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TECHNICAL PROGRESS REPORT

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ATOMIC ENERGY COMMISSION

"CONTROLLED POLYMERIZATION OF ADSORBED MONOLAYERS"

RELEASED FOR ANNOUNCEMENT
IN NUCLEAR SCIENCE ABSTRACTS

H. K. Livingston
Department of Chemistry
College of Liberal Arts
Wayne State University
Detroit, Michigan 48202

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TECHNICAL PROGRESS REPORT

HISTORICAL:

During the initial phase of this project, it was planned to investigate the orientation of polymerizable molecules on solid surfaces and to explore methods of polymerizing molecules that had a known surface concentration and orientation. Considerable progress had been made by the time of writing of this report. As might be expected, there have been slight changes in program. It was decided to concentrate initially on orientation studies in which the adsorbed molecules were flat ("disc-shaped") and the solid surface was homogeneous as regards its surface energy. Adsorption studies on such a surface have led to some new insights into the theory of physical adsorption of condensable vapors on solids. Also, it was decided to use a more powerful radiation source than the 450 curie cobalt-60 source originally contemplated. This has necessitated a minor readjustment in the budget, as discussed below.

In the following paragraphs, the original program is briefly re-stated and the program changes mentioned above are discussed together with the results to date.

The objective outlined in the original report was:

"1. To polymerize adsorbed molecules with known spacial relations to each other and to the adsorbing surface.

2. To determine the scope of the experimental conditions that are necessary for such a polymerization to occur."

Adsorbates specifically proposed were acetaldehyde, acrylonitrile, and β -propiolactone. Adsorbents suggested were carbon, titania, or an inorganic halide. P-33, a carbon black having a homogeneous surface, was mentioned in that report. However, we decided to start our experiments with Graphon, another carbon black. It is almost as homogeneous as P-33 and has a much higher specific surface.

Also, to remove any uncertainty about geometry during adsorption, it was decided to study first the adsorption of "disc-shaped" molecules such as furan and dicyclopentadiene. Depending on whether the "disc" lays flat on the solid surface or stands on edge, the molecular area will vary by a ratio of some such value as (edge):(flat) = 1:1.5. This was a subject where experiments could be planned with some confidence, since there are numerous published data on a non-polymerizable "disc-shaped" molecule, benzene.

PROGRESS TO DATE:

While our adsorption line was being constructed and mounted on the vacuum rack, we carried out literature investigations and some molecular model studies. The model studies were especially designed to evade the limitations of the usual methods for estimating the molecular area of adsorbed substances. No new methods have been proposed in the literature since our 1949 review of this subject (Livingston, 1949)*, but a new method is badly needed. We decided to make use of the fact, first pointed out by Kitaigorodskii in his book "Organic Crystallography", that molecules such as benzene having a plane of symmetry that passes through the center of all atoms must always have six nearest neighbors when in closest packing. This is a geometric characteristic of two-dimensional packing, and packing of molecules with the described symmetry can be treated as a problem in two-dimensional packing.

We recognize that all molecular area data are relative, since there is no molecule for which one knows absolutely the area when close-packed in physical adsorption on a solid surface. Since nitrogen is the adsorbate most studied, we compared the close packing of nitrogen with that of benzene and furan. Studies of some other "disc-shaped" molecules will be completed soon. The data on benzene appear in Table 1.

*For references, see the Bibliography.

TABLE 1

RATIOS OF CROSS - SECTIONAL AREAS
ON HOMOGENEOUS GRAPHITE SURFACES
 C_6H_6 vs. N_2

<u>CARBON</u>	<u>RATIO</u>	<u>REFERENCE</u>
P - 33	2.34	Pierotti 1966
MTg	2.47	Pierce 1962
Av. of Several	2.47	Isirikyan 1961
Graphon	2.53	Smith 1956

Ratio if C_6H_6 is flat and close packed: 2.41 to 2.05*

Ratio if C_6H_6 is edgewise and close packed: 1.65 to 1.41*

*Taking σ_{N_2} as 13.8 - 16.2 $\text{\AA}^2$ / molecule; a range must be given since the cross-sectional area of nitrogen on Graphon is not known absolutely. For details on the general method of calculation, see the reference Livingston, 1949.

For furan it was necessary to consider three different packings in the flat orientation, but the differences in the areas were slight. Since there were no published data, it was necessary to make our own measurements on Graphon. (Incidentally, nitrogen adsorption measurements were made to assure ourselves that our Graphon sample had the same properties as the Graphon samples that had been studied earlier [Emmett, 1947; Beebe, 1947; Emmett, 1952; Kiselev, 1962]; our present adsorption results checked those of the earlier workers.) The furan results (Table 2) also show that the flat orientation is observed experimentally.

TABLE 2

RATIOS OF CROSS-SECTIONAL AREAS FOR FURAN ON GRAPHON

Calcd. of Exptl.	Orientation	Furan cross-section area, $\text{A.}^2/\text{molecule}$	Ratio to Nitrogen area	
			$13.8 \text{ A.}^2/\text{N}_2$	$16.2 \text{ A.}^2/\text{N}_2$
Calcd.	Flat	29.0	2.10	1.79
Calcd.	Edgewise	17.8	1.29	1.10
Exptl.	Must be flat	---	2.07	

Note that areas from models are absolute, but ratios to nitrogen areas are relative. On the other hand, ratios of furan area to nitrogen area is determined experimentally. Back calculation indicates the area of furan is $33.5 \text{ A.}^2/\text{molecule}$ if the usual value of $16.2 \text{ A.}^2/\text{molecule}$ is assumed for nitrogen on Graphon.

The experimental approach in this research relies squarely on the fact that the equilibrium between a bulk liquid and an adsorbed layer on a solid surface yields the same surface concentration of adsorbed molecules and the same orientation of these molecules each time the equilibrium is established, provided the chemical potential of the adsorbate is held constant. Therefore, measurements made with high precision on the vacuum rack can be duplicated in samples prepared for radiation, if the chemical potential is controlled. We have chosen the temperature of a bulk liquid source (or of a solid source near its melting point) exposed to the warmer adsorbing surface as the parameter that will be used to control the chemical potential of the molecules being adsorbed. This has called our attention to the fact that while this temperature is a function of the relative pressure (which is the variable usually considered in plotting adsorption isotherms), the converse is also true. It is possible that the relation between the quantity adsorbed and the temperature of the bulk liquid source is ^{of} as much fundamental importance as the more familiar (quantity adsorbed)-(relative pressure) relation. This subject may be pursued as part of a different research program at some later date.

The program originally visualized was to make use of a six-year-old cobalt-60 source available in our own College of Liberal Arts. However, we were advised to use a stronger source if at all possible. We were fortunate to arrange for the part-time use of a LINAC LM-6 electron accelerator (Applied Radiation Corp.) recently installed in our Medical School. Since it was not immediately obvious that this instrument would be suitable for our purposes, trials were run under conventional solid-state polymerization conditions. The classic monomer, acrylamide, was used in a series of experiments. Conditions were found that gave results entirely comparable to those in the literature. (Table 3 and 4.)

TABLE 3

WEIGHT - % CONVERSION AS A FUNCTION OF DOSE AND
DOSE RATE; ACRYLAMIDE SOLID-STATE POLYMERIZATION

DOSE, RADS	5×10^4	10^5	5×10^5	10^6	2.5×10^6
Dose rate, microamps.					
2	.76%			8.43%	12.00%
3		3.58%	6.48%	10.56%	20.84%
4	1.73%	.63%	7.21%	16.60%	15.45%

These data were obtained by irradiation with high energy electrons in the linear accelerator beam at -78°C . The samples were post-polymerized for 50 hours at 45°C ., then assayed by determining the amount of methanol-insoluble material in the sample.

TABLE 4

WEIGHT - % CONVERSION AS A FUNCTION OF TIME AND TEMPERATURE
AFTER IRRADIATION; ACRYLAMIDE SOLID-STATE POLYMERIZATION

Post-Polymerization Time, Hrs.	0.1	1.0	5	10	50	75
Post-polymerization Temperature, $^\circ\text{C}$.						
25	4.43%	3.38%	4.70%	4.23%		
45	5.68%	9.72%	13.06%	18.17%	18.19%	24.44%
75	7.88%	18.60%	16.32%		33.61%	

These samples were irradiated at 5 microamp. to a calculated dose of 2.5×10^6 rads. Irradiation temperature was -78°C . Post-polymerization was then carried out at the times and temperatures noted, and the samples assayed by determining the amount of methanol-insoluble material.

Subsequently, adsorption polymerization was successfully demonstrated with the electron accelerator. In this experiment, furan was adsorbed on Graphon at 25°C. The chemical potential of the furan was that known to give a quantity of adsorption 20% in excess of the quantity adsorbed at the Brunauer - Emmett - Teller monolayer point. Adsorption is reversible under these conditions, as we showed in some of our early experiments. However, after exposure (at 25°C) to the electron beam at 4.5 microamp. for 30 seconds, the furan could no longer be desorbed. The same result was obtained in two other experiments in which the exposure time was 5 and 50 minutes, respectively. This encouraging preliminary experiment will be followed up with further experiments as soon as possible.

Experimental work on titania or similar adsorbents has been postponed because there is no known way to obtain samples of these adsorbents in which the surfaces are homogeneous with respect to their energy. It was thought best to concentrate on a homogeneous surface in our preliminary work. We have gone ahead with the construction of apparatus to be used in studying adsorption on solids that are catalysts for ionic polymerization, such as inorganic halides or active metals. Our work here has consisted of constructing a Kargin-Kabanov apparatus that will permit us to lay down such active surfaces from beams of atoms or molecules, in what amounts to a crude molecular-beam apparatus. The surfaces will cover certain parts of the glass wall of the evacuated vessel. In the present form, the apparatus will only give semi-quantitative indications of the relation between quantity and orientation of adsorbed molecules and behavior on polymerization, since it will be necessary to extrapolate from results on glass powder to results on vessel walls. However, even these results will represent an important advance. In work to date, we are still improving the quality of the vacuum attainable in the apparatus. We have reached 10^{-5} , with 10^{-7} as our objective. A sketch of the apparatus is given in the Russian literature (Kargin, 1959).

This brief summary of our research to date shows that our initial premises appear to be valid: Orientation of physically adsorbed molecules can be determined and physically adsorbed layers at near monolayer concentration can be polymerized.

Bibliography:

In the preliminary work done on this project, the approach to the question of determining molecular orientation in adsorbed monolayers was judged to be sufficiently novel to justify preparation of an oral presentation, "Physical Adsorption of Vapors of Cyclic Organic Compounds on Solid Surfaces", given at the national meeting of the American Chemical Society in New York on September 12, 1966. It was decided not to submit this work for publication until data had been obtained for a few more monomers.

As for a bibliography of work by others, that relating to polymerization of monomers under constraint (in adsorbed monolayers or solids) has been appended to the "Proposed Technical Program, " submitted under the same title and at the same time as this report. A bibliography of studies of the adsorption of "disc-shaped" molecules on solid surfaces is appended to this report, and begins on the next page. These references are especially pertinent to the research completed during 1966 on the adsorption of furan on Graphon.

The journal abbreviations are based on the system generally used in handling literature references on the computer. This is "CODEN for Periodical Titles", summarized in ASTM Special Technical Publication No. 329. A list of the most common titles follows. "Private" codes are used for patents and for English translations of Russian journals. These are identified on the attached list.

PARTIAL LIST OF JOURNALS FOR POLYMER SCIENCE & TECHNOLOGY

ADAWA	Abhandl. Deut. Akad. Wiss. Berlin, Kl. Chem., Geol. Biol.	CANWA	Chem. Anal. (Warsaw)	HOLZA	Holzforchung	JOCCA	J. Oil Colour Chemists' Assoc.
ACSA	Acta Chem. Scand.	CHBEA	Chem. Ber.	HHTPA	Hua Hsueh Tung Pao	JOTIA	J. Oil Technologists' Assoc. (India)
ACASA	Acta Chim. Acad. Sci. Hung.	CHCAA	Chem. Can.	HHHPA	Hua Hsueh Hsueh Pao	JOC'EA	J. Org. Chem.
ACCRA	Acta Cryst.	CCOMA	Chem. Commun.	HPPRA	Hydrocarbon Process. Petrol. Refiner	JORCA	J. Organometal. Chem.
ADHAA	Adhesion	CHENA	Chem. Eng.		IEEE (Inst. Elec. Electron. Engrs.), Trans. Paris, Mater., Packaging	JPTYA	J. Paint Technol.
ADHAA	Adhesives Age	CENEA	Chem. Eng. News			JPCHA	J. Phys. Chem.
ADCSA	Advan. Chem. Ser.	CEPRA	Chem. Eng. Progr.			JPCSA	J. Phys. Chem. Solids
ACPCA	Am. Chem. Soc., Div. Petrol. Chem., Preprints	CESCA	Chem. Eng. Sci.	ICBEA	Ind. Chim. Belge	JUPSA	J. Phys. Soc. Japan
ACPPA	Am. Chem. Soc., Div. Polymer Chem., Preprints	CMFSA	Chemiefasern	IECHA	Ind. Eng. Chem.	JPLCA	J. Polymer Sci., Pt. A-1
ACOCA	Am. Chem. Soc., Div. Org. Coatings, Plastics Chem., Preprints	CHCLA	Chemik (Gliwice)	IECFA	Ind. Eng. Chem., Fundamentals	JPLPA	J. Polymer Sci., Pt. A-2
AICEA	A.I.Ch.E. (Am. Inst. Chem. Engrs.) J.	CMKZA	Chemiker Ztg.	IEPDA	Ind. Eng. Chem., Process Design Develop.	JPYBA	J. Polymer Sci., Pt. B
ADREA	Am. Dyestuff Reprtr.	CHHUA	Chem. Ind. (Duesseldorf)	IEPRA	Ind. Eng. Chem., Prod. Res. Develop.	JPCFA	J. Prakt. Chem.
AMIKA	Am. Ink Maker	CHINA	Chem. Ind. (London)	IJACA	Indian J. Appl. Chem.	JNBAA	J. Res. Natl. Bur. Std., A
ASTTA	Am. Soc. Testing Mater., Spec. Tech. Publ.	CITEA	Chem. Ingr. Tech.	IJOCA	Indian J. Chem.	JNBAA	J. Res. Natl. Bur. Std., C
AABQA	Anais Assoc. Brasil. Quim.	CHLSA	Chem. Listy	IJOTA	Indian J. Technol.	JNRRA	J. Rubber Res. Inst. Malaya
AAQAA	Anales Assoc. Quim. Arg.	CPROA	Chem. Process.	IPPA	Indian Pulp Paper	JNSRA	J. Sci. Ind. Res. (India)
ARSQA	Anales Real Soc. Espan. Fis. Quim. (Madrid), Ser. B	CPREA	Chem. Process. Eng.	IPQAA	Inform. Quim. Anal. (Madrid)	JSDCA	J. Soc. Dyers Colourists
ANCHA	Anal. Chem.	CHPUA	Chem. Prumysl	INQCA	Inorg. Chem.	JTIPA	J. Textile Inst., Proc.
ACACA	Anal. Chim. Acta	CHREA	Chem. Rev.	IPENA	Intern. Plastics Eng.	JTITA	J. Textile Inst., Trans.
ANALA	Analyst	CSAKA	Chem. Stosowana, Ser. A	ISJCA	Israel J. Chem.	KKGKA	Kagaku Kagaku
ANCEA	Angew. Chem.	CHTEA	Chem. Tech. (Berlin)	ISJTA	Israel J. Technol.	KAKYA	Kagaku (Kyoto)
ANCLA	Ann. Chem. (Rome)	CHZVA	Chem. Zvesti	IARKA	Izv. Akad. Nauk Arm. SSR, Khim. Nauki	KKGOA	Kagaku To Kogyo (Osaka)
APPIA	Appita	CHALA	Chim. Anal. (Paris)	IAKKA	Izv. Akad. Nauk Kaz SSR, Ser. Khim. Nauk	KAKTA	Kagaku To Kogyo (Tokyo)
AMRSA	Appl. Mater. Res.	CCRNA	Chim. Chronika (Athens, Greece)	IASKA	Izv. Akad. Nauk SSR, Ser. Khim.	KAGIA	Kami-pa Gikyoshi
APSPA	Appl. Plastics	CHIMA	Chimia (Aarau)	IZSKA	Izv. Sibirsk. Otd. Akad. Nauk SSR, Ser. Khim. Nauk	KCRZA	Kauchuk i Rezina
ARKEA	Appl. Spectry.	CINMA	Chim. Ind. (Milan)	IVUKA	Izv. Vysshikh Uchebn. Zavendenii, Khim. i Khim. Tekhnol.	KGUKA	Kautschuk Gummi Kunststoffe
AANLA	Atti Accad. Nazl. Lincei, Rend., Classe Sci. Fis., Mat. Nat.	CHIEA	Chim. Ind. (Paris)	IVZLA	Izv. Vysshikh Uchebn. Zavendenii, Lezn. Zh.	KSPUA	Khim. i Fiz. Khim. Prirodn. Sintetich. Polimerov, Akad. Nauk Uz. SSR, Inst. Khim. Polimerov
AJCHA	Australian J. Chem.	CCCCA	Collection Czech. Chem. Commun.	IVULA	Izv. Vysshikh Uchebn. Zavendenii, Tekhnol. Leg-koi Prom.	KTMA	Khim. i Tekhnol. Topliva i Masel
APRJA	Australian Plastics Rubber J.	CONNA	Colloq. Nationaux Centre Natl. Rech. Sci. (Paris)	IVTTA	Izv. Vysshikh Uchebn. Zavendenii, Tekhnol. Tekstil'n. Prom.	KINSA	Khim. Ind. (Sofia)
AUENA	Automob. Eng.	CHDAA	Compt. Rend., Ser. A, B	JACSA	J. Am. Chem. Soc.	KPDSA	Khim. Pererabotka Drevosiny, Nauchn. Tekhn. Sb.
AZKZA	Azerb. Khim. Zh.	CHDCA	Compt. Rend., Ser. C	JJAPA	J. Appl. Chem. (London)	KPNZA	Khim. Prom., Nauk Tekhn. Zh.
BBPCA	Ber. Bunsenges. Physik. Chem.	CHDDA	Compt. Rend., Ser. D	JACHA	J. Appl. Chem. (London)	KVLKA	Khim. Volokna
EIPMA	Biopolymers	CRABA	Compt. Rend. Acad. Bulgare Sci.	JAPIA	J. Appl. Phys.	KNKTA	Kinetika i Kataliz
BOLAA	Boll. Lab. Chim. Provinciali (Bologna)	COPQA	Connais. Plastiques	JAPNA	J. Appl. Polymer Sci.	KOKAA	Kobunshi Kagaku
BSFCA	Boll. Sci. Fac. Chim. Ind. Bologna	CCACA	Croat. Chem. Acta	JANCA	J. Assoc. Offic. Anal. Chemists	KFTPA	Ko Fen Tzu Tung Hsueh
BSQPA	Bol. Soc. Quim. Peru	DMDGA	Duchema Monograph.	JCTLA	J. Catalysis	KCKZA	Kogyo Kagaku Zasshi
BCHEA	Brit. Chem. Eng.	DNKKA	Denki Kagaku	JCPJA	J. Chem. Eng. Data	KHTPA	K'o Hsueh T'ung Pao
BINMA	Brit. Ink Maker	DELPA	Duravoohrabatvayushchaya Prom.	JCPSA	J. Chem. Phys.	KOZHA	Kolloidn. Zh.
BJAPA	Brit. J. Appl. Phys.	DFZTA	Deut. Farben-Z.	JCNIA	J. Chem. Soc., A, Inorg., Phys., Theoret.	KZZPA	Kolloid-Z. Z. Polymere
BRPLA	Brit. Plastics	DTTAA	Deut. Textiltech.	JCSOA	J. Chem. Soc., B, Phys. Org.	KOERA	Koloriz. Ertesito
BAPCA	Bull. Acad. Polon. Sci., Ser. Sci. Chim.	DFSAA	Discussions Faraday Soc.	JCSOA	J. Chem. Soc., C, Org.	KOCMA	Korose Ochrana Mater.
BESJA	Bull. Chem. Soc. Japan	DANAA	Dokl. Akad. Nauk Arm. SSR	JCPQA	J. Chromatog.	KOZAA	Kozarstvi
BICRA	Bull. Inst. Chem. Res., Kyoto Univ.	DAZRA	Dokl. Akad. Nauk Azerb. SSR	JJCRA	J. Colloid Sci.	KUNSA	Kunststoffe
BITFA	Bull. Inst. Textile France	DBLRA	Dokl. Akad. Nauk Belorussk. SSR	JJCRA	J. Franklin Inst.	KUPLA	Kunststoffe-Plastics
BSCFA	Bull. Soc. Chim. France	DANKA	Dokl. Akad. Nauk SSSR	JJCRA	J. Gas. Chromatog.	KURUA	Kunststoff-Rundschau
BSBQA	Bull. Soc. Chim. Belges	DANUA	Dokl. Akad. Nauk Uz. SSR	JJCRA	J. Heterocyclic Chem.	KNKKA	Kyoto Daigaku Nippon Kagakuseni Kenkyusho Koenshu
BUMPA	Bumazha. Prom.	DANTA	Dokl. Akad. Nauk Tadzh. SSR	JJCRA	J. Indian Chem. Soc.	LZAKA	Latvijas PSR Zinatnu Akad. Vestis, Kim. Ser.
BNSKA	Bunseki Kagaku	DOVPA	Dokl. L'vovsk. Politekh. Inst.	JJCRA	J. Inst. Petrol.	LAMCA	Lietuvos TSR Aukstuju Mok-yklu Mokslo Darbai; Chem. ir Chem. Technol.
CCPRA	Can. Chem. Process.	EMTDA	Eng. Mater. Design	JJCRA	J. Macromol. Chem.	MKGFA	Magy. Kem. Folyoirat
CJCHA	Can. J. Chem.	EUPJA	European Polymer J.	JJCRA	J. Mech. Phys. Solids	MCKLA	Magy. Kem. Lapja
CJPHA	Can. J. Phys.	EXPEA	Experientia	JJCRA	J. Mol. Spectry.	MCTXA	Magy. Textiltech.
CPVMA	Can. Paint Varnish Mag.	FCCSA	Fang Chih Chi Shu	JJCRA	J. Mol. Spectry.	MACEA	Makromol. Chem.
CNPLA	Can. Plastics	FALAA	Farbe Lack	JJCRA	J. Mol. Spectry.	MMTXA	Man-Made Textiles
CTJOA	Can. Textile J.	FACHA	Farben-Chemiker	JJCRA	J. Mol. Spectry.	MDENA	Mater. Design Eng.
CHAIA	Chem. Age India	FSTXA	Faserforsch. Textiltech.	JJCRA	J. Mol. Spectry.	MEVEA	Mater. Evaluation
		FSASA	Fette, Seifen, Anstrichmittel	JJCRA	J. Mol. Spectry.	MPLAA	Materiale Plast.
		FOTEA	Food Technol.	JJCRA	J. Mol. Spectry.	MPLAA	Materiale Plastique Elastomeri
		FPJOA	Forest Prod. J.	JJCRA	J. Mol. Spectry.	MAPRA	Mater. Protect.
		HFJOA	Fortsschr. Hochpolymer Forsch.	JJCRA	J. Mol. Spectry.	MTRSA	Mater. Res. Std.
		GCITA	Gazz. Chim. Ital.				
		GCACA	Geochim. Cosmochim. Acta				
		GLKPA	Gidrolizn. Lesokhim. Prom.				
		CAKSA	Gummi, Asbest, Kunststoffe				
		HCACA	Helv. Chim. Acta				

(Over)

MVCVA	Mededel. Vlaam. Chem. Ver.	PDPRA	Plastics Design Process.	RRMPA	Rubber Res. Inst. Malaya,		(London)
MKPLA	Mekhan. Polimerov	PILT	Plastics Electron. Ind.	RUBWA	Planters Bull.	TIRIA	Trans. Inst. Rubber Ind.
METXA	Melliand Textilber.		Plastics Inst. (London),	SAEJA	Rubber World	TSRHA	Trans. Soc. Rheol.
MTXRA	Mitt. Inst. Textiltechnol.		Trans. J.		S.A.E. (Soc. Automotive	TIKNA	Tr. Inst. Khim. Nauk, Akad.
	Chemiefasern Rudolstadt	PLTEA	Plastics Technol.	STPLA	Engrs.) J.	TKFAA	Nauk Kaz. SSR
MOPAA	Mod. Packaging	PLAWA	Plastics World		Sb. Tr., Tsentr. Nauchn.-	TKVVA	Tr. Karel'sk. Filiala Akad.
MOPLA	Mod. Plastics	PMELA	Plastiques Mod. Elastomeres		Issled. i Proekt. Inst.		Nauk SSSR
MTMAA	Mod. Textiles Mag.		(Paris)	SVPVA	Lesokhim. Prom.	TKKTA	Tr. Lab. Khim. Vysokomolekul. Soedin., Voronezhsk. Gos. Univ.
MDAWA	Monatsber. Deut. Akad.	PLTVA	Plastvarlden		Sb. Ved. Praci, Vysoka	TNTBA	Tr. Po Khim. i Khim. Tekhnol.
	Wiss. Berlin	PLARA	Plastverarbeiter		Skola Chem. Technol.,		Inst. Nauchn.-Issled.
MOCHA	Monatsh. Chem.	POLIA	Polymer	SPOCA	Pardubice		Inst. Tselyulozn.-Bumazhn. Prom.
MUANA	Muanyag	POLMA	Polymer		Sb. Vyskum. Prac Odboru	UKZHA	Ukr. Khim. Zh.
MTEAA	Mundo Textil Arg.	PYESA	Polymer Eng. Sci.		Celulozy Papiora	USKHA	Usp. Khim.
NATUA	Nature	PAWPA	Proc. Am. Wood-Preservers' Assoc.	SCIEA	Science	UZKZA	Uzbeksk. Khim. Zh.
NATWA	Naturwissenschaften			SPIPA	Sci. Papers Inst. Phys.	VMUKA	Vostn. Mosk. Univ., Ser. II, Khim.
NVPIA	Nauchn.-Issled. Tr., Vses. Nauchn.-Issled. Inst. Plenochnykh Materialov i Iakusstv. Kozhi	PRLAA	Proc. Roy. Soc. (London), Ser. A		Chem. Res. (Tokyo)		Vysokomolekul. Soedin. Western Plastics
NTMTA	Nauchn. Tr. Mosk. Tekhnol. Inst. Legkoi Prom.	PRFIA	Prod. Finishing (London)	SSINA	Sci. Sinica (Peking)	WBPFA	Wochbl. Papierfabrik
NFATA	Neftekhimiya	PRZPA	Przeglad Papier.	SENGA	Sen-i Gakkaishi	WOPIA	World Petrol.
NGOKA	Nippon Gomu Kyokaishi	PRCHA	Przemysl Chem.	SPACA	Spectrochim. Acta	YKSA	Yogyo Kyokai Shi
NHKNA	Nippon Hoshasen-Kobunshi Kenkyu Kyokai Nempo	PPCAA	Pulp Paper Mag. Can.	SPEJA	SPE (Soc. Plastics Engrs.) J.	YKGA	Yukagaku
NPKZA	Nippon Kagaku Zasshi	PACHA	Pure Appl. Chem.	SWTAA	Spinner Weber Textilveredl.	YKKA	Yuki Gossei Kagaku Kyokai Shi
NMOGA	Nippon Mokuzai Gakkaishi	QUREA	Quart. Rev.	SUECA	Studia Univ. Babes-Bolyai, Ser. Chem.		Z. Anal. Chem.
NOSKA	Norsk Skogind.	QUIBA	Quim. Ind. (Bilbao)	SUKBA	Suomen Kemistilehti, B		Z. Anorg. Allgom. Chem.
NCIAA	Nuovo Cimento, A	RAACA	Radiokhim. Acta	SVPAA	Svensk Papperstid.		Z. Chem.
NCIBA	Nuovo Cimento, B	RADKA	Radiokhimiya	TAPPA	Tappi		Zavodsk. Lab.
OPLCA	Office. Plastiques Caoutchouc	RTCPA	Rec. Trav. Chim. Reinforced Plastics	TQRPA	Tech. Rech. Papetieres		Zellstoff Papier
		RPACA	Rept. Progr. Appl. Chem.	TEINA	Teintex		Zeszyty Nauk. Politech. Lodz., Wlókniennictwo
PANTA	Paintindia	RBPLA	Rev. Belge Matieres Plastiques	TEPSA	Tekstilna Prom. (Sofia)		Z. Ges. Textil-Ind.
PAMAA	Paint Manyf.	RCBUA	Rev. Chim. (Bucharest)	TTLPA	Tekstil'n. Prom.		Z. Krist.
POCJA	Paint, Oil Colour J.	RCPLA	Rev. Gen. Caoutchouc Plastiques	TESDA	Tenside		Z. Physik. Chem. (Frankfurt)
PATEA	Paint Technol.			TEKHA	Teor. i Eksperim. Khim., Akad. Nauk Ukr. SSR		Z. Physik. Chem. (Leipzig)
PVPKA	Paint Varnish Prod.	RPMOA	Rev. Plasticos Mod. (Madrid)	TETRA	Tetrahedron		Zh. Analit. Khim.
PAPUA	Paperi Puu			TELEA	Tetrahedron Letters		Zh. Fiz. Khim.
PAERA	Papier	RRCHA	Rev. Roumaine Chim.	TEBUA	Textile Bull.		Zh. Prikl. Khim.
PCELA	Papir Celulosa	RTXPA	Rev. Textile Progr.	THINA	Textile Inst. Ind.		Zh. Orgao. Khim.
PPVEA	Pointures, Pigments, Vernis	RHEAA	Rheol. Acta	TEMAA	Textile Manuf.		Zh. Neorgan. Khim.
PCHEA	Petro. Chem. Engr.	ROCHA	Roczniiki Chem.	TRECA	Textile Recorder		Zh. Prikl. Khim.
PLKAA	Plaste Kautschuk	RUAGA	Rubber Age (N. Y.)	TRJOA	Textile Res. J.		Zh. Strukt. Khim.
PLASA	Plastica	RCTEA	Rubber Chem. Technol.	TEPRA	Textil-Praxis		Zh. Vses. Khim. Obshchestva im. D. I. Mendeleeva
PLMSA	Plasticheskie Massy	RUDVA	Rubber Develop.	TERUA	Textil-Rundschau		
PHMKA	Plasticheskie Hmoty Kaucuk	RUJOA	Rubber J. Intern. Plastics	TCHAA	Theoret. Chim. Acta		
PLBAA	Plasticos	RUPAA	Rubber J. Intern. Plastics	TINCA	Tinctoria		
PLALA	Plastics (London)	RPLWA	Rubber Plastics Age	TKSHA	Tokyo Kogyo Shikensho		
	Plastics Australia	RRQCA	Rubber Plastics Weekly	TFSOA	Hokoku		
			Rubber Res. Inst. Ceylon, Quart. Circ.	TICEA	Trans. Faraday Soc.		
					Trans. Inst. Chem. Engrs.		

BRPO	British Patent Office
CHCM	Chemical Communications
GEPO	German Patent Office
NEPO	Netherlands Patent Office
NHKK	Nippon Hoshasen Kobunshi Kenkyu Kyokai Nempo
PLMY	Polymery
PSHP	Proceedings Symposium High Power Accelerator Applications (N. Y.)
PSUR	Polymer Science (U. S. S. R.)
RPMO	Revista plasticas modernos
USPO	U. S. Patent Office
VYSO	Vysokomolekulyaryane Soedineniya

	NAME	CODEN	Vol.	P.	Yk.
1947:	RABEEBE	JACSA	69	95	47

	RABEEBE	JACSA	69	229	447
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	PHEMMETT	JPCHA	51	132	947
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1948:	PHEMMETT	JACSA	70	235	348
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	TLHILL	JCPA	16	181	48
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	A MENESSIE	COREA	226	144	848
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1949:	RABEEBE	IECHA	41	143	149
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	BLHARRIS	JPCHA	53	81	149
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	HKLIVINGSTON	JCSA	4	44	749
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1950:	RABEEBE	JACSA	72	40	50
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	C PIERCE	JPCHA	54	35	450
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	GLKINGTON	JACSA	72	40	50
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	C PIERCE	JACSA	72	559	550
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	C PIERCE	JPCHA	54	78	450
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	C PIERCE	JPCHA	54	79	550
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1951:	TLHILL	JACSA	73	510	251
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1952:	PHEMMETT	JPCHA	56	75	652
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	AVKISELEV	DANKA	86	95	52
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1953:	REBEEBE	JACSA	75	83	953
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	MRCINES	JPCHA	57	71	053
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	AVKISELEV	DANKA	92	36	153
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	C PIERCE	JACSA	75	84	653
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	C PIERCE	JPCHA	57	65	753
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	WDSCHAEFER	IECHA	45	172	153
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	WDSCHAEFER	JPCHA	57	46	953
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	ACZETTLEME	JPCHA	57	64	953
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	NAME	CODEN	Vol.	P.	Yk.
1954:	RABEEBE	JPCHA	58	93	54

	GDHALSEY	JPCHA	58	330	54
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	GDHALSEY	JPCHA	58	101	154
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	ACZETTLEME	JPCHA	58	31	354
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1955:	RABEEBE	CJCHA	33	30	555
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	RABEEBE	JPCHA	59	74	655
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	RABEEBE	JPCHA	59	75	455
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	BFHEALEY	JPCHA	59	39	955
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	D PAPEE	BSCFA	955	14	55
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	S ROSS	JCSA	10	31	955
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	S ROSS	JCSA	10	330	55
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1956:	AMRUBINSHTI	IARKA	956	129	456
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	RNSMITH	JPCHA	60	49	556
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	RNSMITH	JPCHA	60	106	356
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1957:	JGASTON	JPCHA	61	61	057
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	JGASTON	JPCHA	61	61	357
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	RABEEBE	JPCHA	61	168	457
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	D GRAHAM	JPCHA	61	131	057
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	GDHALSEY	JPCHA	61	115	857
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	ELPACE	JCPA	27	134	157
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	AI SARAKHOV	DANKA	112	46	457
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	JJ VANVOORH	JPCHA	61	151	357
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1958:	RABEEBE	JPCHA	62	71	958
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	D GRAHAM	JPCHA	62	121	058
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1959:	P FEJES	ZAACA	300	72	59
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	JGHOOLEY	CJCHA	37	89	959
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	VAKARGIN	VMSDA	1	26	559
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1960:	MMDUBIN	IARKA	960	58	860
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	GDHALSEY	JPCHA	64	168	960
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	ELPACE	JPCHA	64	96	160
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	NAME	CODEN	Vol.	P. Yr.
1961:	D GRAHAM	JCSCA	16	18261
	AA ISIRIKIY			
	AVKISELEV	JPCHA	65	60161
	S ROSS	JPCHA	65	60861
	A TSURUIZUBCSJA		34	145761
1962:	LDBELYAKOVRADKA		4	41062
	GDHALSEY	JPCHA	66	215462
	AVKISELEV	KNKTA	3	66762
	C PIERCE	JACSA	84	407062
	S ROSS	JPCHA	66	20562
1963:	MPMAKSIMOV IARKA	963		1763
1964:	BWDAVIS	THESIS		64
	JJKIPLING	TFSOA	60	40164
	C PIERCE	JPCHA	68	256264
1966:	RAPIEROTTI PREPR	966		4066

1964 Davis: Ph. D. Thesis, Univ. of California, Riverside

1966 Pierotti: Preprints of 1966 National Colloid Symposium