

## The Structure of the Reformatsky Reagent

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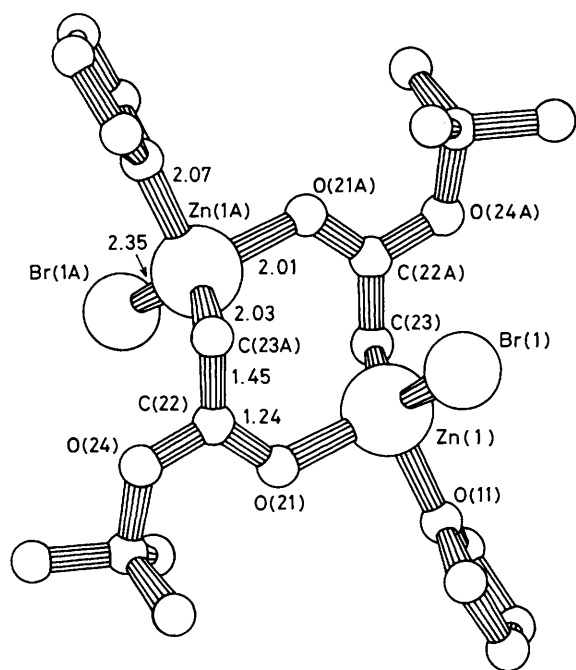
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The Reformatsky reagent 'BrZnCH<sub>2</sub>CO<sub>2</sub>R' is a cyclic dimer with bridging -CH<sub>2</sub>C(OR)O- groups.

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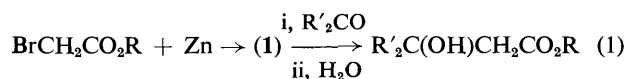
The Reformatsky reaction (1) has been used in synthetic organic chemistry for almost a century. Although various preparative aspects of this reaction have been explored

extensively,<sup>1</sup> only little is known about the true nature of the intermediate (1), the Reformatsky reagent. Both C-metallated (1a) and O-metallated (1b) species have been proposed on the



**Figure 1.** Crystal structure of  $(\text{BrZnCH}_2\text{CO}_2\text{Bu}^t\cdot\text{THF})_2$ , with bond lengths in Å, showing the crystallographic numbering system; bond angles are  $\text{O}(21)\text{-C}(22)\text{-C}(23\text{A})$ ,  $124.8^\circ$ ;  $\text{C}(22)\text{-C}(23\text{A})\text{-Zn}$ ,  $108.9^\circ$ ;  $\text{C}(23\text{A})\text{-Zn-O}(21\text{A})$ ,  $111.0^\circ$ ;  $\text{Zn-O}(21\text{A})\text{-C}(22\text{A})$ ,  $125.5^\circ$ .

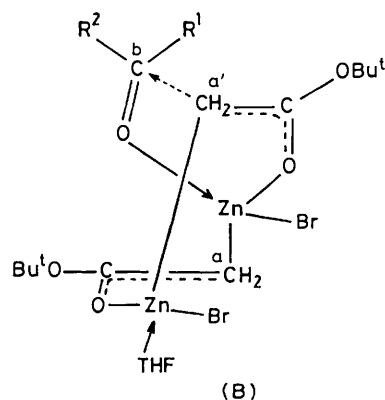
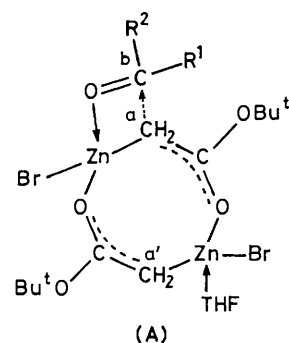
basis of spectroscopic data.<sup>2-4</sup> However, no molecular structures, either in solution or in the solid state, have been established.



In our exploration of organozinc co-ordination chemistry, we have been studying the classical Reformatsky reagent (1) derived from  $\text{BrCH}_2\text{CO}_2\text{Et}$ . Since no single crystals of this species could be obtained, this study had to be confined to the characterization of the species in solution. Recently Orsini *et al.*<sup>4</sup> reported that the Reformatsky reagent prepared from zinc and  $\text{BrCH}_2\text{CO}_2\text{Bu}^t$  in tetrahydrofuran (THF) was a microcrystalline compound. We have grown single crystals of this compound and determined its structure by *X*-ray diffraction analysis.

*Crystal data:* monoclinic, space group  $P2_1/n$ ,  $a = 10.322$ ,  $b = 12.357$ ,  $c = 11.654$  Å,  $\beta = 112.65^\circ$ ,  $Z = 2$  (dimeric units). The refinement, based on a partial data set (1133 reflections), converged at an *R* value of 0.073.

The zinc is almost tetrahedrally surrounded by two oxygen, one bromine, and one carbon atom. The dimeric unit forms an 8-membered non-planar ring,  $(\text{ZnCCO})_2$ , with normal zinc-carbon and zinc-oxygen single bond distances. This unit is depicted in Figure 1, with bond lengths and angles indicated.



**Figure 2.** Proposed intermediates in the reaction of the Reformatsky reagent with a ketone. (A) Four-centre mechanism (attack of  $\text{C}^a$  on  $\text{C}^b$ ). (B) Six-centre mechanism (attack of  $\text{C}^{a'}$  on  $\text{C}^b$ ).

A comparable 8-membered ring,  $(\text{ZnNCO})_2$ , was found some years ago in the structure of methyl *N*-phenyl-*N*-ethylzinciocarbamate.<sup>5</sup>

Ebulliometry in THF showed that the *t*-butyl compound retains its dimeric structure in this solvent. The corresponding reagent derived from  $\text{BrCH}_2\text{CO}_2\text{Et}$  is also a dimer in THF, dioxan, and pyridine. Moreover, the n.m.r. spectra of both reagents in THF,  $\text{Me}_2\text{SO}$ , and pyridine show in each case almost identical chemical shifts for the  $\text{CH}_2$  group bound to zinc. We therefore believe that this dimeric structure is the basic structure of the Reformatsky reagent. For this reason it is, in our opinion, incorrect to describe the reagent as either a *C*-metallated<sup>4</sup> or an *O*-metallated<sup>2</sup> mononuclear species.

Any mechanism operative in the Reformatsky reaction (1) must take into account the dimeric structure of the reagent. The first step will undoubtedly be the displacement of a co-ordinated solvent molecule by a carbonyl compound. In the second step the carbonyl group can react either with the  $\text{CH}_2$  group of the zinc atom to which it is co-ordinated in a four-centre mechanism (Figure 2A), or with the  $\text{CH}_2$  group attached to the other zinc atom of the dimer in a six-centre mechanism (Figure 2B). The first possibility is analogous to the mechanism proposed by Ashby and Bowers<sup>6</sup> for the formation of the 1,2-addition product in the reaction of Grignard reagents with benzophenone. The second one resembles the mechanism for the Reformatsky reaction proposed by Mousseron *et al.*<sup>7</sup>

A model study shows that more steric hindrance occurs between the carbonyl compound and the dimeric reagent in the four-centre mechanism than in the six-centre mechanism. Moreover, in the six-centre mechanism the carbonyl group can more easily approach the carbon atom to which it is going to be attached. On the basis of these considerations, we prefer the six-centre mechanism.

† The atomic co-ordinates for this work are available on request from the Director of the Cambridge Crystallographic Data Centre, University Chemical Laboratory, Lensfield Rd., Cambridge CB2 1EW. Any request should be accompanied by the full literature citation for this communication.

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