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Purines Bearing Phenanthroline or Bipyridine Ligands and Their Ru^{II} Complexes in Position 8 as Model Compounds for Electrochemical DNA Labeling – Synthesis, Crystal Structure, Electrochemistry, Quantum Chemical Calculations, Cytostatic and Antiviral Activity

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A series of ethynyl- or (4-boronophenyl)bipyridines and -phenanthrolines were prepared as versatile building blocks for attachment of bidentate N-ligands to other molecules via cross-coupling reactions. Their complexation with $Ru(bpy)_2Cl_2$ gave the corresponding Ru^{II} complexes. 9-Benzyladenine derivatives bearing the bipyridine or phenanthroline complexes in position 8, attached via a conjugate acetylene or phenylene linker were prepared by cross-coupling reactions of the ethynyl- or 4-boronophenylbipyridines and -phenanthrolines with 9-benzyl-8-bromoadenine. Their complexation with $Ru(bpy)_2Cl_2$ afforded the corresponding Ru complexes as model compounds for electrochemical DNA labeling. The same compounds were also prepared directly by cross-coupling of 9-benzyl-8-bromoadenine with Ru complexes of the alkynes and boronic acids. Both approaches are compared in terms of potential applications for labeling of nucleic acids. The crystal structures of two Ru complexes were determined by X-ray diffraction. The electrochemistry of the model purines bearing the phenanthroline or bipyridine ligands and the Ru complexes was studied by means of cyclic or square-wave voltammetry with carbon paste and mercury electrodes. The experimental redox potentials of the title compounds were compared with quantum chemical calculations. A very good agreement between experiment and theory was obtained, with a standard deviation of 0.13 V. It was shown that theoretical calculations can be of a limited predictive power for new Ru^{II} complexes, though it was difficult to reproduce differences smaller than 0.05 V. Several compounds of this series exhibited a considerable cytostatic effect and activity against the hepatitis C virus (HCV).

Introduction

DNA biosensors and chips[1] are increasingly utilized in current molecular biology, biochemistry, biomedicine and related disciplines. On the basis of DNA hybridization, these devices are used to analyze nucleotide sequences of DNAs or RNAs, searching for mutations, monitoring of gene expression, etc. DNA damage and interaction of DNA with different toxic or biologically active species can also be detected by DNA sensors. In addition to optical methods involved in most of the commercially available systems, electrochemical detection has attracted attention as a less expensive alternative offering comparable sensitivity.

Nucleic acids are electroactive species producing analytically useful oxidation and reduction signals at mercury or solid electrodes.[2,3] In addition to label-free DNA detection, different electroactive (or enzyme) tags tethered to target DNAs or hybridization probes are used to improve sensitivity and/or specificity of the analysis.[3] For example, ferrocene-labeled oligonucleotides (ON) were used as reporter (signaling) probes[4] or as an electrochemical variant of a "molecular beacon."[5] Osmium tetroxide complexes reacting selectively with thymine residues were applied in recently proposed double-surface (biomagnetic) electrochemical DNA hybridization techniques.[3,6] In analogy with the multicolor optical coding, combination of electrochemical tags yielding different signals makes it possible to detect several target DNA sequences in parallel.[7]

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Complexes of transition metals, for instance ferrocene,[8] or complexes of bidentate N-ligands[9] (in particular phenanthrolines and bipyridines) with transition metals (Ru, Rh, Ni, Cu, Co, Pt, Pd, Os etc.) possess unique electrochemical and photophysical properties. Some of the phenanthroline complexes, which are also efficient DNA intercallators, have been extensively used as luminescent and electroactive DNA labels.[10] Attachment of probes based on metal complexes directly to a nucleobase via conjugate linkers should increase the efficiency of the charge transfer and thus enhance sensitivity. There are many examples of such probes connected to pyrimidine nucleobases. 5-(Ferrocenylethynyl)pyrimidine nucleosides were synthesized by Sonogashira coupling of 5-iodopyrimidines with ethynylferrocene and incorporated into DNA as electroactive redox markers.[11] Covalently bound conjugates of pyrimidine nucleotides and phenanthroline complexes of Ru and Os have been studied[12] as fluorescence probes for DNA hybridization and charge transfer through DNA. However, there are very few reports of probes conjugated to purines, presumably due to the greater difficulty in preparation and incorporation. Recently, we have reported[13] on the synthesis of model 9-benzyl-8-(ferrocenylethynyl)adenine by cross-coupling of ethynylferrocene with 8-bromoadenine. Preliminary electrochemical and quantum chemical studies showed that even small electronic changes are effectively transferred through the conjugated system and are electrochemically detectable. Moreover, these effects could be reliably calculated and predicted using ab initio calculations. However, the corresponding protected phosphoramidite of 8-(ferrocenylethynyl)-2′-deoxyadenosine was not efficiently incorporated to oligonucleotides[14] presumably due to oxidation of ferrocene followed by nucleophilic displacement. Therefore, our next probes of choice for labeling purines are complexes (Ru and Os) of bipyridine and phenanthroline. Here we describe the synthesis of model adenine derivatives by two different approaches and the study of their electrochemical properties in order to verify applicability of such complexes as probes for labeling nucleic acids. We were also interested in the biological activity of these novel types of adenine derivatives and metal complex conjugates.

Results and Discussion

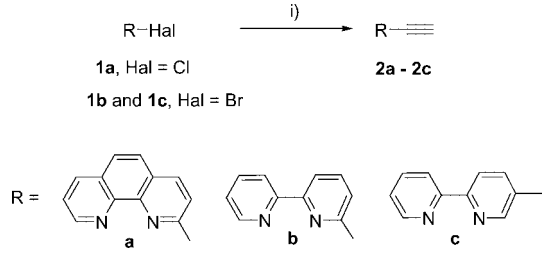
Synthesis

Two different approaches to the synthesis of target 9-benzyladenines bearing phenanthroline complexes Ru^{II} and Os^{II} in position 8 have been designed and verified in terms of their efficiency, practicability, and compatibility with rather labile nucleic acids. The first one consisted of cross-coupling of 8-bromoadenine with ethynyl- or (4-boronophenyl)-2,2′-bipyridines or -phenanthrolines followed by complexation of the resulting purine-ligand conjugates with a metal. The second approach was based on direct cross-coupling of 8-bromoadenine with preformed Ru complexes of the ligand building blocks. For both approaches we needed the acetylene and boronic acid derivatives of the bidentate N-ligands.

Synthesis of Ligand Building Blocks

1,10-Phenanthroline (phen), 2,2′-bipyridine (bpy), and 2,2′:6′,2"-terpyridine (tpy) are the most commonly used polypyridine ligands in the chemistry of coordinating compounds[15] and are often used as building blocks for the construction of molecular and supramolecular devices.[16] Cross-coupling reactions are the most versatile tools for construction of molecules containing these ligands connected via conjugate (and thus charge conducting) acetylene or phenylene linkers. However, the chemistry of the corresponding synthetic equivalents for cross-coupling reactions, i.e. boronic acids and acetylene derivatives of oligopyridine ligands, is still underdeveloped and rather difficult. Therefore our first task was to prepare a series of such reagents (some of them were hitherto unknown compounds) not only by application but also by modification and optimization of known methods.

Common starting compounds in the synthesis of the building blocks were halogenated phenanthrolines and bipyridines **1**. 2-Chloro-1,10-phenanthroline (**1a**) was prepared[17] in four steps from the commercially available phenanthroline monohydrate. The Sonogashira cross-coupling reaction of **1a** with (trimethylsilyl)acetylene and subsequent deprotection of the TMS group by treatment with KF in MeOH/THF mixture, led to the desired new 2-ethynyl-1,10-phenanthroline (**2a**) (Scheme 1). Known 6-(ethynyl)-2,2′-bipyridine (**2b**) and 5-(ethynyl)-2,2′-bipyridine (**2c**) were prepared by analogous literature procedures[18] from 6-bromo-2,2′-bipyridine (**1b**) and 5-bromo-2,2′-bipyridine (**1c**), respectively (Scheme 1, Table 1).



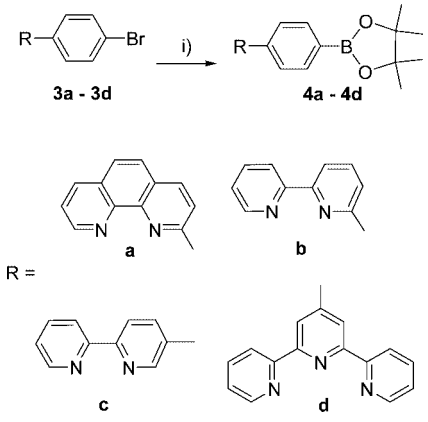
Scheme 1. Synthesis of the ligands: i) 1. $[Pd(PPh_3)_2Cl_2]$ (5–10 mol-%), CuI (10 mol-%), TMSA (2.2 equiv.), Et_3N (3.2 equiv.), DMF or THF, 60–70 °C; 2. MeOH/THF KF (2 equiv.).

Table 1. Synthesis of the ethynyl ligands **2**.

Entry	R-hal	Product	Yield [%]
1	**1a**	**2a**	60
2	**1b**	**2b**	82
3	**1c**	**2c**	83

(4-Bromophenyl)bipyridines, -phenanthroline and -terpyridine **3a**–**3d** were the key intermediates for the synthesis of the corresponding boronates **4a**–**4d**. 2-(4-Bromophenyl)-phenanthroline (**3a**) was prepared in 69% yield by a known[19] procedure involving addition of 4-bromophenyllithium to phenanthroline monohydrate followed by oxi-

dation with MnO_2. The Suzuki cross-coupling reactions of 6-bromo-2,2′-bipyridine or 5-bromo-2,2′-bipyridine with 4-bromophenylboronic acid afforded the *p*-bromophenylene-substituted bipyridines **3b** and **3c** (compound **3c** was reported earlier via heterocyclizations[20]). 4′-(*p*-Bromophenyl)-2,2′:6′,2"-terpyridine **3d** was prepared by a known multistep procedure[21] from 2-acetylpyridine and 4-bromobenzaldehyde. All these bromo derivatives **3a**–**3d** were subjected to cross-coupling reactions with bis(pinacolato)-diboron[22] in the presence of $Pd(dppf)Cl_2$ and KOAc in dioxane at 80 °C to give the series of pinacol boronates **4a**–**4d** in good yields of 60–91% (Scheme 2, Table 2). Compounds **4a** and **4b** were new, while known compounds **4c**[23] and **4d**[21a] were prepared by this method in much higher yields (91 and 81%, respectively) than alternative methods reported in the literature (30 and 42%, respectively).



Scheme 2. Synthesis of the ligands: i) bis(pinacolatodiboron) (1.2 equiv.), [$Pd(dppf)Cl_2$] (5 mol-%), KOAc (1.5 equiv.), dioxane, 80 °C.

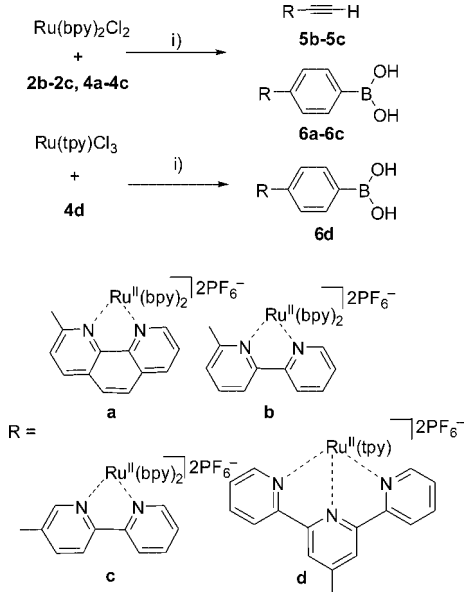
Table 2. Synthesis of the phenylene-bridged ligands.

Entry	Bromo derivative	Product	Yield [%]
1	**3a**	**4a**	60
2	**3b**	**4b**	86
3	**3c**	**4c**	91
4	**3d**	**4d**	81

Synthesis of Ru Complex-Containing Building Blocks

Among many transition metals used in coordination chemistry of bipyridine-type ligands, Ru^{II} complexes are one of the most popular due to their chemical stability and favorable redox and photophysical properties.[24] Surprisingly, acetylene or boronic acid building blocks containing the Ru^{II} complexes, ready for a single-step attachment to any aromatic skeleton by cross-coupling reactions, are virtually unknown with the exception of (3- and 4-ethynyl-1,10-phenanthroline)$Ru^{2+}(bipy)_2 \cdot 2PF_6^-$.[25] We have prepared the whole series of Ru^{II} complexes of the ligands **2b**–**2c** and **4a**–**4d**.

Commercially available $Ru(bpy)_2Cl_2 \cdot 2H_2O$ was the compound of choice for the complexation reactions. Its complexation with ligands **2** and **4a**–**4c** under standard conditions,[26] e.g. mixing of the reagents in MeOH or EtOH and refluxing the mixture for several hours under an inert atmosphere, afforded the desired products **5** and **6** in poor yields (12–30%) accompanied by some byproducts. When ethylene glycol was used as the solvent,[27] the yields were improved up to 66% (Scheme 3, Table 3) and the amounts of byproducts significantly decreased. A typical procedure involved a suspension of the starting compounds in ethylene glycol heating the mixture at 150 °C for 2 h, distillation of the solvent and anion exchange precipitation from aqueous solution by treatment with NH_4PF_6. The solid was further purified on a silica gel column using a mixture of acetonitrile, water, and saturated KNO_3 as the eluent. However, during this separation, partial anion exchange occurred and therefore it was crucial to re-precipitate the final product once again from its aqueous solution by treatment with NH_4PF_6. Only after this procedure and final re-crystallization were pure samples of hexafluorophosphate salts **5b**–**5c** and **6a**–**6c** isolated. In the case of terpyridine derivative **4d**, $Ru(tpy)Cl_3$ complex[28] was used as the complexation agent under the same conditions as described above to yield the complex **6d**. It should be mentioned that all the pinacol esters of boronate ligands **4a**–**4d** were cleaved simultaneously during the complexation to afford free boronic acids **6a**–**6d**.



Scheme 3. Complexation reactions: i) 1. ethylene glycol, 150 °C, 2 h; 2. saturated aqueous solution of NH_4PF_6.

Table 3. Complexations of the ligands **2** and **4**.

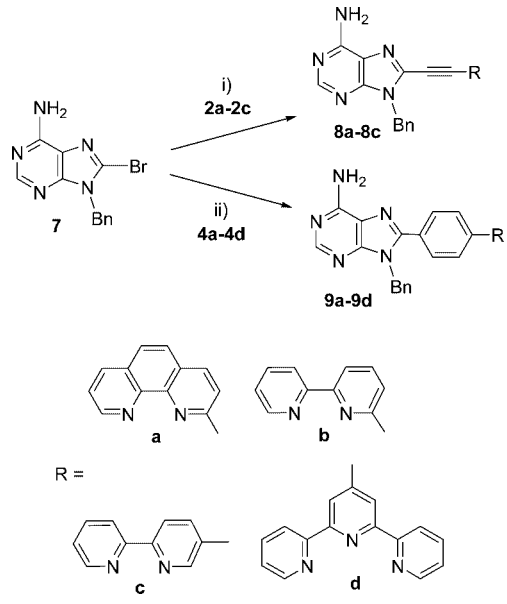
Entry	Ligand	Complex	Yield [%][a]
1	**2b**	**5b**	49
2	**2c**	**5c**	32
3	**4a**	**6a**	66
4	**4b**	**6b**	47
5	**4c**	**6c**	42
6	**4d**	**6d**	69

[a] Yields after crystallization.

Synthesis of Adenine–Ligand Conjugates

Cross-coupling reactions are often used for introduction of C-substituents to position 8 of purines.[29] The Suzuki–Miyaura reactions with arylboronic acids are usually used[30] for attachment of an aryl group while the Sonogashira reactions with terminal acetylenes are used[13,31] for alkynyl groups. Therefore, these reactions were our methods of choice for the synthesis of the conjugates of adenine with oligopyridine-type ligands connected via acetylene or phenylene bridges.

The Sonogashira cross coupling reactions of 9-benzyl-8-bromoadenine (**7**) with the terminal alkynes **2a**–**2c** in the presence of $[Pd(dppf)Cl_2]$, CuI, and Et_3N in DMF at 90 °C afforded the corresponding acetylene-bridged conjugates **8a**–**8c** in the yields of ca. 55% after crystallization (Scheme 4, Table 4). The Suzuki–Miyaura cross coupling reaction of bromoadenine **7** with pinacol boronates **4a**–**4d** gave the phenylene-linked conjugates **9a**–**9d** (Scheme 4) in ca. 50% yield. All the cross-coupling reactions proceeded very well and quite cleanly. Their moderate isolated yields may have been caused by partial complexation of the Pd-catalysts by the oligopyridine moiety and by some loss during the silica gel chromatography of the quite polar substrates.



Scheme 4. Synthesis of the conjugates: i) $[Pd(dppf)Cl_2]$ (5 mol-%), CuI (5 mol%), Et_3N (8 equiv.), DMF, 90 °C; ii) $[Pd(dppf)Cl_2]$ (5 mol-%), K_2CO_3 (4 equiv.), DMF, 90 °C.

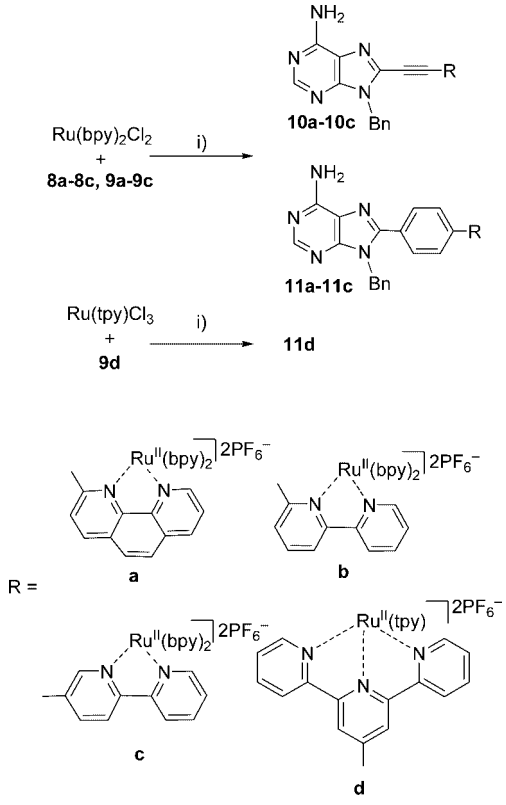
Table 4. Synthesis of the conjugates.

Entry	Ligand	Conjugate	Yield [%][a]
1	**2a**	**8a**	55
2	**2b**	**8b**	58
3	**2c**	**8c**	56
4	**4a**	**9a**	47
5	**4b**	**9b**	53
6	**4c**	**9c**	52
7	**4d**	**9d**	46

[a] Yields after crystallization.

Synthesis of Adenine–Complex Conjugates by Complexation

One of the approaches to the desired title model conjugates of adenine and Ru^{II} complexes is the complexation of the adenine-ligand conjugates **8** and **9** (Scheme 5, Table 5). The complexation reactions with either $Ru(bpy)_2Cl_2 \cdot 2H_2O$ or the $Ru(tpy)Cl_3$ complex were performed in ethylene glycol in analogy to the synthesis of the building blocks **5** and **6**. Once again problems were encountered with anion exchange during chromatography and the desired Ru^{II} complexes **10a**–**10c** and **11a**–**11d** could only be isolated in good yields of 65–81% after re-precipitation and recrystallization (Table 5). There was no significant difference in the rate and yield of complexation between the less sterically hindered 5-substituted bipyridines **8c**,**9c** and the more hindered 6-substituted bipyridines **8b**,**9b**.

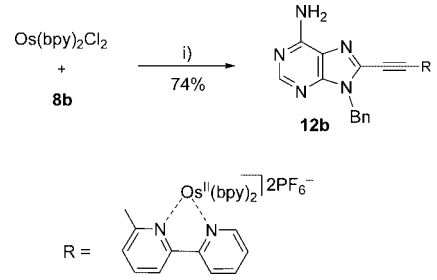


Scheme 5. Complexations of the conjugates: i) 1. ethylene glycol, 150 °C, 2 h; 2. saturated aqueous solution of NH_4PF_6.

In order to compare the chemical and electrochemical properties of the Ru^{II} complexes with the corresponding Os^{II} we have prepared the Os complex **12b** (Scheme 6), using the complexation of **8b** with $Os(bipy)_2Cl_2$[32] under the same conditions as for Ru complexes. In this case the Os complex **12b** was obtained in good yield of 74%.

Table 5. Complexation of conjugates.

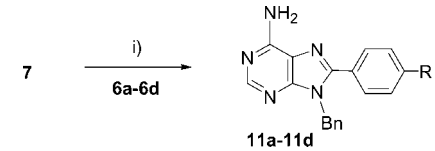
Entry	Conjugate	Complex	Yield [%]
1	**8a**	**10a**	69
2	**8b**	**10b**	80
3	**8c**	**10c**	75
4	**9a**	**11a**	72
5	**9b**	**11b**	74
6	**9c**	**11c**	81
7	**9d**	**11d**	65



Scheme 6. Synthesis of the Os^{II} complex: i) 1. ethylene glycol, 150 °C, 2 h; 2. saturated aqueous solution of NH_4PF_6.

Synthesis of Adenine–Complex Conjugates by Direct Cross-Coupling

The second approach to the title conjugates **10** and **11** was based on direct cross-coupling reactions of **7** with Ru complex containing building blocks **5** and **6**. At first we tried to apply the same cross-coupling conditions utilized in the synthesis of ligand conjugates **8** and **9** (reactions in DMF, $Pd(dppf)Cl_2$ as catalyst and CuI, Et_3N for the terminal alkynes and K_2CO_3 for the boronic acids). Unfortunately, none of these reactions proceeded and partial decomposition of the starting materials was observed under prolonged reaction times. Therefore, we tried to apply the aqueous-phase cross-coupling reactions that have been recently successfully used in the attachment of aryl groups[33] including hydrophilic amino acid residues[34] to the 8-position of purine nucleosides. The cross-coupling reactions of **7** with boronic acids **6a**–**6d** using $Pd(OAc)_2$ as the catalyst, water soluble $P(Ph–SO_3Na)_3$ ligand and Cs_2CO_3 as a base in a mixture of acetonitrile/water (1:1) proceeded relatively well to give the desired products **11a**–**11d** in moderate yields 24–63% (Scheme 7, Table 6). Application of the aqueous conditions for the Sonogashira cross coupling reactions of **7** with acetylenes **5** was not successful. In conclusion, direct cross-coupling of 8-bromoadenine with Ru complex-containing organometallics is possible with the application of aqueous-phase conditions for attachment of aryl groups by the Suzuki–Miyaura reaction. Presumably, due to the relatively mild conditions and tolerance to unprotected functional groups,[34] this could be the method of choice for direct labeling of nucleotides and oligonucleotides with complexes containing phenylene linkers but not for the attachment of acetylenes.



Scheme 7. Cross coupling reactions with complexes. i) $[Pd(OAc)_2]$ (10 mol-%), $P(Ph-SO_3Na)_3$ (50 mol-%), Cs_2CO_3 (3 equiv.), CH_3CN/H_2O (1:1).

Table 6. Cross coupling reactions with Ru complexes.

Entry	Ru complex	Product	Yield [%]
1	**6a**	**11a**	40
2	**6b**	**11b**	24
3	**6c**	**11c**	53
4	**6d**	**11d**	63

Crystal Structures

Complexes **5b** and **10b** gave monocrystals suitable for X-ray diffraction. However, the crystals of **10b** diffracted rather poorly, which resulted in weak reflections. Consequently, the precision of the structure determination is not excellent, but it still describes reasonably well all the main structural features of this Ru complex. The structures of complexes **5b** and **10b** are depicted in Figure 1.

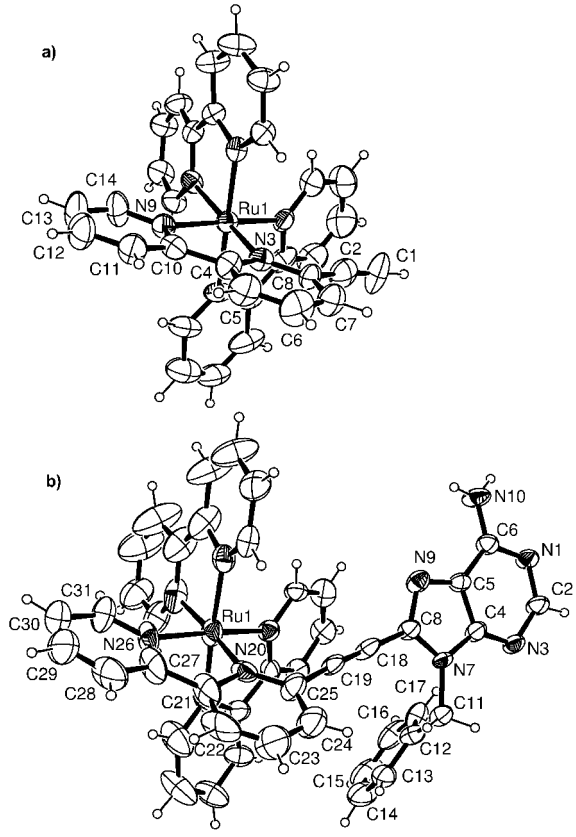


Figure 1. ORTEP diagram of **5b** (a) and **10b** (b) (thermal ellipsoids drawn at the 30% probability level).

The Ru–N bond lengths of **10b** and **5b** are generally comparable to those of the parent ion $[Ru(bpy)_3]^{2+}$ (2.055 Å),[35] with the exception of the shorter bond Ru1–N50 [**10b**,

2.013(9) Å], Ru1–N33 [**5b**, 2.097(10) Å] and especially the significantly elongated bonds Ru1–N20 [**10b**, 2.109(9) Å] and the corresponding bond Ru1–N3 [**5b**, 2.110(6) Å]. This elongation is caused by the steric hindrance of the adjacent 9-benzyl-8-ethynyladenine (**10b**) or acetylene (**5b**) groups and seems to be typical for all structures containing any group attached to the C25 carbon that were found in the Cambridge Structural Database.[36] The structure of the central octahedron in both complexes is more or less the same, but the bipyridine units are slightly shifted due to the presence of substituents (see Figure S1 in the Supporting Information).

Electrochemistry

The conjugates **10a**–**10c**, **11a**–**11d**, and **12b** involve several electrochemically active centers, including the adenine moiety (potentially reducible at mercury and oxidizable at carbon electrodes[37]), triple bond of the ethynyl bridge (reducible at mercury electrodes[38]) as well as the ruthenium or osmium chelates (expected to undergo reversible one-electron Ru^{II}/Ru^{III} or Os^{II}/Os^{III} oxidation[39]). Using the hanging mercury drop electrode (HMDE), we observed cathodic signals attributable to the adenine (with all conjugates) as well to the triple bond (with **10a**–**10c** and **12b**, see Table 7). Potentials of 9-benzyladenine reduction were influenced by the substituents to some extent. In general, the adenine moiety was reduced more easily in bipyridine conjugates with the phenylene linker than in analogues with the ethynyl linker (**10b** vs. **11b** and **10c** vs. **11c**), in the phenanthroline conjugates (**10a** vs. **11a**), the opposite was true. The potential of the adenine signal in the bipyridine conjugates was also influenced by the position of the bipyridine substitution, being markedly more negative for the 5-substituted (**b**) than for 6-substituted (**c**) bipyridines. The ethynyl linker produced a single reduction peak in conjugates of phenanthroline (**a**) and 6-substituted bipyridine (**b**). In the 5-substituted bipyridine compounds (**a**) involving the acetylene moiety, two cathodic peaks were observed. As expected,[38] reduction of the triple bond was easier in the conjugate **10c** (involving disubstituted acetylene) than in the building block **5c** (monosubstituted acetylene).

With respect to the prospective utilization of the conjugates as DNA labels, our attention was focused mainly on processes related to the metal complexes. Cyclic voltammetry (CV) at a carbon paste electrode (CPE) revealed couples of reversible redox signals for all ruthenium complexes at potentials around +1.2 V (not shown). The CV peaks were, however, relatively poorly developed due to their occurrence at rather positive potentials close to background discharge. We therefore chose square-wave voltammetry (SWV), a technique offering better separation of signals from the background,[40] in further experiments. Peak potentials due to the ruthenium complexes resulting from these measurements are summarized in Table 7. All compounds involving the bipyridine ligand covalently linked to the adenine moiety, regardless of the bridge type or position of the bipyridine substitution, produced net SWV peaks at +1.21 V (compounds **10b**, **10c**, **11b**, and **11c**; in Figure 2 shown for

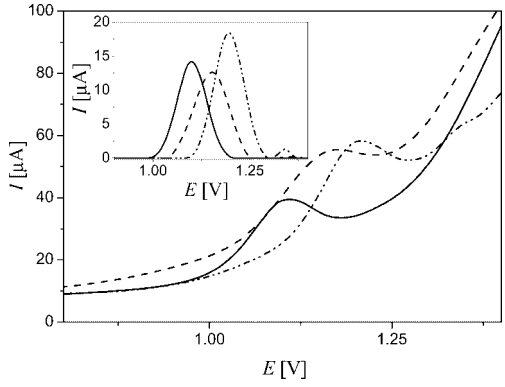


Figure 2. Sections of square-wave voltammograms of unsubstituted complex $[Ru(bipy)_3]^{2+}$ (solid), compound **5b** (dash) and compound **10b** (dash-dot-dot) measured at the CPE. Inset shows the same voltammograms after baseline subtraction.

Table 7. Potentials of electrochemical signals of the synthesized compounds.

	Oxidation at PGE		Reduction at HMDE		
	E^{net} [a] [V]	ΔE^{net} [b] [mV]	E^{ade} [c] [V]	ΔE^{ade} [d] [mV]	E^{eth} [e] [V]
$[Ru(bipy)_3]^{2+}$	1.095	0	–	–	–
9-benzyladenine	–	–	–1.362	0	–
5c	1.175	80	–	–	–1.263; –1.362
10c	1.210	115	–1.355	7	–0.810; –0.886
10b	1.210	115	–1.414	–52	–1.062
6c	1.165	70	–	–	–
11c	1.210	115	–1.316	46	–
11b	1.210	115	–1.378	–16	–
10a	1.220	–	–1.372	–10	–0.950
11a	1.215	–	–1.326	36	–
11d	1.265	–	–	–	–
12b	0.790	–	–1.390	–28	–1.024

[a] E^{net} is the apparent redox potential of the Ru^{II}/Ru^{III} or Os^{II}/Os^{III} couple measured on the net square-wave voltammogram (CPE). [b] ΔE^{net} is the potential shift relative to unsubstituted $[Ru(bipy)_3]^{2+}$ complex. [c] E^{ade} is the potential of reduction of the 9-benzyladenine moiety in the conjugate measured by linear scan voltammetry (HMDE). [d] ΔE^{ade} is the potential shift relative to unsubstituted 9-benzyladenine. [e] E^{eth} are potentials of peaks related to reduction of the ethynyl linker triple bond (HMDE). All potentials are measured against a Ag/AgCl/3 M KCl reference electrode.

10b). Apparent redox potentials of complexes with covalently coupled phenanthroline ligands **10a**,**11a** were slightly more positive (+1.220 or +1.215 V, respectively) than those of the bipyridine analogues, while the complex **11d** (with ruthenium coordinated by two terpyridines) yielded a peak at +1.265 V. The osmium complex **12b** underwent reversible oxidation at +0.79 V, in agreement with a less positive redox potential of the Os^{II}/Os^{III} couple, compared to Ru^{II}/Ru^{III}[39] (not shown).

Compared to unsubstituted $[Ru(bipy)_3]^{2+}$, the apparent redox potentials of compounds **10b–c** and **11b–c** were significantly more positive (see Table 7). This phenomenon can be explained by electron-withdrawing effects of the adenine residue linked via the unsaturated bridges. Reducing electron density at ruthenium results in its more difficult oxidation. Similar effects were recently observed[13] with ferrocenylethyne–adenine conjugates in which the iron oxidation was found to be more difficult, compared to unsubstituted ferrocene or to ferrocene linked to the adenine moiety via a saturated bridge, due to electronic coupling between ferrocene and adenine via the alkyne bridge. Influence of conjugated unsaturated substituents on electrochemical properties of the ruthenium complex is evident from the series $[Ru(bipy)_3]^{2+}$–**5b**–**10b** (Table 7, Figure 2) and series $[Ru(bipy)_3]^{2+}$–**6b**–**11b** (Table 7). The ethynyl (**5b**) or phenylene (**6b**) groups themselves cause shifts in the redox potential of the ruthenium complex by 80 or 70 mV, respectively, towards more positive values. Attachment of the purine moiety offering further electronic conjugation resulted in higher positive potential shifts (about 115 mV relative to the $[Ru(bipy)_3]^{2+}$ for both **10b** and **11b** as well as **10c** and **11c** which involve 5-substituted bipyridine instead of 6-substituted bipyridine present in the series **b**). Similar shifts of the Ru^{II}/Ru^{III} redox potential were observed also with compounds in which the adenine moiety was replaced by another aromatic system (*p*-tolyl, not shown). More details about the electrochemistry of the conjugates and/or the building blocks at carbon or mercury electrodes will be published elsewhere.

Quantum Chemical Calculations of the Redox Potentials of the Studied Complexes

DFT calculations have been performed in order to verify the potential utilization of these methods for theoretical prediction of redox potentials of the title complexes. Listed in Table 8 are the calculated values of redox potentials for the synthesized compounds, using Equations (1) and (2) (see Experimental Section). It can be seen that the calculated and experimental results are in good agreement (with a standard deviation of 130 mV). The systematic (mean) error of –60 mV can be attributed to several factors: (i) neglect of spin-orbit coupling (SOC) in the nonrelativistic treatment which has been estimated to account for approximately +30 mV on the model $Ru^{2+/3+}$ complex[41] (this effect is by one order of magnitude greater for Os^{II} complexes, viz. Table 8, and has been calculated to account for 200 mV on a small model complex),[41] (ii) the single reference treatment of the triple (quasi)degenerate ground state in $[Ru(bipy)_3]^{3+}$ complexes, (iii) the uncertainty in the absolute potential of SHE, (iv) the difference between the theoretical calculations and the experimental setup (presence of counterions and the adsorption of complexes on the electrode).

Table 8. The calculated redox potentials of the synthesized compounds (vs. Ag/AgCl/3 M KCl reference electrode).

	Oxidation $Ru^{2+/3+}$ ($Os^{2+/3+}$)			Reduction
	E^0_{calc} [V][a]	ΔE^0_{calc} [mV][b]	ΔE^0_{exp} [mV][c]	E^0_{calc} [V]
$[Ru(bipy)_3]^{2+}$	1.082a	0	0	–1.450
5c	1.074	–8	80	–1.557
10c	1.183	101	115	–1.144
10b	1.238	156	115	–1.357
6c	1.368	286	70	–1.429
11c	0.987	–95	115	–1.292
11b	1.130	48	115	–1.411
10a	1.165	83	(125)	–1.234
11a	1.189	107	(120)	–1.484
11d	0.960	–122	(170)	–1.389
12b	1.127	45	(–305)	–1.498

[a] E^0_{calc} were calculated using the B3LYP/def2-TZVP//PBE/def2-SVP energies, PBE/def2-SV(P) frequencies, ideal gas approximation for thermodynamic functions, the COSMO solvation model, 4.34 V as the absolute potential of the SHE, and 0.207 V as the potential of the reference electrode used in the electrochemical measurements (Table 7). [b] $\Delta E^0_{calc/exp}(X) = E^0_{calc/exp}(X) - E^0_{calc/exp}([Ru(bipy)_3]^{2+})$. [c] Experimental data taken from Table 7; values in parentheses have not been presented in Table 7 (showing effects of conjugated unsaturated substituents on the $[Ru(bipy)_3]^{2+/3+}$ redox potential) because compounds **10a**, **11a**, **11d** and **12b** involve complexes of different types.

To account for these systematic errors, we further discuss the values of ΔE^0 [$\Delta E^0(X) = E^0(X) - E^0([Ru(bipy)_3]^{2+})$], though it can be noted that an excellent agreement between the calculated and experimental values of $E^0([Ru(bipy)_3]^{2+})$ has been obtained (E^0_{calc} = 1.082 V vs. E^0_{exp} = 1.095 V).

Considering that 100 mV corresponds to ca. 10 kJ mol^{-1}, we can see that most of the calculated values are within an error bar of the quantum chemical methods. Specifically, the values of ΔE^0 for four studied complexes (**10c**, **11b**, **10a**, **11a**) are within 42 mV of the experimental values, which can be considered an excellent agreement between theory and experiment. Another two complexes, **5c** and **11b**, deviate by 88 and 67 mV, respectively, which is still a very good agreement. The largest errors are found for **6c** (+216 mV), **11c** (–210 mV), and **11d** (–292 mV). However, an analysis of the spin densities have shown that for the latter two complexes, the unpaired electron is not localized on the Ru atom (Figure 3), but rather resides on the adenine moiety. This finding explains the observed discrepancy between the calculations and experimental data. Whether this is an artifact of the DFT method or an observable phenomenon is a subject of subsequent study.[41] As mentioned above, the discrepancy of +350 mV for **12b** ($Os^{2+/3+}$ complexes) can be mostly attributed to spin-orbit coupling effects, which are not included in the DFT calculations. This is a general effect exercised in octahedral $Os^{2+/3+}$ complexes and may ex-

plain the lower redox potential of the $Os^{2+/3+}$ pair (compared to $Ru^{2+/3+}$).

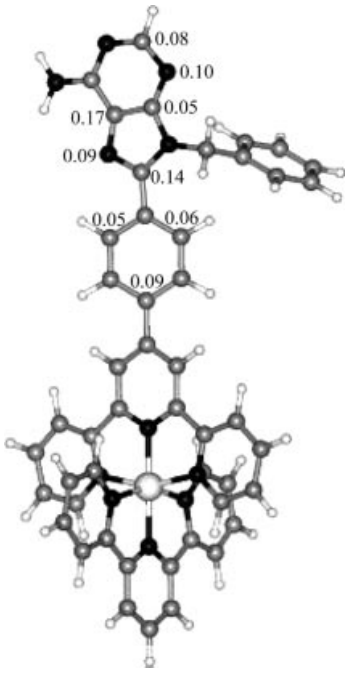


Figure 3. The equilibrium geometry of **11d**. Denoted are the calculated spin densities for the oxidized Ru^{III} complex demonstrating that the unpaired electron is localized on the adenine moiety rather than on the Ru atom.

Structurally, we can observe only very small geometry changes associated with the $Ru^{2+/3+}$ oxidation and $Ru^{2+/1+}$ reduction. The most important parameters, the Ru–N distances, are shortened by ca. 0.004 Å upon the reduction and lengthened by ca. 0.006 Å upon oxidation. All the values of the Ru–N distances are summarized in Table S1 (see supporting information).

Also listed in Table 8 are the values of redox potentials for the reduction of the studied compounds. The interpretation of these values, i.e., the assignment of the formal redox states to subsystems in the studied complexes, is more complicated. In general, the calculated data are in the range of the experimental values: (–1.144, –1.557 V) vs. (–0.810, –1.414 V). The spin densities are strongly delocalized on the ligands, which suggests that these redox potential values do not refer to the reduction of the metal center, in agreement with the experimental data (Table 7).

In summary, it has been demonstrated that the theoretical calculations can satisfactorily reproduce the experimental data and can serve for prediction of redox potentials of new molecules with a reasonable level of fidelity. However, the anticipated differences in redox potential should be higher than ca. 100 mV (which has been shown as an error bar of the method), and care must be taken when interpreting the calculated data, i.e., to formally assign oxidation states and check whether they correspond to the experimentally observed process.

Biological Activity

HCV chronically infects about 170 million people and the only approved therapy (a combination of interferon-α and ribavirin) is expensive and effective in only 50–60% of patients infected with HCV genotype 1. Development of effective antivirals for combating this pathogen is of great interest within pharmaceutical research. Common nucleoside *anti*-HCV agents are intracellularly phosphorylated to their triphosphates and then inhibit viral RNA synthesis mediated by the HCV RNA-dependent RNA polymerase.[42] Apart from that, there are numerous non-nucleoside inhibitors of this enzyme under current study.[43] Ru complexes of oligopyridine ligands are known to bind to DNA and thus exert antitumor and antiparasitic activity.[44] Some other types of Ru complexes are inhibitors of protein kinases.[45] To the best of our knowledge, neither oligopyridine ligands nor their transition metal complexes have been reported to possess *anti*-HCV activity. Therefore, we have also studied the biological activity (cytostatic effect and *anti*-HCV activity) of the model adenine-ligand and adenine complex conjugates.

Selected compounds and their respective Ru or Os complexes were evaluated in the HCV subgenomic replicon assay and their activity is presented in Table 9.[46] In general, the Ru and Os complex-based inhibitors displayed similar or weaker antiviral activity than their corresponding precursors with the exception of **10c**. However, analog **10c** despite improved antiviral activity compared to its precursor **8c** also showed less than 5-fold selectivity thereby confounding further interpretation of the data. Two of the most potent compounds were the structurally related analogs **9a** and **8a** in which the main structural difference is the bridging group between the purine and metal chelating motif

Table 9. Replicon activity and NS5B 1b enzymatic potency of selected compounds.

	Replicon EC_{50}/μM	Huh-7 CC_{50}/μM	NS5B 1b IC_{50}/μM	Ru/Os salt complex	Replicon EC_{50}/μM	Huh-7 CC_{50}/μM
8a[a]	0.73	2	n.d.	**10a**	17	100
8b	5	>50	>2	**10b**	28	cytostatic
8c	>50	>50	n.d.	**10c**	10	50
9a	0.49	0.89	>2	**11a**	27	>100
9b	3.0	14	>2	**11b**	1.0	28
				12b	2.0	32
9c	4.0	50	n.d.	**11c**	11	cytostatic
9d	0.23	>50	>2	**11d**	28	23

[a] Compound required low pH for dissolution in DMSO; n.d. = not determined.

(alkynyl or phenyl). Unfortunately, both of these analogs also displayed poor selectivity (less than 3-fold). Analog **9d** was the most potent and selective (at least 200-fold) inhibitor in the series.

Several compounds, including **9d**, were tested for inhibition toward HCV NS5B polymerase 1b (Table 9).[47] None of the noncomplexed analogs demonstrated activity up to 2 μM. Because of poor solubility in the assay buffer, inhibitory activity beyond 2 μM could not be measured. Therefore, determination of whether **9d** inhibits HCV NS5B weakly through an allosteric mechanism, or whether it has other cellular or viral targets will require further study.

The in vitro evaluation of the cell growth inhibition was estimated in mouse lymphocytic leukemia L1210 cells (ATCC CCL 219), CCRF-CEM T lymphoblastoid cells (human acute lymphoblastic leukemia, ATCC CCL 119), human promyelocytic leukemia HL-60 cells (ATCC CCL 240), and human cervix carcinoma HeLa S3 cells (ATCC CCL 2.2). Significant cytostatic activity was found only in compounds **8a** and **9d**. Surprisingly, compound **9a** in contrast to Huh-7 hepatocytes does not exert any cytotoxicity at 10 μmol L^{-1}. This discrepancy was rechecked by the analysis of the cell cycle course using flow cytometry. The data revealed that 0.7 μM compound **8a** considerably influences the cell cycle profile, which is characterized by apoptosis inducing activity and reduced proportion of G1 (from 49.4 to 17.5%) and G2/M phases (from 19.7 to 4.9%) compensated by an increase of the S phase (from 30.8 to 77.6%). On the other hand, compound **9a** does not affect the cell cycle pattern even at 2 μM, which represents more than twice the Huh7 CC_{50} value. These results indicate different susceptibilities of various cell lines towards the model adenine ligands (Table 10).

Table 10. Cytostatic activity of selected compounds.

	IC_{50}, μmol L^{-1}			
	L1210	HL60	HeLa S3	CCRF-CEM
8a	0.88 ± 0.06	0.57 ± 0.05	1.10 ± 0.08	1.40 ± 0.10
9d	0.97 ± 0.08	1.40 ± 0.08	> 20	1.65 ± 0.11

Conclusions

9-Benzyladenine derivatives bearing Ru complexes in position 8 were prepared as model compounds for electrochemical DNA labeling. Two strategies of synthesis have been explored: (i) synthesis of adenine derivatives of bipyridine ligands followed by complexation with Ru or (ii) cross-coupling of 8-bromoadenine derivatives with boronic acids derived from Ru complexed ligands. None of the two approaches is truly efficient but, due to the relatively harsh conditions, difficult separation, and moderate yields of the complexation in the first approach, the second approach seems to be more suitable for applications in labile nucleosides or oligonucleotides despite its moderate yields. The new Ru-containing acetylene or boronate building blocks **5** and **6** will certainly be useful in labeling of other types of molecules by a direct cross-coupling.

The model compounds have been systematically studied by several methods. Electrochemistry revealed both oxidation and reduction patterns with relatively minor substituent effects. Quantum-chemical calculations were able to predict the values of redox potentials with the precision of ca. 100 mV, which might not always be sufficient for the prediction of differences in redox potentials in DNA. Despite these problems, we will continue our efforts in the synthesis of oligonucleotide probes bearing such transition metal complexes. The most interesting (and rather unexpected) finding was the significant antiviral activity against HCV of the adenine–oligopyridine conjugates, which is unfortunately accompanied by considerable cytotoxicity. Nevertheless, these compounds represent a completely new structural lead in the search for novel antiviral agents.

Experimental Section

General Remarks: All cross-coupling reactions were performed under argon. Et_3N was degassed in vacuo and stored over molecular sieves under argon. Compounds **1a** [ref.[17]], **1b**, **1c**, **2b**, **2c** [ref.[18]], **3a** [ref.[19]], and **3d** [ref.[20]] were prepared according to literature procedures. Other chemicals were purchased from commercial suppliers and used as received. NMR spectra were recorded with Bruker Avance 500 (500 MHz for ^1H and 125.8 MHz for ^{13}C) and Bruker Avance 400 (^1H at 400, ^{13}C at 100.6 MHz) spectrometers in $CDCl_3$, [D_6]DMSO, or [D_6]acetone. Chemical shifts (in ppm, δ scale) were referenced to TMS (for ^1H NMR spectra in $CDCl_3$) and/or to the solvent signal ($CDCl_3$ δ = 7.26 ppm for ^1H NMR and δ = 77.0 ppm for ^{13}C NMR; [D_6]DMSO for ^1H NMR (δ = 2.5 ppm) and for ^{13}C NMR (δ = 39.7 ppm), [D_6]acetone for ^1H NMR (δ = 2.05 ppm) and for ^{13}C NMR (δ = 29.8 ppm, CD_3 group), coupling constants J are given in Hz. The assignment of proton and carbon signals was based on H,H-COSY, H,C-HSQC, and H,C-HMBC experiments. Melting points were determined on a Kofler block and are uncorrected. Mass spectra were measured on a ZAB-EQ (VG Analytical) spectrometer using FAB (ionization by Xe, accelerating voltage 8 kV, glycerol matrix) or on a LCQ classic spectrometer using electrospray ionization (ESI). X-ray crystallographic analysis of single crystals of **10b** (red, 0.03 × 0.14 × 0.27 mm) and **5b** (red, 0.08 × 0.31 × 0.40 mm) was performed with Xcalibur X-ray diffractometer with Cu-K_α (λ = 1.54180 Å), data collected at 150 K (**10b**) and 295 K (**5b**).

2-Ethynyl-1,10-phenanthroline (2a): A solution of 2-chloro-1,10-phenanthroline (0.5 g, 2.3 mmol), bis(triphenylphosphane)palladium dichloride (160 mg, 0.23 mmol), CuI (44 mg, 0.23 mmol), Et_3N (1 mL, 7.2 mmol), and (trimethylsilyl)acetylene (0.7 mL, 5.16 mmol) in DMF (5 mL) was stirred at 60 °C under argon for 12 h. The solvent was removed under reduced pressure, the residue was dissolved in $CHCl_3$, and washed with a saturated solution of EDTA. The organic layers were collected and the solvents evaporated to dryness. The crude intermediate was diluted in methanol (5 mL) and K_2CO_3 (2.17 mmol, 300 mg) was added. The mixture was stirred for 6 h at room temperature. After evaporation of the solvent under reduced pressure, the crude product was purified by column chromatography (ethyl acetate/hexanes, 1:1) to give 285 mg of **1a** (60%) as brownish crystals with m.p. 52–58 °C. ^1H NMR (400 MHz, $CDCl_3$): δ = 3.27 (s, 1 H, HC≡C–), 7.65 (dd, $J_{8,7}$ = 8.1, $J_{8,9}$ = 4.4, 1 H, 8-H), 7.77 (d, $J_{5,6}$ = 8.8, 1 H, 5-H), 7.79 (d, $J_{3,4}$ =

8.2, 1 H, 3-H), 7.81 (d, $J_{6,5}$ = 8.8, 1 H, 6-H), 8.22 (d, $J_{4,3}$ = 8.2, 1 H, 4-H), 8.25 (dd, $J_{7,8}$ = 8.1, $J_{7,9}$ = 1.8, 1 H, 7-H), 9.23 (dd, $J_{9,8}$ = 4.4, $J_{9,7}$ = 1.8, 1 H, 9-H) ppm. ^{13}C NMR (100.6 MHz, $CDCl_3$): δ = 78.43 (H*C*≡C–), 83.56 (–*C*≡CH), 123.31 (C-8), 126.04 (C-5), 126.54 (C-3), 127.43 (C-6), 127.91 (C-4a), 128.89 (C-6a), 135.95 (C-7), 136.12 (C-4), 142.56 (C-2), 145.66 (C-10a), 146.28 (C-10b), 150.70 (C-9) ppm. FAB MS: *m*/*z* (%) = 205 (100) [M$^+$ + H]. HRMS (FAB): for $C_{14}H_9N_2$ calcd. 205.0766; found 205.0769. IR ($CHCl_3$): $\tilde{\nu}$ = 3304, 3049, 2968, 2835, 1505, 853 cm^{-1}. $C_{14}H_8N_2{\cdot}H_2O$ (222.24): calcd. C 75.66, H 4.54, N 12.6; found C 75.71, H 4.88, N 12.3.

6-(4-Bromophenyl)-2,2′-bipyridine (3b): A mixture of 6-bromo-2,2′-bipyridine (1 g, 4.25 mmol), (4-bromophenyl)boronic acid (1.28 g, 5.3 mmol, 1.5 equiv.), K_2CO_3 (1.18 g, 8.5 mmol, 2 equiv.), and $Pd(PPh_3)_4$ (245 mg, 0.21 mmol, 5 mol-%) in toluene (5 mL) was stirred under argon for 8 h at 100 °C. After evaporation of the solvent the residue was dissolved in chloroform, washed with saturated solution of EDTA and dried with $MgSO_4$. The product was purified by silica gel column chromatography (ethyl acetate/hexanes, 1:10). The product was obtained as a colorless solid (1.14 g, 86%). ^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.33 (ddd, $J_{5',4'}$ = 7.5, $J_{5',6'}$ = 4.8, $J_{5',3'}$ = 1.2, 1 H, 5′-H), 7.63 (m, 2 H, H^m phenylene), 7.74 (dd, $J_{5,4}$ = 7.8, $J_{5,3}$ = 1.0, 1 H, 5-H), 7.85 (ddd, $J_{4',3'}$ = 8.0, $J_{4',5'}$ = 7.5, $J_{4',6'}$ = 1.8, 1 H, 4′-H), 7.89 (t, $J_{4,5}$ = 7.8, $J_{4,3}$ = 7.8, 1 H, 4-H), 8.03 (m, 2 H, H^o phenylene), 8.39 (dd, $J_{3,4}$ = 7.8, $J_{3,5}$ = 1.0, 1 H, 3-H), 8.60 (dt, $J_{3',4'}$ = 8.0, $J_{3',5'}$ = 1.2, $J_{3',6'}$ = 0.9, 1 H, 3′-H), 8.70 (ddd, $J_{6',5'}$ = 4.8, $J_{6',4'}$ = 1.8, $J_{6',3'}$ = 0.9, 1 H, 6′-H) ppm. ^{13}C NMR (125.8 MHz, $CDCl_3$): δ = 119.64 (C-3), 120.01 (C-5), 121.25 (C-3′), 123.45 (C^p phenylene), 123.84 (C-5′), 128.49 (C^o phenylene), 131.85 (C^m phenylene), 136.88 (C-4′), 137.84 (C-4), 138.21 (C^i phenylene), 149.11 (C-6′), 155.23 (C-6), 155.88 (C-2), 156.12 (C-2′) ppm. IR ($CHCl_3$): $\tilde{\nu}$ = 3011, 2985, 1582, 1562, 1454, 1431, 1009, 817, 637 cm^{-1}. FAB MS: *m*/*z* (%) = 311 (100). HRMS (FAB): for $C_{16}H_{12}BrN_2$ calcd. 311.0184; found 311.0179. $C_{16}H_{11}BrN_2$ (311.18): calcd. C 61.76, H 3.56, N 9.00; found C 61.82, H 3.61, N 9.05.

5-(4-Bromophenyl)-2,2′-bipyridine (3c): A mixture of 5-bromo-2,2′-bipyridine (1 g, 4.25 mmol), (4-bromophenyl)boronic acid (1.03 g, 5.1 mmol, 1.2 equiv.), K_2CO_3 (1.18 g, 8.5 mmol, 2 equiv.), and $Pd(PPh_3)_4$ (245 mg, 0.21 mmol, 5 mol-%) in DMF (5 mL) was stirred under argon for 8 h at 100 °C. After evaporation of the solvent the residue was dissolved in chloroform, washed with saturated solution of EDTA, and dried with $MgSO_4$. The product was purified by silica gel column chromatography (ethyl acetate/hexanes, 1:10). The product was obtained as a colorless solid (780 mg, 59%), which gave analytical data identical to those previously reported.[20]

General Procedure for Preparation of the Pinacolboronates. Method A: A bromo derivative (**3a/3d**) (3.5 mmol), bis(pinacolato)diboron (4.2 mmol, 1.2 equiv.), $PdCl_2$ (0.175 mmol, 5 mol-%), dppf (0.175 mmol, 5 mol-%), and KOAc (5.25 mmol, 1.5 equiv.) were combined and stirred under argon in dry dioxane at 80 °C until the TLC showed complete consumption of the starting material. After evaporation of the solvent the residue was dissolved in chloroform, washed with a saturated solution of EDTA and purified by silica gel column chromatography (ethyl acetate/hexanes).

Pinacol [4-(1,10-Phenanthroline-3-yl)phenyl]boronate (4a): The product was obtained as brownish crystals in 60% yield (Method A). M.p. 192–193 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 1.39 (s, 12 H, CH_3 dioxaborolane), 7.65 (dd, $J_{8,7}$ = 8.0, $J_{8,9}$ = 4.4, 1 H, 8-H), 7.79 (d, $J_{6,5}$ = 8.8, 1 H, 6-H), 7.83 (d, $J_{5,6}$ = 8.8, 1 H, 5-H), 7.99 (m, 2 H, H^m phenylene), 8.15 (d, $J_{3,4}$ = 8.4, 1 H, 3-H), 8.27 (dd, $J_{7,8}$ = 8.0, $J_{7,9}$ = 1.7, 1 H, 7-H), 8.32 (d, $J_{4,3}$ = 8.4, 1 H, 4-H), 8.36 (m, 2 H, H^o phenylene), 9.26 (dd, $J_{9,8}$ = 4.4, $J_{9,7}$ = 1.7, 1 H, 9-H) ppm. ^{13}C NMR (100.6 MHz, $CDCl_3$): δ = 24.92 (CH_3 dioxaborolane), 83.88 (C dioxaborolane), 120.86 (C-3), 122.89 (C-8), 126.38 and 126.40 (C-5 and C-6), 127.14 (C^o phenylene), 127.73 (C-4a), 129.08 (C-6a), 135.22 (C^m phenylene), 136.14 (C-7), 136.83 (C-4), 141.94 (C^i phenylene), 146.13 (C-10b), 146.42 (C-10a), 150.45 (C-9), 157.36 (C-2) ppm; C^p phenylene signal not observed. FAB MS: *m*/*z* (%) = 282.1 (70), 382.2 (100) [M$^+$]. HRMS (FAB): for $C_{24}H_{24}BN_2O_2$ calcd. 383.1931; found 383.1924. IR ($CHCl_3$): $\tilde{\nu}$ = 3010, 2981, 1610, 1522, 1360, 1144, 1089, 1017, 858, 842, 662, 650 cm^{-1}. $C_{24}H_{23}BN_2O_2{\cdot}1/3H_2O$ (400.28): calcd. C 74.53, H 6.12, N 7.24; found C 74.74, H 6.07, N 6.99.

Pinacol [4-(2,2′-Bipyridin-6-yl)phenyl]boronate (4b): The product was obtained as white crystals in 86% yield (Method A). M.p. 121–123 °C. ^{1}H NMR (500 MHz, $CDCl_3$): δ = 1.38 (s, 12 H, CH_3 dioxaborolane), 7.33 (ddd, $J_{5',4'}$ = 7.5, $J_{5',6'}$ = 4.8, $J_{5',3'}$ = 1.2, 1 H, 5′-H), 7.81 (dd, $J_{5,4}$ = 7.8, $J_{5,3}$ = 1.1, 1 H, 5-H), 7.86 (td, $J_{4',3'}$ = 8.0, $J_{4',5'}$ = 7.5, $J_{4',6'}$ = 1.8, 1 H, 4′-H), 7.89 (t, $J_{4,5}$ = 7.8, $J_{4,3}$ = 7.8, 1 H, 4-H), 7.95 (m, 2 H, H^m phenylene), 8.16 (m, 2 H, H^o phenylene), 8.39 (dd, $J_{3,4}$ = 7.8, $J_{3,5}$ = 1.1, 1 H, 3-H), 8.64 (dt, $J_{3',4'}$ = 8.0, $J_{3',5'}$ = 1.2, $J_{3',6'}$ = 1.0, 1 H, 3′-H), 8.70 (ddd, $J_{6',5'}$ = 4.8, $J_{6',4'}$ = 1.8, $J_{6',3'}$ = 1.0, 1 H, 6′-H) ppm. ^{13}C NMR (125.8 MHz, $CDCl_3$): δ = 24.89 (CH_3 dioxaborolane), 83.88 (C dioxaborolane), 119.57 (C-3), 120.58 (C-5), 121.34 (C-3′), 123.75 (C-5′), 126.13 (C^o phenylene), 135.17 (C^m phenylene), 136.89 (C-4′), 137.67 (C-4), 141.81 (C^i phenylene), 149.04 (C-6′), 155.80 (C-2), 156.23 (C-6), 156.31 (C-2′) ppm; C^p phenylene signal not observed. FAB MS: *m*/*z* (%) = 258.1 (65), 358.2 (100) [M$^+$]. HRMS (FAB): for $C_{22}H_{24}BN_2O_2$ calcd. 359.1931; found 359.1938. IR ($CHCl_3$): $\tilde{\nu}$ = 3010.2998, 2983, 1611, 1566, 1430, 1391, 1361, 1321, 1144, 1088, 1018, 859, 662 cm^{-1}. $C_{22}H_{23}BN_2O_2$ (358.24): calcd. C 73.76, H 6.47, N 7.82; found C 73.58, H 6.47, N 7.60.

Pinacol [4-(2,2′-Bipyridin-5-yl)phenyl]boronate (4c): The product was obtained as white crystals in 91% yield (Method A) which gave analytical data identical to those previously reported.[23] ^{1}H NMR (400 MHz, $CDCl_3$): δ = 1.38 (s, 12 H, CH_3 dioxaborolane), 7.33 (ddd, $J_{5',4'}$ = 8.0, $J_{5',6'}$ = 4.8, $J_{5',3'}$ = 1.2, 1 H, 5′-H), 7.67 (m, 2 H, H^o phenylene), 7.84 (td, $J_{4',3'}$ = $J_{4',5'}$ = 8.0, $J_{4',6'}$ = 1.9, 1 H, 4′-H), 7.94 (m, 2 H, H^m phenylene), 8.05 (dd, $J_{4,3}$ = 8.3, $J_{4,6}$ = 2.4, 1 H, 4-H), 8.45 (dt, $J_{3',4'}$ = 8.0, $J_{3',5'}$ = 1.2, $J_{3',6'}$ = 1.0, 1 H, 3′-H), 8.48 (dd, $J_{3,4}$ = 8.3, $J_{3,6}$ = 0.9, 1 H, 3′-H), 8.71 (ddd, $J_{6',5'}$ = 4.8, $J_{6',4'}$ = 1.9, $J_{6',3'}$ = 1.0, 1 H, 6′-H), 8.94 (dd, $J_{6,4}$ = 2.4, $J_{6,3}$ = 0.9, 1 H, 6-H) ppm. ^{13}C NMR (100.6 MHz, $CDCl_3$): δ = 24.87 (CH_3 dioxaborolane), 83.95 (C dioxaborolane), 120.96 and 121.10 (C-3 and C-3′), 123.72 (C-5′), 126.32 (C^o phenylene), 135.29 (C-4), 135.52 (C^m phenylene), 136.30 (C-5), 136.95 (C-4′), 140.20 (C^i phenylene), 147.72 (C-6), 149.23 (C-6′), 155.14 (C-2), 155.84 (C-2′) ppm; C^p phenylene signal not observed.

Pinacol [4-(2,2′:6′,2"-Terpyridine-4′-yl)phenyl]boronate (4d): The product was isolated as white crystals in 81% yield (Method A). M.p. 187–196 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 1.39 (s, 12 H, CH_3 dioxaborolane), 7.36 (ddd, $J_{5',4'}$ = 7.5, $J_{5',6'}$ = 4.8, $J_{5',3'}$ = 1.2, 2 H, 5′-H), 7.88 (td, $J_{4',3'}$ = 8.0, $J_{4',5'}$ = 7.5, $J_{4',6'}$ = 1.8, 2 H, 4′-H), 7.92 (m, 2 H, H^o phenylene), 7.96 (m, 2 H, H^m phenylene), 8.68 (dt, $J_{3',4'}$ = 8.0, $J_{3',5'}$ = 1.2, $J_{3',6'}$ = 0.9, 2 H, 3′-H), 8.74 (ddd, $J_{6',5'}$ = 4.8, $J_{6',4'}$ = 1.8, $J_{6',3'}$ = 0.9, 2 H, 6′-H), 8.76 (s, 2 H, 3-H) ppm. ^{13}C NMR (100.6 MHz, $CDCl_3$): δ = 24.93 (CH_3 dioxaborolane), 83.98 (C dioxaborolane), 118.94 (C-3), 121.42 (C-3′), 123.85 (C-5′), 126.59 (C^o phenylene), 135.37 (C^m phenylene), 136.90 (C-4′), 140.98 (C^i phenylene), 149.15 (C-6′), 150.15 (C-4), 155.98 (C-2), 156.26 (C-2′) ppm; C^p phenylene signal not observed. FAB MS: *m*/*z* (%) = 336 (25), 436 (100) [M$^+$ + H]. HRMS (FAB): for

$C_{27}H_{27}BN_3O_2$: calcd. 436.2196; found 436.2187. IR ($CHCl_3$): $\tilde{\nu}$ = 3010, 2983, 1603, 1586, 1469, 1388, 1364, 1144, 1092, 1019, 859, 787, 662 cm^{-1}.

9-Benzyl-8-[(1,10-Phenanthroline-2-yl)ethynyl]adenine (8a): 9-Benzyl-8-bromoadenine (0.5 g, 1.64 mmol), 2-ethynylphenanthroline (402 mg, 1.97 mmol, 1.2 equiv.), $PdCl_2$ (14.5 mg, 0.082 mmol, 5 mol-%), dppf (45.5 mg, 0.082 mmol, 5 mol-%), CuI (16 mg, 0.082 mmol, 5 mol-%), and Et_3N (2 mL, 14.3 mmol) were combined in dry DMF (5 mL) and stirred under argon at 90 °C for 12 h. The solvent was removed under reduced pressure, the residue was dissolved in chloroform, washed with a saturated solution of EDTA, evaporated, and purified by silica gel column chromatography ($CHCl_3$ + 1–10% MeOH). Crystallization from $CHCl_3$ (plus a few drops of MeOH) and heptane gave the product as a yellowish solid (385 mg, 55%). M.p. 288–291 °C. ^{1}H NMR (500 MHz, [D_6]-DMSO): δ = 5.60 (s, 2 H, CH_2), 7.29 (m, 1 H, H^p phenylene), 7.37 (m, 2 H, H^m phenylene), 7.49 (m, 2 H, H^o phenylene), 7.62 (br. s, 2 H, NH_2), 7.83 (dd, $J_{8',7'}$ = 8.1, $J_{8',9'}$ = 4.3, 1 H, 8′-H), 8.05 (d, $J_{5',6'}$ = 8.8, 1 H, 5′-H), 8.06 (d, $J_{3',4'}$ = 8.3, 1 H, 3′-H), 8.09 (d, $J_{6',5'}$ = 8.8, 1 H, 6′-H), 8.27 (s, 1 H, H-2), 8.54 (dd, $J_{7',8'}$ = 8.1, $J_{7',9'}$ = 1.8, 1 H, 7′-H), 8.63 (d, $J_{4',3'}$ = 8.3, 1 H, 4′-H), 9.15 (dd, $J_{9',8'}$ = 4.3, $J_{9',7'}$ = 1.8, 1 H, 9′-H) ppm. ^{13}C NMR (125.8 MHz, [D_6]DMSO): δ = 46.61 (CH_2), 78.45 (pur-*C*≡C), 94.32 (phen-*C*≡C), 119.45 (C-5), 124.08 (C-8′), 126.44 and 126.63 (C-3′, C-5′), 127.98 (C^o phenylene), 128.08 (C^p phenylene), 128.46 (C-4a′), 128.52 (C-6′), 128.99 (C^m phenylene), 129.12 (C-6a′), 132.41 (C-8), 136.57 (C-7′), 136.68 (C^i phenylene), 137.37 (C-4′), 140.44 (C-2′), 145.02 (C-10a′), 146.03 (C-10b′), 149.65 (C-4), 150.61 (C-9′), 154.57 (C-2), 156.27 (C-6) ppm. FAB MS: *m*/*z* (%) = 428 (25) [M$^+$ + H], 231 (80). HRMS (FAB): for $C_{26}H_{18}N_7$ calcd. 428.1623; found 428.1630. IR (KBr): $\tilde{\nu}$ = 3481, 3413, 3034, 1631, 1572, 1486, 1287, 850, 732 cm^{-1}. UV/Vis (MeOH): λ_{max} (ε) = 364 (24345), 333 (25380), 279 (21220) nm. $C_{26}H_{17}N_7 \cdot 1/2CHCl_3$ (487.15): calcd. C 65.34, H 3.62, N 20.13; found C 65.95, H 3.62, N 20.15.

9-Benzyl-8-[(2,2′-bipyridine-6-yl)ethynyl]adenine (8b): 9-Benzyl-8-bromoadenine (0.5 g, 1.64 mmol), 6-ethynylbipyridine (355 mg, 1.97 mmol, 1.2 equiv.), $PdCl_2$ (14.5 mg, 0.082 mmol, 5 mol-%), dppf (45.5 mg, 0.082 mmol, 5 mol-%), CuI (16 mg, 0.082 mmol, 5 mol-%), and Et_3N (2 mL, 14.3 mmol) were combined in DMF (3 mL) and stirred under argon at 90 °C for 8 h. The workup was performed in the same way as for **8a**. Crystallization of the crude product from $CHCl_3$ (plus a few drops of MeOH)/heptane gave **8b** as a colorless solid (384 mg, 58%). M.p. 242–244 °C. ^{1}H NMR (500 MHz, [D_6]DMSO): δ = 5.44 (s, 2 H, CH_2), 7.29 (m, 1 H, H^p phenylene), 7.35 (m, 2 H, H^m phenylene), 7.47 (m, 2 H, H^o phenylene), 7.52 (ddd, $J_{5'',4''}$ = 7.5, $J_{5'',6''}$ = 4.7, $J_{5'',3''}$ = 1.2, 1 H, 5″-H), 7.62 (br. s, 2 H, NH_2), 7.83 (dd, $J_{5',4'}$ = 7.7, $J_{5',3'}$ = 1.1, 1 H, 5′-H), 8.01 (td, $J_{4'',3''}$ = 8.0, $J_{4'',5''}$ = 7.5, $J_{4'',6''}$ = 1.8, 1 H, 4″-H), 8.09 (t, $J_{4',3'}$ = 8.0, $J_{4',5'}$ = 7.7, 1 H, 4′-H), 8.27 (s, 1 H, H-2), 8.42 (dt, $J_{3'',4''}$ = 8.0, $J_{3'',5''}$ = 1.2, $J_{3'',6''}$ = 1.0, 1 H, 3″-H), 8.49 (dd, $J_{3',4'}$ = 8.0, $J_{3',5'}$ = 1.1, 1 H, 3′-H), 8.73 (ddd, $J_{6'',5''}$ = 4.7, $J_{6'',4''}$ = 1.8, $J_{6'',3''}$ = 1.0, 1 H, 6″-H) ppm. ^{13}C NMR (125.8 MHz, [D_6]DMSO): δ = 46.54 (CH_2), 77.94 (pur-*C*≡C-), 93.58 (bipy-*C*≡C-), 119.31 (C-5), 120.86 (C-3″), 121.55 (C-3′), 125.00 (C-5″), 128.03 (C^o phenylene), 128.16 (C^p phenylene), 128.27 (C-5′), 128.95 (C^m phenylene), 132.40 (C-8), 136.74 (C^i phenylene), 137.78 (C-4″), 138.63 (C-4′), 140.32 (C-6′), 149.62 (C-4), 149.66 (C-6″), 154.33 (C-2″), 154.56 (C-2), 156.27 (C-6), 156.34 (C-2′) ppm. FAB MS: *m*/*z* (%) = 79.1 (100), 187.0 (20), 279.1 (20), 404.2 (10) [M$^+$ + H]. HRMS (FAB): for $C_{24}H_{18}N_7$ calcd. 404.1624; found 404.1628. IR (KBr): $\tilde{\nu}$ = 3430, 3316, 1649, 1559, 1425, 775 cm^{-1}. UV/Vis (MeOH): λ_{max} (ε) = 327 (23755), 282 (15335) nm. $C_{24}H_{17}N_7 \cdot 1/2H_2O$ (421.45): calcd. C 69.89, H 4.40, N 23.77; found C 70.08, H 4.06, N 23.79.

9-Benzyl-8-[(2,2′-bipyridine-5-yl)ethynyl]adenine (8c): 8-Bromo-9-benzyladenine (0.5 g, 1.64 mmol), 5-ethynylbipyridine (355 mg, 1.97 mmol, 1.2 equiv.), $PdCl_2$ (14.5 mg, 0.082 mmol, 5 mol-%), dppf (45.5 mg, 0.082 mmol, 5 mol-%), CuI (16 mg, 0.082 mmol, 5 mol-%), and Et_3N (2 mL, 14.3 mmol) were combined in DMF (5 mL) and stirred under argon at 85 °C for 12 h. The workup was performed in the same way as for **8a**. Crystallization of crude product from $CHCl_3$ (plus a few drops of MeOH)/heptane gave **8c** as a white solid (373 mg, 56%). M.p. 273–278 °C. ^{1}H NMR (400 MHz, [D_6]DMSO): δ = 5.55 (s, 2 H, CH_2), 7.29 (m, 1 H, H^p phenylene), 7.33–7.41 (m, 4 H, H^{m,o} phenylene), 7.51 (ddd, $J_{5'',4''}$ = 7.5, $J_{5'',6''}$ = 4.7, $J_{5'',3''}$ = 1.2, 1 H, 5″-H), 7.60 (br. s, 2 H, NH_2), 8.00 (td, $J_{4'',3''}$ = 7.9, $J_{4'',5''}$ = 7.5, $J_{4'',6''}$ = 1.8, 1 H, 4″-H), 8.22 (dd, $J_{4',3'}$ = 8.3, $J_{4',6'}$ = 2.2, 1 H, 4′-H), 8.25 (s, 1 H, H-2), 8.43 (dt, $J_{3'',4''}$ = 7.9, $J_{3'',5''}$ = 1.2, $J_{3'',6''}$ = 0.9, 1 H, 3″-H), 8.49 (dd, $J_{3',4'}$ = 8.3, $J_{3',6'}$ = 0.9, 1 H, 3′-H), 8.74 (ddd, $J_{6'',5''}$ = 4.7, $J_{6'',4''}$ = 1.8, $J_{6'',3''}$ = 0.9, 1 H, 6″-H), 8.94 (dd, $J_{6',4'}$ = 2.2, $J_{6',3'}$ = 0.9, 1 H, 6′-H) ppm. ^{13}C NMR (125.8 MHz, [D_6]DMSO): δ = 46.39 (CH_2), 83.01 (pur-*C*≡C-), 91.58 (bipy-*C*≡C-), 117.69 (C-5′), 119.28 (C-5), 120.34 (C-3′), 121.25 (C-3″), 125.04 (C-5″), 127.82 (C^o phenylene), 128.06 (C^p phenylene), 128.96 (C^m phenylene), 132.66 (C-8), 136.83 (C^i phenylene), 137.75 (C-4″), 140.36 (C-4′), 149.66 (C-4), 149.78 (C-6″), 152.01 (C-6′), 154.28 (C-2″), 154.44 (C-2), 155.58 (C-2′), 156.21 (C-6) ppm. FAB MS: *m*/*z* (%) = 93 (100), 259 (5), 404.2 (10) [M$^+$ + H]. HRMS (FAB): for $C_{24}H_{18}N_7$ calcd. 404.1624 found 404.1614. IR (KBr): $\tilde{\nu}$ = 3421, 3321, 3032, 1660, 1586, 1325, 1021, 195, 745 cm^{-1}. UV/Vis (MeOH): λ_{max} (ε) = 336 (21515), 257 (5228) nm. $C_{24}H_{17}N_7 \cdot 1H_2O$ (421.45): calcd. C 69.89, H 4.40, N 23.77; found C 70.20, H 4.15, N 23.63.

9-Benzyl-8-[4-(1,10-phenanthroline-2-yl)phenyl]adenine (9a): 9-Benzyl-8-bromoadenine (0.215 g, 0.7 mmol), 4-(1,10-phenanthroline-3-yl)pinacolboronate (270 mg, 0.7 mmol, 1 equiv.), $PdCl_2$ (6 mg, 0.035 mmol, 5 mol-%), dppf (19 mg, 0.035 mmol, 5 mol-%), K_2CO_3 (390 mg, 2.8 mmol, 4 equiv.) were combined in DMF (4 mL) and three drops of water and stirred under argon at 90 °C for 10 h. The workup was performed in the same way as for **8a**. Crystallization of crude product from $CHCl_3$ (plus a few drops of MeOH)/heptane gave **9a** as a yellowish solid (160 mg, 47%). M.p. 286–293 °C. ^{1}H NMR (400 MHz, [D_6]DMSO): δ = 5.62 (s, 2 H, CH_2), 7.07 (m, 2 H, H^o phenylene), 7.24 (m, 1 H, H^p phenylene), 7.30 (m, 2 H, H^m phenylene), 7.46 (br. s, 2 H, NH_2), 7.81 (dd, $J_{8',7'}$ = 8.1, $J_{8',9'}$ = 4.3, 1 H, 8′-H), 7.94 (m, 2 H, H^o phenylene), 8.01 (d, $J_{6',5'}$ = 8.8, 1 H, 6′-H), 8.05 (d, $J_{5',6'}$ = 8.8, 1 H, 5′-H), 8.22 (s, 1 H, H-2), 8.48 (d, $J_{3',4'}$ = 8.5, 1 H, 3′-H), 8.52 (dd, $J_{7',8'}$ = 8.1, $J_{7',9'}$ = 1.8, 1 H, 7′-H), 8.58 (m, 2 H, H^m phenylene), 8.61 (d, $J_{4',3'}$ = 8.5, 1 H, 4′-H), 9.18 (dd, $J_{9',8'}$ = 4.3, $J_{9',7'}$ = 1.8, 1 H, 9′-H) ppm. ^{13}C NMR (100.6 MHz, [D_6]DMSO): δ = 46.46 (CH_2), 118.89 (C-5), 120.42 (C-3′), 123.66 (C-8′), 126.53 (C^o phenylene), 126.59 (C-5′), 127.06 (C-6′), 127.71 (C^p phenylene, C^m phenylene), 127.95 (C-4a′), 128.96 (C^m Ph), 129.10 (C-6a′), 129.38 (C^o phenylene), 130.90 (C^i phenylene), 136.54 (C-7′), 137.24 (C^i Ph), 137.74 (C-4′), 139.98 (C^p phenylene), 145.51 (C-10b′), 145.76 (C-10a′), 149.51 (C-8), 150.24 (C-9′), 151.76 (C-4), 153.15 (C-2), 154.67 (C-2′), 156.13 (C-6) ppm. FAB MS: *m*/*z* (%) = 282 (5%), 390 (8%) 480 (35) [M$^+$]. HRMS (FAB): for $C_{30}H_{22}N_7$ calcd.480.1937 found 480.1945. IR (KBr): $\tilde{\nu}$ = 3438, 3133, 1666, 1292, 1113 cm^{-1}. UV/Vis (MeOH): λ_{max} (ε) = 355 sh (9720), 321 (21792), 303 sh (21792), 233 (26572) nm. $C_{30}H_{21}N_7 \cdot 1H_2O$ (497.55): calcd. C 72.42, H 4.66, N 19.71; found C 72.40, H 4.19, N 19.53.

9-Benzyl-8-[4-(2,2′-bipyridine-6-yl)phenyl]adenine (9b): 9-Benzyl-8-bromoadenine (0.5 g, 1.64 mmol), 4-(2,2′-bipyridin-6-yl)pinacolboronate (600 mg, 1.8 mmol, 1.1 equiv.), $PdCl_2$ (14.5 mg, 0.082 mmol, 5 mol-%), dppf (45.5 mg, 0.082 mmol, 5 mol-%), and

K_2CO_3 (905 mg, 6.56 mmol, 4 equiv.) were combined in DMF (5 mL) and three drops of water and stirred under argon at 90 °C for 8 h. The workup was performed in the same way as for **8a**. Crystallization of crude product from $CHCl_3$ (plus a few drops of MeOH)/heptane gave **9b** as a white solid (401 mg, 53%). M.p. 252–255 °C. ^{1}H NMR (500 MHz, [D$_6$]DMSO): δ = 5.58 (s, 2 H, CH_2), 7.05 (m, 2 H, H^o Ph), 7.24 (m, 1 H, H^p Ph), 7.29 (m, 2 H, H^m Ph), 7.40 (br. s, 2 H, NH_2), 7.49 (ddd, $J_{5'',4''}$ = 7.5, $J_{5'',6''}$ = 4.7, $J_{5'',3''}$ = 1.2, 1 H, 5″-H), 7.88 (m, 2 H, H^o phenylene), 8.00 (td, $J_{4'',3''}$ = 7.9, $J_{4'',5''}$ = 7.5, $J_{4'',6''}$ = 1.8, 1 H, 4″-H), 8.07 (t, $J_{4',5'}$ = 7.9, $J_{4',3'}$ = 7.7, 1 H, 4′-H), 8.13 (br. d, $J_{5',4'}$ = 7.9, 1 H, 5′-H), 8.21 (s, 1 H, H-2), 8.38 (m, 2 H, H^m phenylene), 8.39 (dd, $J_{3',4'}$ = 7.7, $J_{3',5'}$ = 1.1, 1 H, 3′-H), 8.60 (dt, $J_{3'',4''}$ = 7.9, $J_{3'',5''}$ = 1.2, $J_{3'',6''}$ = 0.9, 1 H, 3″-H), 8.72 (ddd, $J_{6'',5''}$ = 4.7, $J_{6'',4''}$ = 1.8, $J_{6'',3''}$ = 0.9, 1 H, 6″-H) ppm. ^{13}C NMR (125.8 MHz, [D$_6$]DMSO): δ = 46.43 (CH_2), 118.88 (C-5), 119.82 (C-3′), 120.97 (C-3″, C-5′), 124.59 (C-5″), 126.45 (C^o Ph), 127.04 (C^m phenylene), 127.66 (C^p Ph), 128.95 (C^m Ph), 129.36 (C^o phenylene), 130.65 (C^i phenylene), 137.20 (C^i Ph), 137.61 (C-4″), 138.80 (C-4′), 139.61 (C^p phenylene), 149.51 (C-6″, C-8), 151.69 (C-4), 153.11 (C-2), 154.56 (C-6′), 155.32 (C-2′, C-2″), 156.10 (C-6) ppm. FAB MS: *m*/*z* (%) = 91 (100), 258 (10), 366 (15), 456 (75%) [M$^+$ + H]. HRMS (FAB): for $C_{28}H_{22}N_7$ calcd.456.1937 found 456.1927. IR (KBr): $\tilde{\nu}$ = 3444, 3062, 1649, 1582, 1429, 755 cm^{-1}. UV/Vis (MeOH): λ_{max} (ε) = 310 (26420), 238 (21188) nm. $C_{28}H_{21}N_7 \cdot H_2O$ (473.53): calcd. C 71.02, H 4.90, N 20.71; found C 71.24, H 4.55, N 20.59.

9-Benzyl-8-[4 -(2,2′-bipyridine-5-yl)phenyl]adenine (9c): 9-Benzyl-8-bromoadenine (0.5 g, 1.64 mmol), 4-(2,2′-bipyridin-5-yl)pinacolboronate (600 mg, 1.8 mmol, 1.1 equiv.), $PdCl_2$ (28 mg, 0.165 mmol, 10 mol-%), dppf (90 mg, 0.165 mmol, 5 mol-%), and K_2CO_3 (905 mg, 6.56 mmol, 4 equiv.) were combined in DMF (9 mL) and three drops of water and stirred under argon at 90 °C for 8 h. The workup was performed in the same way as for **8a**. Crystallization of crude product from $CHCl_3$ (plus a few drops of MeOH)/heptane gave **9c** as a white solid (400 mg, 52%). M.p. 267–272 °C. ^{1}H NMR (400 MHz, [D$_6$]DMSO): δ = 5.58 (s, 2 H, CH_2), 7.04 (m, 2 H, H^o Ph), 7.22–7.33 (m, 4 H, H^{m,p} Ph), 7.43 (br. s, 2 H, NH_2), 7.48 (ddd, $J_{5'',4''}$ = 7.5, $J_{5'',6''}$ = 4.8, $J_{5'',3''}$ = 1.2, 1 H, 5″-H), 7.86 (m, 2 H, H^o phenylene), 7.95–8.01 (m, 3 H, 4″-H and H^m phenylene), 8.20 (s, 1 H, H-2), 8.34 (dd, $J_{4',3'}$ = 8.3, $J_{4',6'}$ = 2.4, 1 H, 4′-H), 8.44 (dt, $J_{3'',4''}$ = 7.9, $J_{3'',5''}$ = 1.2, $J_{3'',6''}$ = 1.0, 1 H, 3″-H), 8.49 (dd, $J_{3',4'}$ = 8.3, $J_{3',6'}$ = 0.9, 1 H, 3′-H), 8.79 (ddd, $J_{6'',5''}$ = 4.8, $J_{6'',4''}$ = 1.8, $J_{6'',3''}$ = 1.0, 1 H, 6″-H), 9.10 (dd, $J_{6',4'}$ = 2.4, $J_{6',3'}$ = 0.9, 1 H, 6′-H) ppm. ^{13}C NMR (125.8 MHz, [D$_6$]DMSO): δ = 46.42 (CH_2), 118.88 (C-5), 120.67 and 120.70 (C-3′ and C-3″), 124.51 (C-5″), 126.39 (C^o Ph), 127.22 (C^m phenylene), 127.65 (C^p Ph), 128.95 (C^m Ph), 129.60 (C^o phenylene), 129.80 (C^i phenylene), 134.69 (C-5′), 135.43 (C-4′), 137.19 (C^i Ph), 137.57 (C-4″), 137.96 (C^p phenylene), 147.59 (C-6′), 149.41 (C-8), 149.60 (C-6″), 151.69 (C-4), 153.09 (C-2), 154.76 (C-2′), 154.97 (C-2″), 156.08 (C-6) ppm. FAB MS: *m*/*z* (%) = 456.2 (45%) [M$^+$]. HRMS (FAB): for $C_{28}H_{22}N_7$ calcd.456.1937 found 456.1921. IR (KBr): $\tilde{\nu}$ = 3446, 1643, 1589, 1330, 1001, 753 cm^{-1}. UV/Vis (MeOH): λ_{max} (ε) = 315 (20980), 259 (6656) nm. $C_{28}H_{21}N_7 \cdot CHCl_3$ (574.89): calcd. C 60.59, H 3.86, N 17.05; found C 60.43, H 3.36, N 16.73.

9-Benzyl-8-[4′-(2′,2": 6′,2"-terpyridine-1′-yl)phenyl]adenine (9d): 9-Benzyl-8-bromoadenine (0.35 g, 1.15 mmol), 4′-phenylene-2,2′:6′,2′′-terpyridine (500 mg, 1.15 mmol, 1 equiv.), $PdCl_2$ (10 mg, 0.058 mmol, 5 mol-%), dppf (32 mg, 0.058 mmol, 5 mol-%), and K_2CO_3 (475 mg, 3.45 mmol, 3 equiv.) were combined in DMF (5 mL)and three drops of water and stirred under argon at 85 °C for 10 h. The workup was performed in the same way as for **8a**. Crystallization of crude product from $CHCl_3$ (plus a few drops of MeOH)/heptane gave **9d** as a white solid (283 mg, 46%). M.p. 269–271 °C. ^{1}H NMR (400 MHz, [D$_6$]DMSO): δ = 5.60 (s, 2 H, CH_2), 7.06 (m, 2 H, H^o Ph), 7.42 (m, 1 H, H^p Ph), 7.30 (m, 2 H, H^m Ph), 7.46 (br. s, 2 H, NH_2), 7.54 (ddd, 2 H, $J_{5'',4''}$ = 7.5, $J_{5'',6''}$ = 4.8, $J_{5'',3''}$ = 1.2, 2 H, 5″-H), 7.92 (m, 2 H, H^o phenylene), 8.04 (ddd, $J_{4'',3''}$ = 8.0, $J_{4'',5''}$ = 7.5, $J_{4'',6''}$ = 1.8, 2 H, 4″-H), 8.07 (m, 2 H, H^m phenylene), 8.21 (s, 1 H, H-2), 8.68 (dt, $J_{3'',4''}$ = 8.0, $J_{3'',5''}$ = 1.2, $J_{3'',6''}$ = 0.9, 2 H, 3″-H), 8.76 (s, 2 H, H-3′), 8.76 (ddd, $J_{6'',5''}$ = 4.8, $J_{6'',4''}$ = 1.8, $J_{6'',3''}$ = 0.9, 2 H, 6″-H) ppm. ^{13}C NMR (100.6 MHz, [D$_6$]-DMSO): δ = 46.51 (CH_2), 118.14 (C-3′), 118.93 (C-5), 121.22 (C-3″), 124.88 (C-5″), 126.58 (C^o Ph), 127.49 (C^m phenylene), 127.73 (C^p Ph), 128.99 (C^m Ph), 129.86 (C^o phenylene), 130.91 (C^i phenylene), 137.19 (C^i Ph), 137.77 (C-4″), 138.72 (C^p phenylene), 148.65 (C-4′), 149.29 (C-8), 149.59 (C-6″), 151.78 (C-4), 153.22 (C-2), 155.05 (C-2″), 156.06 (C-2′), 156.16 (C-6) ppm. FAB MS: *m*/*z* (%) = 91 (90), 336 (35), 436 (100), 533 (15) [M$^+$]. HRMS (FAB): for $C_{33}H_{25}N_8$ calcd. 533.2202 found 533.2231. IR (KBr): $\tilde{\nu}$ = 3401, 3299, 3060, 1637, 1584, 1390, 1330, 842, 792 cm^{-1}. UV/Vis (MeOH): λ_{max} (ε) = 318 sh (30620), 285 (34170), 248 (32715) nm. $C_{33}H_{24}N_8 \cdot H_2O$ (550.6): calcd. C 71.98, H 4.74, N 20.35; found C 71.24, H 4.47, N 20.31.

General Procedure for the Complexation Reactions. Method B: Compounds **2b**–**2c**, **4a**–**4c**, **8a**–**8c** or **9a**–**9c** (1.5 mmol) were combined with commercially available $Ru(bipy)_2Cl_2 \cdot 2H_2O$ (1.65 mmol, 1.1 equiv.) or **4d** or **9d** with $Ru(terpy)Cl_3$ (1.65 mmol, 1.1 equiv.) in ethylene glycol and were then heated for 2 h at 150 °C. The solvent was distilled off under reduced pressure. The residue was dissolved in water and saturated solution of NH_4PF_6 was added to the mixture. The precipitate thus formed was collected by filtration. The crude product was purified by silica gel column chromatography using a mixture of CH_3CN/H_2O/saturated KNO_3 (10:1:0.1) as eluent. The corresponding fractions were combined and the solvent removed in vacuo. The residue was dissolved in a small amount of EtOH and the KNO_3 was filtered off. The product was dissolved in water and a saturated solution of NH_4PF_6 was added. The product precipitated as hexafluorophosphate salts from the solution. The solid was filtered off. Crystallization from acetone or acetonitrile/*i*PrOH gave pure desired products **5**, **6**, **10** or **11**.

Complex 5b: The product was isolated as a red solid in 49% yield (Method B). M.p. 265–274 °C (decomposition). ^{1}H NMR (400 MHz, [D$_6$]acetone): δ = 3.60 (s, 1 H, HC≡C), 7.43 (ddd, $J_{5,4}$ = 7.6, $J_{5,6}$ = 5.7, $J_{5,3}$ = 1.4, 1 H, 5-H bipy), 7.51–7.59 (m, 3 H, 5′-H and 2 × 5-H bipy), 7.63 (ddd, $J_{5,4}$ = 7.6, $J_{5,6}$ = 5.7, $J_{5,3}$ = 1.4, 1 H, 5-H bipy), 7.82 (dd, $J_{5,4}$ = 7.8, $J_{5,3}$ = 1.3, 1 H, 5-H), 7.91–7.97 (m, 4 H, 6′-H and 3 ×6-H bipy), 8.08 (ddd, $J_{4,3}$ = 8.1, $J_{4,5}$ = 7.6, $J_{4,6}$ = 1.5, 1 H, 4-H bipy), 8.18–8.27 (m, 5 H, 4-H, 4′-H and 3 ×4-H bipy), 8.33 (ddd, $J_{6,5}$ = 5.7, $J_{6,4}$ = 1.5, $J_{6,3}$ = 0.8, 1 H, 6-H bipy), 8.71 (ddd, $J_{3,4}$ = 8.1, $J_{3,5}$ = 1.4, $J_{3,6}$ = 0.8, 1 H, 3-H bipy), 8.78–8.84 (m, 4 H, 3′-H and 3 ×3-H bipy), 8.84 (dd, $J_{3,4}$ = 8.2, $J_{3,5}$ = 1.3, 1 H, 3-H) ppm. ^{13}C NMR (100.6 MHz, [D$_6$]acetone): δ = 79.31 (*C*≡CH), 88.56 (H*C*≡C), 124.92, 124.98, 125.02, 125.50 and 125.53 (C-3′ and C-3 bipy), 126.04 (C-3), 128.45, 128.50, 128.70, 128.79 and 129.08 (C-5′ and C-5 bipy), 135.16 (C-5), 138.88, 138.97, 139.04, 139.10, 139.14 and 139.33 (C-4, C-4′ and C-4 bipy), 148.19 (C-6), 152.39, 152.44, 152.52, 152.91 and 153.75 (C-6′ and C-6 bipy), 158.03, 158.17, 158.25 and 158.32 (C-2 bipy), 158.79 (C-2′), 159.22 (C-2) ppm. ESI MS: *m*/*z* (%) = 739 (65) [M$^+$ + PF$_6^-$], 297 (100) [M^{2+} – 2PF$_6^-$]. IR (KBr): $\tilde{\nu}$ = 3435, 3280, 2118 1568, 1466, 1426, 839, 558 cm^{-1}. $C_{32}H_{24}F_{12}N_6P_2Ru \cdot H_2O$ (901.6): calcd. C 42.63, H 2.91, N 9.32; found C 43.18, H 3.07, N 9.01.

Complex 5c: The product was isolated as a red solid in 32% yield (Method B). M.p. 185–193 °C. ^{1}H NMR (500 MHz, [D$_6$]acetone):

δ = 4.12 (s, 1 H, HC≡C), 7.55–7.62 (m, 5 H, 5″-H and 4×5-H bipy), 7.99–8.10 (m, 6 H, 6′-H, 6″-H and 4×6-H bipy), 8.17–8.27 (m, 6 H, 4′-H, 4″-H and 4×4-H bipy), 8.78–8.85 (m, 6 H, 3′-H, 3″-H, 4×3-H bipy) ppm. ^{13}C NMR (125.8 MHz, [D$_6$]acetone): δ = 78.97 (*C*≡CH), 86.89 (H*C*≡C), 123.71 (C-5′), 124.89, 125.29, 125.33, 125.36, 125.46 and 125.93 (C-3′, C-3″ and C-3 bipy), 128.71, 128.74, 128.80 and 129.04 (C-5″ and C-5 bipy), 138.97, 139.04 and 139.06 (C-4″ and C-4 bipy), 141.42 (C-4′), 152.58, 152.73, 152.82, 152.84 and 153.09 (C-6″ and C-6 bipy), 154.81 (C-6′), 157.50 (C-2′), 157.79, 158.00, 158.09, 158.12 and 158.17 (C-2″ and C-2 bipy) ppm. ESI MS: *m*/*z* (%) = 738.9 (35) [M$^+$ + PF$_6^-$], 297 (100) [M^{2+} – 2PF$_6^-$]. IR (KBr): $\tilde{\nu}$ = 3435, 3270, 2117 1559, 1466, 1465, 839, 558 cm^{-1}. $C_{32}H_{24}F_{12}N_6P_2Ru\cdot H_2O$ (901.6): calcd. C 42.63, H 2.91, N 9.32; found C 42.80, H 3.06, N 9.10.

Complex 6a: The product was isolated as a red solid in 66% yield (Method B). M.p. 182–188 °C. ^{1}H NMR (400 MHz, [D$_6$]acetone): δ = 6.24 (br. m, 1 H, H^m phenylene), 6.94 (ddd, $J_{5,4}$ = 7.6, $J_{5,6}$ = 5.6, $J_{5,3}$ = 1.3, 1 H, 5-H bipy), 7.22 (s, 2 H, B(OH)$_2$), 7.28 (br. m, 1 H, H^o phenylene), 7.31 (ddd, $J_{6,5}$ = 5.6, $J_{6,4}$ = 1.5, $J_{6,3}$ = 0.7, 1 H, 6-H bipy), 7.40, 7.47 and 7.50 (3×ddd, $J_{5,4}$ = 7.6, $J_{5,6}$ = 5.6, $J_{5,3}$ = 1.3, 3×1 H, 3×5-H bipy), 7.55 (br. m, 1 H, H^m phenylene), 7.60 (br. m, 1 H, H^o phenylene), 7.68 (td, $J_{4,3}$ = 8.2, $J_{4,5}$ = 7.6, $J_{4,6}$ = 1.5, 1 H, 4-H bipy), 7.79 and 7.83 (2×ddd, $J_{6,5}$ = 5.6, $J_{6,4}$ = 1.5, $J_{6,3}$ = 0.7, 2×1 H, 2×6-H bipy), 7.84 (d, $J_{3,4}$ = 8.3, 1 H, 3-H), 7.85 (dd, $J_{8,9}$ = 8.3, $J_{8,7}$ = 5.3, 1 H, 8-H), 8.12, 8.14 and 8.23 (3×ddd, $J_{4,3}$ = 8.2, $J_{4,5}$ = 7.6, $J_{4,6}$ = 1.5, 3×1 H, 3×4-H bipy), 8.26 (dd, $J_{9,8}$ = 5.3, $J_{9,7}$ = 1.3, 1 H, 9-H), 8.28 (ddd, $J_{6,5}$ = 5.6, $J_{6,4}$ = 1.5, $J_{6,3}$ = 0.7, 1 H, 6-H bipy), 8.32 (ddd, $J_{3,4}$ = 8.2, $J_{3,5}$ = 1.3, $J_{3,6}$ = 0.7, 1 H, 3-H bipy), 8.45 (d, $J_{6,5}$ = 8.9, 1 H, 6-H), 8.50 (d, $J_{5,6}$ = 8.9, 1 H, 5-H), 8.67, 8.70 and 8.73 (3×dt, $J_{3,4}$ = 8.2, $J_{3,5}$ = 1.3, $J_{3,6}$ = 0.7, 3×1 H, 3×3-H bipy), 8.81 (dd, $J_{7,8}$ = 8.3, $J_{7,9}$ = 1.3, 1 H, 7-H), 8.92 (d, $J_{4,3}$ = 8.3, 1 H, 4-H) ppm. ^{13}C NMR (100.6 MHz, [D$_6$]acetone): δ = 124.18, 125.16, 125.19 and 125.28 (C-3 bipy), 126.77 (C-8′), 126.96 (C^m phenylene), 127.54 (C-5 bipy), 127.81 (C^m phenylene), 127.97, 128.67, 128.95 and 128.97 (C-6 and C-5 bipy), 129.34 and 129.36 (C-3 and C-5), 131.27 (C-4a), 132.60 (C-6a), 134.86 (C^o phenylene), 135.28 (C^i phenylene), 136.90 (C-4 bipy), 137.89 (C-7), 138.53 (C-4), 138.91 and 139.11 (C-4 bipy), 141.28 (C^p phenylene), 148.55 (C-10b), 149.03 (C-10a), 152.13, 152.89 and 152.94 (C-6 bipy), 153.46 (C-9′), 153.81 (C-6 bipy), 157.56, 158.11, 158.43 and 159.03 (C-2 bipy), 168.67 (C-2′) ppm. ESI MS: *m*/*z* (%) = 859 (65) [M$^+$ + PF$_6^-$], 357 (70) [M^{2+} – 2PF$_6^-$]. IR (KBr): $\tilde{\nu}$ = 3435, 3082, 2924, 1242, 1202, 840, 558 cm^{-1}. $C_{38}H_{29}BF_{12}N_6O_2P_2Ru\cdot H_2O$ (1021.5): calcd. C 44.68, H 3.06, N 8.23; found C 44.65, H 2.90, N 8.32.

Complex 6b: The product was isolated as a red solid in 47% yield (Method B). M.p. 180–200 °C. ^{1}H NMR (400 MHz, [D$_6$]acetone): δ = 6.15 (br. m, 1 H, H^m phenylene), 6.78 (br. m, 1 H, H^o phenylene), 6.97 (ddd, $J_{5,4}$ = 7.6, $J_{5,6}$ = 5.6, $J_{5,3}$ = 1.3, 1 H, 5-H bipy), 7.06 (br. m, 1 H, H^o phenylene), 7.27 (ddd, $J_{6,5}$ = 5.6, $J_{6,4}$ = 1.5, $J_{6,3}$ = 0.7, 1 H, 6-H bipy), 7.41 (ddd, $J_{5,4}$ = 7.6, $J_{5,6}$ = 5.6, $J_{5,3}$ = 1.3, 1 H, 5-H bipy), 7.45 (br. m, 1 H, H^m phenylene), 7.48 (dd, $J_{5,4}$ = 7.7, $J_{5,3}$ = 1.4, 1 H, 5-H), 7.50 (ddd, $J_{5',4'}$ = 7.6, $J_{5',6'}$ = 5.6, $J_{5',3'}$ = 1.3, 1 H, 5′-H), 7.61 (ddd, $J_{5,4}$ = 7.6, $J_{5,6}$ = 5.6, $J_{5,3}$ = 1.3, 1 H, 5-H bipy), 7.67 (ddd, $J_{6,5}$ = 5.6, $J_{6,4}$ = 1.5, $J_{6,3}$ = 0.7, 1 H, 6-H bipy), 7.70 (ddd, $J_{5,4}$ = 7.6, $J_{5,6}$ = 5.6, $J_{5,3}$ = 1.3, 1 H, 5-H bipy), 7.73 (ddd, $J_{4,3}$ = 8.2, $J_{4,5}$ = 7.6, $J_{4,6}$ = 1.5, 1 H, 4-H bipy), 7.89 (ddd, $J_{6',5'}$ = 5.6, $J_{6',4'}$ = 1.5, $J_{6',3'}$ = 0.7, 1 H, 6′-H), 8.07 (ddd, $J_{4,3}$ = 8.2, $J_{4,5}$ = 7.6, $J_{4,6}$ = 1.5, 1 H, 4-H bipy), 8.13 (ddd, $J_{6,5}$ = 5.6, $J_{6,4}$ = 1.5, $J_{6,3}$ = 0.7, 1 H, 6-H bipy), 8.21 (ddd, $J_{4,3}$ = 8.2, $J_{4,5}$ = 7.6, $J_{4,6}$ = 1.5, 1 H, 4-H bipy), 8.22 (ddd, $J_{4',3'}$ = 8.2, $J_{4',5'}$ = 7.6, $J_{4',6'}$ = 1.5, 1 H, 4′-H), 8.28 (ddd, $J_{4,3}$ = 8.2, $J_{4,5}$ = 7.6, $J_{4,6}$ = 1.5, 1 H, 4-H bipy), 8.31 (t, 1 H, $J_{4,3}$ = 8.2, $J_{4,5}$ = 7.7, 1 H, 4-H), 8.32 (ddd, $J_{3,4}$ = 8.2, $J_{3,5}$ = 1.3, $J_{3,6}$ = 0.7, 1 H, 3-H bipy), 8.37 (ddd, $J_{6,5}$ = 5.6, $J_{6,4}$ = 1.5, $J_{6,3}$ = 0.7, 1 H, 6-H bipy), 8.64, 8.71 and 8.73 (3×ddd, $J_{3,4}$ = 8.2, $J_{3,5}$ = 1.3, $J_{3,6}$ = 0.7, 3×1 H, 3×3-H bipy), 8.89 (ddd, $J_{3',4'}$ = 8.2, $J_{3',5'}$ = 1.3, $J_{3',6'}$ = 0.7, 1 H, 3′-H), 8.93 (dd, $J_{3,4}$ = 8.2, $J_{3,5}$ = 1.4, 1 H, 3-H) ppm. ^{13}C NMR (100.6 MHz, [D$_6$]-acetone): δ = 124.27 (C-3 bipy), 124.48 (C-3), 125.18, 125.36 and 125.39 (C-3 bipy), 125.97 (C-3′), 127.57 and 128.08 (C-5 bipy), 128.18 (C^m phenylene), 128.27 (C-5′), 128.80 (C^m phenylene), 128.86 and 128.93 (C-5 bipy), 129.31 (C^o phenylene), 130.59 (C-5′), 137.07 (C-4 bipy), 138.94, 138.97, 139.05 and 139.07 (C-4′ and C-4 bipy), 139.18 (C-4), 139.82 (C^p phenylene), 151.90 (C-6 bipy), 152.58 (C-6′), 152.70 and 153.78 (C-6 bipy), 157.30, 158.16 and 158.26 (C-2 bipy), 158.61, 159.06 and 159.10 (C-2, C-2′ and C-2 bipy), 167.75 (C-6) ppm; C^i phenylene signal not observed. ESI MS: *m*/*z* (%) = 834 (5) [M$^+$ + PF$_6^-$], 345 (15) [M^{2+} – 2PF$_6^-$]. IR (KBr): $\tilde{\nu}$ = 3437, 3083, 2342, 1242, 1225, 842, 558 cm^{-1}. $C_{36}H_{29}BF_{12}N_6O_2P_2Ru$ (979.5): calcd. C 44.15, H 2.98, N 8.58; found C 44.11, H 3.16, N 8.29.

Complex 6c: The product was isolated as a red solid in 42% yield (Method B). M.p. 151–172 °C. ^{1}H NMR (500 MHz, [D$_6$]acetone): δ = 7.35 (s, 1 H, B–OH), 7.44 (m, 2 H, H^m phenylene), 7.55–7.65 (m, 5 H, 5″-H and 4×5-H bipy), 7.89 (m, 2 H, H^o phenylene), 8.07, 8.08 and 8.10 (3×ddd, $J_{6,5}$ = 5.6, $J_{6,4}$ = 1.5, $J_{6,3}$ = 0.7, 3×1 H, 3×6-H bipy), 8.11 (dd, $J_{6,4}$ = 2.1, $J_{6,3}$ = 0.6, 1 H, 6′-H), 8.17 (ddd, $J_{6,5}$ = 5.6, $J_{6,4}$ = 1.5, $J_{6,3}$ = 0.7, 1 H, 6-H bipy), 8.18–8.28 (m, 6 H, 6″-H, 4″-H and 4×4-H bipy), 8.50 (dd, $J_{4',3'}$ = 8.6, $J_{4',6'}$ = 2.1, 1 H, 4′-H), 8.70, 8.83, 8.835 and 8.84 (4×dt, $J_{3,4}$ = 8.3, $J_{3,5}$ = 1.3, $J_{3,6}$ = 0.7, 4H 4×3-H bipy), 8.86 (dt, $J_{3,4}$ = 8.3, $J_{3,5}$ = 1.3, $J_{3,6}$ = 0.7, 4 H, 3″-H), 8.89 (dd, $J_{3',4'}$ = 8.6, $J_{3',6'}$ = 0.6, 1 H, 3′-H) ppm. ^{13}C NMR (125.8 MHz, [D$_6$]acetone): δ = 125.24, 125.31, 125.36 and 125.45 (C-3′, C-3″ and C-3 bipy), 126.88 (C^m phenylene), 128.64, 128.68, 128.72 and 128.81 (C-5″ and C-5 bipy), 135.91 (C^o phenylene), 136.65 (C-4′), 137.14 (C^p phenylene), 138.88 and 138.92 (C-4″ and C-4 bipy), 140.77 (C-5′), 149.90 (C-6′), 152.64, 152.68, 153.02 and 153.07 (C-6″ and C-6 bipy), 156.79 (C-2′), 157.91, 158.03, 158.09, 158.15 and 158.27 (C-2″ and C-2 bipy) ppm; C^i phenylene signal not observed. ESI MS: *m*/*z* (%) = 835 (100) [M$^+$ + PF$_6^-$], 345 (30) [M^{2+} – 2PF$_6^-$]. IR (KBr): $\tilde{\nu}$ = 3435, 3083, 2981, 1244, 1222, 840, 558 cm^{-1}. $C_{36}H_{29}BF_{12}N_6O_2P_2Ru$ (979.5): calcd. C 44.15, H 2.98, N 8.58; found C 44.58, H 3.51, N 8.13.

Complex 6d: The product was isolated as a red solid in 69% yield (Method B). M.p. >310 °C. ^{1}H NMR (500 MHz, [D$_6$]acetone): δ = 7.33 and 7.34 (2×ddd, $J_{5',4'}$ = 7.5, $J_{5',6'}$ = 5.5, $J_{5',3'}$ = 1.3, 2×2 H, 5′-H terpy and 5′-H Ph-terpy), 7.52 (br. s, 1 H, B–OH), 7.72 (ddd, $J_{6',5'}$ = 5.5, $J_{6',4'}$ = 1.5, $J_{6',3'}$ = 0.7, 2 H, 6′-H Ph-terpy), 7.81 (ddd, $J_{6',5'}$ = 5.5, $J_{6',4'}$ = 1.5, $J_{6',3'}$ = 0.7, 2 H, 6′-H terpy), 8.08 and 8.09 (2×ddd, $J_{4',3'}$ = 8.2, $J_{4',5'}$ = 7.5, $J_{4',6'}$ = 1.5, 2×2 H, 4′-H terpy and 4′-H Ph-terpy), 8.22 (m, 2 H, H^o phenylene), 8.33 (m, 2 H, H^m phenylene), 8.58 (t, $J_{4,3\&5}$ = 8.2, 1 H, 4-H terpy), 8.82 (ddd, $J_{3',4'}$ = 8.2, $J_{3',5'}$ = 1.3, $J_{3',6'}$ = 0.7, 2 H, 6′-H terpy), 9.07 (ddd, $J_{3',4'}$ = 8.2, $J_{3',5'}$ = 1.3, $J_{3',6'}$ = 0.7, 2 H, 6′-H Ph-terpy), 9.08 (d, $J_{3\&5,4}$ = 8.2, 2 H, 3,5-H terpy), 9.45 (s, 2 H, 3,5-H Ph-terpy) ppm. ^{13}C NMR (125.8 MHz, [D$_6$]acetone): δ = 122.30 (C-3,5 Ph-terpy), 124.78 (C-3,5 terpy), 125.41 (C-3′ terpy), 125.65 (C-3′ Ph-terpy), 127.57 (C^m phenylene), 128.60 (C-5′ Ph-terpy and C-5′ terpy), 136.08 (C^o phenylene), 138.97 (C^p phenylene), 139.05 and 139.12 (C-4′ Ph-terpy and C-4′ terpy), 149.13 (C-4 Ph-terpy), 153.41 and 153.48 (C-6′ Ph-terpy and C-6′ terpy), 156.41 (C-2,6 terpy), 156.65 (C-2,6 Ph-terpy), 159.20 (C-2′ terpy), 159.36 (C-2′ Ph-terpy) ppm; C^i phenylene signal not observed. ESI MS: *m*/*z* (%) = 833 (50) [M$^+$ + PF$_6^-$], 344 (40) [M^{2+} – 2PF$_6^-$], 687 (75) [M$^+$ – 2PF$_6^-$]. IR (KBr): $\tilde{\nu}$ = 3435, 3083, 2981, 1244, 1222, 840, 558 cm^{-1}.

$C_{36}H_{27}BF_{12}N_6O_2P_2Ru·H_2O$ (995.5): calcd. C 43.44, H 2.94, N 8.60; found C 43.63, H 2.95, N 8.23.

Complex 10a: The product was isolated as an orange solid in 69% yield (Method B). M.p. 261–264 °C. ^{1}H NMR (500 MHz, [D$_6$]acetone): δ = 5.28 and 5.42 (2 × d, J_{gem} = 15.5, 2 H, CH_2Ph), 6.91 (br. s, 1 H, NH), 6.99 (ddd, $J_{5,4}$ = 7.6, $J_{5,6}$ = 5.6, $J_{5,3}$ = 1.4, 1 H, 5-H bipy), 7.23 (m, 2 H, H^o Ph), 7.25–7.32 (m, 3 H, H^{m,p} Ph), 7.37 and 7.51 (2 × ddd, $J_{5,4}$ = 7.6, $J_{5,6}$ = 5.6, $J_{5,3}$ = 1.4, 2 × 1 H, 2 × 5-H bipy), 7.52 (ddd, $J_{4,3}$ = 8.3, $J_{4,5}$ = 7.6, $J_{4,6}$ = 1.5, 1 H, 4-H bipy), 7.56 (ddd, $J_{5,4}$ = 7.6, $J_{5,6}$ = 5.6, $J_{5,3}$ = 1.4, 1 H, 5-H bipy), 7.71 and 7.86 (2 × ddd, $J_{6,5}$ = 5.6, $J_{6,4}$ = 1.5, $J_{6,3}$ = 0.7, 2 × 1 H, 2 × 6-H bipy), 7.91 (dd, $J_{8',9'}$ = 8.2, $J_{8',7'}$ = 5.3, 1 H, 8′-H), 7.97 (ddd, $J_{6,5}$ = 5.6, $J_{6,4}$ = 1.5, $J_{6,3}$ = 0.7, 1 H, 6-H bipy), 8.17 (d, $J_{3',4'}$ = 8.4, 1 H, 3′-H), 8.18–8.24 (m, 4 H, 6-H bipy and 3 × 4-H bipy), 8.29 (s, 1 H, H-2), 8.33 (dd, $J_{9',8'}$ = 5.3, $J_{9',7'}$ = 1.3, 1 H, 9′-H), 8.44 (d, $J_{5',6'}$ = 8.9, 1 H, 5′-H), 8.47 (d, $J_{6',5'}$ = 8.9, 1 H, 6′-H), 8.56 (ddd, $J_{3,4}$ = 8.3, $J_{3,5}$ = 1.4, $J_{3,6}$ = 0.7, 1 H, 3-H bipy), 8.78–8.84 (m, 4 H, 7′-H and 3 × 3-H bipy), 8.91 (d, $J_{4',3'}$ = 8.4, 1 H, 4′-H) ppm. ^{13}C NMR (125.8 MHz, [D$_6$]acetone): δ = 47.33 (CH_2Ph), 89.14 (C≡*C* pur), 90.68 (*C*≡C pur), 120.07 (C-5), 125.23, 125.44, 125.49 and 125.51 (C-3 bipy), 127.33 (C-8′), 128.26 and 128.57 (C-5 bipy), 128.61 (C^o Ph), 128.81 (C-5 bipy), 128.97 (C^p Ph), 129.10 and 129.13 (C-5′ and C-5 bipy), 129.65 (C^m Ph), 130.02 (C-6′), 131.60 (C-4a′), 132.12 (C-8), 132.77 (C-6a′), 133.60 (C-3′), 137.29 (C^i Ph), 137.67 (C-4 bipy), 138.07 (C-7′), 138.39 (C-4′), 139.07, 139.15 and 139.41 (C-4 bipy), 147.60 (C-2′), 148.65 (C-10a′), 149.59 (C-10b′), 150.77 (C-4), 152.30, 152.45 and 152.73 (C-6 bipy), 153.67 (C-3′), 153.77 (C-9′), 155.79 (C-2), 157.29 (C-6), 157.82, 158.01, 158.19 and 158.76 (C-2 bipy) ppm. ESI MS: *m*/*z* (%) = 840 (50) [M$^+$ – 2PF$_6^-$], 420 (100) [M^{2+} – 2PF$_6^-$]. IR (KBr): $\tilde{\nu}$ = 2220, 1637, 840, 558 cm^{-1}. UV/Vis (MeOH): λ_{max} (ε) = 439 (14454), 373 (19412), 285 (81332) nm. $C_{46}H_{33}F_{12}N_{11}P_2Ru·H_2O$ (1148.9): calcd. C 48.09, H 3.07, N 13.41; found C 48.40, H 3.29, N 13.09.

Complex 10b: The product was isolated as an orange solid in 80% yield (Method B). M.p. 295–301 °C. ^{1}H NMR (500 MHz, [D$_6$]acetone): δ = 5.22 and 5.34 (2 × d, J_{gem} = 15.5, CH_2Ph), 6.87 (br. s, 1 H, NH), 6.91 (ddd, $J_{5,4}$ = 7.6, $J_{5,6}$ = 5.6, $J_{5,3}$ = 1.3, 1 H, 5-H bipy), 7.20 (m, 2 H, H^o Ph), 7.27–7.31 (m, 3 H, H^{m,p} Ph), 7.47 (ddd, $J_{4,3}$ = 8.5, $J_{4,5}$ = 7.6, $J_{4,6}$ = 1.5, 1 H, 4-H bipy), 7.50 (ddd, $J_{5,4}$ = 7.6, $J_{5,6}$ = 5.6, $J_{5,3}$ = 1.3, 1 H, 5-H bipy), 7.56 (ddd, $J_{5'',4''}$ = 7.6, $J_{5'',6''}$ = 5.6, $J_{5'',3''}$ = 1.3, 1 H, 5″-H), 7.58 and 7.69 (2 × ddd, $J_{5,4}$ = 7.6, $J_{5,6}$ = 5.6, $J_{5,3}$ = 1.3, 2 × 1 H, 5-H bipy), 7.78 and 7.88 (2 × ddd, $J_{6,5}$ = 5.6, $J_{6,4}$ = 1.5, $J_{6,3}$ = 0.7, 2 × 1 H, 6-H bipy), 7.92 (dd, $J_{5',4'}$ = 7.8, $J_{5',3'}$ = 1.4, 1 H, 5′-H), 7.94 (ddd, $J_{6'',5''}$ = 5.6, $J_{6'',4''}$ = 1.5, $J_{6'',3''}$ = 0.7, 1 H, 6″-H), 7.97 (ddd, $J_{6,5}$ = 5.6, $J_{6,4}$ = 1.5, $J_{6,3}$ = 0.7, 1 H, 6-H bipy), 8.17 (ddd, $J_{4,3}$ = 8.5, $J_{4,5}$ = 7.6, $J_{4,6}$ = 1.5, 1 H, 4-H bipy), 8.23 (ddd, $J_{4'',3''}$ = 8.5, $J_{4'',5''}$ = 7.6, $J_{4'',6''}$ = 1.5, 1 H, 4″-H), 8.26 (ddd, $J_{4,3}$ = 8.5, $J_{4,5}$ = 7.6, $J_{4,6}$ = 1.5, 1 H, 4-H bipy), 8.27 (s, 1 H, H-2), 8.28 (ddd, $J_{4,3}$ = 8.5, $J_{4,5}$ = 7.6, $J_{4,6}$ = 1.5, 1 H, 4-H bipy), 8.32 (t, $J_{4',3'}$ = 8.3, $J_{4',5'}$ = 7.8, 1 H, 4′-H), 8.40 (ddd, $J_{6,5}$ = 5.6, $J_{6,4}$ = 1.5, $J_{6,3}$ = 0.7, 1 H, 6-H bipy), 8.49, 8.77 and 8.83 (3 × ddd, $J_{3,4}$ = 8.5, $J_{3,5}$ = 1.3, $J_{3,6}$ = 0.7, 3 × 1 H, 3 × 3-H bipy), 8.87 (ddd, $J_{3'',4''}$ = 8.5, $J_{3'',5''}$ = 1.3, $J_{3'',6''}$ = 0.7, 1 H, 3″-H), 8.92 (dd, $J_{3',4'}$ = 8.3, $J_{3',5'}$ = 1.4, 1 H, 3′-H) ppm. ^{13}C NMR (125.8 MHz, [D$_6$]acetone): δ = 47.27 (CH_2Ph), 87.58 (C≡*C* pur), 90.40 (*C*≡C pur), 118.92 (C-5), 125.31, 125.37, 125.44, 125.57 and 126.19 (C-3′, C-3″ and C-3 bipy), 128.42 and 128.44 (C-5 bipy), 128.59 (C^o Ph), 128.75 (C-5 bipy), 128.94 (C^p Ph and C-5 bipy), 129.06 (C-5″), 129.63 (C^m Ph), 132.23 (C-8), 135.78 (C-5′), 137.26 (C^i Ph), 137.39, 139.03, 139.14, 139.22, 139.25 and 139.37 (C-4′, C-4″ and C-4 bipy), 147.41 (C-6′), 150.72 (C-4), 152.21, 152.23, 152.44, 152.67 and 153.76 (C-6″ and C-6 bipy), 155.70 (C-2), 157.27 (C-6), 157.97, 158.01 and 158.79 (C-2″ and C-2 bipy), 159.72 (C-2′) ppm. ESI MS: *m*/*z* (%) = 816 (15) [M$^+$ – 2PF$_6^-$], 408 (100) [M^{2+} – 2PF$_6^-$]. IR (KBr): $\tilde{\nu}$ = 2218, 1639, 841, 558 cm^{-1}. UV/Vis (MeOH): λ_{max} (ε) = 442 (17095), 355 sh (26410), 287 (88079) nm. $C_{44}H_{33}F_{12}N_{11}P_2Ru·H_2O$ (1124.8): calcd. C 46.98, H 3.14, N 13.7; found C 46.83, H 3.03, N 13.56.

Complex 10c: The product was isolated as an orange solid in 75% yield (Method B). M.p. 284–291 °C. ^{1}H NMR (500 MHz, [D$_6$]acetone): δ = 5.45 (s, 2 H, CH_2Ph), 6.88 (br. s, 2 H, NH_2), 7.26–7.34 (m, 5 H, H-*o,m,p*-Ph), 7.54–7.63 (m, H-5″, 5 H, 4 × 5-H bipy), 8.00, 8.04 and 8.07 (3 × ddd, $J_{6,5}$ = 5.6, $J_{6,4}$ = 1.4, $J_{6,3}$ = 0.6, 1 H, 3 × 6-H bipy), 8.09 (ddd, $J_{6'',5''}$ = 5.6, $J_{6'',4''}$ = 1.4, $J_{6'',3''}$ = 0.6, 1 H, 6″-H), 8.14–8.25 (m, 6 H, 4″-H, 4 × 4-H bipy and 6-H bipy), 8.25 (s, 1 H, H-2), 8.29 (dd, $J_{6',4'}$ = 1.9, $J_{6',3'}$ = 0.7, 1 H, 6′-H), 8.39 (dd, $J_{4',3'}$ = 8.5, $J_{4',6'}$ = 1.9, 1 H, 4′-H), 8.78, 8.81, 8.82 and 8.86 (4 × dt, $J_{3,4}$ = 8.3, $J_{3,5}$ = 1.5, $J_{3,6}$ = 0.6, 5 H, 3″-H and 4 × 3-H bipy), 8.90 (dd, $J_{3',4'}$ = 8.5, $J_{3',6'}$ = 0.7, 1 H, 3′-H) ppm. ^{13}C NMR (100.6 MHz, [D$_6$]acetone): δ = 47.21 (CH_2Ph), 86.09 (C≡*C* pur), 89.84 (*C*≡C pur), 120.62 (C-5), 122.55 (C-5′), 125.00 (C-3′), 125.33, 125.46 and 126.18 (C-3″ and C-3 bipy), 128.50 (C^o Ph), 128.2, 128.75, 128.82, 128.84 and 129.18 (C^p Ph, C-5″ and C-5 bipy), 129.63 (C^m Ph), 133.26 (C-8), 137.50 (C^i Ph), 138.98, 139.03 and 139.10 (C-4″ and C-4 bipy), 141.03 (C-4′), 150.89 (C-4), 152.54, 152.77, 152.84, 152.88 and 153.09 (C-6″ and C-6 bipy), 154.66 (C-6′), 155.50 (C-2), 157.10 (C-6), 157.37 (C-2′), 157.99, 158.04, 158.12, 158.04 and 158.30 (C-2″ and C-2 bipy) ppm. ESI MS: *m*/*z* (%) = 816 (5) [M$^+$ – 2PF$_6^-$], 408 (100) [M^{2+} – 2PF$_6^-$]. IR (KBr): $\tilde{\nu}$ = 2221, 1635, 840, 558 cm^{-1}. UV/Vis (MeOH): λ_{max} (ε) = 442 sh (18007), 365 (34598), 286 (85546) nm. $C_{44}H_{33}F_{12}N_{11}P_2Ru·H_2O$ (1124.8): calcd. C 46.98, H 3.14, N 13.7; found C 46.26, H 3.08, N 13.35.

General Procedure for Cross-Coupling of Complexes 6a–6d with 7 - Method C

9-Benzyl-8-bromoadenine (20 mg, 0.065 mmol), the corresponding complex (**6a**–**6d**) (0.072 mmol, 1.1 equiv.), and Cs_2CO_3 (64 mg, 0.195 mmol, 3 equiv.) were combined and a mixture of degassed CH_3CN/H_2O (1:1, 1 mL) was added. To this mixture was added a solution of Pd(OAc)$_2$ (0.0065 mmol, 10 mol-%) and water soluble P(Ph-*m*SO_3Na)$_3$ (0.0325 mmol, 5 equiv. to Pd, 50 mol-%) in CH_3CN/H_2O (1:1, 0.5 mL). The whole mixture was degassed and the flask filled with argon. The mixture was stirred under argon at 95 °C for 7 h. The solvent was than evaporated and the products were purified by silica gel column chromatography using a mixture of CH_3CN/H_2O/saturated KNO_3 (10:1:0.1) as eluent. The crystallization from acetonitrile or acetone/*i*PrOH, diethylether gave the desired products **11a**–**11d**.

Complex 11a: The product was isolated as an orange solid in 72% yield (Method B) and in 40% yield (Method C). M.p. 210–215 °C. ^{1}H NMR (500 MHz, [D$_6$]acetone): δ = 5.57 and 5.62 (2 × d, J_{gem} = 16.7, 2 H, CH_2Ph), 6.38 (br. m, 1 H, H^m phenylene), 6.98 (ddd, $J_{5,4}$ = 7.7, $J_{5,6}$ = 5.6, $J_{5,3}$ = 1.3, 1 H, 5-H bipy), 7.10 (m, 2 H, H^o Ph), 7.22 (br. m, 1 H, H^o phenylene), 7.29–7.37 (m, 3 H, H^{m,p} Ph), 7.37 (ddd, $J_{6,5}$ = 5.6, $J_{6,4}$ = 1.4, $J_{6,3}$ = 0.7, 1 H, 6-H bipy), 7.41, 7.46 and 7.47 (3 × ddd, $J_{5,4}$ = 7.7, $J_{5,6}$ = 5.6, $J_{5,3}$ = 1.3, 3 × 1 H, 3 × 5-H bipy), 7.51 (br. m, 1 H, H^o phenylene), 7.72 (br. m, 1 H, H^m phenylene), 7.75 (td, $J_{4,3}$ = 8.1, $J_{4,5}$ = 7.7, $J_{4,6}$ = 1.5, 1 H, 4-H bipy), 7.77 (ddd, $J_{6,5}$ = 5.6, $J_{6,4}$ = 1.4, $J_{6,3}$ = 0.7, 1 H, 6-H bipy), 7.85 (dd, $J_{8',9'}$ = 8.2, $J_{8',7'}$ = 5.3, 1 H, 8′-H), 7.88 (d, $J_{3',4'}$ = 8.3, 1 H, 3′-H), 7.89 (ddd, $J_{6,5}$ = 5.6, $J_{6,4}$ = 1.4, $J_{6,3}$ = 0.7, 1 H, 6-H bipy), 8.11, 8.13 and 8.20 (3 × ddd, $J_{4,3}$ = 8.1, $J_{4,5}$ = 7.7, $J_{4,6}$ = 1.5, 3 × 1 H, 3 × 4-H bipy), 8.20 (ddd, $J_{6,5}$ = 5.6, $J_{6,4}$ = 1.4, $J_{6,3}$ = 0.7, 1 H, 6-H bipy), 8.25 (dt, $J_{3,4}$ = 8.1, $J_{3,5}$ = 1.3, $J_{3,6}$ = 0.7, 1 H, 3-H bipy), 8.27 (dd, $J_{9',8'}$ = 5.3, $J_{9',7'}$ = 1.3, 1 H, 9′-H), 8.37 (s, 1 H, H-2), 8.46 (d, $J_{6',5'}$ = 8.9, 1 H, 6′-H), 8.51 (d, $J_{5',6'}$ = 8.9, 1 H, 5′-H),

8.59, 8.66 and 8.69 (3×dt, $J_{3,4}$ = 8.1, $J_{3,5}$ = 1.3, $J_{3,6}$ = 0.7, 3×1 H, 3×3-H bipy), 8.82 (dd, $J_{7',8'}$ = 8.2, $J_{7',9'}$ = 1.3, 1 H, 7′-H), 8.95 (d, $J_{4',3'}$ = 8.3, 1 H, 4′-H) ppm. ^{13}C NMR (125.8 MHz, [D$_6$]acetone): δ = 47.61 (CH_2Ph), 117.89 (C-5), 124.45, 125.16, 125.18 and 125.25 (C-3 bipy), 126.85 (C-8′), 127.29 (C^o Ph), 127.86, 128.04, 128.52, 128.62, 128.74, 128.99, 129.11, 129.30, 129.39, 129.47 and 129.56 (C-3′, C-5′, C-6′, C-5-bipy, C^{o,m} phenylene and C^p Ph), 129.74 (C^m Ph), 131.10 (C^i phenylene), 131.36 (C-4a′), 132.60 (C-6a′), 137.64 (C^i Ph), 137.80 (C-7′), 137.93 (C-4 bipy), 138.69 (C-4′), 138.92 and 139.15 (C-4 bipy), 141.15 (C^p phenylene), 148.75 (C-10b′), 148.95 (C-10a′), 151.04 (C-8), 151.34 (C-2), 152.10 (C-6 bipy), 152.62 (C-4), 152.64 and 153.15 (C-6 bipy), 153.46 (C-9′), 153.67 (C-6 bipy), 155.17 (C-6), 157.40, 158.01, 158.38 and 158.79 (C-2 bipy), 167.55 (C-2′) ppm. ESI MS: *m*/*z* (%) = 892 (25) [M$^+$ – 2PF$_6^-$], 447 (100) [M^{2+} – 2PF$_6^-$]. IR (KBr): ṽ = 1636, 840, 558 cm^{-1}. UV/Vis (MeOH): λ_{max} (ε) = 446 (15810), 287 (72639), 268 sh (63625) nm. $C_{50}H_{37}F_{12}N_{11}P_2Ru{\cdot}2H_2O$ (1218.9): calcd. C 49.27, H 3.39, N 12.64; found C 49.34, H 3.06, N 12.52.

Complex 11b: The product was isolated as an orange solid in 74% yield (Method B) and in 24% yield (Method C). M.p. 208–210 °C. ^{1}H NMR (500 MHz, [D$_6$]acetone): δ = 5.52 and 5.54 (2×d, J_{gem} = 16.8, 2 H, CH_2Ph), 6.25 (br. m, 1 H, H^m phenylene), 6.95 (ddd, $J_{5,4}$ = 7.7, $J_{5,6}$ = 5.6, $J_{5,3}$ = 1.3, 1 H, 5-H bipy), 7.07 (m, 2 H, H^o Ph), 7.13 (br. m, 2 H, H^o phenylene), 7.27–7.36 (m, 4 H, 6-H bipy and H^{m,p} Ph), 7.41 (ddd, $J_{5,4}$ = 7.7, $J_{5,6}$ = 5.6, $J_{5,3}$ = 1.3, 1 H, 5-H bipy), 7.42 (br. m, 1 H, H^m phenylene), 7.51 (ddd, $J_{5'',4''}$ = 7.7, $J_{5'',6''}$ = 5.6, $J_{5'',3''}$ = 1.3, 1 H, 5″-H), 7.92 (dd, $J_{5',4'}$ = 7.7, $J_{5',3'}$ = 1.3, 1 H, 5′-H), 7.61 (ddd, $J_{5,4}$ = 7.7, $J_{5,6}$ = 5.6, $J_{5,3}$ = 1.3, 1 H, 5-H bipy), 7.65 (ddd, $J_{6,5}$ = 5.6, $J_{6,4}$ = 1.5, $J_{6,3}$ = 0.7, 1 H, 6-H bipy), 7.68 (ddd, $J_{5,4}$ = 7.7, $J_{5,6}$ = 5.6, $J_{5,3}$ = 1.3, 1 H, 5-H bipy), 7.73 (ddd, $J_{4,3}$ = 8.2, $J_{4,5}$ = 7.7, $J_{4,6}$ = 1.5, 1 H, 4-H bipy), 7.91 (ddd, $J_{6'',5''}$ = 5.6, $J_{6'',4''}$ = 1.5, $J_{6'',3''}$ = 0.7, 1 H, 6″-H), 8.07 (ddd, $J_{4,3}$ = 8.2, $J_{4,5}$ = 7.7, $J_{4,6}$ = 1.5, 1 H, 4-H bipy), 8.17 (ddd, $J_{6,5}$ = 5.6, $J_{6,4}$ = 1.5, $J_{6,3}$ = 0.7, 1 H, 6-H bipy), 8.19–8.28 (m, 4 H, 4″-H, 3-H bipy, 2×4-H bipy and 6-H bipy), 8.31 (s, 1 H, H-2), 8.34 (t, $J_{4',3'}$ = 8.2, $J_{4',5'}$ = 7.7, 1 H, 4′-H), 8.58, 8.62 and 8.70 (3×ddd, $J_{3,4}$ = 8.2, $J_{3,5}$ = 1.3, $J_{3,6}$ = 0.7, 3×1 H, 3×3-H bipy), 8.88 (ddd, $J_{3'',4''}$ = 8.2, $J_{3'',5''}$ = 1.3, $J_{3'',6''}$ = 0.7, 1 H, 3″-H), 8.93 (dd, $J_{3',4'}$ = 8.2, $J_{3',5'}$ = 1.3, 1 H, 3′-H) ppm. ^{13}C NMR (100.6 MHz, [D$_6$]acetone): δ = 47.45 (CH_2Ph), 120.18 (C-5), 124.49 (C-3 bipy), 124.61 (C-3′), 125.13, 125.29 and 125.36 (C-3 bipy), 125.94 (C-3″), 127.24 (C^o Ph), 127.73 and 128.12 (C-5 bipy), 128.34 (C-5″), 128.44 (C^m phenylene), 128.54 (C^p Ph), 128.93 and 128.97 (C-5 bipy), 129.37 (C^m phenylene), 129.49 (C^o phenylene), 129.70 (C^m Ph), 130.41 (C-5′), 131.12 (C^i phenylene), 137.67 (C-4 bipy), 137.85 (C^i Ph), 138.95, 138.98, 139.06 and 139.08 (C-4″ and C-4 bipy), 139.35 (C-4′), 140.96 (C^p phenylene), 150.52 (C-8), 151.83 (C-6 bipy), 152.41 (C-2), 152.57 (C-6″), 152.76 (C-4), 152.90 and 153.62 (C-6 bipy), 155.98 (C-6), 157.11, 158.07 and 158.21 (C-2 bipy), 158.88 and 158.92 (C-2′, C-2″ and C-2 bipy), 166.81 (C-6′) ppm. ESI MS: *m*/*z* (%) = 868 (5) [M$^+$ – 2PF$_6^-$], 434 (65) [M^{2+} – 2PF$_6^-$]. IR (KBr): ṽ = 1634, 841, 558 cm^{-1}. UV/Vis (MeOH): λ_{max} (ε) = 448 (10816), 289 (63986) nm. $C_{48}H_{37}F_{12}N_{11}P_2Ru{\cdot}3H_2O$ (1212.9): calcd. C 47.53, H 3.57, N 12.7; found C 47.62, H 3.09, N 12.58.

Complex 11c: The product was isolated as an orange solid in 81% yield (Method B) and in 53% yield (Method C). M.p. 280–283 °C. ^{1}H NMR (500 MHz, [D$_6$]acetone): δ = 5.58 (s, 2 H, CH_2Ph), 6.76 (br. s, 2 H, NH_2), 7.06 (m, 2 H, H^o Ph), 7.23–7.30 (m, 3 H, H^{m,p} Ph), 7.54–7.65 (m, 7 H, 5″-H, 4×5-H bipy and H^m phenylene), 7.79 (m, 2 H, H^o phenylene), 8.05 (ddd, $J_{6,5}$ = 5.6, $J_{6,4}$ = 1.5, $J_{6,3}$ = 0.7, 1 H, 6-H bipy), 8.08 (ddd, $J_{6'',5''}$ = 5.6, $J_{6'',4''}$ = 1.5, $J_{6'',3''}$ = 0.7, 1 H, 6″-H), 8.10 (ddd, $J_{6,5}$ = 5.6, $J_{6,4}$ = 1.5, $J_{6,3}$ = 0.7, 1 H, 6-H bipy), 8.16–8.24 (m, 7 H, 6′-H, 4″-H, 3×4-H bipy and 2×6-H bipy), 8.24 (s, 1 H, H-2), 8.26 (td, $J_{4,3}$ = 8.3, $J_{4,5}$ = 7.6, $J_{4,6}$ = 1.5, 1 H, 4-H bipy), 8.54 (dd, $J_{4',3'}$ = 8.6, $J_{4',6'}$ = 2.1, 1 H, 4′-H), 8.79, 8.82, 8.83 and 8.88 (4×dt, $J_{3,4}$ = 8.3, $J_{3,5}$ = 1.5, $J_{3,6}$ = 0.7, 5 H, 3″-H and 4×3-H bipy), 8.91 (dd, $J_{3',4'}$ = 8.6, $J_{3',6'}$ = 0.6, 1 H, 3′-H) ppm. ^{13}C NMR (100.6 MHz, [D$_6$]acetone): δ = 47.35 (CH_2Ph), 120.09 (C-5), 125.24, 125.31, 125.34, 125.45 and 125.48 (C-3′, C-3″ and C-3 bipy), 127.32 (C^o Ph), 128.16 (C^m phenylene), 128.42 (C^p Ph), 128.69, 128.72 and 128.81 (C-5″ and C-5 bipy), 129.58 (C^m Ph), 130.55 (C^o phenylene), 132.21 (C^i phenylene), 136.75 (C-4′), 136.88 (C^p phenylene), 137.99 (C^i Ph), 138.94 (C-4″ and C-4 bipy), 139.81 (C-5′), 150.02 (C-6′), 150.37 (C-8), 152.62 and 152.66 (C-6 bipy), 153.00 (C-4), 153.03 and 153.08 (C-6″ and C-6 bipy), 153.80 (C-2), 156.73 (C-6), 157.12 (C-2′), 157.82, 158.00, 158.10, 158.14 and 158.26 (C-2″ and C-2 bipy) ppm. ESI MS: *m*/*z* (%) = 1014 (70) [M$^+$ – PF$_6^-$], 434 (100) [M^{2+} – 2PF$_6^-$]. IR (KBr): ṽ = 1635, 840, 558 cm^{-1}. UV/Vis (MeOH): λ_{max} (ε) = 451 (13145), 320 sh (34814), 286 (77563) nm. $C_{48}H_{37}F_{12}N_{11}P_2Ru{\cdot}2H_2O$ (1194.9): calcd. C 48.25, H 3.46, N 12.89; found C 48.10, H 3.24, N 12.84.

Complex 11d: The product was isolated as an orange solid in 65% yield (Method B) and in 63% yield (Method C). M.p. >320 °C. ^{1}H NMR (500 MHz, [D$_6$]acetone): δ = 5.74 (s, 2 H, CH_2Ph), 6.82 (br. s, 2 H, NH_2), 7.19 (m, 2 H, H^o Ph), 7.29–7.39 (m, 7 H, 5′-H terpy, 5′-H Ph-terpy, H^{m,p} Ph), 7.73 (ddd, $J_{6',5'}$ = 5.6, $J_{6',4'}$ = 1.5, $J_{6',3'}$ = 0.6, 2 H, 6′-H Ph-terpy), 7.81 (ddd, $J_{6',5'}$ = 5.6, $J_{6',4'}$ = 1.5, $J_{6',3'}$ = 0.6, 2 H, 6′-H terpy), 8.08 (ddd, $J_{4',3'}$ = 8.2, $J_{4',5'}$ = 7.5, $J_{4',6'}$ = 1.5, 2 H, 4′-H Ph-terpy), 8.09 (ddd, $J_{4',3'}$ = 8.2, $J_{4',5'}$ = 7.5, $J_{4',6'}$ = 1.5, 2 H, 4′-H terpy), 8.10 (m, 2 H, H^o phenylene), 8.48 (m, 2 H, H^m phenylene), 8.59 (t, $J_{4,3\&5}$ = 8.2, 1 H, 4-H terpy), 8.82 (ddd, $J_{3',4'}$ = 8.2, $J_{3',5'}$ = 1.3, $J_{3',6'}$ = 0.6, 2 H, 6′-H terpy), 9.06 (ddd, $J_{3',4'}$ = 8.2, $J_{3',5'}$ = 1.3, $J_{3',6'}$ = 0.6, 2 H, 6′-H Ph-terpy), 9.09 (d, $J_{3\&5,4}$ = 8.2, 2 H, 3,5-H terpy), 9.49 (s, 2 H, 3,5-H Ph-terpy) ppm. ^{13}C NMR (125.8 MHz, [D$_6$]acetone): δ = 47.48 (CH_2Ph), 120.24 (C-5), 122.26 (C-3,5 Ph-terpy), 124.81 (C-3,5 terpy), 125.43 (C-3′ terpy), 125.71 (C-3′-Ph_terpy), 127.41 (C^o Ph), 128.50 (C^p Ph), 128.62 and 128.67 (C-5′ Ph-terpy and C-5′ terpy), 128.80 (C^m phenylene), 129.69 (C^m Ph), 133.02 (C^i Ph), 137.08 (C^o phenylene), 138.16 (C^i Ph), 138.60 (C^p phenylene), 139.07 and 139.16 (C-4′ Ph-terpy and C-4′ terpy), 147.88 (C-4 Ph-terpy), 150.44 (C-8), 153.15 (C-4), 153.45 and 153.48 (C-6′ Ph-terpy and C-6′ terpy), 154.14 (C-2), 156.38 (C-2,6 terpy), 156.77 (C-2,6 Ph-terpy), 157.02 (C-6), 159.18 and 159.29 (C-2′ terpy and C-2′ Ph-terpy) ppm. ESI MS: *m*/*z* (%) = 866 (15) [M$^+$ – PF$_6^-$], 433 (100) [M^{2+} – 2PF$_6^-$]. IR (KBr): ṽ = 1633, 842, 558 cm^{-1}. UV/Vis (MeOH): λ_{max} (ε) = 490 (32975), 333 sh (60225), 311 (71050), 283 (60350), 275 sh (59375) nm. $C_{48}H_{35}F_{12}N_{11}P_2Ru{\cdot}3H_2O$ (1210.9): calcd. C 47.61, H 3.41, N 12.72; found C 47.70, H 3.21, N 12.70.

Complex 12b: The complex was prepared according to general procedures for complexation (Method B) using Os(bipy)$_2$Cl$_2$ as the complexation agent. The product was isolated as a dark green solid in 74% yield. M.p. >320 °C. ^{1}H NMR (500 MHz, [D$_6$]acetone): δ = 5.21 and 5.34 (2×d, J_{gem} = 15.4, CH_2Ph), 6.86 (ddd, $J_{5,4}$ = 7.4, $J_{5,6}$ = 5.7, $J_{5,3}$ = 1.4, 1 H, 5-H bipy), 6.87 (br. s, 1 H, NH), 7.19 (m, 2 H, H^o Ph), 7.26–7.31 (m, 4 H, 4-H bipy and H^{m,p} Ph), 7.44 (ddd, $J_{5,4}$ = 7.4, $J_{5,6}$ = 5.7, $J_{5,3}$ = 1.4, 1 H, 5-H bipy), 7.46 (ddd, $J_{5'',4''}$ = 7.4, $J_{5'',6''}$ = 5.7, $J_{5'',3''}$ = 1.4, 1 H, 5″-H), 7.50 and 7.59 (2×ddd, $J_{5,4}$ = 7.4, $J_{5,6}$ = 5.7, $J_{5,3}$ = 1.4, 2×1 H, 2×5-H bipy), 7.65, 7.73 and 7.81 (3×ddd, $J_{6,5}$ = 5.7, $J_{6,4}$ = 1.5, $J_{6,3}$ = 0.7, 3×1 H, 3×6-H bipy), 7.84 (dd, $J_{5',4'}$ = 7.8, $J_{5',3'}$ = 1.4, 1 H, 5′-H), 7.87 (ddd, $J_{6'',5''}$ = 5.7, $J_{6'',4''}$ = 1.5, $J_{6'',3''}$ = 0.7, 1 H, 6″-H), 7.99 (ddd, $J_{4,3}$ = 8.4, $J_{4,5}$ = 7.4, $J_{4,6}$ = 1.5, 1 H, 4-H bipy), 8.02 (ddd, $J_{4'',3''}$ = 8.4, $J_{4'',5''}$ = 7.4, $J_{4'',6''}$ = 1.5, 1 H, 4″-H), 8.08 and 8.09 (2×ddd, $J_{4,3}$ = 8.4, $J_{4,5}$ = 7.4, $J_{4,6}$ = 1.5, 2×1 H, 2×4-H bipy), 8.13 (t, $J_{4',3'}$ = 8.3, $J_{4',5'}$ = 7.8, 1 H, 4′-H), 8.27 (s, 1 H, H-2), 8.31 (ddd, $J_{6,5}$ =

5.6, $J_{6,4}$ = 1.5, $J_{6,3}$ = 0.7, 1 H, 6-H bipy), 8.49, 8.77, 8.79 and 8.81 (4 × ddd, $J_{3,4}$ = 8.4, $J_{3,5}$ = 1.4, $J_{3,6}$ = 0.7, 4 × 1 H, 4 × 3-H bipy), 8.86 (ddd, $J_{3'',4''}$ = 8.4, $J_{3'',5''}$ = 1.4, $J_{3'',6''}$ = 0.7, 1 H, 3″-H), 8.90 (dd, $J_{3',4'}$ = 8.3, $J_{3',5'}$ = 1.4, 1 H, 3′-H) ppm. ^{13}C NMR (125.8 MHz, [D$_6$]acetone): δ = 47.29 (CH_2Ph), 88.05 (C≡*C* pur), 90.45 (*C*≡C pur), 120.12 (C-5), 125.34, 125.41, 125.48, 125.57 and 125.76 (C-3′ and C-3 bipy), 126.35 (C-3″), 128.59 (C^o Ph), 128.74, 128.92, 128.94, 129.12, 129.40 and 129.46 (C-5″ C-5-bipy and C^p Ph), 129.63 (C^m Ph), 132.25 (C-8), 135.97 (C-5′), 136.83 (C-4 bipy), 137.26 (C^i Ph), 138.36, 138.47, 138.64 and 139.09 (C-4′, C-4″ and C-4 bipy), 146.91 (C-6′), 150.72 (C-4), 151.15, 151.19 and 151.40 (C-6 bipy), 151.99 (C-6″), 153.33 C-6 bipy), 155.68 (C-2), 157.24 (C-6), 159.02, 159.79, 159.92 and 160.64 (C-2″ and C-2 bipy), 162.53 (C-2′) ppm. ESI MS: *m*/*z* (%) = 1052 (100) [M$^+$ – PF_6^-], 453 (15) [M^{2+} – 2PF_6^-]. IR (KBr): $\tilde{\nu}$ = 1635, 842, 558 cm^{-1}. $C_{44}H_{33}F_{12}N_{11}OsP_2$ (1197.2): calcd. C 44.19, H 2.78, N 12.88; found C 44.15, H 2.74, N 12.83.

Electrochemistry: All voltammetric measurements were performed with an Autolab analyzer (Eco Chemie, The Netherlands) in connection with VA-Stand 663 (Metrohm, Switzerland). The three-electrode system was always used. Carbon paste electrodes (CPE) or hanging mercury drop electrodes (HMDE) were used as working electrodes, a Ag/AgCl/3 M KCl electrode as reference and platinum wire as the auxiliary electrode. The CPE was prepared by hand mixing of graphite powder CR-5 (Tesla, Czech Republic) with mineral oil (Sigma) in a weight ratio of 70/30 and filled in a Teflon electrode body. The surface of the CPE was renewed by wiping with wet filtration paper. Square-wave voltammetric measurements at the CPEs were performed with the following settings: frequency 200 Hz, amplitude 25 mV, potential step 5 mV, scan rate: 1 V s^{-1}, initial potential: –1.0 V, end potential: +1.6 V. For measurements at the HMDE, linear sweep or cyclic voltammetry was used: scan rate: 1 V s^{-1}, potential step 5 mV, initial potential: 0.0 V, end (switching) potential: –1.6 V. All measurements were performed in 0.2 acetate buffer (pH 5.0) at room temperature (22 to 25 °C). Before each measurement at the HMDE, the solution of the background electrolyte was deaerated with argon.

Computational Details: All density functional theory (DFT) calculations reported in the study were carried out using the Turbomole 5.8 program.[48] The Perdew–Burke–Ernzerhof (PBE)[49] and hybrid three-parameter Becke's[50] (B3LYP) functionals were used throughout. The calculations were expedited by expanding the Coulomb integrals in an auxiliary basis set, the resolution-of-identity (RI-J) approximation.[51,52] All the geometry optimizations were carried out using the def2-SVP basis set,[53] whereas the single point energies were recomputed in a larger basis set, def2-TZVP (triple-zeta valence with two polarization functions on each atom).[53]

To account for solvation effects, the conductor-like screening model (COSMO) method[54,55] was used with the dielectric constant corresponding to an equimolar mixture of water and acetonitrile (ε_r = 57). The Gibbs free energy was then calculated as the sum of these contributions [Equation (1)]

$$G = E_{el} + G_{solv} + (E_{ZPE} + nRT - TS) \quad (1)$$

where E_{el} is the in vacuo energy of the system (at the B3LYP/def2-TZVP level and the geometry optimized at the RI-PBE/def2-SVP level), G_{solv} is the solvation free energy (at the RI-PBE/def2-SVP level) and the (E_{ZPE} + nRT – TS) term is the zero-point energy, thermal correction to the Gibbs free energy, and entropic term (obtained from a frequency calculation with the same method and software as for the geometry optimizations at the RI-PBE/def2-SV(P) level, 298 K and 1 atm pressure, using an ideal-gas approximation.[56])

The redox potentials were then calculated according to the equation (2)

$$E^0\,[\mathrm{V}] = 27.21(G_{ox}\,[\mathrm{a.u.}] - G_{red}\,[\mathrm{a.u.}]) - 4.34\,\mathrm{V} \quad (2),$$

where $G_{ox/red}$ are free energy values calculated according to Equation (1), and 4.34 V is an absolute redox potential of the standard hydrogen electrode (SHE).[57]

X-ray Diffraction: X-ray crystallographic analysis of single crystals of **10b** (red, 0.03 × 0.14 × 0.27 mm) and **5b** (red, 0.08 × 0.31 × 0.40 mm) was performed with the Xcalibur X-ray diffractometer with Cu-K_α (λ = 1.54180 Å), data collected at 150 K (**10b**) and 295 K (**5b**). Both structures were solved by direct methods with SIR92[58] and refined by full-matrix least-squares methods based on F with CRYSTALS.[59] Friedel pairs were not merged. Hydrogen atoms were located in a difference map, but those attached to carbon atoms were repositioned geometrically and then refined with riding constraints, all other atoms were refined anisotropically in both cases.

Crystal Data for 10b: $C_{44}H_{33}F_{12}N_{11}P_2Ru_1$, monoclinic, space group $P2_1/n$, a = 9.041(4), b = 11.983(4), c = 45.72(2) Å, β = 94.34(4)°, V = 4939(3) Å^3, Z = 4, M = 1106.81, 73413 reflections measured, 18674 independent reflections. Final R = 0.0866, wR = 0.0701 for 5598 reflections with $I > 1.96\sigma(I)$ and 694 parameters. Several thermal similarity restraints were used in the refinement of the bipyridine units and the hexafluorophosphate anions. The two hexafluorophosphate anions were found to be disordered in three positions with their site occupation factors being 0.75, 0.75, and 0.50.

Crystal Data for 5b: $C_{34}H_{24}F_{12}N_6P_2Ru_1$, orthorhombic, space group $Pna2_1$, a = 13.5397(2), b = 25.6956(3), c = 10.0094(2) Å, V = 3482.38(10) Å^3, Z = 4, M = 883.58, 56076 reflections measured, 7377 independent reflections. Final R = 0.0331, wR = 0.0380 for 2940 reflections with $I > 1.96\sigma(I)$ and 478 parameters.

CCDC-628693 (for **10b**) and -629224 (for **5b**) contain the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data_request/cif.

Biological Activity Screening: The HCV subgenomic replicon assay was performed according to the published procedure.[46] Inhibition of HCV NS5B polymerase 1b assay was performed according to ref.[47] Cytostatic activity screening was done according to ref.[60] The cell cycle analysis was carried out by the propidium iodide method[61] and evaluated by means of ModFit LT software (Verity Software House, Topsham, ME, USA).

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[1] M. J. Heller, *Annu. Rev. Biomed. Eng.* **2002**, *4*, 129–153.
[2] a) M. Fojta, *Electroanalysis* **2002**, *14*, 1449–1463; b) M. Fojta, *Collect Czech. Chem. Commun.* **2004**, *69*, 715–747; c) M. Fojta

in *Electrochemistry of Nucleic Acids and Proteins. Towards Electrochemical Sensors for Genomics and Proteomics* (Eds.: E. Paleček, F. Scheller, J. Wang), Elsevier, Amsterdam, **2005**, pp. 386–430.

[3] a) E. Paleček, M. Fojta, *Anal. Chem.* **2001**, *73*, 74A–83A; b) E. Paleček, M. Fojta in *Bioelectronics* (Eds.: I. Wilner, E. Katz), Wiley VCH, Weinheim, **2005**, pp. 127–192; c) N. Popovich, H. Thorp, *Interface* **2002**, *11*, 30–34; d) J. Wang in *Electrochemistry of Nucleic Acids and Proteins. Towards Electrochemical Sensors for Genomics and Proteomics* (Eds.: E. Paleček, F. Scheller, J. Wang), Elsevier, Amsterdam, **2005**, pp. 175–190.

[4] T. Ihara, M. Nakayama, M. Murata, K. Nakano, M. Maeda, *Chem. Commun.* **1997**, *17*, 1609–1610.

[5] a) C. Fan, K. W. Plaxco, A. J. Heeger, *Proc. Natl. Acad. Sci. USA* **2003**, *100*, 9134–9137; b) E. Paleček, *Trends Biotechnol.* **2004**, *22*, 55–58; c) A. E. Radi, J. L. A. Sanchez, E. Baldrich, C. K. O′Sullivan, *J. Am. Chem. Soc.* **2006**, *128*, 117.

[6] a) M. Fojta, L. Havran, S. Billová, P. Kostecka, M. Masarik, R. Kizek, *Electroanalysis* **2003**, *15*, 431–440; b) M. Fojta, L. Havran, R. Kizek, S. Billová, E. Paleček, *Biosens. Bioelectron.* **2004**, *20*, 985–994; c) E. Paleček, M. Fojta, F. Jelen, *Bioelectrochemistry* **2002**, *56*, 85–90.

[7] J. Wang, G. Liu, A. Merkoci, *J. Am. Chem. Soc.* **2003**, *125*, 3214–3215.

[8] D. R. Van Staveren, N. Metzler-Nolte, *Chem. Rev.* **2004**, *104*, 5931–5985.

[9] V. Balzani, A. Juris, M. Venturi, *Chem. Rev.* **1996**, *96*, 759–833.

[10] a) P. K. Bhattacharya, H. J. Lawson, J. K. Barton, *Inorg. Chem.* **2003**, *42*, 8811–8818; b) C. Stinner, M. D. Wightman, S. O. Kelley, M. G. Hill, J. K. Barton, *Inorg. Chem.* **2001**, *40*, 5245–5250; c) J. L. Kisko, J. K. Barton, *Inorg. Chem.* **2000**, *39*, 4942–4949; d) R. E. Holmlin, J. A. Yao, J. K. Barton, *Inorg. Chem.* **1999**, *38*, 174–189; e) S. J. Franklin, C. R. Treadway, J. K. Barton, *Inorg. Chem.* **1998**, *37*, 5198–5210.

[11] a) P. Meunier, I. Ouattara, B. Gautheron, J. Tirouflet, D. Camboli, J. Besancon, *Eur. J. Med. Chem.* **1991**, *26*, 351–362; b) E. Bucci, L. De Napoli, G. Di Fabio, A. Messere, D. Montesarchio, A. Romanelli, G. Piccialli, M. Varra, *Tetrahedron* **1999**, *55*, 14435–14450; c) C. J. Yu, H. Yowanto, Y. J. Wan, T. J. Meade, Y. Chong, M. Strong, L. H. Donilon, J. F. Kayyem, M. Gozin, G. F. Blackburn, *J. Am. Chem. Soc.* **2000**, *122*, 6767–6768; d) A. R. Pike, L. C. Ryder, B. R. Horrocks, W. Clegg, M. R. J. Elsegood, B. A. Connolly, A. Houlton, *Chem. Eur. J.* **2002**, *8*, 2891–2899; e) W. A. Wlassoff, G. C. King, *Nucleic Acids Res.* **2002**, *30*, e58.

[12] a) D. J. Hurley, Y. Tor, *J. Am. Chem. Soc.* **2002**, *124*, 3749–3762; b) D. J. Hurley, Y. Tor, *J. Am. Chem. Soc.* **2002**, *124*, 13231–13241; c) H. Weizman, Y. Tor, *J. Am. Chem. Soc.* **2002**, *124*, 1568–1569; d) D. J. Hurley, Y. Tor, *J. Am. Chem. Soc.* **1998**, *120*, 2194–2195; e) D. J. Hurley, S. E. Seaman, J. C. Mazura, Y. Tor, *Org. Lett.* **2002**, *4*, 2305–2308.

[13] M. Hocek, P. Štěpnička, J. Ludvík, I. Císařová, I. Votruba, D. Řeha, P. Hobza, *Chem. Eur. J.* **2004**, *10*, 2058–2066.

[14] a) M. Hocek, I. Rosenberg, unpublished results. Independently, it was confirmed by another laboratory; b) A. R. Pike, L. C. Ryder, B. R. Horrocks, W. Clegg, B. A. Connoly, A. Houlton, *Chem. Eur. J.* **2005**, *11*, 344–353.

[15] a) Y. Tor, *Synlett* **2002**, 1043–1054; b) U. S. Schubert, C. Eschenbauer, *Angew. Chem. Int. Ed.* **2002**, *41*, 2892–2926; c) J. P. Sauvage, J. P. Collin, J. C. Chamdron, S. Guillerez, Ch. Coudret, *Chem. Rev.* **1994**, *94*, 993–1019.

[16] Selected references for metal-containing materials: a) C.-T. Chen, K. S. Suslick, *Coord. Chem. Rev.* **1993**, *128*, 293–322; b) I. Manners, *Angew. Chem. Int. Ed. Engl.* **1996**, *35*, 1602–1621; c) V. Balzani, A. Credi, M. Venturi, *Coord. Chem. Rev.* **1998**, *171*, 3–16; d) R. Ziessel, M. Hissler, A. El-ghayoury, A. Harriman, *Coord. Chem. Rev.* **1998**, *180*, 1251–1298; e) For multiphoton, multielectron transfer processes in metal-containing polymers, see: L. A. Worl, W. E. Jones, G. F. Strouse, J. N. Younathan, E. Danielson, K. A. Maxwell, M. Sykora, T. J. Meyer, *Inorg. Chem.* **1999**, *38*, 2705–2708.

[17] B. E. Halcrow, W. O. Kermack, *J. Chem. Soc.* **1946**, 155–157.

[18] V. Grosshenny, F. M. Romero, R. Ziessel, *J. Org. Chem.* **1997**, *62*, 1491–1500.

[19] C. D. Buchecker, B. Colasson, M. Fujita, A. Hori, N. Geum, S. Sakamoto, K. Yamaguchi, J. P. Sauvage, *J. Am. Chem. Soc.* **2003**, *125*, 5717–5725.

[20] a) B. M. Kelly-Basetti, D. J. Cundy, S. M. Pereira, W. H. F. Sasse, G. P. Savage, G. W. Simpson, *Bioorg. Med. Chem. Lett.* **1995**, *24*, 2989–2992; b) V. N. Kozhevnikov, D. N. Kozhevnikov, O. V. Shabunina, V. L. Rusinov, O. N. Chupakhin, *Tetrahedron Lett.* **2005**, *46*, 1791–1793.

[21] a) C. J. Aspley, J. A. G. Williams, *New J. Chem.* **2001**, *25*, 1136–1147; b) G. W. V. Cave, C. L. Raston, *J. Chem. Soc., Perkin Trans. 1* **2001**, 3258–3264.

[22] T. Isiyama, M. Murate, N. Miyaura, *J. Org. Chem.* **1995**, *60*, 7508–7510.

[23] T. Haino, H. Araki, Y. Fujiwara, Y. Tanimoto, Y. Fukazawa, *Chem. Commun.* **2002**, 2148–2149.

[24] a) V. Balzani, A. Juris, M. Venturi, *Chem. Rev.* **1996**, *96*, 759–833; b) C. M. Elliott, E. J. Hershenhart, *J. Am. Chem. Soc.* **1982**, *104*, 7519–7526; c) A. Juris, V. Balzani, F. Barigelletti, S. Campagna, P. Belser, A. Von Zelewsky, *Coord. Chem. Rev.* **1988**, *84*, 85–277.

[25] a) D. Tzalis, Y. Tor, *Chem. Commun.* **1996**, 1043–1044; b) E. C. Glazer, D. Magde, Y. Tor, *J. Am. Chem. Soc.* **2005**, *127*, 4190–4192.

[26] P. J. Connors, D. Tzalis, A. L. Dunnick, Y. Tor, *Inorg. Chem.* **1998**, *37*, 1121–1123.

[27] a) F. Hartl, S. Vernier, P. Belser, *Collect. Czech. Chem. Commun.* **2005**, *70*, 1891–1908; b) D. Martineau, P. Gros, M. Beley, Y. Fort, *Eur. J. Inorg. Chem.* **2004**, 3984–3986.

[28] B. P. Sullivan, J. M. Calvert, T. J. Meyer, *Inorg. Chem.* **1980**, *19*, 1404–1407.

[29] a) Reviews: M. Hocek, *Eur. J. Org. Chem.* **2003**, 245–254; b) L. A. Agrofoglio, I. Gillaizeau, Y. Saito, *Chem. Rev.* **2003**, *103*, 1875–1916; c) M. K. Lakshman, *J. Organomet. Chem.* **2002**, *653*, 234–251.

[30] a) Examples: M. Havelková, D. Dvořák, M. Hocek, *Synthesis* **2001**, 1704–1710; b) M. Hocek, D. Hocková, J. Štambaský, *Collect. Czech. Chem. Commun.* **2003**, *68*, 837–848; c) M. Hocek, D. Hocková, H. Dvořáková, *Synthesis* **2004**, 889–894; d) N. Amann, H.-A. Wagenknecht, *Synlett* **2002**, 687–691; e) E. Mayer, L. Valis, R. Huber, N. Amann, H.-A. Wagenknecht, *Synthesis* **2003**, 2335–2340; f) N. Kohyama, T. Katashima, Y. Yamamoto, *Synthesis* **2004**, 2799–2804.

[31] a) Examples: R. Volpini, S. Constanzi, C. Lambertucci, S. Vittori, K.-N. Klotz, A. Lorenzen, G. Cristalli, *Bioorg. Med. Chem. Lett.* **2001**, *11*, 1931–1934; b) S. Manfredini, P. G. Baraldi, R. Bazzanini, M. Marangoni, D. Simoni, J. Balzarini, E. De Clercq, *J. Med. Chem.* **1995**, *38*, 199–203; c) H. Gunji, A. Vasella, *Helv. Chim. Acta* **2000**, *83*, 2975–2992; d) P. Lang, G. Magnin, G. Mathis, A. Burger, J.-F. Biellmann, *J. Org. Chem.* **2000**, *65*, 7825–7832; e) J. L. Sessler, R. Wang, *J. Am. Chem. Soc.* **1996**, *118*, 9808–9809; f) J. L. Sessler, R. Wang, *J. Org. Chem.* **1998**, *63*, 4079–4091; g) J. L. Sessler, R. Wang, *Angew. Chem. Int. Ed.* **1998**, *37*, 1726–1729; h) J. L. Sessler, M. Sathiosatham, C. T. Brown, T. A. Rhodes, G. Wiederrecht, *J. Am. Chem. Soc.* **2001**, *123*, 3655–3660.

[32] E. M. Kober, J. V. Caspar, B. P. Sullivan, T. J. Meyer, *Inorg. Chem.* **1988**, *27*, 4587–4598.

[33] a) E. C. Western, J. R. Daft, E. M. Johnson, P. M. Gannett, K. H. Shaughnessy, *J. Org. Chem.* **2003**, *68*, 6767–6774; b) E. C. Western, K. H. Shaughnessy, *J. Org. Chem.* **2005**, *70*, 6378–6388; c) P. Čapek, M. Vrábel, Z. Hasník, R. Pohl, M. Hocek, *Synthesis* **2006**, 3515–3526.

[34] a) P. Čapek, M. Hocek, *Synlett* **2005**, 3005–3007; b) P. Čapek, R. Pohl, M. Hocek, *Org. Biomol. Chem.* **2006**, *4*, 2278–2284.

[35] D. P. Rillema, D. S. Jones, H. A. Levy, *J. Chem. Soc., Chem. Commun.* **1979**, 849–851.
[36] a) D. Onggo, M. L. Scudder, D. C. Craig, H. A. Goodwin, *J. Mol. Struct.* **2005**, *738*, 129–136; b) R. Chotalia, E. C. Constable, M. J. Hannon, D. A. Tocher, *J. Chem. Soc., Dalton Trans.* **1995**, *22*, 3571–3580; c) S. Encias, A. F. Morales, F. Barigelletti, A. M. Barthram, C. M. White, S. M. Couchman, J. C. Jeffery, M. D. Ward, D. C. Grills, M. W. George, *J. Chem. Soc., Dalton Trans.* **2001**, *22*, 3312–3319.
[37] E. Paleček, F. Jelen in *Electrochemistry of Nucleic Acids and Proteins. Towards Electrochemical Sensors for Genomics and Proteomics* (Eds.: E. Palecek, F. Scheller, J. Wang), Elsevier, Amsterdam, **2005**, pp. 74–174.
[38] H. Kiesele, J. Heinze in *Organic Electrochemistry* (Eds.: H. Lund, M. M. Baizer), Dekker, New York, **1991**, p. 331.
[39] P. A. Ropp, H. H. Thorp, *Chem. Biol.* **1999**, *6*, 599–605.
[40] A. J. Bard, L. R. Faulkner, Electrochemical Methods, 2nd ed., John Wiley, New York, **2001**.
[41] M. Srnec, J. Chalupský, M. Hocek, L. Zendlová, P. Hobza, L. Rulíšek, to be published.
[42] a) Examples: A. B. Eldrup, C. R. Allerson, C. F. Bennett, S. Bera, B. Bhat, N. Bhat, M. R. Bosserman, J. Brooks, C. Burlein, S. S. Carroll, P. D. Cook, K. L. Getty, M. MacCoss, D. R. McMasters, D. B. Olsen, T. P. Prakash, M. Prhavc, Q. L. Song, J. E. Tomassini, J. Xia, *J. Med. Chem.* **2004**, *47*, 2283–2295; b) D. B. Olsen, A. B. Eldrup, L. Bartholomew, B. Bhat, M. R. Bosserman, A. Ceccacci, L. F. Colwell, J. F. Fay, O. A. Flores, K. L. Getty, J. A. Grobler, R. L. LaFemina, E. J. Markel, G. Migliaccio, M. Prhavc, M. W. Stahlhut, J. E. Tomassini, M. MacCoss, D. J. Hazuda, S. S. Carroll, *Antimicrob. Agents Chemother.* **2004**, *48*, 3944–3953; c) A. B. Eldrup, M. Prhavc, J. Brooks, B. Bhat, T. P. Prakash, Q. L. Song, S. Bera, N. Bhat, P. Dande, P. D. Cook, C. F. Bennett, S. S. Carroll, R. G. Ball, M. Bosserman, C. Burlein, L. F. Colwell, J. F. Fay, O. A. Flores, K. Getty, R. L. LaFemina, J. Leone, M. MacCoss, D. R. McMasters, J. E. Tomassini, D. Von Langen, B. Wolanski, D. B. Olsen, *J. Med. Chem.* **2004**, *47*, 5284–5297.
[43] Recent examples: a) P. L. Beaulieu, J. Gillard, D. Bykowski, C. Brochu, N. Dansereau, J. S. Duceppe, B. Hache, A. Jakalian, L. Lagace, S. LaPlante, G. McKercher, E. Moreau, S. Perreault, T. Stammers, L. Thauvette, J. Warrington, G. Kukolj, *Bioorg. Med. Chem. Lett.* **2006**, *16*, 4987–4993; b) H. Li, J. Tatlock, A. Linton, J. Gonzalez, A. Borchardt, P. Dragovich, T. Jewell, T. Prins, R. Zhou, J. Blazel, H. Parge, R. Love, M. Hickey, C. Doan, S. Shi, R. Duggal, C. Lewis, S. Fuhrman, *Bioorg. Med. Chem. Lett.* **2006**, *16*, 4834–4838; c) B. K. Biswal, M. T. Wang, M. M. Cherney, L. Chan, C. G. Yannopoulos, D. Bilimoria, J. Bedard, M. N. G. James, *J. Mol. Biol.* **2006**, *361*, 33–45.
[44] Recent reviews: a) I. Kostova, *Curr. Med. Chem.* **2006**, *13*, 1085–1107; b) M. J. Clarke, *Coord. Chem. Rev.* **2002**, *232*, 69–93.
[45] a) G. E. Atilla-Gokcumen, D. S. Williams, H. Bregman, N. Pagano, E. Meggers, *ChemBioChem* **2006**, *7*, 1443–1450; b) J. E. Debreczeni, A. N. Bullock, G. E. Atilla, D. S. Williams, H. Bregman, S. Knapp, E. Meggers, *Angew. Chem. Int. Ed.* **2006**, *45*, 1580–1585; c) H. Bregman, P. J. Carroll, E. Meggers, *J. Am. Chem. Soc.* **2006**, *128*, 877–884; d) D. S. Williams, G. E. Atilla, H. Bregman, A. Arzoumanian, P. S. Klein, E. Meggers, *Angew. Chem. Int. Ed.* **2005**, *44*, 1984–1987.
[46] V. Lohmann, F. Korner, J. O. Koch, U. Herian, L. Theilmann, R. Bartenschlager, *Science* **1999**, *285*, 110–113.
[47] a) M. Hung, C. S. Gibbs, M. Tsiang, *Antiviral Res.* **2002**, *56*, 99–114; b) M. Hocek, P. Šilhár, I. H. Shih, E. Mabery, R. Mackman, *Bioorg. Med. Chem. Lett.* **2006**, *16*, 5290–5293.
[48] R. Ahlrichs, M. Bär, M. Häser, H. Horn, C. Kölmel, *Chem. Phys. Lett.* **1989**, *162*, 165.
[49] J. P. Perdew, K. Burke, M. Ernzerhof, *Phys. Rev. Lett.* **1996**, *77*, 3865–3868.
[50] a) A. D. Becke, *Phys. Rev. A* **1988**, *38*, 3098–3100; b) C. T. Lee, W. T. Yang, R. G. Parr, *Phys. Rev. B* **1988**, *37*, 785–789; c) A. D. Becke, *J. Chem. Phys.* **1993**, *98*, 5648–5652; d) P. J. Stephens, F. J. Devlin, C. F. Chabalowski, M. J. Frisch, *J. Phys. Chem.* **1994**, *98*, 11623–11627.
[51] K. Eichkorn, O. Treutler, H. Öhm, M. Häser, R. Ahlrichs, *Chem. Phys. Lett.* **1995**, *240*, 283–290.
[52] K. Eichkorn, F. Weigen, O. Treutler, R. Ahlrichs, *Theor. Chim. Acta* **1997**, *97*, 119–124.
[53] a) A. Schäfer, H. Horn, R. Ahlrichs, *J. Chem. Phys.* **1992**, *97*, 2571–2577; b) F. Weigend, R. Ahlrichs, *Phys. Chem. Chem. Phys.* **2006**, *7*, 3297–3305.
[54] A. Klamt, G. Schuurmann, *J. Chem. Soc., Perkin Trans. 2* **1993**, 799–805.
[55] A. Schäfer, A. Klamt, D. Sattel, J. C. W. Lohrenz, F. Eckert, *Phys. Chem. Chem. Phys.* **2000**, *2*, 2187–2193.
[56] F. Jensen, *Introduction to Computational Chemistry*, John Wiley & Sons, New York, **1999**.
[57] J. Llano, L. A. Ericsson, *Phys. Chem. Chem. Phys.* **2004**, *6*, 4707–4713.
[58] A. Altomare, G. Cascarano, G. Giacovazzo, A. Guagliardi, M. C. Burla, G. Polidori, M. Camalli, *J. Appl. Crystallogr.* **1994**, *27*, 435–435.
[59] P. W. Betteridge, J. R. Carruthers, R. I. Cooper, K. Prout, D. J. Watkin, *J. Appl. Crystallogr.* **2003**, *36*, 1487–1487.
[60] M. Hocek, A. Holý, I. Votruba, H. Dvořáková, *J. Med. Chem.* **2000**, *43*, 1817–1825.
[61] J. You, R. C. Bird, *J. Cell Physiol.* **1995**, *164*, 424–433.

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