C.I.C. R. and D. SURVEY

Committee 10 - Chemical Kinetics etc.

Final Report

This committee was assigned a assortment of physical chemistry topics, some related and some not. For reasons of convenience these topics were placed in three groups, and each of the three members of the committee prepared what are essentially separate reports on these subsections. C.H. Amberg prepared a report on subsection 2694, catalysis and surface chemistry; R.A. Back prepared a report combining subsections 2695 (chemical kinetics), 2708 (molecular dynamics), and 2711 (photochemistry and energy transfer); and D.M. Wiles prepared a report on subsection 2712, polymer chemistry. In this way each of us was dealing with subjects close to his own research field and reasonably related to one another.

R.A. Back
Committee Chairman

A few statistics from the C.I.C. survey of chemistry[1] R. and D. in Canada are given in Tables 9.10.1 and 9.10.2 at the end of this report. Expenditures and manpower effort for the C.I.C. R. and D. areas assigned to the committee are compared with the totals for all such areas.

In Table 9.10.1, government expenditures assigned to this committee's areas are about 3% of the total. For industry, this percentage is about 1% and for universities (institutes) about 10%. Universities and government favour basic research while industry favours applied research.

In Table 9.10.2, it is seen that government relies largely on Ph.D's and industry less so. The comparison of manpower assigned to committee areas with that assigned to all areas is quite similar to the comparison of expenditures in Table 9.10.1.

The overall picture presented is about what one would expect considering the character of the areas covered by the committee.

Subsection 2694: Catalysis and Surface Chemistry

This subsection includes the field of heterogeneous catalysis where the emphasis is on chemical-kinetic studies and examination of surface-chemical processes and systems. Excluded are: Homogeneous catalysis; areas in which chemical engineering aspects predominate; surface physics. The latter exclusion is particularly arbitrary and excludes only a small number of workers who are, however, making important contributions. Colloid chemistry, covered by Committee 11, is also excluded.

Research and development work in catalysis is of prime importance to Canadian industry, particularly the petrochemical industry. Better understanding of catalysts and catalytic processes can lead ultimately to the ability to design new catalyst systems rather than use current trial-and-error methods; it can lead to the development of new chemical processes and to the improvement of existing processes and catalysts. Heterogeneous catalysis is largely an interdisciplinary subject, closely involving such related fields as the structure of solids, metals and semiconductors, surface structure, transport properties (diffusion in solids, sintering processes, fluids in porous systems), the kinetics of reactions on surfaces, and thermodynamic equilibria of solid and solid-gas systems.

Unfortunately there had been no continuous, consistent R.and D. effort in catalysis in Canada. Some very few industries have developed catalytic processes of their own rather than using imported "know-how". Catalytic effort in general was probably initiated by Shawinagan Chemicals in the 1920's under McIntosh. Chemcell in Edmonton were the first to use a fluid-bed catalytic dehydrogenation some 3 decades later. Both firms have devoted considerable attention to the development of new processes and the improvement of old ones.

Industries whose primary interests lie in the field of polymerization (Polymer Corp., Dow, Imperial, Dupont, C.I.L.) and thus mostly in homogeneous reactions are known to have been actively engaged in the development of solid catalysts for the production of initial reactants. A major programme on the catalytic oxidation of ethylene was undertaken by N.R.C. following the development of the Cambron silver catalyst. This has extended over a period of about 15 years and sparked a great variety of associated projects.

In surface chemistry, the first important research in Canada was done by Maass and coworkers at McGill in 1927 on the surface energy and heat of solution of sodium chloride and was followed by a series of papers on the adsorption of water vapour by wood and cellulose. Tremendous activity in the field was stimulated by World War II, when the Chemical Warfare group spent much of its R. and D. effort on producing efficient charcoals for respirators. A number of Maass's collaborators and others involved in chemical warfare are now pursuing fundamental studies in surface and colloid chemistry in universities and government laboratories. Major contributions to the present time have been made by E.A. Flood, J.R. Dacey, R.L. McIntosh, S.G. Mason and J.A. Morrison, to name only a few. In several instances one may now perceive a "second generation" of former pupils and collaborators of the latter group developing research in related topics. This reporter attaches considerable importance to such master-apprentice relationships.

In the following list are groups active in heterogeneous catalysis and surface chemistry in Canada. Each entry shows the institution, department, name of supervisor, main emphasis of research (S = surface chemistry, C = catalysis), and the number of people known to be involved, including supervisors, other professionals, and graduate students.

U.B.C., Chem.: Harrison (C,2); Samis (S,3).

U.B.C., Chem. Eng.: Lielmezs (C,2).

U.B.C., Mineral Eng.: Leja (S,3).

Simon Fraser U., Chem.: Gay (C,1).

U. of Alberta, Chem. Eng.: Dalla Lana (C,6).

Alberta Research Council, Fuels Div.: Habgood (C,3).

U. of Manitoba, Chem.: Gesser (C,3).

U. of Western Ont., Chem. Eng.: Shelstad (C,5).

Waterloo U., Chem.: Moffat (c and S, 4).

Waterloo U., Chem. Eng.: Silveston (C,2).

McMaster U., Chem. Eng.: Anderson (S,2;C,2); Crowe (C,2).

McMaster U., Chem.: Dawson (S,1).

Toronto U., Chem.: Barradas (S,2).

Toronto U., Chem. Eng.: Basmadjian (S,2); Graydon (C,2).

Ont. Research Foundation: McAdie (C,2).

Queen's U., Chem.: McIntosh (S,6).

Queen's U., Chem. Eng.: Downie (C,2); Wojciechowski (C,1).

R.M.C., Chem.: Dacey (S,3).

Ottawa U., Chem. Eng.: Lu (S,2); Mann (C,5).

Carleton U., Chem.: Amberg (C,4); Holmes (S,2); Shigeishi (S,1).

N.R.C., Ottawa, Pure Chem.: Morrison (S,2); Flood (S,3).

N.R.C., Ottawa, Applied Chem.: Antoniou (S,3); Cvetanovic (C,3).

N.R.C., Ottawa, Bldg. Res.: Litvan (S,1).

Mines Branch, Fuels: Parsons (C,4).

McGill U., Chem.: Mason (S,3).

McGill, Chem. Eng.: Fuller (C,2).

U. of Montreal, Chem. Eng.: Rouleau (C,3).

U.N.B., Chem. Eng.: Ruthven (C,3).

Mt. Allison U., Chem.: Read (C,2).

Dalhousie U., Chem.: Davies (S,1); Hayes (C,7).

Memorial U., Chem.: Machin (S,3).

Total numbers in this list are 45 in surface chemistry (18 supervisors, 27 others), and 72 in catalysis (25 supervisors 47 others).

The information that could be obtained about industrial research is very sketchy. It is estimated that Shawinigan have the full-time equivalent of about 4 professionals plus several technicians on R. and D. in heterogeneous catalysis. Chemcell at Edmonton appear to operate on a similar scale. Dupont of Canada probably devote about 50% more effort in this area. Only a limited effort is expended by all the other companies mentioned previously.

Research and development in catalysis and surface chemistry in Canada is clearly not very extensive. It can be argued, for instance, that with petroleum being one of our major national resources and the petrochemical industry an active sector of the economy, major fundamental research is indispensable for healthy growth and development. From all appearances, however, many of the petroleum industries prefer old, tried catalysts, with, possibly, engineering modifications of the process employed.

A comparison with the activities of other nations may be helpful. Several of the smaller European countries such as Holland, Poland, and Czechoslovakia, have active and coherent research groups in catalysis, and surface and colloid chemistry where excellent fundamental and applied work is done. Of the large nations, in the U.S.S.R. the Siberian Institute of Catalysis alone has a staff of 200, and there are many other renowned groups in both catalysis and in surface and colloid chemistry. The Catalysis Society of Japan has a membership in excess of 1000. By comparison, I would estimate that a formal constitution of our Canadian catalysis group would result in no more than 100 members. Even with due allowance for differences in national populations, our own effort is still well below the level of the two latter countries. Comparisons on the basis of economic growth or of export volume would undoubtedly be more meaningful (and at a guess would show us up in an even worse light).

Can anything be done to stimulate the growth of research and development in catalysis and surface chemistry? It is my opinion that potentially, neither funds nor equipment have been lacking, but rather (a) a strong "center of gravity" alluded to earlier, and (b) positive and identifiable motivation on the part of industries that would be the chief users of R. and D. findings. As a working hypothesis the following steps might be proposed to initiate increased activities:

(i) Concensus should be sought among the pertinent industries in Canada that this would indeed be desirable and fruitful. This concensus probably already exists in academic circles.

(ii) The extent should be ascertained to which such industries might be willing to back increased activities either by direct funding, through contract research, or through the use of consultants.

(iii) A working group (or institute) could be established at one of the academic centers now engaged in catalytic and surface-chemical research. Possibly two or three different centers might be set up as a co-operative association or with liaison between them.

(iv) If such an institute is to be set up, it should be headed by an outstanding scientist in the field who could, if necessary, be brought in from outside Canada. If this could not be done, a visiting scientist of outstanding caliber should be retained for a one or two year period, after which time he might act in an advisory capacity.

(v) Although the initiative for this type of undertaking must come from within the scientific community, government agencies could assist, particularly with points (i) and (ii). Inevitably, government funding would also add considerable incentive.

C.H. Amberg
February 26, 1968

Subsections 2695: Chemical Kinetics
2708: Molecular Dynamics
2711: Photochemistry and Energy Transfer

These three somewhat related subsections have been grouped together for convenience in a single report. Chemical kinetics is concerned with the quantitative measurement of reaction rates and the factors that control them. Kinetics cuts across many branches of chemistry, as it represents a method of investigation rather than a clearly defined area of research, and the resulting overlap with many other sections of this survey will be fairly obvious. Molecular dynamics involves the study of collisions between molecules, both reactive and unreactive, and may be regarded as a special, very fundamental branch of kinetics. It includes both molecular beam experiments and studies of builk phenomena which are designed to yield information about collision processes at the molecular level. Collisional quenching of excited species, electron impact, photon impact and molecular scattering studies are among those included. Photochemistry is concerned with the chemical effects of light, and may range from simple identification of products and measurements of relative yields, as in much organic photochemistry, to very detailed and sophisticated investigations providing information about primary processes, transient intermediates, and the basic molecular dynamics of the system. Photochemistry is a very powerful tool in the study of fundamental chemical kinetics. Energy transfer includes interchange and transfer of translational, rotational, vibrational and electronic excitation energy between molecules. It is of basic importance in kinetics, molecular dynamics and photochemistry, and indeed is basic to an understanding of all chemical processes.

In both chemical kinetics and photochemistry, there is very extensive use of analytical techniques, notably gas chromatography, mass spectrometry and spectrophotometry; this should be noted in reference to the report of committee 01 on analytical chemistry.

Research in these fields is essentially fundamental rather than applied and its purpose is to increase our basic understanding of chemical reactions. It is thus of the greatest ultimate significance to all branches of chemistry. Kinetic studies may often be of more direct practical value, as for example, the study of the kinetics of an industrial process can be used to determine optimum conditions. A few photochemical reactions are of industrial importance, although to the best of our knowledge none are being employed on a large scale in Canada. Photochemical and kinetic studies are also of some practical importance to the understanding and control of air pollution.

Canadian laboratories have played a role of considerable importance in the development of these fields, particularly in the past 30 or 40 years. The contributions of the late E.W.R. Steacie to Canadian achievements was outstanding, both in his own research activities and in the stimulation of students and colleagues. Steacie had by the late thirties established a strong school of photochemistry and kinetics at McGill. He came to N.R.C. early in the war, and in the post-war years built up at at the Council a photochemistry and kinetics group which established an international reputation in this field, and attracted to it a number of excellent scientists both from Canada and abroad. Many of these men are now established in universities and other laboratories across the country, and account to a considerable extent for the present high level of activities in these fields.

A number of other names must be mentioned. Winkler continued the kinetics tradition at McGill; Thode, at McMaster, pioneered mass spectrometry in Canada; LeRoy (Toronto), Gunning (Alberta), Laidler (Ottawa), Giguerre (Laval), McDowell (U.B.C.) and Schiff (McGill, York), are among those who established and maintained strong research groups in kinetics, molecular dynamics and photochemistry.

The present level of activity in these fields in Canada is relatively high and will probably remain so. Most of the work is being done in university and government laboratories, with very little in industrial laboratories. The latter lack of activity is not surprising because of the essentially fundamental nature of research in these fields, and because few industrial laboratories in Canada are large enough to support extensive research which has little immediate value to them. There appears to be general but not universal agreement among chemists active in these fields that the present level of financial support in university and government laboratories is fair and reasonable. A general shortage of good graduate students and technicians appears to be a much more serious limiting factor than lack of money. Good arguments may be put forward for maintaining the present strong support for research in kinetics, molecular dynamics, etc., as it makes good sense to reinforce our effort in areas in which we are already strong rather than to spread our research resources too thinly.

The following list of laboratories active in the fields of kinetics, molecular dynamics, photochemistry and energy transfer has been compiled from a variety of sources. These include personal knowledge and communication, surveys of scientific journals, abstracts from recent C.I.C. meetings, annual reports of government laboratories, and N.R.C. lists of research grants and graduate students in Canadian universities. Research in industrial laboratories has been difficult to assess. Once again the marked overlap with other fields should be noted, particularly in chemical kinetics (as one can do kinetic studies in almost any branch of chemistry) and in photochemistry, where the overlap of organic photochemistry with organic chemistry is obvious. In the list are shown the institution, department, supervisor, and field of research (K = kinetics, P = photochemistry, M = molecular dynamics and E = energy transfer).

U. of Victoria, Chem.: Kirk (P)

U.B.C., Chem.: McDowell (KM), Walker (K), D.G.L. James (PK), Porter (PKE), Farmer (KM), Ogryzlo (K), Basco (PK), Brion (M), B.R. James (K), Coope (M), McGreer (KP), Hayward (P), Snider (M), Stewart (K).

U.B.C., Metallurgy: Warren (K), Samis (K).

S.F.U., Chem.: Chow (P), Sherwood (K), Bell (K), Funt (K).

B.C. Research Council: Harkness (K), Murray (K).

Fisheries Research Board: Werner (K).

U. of Alberta, Chem.: Gunning (PK), Strausz (PK), Freeman (K), Dunford (K), Kebarle (PK), Pertel (P), Allen (PK), McGeachin (P), Sandin (P), Tanner (PK), Kopecky (P), Crawford (K).

U. of Alberta, Chem. Eng.: Dalla Lana (K).

U. of Calgary, Chem.: Hyne (K), Armstrong (PK), Tschuikow-Roux (PK), Swaddle (K), Tavares (P).

Alberta Research Council: Blades (K), Klemm (PK), Habgood (K), Berkowitz (K).

U. of Sask. (Saskatoon), Chem.: Bakhshi (K), Knight (PK), Lee (K), Eager (K), Bardwell (K), Roberts (K), Tinker (K), McCallum (K),

U. of Manitoba, Chem.: Gesser (K), Queen (K).

A.E.C.L. Whiteshell: Singh (PE).

Selkirk College, Phys.: Schulz (E).

Lakehead U., Chem.: Hawton (K).

McMaster U., Chem. Eng.: Anderson (K).

McMaster U., Metall. Eng.: Lu (K).

McMaster U., Chem.: Thode (K), McCullough (P), Yarwood (PK), Warkentin (K).

Brock U., Chem.: Cherniak (PK), Hiatt (K).

Waterloo U, Chem. Eng.: Byerley (K), Enns (PK), Silveston (K).

Waterloo U., Chem.: Fraser-Reid (P).

Windsor U., Chem. Eng.: Mathur (K).

Windsor U., Chem.: McKenney (K), Price (K), Rutherford (K).

Windsor U., Physics: Krause (E).

U. of Western Ont., Chem: Bidinosti (M), de Mayo (P), Jacobs (K), Graham (PK), Stothers (K), Baldwin (K).

U. of Western Ont., Eng. Sci.: Shelstad (K).

Federal Dept. of Agriculture, London Laboratory: Stoessl (P).

U. of Toronto, Chem.: Burns (PK), Deckers (MK), Dove (K), Barradas (K), Cook (K), Harrison (K), LeRoy (PK), Polanyi (MK), Riddick (K), Schmid (K), Still (P), Yates (K), Lister (K), Allen (K).

U. of Toronto, Chem. Eng.: Rapson (K), Sandler (K).

York U., Chem.: Goodings (K), Hunter (M), Lundell (K),Pritchard (K), Schiff (K).

Dow Chemical Co., Sarnia: Quinn (K), Tolgyesi (K), Glew (K).

Queen's U. Chem.: Davis (K), Russell (K), Wheeler (KM), Buncel (K).

Queen's U., Chem. Eng.: Downie (K), Wojciechowski (K).

R.M.C., Chem.: Dacey (P), Barton (K), Jones (K), Venugopalan (K).

Ottawa U., Chem.: Laidler (K), Back (K), Conway (K), Durst (P), Holmes (PK).

Ottawa U., Chem. Eng.: Mann (K).

Carleton U., Chem.: Ap Simon (P), Laughton (K).

Trent U., Chem.: March (K).

N.R.C., Ottawa, Applied Chem.: Cvetanovic (KP), Ingold (K), Pottie (K), Preston (PK), Amenomiya (K), Bywater (K), Whalley (K).

N.R.C., Ottawa. N.A.E.: Elias (K).

N.R.C., Applied Phys.: Klassen (PK), Turner (E), Gillis (K).

N.R.C., Pure Chem.: Lossing (K), Robertson (K), Kutschke (PK), Back (PK), Yip (P), Edwards (P), Jones (P).

Mines Branch, Ottawa: Ingraham (K), Bright (K), Parsons (K), Boyd (K).

McGill U., Chem.: Chan (KE), Grosser (M), Harpp (P), Butler (K), Just (P), Sehon (K), Winkler (K).

C.A.R.D.E.: Hampson (K).

U. of Montreal, Chem.: Gravel (P), Rousseau (PK), Zador (K).

Sir G. Williams U., Chem.: Rye (K).

Loyola College, Chem.: McElcheran (K).

Laval U., Chem.: Forst (KE), Oullet (K), Giguerre (K), Herman (PK), Kerwin (M).

Laval U., Chem. Eng.: Blanchet (K).

Laval U., Mines and Metallurgy: Beaulieu (K).

Bishops U., Chem.: Arnot (K), Bauslaugh (P).

Mt. Allison U., Chem.: Grant (K).

U. of N.B., Chem.: Unger (PK), Semeluk (PK), Findlay (P).

U. of N.B., Chem. Eng.: Washington (K).

Dalhousie U., Chem.: Leffek (K), Jones (K), Hayes (K), Jamieson (K).

N.S. Tech. Coll., Chem. Eng.: Dillon (K)

St. F.X. U., Chem.: Berry (PK), Secco (K), Bunbury (P), McDonald (K).

St. Dunstans U., Chem.: Abu-Isa (K).

Memorial U., Chem.: Barton (K), Thorne (K).

The names in the list above are of permanent staff members. Total numbers of staff members active in each field are as follows: kinetics 152; photochemistry, 55; molecular dynamics, 10; energy transfer, 6. There will be associated with them the usual numbers of graduate students, technicians, postdoctoral fellows, etc.

R.A. Back

February 28, 1968

Subsection 2712: Polymer Chemistry

The aspects of polymer chemistry covered in this report are the physical-chemical investigations of natural or synthetic macromolecules, i.e., rheology, morphology, electrical, optical, and other physical properties in bulk and in solution. In view of the committee heading, it is important to note that kinetics of polymerization and of depolymerization are not dealt with here but in the report of Committee 07, area 091, under Organic Chemistry.

R. and D. in this area is important because it fills the gap between research on the preparation of polymers and polymer derivatives and that on the usefulness or applicability of these materials. Investigations of the "academic" type are important in trying to establish patterns of behaviour for big molecules in the liquid state, for example, or in liquid-solid transitions. Except in the case of severe space, personnel, or financial limitations all non-commercial laboratories in the country in which research is being done with macromolecules should be investigating one or more physical-chemical properties of polymers. All industrial R. and D. laboratories must be concerned with the physical aspects of polymer chemistry systems (e.g. extrudability moldability; flow, film- and fiber-forming properties) because these largely determine the commercial potentialities of the systems.

Studies of the structure and properties of polymers have been underway in this country for perhaps 50 years or more, although publications in the field first appeared in quantity in the 1920's. Much excellent work during this period is associated with Whitby, Hibbert and Chalmers at McGill originally involving natural rubber and cellulose-based polymers. Blaikie and his colleagues, at the Shawinigan Chemical Company, were responsible for notable developments in the preparation of vinyl acetate and related polymers and presumably they were concerned with polymer characterization studies as well. Courtaulds, Canadian Celanese and C.I.L. introduced polymeric products based on cellulose in the period between the two world wars.

Early in the second world war, a period of intensified activity resulted from the need to establish a synthetic rubber producing capability. The facilities which are now part of the Polymer Corporation were built, and interest in the properties of an ever-widening group of synthetic polymers followed, resulting in the beginning of research groups in universities, in industrial laboratories and in government laboratories such as N.R.C. and O.R.F. Excellent work on colloidal, solution and other properties of cellulose-based polymers has been carried out for many years at the Pulp and Paper Research Institute.

Since the war, an Associate Committee on High Polymer Research has operated under the sponsorship of the N.R.C. A useful liaison was established in this way among Canadian scientists engaged in research on various aspects of polymer science. The effectiveness of the committee was limited, however, because of the reluctance of members representing industrial laboratories (excluding the Polymer Corporation) to discuss the work in their laboratories. This same reluctance made it difficult to obtain some of the data on which this report is based. Credit is due the Associate Committee for initiating the Canadian High Polymer Forum, a conference devoted to all aspects of macromolecular science which has been held at approximately 18-month intervals since its inception 18 years ago. The recent formation of the Division of Macromolecular Science of the C.I.C. is a result of increased interest in this area of science in Canada and a desire to provide for applied as well as fundamental studies on macromolecular systems. The forum will continue to operate as a significant part of the new C.I.C. Division.

Perhaps the major factors which have resulted in the current moderately high level of activity in industrial laboratories have been: (i) development of the capability for synthesizing polymer molecules having controllable configurations with respect to the main chain atoms; (ii) the necessity for large quantities of technological "know-how" in the preparation and processing of plastics and synthetic fibers. Research and Development efforts have probably produced adequate technology to enable industry to keep up with the latest advances in the processing and applications of stereoregular polymers and fiberforming macromolecules. There have not been, however, significant major advances which are clearly the result of Canadian research and/or are specific to Canadian needs. Encouraging exceptions to this lack of distinguished work are probably the Polymer Corporation, Dunlop Canada Ltd. and the Pulp and Paper Research Institute.

It is difficult to estimate the level of research on the physical properties of polymers in industrial laboratories. However, owing to the fact that most of our chemical industries are subsidiaries of foreign-based companies, it is safe to say that a higher level of R. and D. is justifiable (if not essential) in order to do more than just try to keep up with the technological advances which originate in other countries. Interest in this area of polymer chemistry in universities has been abysmally low and is only just starting to pick up. This is probably due to the lack of course work, even at the introductory, undergraduate level, at most universities. Finally, considering the very large commercial and industrial importance of polymers, the R. and D. effort in government laboratories is sporadic and lacks direction and/or coordination.

One of the greatest handicaps to an increase in R. and D. has been a lack of qualified personnel. Hopefully, this will soon be eased by the output from the new polymer schools at the University of Toronto, the University of Waterloo and McGill University. There is a "vicious circle" aspect to the situation, however, because many properly-trained people will find employment in the U.S.A. unless more research of a challenging nature is undertaken in industrial and government laboratories. Lack of funds to purchase major pieces of equipment is also a problem. As in many other areas of chemical research, "analysis" (in the broadest sense) or characterization of polymers is of the utmost importance. Unfortunately, the equipment required for this purpose is expensive by the normal standards for chemical instrumentation. Nuclear magnetic resonance, low-angle X-ray diffraction, electron microscopy, ultra centrifugation are a few examples of techniques which require expensive apparatus.

It must be emphasized that the list of research programs attached to this report could give the misleading impression that the level of R. and D. activity in the physical-chemical aspects of polymer science is high. The list might seem to indicate an acceptable level of interest in universities whereas this is not the case. The problem is that there is no obvious fair way to distinguish between members of staff who are dabbling in the field in a rather unproductive way and others who are turning out good work. It could be said that polymer research constituted a high proportion of the fundamental research effort in Canada 30 to 40 years ago than it does today, in the "age of plastics".

A more general discussion of polymer R. and D. is given by Committee 7.

D.M. Wiles

Universities

Calgary:	(A.L. Jacobson)	Salt interactions of polyelectrolytes
	(R.S. Roche)	Polymer solutions
Guelph:	(H.R. Richards)	Torsional regidity of fibers Static electrification of polymers
	(J.R. Stevens)	Continuum theory for elastic materials at high deformations; Glass transitions; % crystallinity
Laval:	(L.P. Blanchard)	Thermal properties of polymers (DTA); Characterization of polymers
Manitoba:	(N.K. Patel)	Interaction of macromolecules with some pharamaceuticals
McGill:	(W.J.M. Douglas)	Ion exchange resins and membranes
	(D.F.R. Gilson)	NMR of polymers
	(D.D. Patterson)	Thermodynamics of polymer solutions
	(A.H. Sehon)	Interaction between synthetic polymers and biologically important macromolecules
	(L.E. St.Pierre)	Thermochemistry of polymer solutions; Stress relaxation; Energy transfer in the glassy state; Surface energy of copolymers; Bonding of carbon black and polymers
McGill + P.P.R.I.C.:	(D.A.I. Goring)	Viscosity, light scattering and electroviscous measurements on charged macromolecules; Physical chemistry of polyelectrolytes, adhesion of fibrils
	(R. St.J. Manley)	Morphology of stereoregular, as polymerized polyolefins; Molecular morphology of native celluloses; Crystallization of polymers

McGill + P.P.R.I.C.:	(S.G. Mason)	Aggregation and coalescence; Flow properties of suspensions and dispersions; Particle behaviour in sheer and electrical fields
	(A.A. Robertson)	Physical interactions in fiber suspensions; Accessibility of fibers
McMaster:	(J.W. Hodgins, A.E. Hamielec)	Binary diffusion coefficients for polymer standards
Montreal:	(H. Daoust)	Solution properties - conformations and dimensions of polymers; polyelectrolytes: Thermodynamics of polymer solutions
	(A.M. Lamonde)	Induced macromolecule-drug entrapment
	(M. Rinfret)	Polymer solutions - micro-calorimetry, diffusion, solvation
	(Y. Sicotte)	Light scattering of polymer solutions
Mount Allison:	(L.H. Cragg)	Intrinsic viscosity, light scattering and fractionation studies of polymers and polyelectrolytes
Toronto:	(W.H. Burgess)	Properties of Chelate resins
	(J.E. Guillet)	Synthetic polymers compatible with biological systems; Critical solution temperature and molecular weight distribution studies
	(W.H. Rapson)	Influence of degree of crystallinity on effect of high energy radiation on cellulose reactivity
	(I.H. Spinner)	Redox polymers; Ion exchange polymer membranes
	(C.E. Chaffey)	Rheology

Toronto:	(H.L. Williams)	Rheo-optical properties of polymers and solutions
Waterloo:	(A.A. Bruneau)	Elastic properties of two phase systems: Microstructural changes in spun filaments
	(C.D. Burns)	Mixed polymeric solutions; heterogeneous systems
	(W.L. Elsdon)	Thermoproperties of elastomers; ESR studies
	(M. Hillier)	Polymer processing
	(P. Pindera)	Photoelastic behaviour of polymers
	(A. Rudin)	Melt flow properties: crystallization
	(B.M.E. van der Hoff)	Filler-elastomer interaction: stress compression
Western Ontario:	(J.W. Lorimer)	Inorganic polymers; transport in ion-selective membranes
Windsor:	(R.A. Stager)	Effect of pressure on dielectric constant and on shearing stress of polymers

Government Laboratories

HEPC (Ontario):	(J.W. Suggitt)	Effect of petroleum oils on physical properties of polyetheylene resin
	(A.W.W. Cameron)	Electrical properties of synthetic polymers for insulation
N.R.C.:	(Bywater, Worsfold et al)	High resolution NMR investigations of synthetic polymer tacticities: Solution properties - light scattering, osmometry, ultra centrifugation - of macromolecules
	(Wiles et al)	Physical and chemical modification of cotton cellulose; Effect of structure on photodegradation of polypropylene

O.R.F.: (Jones, Staples et al) Flame-resistant polyethers; Effect of chemical modification of Cellulosic fibers on physical properties; Effect of polyelectrolytes on rheological properties of suspensions

Industry

Celanese (Chemcell): Thermal, melt-flow, crystallization, and other physical properties of synthetic, fiberforming polymers

C.I.L.: Flow extrusion and thermal properties of polyethylene; Fractionation during flow; Solution thermochemistry

Domtar: Synthetic and natural polymers; Phenolic resins

Dow: Properties of polyolefins; Melt flow; Molecular weight distribution; Processability

Dunlop: Properties of ethylene copolymers and of heteroatom polymers

Dupont: Polyolefins and polyamides - molecular structure and physical properties; Electrical properties of resins for insulation

Fiberglass: Polymers as binders and finishers for glass fiber products

Imperial Oil: Properties of poly(vinyl chlorides)

Polymer: Dependence of processibility on the molecular and network structure of the polymer; Mechanism of development of tensile strength; Crystallization and orientation; Properties of polymers in dilute solution

<u>Reichold</u>: Phenol and urea formaldehyde resins; Alkyd resins

<u>Shawinigan</u>: Influence of M. Wt. distribution and particle geometry of vinyl polymers on polymer properties; Boundary layer potentials in suspensions and emulsions; Factors influencing draw-ratios of PVC films; Effect of blending technique on the melt flow of PVC; Melt flow properties of vinyl polymers and copolymers

<u>Union Carbide</u>: Polyethylenes and polyethers: polydispersities, electrical and thermal properties, extrusion characteristics, stress cracking

<u>Uniroyal</u>: Thermoplastic resins; Stability, reactivity and processibility

TABLE ~~9~~ 4.10.1

INTRAMURAL CHEMISTRY[1] OPERATING R. and D.
EXPENDITURES (1966 or 1966-67) (Tables 11a, 26 and 39, Section 18)
(in thousands of dollars)

	Basic	Applied	Development	Totals
Government				
Committee 10 Areas	~~399.9~~ 510.9	~~205.4~~ 235.4	25.6	~~630.9~~ 771.9
All C.I.C. Areas	~~7,892.3~~ 8,237.0	~~9,920.1~~ 9,936.5	~~6,611.2~~ 6,562.6	~~24,423.6~~ 24,736.1
Industry				
Committee 10 Areas	190.7	566.5	221.3	978.6
All C.I.C. Areas	8,299.~~2~~0	~~40,293.8~~ 40,622.7	~~42,210.6~~ 42,511.8	~~90,803.1~~ 91,433.5
Univ. (Inst.)				
Committee 10 Areas	1,768.3	47.3	3.4	1,819.0
All C.I.C. Areas	17,000.5	2,945.7	881.7	20,837.0

1. Including chemical engineering and other related disciplines - See Section 3.1

TABLE ~~9~~4.10.2

MANPOWER EFFORT ON CHEMISTRY[1] INTRAMURAL

R. and D. (1966 or 1966-67) (Tables 16, 27A, and 38 - Section 18

(man-years)

	Dr.	Ma.	Ba.	Techn.	Total
Government					
Committee 10 Areas	~~38.0~~ 40.0	~~0.0~~ 0.5	0.0	~~12.0~~ 15.0	~~50.0~~ 55.5
All C.I.C. Areas	~~471.7~~ 477.7	~~115.4~~ 117.9	~~224.8~~ 227.8	~~833.0~~ 848.0	~~1,644.9~~ 1,673.4
Industry					
Committee 10 Areas	9.0	6.0	17.0	26.0	58.0
All C.I.C. Areas	686.0	442.0	~~1,644.0~~ 1,694.0	2,919.0	~~5,751.0~~ 5,791.0
	Acad.	**P.D.F.**	**Grad. Stud.**	**Techn.**	**Total**
University (Inst)					
Committee 10 Areas	83.0	48.0	193.0	19.0	343.0
All C.I.C. Areas	1,042.0	378.0	2,187.0	598.0	4,205.0

1. Including chemical engineering and other related disciplines see Section 3.1

...ment: Committee Reports 11-20, to:
Special Study no. 9

Special Study No 9

Supplement: Committee Reports 11-20
[v.2]

Chemistry and Chemical Engineering

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Study Director