Tetrahedron Letters No. 36, pp 3121 - 3124, 1977. Pergamon Press. Printed in Great Britain.

SYNTHETIC USES OF ALKALI METALS ON CHARCOAL AND GRAPHITE: KETONE ALKYLATION

Harold Hart,* Bing-lin Chen and Cheng-tai Peng
Department of Chemistry, Michigan State University, East Lansing, Michigan, 48824, U.S.A.

(Received in USA 9 June 1977; received in UK for publication 14 July 1977)

Potassium and the higher alkali metals form lamellar compounds with graphite.[1] The best known is C_8K which, though easily prepared,[2] has seen only limited use in synthesis.[3] Pertinent to the present work is its reaction with ketones, where it has been reported to function primarily as a reducing agent.[2] Recently, however, C_8K has been shown also to have Lewis base properties toward weak acids,[4] and it has been used to generate anions from nitriles and activated esters.[5]

Sodium has a lesser tendency to intercalate in graphite, but it can be adsorbed on the surface of amorphous carbon (charcoal) to produce a highly reactive, pyrophoric form of the metal. Highly reactive forms of sodium and potassium also can be obtained by dispersal on other surfaces. We wish to describe here the synthetic use of these materials, as well as C_8K, in generating ketone enolates on surfaces. We will use the following abbreviations: HSS-C[6] or HSP-C (high surface sodium or potassium on charcoal) HSS-G or HSS-A (high surface sodium on graphite or alumina).

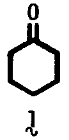
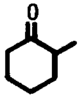
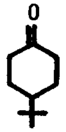
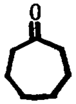
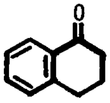
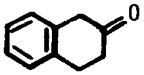
Preparation of HSS.[6] The apparatus consists of a flask equipped with a stainless steel sweep-type stirrer, an inert gas inlet and outlet, and a port for adding the metal. Activated charcoal[7] (weighed and predried at 200°C under vacuum for 1 h) was heated to 120°C under nitrogen with the stirrer at 100-300 RPM (the charcoal expands to about twice its settled volume). Sodium (weighed, and cut in 5-50 mg pieces) was added over 15 min. As soon as the metal melted, the contents were stirred more rapidly (10 min), then cooled to room temperature.[8]

Other alkali metal preparations were carried out in a similar manner.[9]

Ketone Alkylation. A condenser and addition funnel were added to the apparatus, and hexane was added to the cooled HSS, HSP or C_8K, to make a slurry. A solution of ketone in hexane was added slowly at room temperature, and the mixture was stirred until hydrogen evolution ceased (the reaction is exothermic; if bubbling became too vigorous the flask was cooled briefly in an ice bath). A solution of alkyl halide in hexane was added, the mixture was refluxed for 0.5-2 h, then cooled to room temperature. Unreacted sodium was destroyed, first with ethanol, then water, and the reaction was worked up.[10]

Results. The Table shows the results of several ketone alkylations. The percentages are calibrated true yields based on standardized glpc responses. We can make several generalizations: (a) monoalkylation predominates, usually to a greater extent than for comparable reactions in

Table 1. Ketone Alkylation with High Surface Alkali Metals[a]

Ketone	Metal (%)	Alkyl Halide	Products (%)			
			Reduction[b]	Monoalkyl	Dialkyl	Other
 **1**	HSS-C(20)	CH$_3$I	11	53	18[e]	11[c]
	HSS-G(20)	CH$_3$I	4	40	27[e]	19[c]
	HSS-G(20)	CH$_3$I[d]	27	23	29[e]	5[c]
	HSP-C(10)	CH$_3$I	10	41	5[e]	-
 **2**	HSS-C(20)	CH$_3$I	15	62[e]	7	-
	HSS-G(20)	CH$_3$I	9	65[e]	15	<1[c]
	HSP-C(10)	CH$_3$I	11	31[e]	3	-
	HSS-A(15)	CH$_3$I	13	62[e]	9	-
	HSS-C(15)	CH$_2$=CHCH$_2$Br	13	76[f]	-	-
 **3**	HSS-C(20)	CH$_3$I	7	30[g]	3[h]	-
 **4**	HSS-C(20)	CH$_3$I	6	45	4[i]	-
 **5**	HSS-C(20)	CH$_3$I	-	85	15	-
	HSS-C(20)	CH$_2$=CHCH$_2$Br	-	95	5	-
	HSS-C(20)	CH$_2$=CHCH$_2$Br[d]	-	68	32	-
	C$_8$K	CH$_2$=CHCH$_2$Br	-	98	2	-
	C$_8$K	CH$_2$=CHCH$_2$Br[d]	-	62	38	-
 **6**	HSS-C(20)	CH$_3$I	-	89[j]	10[j]	-
	HSS-C(20)	CH$_2$=CHCH$_2$Br	-	90	10	-
	C$_8$K	CH$_2$=CHCH$_2$Br[d]	-	57	43	-
	HSS-C(20)	BrCH$_2$CO$_2$Et	-	87	13	-
	HSS-C(20)	CH$_2$=C(Cl)CH$_2$Cl	-	88	-	-
	HSS-C(20)	C$_6$H$_5$CH$_2$Cl	-	81	19	-

---

[a] Equimolar amounts of metal, ketone and alkyl halide were used; most runs were on an approximately 0.1 mol scale; the solvent was hexane except where specified as THF; yields are corrected for a small amount of recovered ketone, usually about 10±5% [b] secondary alcohol corresponding to the ketone [c] pinacol-type reduction [d] THF in place of hexane [e] approximately 90% 2,2- and 10% 2,6-dimethylcyclohexanone [f] 2-methyl-2-allylcyclohexanone [g] c/t = 93/7 [h] cis-cis-2,6-isomer [i] 2,2-isomer [j] in all cases, the substituents are α to the aryl ring

solution.[11] For example, essentially no tri- or tetraalkylated products were formed in the methylation of **1** or **2**. The selectivity for mono vis-a-vis di- or polyalkylation is favored by hexane over THF. The results with 1-tetralone (**5**) and allyl bromide, using either HSS-C or C_8K, are striking in this regard. One possible explanation is that the metal enolate remains adsorbed on the surface in hexane but is somewhat soluble in THF. (b) with hexane (and other nonpolar solvents) the surface may provide some selectivity regarding different enolates. For example, the monoalkylation product of **2** is mainly (>90%) the 2,2-isomer. In solution, the predominance of 2,2- over 2,6- is usually not so large.[11] (c) reactions of the two ketones with an aryl ring (**5** and **6**) are especially clean and free of competing reduction. The regiospecific monoalkylation of **6**, a ketone notable for facile dialkylation, with a variety of alkyl halides promises to be synthetically useful. (d) the main competing reaction is reduction, either to the corresponding alcohol or to a pinacol. This side-reaction was most serious with cyclohexanone. Reduction is less important with hexane than with THF (the latter solvent was used to reduce ketones with C_8K[2]). For example, treatment of cyclohexanone with 20% HSS-C (1:1 mol ratio) gave 67% recovered ketone, 17% cyclohexanol and 6% pinacol in hexane; in THF, these percentages were 31, 56, and 4. Alkylation of 2,2,6,6-tetradeuterocyclohexanone in an experiment otherwise identical to that shown in the first line of Table 1 gave as the reduction product 1,2,2,6,6-pentadeuterocyclohexanol, showing that the α-protons of the ketone (not the solvent) are the proton source for the reduction. (e) In the alkylation of **3**, the cis/trans ratio in the monoalkylation product was the equilibrium[12] rather than the kinetic[13] ratio.

We conclude that alkali metals adsorbed on surfaces, and also the intercalation compound C_8K, provide a novel way to generate ketone enolates which may react differently under these conditions than they do in solution. We are continuing to explore the general synthetic utility of sodium, potassium, lithium and other reagents adsorbed on surfaces.

Acknowledgement. We are indebted to the National Science Foundation (GP 43659-X) and the National Institutes of Health (GM 15997) for support of this research.

References and Notes

1. For reviews, see D. Berger, B. Carton, A. Métrot and A. Hérold, Chem. Phys. Carbon, **12**, 1 (1975); M.C. Robert, M. Oberlin and J. Mering, ibid., **10**, 141 (1973); Y.N. Novikov and M.E. Vol'pin, Russ. Chem. Rev., **40**, 733 (1971).
2. J.M. Lalancette, G. Rollin and A.P. Giraitis, Can. J. Chem., **50**, 3058 (1972).
3. H.E. Podal, N.E. Foster, and A.P. Giraitis, J. Org. Chem., **23**, 82 (1958) (alkene polymerization); H.E. Podal and N.E. Foster, ibid., **23**, 401 (1958) (ring and side-chain alkylation of benzene derivatives); F. Glockling and D. Kingston, Chem. and Ind., 1037 (1961) (aryl and benzyl halide coupling): G. Ungurenasu and M. Palie, J. Chem. Soc., Chem. Comm., 388 (1975) (reduction of metal carbonyls). Other lamellar compounds of graphite have also seen limited synthetic use. For an example and leading references, see J. Bertin, H.B. Kagan, J-L. Luche and R. Setton, J. Am. Chem. Soc., **96**, 8113 (1974).
4. D.E. Bergbreiter and J.M. Killough, J. Chem. Soc., Chem. Comm., 913 (1976).
5. D. Savoia, C. Trombini and A. Umani-Ronchi, Tetrahedron Lett., 653 (1977).

6. The term "high surface sodium" (HSS) was used by the National Distillers Chemical Co. to describe films of sodium approaching colloidal dimensions spread over various inert solids. Detailed procedures for preparing HSS are given in a booklet published by that company in 1953; since copies are no longer available and most of the original literature is in patents, a brief description is presented here.
7. Several grades of Norit and other charcoals from several suppliers were used without a noticeable effect on the quality of the HSS produced. In experiments where graphite replaced charcoal, we used Fisher Scientific Company graphite powder, Acheson grade #38.
8. A small sample, when exposed to air, becomes red hot. 10% HSS-C is black, but at higher Na percentages, the powder takes on a deep purple cast.
9. C_8K, a bronze-colored powder, was prepared according to ref. 2.
10. To obtain a good material balance, adsorbed product is removed from the charcoal by extraction with ether/methylene chloride/methanol (1:1:1).
11. For an excellent review and leading references, see H.O. House, "Modern Synthetic Reactions", W.A. Benjamin, Inc., California, 1972, pp. 557-570 and 586-595.
12. N.L. Allinger, H.M. Blatter, L.A. Freiberg and F.M. Karkowski, *J. Am. Chem. Soc.*, **88**, 2999 (1966).
13. H.O. House, B.A. Terfiller and H.D. Olmstead, *J. Org. Chem.*, **33**, 935 (1968); B.J.L. Huff, F.N. Tuller and D. Caine, *ibid.*, **34**, 3070 (1969).