marized in the table. For the following reasons, we believe that the structure proposed by Sheline is untenable.

PRINCIPAL INFRARED ABSORPTION BANDS OF $Fe_3(CO)_{12}$[a]

Frequency, cm.$^{-1}$	Relative[b] intensity
2043	10
2020	8
1997	~4
1858	~0.5
1826	~0.5
594	...
575	...

[a] Solvents: CS_2, CCl_4, $CHCl_3$. [b] Estimated from a plot of (cm.$^{-1}$ × optical density) *vs.* cm.$^{-1}$ for the spectrum in CS_2 in which the best resolution was obtained.

The extremely low relative intensity of the absorption in the region 1820–1860 cm.$^{-1}$ strongly suggests that the bands are not fundamentals, and hence that there are no ketonic bridging carbon monoxide groups of the type previously proposed for $Fe_2(CO)_9$,[3] and $Co_2(CO)_8$.[4] Furthermore, if the spectra are taken in CS_2, CCl_4 or $CHCl_3$, rather than the toluene used previously,[1] two bands are clearly discernible; the model favored by Sheline would produce only one fundamental in this region.

Although only two bands at ~2000 cm.$^{-1}$ are observed using rock salt optics (*cf.* also ref. 1), a third band at ~1997 cm.$^{-1}$ is resolved easily with a lithium fluoride prism. Throughout the range 450–3000 cm.$^{-1}$ the only other significant absorptions were the two bands at 594 and 575 cm.$^{-1}$, which seem best assigned as carbon–metal stretching frequencies. It is possible to assign the very weak bands at 1858 and 1826 cm.$^{-1}$ as triple combinations among the metal–carbon stretching frequencies, an assignment more in keeping with their low intensity.

Before any conclusion can be reached concerning the structure of the free molecule, $Fe_3(CO)_{12}$, the band at 1997 cm.$^{-1}$ must be assigned. There are three main possibilities: (i) that it is a fundamental, though it is perhaps a little weak; (ii) that it is a combination involving one of the other C–O stretching frequencies, but this would require the presence of a fundamental frequency at least as low as ~50 cm.$^{-1}$, which would seem unlikely although not impossible; (iii) that it is the C^{13} analog of the 2043 cm.$^{-1}$ band which would be expected in this position, but our estimate of the relative intensities (~$^1/_{100}$ expected) seems to rule this out. If the 1997 cm.$^{-1}$ band is in fact a third fundamental, then another structure (IV) considered by Sheline involving an equilateral triangle of three iron atoms bonded directly to one another is again eliminated.

(3) R. K. Sheline and K. S. Pitzer, THIS JOURNAL, **72**, 1107 (1950).
(4) J. W. Cable, R. S. Nyholm and R. K. Sheline, *ibid.*, **76**, 3375 (1954).

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A NOVEL REARRANGEMENT OF N-BROMOSUCCINIMIDE

Sir:

We have found that the reaction of N-bromosuccinimide (NBS) with allyl chloride, allyl bromide, or β-methallyl chloride in chloroform solution with trace quantities of benzoyl peroxide yields β-bromopropionyl isocyanate $BrCH_2CH_2CONCO$ (I). The product was isolated by distillation at reduced pressure to yield I, b.p. 68–69° (10 mm.), $n^{27}D$ 1.4915, intense infrared absorption maxima, *inter alia*, at 2250, 1735, and 1400 cm.$^{-1}$. A mass spectrometer was used to obtain the molecular weight (calcd.: 177; found, 177); the cracking pattern was consistent with the postulated structure.

Reaction of I with water gave carbon dioxide and β-bromopropionamide,[1] m.p. 115–116° (from chloroform), undepressed by admixture with a sample prepared from β-bromopropionyl bromide and ammonia. Reaction of I with methanol gave colorless needles (II), m.p. 137–138° (from methanol). *Anal.* Calcd. for $C_5H_8O_3NBr$: C, 28.60; H, 3.84; N, 6.67; Br, 38.05. Found: C, 28.7; H, 3.8; N, 6.5; Br, 38.0. Reaction of I with aniline in methylene chloride yielded colorless needles (III), m.p. 181–183° (from methanol). *Anal.* Calcd. for $C_{10}H_{11}N_2O_2Br$: C, 44.30; H, 4.09; N, 10.33; Br, 29.47. Found; C, 44.7; H, 4.3; N, 10.3; Br, 29.3. The infrared spectra of II and III were consistent with their formulation as methyl β-bromopropionylcarbamate and N-phenyl-N′-β-bromopropionyl urea, respectively.

To synthesize I, β-bromopropionic acid was treated with phosphorus tribromide in benzene to yield 59% of β-bromopropionyl bromide, b.p. 50–52° (4 mm.), $n^{27}D$ 1.5320. *Anal.* Calcd. for $C_3H_4OBr_2$; C, 16.67; H, 1.87; Br, 74.03. Found: C, 16.4; H, 1.7; Br, 74.4. Treatment of the acid bromide with dry, powdered silver cyanate[2] gave 40% I, b.p. 68–69° (10 mm.), $n^{29}D$ 1.4900, infrared spectrum superimposable on that of I isolated from the NBS reaction. *Anal.* Calcd. for $C_4H_4NO_2Br$; C, 26.99; H, 2.26; N, 7.87; Br, 44.90. Found: C, 26.9; H, 2.3; N, 7.8; Br, 44.9. Samples of II and III prepared from this sample of I had m.ps. of 137–138° and 183–184°, respectively, undepressed by admixture with the previously described samples. The infrared spectra of the samples of II and III from both sources were identical.

No satisfactory analysis of I isolated from the reaction of NBS has been obtained as yet; a typical analysis is shown. *Anal.* Calcd. for $C_4H_4NO_2Br$: C, 26.99; H, 2.26; N, 7.87; Br, 44.90. Found: C, 26.8; H, 2.5; N, 7.2; Br, 49.0. Mass spectra indicated the presence of 1–2% of a chlorobromopropene in the sample; X-ray absorption indicated the same sample contained 45 ± 1% Br and 2 ± 1% Cl. Presumably the chlorobromopropene was responsible for the discrepancy in the analytical data.

The identity of the samples of I from the reaction of NBS with allyl chloride, allyl bromide, and

(1) C. S. Hamilton and C. L. Simpson, THIS JOURNAL, **71**, 3158 (1924).
(2) O. C. Belliter, *Ber.*, **36**, 3213 (1903).

methallyl chloride was established with the m.ps. and mixed m.ps. of samples of II prepared from each sample of I.

The rearrangement has been found to occur only in chloroform solution as yet. The allylic halide is required for the rearrangement; in its absence NBS, chloroform, and benzoyl peroxide did not react (except to form a small amount of free bromine) when refluxed for periods four times as long as those required for the rearrangement to go to 70% completion. Since the reaction was inhibited by picric acid or trinitrobenzene, it appears to be free radical in nature and, indeed, to be a free radical analog of the Hofmann hypohalite reaction of amides.[3] Work on this reaction is continuing.[4]

(3) E. S. Wallis and J. F. Lane, "Organic Reactions," Vol. III, John Wiley and Sons, Inc., New York, N. Y., 1946, p. 267.

(4) This work was supported in part by a University of California Research Grant and by a grant from the Research Corporation. H. W. J. acknowledges a summer position at The Dow Chemical Company, Midland, Michigan, during which part of this work was completed.

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2-METHOXYESTRONE, A METABOLITE OF ESTRADIOL-17β IN THE HUMAN[1]

Sir:

After the administration of small or large doses of estradiol-17β-16-C^{14} or estrone-16-C^{14} to humans, the phenolic fraction of urine contained considerable radioactivity other than that associated with estrone, estradiol or any of the isomers of estriol. Counter-current distribution in the system 70% aqueous methanol as the upper phase and carbon tetrachloride as the lower phase showed a peak of radioactivity with a partition coefficient[2] = 0.30 (estrone = 1.3). The same peak of radioactivity was observed after either hot acid or β-glucuronidase[3] hydrolysis of the urinary conjugates; the amount of material present was greater in the first and second days' urine than thereafter. The new metabolite was a ketone as evidenced by the essentially quantitative reaction with Girard Reagent T; counter-current distribution studies indicated that it was not identical with 3-hydroxy-$\Delta^{1,3,5(10)}$-estratriene-16-one.

A pure sample of the new metabolite was isolated from urine after the administration of 1 g. of estradiol-17β-16-C^{14} (specific activity = 191 counts per minute per milligram (c.p.m./mg.)) over a period of ten days. The product melted 187–189.5°; $[\alpha]^{28}D$ +179° (ethanol); λmax. 284.5–288.5 mμ (ϵ = 4000), λmin. 254 mμ (ϵ = 420); specific activity = 172 c.p.m./mg.; the infrared spectrum in carbon tetrachloride solution exhibited bands at 3560 (hydroxyl group), 1743 (17-ketone), 1508, 1503 (C=C stretching in aromatic ring), 1409 (unsubstituted CH_2 at C-16) and 1374 (C-18 methyl group) cm.$^{-1}$. A prominent band at 874 cm.$^{-1}$ in carbon disulfide was interpreted as the out of plane C–H deformation of isolated hydrogens in ring A. Comparable bands were noted in the spectrum of a dispersion in potassium bromide.

Anal. Calcd. for $C_{19}H_{24}O_3$: C, 75.97; H, 8.05. Found: C, 75.82; H, 8.40.

The compound formed a monoacetate, m.p. 152–153.5°; *Anal.* Calcd. for $C_{21}H_{26}O_4$: C, 73.66; H, 7.65. Found: C, 73.29; H, 7.93.

With this information it seemed that the compound might be a methoxy derivative of estrone and in view of the lack of polarity of the phenolic hydroxyl as evidenced by the partition coefficient relative to that of estrone, a monomethyl ether of 2- or 4-hydroxyestrone was considered probable. The four possible monomethyl ether isomers of 2- and 4-hydroxyestrone were synthesized by methods based upon the work of Mueller and Mills,[4] and Horner and Stöhr.[5] The synthetic route to the metabolite involved the following reactions: 2-nitroestrone, 2-aminoestrone diazonium salt, photodecomposition in methanol. The details of the synthetic work will be reported in the near future. The new metabolite proved identical with 2-methoxyestrone (synthetic product, m.p. 184.5–188.5°; $[\alpha]^{24}D$ +178°) as judged by identity of the infrared spectrum[6] in both carbon disulfide solution and potassium bromide dispersion as well as the m.p. and rotation; there was no depression of the melting point on admixture of the natural and synthetic samples.

2-Methoxyestrone failed to exhibit fluorescence[6] with sulfuric acid in a test commonly employed for estrogens and their metabolites.[7] Biologically[6] the compound is a very weak estrogen with activity less than 1/20,000 that of estradiol-17β as judged by the intravaginal assay of Emmens.[8]

Quite apart from the interest attached to the identification of another metabolite of the estrogenic hormone, the biochemical introduction of a methoxyl group is a novel reaction in the steroid field. The significance of this new type of transformation is under further investigation.

(1) This investigation was supported in part by a grant from the American Cancer Society and a research grant (C-2271) from the National Cancer Institute of the National Institutes of Health, United States Public Health Service.

(2) B. Williamson and L. C. Craig, *J. Biol. Chem.*, **168**, 687 (1947).

(3) Ketodase, obtained from the Warner Chilcott Laboratories, a division of Warner-Lambert Pharmaceutical Co., New York.

(4) G. C. Mueller and M. E. Mills, personal communication; *cf.* Mueller, *Nature*, **176**, 127 (1955). The work of these authors related to the proof of structure of 2-nitro and 4-nitroestrone. Independent evidence for the correctness of these assignments has been obtained in these laboratories from infrared and ultraviolet spectrometry; Werbin (*Fed. Proc.*, **15**, 382 (1956)) has also reached similar conclusions.

(5) L. Horner and H. Stöhr, *Chem. Ber.*, **85**, 993 (1952).

(6) The authors are indebted to the several staff members of this Institute: Dr. William L. Money for the bioassays, Dr. C. D. West for the fluorescence analysis and Dr. G. Roberts for help with the infrared spectra. The technical assistance of Rosemarie Lehman, Jerome Boxer and Albert Klutch is gratefully acknowledged.

(7) L. L. Engel, *Rec. Prog. in Hormone Res.*, **5**, 335 (1950).

(8) C. W. Emmens, Med. Res. Council, Spec. Rept. Series 234, H. M. Stat. Office (1939).

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