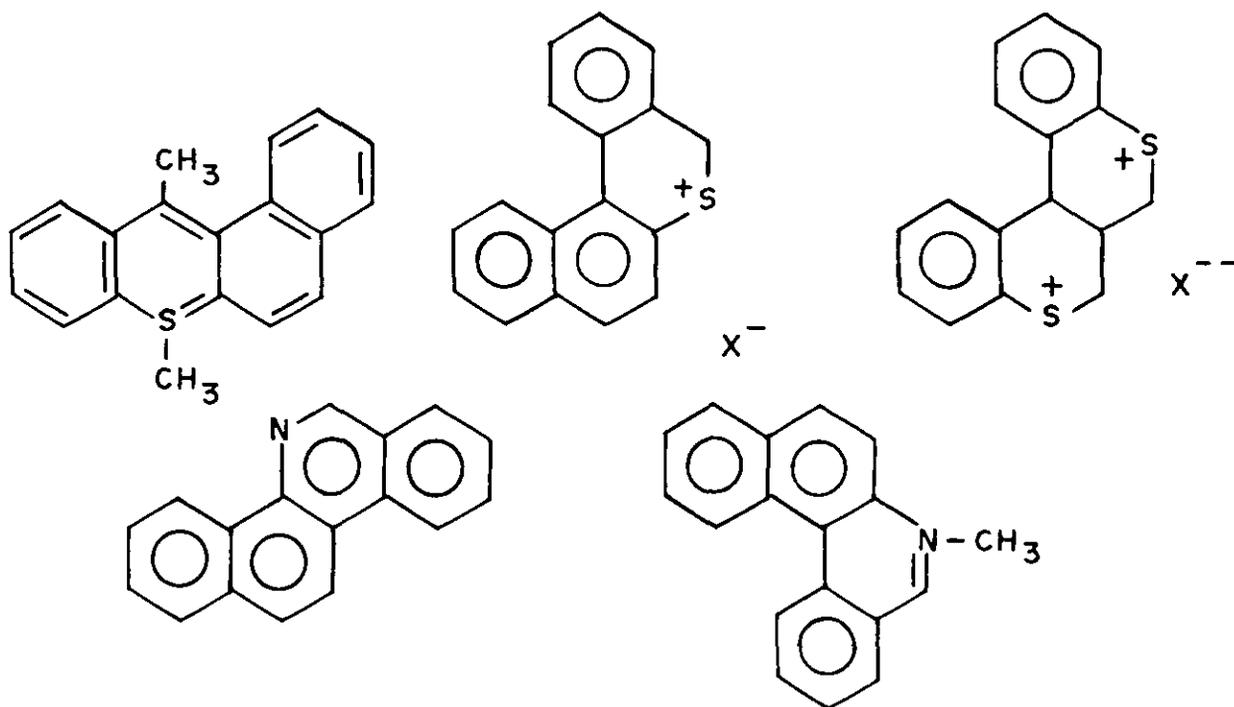
vi) Carcinogenic and carcinostatic heterocyclics

Synthesis of compounds of the types given below by suitable routes will be undertaken and their physiological activity evaluated. (See figure on page 54).

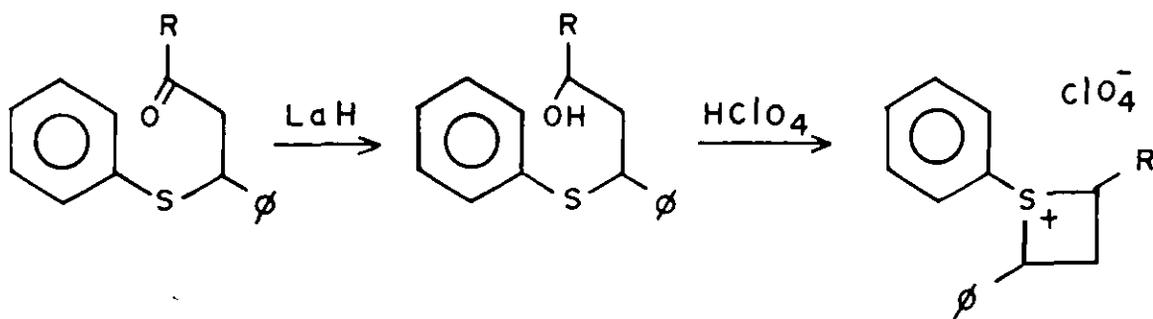
SYNTHESIS OF CATIONOID DYES (P. 53)

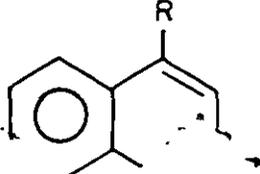


CARCINOGENIC AND CARCINOSTATIC HETEROCYCLICS (53)

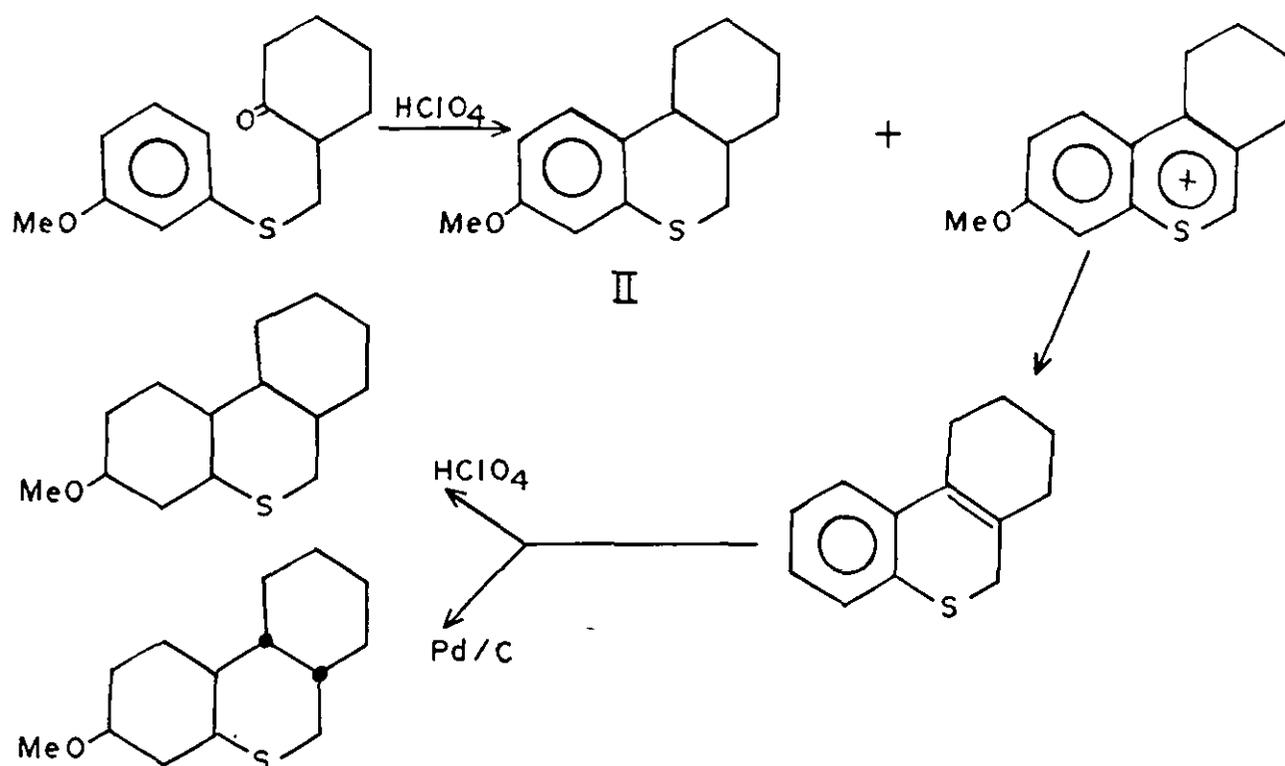


CHEMISTRY OF SULFONIUM SALTS (P 56)

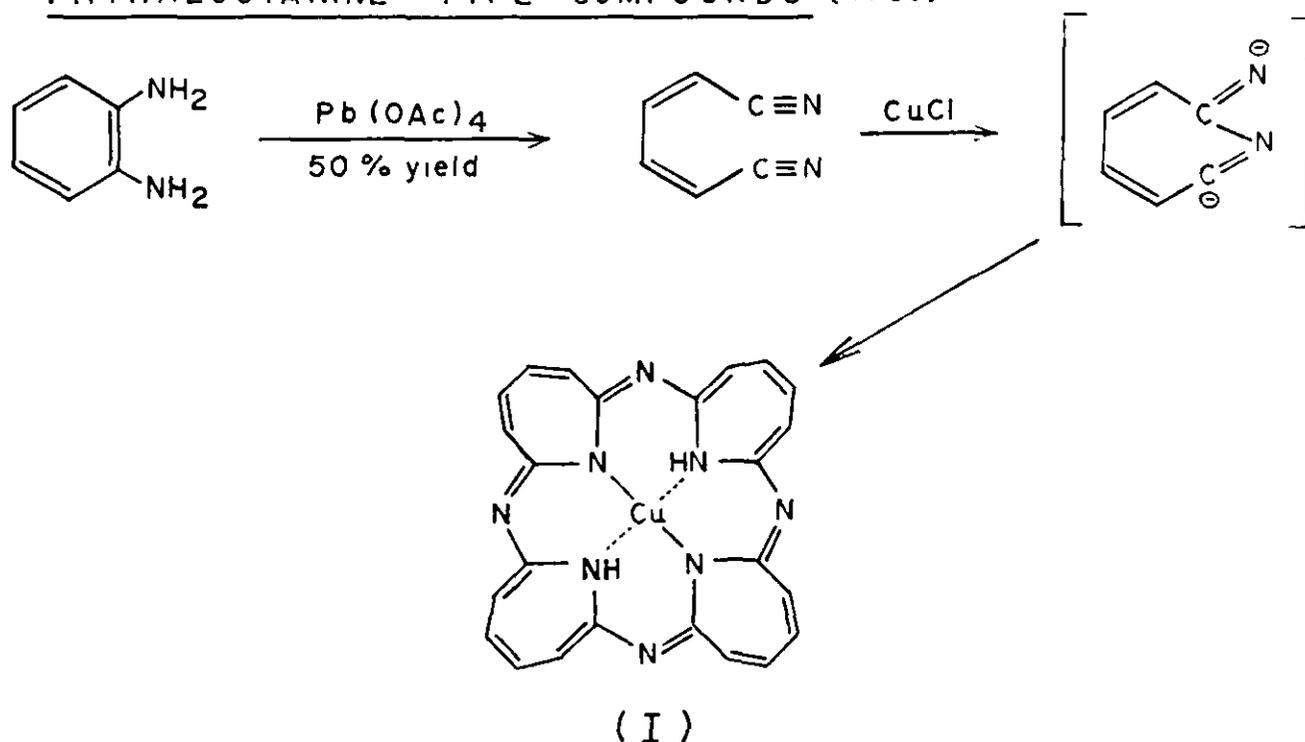


ALSO COMPOUNDS OF THE TYPE  WILL

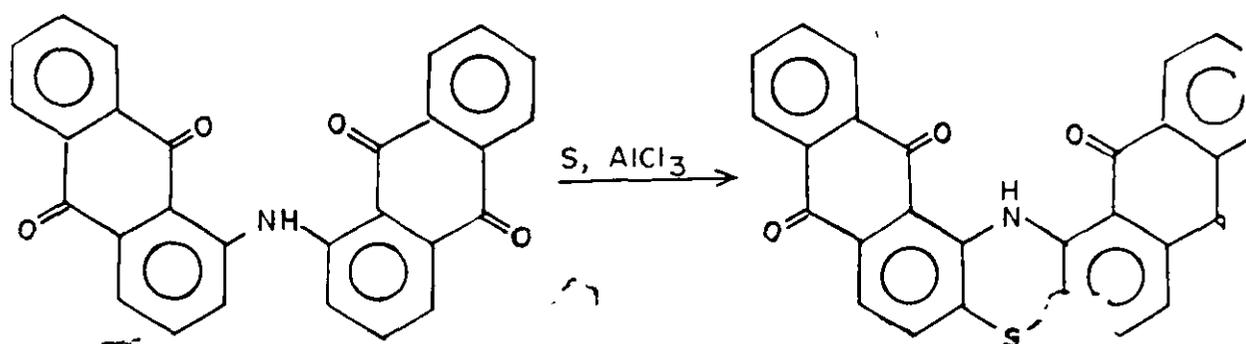
REACTIONS INVOLVING HYDRIDE TRANSFER (P 56)



PHTHALOCYANINE TYPE COMPOUNDS (P. 56)



SULFURISED VAT DYES (P 56)



vii) Chemistry of sulfonium salts

The synthesis of several sulfonium salts by the hydride reduction of ketosulfides followed by treatment with perchloric acid according to the following reaction sequence will be started and the structural studies on these products and their potential use as intermediates for polymethine type of dyes will be investigated. (See figure on page 54).

viii) Reactions involving hydride transfer

The cyclohehydration of ketosulfides with polyphosphoric acid leading to thiochroman and thiochromenes has been reported earlier. The following synthetic route would lead to compound (I) in which the hydrogen atoms at C<sub>3</sub> and C<sub>4</sub> are in all likelihood cis to each other and the stereochemistry of compounds (II) and (III) will be studied by NMR on the basis of information obtained from (I). (See figure on page 55). The nitrogen analogues of the above series will be synthesized and their stereochemistry studied.

ix) Mechanism of formation of triphenylmethane type dyes

A study of the mechanism of formation of triphenylmethane type of dyes by the action of trityl chloride and other hydride abstracting agents will be undertaken.

x) Phthalocyanine type compounds

The synthesis of (I) starting from o-phenylene diamine will be attempted. It would be interesting to study the color of (I) and its properties as a pigment. (See figure on page 55).

xi) Sulfurised vat dyes

Synthesis of new sulfurised vat dyes starting from anthrinides will be attempted. (See figure on page 55). The dyes so obtained will be interesting from the point of view of study of inter-relation between substantivity and coplanarity.

xii) Transformation products of terpenoids

Additional oxygen function in a terpene molecule can often be introduced by oxidation with selenium dioxide lead tetra-acetate. Prins reaction and other chemical operations. Investigation in this area has led to a simple synthesis of lavandulol, a conversion of eudesmol to santanolide, 'c' elemol to tetrahydraussurea lactone, dihydroguaïol to guaianolide, santalene to corresponding alcohols and aldehydes, citronellal to roseoxide and several other interesting products. It is proposed to extend the work in this area to develop synthesis of practical value from easily available raw materials from Indian sources. This will include also conversion of sterols, bile acids and saponin to steroidal compounds of medicinal value.

10. Physical organic chemistry

i) NMR spectroscopy

Preliminary work on the changes in benzene ring geometry introduced by strongly interacting substituent groups has been initiated. Work will be further explored.

Work on halogenation, nitration and alkylation of aromatic compounds is proposed. Attention will be devoted to both isomer distribution and mechanistic details.

The NMR spectra of several carbonium ions have been obtained with interesting results. They seem to have a direct bearing on the current controversy of the nature of "non-classical" carbonium ions. The work will be continued.

A study on solvent-solute interactions using NMR as a tool has been started with the hope of throwing some light on the solvent effect on isomer distribution in aromatic halogenation. The work will be continued.

Some preparative work is being done to get suitable materials for re-examination of the concept of "inherent"

asymmetry of freely rotating - CH<sub>2</sub>X groups in asymmetric environments in molecules.

ii) Mass spectrometry

After the installation of double focussing mass spectrometer, CEC21-110B, it is proposed to organize a mass spectrometry group.

Studies on the fragmentation modes of various oxygen and nitrogen heterocyclic compounds will be undertaken from the structure elucidation point of view. Attempts will be made to correlate fragmentation modes with stereochemistry.

Molecular rearrangement induced by electron impact is a new phenomenon which needs further investigations. These investigations will give a further understanding of the mechanisms of molecular rearrangements and fragments modes. It is proposed to study the migration of different heterocyclic groups and compare the migratory aptitudes. Few molecular rearrangements mediated via carbonium ions will also be studied.

Use of spectral methods and stable isotopes in the biogenetic studies of mitomycin-c will be undertaken.

In all the above work, use of computer techniques will be developed.

iii) PMR spectroscopy

Dependence of long range coupling in PMR spectroscopy on dihedral angles have been studied using rigid cyclic compounds. Influence of other factors on this coupling is proposed to be investigated.

Methods to find stereochemical relations in cyclic compounds were elucidated. This will be extended to the study of the stereochemistry of lactones.

iv) Gas liquid chromatography

Mathematical formulation on the contribution of a single methylene group occurring in the dicarboxylic acid part of a polyester stationary phase has been obtained. It is now possible to make "a Tailor made" polyester stationary phase. These results will be of great help in preparative gas chromatography. Influence of cross conjugation and development of optically active stationary phases will be studied.

Service work including analysis of samples from different divisions and universities will be continued.

11. Metabolic studies

i) Growth of plant cells

The object of this work is to study the growth and metabolism of cells from different plant tissues in vitro. A few tissues of capable of rapid growth have now been obtained with a cell division time of about 3 days. Work to reduce the cell division time to about 1 day or less is in view. Maize tissue was grown for the first time in this laboratory and the role of diphenylurea which is required for its growth will be investigated. Normal and tumour tissues from the same source have been obtained and comparative study of their metabolism and the effect of different compounds which can selectively inhibit the growth of tumours is being studied.

ii) Enzymes

Work on the following enzymes which were discovered or solubilized for the first time in this laboratory will be continued: phytase, hexokinase, acetylcholineesterase, DP-Nase.

Work on the bacterial enzyme citrase, which has been obtained in pure form in this laboratory will be continued. Mechanism of the reaction between the citrase and oxaloacetate and the nature of the complex form will be studied. The sedimentation

and electrophoretic behaviour of the enzyme will be compared with that of the complex. The effect of metals on the enzyme-inhibitor reaction and its stoichiometry will be investigated. The effect of reducing agents on the enzyme-substrate and enzyme-inhibitor systems will also be studied.

iii) Inorganic nitrogen metabolism

The object of the work is to elucidate the mechanisms of nitrate and nitrite utilization by the x luminous bacterium. The work has a bearing on understanding the soil fertility. Earlier studies resulted in the characterisation of nitrate reductase from P.fischeri. The data obtained strongly suggest that the nitrate reductase is not an haem-containing protein while the nitrite reductase obtained from P. fischeri is an haem-containing protein. It is proposed to obtain these enzymes in pure form and study in detail their properties. The biosynthesis of nitrate and nitrite reductases by P.fischeri will be studied, during balanced growth at 26° and growth restricting temperature with a view to elucidate the regulatory mechanism of the formation of these reductases.

iv) Metabolism of branched chain C<sub>5</sub>-dicarboxylic and C<sub>6</sub>-tricarboxylic acid

The earlier work has resulted into (a) an elucidation of the early metabolic reactions of these compounds, (b) the isolation and characterization of three new enzymes, and (c) evidence for the presence of two more new enzymes - (+) and (-) methylsuccinate dehydrogenases. Besides providing data on the specificity of the enzymes, this has led to an explanation of the biosynthesis of trans-aconitic acid in sugarcane.

Work on this will be continued with special reference to the isolation, characterization and purification of

the factor catalysing the conversion of cis- to trans-aconitic acid in sugarcane, and

the enzymes acting on C<sub>5</sub>- and C<sub>6</sub>-acids.

## 12. Microbiological transformations

Studies will be continued to investigate the pathways of degradation of various mono and sesquiterpenoid hydrocarbons by microorganisms. The isolation and characterization of the metabolites as well as the enzymes responsible for bringing about chemical changes will be continued.

In collaboration with the Biochemistry Division, University of Illinois and the Pseudomonas Workshop at Cold Spring Harbor, New York, genetic studies on the microorganisms bringing about the transformation have been initiated. This work will be pursued further.

Earlier ~~work has been obtained~~ have been obtained ~~Earlier work has been obtained~~ 18-substituted steroids by transformation of Kurchi alkaloids. Recently some interesting pharmacological properties of 18 and 20 amino steroids which can be derived from Kurchi alkaloids have been reported. It is, therefore, proposed to revise our earlier work to obtain new steroid analogues and screen them for specific pharmacological properties, at CDRI, Lucknow.

## 13. Polymer chemistry

### i) Stereospecific polymerisation

Further to zirconium tetrachloride and vanadium oxytrichloride catalyst systems, zirconium trichloride using cyclopentadienyl organometallic compounds in combination with transition metal halides will be tried for the polymerisation of styrene into a high molecular weight crystalline polymer.

Copolymerisation of styrene with hexene-1, heptene-1 and octene-1 using vanadium catalyst systems will be studied. Copolymerisation of styrene with acrylonitrile using ziegler catalysts will be attempted to produce an unbreakable and transparent glass-like product.

ii) Solution behaviour of polymers

The extrapolation method which was tried for the determination of molecular weights of polymers from their solution viscosities when applied on polyvinyl acetate, was found unconvulsive due to "specific solvent effects" on the unperturbed dimensions of the polymer. It is proposed to extend this method to stereospecific polystyrene and other polymeric systems.

Studies on the solution behaviour of p-chlorostyrene-methyl methacrylate copolymer and homopolymer fractions will be continued. Studies are also proposed on the solution behaviour of tailor-made model branched polymer systems.

14. Chemical engineering studies

i) Studies in fluidization

Work will be carried out on the use of fluidization as a means of heat transfer in reactors of the heat-exchanger type.

The use of fluidized solids to control highly exothermic reactions carried out on the surface of catalyst coated plates will be investigated. This work will be extended to unsteady state fluidization where the plate constitutes a reactant and is progressively consumed.

Work on the theoretical and experimental aspect of semi-fluidization will be continued. A technique has been developed (with the assistance of the Instrumentation Section) to measure the quality of fluidization as the region of semi-fluidization is approached. This technique will be used for the correlation of experimental data.

ii) Studies in mass transfer

Experimental work has been completed on the determination of flooding rates in liquid-liquid extraction columns and on the effect of pulsation on extractor efficiency and throughput. The data will be statistically analysed and correlated to obtain a generalized equation.

Work will be carried out on the use of fluidization in absorption and extraction columns.

Experimental work on the determination of mass transfer during drop formation in liquid-liquid extraction will be continued. The data will be correlated using a modified unsteady state diffusion equation.

Work on modified RDC will be continued and performance data collected with use of sieve-rotors and perforated rotors of different patterns with various fluid systems. Flooding and mass transfer data will be determined.

iii) Thermodynamics

The work on theoretical methods for the estimation of thermodynamic properties will be extended to include liquid heat capacity, heat of fusion, entropy of formation, thermal conductivity and other important thermodynamic and transport properties.

It has so far not been possible to set up experimental assemblies for the determination of thermodynamic properties. Attempts will be made to fabricate and assemble apparatus for determining liquid heat capacity and thermal conductivity during this period.

Experimental data will be collected on the vapour-liquid equilibrium of some important systems connected with the industrial projects of this laboratory.