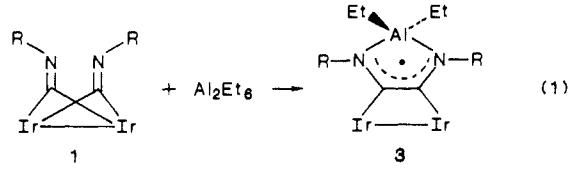
geometry and a metal-metal bond, d(Ir-Ir) = 2.7861 (6) Å.

Complex **3** has one unpaired electron, which is introduced by the addition of a neutral $^{\bullet}AlEt_2$ radical to the diamagnetic complex **1**. At −150 °C the EPR powder spectrum of **3** exhibits a completely isotropic signal with g = 2.005. The isotropic nature of the low-temperature powder spectrum suggests that the unpaired electron **3** resides in a molecular orbital with essentially no contribution from the iridium atoms. This result is in accord with FTIR ν(CN) data which suggest no change in the formal oxidation state of **3** compared to **1** and indicates the unpaired electron likely is delocalized exclusively within the C_2N_2Al ring of **3**.

The formation of **3** by annulation of two μ-isocyanides with an $AlEt_2$ radical is unprecedented, eq 1. The $^{\bullet}AlEt_2$ radical is



1 3

presumably formed by $AlEt_3$ abstraction of $C_2H_5^-$ from an N-complexed $AlEt_3$ followed by electron transfer. The complexation of 1 equiv of $AlEt_3$ to **1** is observed in the early stages of reaction (vide supra). Upon abstraction of $C_2H_5^-$ from the initial adduct, one would expect formation of the species $[Ir_2\{C_2(NR)_2AlEt_2\}(CNR)_2(dmpm)_2]^+[AlEt_4]^-$, $[3^+][AlEt_4^-]$. We note Schmidbaur has reported an apparently similar disproportionation of Al_2Me_6 to $[AlMe_2^+]/[AlMe_4^-]$ and annulation of $[AlMe_2^+]$ in the case of bis(trialkylphosphoranylimino)silanes.[31] We find the molecular cation 3^+ can be prepared by one-electron oxidation of **3**. Cyclic voltammetric studies of **3** in THF reveal one reversible oxidation, $E_{1/2}(3^+/3)$ = −0.22 V versus SCE. Chemical oxidation of **3** with $[FeCp_2][PF_6]$ affords $[3^+][PF_6^-]$. The cationic species 3^+ does not show any ν(CN) band in the 1700–1450-cm^{-1} region, suggesting that the carbon–carbon bond in the C_2N_2Al ring of **3** is not cleaved by one-electron oxidation. The diamagnetic cation 3^+ is however reducible by $AlEt_4^-$ to yield the isolated radical product **3**. Our results thus imply that it is the condensation of an $AlEt_2^+$ fragment with two bridging isocyanide ligands which induces carbon–carbon bond formation, not the injection of an electron from $AlEt_4^-$, formed during the coupling reaction. Our studies of the relative importance of the Lewis acid employed in ligand coupling versus electron transfer are continuing.

Acknowledgment. This work was supported by the National Science Foundation (CHE-8411836 and CHE-8707963). NSF support of the Chemical X-ray Diffraction Facility at Purdue is also gratefully acknowledged.

Supplementary Material Available: Tables consisting of crystal data and data collection parameters for **1** and **3** (Table I), positional parameters for **1** and **3** (Tables II and VII, respectively), temperature factor expressions for **1** and **3** (Tables III and VIII, respectively), bond distances and angles for **1** and **3** (Tables IV and IX, respectively), least-squares planes and dihedral angles for **1** and **3** (Tables V and X, respectively) (30 pages); tables consisting of observed and calculated structure factors for **1** and **3** (Tables VI and XI, respectively) (51 pages). Ordering information is given on any current masthead page.

(27) The Al-N bond distances of 1.939 (9) Å and 1.896 (9) Å lie at the extrema for known Al-N distances, 1.937 (5)–1.902 (4) Å.[28]

(28) (a) Hitchcock, P. B.; Smith, J. D.; Thomas, K. M. *J. Chem. Soc., Dalton Trans.* **1974**, 1433. (b) Amirkhalili, S.; Hitchcock, P. B.; Smith, J. D. *J. Chem. Soc., Dalton Trans.* **1979**, 1206. (c) Piero, G. D.; Cesari, M.; Dozzi, G.; Mazzei, A. *J. Organomet. Chem.* **1977**, *129*, 281. (d) Piero, G. D.; Cesari, M.; Perego, G.; Cucinella, S.; Cernia, E. *Ibid.* **1977**, *129*, 289. (e) Piero, G. D.; Cesari, M.; Cucinella, S.; Mazzei, A. *J. Organomet. Chem.* **1977**, *137*, 265.

(29) The detailed studies of complex **1**, **2**, and **3** will be reported in a full paper.

(30) Schmidbaur, H.; Wolfsberger, W.; Schwirten, K. *Chem. Ber.* **1969**, *102*, 556.

(31) Cowie, M.; Dickson, R. S. *Inorg. Chem.* **1981**, *20*, 2682.

(32) Cowie, M.; Southern, T. G. *J. Organomet. Chem.* **1980**, *193*, C46.

Total Synthesis of (+)-CC-1065 and *ent*-(−)-CC-1065

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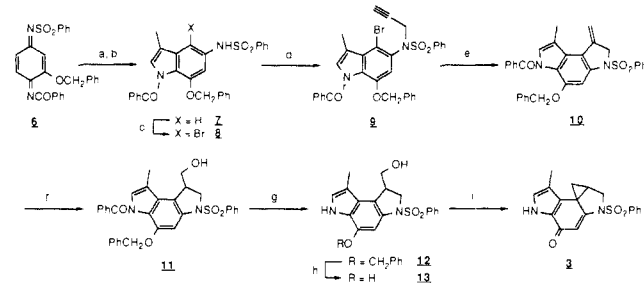
Received October 7, 1987

CC-1065 (**1**, NSC-298223), an antitumor–antibiotic isolated from *Streptomyces zelensis*[2] initially identified by spectroscopic techniques[3a] and confirmed in a single-crystal X-ray structure determination,[3b] has been shown to possess exceptional, potent in vitro cytotoxic activity, antimicrobial activity, and confirmed, potent in vivo antitumor activity.[4] In sharp contrast to the early observations made with simplified analogues of CC-1065 bearing modified central and right-hand subunits, e.g., U-71,184,[5] in which the antitumor activity and DNA binding properties have been found to be restricted primarily to the agent enantiomer bearing the natural 3*bR*,4*aS*-CPI left-hand segment,[6] recent efforts have

Scheme I[a]



[a] (a) 1.10 equiv of 1-piperidino-1-propene, CH_2Cl_2, 0–23 °C, 12 h; (b) 10% aqueous HCl–THF (1:5), 23 °C, 12 h; (c) 1.0 equiv of *N*-bromosuccinimide, THF, H_2SO_4 (catalyst), −23 °C, 1 h, 97%; (d) 1.1 equiv of NaH, DMF, 23 °C, 15 min; 3 equiv of 3-bromopropyne, DMF, 23 °C, 3 h, 67% from **7**; (e) 2.1 equiv of *n*-Bu_3SnH, AIBN (catalyst), benzene, 80 °C, 4–5 h; (f) 2–3 equiv of $BH_3{\cdot}SMe_2$, THF, 0–23 °C, 1–3 h; 1 equiv of 2 N aqueous NaOH, 3 equiv of 30% H_2O_2, 45 °C, 30 min, 40% from **9**; (g) 5% anhydrous HCl–CH_3OH, 50 °C, 2 h, 83%; (h) 1 atm of H_2, 10% Pd/C, EtOAc, 23 °C, 20 h, 85%; (i) 1.5 equiv of Ph_3P, 1.95 equiv of diethyl azodicarboxylate, THF, 23 °C, 3 h, 50%.

(1) (a) National Institutes of Health research career development award recipient, 1983–1988 (CA 01134). Alfred P. Sloan research fellow, 1985–1989. (b) National Institutes of Health predoctoral trainee, 1984–1985 (GM 07775). David Ross Fellow, Purdue University, 1986–1987.

(2) Hanka, L. J.; Dietz, A.; Gerpheide, S. A.; Kuentzel, S. L.; Martin, D. G. *J. Antibiot.* **1978**, *31*, 1211. Martin, D. G.; Biles, C.; Gerpheide, S. A.; Hanka, L. J.; Krueger, W. C.; McGovren, J. P.; Mizsak, S. A.; Neil, G. L.; Stewart, J. C.; Visser, J. *J. Antibiot.* **1981**, *34*, 1119.

(3) (a) Martin, D. G.; Chidester, C. G.; Duchamp, D. J.; Mizsak, S. A. *J. Antibiot.* **1980**, *33*, 902. (b) Chidester, C. G.; Krueger, W. C.; Mizsak, S. A.; Duchamp, D. J.; Martin, D. G. *J. Am. Chem. Soc.* **1981**, *103*, 7629.

(4) For a recent review of the chemistry, mechanism of action, and biological properties of CC-1065, see: Reynolds, V. L.; McGovren, P. J.; Hurley, L. H. *J. Antibiot.* **1986**, *31*, 319 and references cited therein. For a review on the covalent binding of CC-1065 to the minor groove of DNA, see: Hurley, L. H.; Needham-VanDevanter, D. A. *Acc. Chem. Res.* **1986**, *19*, 230 and references cited therein. See, also: Hurley, L. H.; Reynolds, V. L.; Swenson, D. H.; Petzold, G. L.; Scahill, T. A. *Science (Washington, D.C.)* **1984**, *226*, 843. Needham-VanDevanter, D. R.; Hurley, L. H.; Reynolds, V. L.; Theriault, N. Y.; Krueger, W. C.; Wierenga, W. *Nucleic Acids Res.* **1984**, *12*, 6159.

(5) (a) Warpehoski, M. A. *Tetrahedron Lett.* **1986**, *27*, 4103. (b) Warpehoski, M. A.; Gebhard, I.; Kelly, R. C.; Krueger, W. C.; Li, L. H.; McGovren, J. P.; Prairie, M. D.; Wicneinski, N.; Wierenga, W. *J. Med. Chem.*, **1988**, in press. (c) Li, L. H.; Wallace, T. L.; DeKoning, T. F.; Warpehoski, M. A.; Kelly, R. C.; Prairie, M. D.; Krueger, W. C. *Investigational New* Drugs, in press. (d) For a review of the biological activity of analogues of CC-1065, see: Wierenga, W.; Bhuyan, B. K.; Kelly, R. C.; Krueger, W. C.; Li, L. H.; McGovern, J. P.; Swenson, D. H.; Warpehoski, M. A. *Adv. Enz. Reg.* **1986**, *25*, 141.

(6) The assignment of absolute configuration of natural (+)-CC-1065 has been unambiguously established in a single-crystal X-ray analysis of N^2-*p*-chlorobenzoyl CPI derived from natural (+)-CC-1065: Martin, D. G., The Upjohn Company, unpublished observations. The assignment of the absolute configuration of (−)-1*S*-4 is based on the successful correlation with natural (+)-CC-1065.

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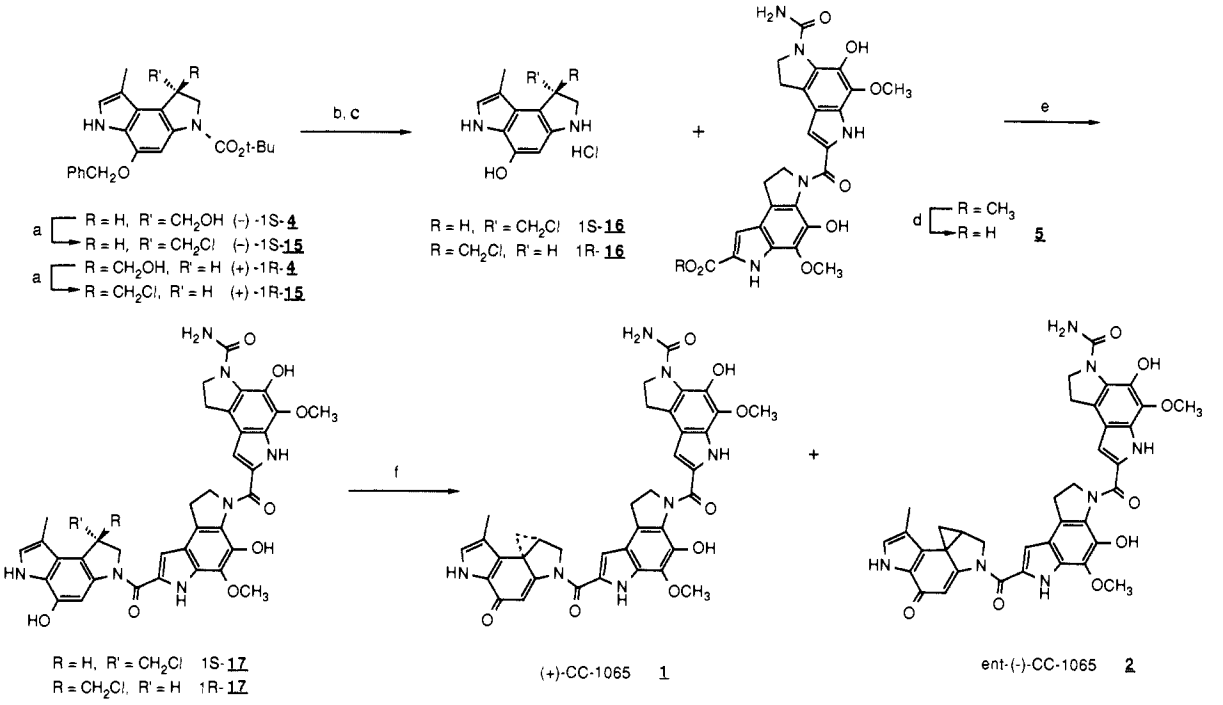
Scheme II[a]



[a](a) 1.5 equiv of Ph_3P, 1.5 equiv of CCl_4, CH_2Cl_2, 23 °C, 12 h, 87%; (b) 25% aqueous HCO_2NH_4/THF 1:4, 10% Pd/C, 23 °C, 30–45 min, 100%; (c) 3 N anhydrous HCl–EtOAc, 23 °C, 30–45 min; (d) 10 equiv of LiOH, 3 equiv of $Na_2S_2O_4$, THF/CH_3OH/H_2O (3:2:1), 45 °C, 10 h, 84%; (e) 0.9 equiv of **5**, 3 equiv of 1-(3-(dimethylamino)propyl)-3-ethylcarbodiimide hydrochloride (EDCI), $NaHCO_3$, DMF, 23 °C, 24 h; (f) 1:1:1 Et_3N/H_2O/CH_3CN, 23 °C, 30 min, 34% from **5**.

revealed that the enantiomeric pairs (+)-CC-1065/*ent*-(−)-CC-1065[7] and (+)-CPI-$CDPI_2$/(−)-CPI-$CDPI_2$[8] possess indistinguishable in vitro cytotoxic activity. Herein we detail the preparation of **3**, the spirobicyclo[5.2.0]octa-2,5-dien-4-one bearing left-hand segment of CC-1065 (CPI),[9] the coupling of its resolved, immediate precursors (−)-1*S*-**15** and (+)-1*R*-**15** to synthetic PDE-I dimer (**5**),[10] and incorporation into the total syntheses of natural (+)-CC-1065 (**1**) and unnatural *ent*-(−)-CC-1065 (**2**), respectively.

Treatment of the selectively activated 2-benzyloxy-*p*-quinonediimide **6**[11] with 1-piperidino-1-propene (CH_2Cl_2, 0–23 °C, 2–12 h) followed by acid-catalyzed elimination of piperidine (10% aqueous HCl/THF 1:5, 23 °C, 12 h)[12] afforded 3-methylindole **7**. Selective C-4 bromination of **7** (1.0 equiv NBS, THF, catalytic H_2SO_4, −23 °C, 1 h) afforded **8** (97%), and subsequent benzenesulfonamide alkylation (NaH, DMF; 3-bromopropyne, 23 °C, 3 h) provided **9** (67% overall from **7**). 5-*Exo-Dig* aryl radical–alkyne cyclization[13] (2.1 equiv *n*-Bu_3SnH, catalytic AIBN, benzene, 80 °C, 4–5 h) afforded 3-methylideneindoline **10**, which proved unstable to chromatographic purification and was subjected directly to the conditions of hydroboration (2–3 equiv of BH_3·SMe_2, THF, 0–23 °C, 1–3 h) and subsequent oxidation (2 N NaOH, 30% aqueous H_2O_2, 45 °C, 30 min) to provide 3-hydroxymethylindoline **11** (40% overall from **9**). Indole deprotection (5% anhydrous HCl–CH_3OH, 50 °C, 2 h) afforded **12**, and hydrogenolysis of the benzyl ether (1 atm of H_2, 10% Pd/C, EtOAc, 23 °C, 20 h) provided **13**. Final closure of **13** directly to the spirocyclopropylquinone was achieved by employing the Mitsunobu activation and intramolecular alkylation conditions detailed by Magnus and co-workers (Ph_3P, diethyl azodicarboxylate, THF, 23 °C, 3 h),[9b] affording N^2-benzenesulfonyl CPI (**3**),[9c] and completing the preparation of the protected left-hand segment of CC-1065.[9]

The resolution of **4**[8] and its subsequent incorporation into the total synthesis of (+)- and (−)-CC-1065 is detailed in Scheme II. Reductive removal of the indoline *N*-benzenesulfonamide group of **12** (6 equiv of sodium bis(2-methoxyethoxy)aluminum hydride, toluene, 100 °C, 3 h)[7,14] followed by acylation of the unstable free indoline (2 equiv of di-*tert*-butyldicarbonate, THF, 23 °C, 3 h) afforded **4** (60% from **12**). Resolution of alcohol **4** was achieved by chromatographic separation of the corresponding diastereomeric (*R*)-(−)-*O*-acetylmandelate esters (**14**),[8] providing 1*R*,2'*R*-**14** and 1*S*,2'*R*-**14**, which were independently subjected to base-promoted hydrolysis (3 equiv of LiOH, THF/CH_3OH/H_2O 3:2:1, 20 °C, 3 h) to provide the enantiomeric alcohols (+)-1*R*-**4** ($[\alpha]^{23}_{578}$ = +8.1° (*c* 0.63, CH_2Cl_2)) and (−)-1*S*-**4** ($[\alpha]^{23}_{578}$ = −8.3° (*c* 0.74, CH_2Cl_2)).[15] Independent conversion of (−)-1*S*-**4** and (+)-1*R*-**4** to the corresponding *primary* chlorides (1.5 equiv of Ph_3P, 1.5 equiv of CCl_4, CH_2Cl_2, 23 °C, 12 h)[16] afforded (−)-1*S*-**15** ($[\alpha]^{23}_{578}$ = −12.8° (*c* 0.51, CH_2Cl_2)) and (+)-1*R*-**15** ($[\alpha]23_{578}$ = +13.1° (*c* 0.66, CH_2Cl_2)),[15] respectively, constituting the resolved substrates for incorporation into the total synthesis of (+)- and (−)-CC-1065.[7] Following the conditions described by Kelly and co-workers,[7] sequential removal of the

(7) Kelly, R. C.; Gebhard, I.; Wicnienski, N.; Aristoff, P. A.; Johnson, P. D.; Martin, D. G. *J. Am. Chem. Soc.* **1987**, *109*, 6837.
(8) Boger, D. L.; Coleman, R. S. *J. Org. Chem.* **1988**, in press.
(9) (a) Wierenga, W. *J. Am. Chem. Soc.* **1981**, *103*, 5621. (b) Magnus, P.; Gallagher, T.; Schultz, J.; Or. Y.-S.; Ananthanarayan, T. P. *J. Am. Chem. Soc.* **1987**, *109*, 2706. (c) Kraus, G. A.; Yue, S.; Sy, J. *J. Org. Chem.* **1985**, *50*, 283. (d) Moody, C. J.; Pass, M.; Rees, C. W.; Tojo, G. *J. Chem. Soc., Chem. Commun.* **1986**, 1062. (e) Sundberg, R. J.; Nishiguchi, T. *Tetrahedron Lett.* **1983**, *24*, 4773. Sundberg, R. J.; Baxter, E. W. *Tetrahedron Lett.* **1986**, *27*, 2687. For a review of synthetic studies on CC-1065 and functionally related agents, see: Coleman, R. S.; Boger, D. L. In *Studies in Natural Products Chemistry*; Atta-ur-Rahman, Ed.; Elsevier: Amsterdam, Vol. 1, in press.
(10) Boger, D. L.; Coleman, R. S. *J. Am. Chem. Soc.* **1987**, *109*, 2717.
(11) Prepared from 2-amino-5-nitrophenol by the following sequence: (a) PhCOCl, K_2CO_3, THF, 92%; (b) $PhCH_2Br$, K_2CO_3, acetone, *n*-Bu_4NI (catalyst), reflux, 94%; (c) $Na_2S_2O_4$, THF/H_2O, reflux; $PhSO_2Cl$, pyridine, THF, 73%; (d) $Pb(OAc)_4$, benzene, 84%.
(12) Domschke, G.; Heller, G.; Natzeck, U. *Chem. Ber.* **1966**, *99*, 939.
(13) For selected examples of alkyl radical–alkyne cyclizations, see: Clive, D. L. J.; Angoh, A. G.; Bennett, S. M. *J. Org. Chem.* **1987**, *52*, 1339. Curran, D. P.; Chen, M.-H.; Kim, D. *J. Am. Chem. Soc.* **1986**, *108*, 2489. Okabe, M.; Abe, M.; Tada, M. *J. Org. Chem.* **1982**, *47*, 1775. Stork, G.; Mook, R., Jr. *J. Am. Chem. Soc.* **1983**, *105*, 3720.
(14) Gold, E. H.; Babad, E. *J. Org. Chem.* **1972**, *37*, 2208.
(15) HPLC analysis of the separated diastereomers showed the faster eluting diastereomer (1*R*,2'*R*-**14**) was ≥99% pure, and the slower eluting diastereomer (1*S*,2'*R*-**14**) was 97–98% diastereomerically pure.
(16) Appel, R. *Angew. Chem., Int. Ed. Engl.* **1975**, *14*, 801.

benzyl ether (HCO_2NH_4, THF/H_2O 4:1, 10% Pd/C, 23 °C, 30 min, 100%) and the *t*-BOC protecting groups (3 N anhydrous HCl–EtOAc, 23 °C, 30 min) of (–)-1*S*-**15** and (+)-1*R*-**15** afforded the unstable indoline hydrochlorides **16**, which were coupled directly with synthetic PDE-I dimer (**5**)[10] in the presence of EDCI (3 equiv, DMF, $NaHCO_3$, 23 °C, 24 h) to provide 1*S*-**17** and 1*R*-**17**, respectively. Final spirocyclization (Wierenga–Kelly Winstein Ar-3' alkylation)[7] was effected by treatment of 1*S*-**17** and 1*R*-**17** with 1:1:1 $Et_3N/H_2O/CH_3CN$ (23 °C, 30 min) and afforded (+)-CC-1065 (**1**, $[\alpha]_{578}^{23} = +90°$ (*c* 0.062, DMF)) and *ent*-(–)-CC-1065 (**2**, $[\alpha]_{578}^{23} = -92°$ (*c* 0.075, DMF)),[15] respectively.[17]

Acknowledgment. This work was assisted by the financial support of the National Institutes of Health (CA 41986), the Alfred P. Sloan Foundation, and Purdue University (David Ross Fellowship to R.S.C.). We thank Dr. Robert C. Kelly of The Upjohn Company for providing a comparison sample of naturally occurring (+)-CC-1065, for preprints of their work (ref 5 and 7), and for many helpful discussions.

Supplementary Material Available: Full physical and spectral characterizations of **3–17**, **1**, and **2** are provided (8 pages). Ordering information is given on any current masthead page.

(17) Synthetic CC-1065 prepared in this manner was shown to be identical by SiO_2 TLC (20% DMF–toluene), $[\alpha]_{578}^{23}$, ^1H NMR (DMSO-d_6, 300 MHz), IR (KBr), and FABMS with an authentic sample of natural (+)-CC-1065. The $[\alpha]_D^{25}$ for natural (+)-, semisynthetic (+)-, and semisynthetic *ent*-(–)-CC-1065 have been reported to be +97°, +98°, and –96° (*c* 0.2, DMF),[7] respectively. In the present investigation, $[\alpha]_{578}^{23}$ for natural (+)-CC-1065 was determined to be +93° (*c* 0.067, DMF). In the present investigation, the in vitro cytotoxic activity of natural (+)-, synthetic (+)-, and synthetic *ent*-(–)-CC-1065, respectively, were determined to be the following: 1.1, 1.2, and 1.3×10^{-5} μg/mL (L1210); 1.4, 1.8, 1.3×10^{-5} μg/mL (B16).

Additions and Corrections

Remarkable Effects of Lone Pair–Lone Pair Interactions on the Extremely Stereoselective [2 + 2] Cycloaddition of Azidoketene to Chiral 3-Imino-β-lactams [*J. Am. Chem. Soc.* **1987**, *109*, 1798]. IWAO OJIMA,* KAZUAKI NAKAHASHI, STEPHAN M. BRANDSTADTER, and NAOTO HATANAKA

Page 1801: In Scheme V, the compound designations for IIA and IIB should be reversed.

*Book Reviews**

Advances in Heterocyclic Chemistry. Volume 41. Edited by A. R. Katritzky. Academic Press: Orlando. 1987. vii + 376 pp. $85.00. ISBN 0-12-020641-2

The six chapters in this volume treat subjects new to the series. Synthesis of Heterocycles from Hydrogen Cyanide Derivatives, by D. S. Donald and O. W. Webster, deals with the elaborate chemistry built upon the drimers and oligomers of HCN, important industrially and in the search for insight into the paleological origin of organic compounds. T. S. Gilchrist reviews the anions of 5-membered heteroaromatic rings with attention to ring-opening reactions. F. Taddei and colleagues present a critical discussion of the barriers to free rotation in the *C*-acyl and *N*-acyl heterocycles. The Basicity and Acidity of Azoles is the subject of a chapter by J. Catalan, J. L. M. Abbond, and J. Elguero. Oxidative Transformations of Heteroaromatic Iminium Salts, exemplified by pyridinium salts, have been the subject of much recent attention and are reviewed by H. Weber. A ring system not reviewed before, the pyrazolopyrimidines, is the subject of the final chapter, by M. H. El Nagadi, M. R. H. El Moghayar, and G. E. H. El Gemeie. The high quality of content and production that characterizes this series is maintained.

High-Energy Processes in Organometallic Chemistry. ACS Symposium Series. No. 333. Edited by Kenneth S. Suslick (University of Illinois at Urbana—Champaign). American Chemical Society: Washington, DC. 1987. vii + 336 pp. $69.95. ISBN 0-8412-1018-7

This book, which was developed from a symposium sponsored by the division of inorganic chemistry at the 192nd meeting of the American chemical society, Anaheim, Ca, is composed of 19 chapters and author and subject indexes. It is written by academic and industrial researchers who are currently very active in high-energy processes in organometallic chemistry.

The first chapter gives a historical background to the development of high-energy processes, which started as early as 1929, by F. A. Paneth. Some of the chapters discuss different aspects of high-energy processes, from current studies in the gas phase of the organometallic chemistry to the study of photochemical reactions and the investigation of some highly reactive intermediates and metal powders. The remaining chapters discuss some techniques and applications in high-energy processes involving infrared spectroscopy for examining the structure and behavior of intermediates involved in organometallic chemistry, electron spin resonance spectroscopy in the study of radiolysis of transition-metal compounds, ultrasonic waves for heterogeneous reactions, electrochemiluminescence of organometallics and finally plasma, and ion and electron beams for synthesis and modification of inorganic systems.

Sultan T. Abu-Orabi, *Yarmouk University, Jordan*

Formulas, Facts and Constants, For Students and Professionals in Engineering, Chemistry and Physics. Second Edition. By Harold J. Fischbeck (University of Oklahoma) and Kurt H. Fischbeck (University of Heidelberg). Springer-Verlag: Berlin, Heidelberg, and New York. 1987. xv + 260 pp. $23.00. ISBN 3-540-17610-1

Although the title identifies chemists as one of the groups for whom this book is intended, only those whose work is very close to engineering will find it useful. The first section (108 pages) is essentially mathematical and includes trigonometric functions, vectors, etc. The second part is headed "Units, conversion factors, and constants" and is arranged according to kind of property: mass, pressure, energy, etc. This is a useful arrangement. Section 3, "Spectroscopy and atomic structure", considers only the spectroscopy of atoms and totally ignores molecular spectroscopy. The fourth section is on wave mechanics and includes a range of equations. The last section is called "Facts, figures, and data useful in the laboratory". It is concerned with vacuum phenomena, flow, electronic properties, and radiation (especially γ), for the most part. Some physical-chemistry laboratories would find it useful; those who

*Unsigned book reviews are by the Book Review Editor.