Hurd[6] reported the preparation of O,N-bis-(phenylcarbamyl)-N-benzoylhydroxylamine, $C_6H_5CON(CONHC_6H_5)OCONHC_6H_5$ (III), by reaction of a large excess of phenyl isocyanate with benzohydroxamic acid. The same product would be expected from the reaction of I with phenyl isocyanate. When the latter reaction was performed the product obtained had a melting point very close to that reported by Hurd and an elemental analysis corresponding to formula III. Repetition of Hurd's synthesis with benzohydroxamic acid and phenyl isocyanate yielded a product having similar properties and a satisfactory nitrogen analysis; however, the carbon and hydrogen values were too high. Apparently unidentified by-products were formed in this preparation.

Experimental

O-Phenylcarbamyl Benzohydroxamate (I). A. Reaction of Benzenesulfonyl Chloride with Benzhydroxamic Acid. (a) In Aqueous Solution.—A suspension of 1.0 g. (0.0072 mole) of benzohydroxamic acid in 100 ml. of water was adjusted to *p*H 7.6 with sodium hydroxide and the resulting solution diluted to 125 ml. One ml. of benzenesulfonyl chloride (0.0073 mole) was added and the *p*H maintained at 7.6 by automatic addition of *N* NaOH using the Beckman Autotitrator. Ten minutes after the addition of the benzenesulfonyl chloride, a precipitate started to form which increased in quantity during the next hour. The reaction slowed appreciably and during the next two hours produced only a small amount of acid.

The mixture was filtered and the precipitate washed with cold water. Diphenylurea was removed by dissolving the crude product in sodium hydroxide, filtering the very small quantity of the insoluble material and acidifying the filtrate with hydrochloric acid. The resulting precipitate, after drying, weighed 0.7 g., equivalent to a yield of 75%. (A large quantity of diphenylurea and a smaller yield of O-phenylcarbamyl benzohydroxamate was obtained when the reaction mixture was permitted to stand at *p*H 7.6 overnight.) The reaction product, which was soluble in sodium hydroxide, sodium bicarbonate, alcohol and ether, but insoluble in water and dilute acid, was recrystallized from aqueous alcohol and dried over phosphorus pentoxide in vacuum. The resulting white needles decomposed at 176–177°, with evolution of carbon dioxide, and finally melted at 234° (m.p. diphenylurea, 238°). The substance is an acid, having pK_a of 6.4. The analysis and neutralization equivalent correspond to O-phenylcarbamyl benzohydroxamate.

Anal. Calcd. for $C_{14}H_{12}N_2O_3$: C, 65.6; H, 4.7; N, 10.9; equiv. wt., 256. Found: C, 65.7; H, 4.6; N, 11.2; equiv. wt., 253.

The same product was obtained when one-half the molar quantity of benzenesulfonyl chloride was added to benzohydroxamic acid. The yield, however, was reduced to 0.5 g., 53%, based upon benzohydroxamic acid.

(b) In Pyridine.—A solution of 2.0 g. (0.015 mole) of benzohydroxamic acid in 50 ml. of dry pyridine was cooled and 1.96 ml. (0.015 mole) of benzenesulfonyl chloride was added with stirring. A reaction occurred immediately with the evolution of heat. The solution became cherry-red and was stirred for an hour at room temperature. No color reaction with ferric chloride was obtained after this time. The pyridine was vacuum stripped, the resulting dark red viscous residue dissolved in sodium hydroxide and an orange precipitate was obtained upon acidification with hydrochloric acid. The product was decolorized with charcoal in alcohol. Upon dilution with water, there were obtained white needles which decomposed at 176–177°, with the evolution of carbon dioxide, and finally melted at 230°.

B. Reaction of *o*-Nitrobenzoyl Chloride with Benzhydroxamic Acid.—To a mixture of 1.9 g. (0.012 mole) of sodium benzohydroxamate in 250 ml. of water and 50 ml. of dioxane which was adjusted to *p*H 9.0, there was added a solution of 1.1 g. (0.006 mole) of *o*-nitrobenzoyl chloride in 20 ml. of dioxane. The *o*-nitrobenzoyl chloride was almost insoluble in the reaction mixture and upon mechanical stirring formed small globules of oil. During the next five hours, the solution was maintained at *p*H 9.0 by the addition of base using a Beckman Autotitrator. In the course of the reaction the volume of acid chloride diminished considerably and by the time the reaction was stopped the remaining insoluble material had become a solid.

The aqueous solution was decanted, acidified and the precipitate that formed filtered and dried. There was obtained 0.49 g. (32%) of a white solid which decomposed at 174–177°, with evolution of carbon dioxide, and finally melted at 220–225°. A mixed melting point with an authentic sample of O-phenylcarbamyl benzohydroxamate obtained from the reaction of benzohydroxamic acid with phenyl isocyanate gave no depression.

The insoluble fraction was dried under vacuum; it melted at 126–130°. The melting point of O-(*o*-nitrobenzoyl) benzohydroxamate is 131–132°. The yield of this material was 0.3 g., equivalent to 17% of theory based upon benzohydroxamic acid.

Formation of Diphenylurea from O-Phenylcarbamyl Benzohydroxamate.—A small quantity of O-phenylcarbamyl benzohydroxamate was heated for 30 minutes, at 180–190°, and the carbon dioxide which was evolved was passed into a solution of barium hydroxide and precipitated as barium carbonate. The residual solid was insoluble in sodium hydroxide. After recrystallization from 95% alcohol, its melting point was 238–240°. A mixed melting point with an authentic sample of diphenylurea gave no depression.

O,N-Bis-phenylcarbamyl Benzohydroxamate (III). A. Addition of One Mole of Phenyl Isocyanate to One Mole of O-Phenylcarbamyl Benzohydroxamate.—An excess (3 ml.) of phenyl isocyanate was added to 0.2 g. of O-phenylcarbamyl benzohydroxamate, and the mixture was heated cautiously over a free flame until solution occurred. The resulting oil was permitted to stand at room temperature for an hour, after which 60 ml. of dry ligroin (b.p. 30–65°) was added. When this mixture was cooled in a Dry Ice–acetone-bath, a precipitate formed which was filtered and washed with ligroin. The product was recrystallized from benzene and ligroin. Upon treatment with 2% sodium bicarbonate solution, a small amount of the crystalline product dissolved. The insoluble residue was washed with water and with ligroin.

The product shrinks at 118–120°, and evolves carbon dioxide at 148°.

Anal. Calcd. for $C_{21}H_{17}O_4N_3$: C, 67.2; H, 4.6; N, 11.2. Found: C, 67.2; H, 4.8; N, 11.1.

B. Reaction of Excess Phenyl Isocyanate with Benzohydroxamic Acid.—A mixture of 0.3 g. of benzohydroxamic acid and 2.5 ml. of phenyl isocyanate was heated and the reaction product isolated according to the method of Hurd.[6] The product shrinks at 115° and evolves carbon dioxide at 148°.

Anal. Calcd. for $C_{21}H_{17}O_4N_3$: C, 67.2; H, 4.57; N, 11.2. Found: C, 72.1; H, 5.1; N, 11.6.

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A System for Paper Chromatography of 3,4-Benzpyrene, Some Derivatives and Other Polycyclic Aromatic Hydrocarbons[1]

BY D. S. TARBELL, E. G. BROOKER, A. VANTERPOOL, W. CONWAY, C. J. CLAUS AND T. J. HALL

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During a study[2] of the nature of the fluorescent material which is chemically bound to the skin protein of mice after painting with 3,4-benzpyrene,[3] it was necessary to develop a system for paper

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[1] This work was supported by a grant from the Damon Runyon Memorial Fund.

[2] D. S. Tarbell, E. G. Brooker, P. Seifert and T. J. Hall, Abstracts of the N. Y. Meeting of the American Chemical Society, September, 1954, p. 5N.

[3] E. C. Miller, *Cancer Research*, **11**, 100 (1951).

chromatography of benzpyrene and its derivatives. The procedure described in this note,[4] which is the result of the examination of a large number of solvent systems, shows promise in dealing with these compounds as well as with other polycyclic hydrocarbons. It has already been found useful in examining reaction mixtures obtained from benzpyrene by the action of various reagents, and may be applicable to the detection of 3,4-benzpyrene in smokes and fogs.

The results obtained with a number of benzpyrene derivatives and other polycyclic hydrocarbons are indicated in Table I. Considerable variation in the absolute R_F values was observed from run to run; similar variations were noted in paper chromatography of oxygenated steroids in analogous solvent systems.[4] However, the relative order of the different compounds was the same in different runs; a known spot of benzpyrene was used as a control, and was readily detected by its characteristic fluorescence. It will be noted that with the hexane–dimethylformamide system the more polar the compounds, the lower the R_F values which were observed.

TABLE I

AVERAGE R_F VALUES OF 3,4-BENZPYRENE, SOME OF ITS DERIVATIVES AND SOME OTHER POLYCYCLIC AROMATIC HYDROCARBONS USING THE HEXANE–DIMETHYLFORMAMIDE SOLVENT SYSTEM

Compounds	No. of runs (av.)	Av. of R_F values	Color under ultraviolet light
3,4-Benzpyrene	10	0.54	Blue
Benzpyrene derivatives			
10-Ethyl	4	.80	Blue
10-Acetyl	4	.26	Green
α-Hydroxy-10-ethyl	4	.07	Blue
4′-Hydroxy-1′,2′,3′,4′-tetrahydro	3	.14	Greenish-blue
4′-Keto-1′,2′,3′,4′-tetrahydro	2	.37	Greenish-blue
Anthracene	4	.84	Blue
Naphthacene	3	.51	Orange
Chrysene	4	.72	Dark blue
Pyrene	5	.62	Green
Fluoranthene	4	.82	Green
20-Methylchlolanthrene	3	.89	Blue
1,2-Benzanthracene	3	.66	Blue
1,2,5,6-Dibenzanthracene	3	.54[a]	Blue

[a] Considerable tailing occurs.

Experimental

The polycyclic hydrocarbons were purified by chromatography and by conversion to trinitrobenzene complexes. The benzpyrene derivatives were synthesized mainly by known procedures; some new procedures are noted below.

10-(α-Hydroxyethyl)-benzpyrene.—10-Acetylbenzpyrene[5] (0.10 g.) in 50 cc. of dry benzene was added dropwise to 50 cc. of dry ether, containing 2 cc. of approximately 1.0 *M* ethereal lithium aluminum hydride. The mixture was refluxed for 2.5 hr., cooled, and water was added to decompose excess reagent, followed by dilute hydrochloric acid. The organic layer was separated, washed with water and bicarbonate, was then dried and the solvent was removed. The yellow solid remaining was chromatographed on alumina from benzene solution. A small amount of the starting ketone was eluted with benzene, and the product was eluted by 1:1 chloroform–ethyl acetate; the product, fine yellow needles, m.p. 150–156°, yielded 0.07 g. (73%), m.p. 163–166°, after two crystallizations from benzene.

Anal. Calcd. for $C_{22}H_{16}O$: C, 89.19; H, 5.45. Found: C, 89.23; H, 5.34.

The reported[5b] m.p. is 153–154°.

10-Ethylbenzpyrene (IV).—10-Acetylbenzpyrene (350 mg.) in 25 cc. of triethylene glycol was heated with 0.3 cc. of 85% hydrazine hydrate and 0.25 g. of potassium hydroxide at 140–160° for 1.5 hr. The condenser was then removed, and the vapors were allowed to escape while the temperature was raised to 195–200°. The condenser was dried and replaced, and the solution was heated at 190–200° for 4.5 hr. The mixture was then poured into water, extracted three times with ether, the solvent dried and removed, the residue was taken up with 1:1 petroleum ether–benzene, and chromatographed on 5 g. of alumina. Elution with six fractions (300 cc. each) of the same solvent gave, after crystallization from benzene, 280 mg. (89%) of material melting at 115–116°. The compound was obtained by Windaus[5a] in poor yield melting at 112°.

Paper Chromatography.—A 4″ × 18″ strip of Whatman No. 1 filter paper was completely saturated with redistilled N,N-dimethylformamide,[6] then dried by hanging in the air for 1 hr. During this time, about 1 μg. of the sample, in benzene solution, was applied to a marked spot 2″ from the lower end of the paper, using a micro-pipet. A stream of nitrogen was used to dry the spot.

The developing chamber, which consisted of a Pyrex jar covered with a glass plate, was lined with filter paper which was kept saturated with the developing solvent. The paper strip was equilibrated in the chamber overnight before being developed by the ascending technique with hexane saturated with N,N-dimethylformamide. All experiments were conducted in the dark to prevent photodecomposition of the samples, the position of the spots being checked by observation under ultraviolet light.

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[4] *Cf.* A. Zaffaroni, R. B. Burton and E. H. Keutmann, *Science*, **111**, 6 (1950); *J. Biol. Chem.*, **188**, 763 (1951).

[5] A. Windaus and K. Raichle, *Ann.*, **537**, 157 (1938); (b) L. F. Fieser and E. B. Hershberg, THIS JOURNAL, **61**, 1565 (1939).

[6] We are indebted to the Electrochemical Department of duPont for this material.

Free Radical Additions Involving Fluorine Compounds. III. The Addition of Bromochlorodifluoromethane to Olefins[1,2]

BY PAUL TARRANT AND ALAN M. LOVELACE

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An earlier paper in this series[3] reported that dibromodifluoromethane reacted with various hydrocarbon olefins to give one-to-one addition products; however, the presence of chlorine atoms near the double bond of the olefin prevented the addition from occurring. In order to determine whether steric effects were responsible for the lack of reactivity in this instance, a study was made of the reaction of bromochlorodifluoromethane with various olefins. It was found that the reaction took place readily with olefins which reacted with CF_2Br_2, *e.g.*, $CH_2{=}CF_2$, $CH_2{=}CHCH_3$, $CH_2{=}C(CH_3)_2$ and $CH_3CH{=}CHCH_3$, and the corresponding addition products containing the chlorodifluoromethyl group were obtained in comparable yields. It is therefore interesting to note that the substitution of one of the bromine atoms of di-

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[2] We wish to thank the Dow Chemical Co., Midland, Mich., for furnishing us a generous quantity of bromochlorodifluoromethane.

[3] P. Tarrant and A. M. Lovelace, THIS JOURNAL, **76**, 3466 (1954).