# Synthesis of a Small Library of 3-(Carboranylalkyl)thymidines and Their Biological Evaluation as Substrates for Human Thymidine Kinases 1 and 2

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A small library consisting of two series of thymidine derivatives containing *o*-carboranylalkyl groups at the N-3 position was prepared. In both series, alkyl spacers of 2−7 methylene units were placed between the *o*-carborane cage and the thymidine scaffold. In one series, an additional dihydroxypropyl substituent was introduced at the second carbon atom of the carborane cage. In the series of N-3-substituted carboranyl thymidines without additional dihydroxypropyl substituent, three steps were required to obtain the target compounds in overall yields as high as 75%, while in the series of N-3-substituted carboranyl thymidines with additional dihydroxypropyl substituent, 9−10 steps were necessary with significantly lower overall yield. All target compounds were good substrates of human cytosolic thymidine kinase 1 while they were, if at all, poor substrates of the mitochondrial thymidine kinase 2. There was only a minor difference in phosphorylation rates between N-3-substituted carboranyl thymidines with additional dihydroxypropyl substituents with thymidine kinase 1 (range: 13−49% relative to thymidine) and their counterparts lacking this group (range: 11−57% relative to thymidine). Tether lengths of two and five methylene groups in both series gave the highest enzyme activities in the present study. A hypothesis for this result is presented.

## Introduction

Boron neutron capture therapy (BNCT) is a chemo-radiotherapeutic method for the treatment of cancer.[1] This therapy is based on the capture reaction of thermal neutrons with nonradioactive $^{10}B$ to produce unstable $^{11}B$, which subsequently undergoes fission generating cytotoxic α-particles and lithium nuclei. These high linear energy transfer particles have a limited range of 5−9 $\mu$m in biological tissue ensuring that their destructive effects are restricted only to boron-containing cells in which the capture reaction occurs. In order for this therapy to be effective, $^{10}B$ has to be delivered selectively to the targeted tumor cells. The amount of $^{10}B$ required to obtain lethal tumor cell damage has been calculated to be in the range of 20−30 $\mu$g/g of tumor tissue provided the $^{10}B$ concentration in surrounding normal tissue is significantly lower (<5 $\mu$g of $^{10}B$/g of cells).[1]

Extensive research has been carried out to develop potential BNCT agents. Their properties should ideally include high selectivity for and retention in malignant cells, low systemic toxicity, and sufficient bioavailability for tumor cell targeting.[1] These boron-containing agents were mainly analogues of biologically active compounds such as amino acids, nucleosides/nucleotides, and peptides but also porphyrins and DNA intercalators/binders.[1] The rationale for their synthesis was that they may interact in a similar fashion with biological material as their naturally occurring counterparts and become selectively incorporated in malignant cells.

Boronated nucleosides may be good candidates for BNCT because of their metabolic potential for incorporation into rapidly dividing cells.[2] Boronated thymidines, for example, may be converted to their corresponding 5′-monophosphates by cytosolic thymidine kinase 1 (TK1). This would occur primarily in proliferating tumor cells in which TK1 has elevated activity levels in contrast to quiescent cells.[3] Cellular efflux of such 5′-monophosphates should be retarded due to the negatively charged phosphate moiety enabling selective intracellular entrapment in tumor cells. Further conversion to the di- and triphosphates and possible subsequent incorporation into tumor cell DNA could result in the relocation of boron in close proximity to DNA, the most critical target of the α-particles and lithium nuclei.[4] For these reasons, boronated nucleosides have been a focus of BNCT compound development and evaluation.[5−22]

Previously, we have evaluated several C-5-substituted carboranyl 2′-deoxyuridine analogues and a small number of N-3-substituted carboranyl thymidines in phosphoryl transfer assays with recombinant human TK1 and recombinant human mitochondrial thymidine kinase (TK2),[23] the only two thymidine phosphorylating enzymes in animal cells.[3] The results indicated that the N-3-substituted carboranyl thymidines were good substrates for TK1 but not for TK2. We have now prepared a small library consisting of two extended series of N-3-

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substituted carboranyl thymidines (Schemes 1 and 2) to evaluate in greater detail the influence of factors such as water solubility and tether length between the carborane cage and the nucleoside scaffold on the TK1 substrate properties. The concept of applying a tether to overcome steric hindrance has been proven useful in the application of affinity chromatography that exploits the binding of enzymes to substrates covalently linked to a solid support matrix.[24,25] Thus, hydrocarbon tethers of various lengths (2−7 methylene groups) between the carborane and the nucleoside moiety were used to propel the bulky boron cluster away from the nucleoside decreasing possible steric interference of the carborane cage with the binding of the nucleoside to the active site of TK1.

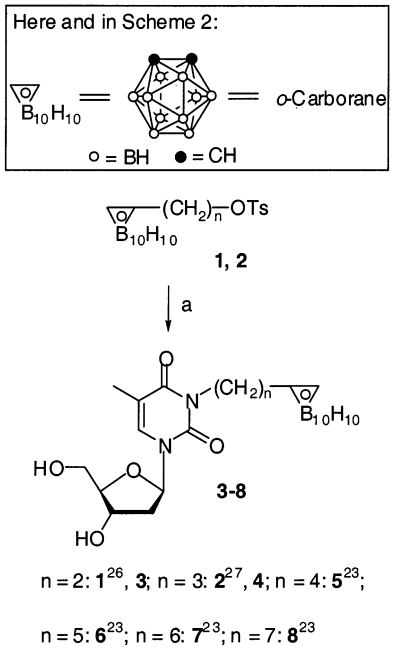
The advantage of the carboranyl thymidine derivatives is their high boron content. This could be an important factor in obtaining the necessary $^{10}B$ concentrations for lethal tumor cell damage. However, the carborane moiety is bulky and highly lipophilic[1,2] and such properties may impede the interaction of carboranyl thymidines with TK1. In addition, their relatively low water solubility may prevent an accurate assessment in TK1 phosphoryl transfer assays. One approach to improve the low water solubility of carboranyl thymidines could be the conversion of the closo-carborane moiety to the negatively charged nido form.[1,2] However, with a negative charge, such thymidine analogues are unlikely to pass cell membranes by passive diffusion, which may render them ineffective.[2] Attaching additional hydroxyl groups to the carborane cage may improve upon the water solubility of *closo*-carboranyl thymidines and increase their affinity for TK1 phosphorylation while still ensuring the necessary hydrophilicity/hydrophobicity balance for passive diffusion through various lipophilic barriers. It is, of course, possible that carboranyl thymidine analogues are substrates for the cellular nucleoside transporter. In the present study, we describe the synthesis of a small library of N-3-substituted carboranyl thymidine analogues, either with or without additional hydroxyl groups attached to the carborane cage, and their evaluation as enzyme substrates using recombinant TK1 and TK2 in phosphoryl transfer assays.

## Results and Discussion

**Chemistry.** The syntheses of compounds **5**−**8** have been described recently by us[23] (Scheme 1), and compounds **3** and **4** were newly synthesized according to the same procedure (Scheme 1) starting from tosylates **1**[26] and **2**,[27] respectively. It should be noted that the yields for the syntheses of compounds **7** (52%) and **8** (71%) were somewhat lower than those previously reported[23] for the syntheses of compounds **5**−**8** (81−92%) from their precursors. This might be due to the electron-withdrawing effect and bulkiness of the carborane cage,[1] which may have a negative impact on the alkylation reactions (Scheme 1) because of the shorter tether lengths in compounds **3** and **4** as compared with **5**−**8**.

Target compounds **46**−**51** (Scheme 2) are dihydroxypropyl analogues of compounds **3**−**8**. Initial attempts to attach a dihydroxypropyl group to the second carbon atom of the carborane clusters in 3′- and 5′-protected

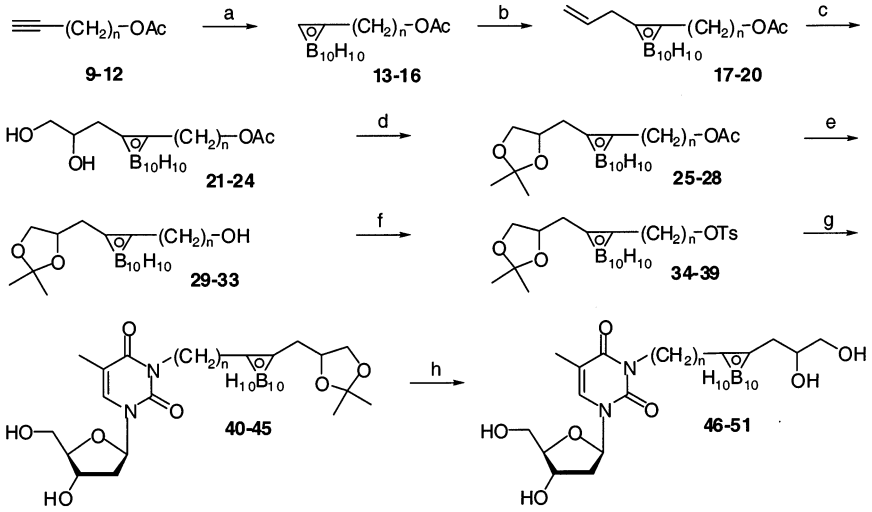
**Scheme 1**[a]




[a] Reagents: (a) Thymidine, $K_2CO_3$, DMF:acetone (1:1), 50 °C, 1−2 days.

derivatives of compounds **3**−**8** by palladium-catalyzed introduction of an allyl function and subsequent dihydroxylation of this function using osmium tetroxide/4-methylmorpholine-*N*-oxide failed at the allylating step for reasons that remain to be investigated. Therefore, a new synthetic route was developed. The acetylenic acetates **9**,[28] **10**,[29] **11**,[30] and **12**[31] were reacted with a bis(acetonitrile)decaborane complex in toluene under reflux conditions to yield 42−70% of carboranyl derivatives **13**−**16**. Palladium-catalyzed allylations of compounds **13**−**16** were carried out according to a procedure developed by Nemoto et al.[32] yielding 78−86% of compounds **17**−**20**. The allyl functions of compound **17**−**20** were then dihydroxylated using a catalytic amount of osmium tetraoxide and 4-methylmorpholine-*N*-oxide as the reoxidizing reagent.[33] No attempt was carried out to investigate and isolate the diastereoisomers formed in this dihydroxylation step. The newly formed diols **21**−**24**, obtained in 80−89% yield, were then protected as isopropylidene ketals (compounds **25**−**28**) to prevent undesired side reactions at these functions during subsequent alkylation/tosylation procedures. Using 2,2-dimethoxypropane and *p*-toluenesulfonic acid monohydrate in dimethylformamide (DMF) at room temperature, almost quantitative yields of the ketals were obtained. The acetyl protecting groups were removed using potassium carbonate in methanol/water (compounds **29** and **31**−**33**) in quantitative yields. Compounds **29**, **30**,[34] and **31**−**33** were tosylated in dichloromethane at 0 °C using *p*-toluenesulfonyl chloride to give compounds **34**, **35**, and **37**−**39** in 77−90% yield. Prior to their tosylations, compounds **34**, **35**, **36**,[35] and **37**−**39** were stored at −20 °C to prevent the migration of the isopropylidene group to the free hydroxyl group to form a cyclic derivative. After prolonged storage of compounds **34**−**39** at room temperature, small quantities of these cyclic derivatives could be detected, particularly for compounds with a longer tether arm. The tosylates then alkylated thymidine selectively at the N-3

**Scheme 2**[a]




[a] Reagents: (a) $B_{10}H_{14}$, acetonitrile, toluene, reflux, 2.5 days. (b) Tris(dibenzylideneacetone) dipalladium(0), bis(dipheylphosphino)ethane, allyl ethyl carbonate, THF, room temperature, 30 min. (c) 2.5 wt % osmium tetraoxide in *n*-butanol, *N*-methylmorpholine *N*-oxide, pyridine, acetone:$H_2O$ (30:1), room temperature, 12 h. (d) *p*-Toluene sulfonic acid, $Me_2C(OMe)_2$, room temperature, 12 h. (e) $K_2CO_3$, MeOH:$H_2O$ (10:1), room temperature, 4 h. (f) *p*-Toluene sulfonyl chloride, $Et_3N$, DMAP, $CH_2Cl_2$, 0 °C, 3.5 h. (g) Thymidine, $K_2CO_3$, DMF:acetone (1:1), 50 °C, 1−2 days. (h) 17% HCl in MeOH, room temperature, 12 h.

position in acetone/DMF using potassium carbonate as the base to obtain compounds **40**−**45** in 70−96% yield. As previously observed,[23] no alkylation of the 3′- and 5′-hydroxyl groups was observed. The isopropylidene protective groups of compounds **40**−**45** were removed with 17% HCl in methanol to give target compounds **46**−**51** in 70−97% yield.

**Biological Results.** Phosphoryl transfer assays of compounds **3**−**8** and **46**−**51** were carried out at fixed concentrations (100, 10, and 5 $\mu$M) using recombinant human cytosolic TK1 and mitochondrial TK2, both highly purified from bacterial expression systems. The results of the present assays confirm those of previous assays[23] that have identified N-3-substituted carboranylalkyl thymidine analogues as good substrates for TK1 while there was no indication for substantial phosphorylation with TK2 even when high substrate concentrations of 100 $\mu$M were used (Table 1). However, in the present study, we have also found that a small N-3 substituent such as the methyl group is tolerated by TK2 to a significant extent (~5% that of thymidine).

To establish the presence of monophosphate forms of compounds **3**−**8** and **46**−**51** following TK1 phosphorylation in the presence of radiolabeled [$\gamma$-$^{32}$P]adenosine 5′-triphosphate (ATP), a $\beta$-radiogram was developed after PEI-cellulose chromatography of their phosphoryl transfer assay mixtures for phosphorus detection (Figure 1). For boron detection, an additional $\alpha$-radiogram was developed, as described previously,[23] using a PEI-cellulose thin-layer chromatography (TLC) plate obtained from assay mixtures containing either compound **4** or compound **47** and [$^{31}$P]ATP. The results indicate that in the case of both **4** and **47**, the compounds generating the upper spots on the $\beta$-radiogram in Figure 1 also contain boron (data not shown). This strongly indicated the presence of monophosphate forms of compounds **4** and **47**. $\alpha$- and $\beta$-radiography also indicate the existence of minor quantities of phosphorylated and/or boronated compounds other than **3**−**8** and **46**−**51** and their respective monophosphates in the phosphoryl transfer assay mixtures. These include thymidine-5′-monophosphate, which may have been produced by small amounts of thymidine impurities or by removal of the N-3 carboranylalkyl side chain from monophosphates of N-3-substituted carboranyl thymidine analogues during the phosphoryl transfer assay.

Previous phosphoryl transfer assays[23,36,37] with TK1 were carried out using relatively high concentrations of 100 $\mu$M compounds **3**−**8** and **46**−**51**, and it was not possible to draw a definitive conclusion regarding the validity of the tether concept from the results obtained at this substrate concentration. The main reason may have been the low aqueous solubilities of compounds

**Table 1.** Phosphorylation of 3-Carboranyl-alkyl Thymidine Analogues

| | TK1 | | TK2 |
|---|---|---|---|
| compd | 10 $\mu$M | 5 $\mu$M | 100 $\mu$M |
| thymidine | 1[a] | 1 | 1 |
| **3** | 0.39 ± 0.03 | 0.42 ± 0.02 | 0.002 |
| **4** | 0.30 ± 0.05 | 0.27 ± 0.03 | 0.002 |
| **5** | 0.13 ± 0.04 | 0.17 ± 0.02 | 0.003 |
| **6** | 0.41 ± 0.06 | 0.57 ± 0.04 | 0.001 |
| **7** | 0.28 ± 0.05 | 0.31 ± 0.06 | <0.001 |
| **8** | 0.11 ± 0.03 | 0.15 ± 0.02 | <0.001 |
| **46** | 0.45 ± 0.03 | 0.49 ± 0.05 | 0.002 |
| **47** | 0.40 ± 0.04 | 0.43 ± 0.03 | 0.004 |
| **48** | 0.21 ± 0.01 | 0.21 ± 0.06 | 0.003 |
| **49** | 0.41 ± 0.05 | 0.39 ± 0.04 | 0.002 |
| **50** | 0.32 ± 0.08 | 0.22 ± 0.06 | 0.002 |
| **51** | 0.13 ± 0.07 | 0.13 ± 0.08 | <0.001 |

[a] The obtained values for thymidine were set to 1. The final DMSO concentration in the enzyme assays was 1%. Mean ± SD values are based on three experiments for recombinant TK1 except for compound **7**, which is based on two experiments.

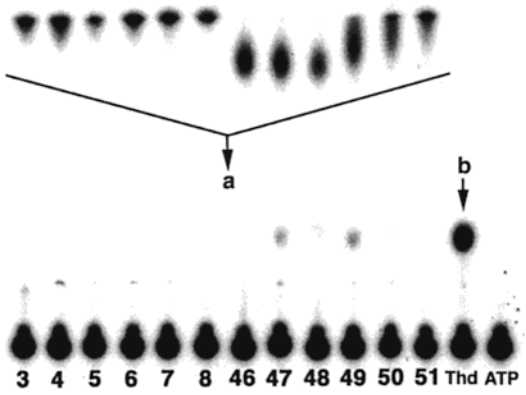



**Figure 1.** Phosphorylation of compounds **3**−**8**, **46**−**51**, and thymidine by recombinant TK1. The reaction products were separated by PEI-cellulose TLC. The concentrations of substrates and [$\gamma$-$^{32}$P]ATP were 10 and 100 $\mu$M, respectively. (a) Monophosphate products of compounds **3**−**8** and **46**−**51**. (b) Thymidine-5′-monophosphate.

**3**−**8** and **46**−**51**. However, under these conditions,[36,37] compounds **46**−**51**, containing a dihydroxypropyl group at the second carbon atom of the carborane cage, appeared to be better substrates than their counterparts (**3**−**8**) lacking this group, probably due to slightly improved water solubility.[36,37] Differences between enzyme preparations and the generally low aqueous solubilities of compounds **3**−**8** and **46**−**51** may have also been responsible for differences observed in phosphorylation rates found in these studies.[23,36,37]

We have now carried out TK1 phosphoryl transfer assays with the library of N-3-substituted carboranyl thymidines (**3**−**8** and **46**−**51**) out at lower substrate concentrations of 5 and 10 $\mu$M in the presence of 1% solubilizing dimethyl sulfoxide (DMSO), and a more defined pattern emerged with respect to the tether concept. The data obtained revealed that compounds **3**−**8** and **46**−**51** were phosphorylated by TK1 at rates ranging from 11 to 57% and 13 to 49%, respectively, relative to thymidine as a reference. There were only minor differences in phosphorylation rates in the case of compounds **3**−**5** and **46**−**48**, respectively, with higher values for **46**−**48**. In the case of compounds **6**−**8** and **49**−**51**, no significant difference between both series could be observed (Table 1). The TK1 phosphorylation rates of both series of N-3-substituted carboranyl thymidine analogues generally decreased with increasing tether length. However, this tendency was not observed for all compounds. In both series, the compounds with a spacer of five methylene groups (**6** and **49**) showed significantly better TK1 activities than their immediate neighbors with spacers of four and six methylene groups.

On the basis of this result, we postulate the following hypothesis. The synthesized library of carboranyl thymidines can be classified into two groups. One group has a short tether length in compounds **3**−**5** and **46**−**48**, and the other group has a longer spacer including compounds **6**−**8** and **49**−**51**. In the case of compounds with the short tether arm, the active site of TK1 may have sufficient space to accommodate the carborane cage. As the length of the tether arm increases, the carborane cluster appears to interfere increasingly with the enzymatic activity. In the case of compounds with a tether arm of five methylene groups (**6** and **49**), the carborane cluster may be located outside the active site resulting in significantly improved activity as compared with **5** and **48** having only a spacer with four methylene groups. In the case of the compounds with longer tether arms (**7**, **8**, **50**, and **51**), the carborane cluster could fold back to the active site and thus interfere with the phosphorylation reaction. Unfortunately, neither NMR nor X-ray data of the three-dimensional structure for human TK1 are presently available that would allow computer-aided modeling studies to either support or dismiss this hypothesis. However, similar observations have been made in affinity chromatography studies using thymidine linked to a solid support matrix for the purification of thymidine kinases.[24,25] The results of these studies indicated that a tether length of approximately seven methylene units provides optimal binding. It was speculated that shorter tethers bind enzyme less efficiently because of possible steric interference by the nearby column matrix and longer tethers may have folded back on themselves thereby reducing the effective tether length.[24,25]

## Summary and Conclusion

In previous studies, we have identified the N-3 position of thymidine as the optimal substitution site for bulky carboranylalkyl groups to preserve the TK1 activity of carboranyl thymidine analogues.[23] We were also able to establish that hydrophilicity has an impact on the phosphorylation rates of N-3-substituted carboranyl thymidines.[36,37] We have now synthesized and evaluated an extended library of N-3-substituted carboranyl thymidines to further study the influence of factors such as water solubility and tether length between the carborane cage and the nucleoside scaffold on the TK1 substrate characteristics. The obtained results indicated that spacers of two and five methylene groups between carborane and thymidine are optimal for the binding of N-3-substituted carboranyl thymidines to the active site of TK1. This information is of crucial importance in the design and synthesis of carboranyl thymidine analogues that may eventually be used in clinical BNCT, and it may also have an impact on general design strategies for thymidine analogues to be used in the conventional diagnosis and therapy of cancer and viral diseases. Further studies are under way in our laboratories to improve on the physicochemical properties of N-3-substituted carboranyl for optimal binding to TK1.

## Experimental Section

Proton and carbon-13 NMR spectra were obtained on Bruker (250 or 270 MHz) FT-NMRs at The Ohio State University College of Pharmacy. Chemical shifts ($\delta$) are reported in parts per million from an internal tetramethylsilane standard. Coupling constants are reported in hertz. Exact mass data were obtained at The Ohio State University Campus Chemical Instrumentation Center (CCIC) by group members including Dr. Johnie Brown, Dr. Kari Green-Church, Nan Kleinholz, and Ben Jones. High-resolution electron impact mass spectra (HR-EI), high-resolution fast atom bombardment (HR-FAB) mass spectra, and high-resolution eletrospray mass spectra (HR-ESI) were recorded on a VG70-250S mass spectrometer, a Finnigan MAT-900 mass spectrometer, and a Micromass QTOF Electrospray mass spectrometer, respectively. The theoretical exact mass was provided by The Ohio State University CCIC and was verified with a software package available at http://www.geocities.com/junhuayan/pattern.htm.

Elemental analysis was performed by Robertson Microlit Laboratories, Inc., Madison, NJ. Precoated glass-backed TLC plates with silica gel 60 $F_{254}$ (0.25 mm layer thickness) and silica gel 60 (70−230 mesh) from Merck were used for TLC and column chromatography, respectively. General compound visualization for TLC was attained by UV light, $KMnO_4$ spray, and $I_2$ vapor. Carbohydrate-containing compounds were selectively visualized by spraying the plate with 1% $H_2SO_4$ and heating at 120 °C. Carborane-containing compounds were selectively visualized by spraying the plate with a 0.06% $PdCl_2$/1% HCl solution and heating at 120 °C, which caused the slow (15−45 s) formation of a gray spot due to reduction of $Pd^{2+}$ to $Pd^0$. Reagent grade solvents were used for column chromatography. The purities of new target compounds were determined by HPLC. Reversed phase (RP-18 (5 $\mu$m)) HPLC was performed with a Dynamax DA controller, a Dynamax UV-1 detector, and a LiChrosphere 100 Å (250 mm/4 mm) column. The solvent system was water:methanol, and gradients were run from 100:0 to 5:95 for 10 min and from 5:95 to 0:100 for 20 min. Reversed phase (RP-8 (5 $\mu$m)) HPLC was performed with a Dynamax DA controller, a Dynamax UV-1 detector, and a LiChrosphere 100 Å (250 mm/4 mm) column. The solvent system was water:methanol, and gradients were run from 100:0 to 5:95 for 10 min and from 5:95 to 0:100 for 30 min. All reagents were used as received unless specified otherwise. Acetonitrile was dried over 4 Å molecular sieves. Anhydrous DMF, anhydrous tetrahydrofuran (THF), and anhydrous toluene were purchased from VWR Scientific Products.

**3-[2-(*o*-Carboran-1-yl)ethyl]thymidine (3).** A solution of 1 g (2.92 mmol) of 2-(*o*-carboran-1-yl)ethyl tosylate (**1**), 0.83 g (6 mmol) of $K_2CO_3$, and 0.078 g (3.2 mmol) of thymidine in 10 mL of anhydrous DMF:acetone (1:1) was stirred at 50 °C for 1−2 days. The product was isolated by filtration, dried under reduced pressure, and purified by silica gel column chromatography. The product was taken up in diethyl ether and washed several times with small amounts of water to remove trace amounts of DMF. Evaporation of the diethyl ether yielded 0.63 g (52%) of product as a white foam; $R_f$ 0.48 (ethyl acetate). $^1$H NMR ($CDCl_3$): $\delta$ 1.89 (d, $J$ = 1.0, 3H, $CH_3$), 2.26−2.40 (m, 2H, H-2′), 2.44−2.48 (m, 2H, $CH_2$−$C_{carborane}$), 3.70 (s, 1H, CH−B), 3.82 (dd, $J$ = 12.0, 3.0, 1H, H-5′), 3.92 (dd, $J$ = 12.0, 3.0, 1H, H-5′), 3.98−4.05 (m, 3H, H-3′ and $CH_2$−N), 4.57−4.61 (m, 1H, H-4′), 6.15 (t, $J$ = 7.0, 1H, H-1′), 7.38 (d, $J$ = 1.0, 1H, H-6). $^{13}$C NMR ($CDCl_3$): $\delta$ 13.16 ($CH_3$), 34.39 ($CH_2$), 39.88 ($CH_2$), 40.21 (C-2′), 61.41 ($C_{carborane}$-H), 62.43 (C-5′), 71.69 (C-3′), 72.10 ($C_{carborane}$-C), 86.83 (C-1′), 87.42 (C-4′), 110.38 (C-5), 135.19 (C-6), 150.45 (C-2), 162.83 (C-4). MS (HR-FAB$^+$, PEG400) $C_{14}H_{29}O_5N_2B_{10}$ (M + 1) calcd, 415.3007; found, 415.2593. Reverse phase-18 HPLC retention time: 19.2 min; reverse phase-8: 19.1 min, >99% pure.

**3-[3-(*o*-Carboran-1-yl)propyl]thymidine (4).** The procedure for the synthesis of this compound was identical to that of compound **3**. The amount of 1.1 g (3.3 mmol) of 3-(*o*-carboran-1-yl)propyl tosylate (**2**) yielded 1.0 g (71%) of compound **4** as a white foam; $R_f$ 0.50 (ethyl acetate). $^1$H NMR ($CDCl_3$): $\delta$ 1.72−1.82 (m, 2H, $CH_2$), 1.90 (d, $J$ = 1.0, 3H, $CH_3$), 2.22−2.28 (m, 2H, H-2′), 2.28−2.42 (m, 2H, $CH_2$−$C_{carborane}$), 3.68 (s, 1H, CH−B), 3.80−3.94 (m, 4H, H-5′ and $CH_2$−N), 3.95−4.05 (m, 1H, H-3′), 4.54−4.60 (m, 1H, H-4′), 6.19 (t, $J$ = 6.9, 1H, H-1′), 7.39 (d, $J$ = 1.0, 1H, H-6). $^{13}$C NMR ($CDCl_3$): $\delta$ 13.27 ($CH_3$), 27.22 ($CH_2$), 35.30 ($CH_2$), 40.13 ($CH_2$), 40.20 (C-2′), 60.97 ($C_{carborane}$-H), 62.40 (C-5′), 71.57 (C-3′), 74.57 ($C_{carborane}$-C), 86.84 (C-1′), 87.24 (C-4′), 110.37 (C-5), 135.05 (C-6), 150.79 (C-2), 163.21 (C-4). MS (HR-FAB$^+$, PEG400) $C_{15}H_{31}O_5N_2B_{10}$ (M + 1) calcd, 429.3163; found, 429.3140. Reverse phase-18 HPLC retention time: 19.2 min; reverse phase-8: 19.3 min, >98% pure.

**2-(*o*-Carboran-1-yl)ethyl Acetate (13).** With reference to the standard procedure described earlier,[34] a bis(acetonitrile)-decaborane complex was prepared by refluxing the amount of 4.5 g (37 mmol) of decaborane in 150 mL of anhydrous acetonitrile:benzene (1:10) for 4 h. *Decaborane is a highly toxic, impact sensitive compound, which forms explosive mixtures especially in the presence of halogenated materials. A careful study of the MSDS is advisable before usage.* The complex was precipitated, isolated by filtration, and washed with diisopropyl ether to yield 6.3 g (85%) of a white powder. The amounts of 2.5 g (22.1 mmol) of 3-butynyl acetate (**9**) and 5.3 g (26.4 mmol) of bis(acetonitrile)decaborane complex were dissolved in 75 mL of toluene and refluxed for 2.5 days. The solvent was evaporated leaving red syrup, which was extracted several times with diethyl ether. After the products were almost completely extracted, the syrup yielded a yellow residue, which was removed by filtration. The ether extracts were combined and evaporated to a crude oil, which was purified by silica gel column chromatography yielding 3.4 g (70%) of compound **13** as a colorless oil; $R_f$ 0.31 (5:1 hexane:ethyl acetate). $^1$H NMR ($CDCl_3$): $\delta$ 2.04 (s, 3H, $CH_3$), 2.55 (t, $J$ = 6.4, 2H, $CH_2$−$C_{carborane}$), 3.65 (s, 1H, H−$C_{carborane}$), 4.13 (t, $J$ = 6.4, 2H, $CH_2$−O). $^{13}$C NMR ($CDCl_3$): $\delta$ 20.76 ($CH_3$), 36.49 ($CH_2$−$C_{carborane}$), 60.68 ($C_{carborane}$-H), 61.69 ($CH_2$−O), 71.94 ($C_{carborane}$-C), 170.29 (C═O). MS (HR-EI) $C_6H_{18}O_2B_{10}$ calcd, 232.2237; found, 232.2162.

**5-(*o*-Carboran-1-yl)pentyl Acetate (14).** The procedure for the synthesis of this compound was identical to that of compound **13**. The amount of 4.7 g (30.5 mmol) of 6-heptynyl acetate (**10**) and 7.3 g (36.6 mmol) of bis(acetonitrile)decaborane yielded 3.5 g (42%) of compound **14** as a colorless oil; $R_f$ 0.39 (2:1 hexane:ethyl acetate). $^1$H NMR ($CDCl_3$): $\delta$ 1.20−1.40 (m, 2H, alkane), 1.40−1.70 (m, 4H, alkane), 2.02 (s, 3H, $CH_3$), 2.17−2.23 (m, 2H, $CH_2$-$C_{carborane}$), 3.54 (br s, 1H, H−$C_{carborane}$), 4.02 (t, $J$ = 6.5, 2H, $CH_2$−O). $^{13}$C NMR ($CDCl_3$): $\delta$ 20.73 ($CH_3$), 25.20 ($CH_2$), 27.95 ($CH_2$), 28.67 ($CH_2$), 37.69 ($CH_2$-$C_{carborane}$), 61.04 ($C_{carborane}$-H), 63.79 ($CH_2$−O), 75.13 ($C_{carborane}$-C), 170.86 (C═O). MS (HR-ESI) $C_9H_{24}O_2B_{10}Na$ (M + Na)$^+$ calcd, 297.2605; found, 297.2628.

**6-(*o*-Carboran-1-yl)hexyl Acetate (15).** The procedure for the synthesis of this compound was identical to that of compound **13**. The amount of 3.8 g (22.2 mmol) of 7-octynyl acetate (**11**) and 5.3 g (26.6 mmol) of bis(acetonitrile)decaborane yielded 3.7 g (58%) of compound **15** as a colorless oil; $R_f$ 0.40 (2:1 hexane:ethyl acetate). $^1$H NMR ($CDCl_3$): $\delta$ 1.20−1.35 (m, 4H, alkane), 1.41−1.48 (m, 2H, alkane), 1.52−1.61 (m, 2H, alkane), 2.01 (s, 3H, $CH_3$), 2.12−2.19 (m, 2H, $CH_2$−$C_{carborane}$), 3.56 (br s, 1H, H−$C_{carborane}$), 4.00 (t, $J$ = 6.6, 2H, $CH_2$−O). $^{13}$C NMR ($CDCl_3$): $\delta$ 20.92 ($CH_3$), 25.41 ($CH_2$), 28.30 ($CH_2$), 28.44 ($CH_2$), 29.01 ($CH_2$), 37.87 ($CH_2$−$C_{carborane}$), 60.97 ($C_{carborane}$-H), 64.13 ($CH_2$−O), 75.24 ($C_{carborane}$-C), 171.11 (C═O). MS (HR-EI) $C_{10}H_{26}O_2B_{10}$ calcd, 288.2863; found, 288.2924.

**7-(*o*-Carboran-1-yl)heptyl Acetate (16).** The procedure for the synthesis of this compound was identical to that of compound **13**. The amount of 3 g (16.4 mmol) of 8-nonynyl acetate (**12**) and 4 g (20 mmol) of bis(acetonitrile)decaborane yielded 3.3 g (67%) of compound **16** as a colorless oil; $R_f$ 0.45 (2:1 hexane:ethyl acetate). $^1$H NMR ($CDCl_3$): $\delta$ 1.20−1.34 (m, 6H, alkane), 1.38−1.47 (m, 2H, alkane), 1.54−1.62 (m, 2H, alkane), 2.02 (s, 3H, $CH_3$), 2.13−2.19 (m, 2H, $CH_2$-$C_{carborane}$), 3.55 (br s, 1H, H−$C_{carborane}$), 4.02 (t, $J$ = 6.7, 2H, $CH_2$−O). $^{13}$C NMR ($CDCl_3$): $\delta$ 20.99 ($CH_3$), 25.63 ($CH_2$), 28.42 ($CH_2$), 28.67 ($CH_2$), 28.75 ($CH_2$), 29.06 ($CH_2$), 37.99 ($CH_2$−$C_{carborane}$), 60.95 ($C_{carborane}$-H), 64.32 ($CH_2$−O), 75.30 ($C_{carborane}$-C), 171.20 (C═O). MS (HR-EI) $C_{11}H_{28}O_2B_{10}$ calcd, 302.3019; found, 302.3093.

**2-(2-(2,3-Propene-1-yl)-*o*-carboran-1-yl)ethyl Acetate (17).** A solution of 1.27 g (1.23 mmol) of tris(dibenzylideneacetone)dipalladium(0) and 0.88 g (2.2 mmol) of 1,2-bis(diphenylphosphino)ethane in 120 mL of dry THF was stirred for 30 min at room temperature under argon. To this solution, the amount of 4.8 g (36.8 mmol) of allyl ethyl carbonate was added. When the color of the mixture changed from black to yellow, 2.8 g (12.3 mmol) of **13** in 5 mL of THF was added. The reaction mixture was refluxed overnight. The product was filtered through Celite 545 and dried under reduced pressure. Purification by silica gel column chromatography yielded 2.7 g (83%) of compound **17** as a colorless oil; $R_f$ 0.37 (5:1 hexane:ethyl acetate). $^1$H NMR ($CDCl_3$): $\delta$ 2.06 (s, 3H, $CH_3$), 2.12−2.25 (m, 2H, $CH_2$-$C_{carborane}$), 2.94 (d, $J$ = 7.2, 2H, $CH_2$−CH═$CH_2$), 4.02 (t, $J$ = 6.1, 2H, $CH_2$−O), 5.09 (ddt, $J$ = 16.5, 1.5, 1.0, 1H, $CH_2$═CH), 5.16 (ddt, $J$ = 10.0, 1.5, 1.0, 1H, $CH_2$═CH),

5.78 (ddt, $J$ = 16.5, 10.0, 7.2, 1H, CH=$CH_2$). $^{13}$C NMR ($CDCl_3$): $\delta$ 20.75 ($CH_3$), 31.64 ($CH_2$), 39.42 ($CH_2$), 63.04 ($CH_2$−O), 78.11 ($C_{carborane}$-C), 78.33 ($C_{carborane}$-C), 119.62 ($CH_2$=CH), 132.71 (CH=$CH_2$), 170.92 (C=O). MS (HR-ESI) $C_9H_{22}O_2B_{10}$-Na $(M + Na)^+$ calcd, 295.2448; found, 295.2535.

**5-(2-(2,3-Propene-1-yl)-*o*-carboran-1-yl)pentyl Acetate (18).** The procedure for the synthesis of this product was identical to that described for **17**. The amount of 4.1 g (15 mmol) of **14** and 5.4 g (41.9 mmol) of allyl ethyl carbonate yielded 3.6 g (78%) of compound **18** as a colorless oil; $R_f$ 0.45 (5:1 hexane:ethyl acetate). $^1$H NMR ($CDCl_3$): $\delta$ 1.30−1.34 (m, 2H, alkane), 1.42−1.68 (m, 4H, alkane), 2.01 (s, 3H, $CH_3$), 2.13−2.15 (m, 2H, $CH_2$−$C_{carborane}$), 2.90 (br d, $J$ = 7.2, 2H, $CH_2$−CH=$CH_2$), 4.01 (t, $J$ = 6.5, 2H, $CH_2$−O), 5.11 (ddt, $J$ = 17, $J$ = 10, $J$ = 1, 2H, $CH_2$=CH), 5.73 (ddt, $J$ = 17, $J$ =10, $J$ = 7.2, 1H, CH=$CH_2$). $^{13}$C NMR ($CDCl_3$): $\delta$ 20.90 ($CH_3$), 25.73 ($CH_2$), 28.19 ($CH_2$), 29.26 ($CH_2$), 34.81 ($CH_2$−$C_{carborane}$), 39.35 ($CH_2$−CH=$CH_2$), 64.01 ($CH_2$−O), 77.95 ($C_{carborane}$-C), 79.07 ($C_{carborane}$-C), 119.39 ($CH_2$=CH), 132.61 (CH=$CH_2$), 171.03 (C=O). MS (HR-ESI) $C_{12}H_{28}O_2B_{10}Na$ $(M + Na)^+$ calcd, 337.2917; found, 337.2923.

**6-(2-(2,3-Propene-1-yl)-*o*-carboran-1-yl)hexyl Acetate (19).** The procedure for the synthesis of this compound was identical to that described for **17**. The amount of 2.8 g (12.8 mmol) of **15** and 5 g (38.5 mmol) of allyl ethyl carbonate yielded 3.5 g (80%) of compound **19** as a colorless oil; $R_f$ 0.45 (5:1 hexane:ethyl acetate). $^1$H NMR ($CDCl_3$): $\delta$ 1.25−1.38 (m, 4H, alkane), 1.47−1.53 (m, 2H, alkane), 1.54−1.63 (m, 2H, alkane), 2.02 (s, 3H, $CH_3$), 2.09−2.16 (m, 2H, $CH_2$-$C_{carborane}$), 2.85−2.95 (m, 2H, $CH_2$−CH=$CH_2$), 4.02 (t, $J$ = 6.6, 2H, $CH_2$−O), 5.07 (ddt, $J$ = 17.0, 1.2, 1.0, 1H, $CH_2$=CH), 5.15 (ddt, $J$ = 10.0, 1.0, 0.8, 1H, $CH_2$=CH), 5.73 (ddt, $J$ = 16.8, 10.0, 7.3, 1H, CH=$CH_2$). $^{13}$C NMR ($CDCl_3$): $\delta$ 20.94 ($CH_3$), 25.48 ($CH_2$), 28.34 ($CH_2$), 28.79 ($CH_2$), 29.48 ($CH_2$), 34.87 ($CH_2$−$C_{carborane}$), 39.29 ($CH_2$−CH=$CH_2$), 64.16 ($CH_2$−O), 77.88 ($C_{carborane}$-C), 79.18 ($C_{carborane}$-C), 119.36 ($CH_2$=CH), 132.59 (CH=$CH_2$), 171.12 (C=O). MS (HR-EI) $C_{13}H_{30}O_2B_{10}$ calcd, 328.3197; found, 328.3195.

**7-(2-(2,3-Propene-1-yl)-*o*-carboran-1-yl)heptyl Acetate (20).** The procedure for the synthesis of this compound was identical to that described for **17**. The amount of 3 g (14 mmol) of **16** and 5.4 g (41.9 mmol) of allyl ethyl carbonate yielded 4.1 g (86%) of compound **20** as a colorless oil; $R_f$ 0.47 (5:1 hexane:ethyl acetate). $^1$H NMR ($CDCl_3$): $\delta$ 1.22−1.36 (m, 6H, alkane), 1.46−1.54 (m, 2H, alkane), 1.54−1.64 (m, 2H, alkane), 2.02 (s, 3H, $CH_3$), 2.10−2.16 (m, 2H, $CH_2$-$C_{carborane}$), 2.90 (ddd, $J$ = 7.3, 1.2, 1.0, 2H, $CH_2$−CH=$CH_2$), 4.02 (t, $J$ = 6.7, 2H, $CH_2$−O), 5.16 (ddt, $J$ = 10.0, 1.0, 1.0, 1H, $CH_2$=CH), 5.17 (ddt, $J$ = 17.0, 1.2, 1.0, 1H, $CH_2$=CH), 5.75 (ddt, $J$ = 17.0, 10.0, 7.3, 1H, CH=$CH_2$). $^{13}$C NMR ($CDCl_3$): $\delta$ 20.99 ($CH_3$), 25.69 ($CH_2$), 28.44 ($CH_2$), 28.74 ($CH_2$), 29.09 ($CH_2$), 29.52 ($CH_2$), 34.87 ($CH_2$−$C_{carborane}$), 39.32 ($CH_2$−CH=$CH_2$), 64.36 ($CH_2$−O), 77.86 ($C_{carborane}$-C), 79.28 ($C_{carborane}$-C), 119.36 ($CH_2$=CH), 132.65 (CH=$CH_2$), 171.21 (C=O). MS (HR-EI) $C_{14}H_{32}O_2B_{10}$ calcd, 342.3333; found, 342.3335.

**2-(2-(2,3-Dihydroxyprop-1-yl)-*o*-carboran-1-yl)ethyl Acetate (21).** To a solution of 3.4 g (12 mmol) of **17** and 2.8 g (23.9 mmol) of *N*-methylmorpholine oxide in 250 mL of water: acetone (1:30), 30 mL (2.39 mmol) of 2.5 wt % osmium tetraoxide in *n*-butanol and 0.6 g (7.39 mmol) of pyridine were added slowly at 0 °C. *Osmium tetraoxide is highly toxic and flammable liquid. A careful study of the MSDS is advisable before usage.* The mixture was stirred at room temperature for 12 h. To this mixture, 10 mL of 10 wt % aqueous sodium thiosulfate was added to quench the reaction. This solution was stirred for an additional 2 h. After it was dried over anhydrous sodium sulfate and filtered and the solvent was evaporated, the residue was purified by silica gel column chromatography yielding 3.0 g (82%) of **21** as a colorless oil; $R_f$ 0.32 (2:1 ethyl acetate:hexane). $^1$H NMR ($CDCl_3$): $\delta$ 2.04 (s, 3H, $CH_3$), 2.31−2.36 (m, 2H, $CH_2$−$C_{carborane}$), 2.53−2.67 (m, 2H, $CH_2$-$C_{carborane}$), 3.20 (s br, 2H, $CH_2$−OH), 3.45 (dd, $J$ = 11.2, 6.6, 1H, HO−$CH_2$), 3.60 (dd, $J$ = 11.2, 3.8, 1H, HO−CH), 3.89−3.94 (m, 1H, CH−$CH_2$OH), 4.15−4.19 (m, 2H, $CH_2$−O). $^{13}$C NMR ($CDCl_3$): $\delta$ 20.82 ($CH_3$), 33.22 ($CH_2$−$C_{carborane}$), 38.65 ($CH_2$−$C_{carborane}$), 62.20 ($CH_2$−O), 66.20 ($CH_2$−OH), 70.82 (CH−$CH_2$OH), 76.39 ($C_{carborane}$-C), 77.77 ($C_{carborane}$-C), 171.10 (C=O). MS (HR-EI) $C_9H_{24}O_4B_{10}$ calcd, 306.2626; found, 306.2560.

**5-(2-(2,3-Dihydroxyprop-1-yl)-*o*-carboran-1-yl)pentyl Acetate (22).** The synthetic procedure of this compound was identical to that described for compound **21**. The amount of 2.2 g (7 mmol) of **18**, 1.8 g (15 mmol) of *N*-methylmorphline oxide, and 30 mL (2 mmol) of 2.5 wt % osmium tetraoxide in *n*-butanol yielded 1.9 g (86%) of compound **22** as a colorless oil; $R_f$ 0.65 (ethyl acetate). $^1$H NMR ($CDCl_3$ + $D_2O$): $\delta$ 1.30−1.36 (m, 2H, alkane), 1.43−1.72 (m, 4H, alkane), 2.02 (s, 3H, $CH_3$), 2.20−2.24 (m, 2H, $CH_2$−$C_{carborane}$), 2.26−2.32 (m, 2H, $CH_2$−$C_{carborane}$), 3.88−3.98 (m, 1H, CH−$CH_2$OH), 4.02 (t, $J$ = 6.5, 2H, $CH_2$−O), 5.11 (dd+dd, $J$ = 6.5, $J$ = 4, $J$ = 11, 2H, $CH_2$−OH). $^{13}$C NMR ($CDCl_3$): $\delta$ 20.96 ($CH_3$), 25.44 ($CH_2$), 27.99 ($CH_2$), 29.07 ($CH_2$), 34.87 ($CH_2$−$C_{carborane}$), 38.58 ($CH_2$−$C_{carborane}$), 64.05 ($CH_2$−O), 66.19 ($CH_2$−OH), 70.83 (CH−$CH_2$OH), 77.63 ($C_{carborane}$-C), 80.01 ($C_{carborane}$-C), 171.61 (C=O). MS (HR-ESI) $C_{12}H_{30}O_4B_{10}Na$ $(M + Na)^+$ calcd, 371.2972; found, 371.2963.

**6-(2-(2,3-Dihydroxyprop-1-yl)-*o*-carboran-1-yl)hexyl Acetate (23).** The synthetic procedure for this compound was identical to that described for compound **21**. The amount of 2.6 g (8 mmol) of **19**, 1.8 g (15 mmol) of *N*-methylmorpholine oxide, and 30 mL (2 mmol) of 2.5 wt % osmium tetraoxide in *n*-butanol yielded 2.5 g (89%) of compound **23** as a colorless oil; $R_f$ 0.25 (3:2 hexane:ethyl acetate). $^1$H NMR ($CDCl_3$): $\delta$ 1.32−1.38 (m, 4H, alkane), 1.42−1.62 (m, 4H, alkane), 2.02 (s, 3H, $CH_3$), 2.10−2.27 (m, 2H, $CH_2$−$C_{carborane}$), 2.27−2.30 (m, 2H, $CH_2$-$C_{carborane}$), 2.74 (s br, 2H, $CH_2$−OH), 3.45 (dd, $J$ = 11.0, $J$ = 6.4, 1H, HO−$CH_2$), 3.61 (dd, $J$ = 11.0, $J$ = 3.9, 1H, HO−CH), 3.90−3.94 (m, 1H, CH−$CH_2$OH), 3.96−4.08 (m, 2H, $CH_2$−O). $^{13}$C NMR ($CDCl_3$): $\delta$ 21.02 ($CH_3$), 25.26 ($CH_2$), 28.22 ($CH_2$), 28.60 ($CH_2$), 29.40 ($CH_2$), 34.87 ($CH_2$−$C_{carborane}$), 38.51 ($CH_2$−$C_{carborane}$), 64.33 ($CH_2$−O), 66.19 ($CH_2$−OH), 70.81 (CH−$CH_2$OH), 77.57 ($C_{carborane}$-C), 80.09 ($C_{carborane}$-C), 171.65 (C=O). MS (HR-EI) $C_{13}H_{32}O_4B_{10}$ calcd, 362.3231; found, 362.3324.

**7-(2-(2,3-Dihydroxyprop-1-yl)-*o*-carboran-1-yl)heptyl Acetate (24).** The synthetic procedure for the compound was identical to that described for compound **21**. The amount of 2.6 g (7.5 mmol) of **20**, 1.8 g (15 mmol) of *N*-methylmorpholine oxide, and 30 mL (2 mmol) of 2.5% osmium tetraoxide in *n*-butanol yielded 2.2 g (80%) of compound **24** as a colorless oil; $R_f$ 0.30 (3:2 hexane:ethyl acetate). $^1$H NMR ($CDCl_3$): $\delta$ 1.25−1.34 (m, 6H, alkane), 1.45−1.63 (m, 4H, alkane), 2.03 (s, 3H, $CH_3$), 2.10−2.27 (m, 2H, $CH_2$−$C_{carborane}$), 2.29−2.33 (m, 2H, $CH_2$−$C_{carborane}$), 3.47 (dd, $J$ = 11.0, 6.4, 1H, $CH_2$−OH), 3.63 (dd, $J$ = 11.0, 3.9, 1H, $CH_2$−OH), 3.93−3.97 (m, 1H, CH−$CH_2$OH), 4.03 (t, $J$ = 6.9, 2H, $CH_2$−O). $^{13}$C NMR ($CDCl_3$): $\delta$ 21.05 ($CH_3$), 25.48 ($CH_2$), 28.36 ($CH_2$), 28.50 ($CH_2$), 28.90 ($CH_2$), 29.43 ($CH_2$), 34.97 ($CH_2$−$C_{carborane}$), 38.61 ($CH_2$−$C_{carborane}$), 64.43 ($CH_2$−OH), 66.21 ($CH_2$−OH), 70.83 (CH−$CH_2$OH), 77.52 ($C_{carborane}$-C), 80.18 ($C_{carborane}$-C), 171.52 (C=O). MS (HR-EI) $C_{14}H_{34}O_4B_{10}$ calcd, 376.3387; found, 376.3416.

**2-(2-(2,3-Isopropylidenedioxyprop-1-yl)-*o*-carboran-1-yl)ethyl Acetate (25).** To a solution of 2.5 g (8.6 mmol) of **21** and 0.17 g (0.9 mmol) of *p*-toluenesulfonic acid monohydrate in 60 mL of DMF was added 2.32 mL (19.8 mmol) of dimethoxypropane. This reaction mixture was stirred overnight at room temperature. The compound was filtered through Alumina (80−200 mesh), dried under reduced pressure, and purified by silica gel column chromatography to yield 2.9 g (98%) of compound **25** as a colorless oil; $R_f$ 0.63 (3:2 hexane:ethyl acetate). $^1$H NMR ($CDCl_3$): $\delta$ 1.32 (s, 3H, $CH_3$), 1.36 (s, 3H, $CH_3$), 2.04 (s, 3H, $CH_3$), 2.41 (dd, $J$ = 15.7, 4.9, 1H, $CH_2$−$C_{carborane}$), 2.49 (dd, $J$ = 15.7, 6.9, 1H, $CH_2$−$C_{carborane}$), 2.53−2.68 (m, 2H, $CH_2$−$C_{carborane}$), 3.54 (dd, $J$ = 8.3, 6.3, 1H, $CH_2$−CH), 4.10 (dd, $J$ = 8.3, 6.0, 1H, $CH_2$−CH), 4.18 (td, $J$ = 7.1, 2.0, 2H, $CH_2$−O), 4.20−4.28 (m, 1H, CH−$CH_2$). $^{13}$C NMR ($CDCl_3$): $\delta$ 20.74 ($CH_3$), 25.27 ($CH_3$), 26.70 ($CH_3$), 33.47 ($CH_2$−$C_{carborane}$), 39.71 ($CH_2$−$C_{carborane}$), 62.09 ($CH_2$−O), 69.01 ($CH_2$−CH), 74.38 (CH−$CH_2$), 76.48 ($C_{carborane}$-C), 77.06 ($C_{carborane}$-C),

109.74 (O−C−O), 170.43 (C═O). MS (HR-EI) $C_{12}H_{28}O_4B_{10}$ calcd, 346.2918; found, 346.3046.

**5-(2-(2,3-Isopropylidenedioxyprop-1-yl)-*o*-carboran-1-yl)pentyl Acetate (26).** The synthesis of this compound was similar to that described for compound **25**. The amount of 3 g (9 mmol) of **22** and 2.2 mL (18 mmol) of dimethoxypropane yielded 3.3 g (95%) of compound **26** as a colorless oil; $R_f$ 0.94 (2:3 hexane:ethyl acetate). $^1$H NMR ($CDCl_3$): $\delta$ 1.20−1.45 (m, 2H, alkane), 1.29 (s, 3H, $CH_3$), 1.34 (s, 3H, $CH_3$), 1.71−1.91 (m, 4H, alkane), 1.99 (s, 3H, $CH_3$), 2.19−2.23 (m, 2H, $CH_2$−$C_{carborane}$), 2.38 (dd+dd, $J$ = 5.2, $J$ = 6.4, $J$ = 15.5, 2H, $CH_2$−$C_{carborane}$), 3.82 (dd+dd, $J$ = 6.4, $J$ = 6.0, $J$ = 8.2, 2H, $CH_2$−CH), 4.00 (t, $J$ = 6.5, 2H, $CH_2$−O), 4.19−4.23 (m, 1H, CH−$CH_2$). $^{13}$C NMR ($CDCl_3$): $\delta$ 20.97 ($CH_3$), 25.22 ($CH_3$), 25.48 ($CH_3$), 28.43 ($CH_2$), 28.76 ($CH_2$), 29.09 ($CH_2$), 35.08 ($CH_2$−$C_{carborane}$), 39.40 ($CH_2$−$C_{carborane}$), 64.34 ($CH_2$−O), 69.09 ($CH_2$−CH), 74.42 (CH−$CH_2$), 76.68 ($C_{carborane}$-C), 80.08 ($C_{carborane}$-C), 109.47 (O−C−O), 171.1 (C═O). MS (HR-ESI) $(M + Na)^+$ $C_{15}H_{34}O_4B_{10}Na$ calcd, 411.3285; found, 411.3278.

**6-(2-(2,3-Isopropylidenedioxyprop-1-yl)-*o*-carboran-1-yl)hexyl Acetate (27).** The synthesis of this compound was similar to that described for compound **25**. The amount of 3.2 g (9 mmol) of **23** and 2.2 mL (18 mmol) of dimethoxypropane yielded 3.2 g (90%) of compound **27** as a colorless oil; $R_f$ 0.55 (3:2 hexane:ethyl acetate). $^1$H NMR ($CDCl_3$): $\delta$ 1.29 (s, 3H, $CH_3$), 1.34 (s, 3H, $CH_3$), 1.25−1.38 (m, 4H, $CH_2$), 1.42−1.62 (m, 4H, $CH_2$), 2.00 (s, 3H, $CH_3$), 2.11−2.25 (m, 2H, $CH_2$−$C_{carborane}$), 2.33 (dd, $J$ = 15.5, 5.3, 1H, $CH_2$−$C_{carborane}$), 2.42 (dd, $J$ = 15.5, 6.4, 1H, $CH_2$−$C_{carborane}$), 3.53 (dd, $J$ = 8.3, 6.3, 1H, $CH_2$−CH), 3.99 (t, $J$ = 6.6, 2H, $CH_2$−O), 4.10 (dd, $J$ = 8.3, 6.0, 1H, $CH_2$−CH), 4.19−4.23 (m, 1H, CH−$CH_2$). $^{13}$C NMR ($CDCl_3$): $\delta$ 20.89 ($CH_3$), 25.17 ($CH_3$), 25.47 ($CH_3$), 26.72 ($CH_2$), 28.32 ($CH_2$), 28.77 ($CH_2$), 29.49 ($CH_2$), 34.95 ($CH_2$−$C_{carborane}$), 39.35 ($CH_2$−$C_{carborane}$), 64.14 ($CH_2$−O), 69.01 ($CH_2$−CH), 74.36 (CH−$CH_2$), 76.69 ($C_{carborane}$-C), 79.94 ($C_{carborane}$-C), 109.42 (O−C−O), 171.06 (C═O). MS (HR-EI) $C_{16}H_{36}O_4B_{10}$ calcd, 402.3544; found, 402.3672.

**7-(2-(2,3-Isopropylidenedioxyprop-1-yl)-*o*-carboran-1-yl)heptyl Acetate (28).** The synthesis of this compound was identical to that described for compound **25**. The amount of 3.4 g (9 mmol) of **24** and 2.2 mL (18 mmol) of dimethoxypropane yielded 3.3 g (90%) of compound **28** as a colorless oil; $R_f$ 0.67 (3:2 hexane:ethyl acetate). $^1$H NMR ($CDCl_3$): $\delta$ 1.31 (s, 3H, $CH_3$), 1.26−1.34 (m, 6H, alkane), 1.36 (s, 3H, $CH_3$), 1.44−1.63 (m, 4H, alkane), 2.02 (s, 3H, $CH_3$), 2.11−2.25 (m, 2H, $CH_2$−$C_{carborane}$), 2.35 (dd, $J$ = 15.5, 5.3, 1H, $CH_2$−$C_{carborane}$), 2.44 (dd, $J$ = 15.5, 6.4, 1H, $CH_2$−$C_{carborane}$), 3.55 (dd, $J$ = 8.3, 6.3, 1H, $CH_2$−CH), 4.02 (t, $J$ = 6.7, 2H, $CH_2$−O), 4.12 (dd, $J$ = 8.3, 6.0, 1H, $CH_2$−CH), 4.23 (m, 1H, CH−$CH_2$). $^{13}$C NMR ($CDCl_3$): $\delta$ 20.97 ($CH_3$), 25.22 ($CH_3$), 25.48 ($CH_3$), 26.78 ($CH_2$), 28.43 ($CH_2$), 28.76 ($CH_2$), 29.09 ($CH_2$), 29.56 ($CH_2$), 35.08 ($CH_2$−$C_{carborane}$), 39.40 ($CH_2$−$C_{carborane}$), 64.34 ($CH_2$−O), 69.09 ($CH_2$−CH), 74.42 (CH−$CH_2$), 76.68 ($C_{carborane}$-C), 80.08 ($C_{carborane}$-C), 109.47 (O−C−O), 171.1 (C═O). MS (HR-ESI) $C_{17}H_{38}O_4B_{10}Na$ $(M + Na)^+$ calcd, 439.3598; found, 439.3587.

**2-(2-(2,3-Isopropylidenedioxyprop-1-yl)-*o*-carboran-1-yl)ethanol (29).** A solution of 2.4 g (7 mmol) of **25** and 1.89 g (13.68 mmol) of potassium carbonate in 100 mL of water:methanol (1:10) was stirred for 4 h at room temperature. Filtration of the precipitate and evaporation of the solvents yielded 2.1 g (98%) of compound **29** as a colorless oil; $R_f$ 0.70 (3:2 hexane:ethyl acetate). $^1$H NMR ($CDCl_3$): $\delta$ 1.32 (s, 3H, $CH_3$), 1.37 (s, 3H, $CH_3$), 2.40−2.57 (m, 4H, $CH_2$−$C_{carborane}$), 3.55 (dd, $J$ = 8.3, 6.3, 1H, $CH_2$−CH), 3.81 (t, $J$ = 6.7, 2H, $CH_2$−OH), 4.12 (dd, $J$ = 8.3, 6.0, 1H, $CH_2$−CH), 4.23−4.29 (m, 1H, CH−$CH_2$). $^{13}$C NMR ($CDCl_3$): $\delta$ 25.32 ($CH_3$), 26.77 ($CH_3$), 37.23 ($CH_2$−$C_{carborane}$), 39.54 ($CH_2$−$C_{carborane}$), 61.18 ($CH_2$−OH), 69.07 ($CH_2$−CH), 74.44 (CH−$CH_2$), 76.91 ($C_{carborane}$-C), 77.40 ($C_{carborane}$-C), 109.67 (C═O). MS (HR-EI) $C_{10}H_{26}O_3B_{10}$ calcd, 304.2833; found, 304.2849.

**5-(2-(2,3-Isopropylidenedioxyprop-1-yl)-*o*-carboran-1-yl)pentanol (31).** The preparation of this compound was identical to that described for compound **29**. The amount of 2.3 g (6 mmol) of **26** yielded 2.0 g (97%) of compound **31** as a colorless oil; $R_f$ 0.75 (3:2 hexane:ethyl acetate). $^1$H NMR ($CDCl_3$): $\delta$ 1.29 (s, 3H, $CH_3$), 1.34 (s, 3H, $CH_3$), 1.25−1.43 (m, 2H, alkane), 1.52 (q, $J$ = 7, 4H, alkane), 2.14−2.22 (m, 2H, $CH_2$−$C_{carborane}$), 2.37 (dd+dd, $J$ = 5.3, $J$ = 6.3, $J$ = 15.5, 2H, $CH_2$−$C_{carborane}$), 3.57 (t, $J$ = 6.5, 2H, $CH_2$−OH), 3.84−3.76 (m, 2H, $CH_2$−CH), 4.21 (q, $J$ = 6, 1H, CH−$CH_2$). $^{13}$C NMR ($CDCl_3$): $\delta$ 25.16 ($CH_3$), 25.38 ($CH_3$), 26.69 ($CH_2$), 29.34 ($CH_2$), 31.99 ($CH_2$), 34.98 ($CH_2$−$C_{carborane}$), 39.34 ($CH_2$−$C_{carborane}$), 62.18 ($CH_2$−OH), 68.99 ($CH_2$−CH), 74.35 (CH−$CH_2$), 76.76 ($C_{carborane}$-C), 79.99 ($C_{carborane}$-C), 109.45 (O−C−O). MS (HR-ESI) $C_{13}H_{32}O_3B_{10}Na$ $(M + Na)^+$ calcd, 369.3179; found, 369.3180.

**6-(2-(2,3-Isopropylidenedioxyprop-1-yl)-*o*-carboran-1-yl)hexanol (32).** The preparation of this compound was identical to that described for compound **29**. The amount of 2.6 g (6.5 mmol) of **27** yielded 2.1 g (90%) of compound **32** as a colorless oil; $R_f$ 0.77 (3:2 hexane:ethyl acetate). $^1$H NMR ($CDCl_3$): $\delta$ 1.32 (s, 3H, $CH_3$), 1.36 (s, 3H, $CH_3$), 1.30−1.38 (m, 4H, alkane), 1.48−1.59 (m, 4H, alkane), 2.03−2.26 (m, 2H, $CH_2$−$C_{carborane}$), 2.35 (dd, $J$ = 15.6, 5.5, 1H, $CH_2$−$C_{carborane}$), 2.44 (dd, $J$ = 15.6, 6.3, 1H, $CH_2$−$C_{carborane}$), 3.55 (dd, $J$ = 8.3, 6.2, 1H, $CH_2$−CH), 3.61 (t, $J$ = 6.5, 2H, $CH_2$−OH), 4.12 (dd, $J$ = 8.3, 6.0, 1H, $CH_2$−CH), 4.21−4.27 (m, 1H, CH−$CH_2$). $^{13}$C NMR ($CDCl_3$): $\delta$ 25.21 ($CH_3$), 25.30 ($CH_3$), 26.78 ($CH_2$), 28.96 ($CH_2$), 29.59 ($CH_2$), 32.40 ($CH_2$), 35.02 ($CH_2$−$C_{carborane}$), 39.38 ($CH_2$−$C_{carborane}$), 62.65 ($CH_2$−OH), 69.08 ($CH_2$−CH), 74.42 (CH−$CH_2$), 76.43 ($C_{carborane}$-C), 80.09 ($C_{carborane}$-C), 109.48 (O−C−O). MS (HR-EI) $C_{14}H_{34}O_3B_{10}$ calcd, 360.3459; found, 360.3398.

**7-(2-(2,3-Isopropylidenedioxyprop-1-yl)-*o*-carboran-1-yl)heptanol (33).** The preparation of this compound was identical to that described for compound **29**. The amount of 2.5 g (6 mmol) of **28** yielded 2.1 g (95%) of compound **33** as a colorless oil; $R_f$ 0.80 (3:2 hexane:ethyl acetate). $^1$H NMR ($CDCl_3$): $\delta$ 1.32 (s, 3H, $CH_3$), 1.26−1.36 (m, 6H, alkane), 1.36 (s, 3H, $CH_3$), 1.45−1.58 (m, 4H, alkane), 1.60 (s br, 1H, HO−$CH_2$), 2.10−2.26 (m, 2H, $CH_2$−$C_{carborane}$), 2.34 (dd, $J$ = 15.6, 5.5, 1H, $CH_2$−$C_{carborane}$), 2.44 (dd, $J$ = 15.6, 6.3, 1H, $CH_2$−$C_{carborane}$), 3.56 (dd, $J$ = 8.3, 6.2, 1H, $CH_2$−CH), 3.61 (t, $J$ = 6.5, 2H, $CH_2$−OH), 4.12 (dd, $J$ = 8.3, 6.0, 1H, $CH_2$−CH), 4.21−4.27 (m, 1H, CH−$CH_2$). $^{13}$C NMR ($CDCl_3$): $\delta$ 25.21 ($CH_3$), 25.54 ($CH_3$), 26.78 ($CH_2$), 28.91 ($CH_2$), 29.15 ($CH_2$), 29.56 ($CH_2$), 32.52 ($CH_2$), 35.09 ($CH_2$−$C_{carborane}$), 39.38 ($CH_2$−$C_{carborane}$), 62.78 ($CH_2$−OH), 69.08 ($CH_2$−CH), 74.42 (CH−$CH_2$), 76.63 ($C_{carborane}$-C), 80.15 ($C_{carborane}$-C), 109.47 (O−C−O). MS (HR-EI) $C_{15}H_{36}O_3B_{10}$ calcd, 374.3595; found, 374.3568.

**2-(2-(2,3-Isopropylidenedioxyprop-1-yl)-*o*-carboran-1-yl)ethyl Tosylate (34).** The amount of 1.36 g (7.15 mmol) of *p*-toluenesulfonyl chloride was added to a solution of 1.6 g (5.5 mmol) of **29**, 1 mL (7.1 mmol) of triethylamine, and 0.14 g (1.1 mmol) of 4-(dimethylamino)pyridine in 10 mL of $CH_2Cl_2$ at 0 °C. The reaction mixture was stirred at room temperature for 3.5 h. The reaction was quenched with a saturated $NH_4Cl$ aqueous solution. The organic phase was washed with water and brine, dried over magnesium sulfate, evaporated, and purified by silica gel column chromatography to yield 2.2 g (88%) of compound **34** as a colorless oil; $R_f$ 0.55 (2:1 hexane:ethyl acetate). $^1$H NMR ($CDCl_3$): $\delta$ 1.32 (s, 3H, $CH_3$), 1.36 (s, 3H, $CH_3$), 2.38−2.41 (m, 2H, $CH_2$−$C_{carborane}$), 2.45 (s, 3H, $CH_3$), 2.60−2.76 (m, 2H, $CH_2$-$C_{carborane}$), 3.49 (dd, $J$ = 8.2, 6.8, 1H, $CH_2$−CH), 4.07−4.24 (m, 4H, $CH_2$−O, $CH_2$−CH and CH−$CH_2$), 7.32−7.40 (m, 2H, H−Ar), 7.74−7.80 (m, 2H, H−Ar). $^{13}$C NMR ($CDCl_3$): $\delta$ 21.66 ($CH_3$), 25.34 ($CH_3$), 26.66 ($CH_3$), 33.75 ($CH_2$−$C_{carborane}$), 39.71 ($CH_2$−$C_{carborane}$), 67.04 ($CH_2$−O), 68.89 ($CH_2$−CH), 74.30 (CH−$CH_2$), 75.21 ($C_{carborane}$-C), 77.48 ($C_{carborane}$-C), 109.93 (O−C−O), 127.86 (C−Ar), 130.02 (C−Ar), 132.35 (C−Ar), 145.38 (C−Ar). MS (HR-EI) $C_{17}H_{32}O_5SB_{10}Na$ $(M + Na)^+$ calcd, 481.2799; found, 481.2832.

**3-(2-(2,3-Isopropylidenedioxyprop-1-yl)-*o*-carboran-1-yl)propyl Tosylate (35).** The preparation of this compound was identical to that described for compound **34**. The amount of 1.7 g (5.5 mmol) of **30** and 1.36 g (7.15 mmol) of *p*-toluenesulfonyl chloride yielded 2.1 g (77%) of compound **35** as a colorless oil; $R_f$ 0.55 (3:2 hexane:ethyl acetate). $^1$H NMR ($CDCl_3$): $\delta$ 1.31 (s, 3H, $CH_3$), 1.35 (s, 3H, $CH_3$), 1.80−1.92 (m, 2H, $CH_2$), 2.20−2.35 (m, 2H, $CH_2$−$C_{carborane}$), 2.35 (dd, $J$ = 14.0,

5.0, 1H, $CH_2-C_{carborane}$), 2.40 (dd, $J$ = 14.0, 5.0, 1H, $CH_2-C_{carborane}$), 2.43 (s, 3H, $CH_3$), 3.52 (dd, $J$ = 8.3, 6.7, 1H, $CH_2-CH$), 3.98−4.04 (m, 2H, $CH_2-O$), 4.10 (dd, $J$ = 8.3, 6.0, 1H, $CH_2-CH$), 4.18−4.32 (m, 1H, $CH-CH_2$), 7.30−7.36 (m, 2H, H−Ar), 7.70−7.78 (m, 2H, H−Ar). $^{13}$C NMR ($CDCl_3$): $\delta$ 21.62 ($CH_3$), 25.30 ($CH_3$), 26.72 ($CH_3$), 28.81 ($CH_2$), 31.21 ($CH_2-C_{carborane}$), 39.45 ($CH_2-C_{carborane}$), 68.86 ($CH_2-O$), 68.96 ($CH_2-CH$), 74.33 ($CH-CH_2$), 77.24 ($C_{carborane}$-C), 78.41 ($C_{carborane}$-C), 109.70 (O−C−O), 127.82 (C−Ar), 129.98 (C−Ar), 132.56 (C−Ar), 145.19 (C−Ar). MS (HR-ESI) $C_{18}H_{34}O_5SB_{10}Na$ $(M + Na)^+$ calcd, 495.2972; found, 495.2990.

**5-(2-(2,3-Isopropylidenedioxyprop-1-yl)-*o*-carboran-1-yl)pentyl Tosylate (37).** The preparation of this compound was identical to that described for compound **34**. The amount of 1.9 g (5.5 mmol) of **31** and 1.36 g (7.15 mmol) of *p*-toluenesulfonyl chloride yielded 2.3 g (86%) of compound **37** as a colorless oil; $R_f$ 0.60 (2:1 hexane:ethyl acetate). $^1$H NMR ($CDCl_3$): $\delta$ 1.31 (s, 3H, $CH_3$), 1.36 (s, 3H, $CH_3$), 1.09−1.59 (m, 4H, alkane), 1.64 (q, $J$ = 7, 2H, alkane), 2.12−2.18 (m, 2H, $CH_2-C_{carborane}$), 2.37 (dd+dd, $J$ = 5.2, $J$ = 6.4, $J$ = 15.5, 2H, $CH_2-C_{carborane}$), 2.43 (s, 3H, $CH_3$), 3.82 (dd+dd, $J$ = 6, $J$ = 6.4, $J$ = 8.3, 2H, $CH_2-CH$), 3.99 (t, $J$ = 6.2, 2H, $CH_2-O$), 4.22 (qn, $J$ = 6, 1H, $CH-CH_2$), 7.34−7.38 (m, 2H, H−Ar), 7.76−7.82 (m, 2H, H−Ar). $^{13}$C NMR ($CDCl_3$): $\delta$ 21.58 ($CH_3$), 25.05 ($CH_3$), 25.25 ($CH_2$), 26.78 ($CH_3$), 28.36 ($CH_2$), 28.86 ($CH_2$), 34.82 ($CH_2-C_{carborane}$), 39.44 ($CH_2-C_{carborane}$), 69.06 ($CH_2-O$), 69.81 ($CH_2-CH$), 74.40 ($CH-CH_2$), 76.92 ($C_{carborane}$-C), 79.66 ($C_{carborane}$-C), 109.55 (O−C−O), 127.78 (C−Ar), 129.86 (C−Ar), 133.01 (C−Ar), 144.85 (C−Ar). MS (HR-ESI) $C_{20}H_{38}O_5SB_{10}Na$ $(M + Na)^+$ calcd, 523.3268; found, 523.3278.

**6-(2-(2,3-Isopropylidenedioxyprop-1-yl)-*o*-carboran-1-yl)hexyl Tosylate (38).** The preparation of this compound was identical to that described for **34**. The amount of 2 g (5.5 mmol) of **32** and 1.36 g (7.15 mmol) of *p*-toluenesulfonyl chloride yielded 2.5 g (90%) of compound **38** as a colorless oil; $R_f$ 0.65 (2:1 hexane:ethyl acetate). $^1$H NMR ($CDCl_3$): $\delta$ 1.18−1.35 (m, 4H, alkane), 1.31 (s, 3H, $CH_3$), 1.36 (s, 3H, $CH_3$), 1.38−1.55 (m, 2H, alkane), 1.57−1.65 (m, 2H, alkane), 2.08−2.23 (m, 2H, $CH_2-C_{carborane}$), 2.34 (dd, $J$ = 15.6, 5.3, 1H, $CH_2-C_{carborane}$), 2.42 (dd, $J$ = 15.6, 6.4, 1H, $CH_2-C_{carborane}$), 2.43 (s, 3H, $CH_3$), 3.55 (dd, $J$ = 8.3, 6.3, 1H, $CH_2-CH$), 3.99 (t, $J$ = 6.4, 2H, $CH_2-O$), 4.12 (dd, $J$ = 8.3, 6.0, 1H, $CH_2-CH$), 4.20−4.25 (m, 1H, $CH-CH_2$), 7.30−7.36 (m, 2H, H−Ar), 7.70−7.78 (m, 2H, H−Ar). $^{13}$C NMR ($CDCl_3$): $\delta$ 21.62 ($CH_3$), 25.00 ($CH_2$), 25.23 ($CH_3$), 26.79 ($CH_3$), 28.51 ($CH_2$), 28.59 ($CH_2$), 29.40 ($CH_2$), 34.92 ($CH_2-C_{carborane}$), 39.39 ($CH_2-C_{carborane}$), 69.06 ($CH_2-O$), 70.22 ($CH_2-CH$), 74.40 ($CH-CH_2$), 76.73 ($C_{carborane}$-C), 79.88 ($C_{carborane}$-C), 109.49 (O−C−O), 127.81 (C−Ar), 129.82 (C−Ar), 133.00 (C−Ar), 144.76 (C−Ar). MS (HR-EI) $C_{21}H_{40}O_5SB_{10}$ calcd, 514.3527; found, 514.3583.

**7-(2-(2,3-Isopropylidenedioxyprop-1-yl)-*o*-carboran-1-yl)heptyl Tosylate (39).** The preparation of this compound was identical to that described for compound **34**. The amount of 2 g (5.5 mmol) of **33** and 1.36 g (7.15 mmol) of *p*-toluenesulfonyl chloride yielded 2.4 g (84%) of compound **39** as a colorless oil; $R_f$ 0.70 (2:1 hexane:ethyl acetate). $^1$H NMR ($CDCl_3$): $\delta$ 1.31 (s, 3H, $CH_3$), 1.18−1.33 (m, 6H, alkane), 1.36 (s, 3H, $CH_3$), 1.40−1.54 (m, 2H, alkane), 1.57−1.65 (m, 2H, alkane), 2.08−2.24 (m, 2H, $CH_2-C_{carborane}$), 2.34 (dd, $J$ = 15.6, 5.3, 1H, $CH_2-C_{carborane}$), 2.43 (s, 3H, $CH_3$), 2.44 (dd, $J$ = 15.6, 6.4, 1H, $CH_2-C_{carborane}$), 3.55 (dd, $J$ = 8.3, 6.3, 1H, $CH_2-CH$), 3.99 (t, $J$ = 6.5, 2H, $CH_2-O$), 4.12 (dd, $J$ = 8.3, 6.0, 1H, $CH_2-CH$), 4.22−4.28 (m, 1H, $CH-CH_2$), 7.30−7.38 (m, 2H, H−Ar), 7.70−7.78 (m, 2H, H−Ar). $^{13}$C NMR ($CDCl_3$): $\delta$ 21.62 ($CH_3$), 25.21 ($CH_2$), 25.23 ($CH_3$), 26.80 ($CH_3$), 28.50 ($CH_2$), 28.67 ($CH_2$), 28.99 ($CH_2$), 29.51 ($CH_2$), 35.03 ($CH_2-C_{carborane}$), 39.40 ($CH_2-C_{carborane}$), 69.08 ($CH_2-O$), 70.38 ($CH_2-CH$), 74.42 ($CH-CH_2$), 76.71 ($C_{carborane}$-C), 80.02 ($C_{carborane}$-C), 109.48 (O−C−O), 127.82 (C−Ar), 129.77 (C−Ar), 133.05 (C−Ar), 144.70 (C−Ar). MS (HR-EI) $C_{22}H_{42}O_5SB_{10}$ calcd, 528.3683; found, 528.3760.

**3-[2-(2-(2,3-Isopropylidenedioxyprop-1-yl)-*o*-carboran-1-yl)ethan-1-yl]thymidine (40).** A solution of 1.3 g (5.4 mmol) of thymidine, 1.9 g (13.5 mmol) of potassium carbonate and 2.1 g (4.5 mmol) of **34** in 10 mL of anhydrous DMF:acetone (1:1) was stirred 1−2 days at 50°C. The product was separated by filtration, dried under reduced pressure, and purified by silica gel column chromatography. To remove trace amounts of DMF after isolation, the product was taken up in diethyl ether and washed with small amounts of water. This was repeated until the evaporation yielded 1.8 g (76%) of **40** as a sticky white foam; $R_f$ 0.30 (1:1 $CHCl_3$:acetone). $^1$H NMR ($CDCl_3$): $\delta$ 1.32 (s, 3H, $CH_3$), 1.34 (s, 3H, $CH_3$), 1.89 (d, $J$ = 1.0, 3H, $CH_3$), 2.28−2.62 (m, 6H, H-2′ and $CH_2-C_{carborane}$), 3.58 (dd, $J$ = 8.3, 6.7, 1H, $CH_2-CH$), 3.82 (dd, $J$ = 12.0, 3.0, 1H, H-5′), 3.90 (dd, $J$ = 12.0, 3.0, 1H, H-5′), 3.96−4.02 (m, 2H, $CH_2-N$), 4.03−4.08 (m, 1H, H-3′), 4.11 (dd, $J$ = 8.3, 6.0, 1H, $CH_2-CH$), 4.23−4.27 (m, 1H, $CH-CH_2$), 4.54−4.58 (m, 1H, H-4′), 6.16 (t, $J$ = 6.9, 1H, H-1′), 7.38 (q, $J$ = 1.0, 1H, H-6). $^{13}$C NMR ($CDCl_3$): $\delta$ 13.16 ($CH_3$), 25.46 ($CH_3$), 26.69 ($CH_3$), 31.52 ($CH_2-C_{carborane}$), 39.20 ($CH_2-C_{carborane}$), 40.17 ($CH_2-N$), 40.27 (C-2′), 62.40 (C-5′), 69.04 ($CH_2-CH$), 71.62 (C-3′), 74.38 ($CH-CH_2$), 76.84 ($C_{carborane}$-C), 77.77 ($C_{carborane}$-C), 86.82 (C-1′), 87.25 (C-4′), 109.68 (O−C−O), 110.33 (C-5), 135.11 (C-6), 150.46 (C-2), 162.84 (C-4). MS (HR-ESI) $C_{20}H_{38}O_7N_2B_{10}Na$ $(M + Na)^+$ calcd, 551.3507; found, 551.3505.

**3-[3-(2-(2,3-Isopropylidenedioxyprop-1-yl)-*o*-carboran-1-yl)propan-1-yl]thymidine (41).** The preparation of this compound was identical to that described for **40**. The amount of 1.3 g (5.4 mmol) of thymidine, 2.1 g (4.5 mmol) of **35** and 1.9 g (13.5 mmol) of $K_2CO_3$ yielded 1.7 g (70%) of compound **41** as a sticky white foam; $R_f$ 0.35 (1:1 $CHCl_3$:acetone). $^1$H NMR (MeOH-$d_4$): $\delta$ 1.33 (s, 3H, $CH_3$), 1.39 (s, 3H, $CH_3$), 1.79−1.89 (m, 2H, $CH_2$), 1.90 (d, $J$ = 1.0, 3H, $CH_3$), 2.20 (ddd, $J$ = 13.7, 7.0, 6.2, 1H, H-2′), 2.28 (ddd, $J$ = 13.7, 6.2, 3.7, 1H, H-2′), 2.33−2.47 (m, 2H, $CH_2-C_{carborane}$), 2.49 (dd, $J$ = 16.0, 8.0, 1H, $CH_2-C_{carborane}$), 2.57 (dd, $J$ = 16.0, 3.3, 1H, $CH_2-C_{carborane}$), 3.53 (dd, $J$ = 8.3, 7.0, 1H, $CH_2-CH$), 3.74 (dd, $J$ = 12.0, 3.7, 1H, H-5′), 3.80 (dd, $J$ = 12.0, 3.0, 1H, H-5′), 3.87−3.94 (m, 3H, H-3′ and $CH_2-N$), 4.11 (ddd, $J$ = 8.3, 6.0, 0.5, 1H, $CH_2-CH$), 4.23−4.28 (m, 1H, $CH-CH_2$), 4.36−4.42 (m, 1H, H-4′), 6.30 (t, $J$ = 6.7, 1H, H-1′), 7.85 (q, $J$ = 1.0, 1H, H-6). $^{13}$C NMR (MeOH-$d_4$): $\delta$ 13.21 ($CH_3$), 25.84 ($CH_3$), 27.19 ($CH_3$), 28.94 ($CH_2$), 33.41 ($CH_2-C_{carborane}$), 40.29 ($CH_2-C_{carborane}$), 41.31 ($CH_2-N$), 41.51 (C-2′), 62.74 (C-5′), 69.97 ($CH_2-CH$), 72.09 (C-3′), 75.85 ($CH-CH_2$), 79.50 ($C_{carborane}$-C), 81.04 ($C_{carborane}$-C), 87.11 (C-1′), 88.88 (C-4′), 110.69 (O−C−O), 111.00 (C-5), 136.67 (C-6), 152.27 (C-2), 165.31 (C-4). MS (HR-FAB$^+$, PEG 600) $C_{21}H_{41}O_7N_2B_{10}$ (M + 1) calcd, 543.3844; found, 543.3891.

**3-[4-(2-(2,3-Isopropylidenedioxyprop-1-yl)-*o*-carboran-1-yl)butan-1-yl]thymidine (42).** The preparation of this compound was identical to that described for **40**. The amount of 1.3 g (5.4 mmol) of thymidine, 2.1 g (4.5 mmol) of **36**, and 1.9 g (13.5 mmol) of $K_2CO_3$ yielded 1.8 g (72%) of compound **42** as a sticky white foam; $R_f$ 0.40 (1:1 $CHCl_3$:acetone). $^1$H NMR (MeOH-$d_4$): $\delta$ 1.32 (s, 3H, $CH_3$), 1.36 (s, 3H, $CH_3$), 1.48−1.69 (m, 4H, alkane), 1.90 (d, $J$ = 1.0, 3H, $CH_3$), 2.20 (dt, $J$ = 13.7, 6.7, 1H, H-2′), 2.27 (ddd, $J$ = 13.7, 6.2, 3.6, 1H, H-2′), 2.36−2.43 (m, 2H, $CH_2-C_{carborane}$), 2.52 (dd, $J$ = 16.0, 7.8, 1H, $CH_2-C_{carborane}$), 2.59 (dd, $J$ = 16.0, 3.3, 1H, $CH_2-C_{carborane}$), 3.54 (ddd, $J$ = 8.2, 7.0, 0.5, 1H, $CH_2-CH$), 3.72 (dd, $J$ = 12.2, 3.7, 1H, H-5′), 3.80 (dd, $J$ = 12.2, 3.2, 1H, H-5′), 3.88−3.97 (m, 3H, $CH_2-N$ and H-3′), 4.11 (dd, $J$ = 8.2, 6.0, 1H, $CH_2-CH$), 4.24−4.28 (m, 1H, $CH-CH_2$), 4.38−4.41 (m, 1H, H-4′), 6.30 (dd, $J$ = 6.7, 6.2, 1H, H-1′), 7.84 (q, $J$ = 1.0, 1H, H-6). $^{13}$C NMR (MeOH-$d_4$): $\delta$ 13.27 ($CH_3$), 25.88 ($CH_3$), 27.22 ($CH_3$), 28.02 ($CH_2$), 28.08 ($CH_2$), 35.43 ($CH_2-C_{carborane}$), 40.27 ($CH_2-C_{carborane}$), 41.28 ($CH_2-N$), 41.38 (C-2′), 62.77 (C-5′), 70.02 ($CH_2-CH$), 72.12 (C-3′), 75.97 ($CH-CH_2$), 79.64 ($C_{carborane}$-C), 81.70 ($C_{carborane}$-C), 87.12 (C-1′), 88.89 (C-4′), 110.69 (O−C−O), 110.94 (C-5), 136.53 (C-6), 152.31 (C-2), 165.34 (C-4). MS (HR-FAB$^+$, PEG600) $C_{22}H_{43}O_7N_2B_{10}$ (M + 1) calcd, 557.4001; found, 557.4054.

**3-[5-(2-(2,3-Isopropylidenedioxyprop-1-yl)-*o*-carboran-1-yl)pentan-1-yl]thymidine (43).** The preparation of this compound was identical to that described for **40**. The amount of 1.3 g (5.4 mmol) of thymidine, 2.2 g (4.5 mmol) of **37**, and 1.9 g (13.5 mmol) of $K_2CO_3$ yielded 2.0 g (80%) of compound **43** as a sticky white foam; $R_f$ 0.43 (1:1 $CHCl_3$:acetone). $^1$H NMR (MeOH-$d_4$): $\delta$ 1.217−1.39 (m, 2H, alkane), 1.32 (s, 3H, $CH_3$),

1.34 (s, 3H, $CH_3$), 1.55−1.65 (m, 4H, alkane), 1.89 (s, 3H, $CH_3$), 2.15−2.28 (m, 2H, H-2′), 2.30−2.36 (dd, $J$ = 5.4, $J$ = 10, 2H, $CH_2$−$C_{carborane}$), 2.49−2.61 (m, 2H, $CH_2$−$C_{carborane}$), 3.52−3.56 (m, 1H, $CH_2$−CH), 3.70−3.81(m, 2H, H-5′), 3.88−3.92 (m, 3H, H-3′ and $CH_2$−N), 4.08−4.12 (m, 1H, $CH_2$−CH), 4.23−4.30 (m, 1H, CH−$CH_2$), 4.35−4.40 (m, 1H, H-4′), 6.30 (t, 1H, H-1′), 7.83 (s, 1H, H-6). $^{13}$C NMR (MeOH-$d_4$): $\delta$ 13.25 ($CH_3$), 25.85 ($CH_3$), 27.20 ($CH_3$), 27.26 ($CH_2$), 27.92 ($CH_2$), 30.35 ($CH_2$), 35.73 ($CH_2$−$C_{carborane}$), 40.24 ($CH_2$−$C_{carborane}$), 41.35 ($CH_2$−N), 41.87 (C-2′), 62.75 (C-5′), 69.99 ($CH_2$−CH), 72.10 (C-3′), 75.95 (CH−$CH_2$), 79.52 ($C_{carborane}$-C), 81.77 ($C_{carborane}$-C), 87.04 (C-1′), 88.85 (C-4′), 110.69 (O−C−O), 110.89 (C-5), 136.44 (C-6), 152.29 (C-2), 165.35 (C-4). MS (HR-ESI) $C_{23}H_{44}O_7N_2B_{10}Na$ $(M + Na)^+$ calcd, 593.3977; found, 593.3981.

**3-[6-(2-(2,3-Isopropylidenedioxyprop-1-yl)-*o*-carboran-1-yl)hexan-1-yl]thymidine (44).** The preparation of this compound was identical to that described for **40**. The amount of 1.3 g (5.4 mmol) of thymidine, 2.3 g (4.5 mmol) of **38**, and 1.9 g (13.5 mmol) of $K_2CO_3$ yielded 2.1 g (80%) of compound **44** as a sticky white foam; $R_f$ 0.46 (1:1 $CHCl_3$:acetone). $^1$H NMR (MeOH-$d_4$): $\delta$ 1.32 (s, 3H, $CH_3$), 1.36 (s, 3H, $CH_3$), 1.31−1.42 (m, 4H, alkane), 1.50−1.63 (m, 4H, alkane), 1.90 (d, $J$ = 1.0, 3H, $CH_3$), 2.19 (ddd, $J$ = 13.6, 7.0, 6.3, 1H, H-2′), 2.26 (ddd, $J$ = 13.6, 6.2, 3.7, 1H, H-2′), 2.27−2.39 (m, 2H, $CH_2$−$C_{carborane}$), 2.49 (dd, $J$ = 16.0, 8.0, 1H, $CH_2$−$C_{carborane}$), 2.57 (dd, $J$ = 16.0, 3.5, 1H, $CH_2$−$C_{carborane}$), 3.53 (ddd, $J$ = 8.2, 7.0, 0.5, 1H, $CH_2$−CH), 3.72 (dd, $J$ = 12.0, 3.6, 1H, H-5′), 3.79 (dd, $J$ = 12.0, 3.1, 1H, H-5′), 3.87−3.93 (m, 3H, $CH_2$−N and H-3′), 4.11 (dd, $J$ = 8.2, 6.0, 1H, $CH_2$−CH), 4.22−4.28 (m, 1H, CH−$CH_2$), 4.38−4.42 (m, 1H, H-4′), 6.30 (dd, $J$ = 7.0, 6.2, 1H, H-1′), 7.83 (q, $J$ = 1.0, 1H, H-6). $^{13}$C NMR (MeOH-$d_4$): $\delta$ 13.25 ($CH_3$), 25.84 ($CH_3$), 27.21 ($CH_3$), 27.39 ($CH_2$), 28.29 ($CH_2$), 29.72 ($CH_2$), 30.70 ($CH_2$), 35.93 ($CH_2$−$C_{carborane}$), 40.25 ($CH_2$−$C_{carborane}$), 41.33 ($CH_2$−N), 42.08 (C-2′), 62.75 (C-5′), 70.00 ($CH_2$−CH), 72.10 (C-3′), 75.92 (CH−$CH_2$), 79.37 ($C_{carborane}$-C), 81.87 ($C_{carborane}$-C), 87.06 (C-1′), 88.86 (C-4′), 110.70 (O−C−O), 110.88 (C-5), 136.44 (C-6), 152.29 (C-2), 165.37 (C-4). MS (HR-FAB$^+$, PEG600) $C_{24}H_{47}O_7N_2B_{10}$ $(M + 1)$ calcd, 585.4314; found, 585.4384.

**3-[7-(2-(2,3-Isopropylidenedioxyprop-1-yl)-*o*-carboran-1-yl)heptan-1-yl]thymidine (45).** The preparation of this compound was identical to that described for compound **40**. The amount of 1.3 g (5.4 mmol) of thymidine, 2.4 g (4.5 mmol) of **39**, and 1.9 g (13.5 mmol) of $K_2CO_3$ yielded 1.2 g (96%) of compound **45** as a sticky white foam; $R_f$ 0.50 (1:1 $CHCl_3$:acetone). $^1$H NMR (MeOH-$d_4$): $\delta$ 1.32 (s, 3H, $CH_3$), 1.36 (s, 3H, $CH_3$), 1.28−1.42 (m, 6H, alkane), 1.49−1.63 (m, 4H, alkane), 1.89 (d, $J$ = 1.0, 3H, $CH_3$), 2.11−2.39 (m, 4H, H-2′ and $CH_2$−$C_{carborane}$), 2.49 (dd, $J$ = 16.0, 8.0, 1H, $CH_2$−$C_{carborane}$), 2.57 (dd, $J$ = 16.0, 3.5, 1H, $CH_2$−$C_{carborane}$), 3.53 (dd, $J$ = 8.0, 7.1, 1H, $CH_2$−CH), 3.72 (dd, $J$ = 12.0, 3.6, 1H, H-5′), 3.79 (dd, $J$ = 12.0, 3.0, 1H, H-5′), 3.86−3.90 (m, 3H, $CH_2$−N and H-3′), 4.11 (dd, $J$ = 8.2, 6.0, 1H, $CH_2$−CH), 4.25−4.29 (m, 1H, CH−$CH_2$), 4.36−4.42 (m, 1H, H-4′), 6.30 (dd, $J$ = 7.0, 6.3, 1H, H-1′), 7.83 (q, $J$ = 1.0, 1H, H-6). $^{13}$C NMR (MeOH-$d_4$): $\delta$ 13.25 ($CH_3$), 25.86 ($CH_3$), 27.21 ($CH_3$), 27.66 ($CH_2$), 28.36 ($CH_2$), 29.77 ($CH_2$), 29.98 ($CH_2$), 30.79 ($CH_2$), 35.93 ($CH_2$−$C_{carborane}$), 40.27 ($CH_2$−$C_{carborane}$), 41.34 ($CH_2$−N), 42.17 (C-2′), 62.75 (C-5′), 69.98 ($CH_2$−CH), 72.09 (C-3′), 75.90 (CH−$CH_2$), 79.40 ($C_{carborane}$-C), 81.90 ($C_{carborane}$-C), 87.02 (C-1′), 88.84 (C-4′), 110.65 (O−C−O), 110.84 (C-5), 136.39 (C-6), 152.24 (C-2), 165.29 (C-4). MS (HR-ESI) $C_{25}H_{48}N_2O_7B_{10}Na$ $(M + Na)^+$ calcd, 621.4289; found, 621.4256.

**3-[2-(2-(2,3-Dihydroxyprop-1-yl)-*o*-carboran-1-yl)ethan-1-yl]thymidine (46).** To a solution of 1.5 g (3.1 mmol) of **40** in 10 mL of MeOH was added ∼1 mL of 17% HCl in EtOH to adjust the pH to 2 mL. The reaction was stirred at room temperature for 12 h. To this solution, 0.5 g of $K_2CO_3$ was added and the mixture was stirred for 15 min. The reaction mixture was filtered, and the compound was isolated from the filtrate by evaporation as a colorless residue. The product was then purified by silica gel column chromatography yielding 1.2 g (80%) of compound **46** as a sticky white foam; $R_f$ 0.12 (1:1 $CHCl_3$:acetone). $^1$H NMR (MeOH-$d_4$): $\delta$ 1.89 (d, $J$ = 1.0, 3H, $CH_3$), 2.19 (dddd, $J$ = 13.8, 7.0, 6.3, 0.9, 1H, H-2′), 2.26 (ddd, $J$ = 13.8, 6.2, 3.7, 1H, H-2′), 2.34 (dd, $J$ = 16.0, 9.0, 1H, $CH_2$−$C_{carborane}$), 2.51−2.59 (m, 2H, $CH_2$−$C_{carborane}$), 2.61 (dd, $J$ = 16.0, 1.7, 1H, $CH_2$−$C_{carborane}$), 3.37 (dd, $J$ = 11.2, 6.2, 1H, $CH_2$−CH), 3.47 (dd, $J$ = 11.2, 5.6, 1H, $CH_2$−CH), 3.72 (dd, $J$ = 12.0, 3.6, 1H, H-5′), 3.76−3.83 (m, 1H, CH−$CH_2$), 3.79 (dd, $J$ = 12.0, 3.0, 1H, H-5′), 3.90 (ddd, $J$ = 3.6, 3.3, 3.0, 1H, H-3′), 3.99−4.14 (m, 2H, $CH_2$−N), 4.38 (ddd, $J$ = 6.3, 3.7, 3.3, 1H, H-4′), 6.27 (dd, $J$ = 7.0, 6.2, 1H), 7.84 (q, $J$ = 1.0, 1H, H-6). $^{13}$C NMR (MeOH-$d_4$): $\delta$ 13.11 ($CH_3$), 28.94 ($CH_2$), 32.47 ($CH_2$−$C_{carborane}$), 39.88 ($CH_2$−$C_{carborane}$), 41.33 (C-2′), 62.7 (C-5′), 66.99 ($CH_2$−CH), 72.06 (CH−$CH_2$), 72.15 (C-3′), 78.79 ($C_{carborane}$-C), 80.43 ($C_{carborane}$-C), 87.17 (C-1′), 88.90 (C-4′), 110.66 (C-5), 136.76 (C-6), 151.95 (C-2), 164.97 (C-4). MS (HR-FAB$^+$, 3-NBA) $C_{17}H_{35}O_7N_2B_{10}$ $(M + 1)$ calcd, 489.3375; found, 489.3300. Reverse phase-18 HPLC retention time: 18.1 min; reverse phase-8: 18.2 min, >98% pure.

**3-[3-(2-(2,3-Dihydroxyprop-1-yl)-*o*-carboran-1-yl)propan-1-yl]thymidine (47).** The procedure for the synthesis of this compound was identical to that described for compound **46**. The amount of 1.6 g (3.2 mmol) of **41** yielded 1.3 g (82%) of compound **47** as a sticky white foam; $R_f$ 0.39 (1:1 $CHCl_3$:acetone). $^1$H NMR (MeOH-$d_4$): $\delta$ 1.80−1.89 (m, 2H, $CH_2$), 1.90 (d, $J$ = 1.0, 3H, $CH_3$), 2.16−2.43 (m, 5H, H-2′ and $CH_2$−$C_{carborane}$), 2.55 (dd, $J$ = 16.0, 1.5, 1H, $CH_2$−$C_{carborane}$), 3.28−3.34 (m, 1H, $CH_2$−CH), 3.40−3.46 (m, 1H, $CH_2$−CH), 3.72 (dd, $J$ = 12.0, 3.7, 1H, H-5′), 3.70−3.77 (m, 1H, CH−$CH_2$), 3.79 (ddd, $J$ = 12.0, 3.0, 1.0, 1H, H-5′), 3.88−3.98 (m, 3H, H-3′ and $CH_2$−N), 4.38−4.42 (m, 1H, H-4′), 6.29 (dd, $J$ = 7.0, 6.2, 1H, H-1′), 7.83 (q, $J$ = 1.0, 1H, H-6). $^{13}$C NMR (MeOH-$d_4$): $\delta$ 13.21 ($CH_3$), 28.98 ($CH_2$), 33.38 ($CH_2$−$C_{carborane}$), 39.96 ($CH_2$−$C_{carborane}$), 41.30 ($CH_2$−N), 41.46 (C-2′), 62.74 (C-5′), 66.94 ($CH_2$−CH), 72.08 (CH−$CH_2$), 72.13 (C-3′), 80.76 ($C_{carborane}$-C), 81.06 ($C_{carborane}$-C), 87.15 (C-1′), 88.87 (C-4′), 110.74 (C-5), 136.68 (C-6), 152.34 (C-2), 165.44 (C-4). MS (HR-FAB$^+$, PEG600) $C_{18}H_{37}O_7N_2B_{10}$ $(M + 1)$ calcd, 503.3531; found, 503.3604. Reverse phase-18 HPLC retention time: 18.5 min; reverse phase-8: 18.3 min, >98% pure.

**3-[4-(2-(2,3-Dihydroxyprop-1-yl)-*o*-carboran-1-yl)butan-1-yl]thymidine (48).** The procedure for the synthesis of this compound was the same as described for compound **46**. The amount of 1.6 g (3 mmol) of **42** yielded 1.5 g (97%) of compound **48** as a sticky white foam; $R_f$ 0.20 (1:1 $CHCl_3$:acetone). $^1$H NMR (MeOH-$d_4$): $\delta$ 1.50−1.68 (m, 4H, alkane), 1.90 (d, $J$ = 1.0, 3H, $CH_3$), 2.19 (ddd, $J$ = 13.8, 7.2, 6.2, 1H, H-2′), 2.25 (dd, $J$ = 16.0, 9.0, 1H, $CH_2$−$C_{carborane}$), 2.27 (ddd, $J$ = 13.8, 6.2, 3.5, 1H, H-2′), 2.34−2.43 (m, 2H, $CH_2$−$C_{carborane}$), 2.57 (dd, $J$ = 16.0, 1.6, 1H, $CH_2$−$C_{carborane}$), 3.34 (dd, $J$ = 11.2, 6.5, 1H, $CH_2$−CH), 3.47 (dd, $J$ = 11.2, 5.3, 1H, $CH_2$−CH), 3.72 (dd, $J$ = 12.0, 3.6, 1H, H-5′), 3.75−3.80 (m, 1H, CH−$CH_2$), 3.80 (dd, $J$ = 12.0, 3.0, 1H, H-5′), 3.89−3.97 (m, 3H, $CH_2$−N and H-3′), 4.39 (ddd, $J$ = 6.2, 3.5, 3.3, 1H, H-4′), 6.27 (dd, $J$ = 7.0, 6.2, 1H, H-4′), 7.84 (q, $J$ = 1.0, 1H, H-6). $^{13}$C NMR (MeOH-$d_4$): $\delta$ 13.22 ($CH_3$), 28.04 ($CH_2$), 35.47 ($CH_2$−$C_{carborane}$), 39.90 ($CH_2$−$C_{carborane}$), 41.36 (C-2′), 41.42 ($CH_2$−N), 62.75 (C-5′), 66.92 ($CH_2$−CH), 72.11 (CH−$CH_2$), 72.22 (C-3′), 80.54 ($C_{carborane}$-C), 81.75 ($C_{carborane}$-C), 87.14 (C-1′), 88.89 (C-4′), 110.69 (C-5), 136.53 (C-6), 152.31 (C-2), 165.39 (C-4). MS (HR-FAB$^+$, PEG600) $C_{19}H_{39}O_7N_2B_{10}$ $(M + 1)$ calcd, 517.3687; found, 517.3690. Reverse phase-18 HPLC retention time: 18.8 min; reverse phase-8: 18.6 min, >98% pure.

**3-[5-(2-(2,3-Dihydroxyprop-1-yl)-*o*-carboran-1-yl)pentan-1-yl]thymidine (49).** The procedure for the synthesis of this compound was identical to that described for compound **46**. The amount of 7.8 g (3.2 mmol) of **43** yielded 1.6 g (95%) of compound **49** as a sticky white foam; $R_f$ 0.29 (1:1 $CHCl_3$:acetone). $^1$H NMR (MeOH-$d_4$): $\delta$ 1.30−1.39 (m, 2H, alkane), 1.54−1.66 (m, 4H, alkane), 1.90 (d, $J$ = 1.1, 3H, $CH_3$), 2.19 (ddd, $J$ = 13.8, 7.2, 6.2, 1H, H-2′), 2.25 (dd, $J$ = 16.0, 9.0, 1H, $CH_2$−$C_{carborane}$), 2.27 (ddd, $J$ = 13.8, 6.2, 3.5, 1H, H-2′), 2.28−2.40 (m, 2H, $CH_2$−$C_{carborane}$), 2.57 (dd, $J$ = 16.0, 1.8, 1H, $CH_2$−$C_{carborane}$), 3.33 (dd, $J$ = 11.2, 6.7, 1H, $CH_2$−CH), 3.47 (dd, $J$ = 11.2, 5.3, 1H, $CH_2$−CH), 3.72 (dd, $J$ = 12.0, 3.7, 1H, H-5′), 3.79 (dd, $J$ = 12.0, 3.1, 1H, H-5′), 3.75−3.80 (m, 1H, CH−$CH_2$), 3.88−3.94 (m, 3H, $CH_2$−N and H-3′), 4.39 (ddd, $J$ = 6.2, 3.5,

3.3, 1H, H-4′), 6.30 (dd, $J$ = 7.0, 6.3, 1H, H-1′), 7.84 (q, $J$ = 1.1, 1H. H-6). $^{13}$C NMR (MeOH-$d_4$): $\delta$ 13.23 ($CH_3$), 27.29 ($CH_2$), 27.91 ($CH_2$), 30.39 ($CH_2$), 35.81 ($CH_2-C_{carborane}$), 39.89 ($CH_2-C_{carborane}$), 41.34 ($CH_2-N$), 41.92 (C-2′), 62.76 (C-5′), 66.91 ($CH_2-CH$), 72.12 ($CH-CH_2$), 72.21 (C-3′), 80.45 ($C_{carborane}$-C), 81.90 ($C_{carborane}$-C), 87.10 (C-1′), 88.88 (C-4′), 110.71 (C-5), 136.49 (C-6), 152.33 (C-2), 165.44 (C-4). Anal. ($C_{20}H_{40}O_7N_2B_{10}$) C, H, N, B. MS (HR-ESI) $C_{20}H_{40}O_7N_2B_{10}Na$ ($M + Na$)$^+$ calcd, 553.3664; found, 553.3676. Reverse phase-18 HPLC retention time: 18.5 min; reverse phase-8: 18.8 min, >97% pure.

**3-[6-(2-(2,3-Dihydroxyprop-1-yl)-*o*-carboran-1-yl)hexan-1-yl]thymidine (50).** The procedure for the synthesis of this compound was identical to that described for compound **46**. The amount of 1.7 g (3 mmol) of **44** yielded 1.3 g (80%) of compound **50** as a sticky white foam; $R_f$ 0.14 (1:1 $CHCl_3$:acetone). $^1$H NMR (MeOH-$d_4$): $\delta$ 1.31−1.36 (m, 4H, alkane), 1.90 (d, $J$ = 1.1, 3H, $CH_3$), 1.50−1.63 (m, 4H, alkane), 2.19 (ddd, $J$ = 13.8, 7.0, 6.2, 1H, H-2′), 2.23 (dd, $J$ = 16.0, 9.0, 1H, $CH_2-C_{carborane}$), 2.27 (ddd, $J$ = 13.8, 6.2, 3.5, 1H, H-2′), 2.28−2.40 (m, 2H, $CH_2-C_{carborane}$), 2.56 (dd, $J$ = 16.0, 1.6, 1H, $CH_2-C_{carborane}$), 3.33 (dd, $J$ = 11.2, 6.7, 1H, $CH_2-CH$), 3.47 (dd, $J$ = 11.2, 5.3, 1H, $CH_2-CH$), 3.72 (dd, $J$ = 12.0, 3.7, 1H, H-5′), 3.74−3.80 (m, 1H, $CH-CH_2$), 3.80 (dd, $J$ = 12.0, 3.0, 1H, H-5′), 3.87−3.93 (m, 3H, $CH_2-N$ and H-3′), 4.39 (ddd, $J$ = 6.2, 3.5, 3.3, 1H, H-4′), 6.30 (dd, $J$ = 7.0, 6.3, 1H, H-1′), 7.83 (q, $J$ = 1.1, 1H, H-6). $^{13}$C NMR (MeOH-$d_4$): $\delta$ 13.23 ($CH_3$), 27.35 ($CH_2$), 28.27 ($CH_2$), 29.71 ($CH_2$), 30.72 ($CH_2$), 35.92 ($CH_2-C_{carborane}$), 39.90 ($CH_2-C_{carborane}$), 41.32 (C-2′), 42.14 ($CH_2-N$), 62.76 (C-5′), 66.90 ($CH_2-CH$), 72.11 ($CH-CH_2$), 72.20 (C-3′), 80.42 ($C_{carborane}$-C), 81.95 ($C_{carborane}$-C), 87.09 (C-1′), 88.87 (C-4′), 110.72 (C-5), 136.47 (C-6), 152.32 (C-2), 165.42 (C-4). MS (HR-FAB$^+$, PEG 600) $C_{21}H_{43}O_7N_2B_{10}$ ($M + 1$) calcd, 545.4000; found, 545.4007. Reverse phase-18 HPLC retention time: 18.8 min; reverse phase-8: 18.9 min, >97% pure.

**3-[7-(2-(2,3-dihydroxyprop-1-yl)-*o*-carboran-1-yl)heptan-1-yl]thymidine (51).** The procedure for the synthesis of this compound was identical to that described for compound **46**. The amount of 1.6 g (3.2 mmol) of **45** yielded 1.3 g (70%) of compound **51** as a sticky white foam; $R_f$ 0.19 (1:1 $CHCl_3$:acetone). $^1$H NMR (MeOH-$d_4$): $\delta$ 1.29−1.37 (m, 6H, alkane), 1.90 (d, $J$ = 1.0, 3H, $CH_3$), 1.49−1.63 (m, 4H, alkane), 2.14−2.39 (m, 5H, H-2′ and $CH_2-C_{carborane}$), 2.56 (dd, $J$ = 16.0, 1.6, 1H, $CH_2-C_{carborane}$), 3.32 (dd, $J$ = 11.2, 6.7, 1H, $CH_2-CH$), 3.47 (dd, $J$ = 11.2, 5.3, 1H, $CH_2-CH$), 3.72 (dd, $J$ = 12.0, 3.7, 1H, H-5′), 3.79 (dd, $J$ = 12.0, 3.0, 1H, H-5′), 3.74−3.80 (m, 1H, $CH-CH_2$), 3.87−3.93 (m, 3H, H-3′ and $CH_2-N$), 4.38−4.44 (m, 1H, H-4′), 6.30 (dd, $J$ = 7.0, 6.4, 1H, H-1′), 7.83 (q, $J$ = 1.0, 1H, H-6). $^{13}$C NMR (MeOH-$d_4$): $\delta$ 13.22 ($CH_3$), 27.65 ($CH_2$), 28.37 ($CH_2$), 29.74 ($CH_2$), 29.95 ($CH_2$), 30.79 ($CH_2$), 35.62 ($CH_2-C_{carborane}$), 39.90 ($CH_2-C_{carborane}$), 41.34 (C-2′), 42.23 ($CH_2-N$), 62.76 (C-5′), 66.90 ($CH_2-CH$), 72.11 ($CH-CH_2$), 72.19 (C-3′), 80.42 ($C_{carborane}$-C), 82.00 ($C_{carborane}$-C), 87.09 (C-1′), 88.87 (C-4′), 110.72 (C-5), 136.45 (C-6), 152.31 (C-2), 165.41 (C-4). MS (HR-ESI) $C_{22}H_{44}O_7N_2B_{10}Na$ ($M + Na$)$^+$ calcd, 581.3976; found, 581.4006. Reverse phase-18 HPLC retention time: 19.6 min; reverse phase-8: 19.2 min, >98% pure.

**Expression and Purification of Recombinant Human TK1 and TK2.** The recombinant enzymes TK1 and TK2 were expressed and purified from the bacterial expression system according to the procedures described previously.[23,38] The enzymes were 95% pure.

**Phosphoryl Transfer Assay with Recombinant TK1 and TK2.** Thymidine and the boronated nucleoside analogues were dissolved in DMSO to produce stock solutions of various concentrations (30−140 $\mu$M). The assays were carried out as described previously[23] with minor modifications. In TK1 assays, the reaction mixture contained 5 or 10 $\mu$M nucleoside and 100 $\mu$M ATP (a small fraction of 0.0325 $\mu$M [$\gamma$-$^{32}$P]ATP (Amersham)), was included in the reaction, to detect the phosphorylation pattern by TLC), 50 mM Tris-HCl (pH 7.6), 5 mM $MgCl_2$, 125 mM KCl, 10 mM DTT, and 0.5 mg/mL bovine serum albumin (BSA). The TK2 assays were performed as described for the experiments with TK1, except that the nucleoside concentration was 100 $\mu$M. We were not able to detect any TK2 activity at lower nucleoside concentrations. In all reactions, the final concentration of DMSO was set to 1%. The reaction mixture was incubated at 37 °C for 20 min in the presence of 100 ng of enzyme. Following the incubation period, the enzyme was inactivated by heating for 2 min at 95 °C. The reaction mixture was centrifuged and 1 $\mu$L sample portions were spotted on PEI-cellulose TLC plates (Merck). The TLC plates were placed overnight in a solvent system containing isobutyric acid:ammonium hydroxide:water (66:1:33). The radiolabeled spots were visualized by a phosphoimager (Fuji Film, Science Lab., Image Gauge V3.3).

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**Supporting Information Available:** HPLC (RP18 and RP8) to demonstrate the purity of target compounds **3**, **4**, and **46**−**51**. This material is available free of charge at http://pubs.acs.org.

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