Inorg. Chem. **1995,** *34,* 4271−4274

Chromium-Centered Imido Group Transfer

Wa-Hung Leung,*[†] Man-Ching Wu,[†]
Tai-Chu Lau,[‡] and Wing-Tak Wong[§,‖]

Department of Chemistry, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong, Department of Biology and Chemistry, The City University of Hong Kong, Tat Chee Avenue, Kowloon, Hong Kong, and Department of Chemistry, The University of Hong Kong, Pokfulam Road, Hong Kong

Received December 21, 1994

Introduction

Although high-valent chromium oxides and chromyl chloride are widely used in organic oxidations,[1] examples of chromium-centered nitrogen atom transfer reactions are rare. The organoimido−Cr complexes isolated thus far are relatively inert toward imido group transfer.[2,3,4] In fact, there are few mechanistic studies on the atom transfer reactions of organoimido complexes,[5] in constrast to a wealth of information on oxo transfer chemistry of the isoelectronic oxometal counterparts.[6] Metal-catalyzed aziridination of olefins by PhI=NTs (Ts = *p*-toluenesulfonyl), presumably via the unisolated (tosylimido)-metal intermediates, is well documented, however.[7] Recently, Bruice and coworkers demonstrated that the rate of olefin epoxidation by oxochromium(V) porphyrins correlates with the $Cr^{VI}-Cr^{V}$ reduction potential, suggesting that charge transfer plays a key role in the chromium-centered oxo transfer.[8] In this regard, we believe that cationic imido−Cr complexes with high formal potentials could be more reactive toward atom transfer reactions than their neutral analogues. As our continuous effort in elucidating the factors governing metal-mediated nitrogen atom transfer reaction, we here report the synthesis, crystal structure, and imido transfer reaction of a dicationic diimido−Cr(VI) complex.

Experimental Section

All solvents were dried and distilled prior to use. NMR spectra were recorded on a JEOL EX 400 spectrometer, mass spectra on a Kratos MS 80FRAQ spectrometer, and UV/vis spectra on a Milton Roy Spectronic 3000 diode array spectrophotometer. Cyclic voltammetry was performed with a Princeton Applied Research (PAR) Model 273A potentiostat. Potentials were with respect to a Ag^+/Ag reference electrode in acetonitrile but are reported respect to the ferrocenium/ferrocene couple as measured in the same solution. Elemental analyses were done by Medac Ltd., Brunel University, U.K.

Table 1. Crystallographic Data for **1**·$0.5C_6H_{14}$

chem formula	$[C_{23}H_{29}N_5B_2F_8Cr]\cdot 0.5C_6H_{14}$	T, °C	25
a, Å	12.302 (7)	λ, Å	0.71073
b, Å	20.483 (3)	ϱ_{calcd}, g cm^{-3}	1.338
c, Å	25.384 (8)	μ, cm^{-1}	4.17
V, Å^3	6396 (5)	R[a]	0.091
Z	8	R_w[b]	0.090
fw	644.21	GOF[c]	1.180
space group	*Pbcn* (No. 60)		

[a] $R = \Sigma|F_o| - |F_c|/|F_o|$. [b] $R_w = [\Sigma w(|F_o| - |F_c|)^2/\Sigma w|F_o|^2)]^{1/2}$. [c] GOF $= [\Sigma w(|F_c| - |F_o|)^2/ (N_{obs} - N_{param})]^{1/2}$.

Table 2. Selected Bond Lengths (Å) and Angles (deg) for **1**·$0.5C_6H_{14}$

Cr(1)−N(1)	2.04(1)	Cr(1)−N(2)	2.03(1)
Cr(1)−N(3)	2.05(1)	Cr(1)−N(4)	1.62(1)
Cr(1)−N(5)	1.65(1)	N(1)−C(1)	1.40(2)
N(1)−C(5)	1.35(2)	N(2)−C(10)	1.30(2)
N(3)−C(11)	1.35(2)	N(3)−C(15)	1.32(2)
N(4)−C(16)	1.47(2)	N(5)−C(2)	1.45(2)
N(1)−Cr(1)−N(2)	75.7(6)	N(1)−Cr(1)−N(3)	153.4(5)
N(1)−Cr(1)−N(4)	94.9(7)	N(1)−Cr(1)−N(5)	100.1(7)
N(2)−Cr(1)−N(3)	77.8(6)	N(2)−Cr(1)−N(4)	125.8(6)
N(2)−Cr(1)−N(5)	118.7(6)	N(3)−Cr(1)−N(4)	98.7(7)
N(3)−Cr(1)−N(5)	94.5(7)	N(4)−Cr(1)−N(5)	115.6(6)
Cr(1)−N(1)−C(5)	117(1)	C(1)−N(1)−C(5)	117(1)
Cr(1)−N(1)−C(1)	124(1)	Cr(1)−N(2)−C(6)	118(1)
Cr(1)−N(2)−C(10)	118(1)	C(6)−N(2)−C(10)	122(1)
Cr(1)−N(3)−C(11)	118(1)	Cr(1)−N(3)−C(15)	124(1)
C(11)−N(3)−C(15)	117(1)	Cr(1)−N(4)−C(16)	168(1)
Cr(1) N(5) C(20)	165(1)		

Caution! High-valent chromium compounds are potentially carcinogenic and should be handled appropriately, avoiding skin contact and inhalation. $[Cr(N\text{-}t\text{-}Bu)_2Cl_2]$[2b] was prepared as described previously. The terpy (2,2′:6′,2″-terpyridine) ligand was obtained from Aldrich and used as received. NaOAr (Ar = 2,6-diisopropylphenyl) was synthesized by reaction of HOAr with 2 equiv of NaH in THF.

Preparation. $[Cr(N\text{-}t\text{-}Bu)_2(terpy)](BF_4)_2$ (1). To a solution of $Cr(N\text{-}t\text{-}Bu)_2Cl_2$ (0.3 g, 1.13 mmol) in CH_2Cl_2 (10 mL) was added 1 equiv of terpy (0.26 g, 1.13 mmol) and the mixture was stirred at room temperature for 2 h. The orange precipitate was collected and washed with ether. To the orange solid was added acetonitrile (10 mL) and $AgBF_4$ (0.44 g, 2.26 mmol), and the resulting mixture was stirred overnight and filtered. The filtrate was layered with ether (20 mL) and left to stand at room temperature for 2 day. The orange crystals was collected and washed with ether (Yield 75%). ^1H-NMR (CD_3CN): δ 1.55 (s, 18H, N-*t*-Bu), 7.84−8.77 (m, 11H, terpy). IR: ν (Cr=N) 1176 cm^{-1}. MS (FAB) *m/e* 427 ($M^+ - 2BF_4$). UV/vis (CH_3CN): λ_{max}/nm (ϵ/ M^{-1} cm^{-1}): 354 (10 600), 370 (10300). Anal. Calcd for $[C_{23}H_{29}N_5B_2F_8Cr]$: C, 46.0; H, 4.8; N, 11.7. Found: C, 45.5; H, 4.8; N, 11.3. The triflate salt can be prepared similarly using Ag(OTf) (OTf = triflate) instead of $AgBF_4$.

$[Cr(terpy)(PMe_3)_3](BF_4)_3$ (2). To a solution of **1** (0.3 g, 0.5 mmol) in acetonitrile (10 mL) was added excess PMe_3 (3 mmol, 3 mL of a 1M solution in toluene), and the solution was stirred at room temperature for 4 h, during which the color changed from orange to yellowish-green to dark green. The solvent was pumped off, and the residue was washed with ether and extracted with CH_2Cl_2 (12 mL). The filtrate was concentrated and layered with ether for 2 days to give green crystals (yield 0.17 g, 45%). UV/vis (CH_3CN): λ_{max}/nm (ϵ/M^{-1} cm^{-1}) 285 (17 100), 334 (11 200), 441 (2090), 642 (963). μ_{eff} = 3.3

---

* Author to whom correspondence should be addressed.

[†] The Hong Kong University of Science and Technology.

[‡] The City University of Hong Kong.

[§] The University of Hong Kong.

[‖] Author to whom crystallographic enquires should be addressed.

(1) Cainelli, G.; Gardillo, G. *Chromium Oxidations in Organic Chemistry*; Springer Verlag: Berlin, 1984.

(2) Cr^{VI}: (a) Nugent W. A.; Harlow, R. L. *Inorg. Chem.* **1980**, *19*, 777. (b) Danopoulos, A. A.; Leung, W.-H.; Wilkinson, G.; Hussain-Bates, B.; Hursthouse, M. B. *Polyhedron* **1990**, *9*, 2625. (c) Meijboom, N.; Schaverien, C. J.; Orpen, A. G. *Organometallics* **1990**, *9*, 774. (d) Sundermeyer, J.; Weber, K.; Pritzkow, H. *Angew. Chem., Int. Ed. Engl.* **1993**, *32*, 731.

(3) Cr^{V}: (a) Leung, W.-H.; Danopoulos, A. A.; Hussain-Bates, B.; . Hursthouse, M. B; Wilkinson, G. *J. Chem. Soc., Dalton Trans.* **1991**, 2051. (b) Leung, W.-H.; Wu, M.-C.; Wong, K.-Y.; Wang, Y. *J. Chem. Soc., Dalton Trans.* **1994**, 1659.

(4) Imido tranfer reactions of imido-Cr^{IV} porphyrins was reported recently: Moubaraki, B.; Murray, K. S.; Nicola, P. J.; West, B. O. *Polyhedron*, **1994**, *13*, 485.

(5) Holm, R. H. *Chem. Rev.* **1987**, *87*, 1401 and references cited therein.

(6) Harlan, E. W.; Holm, R. H. *J. Am. Chem. Soc.*, **1990**, *112*, 186. (b) Perez, P. J.; White, P. S.; Brookhart, M.; Templeton, *Inorg. Chem.* **1994**, *33*, 6050.

(7) See, for example: (a) Mahy J-P.; Bedi G.; Battioni, P.; Mansuy, D.; *J. Chem. Soc., Perkin Trans. 2* **1988**, 1517. (b) Evans, D. A.; Faul, M. M.; Bilodeau, M. T. *J. Am. Chem. Soc.* **1994**, *116*, 2742 and references cited therein.

(8) (a) Ostovic, D.; Bruice, T. C. *Acc. Chem. Res.* **1992**, *25*, 314. (b) Ostovic D.; He, G.-X.; Brucie, T. C. In *Metalloporphyrins in Catalytic Oxidations*; Sheldon R., A., Ed., Marcel Dekker: New York, 1994.

0020-1669/95/1334-4271$09.00/0

Table 3. Atomic Coordinates

atom	*x*	*y*	*z*
Cr(1)	0.7880(2)	0.3326(1)	0.1234(1)
F(1)	0.223(3)	0.094(2)	0.207(2)
F(2)	0.281(2)	0.178(2)	0.175(2)
F(3)	0.378(2)	0.092(2)	0.196(2)
F(4)	0.316(3)	0.154(2)	0.255(2)
F(5)	0.403(2)	0.161(3)	0.501(2)
F(6)	0.414(2)	0.100(2)	0.562(3)
F(7)	0.314(2)	0.184(2)	0.576(2)
F(8)	0.275(3)	0.113(2)	0.527(2)
N(1)	0.798(1)	0.3541(7)	0.0453(4)
N(2)	0.8460(10)	0.4253(5)	0.1216(6)
N(3)	0.811(1)	0.3525(7)	0.2019(5)
N(4)	0.860(1)	0.2666(6)	0.1195(6)
N(5)	0.6556(10)	0.3214(6)	0.1291(6)
C(1)	0.766(1)	0.3118(8)	0.0049(7)
C(2)	0.770(2)	0.327(1)	−0.0456(6)
C(3)	0.800(2)	0.386(1)	−0.0571(7)
C(4)	0.833(2)	0.4344(10)	−0.0198(8)
C(5)	0.829(1)	0.4152(8)	0.0317(6)
C(6)	0.862(1)	0.4554(10)	0.0729(7)
C(7)	0.900(2)	0.520(1)	0.0743(7)
C(8)	0.922(1)	0.5481(8)	0.119(1)
C(9)	0.902(2)	0.518(1)	0.1687(8)
C(10)	0.864(1)	0.4554(9)	0.1659(8)
C(11)	0.844(1)	0.4130(9)	0.2157(7)
C(12)	0.858(2)	0.4327(9)	0.2661(7)
C(13)	0.838(2)	0.392(1)	0.3061(7)
C(14)	0.808(2)	0.328(1)	0.2946(8)
C(15)	0.791(1)	0.3108(9)	0.2404(6)
C(16)	0.905(1)	0.2001(8)	0.1176(8)
C(17)	0.967(2)	0.196(1)	0.067(1)
C(18)	0.818(1)	0.1521(7)	0.1269(9)
C(19)	0.979(2)	0.198(1)	0.164(1)
C(20)	0.547(1)	0.295(1)	0.1291(10)
C(21)	0.489(2)	0.318(2)	0.085(1)
C(22)	0.542(2)	0.229(1)	0.121(3)
C(23)	0.505(3)	0.322(2)	0.179(1)
C(24)	0.5971	0.5026	0.3997
C(25)	0.6271	0.4650	0.4481
C(26)	0.5673	0.4979	0.4865
C(27)	0.5864	0.5084	0.6552
C(28)	0.6031	0.5080	0.7077
C(29)	0.5273	0.4869	0.7296
B(1)	0.295(3)	0.128(2)	0.208(2)
B(2)	0.347(3)	0.139(2)	0.539(2)
H(1)	0.7412	0.2680	0.0143
H(2)	0.7474	0.2967	−0.0734
H(3)	0.8080	0.3976	−0.0952
H(4)	0.8553	0.4782	−0.0311
H(5)	0.9073	0.5464	0.0423
H(6)	0.9530	0.5922	0.1210
H(7)	0.9182	0.5393	0.2036
H(8)	0.8808	0.4792	0.2729
H(9)	0.8419	0.4091	0.3434
H(10)	0.7992	0.2959	0.3233
H(11)	0.7634	0.2659	0.2315
H(12)	1.0001	0.1542	0.0621
H(13)	0.9152	0.2017	0.0382
H(14)	1.0200	0.2289	0.0641
H(15)	0.7800	0.1584	0.1579
H(16)	0.7647	0.1557	0.0972
H(17)	0.8431	0.1072	0.1248
H(18)	1.0172	0.1546	0.1683
H(19)	1.0383	0.2290	0.1631
H(20)	0.9426	0.2039	0.1974
H(21)	0.4872	0.3640	0.0836
H(22)	0.5245	0.3027	0.0526
H(23)	0.4158	0.3016	0.0836
H(24)	0.4700	0.2121	0.1267
H(25)	0.5781	0.2131	0.0952
H(26)	0.5803	0.2103	0.1563
H(27)	0.5443	0.3080	0.2094
H(28)	0.5044	0.3698	0.1797
H(29)	0.4276	0.3102	0.1862

μ_B (Evans method[9]). Anal. Calcd: C, 37.2; H, 4.9; N, 5.4. Found: C, 37.2; H, 5.0; N, 5.7.

[Cr(N-*t*-Bu)$_2$(OAr)$_2$] (3). A mixture of [Cr(N-*t*-Bu)$_2$Cl$_2$] (0.3 g, 1.13 mmol) and 2 equiv of NaOAr (0.45g, 2.26 mmol) in toluene (15 mL) was stirred at room temperature overnight. The solvent was evaporated to dryness, and the residue was extracted with hexane. Concentrating and cooling the hexane extract at −10 °C afforded air-stable dark red crystals (yield 0.46 g, 75%). ^{1}H-NMR (CDCl$_3$): δ 1.16 (s, 18H, *t*-Bu), 1.26 (d, 24H, C*H*(CH$_3$)$_2$), 3.54 (sept, 4H, CH(C*H*$_3$)$_2$), 6.87–7.07 (m, 6H, aromatic). Anal. Calcd for [$C_{32}H_{35}N_2O_2Cr$]: C, 67.3; H, 6.6; N, 5.3. Found: C, 66.2; H, 6.8; N, 5.4.

Kinetic Measurement. Kinetic experiments were performed spectrophotometrically under pseudo-first-order conditions in acetonitrile using a Hewlett-Packard 8452A diode array spectrophotometer. The progress of the reaction was monitored at 362 nm. The decay of **1** was found to exhibit biphasic behavior and the pseudo-first-order rate constants k_{obs1} and k_{obs2} for the first and second step respectively were obtained by a non-linear least-square fit of the absorbance (A_t) to time t according to the equation $A_t = A_1 \exp(-k_{obs1}t) + A_2 \exp(-k_{obs2}t) + A_3$.

X-ray Analysis. A summary of the crystal and data processing parameters is given in Table 1 and selected bond lengths and angles are given in Table 2. X-ray quality crystals were obtained by slow diffusion of ether to an acetonitrile solution. Three independent batches of crystals were examined, all suffering solvent loss during crystallization; the reported set is the best of the these three. An orange block (0.22 × 0.24 × 0.36 mm) was used for data collection on a Rigaku RU200-AFC7R diffractometer. Intensity data were corrected for Lorentz and polarization efffects. Absorption correction by ω-scan method was also applied. The structure was solved by Patterson method and refined by a full-matrix least-squares analysis. A partially occupied hexane molecule (occupany factor 0.5) was revealed. Their contributions are included in the structure factor calculations but were not refined. All hydrogen atoms were refined isotropically and all other atoms except B were refined anisotropically. The hydrogen atoms were included as fixed atoms in idealized positions (C−H, 0.95 Å).

Results and Discussion

Syntheses. Interaction of [Cr(N-*t*-Bu)$_2$Cl$_2$] with terpy (2,2′:6′,2″-terpyridine) followed by treatment with 2 equiv of AgBF$_4$ afforded air-stable orange [Cr(N-*t*-Bu)$_2$(terpy)](BF$_4$)$_2$ (**1**). The structure of **1** has been established by X-ray crystallography, and Figure 1 shows a perspective view of the cation [Cr(N-*t*-Bu)$_2$(terpy)]$^{2+}$; selected bond lengths and angles are given in Table 2. To our knowledge, complex **1** is the first example of structurally characterized dicationic chromium(VI) complex. The geometry around Cr in **1** is best described as trigonal bipyramidal with two imide ligands and one terpyridyl nitrogen in the equatorial plane. The Cr−N(imido) distance of ca. 1.64 Å and Cr−N−C angle of ca. 167° are typical for diimido−Cr(VI) complexes,[2] indicative of triple bond character of the Cr−N(imido) bond. The Cr−N(terpy) distance of ca. 2.03 Å is comparable to that for Cr(VI)−N(pyridine) in [Cr(N-*t*-Bu)$_2$py$_2$(η^1-O$_3$SCF$_3$)](CF$_3$SO$_3$).[2b] The IR band at 1010 cm^{-1} is attributed to the Cr=N-*t*-Bu stretching mode. The UV/vis spectrum of **1** in acetonitrile displays a characteristic absorption at ca. 300−400 nm, which is tentatively assigned to the N(terpy) → Cr LMCT transition.

1 reacts with tertiary phosphines such as PMe$_3$ cleanly to give phosphinimines *t*-BuN=PR$_3$, identified by ^{31}P NMR spectroscopy, along with a green Cr-containing species analyzed as [Cr^{III}(terpy)(PMe$_3$)$_3$](BF$_4$)$_3$ (**2**). Complex **2** was formed presumably via oxidation of the Cr(II) product [Cr^{II}(terpy)-

---

(9) Evans, D. *J. Chem. Soc.* **1959**, 2003.

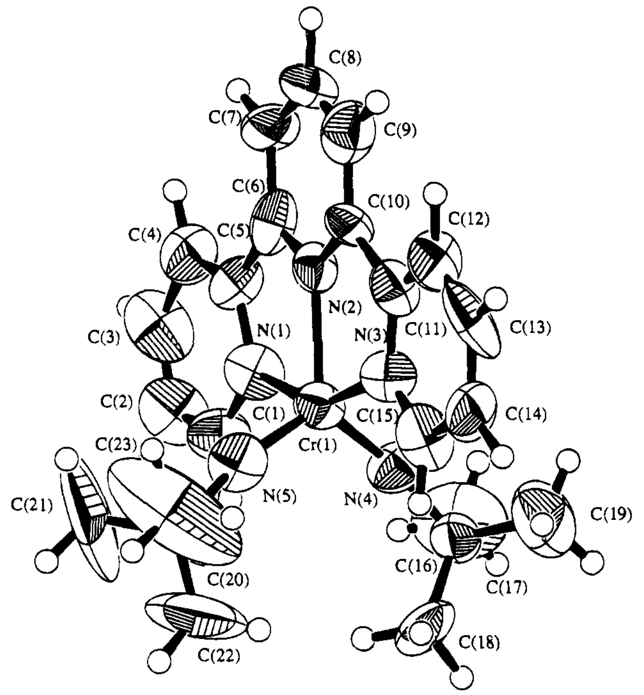

Figure 1. Perspective view of the cation $[Cr(N\text{-}t\text{-}Bu)_2(terpy)]^{2+}$.

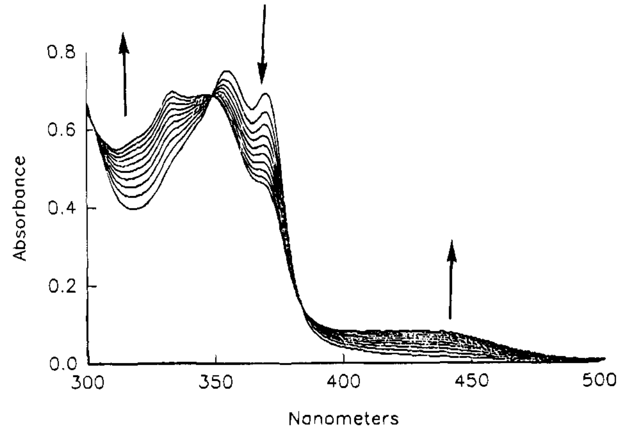

Figure 2. Optical spectral trace for the reaction between **1** and PMe_3 in CH_3CN ([**1**] = 0.1 mM, $[PMe_3]$ = 10 mM).

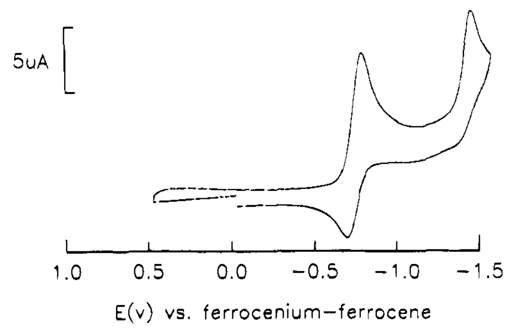

Figure 3. Cyclic voltammogram of **1** at a glassy carbon electrode with 0.1 M $[n\text{-}Bu_4N]BF_4$ in CH_3CN as supporting electrolyte, scan rate = 100 mV s^{-1}.

Table 4. Pseudo-First-Order Rate Constants for the Reaction of **1** with PMe_3 at 25.0 °C in Acetonitrile

$10^2[PMe_3]$, M	10^3k_{obs1}, s^{-1}	10^4k_{obs2}, s^{-1}
4.50	1.6	1.0
5.50	4.0	2.9
16.5	6.6	5.4
27.5	9.2	9.9
33.5	19	18

$(PMe_3)_3](BF_4)_2$ by adventitious air during crystallization. It should be noted that reaction of PMe_3 with neutral $[Cr(N\text{-}t\text{-}Bu)_2Cl_2]$ only yields the phosphine adduct $[Cr(N\text{-}t\text{-}Bu)_2Cl_2(PMe_3)]$.

Kinetics of Imido Transfer from Bis(imido)−Cr(VI). The imido transfer reactions of **1** with tertiary phosphines have been followed by UV/vis spectroscopy. Figure 2 displays a spectral trace for a reaction mixture containing ca. 0.1 mM **1** and 10 mM PMe_3, which shows well-defined isosbestic points at 348 and 382 nm. The kinetics of reaction was followed at 362 nm with a large excess of PMe_3: [**1**] = 0.1 mM and $[PMe_3] = 9 \times 10^{-3}$ to 7×10^{-2} M. Under these conditions the decay of **1** was found to follow biphasic kinetics and absorbance−time data fitted well to a biexponential model. Representative pseudo-first-order rate constants k_{obs1} and k_{obs2} at 25.0 °C for steps 1 and 2, respectively, are listed in Table 4. Plot of k_{obs1} vs $[PMe_3]$ is linear, i.e. rate = k_2 $[PMe_3]$. On the other hand, a plot of k_{obs2} vs $[PMe_3]^2$ is linear, i.e. rate = k_3 $[PMe_3]^2$. At 25.0 °C $k_2 = 0.48 \pm 0.10$ M^{-1} s^{-1} and $k_3 = 1.44 \pm 0.16$ M^{-2} s^{-1}. These results are consistent with the following mechanism (Scheme 1). For step 2, at $K[PMe_3] \gg 1$, rate $\approx Kk'[Cr^{IV}][PMe_3]^2$, which agrees with the observed rate law with $k_3 = Kk'$. Despite many attempts we have been unable to isolate the imido−Cr(IV) intermediate.

Scheme 1

step 1

$$[Cr(N\text{-}t\text{-}Bu)_2(terpy)]^{2+} + PMe_3 \xrightarrow{k_2} [Cr(N\text{-}t\text{-}Bu)(terpy)]^{2+} + t\text{-}BuN{=}PMe_3$$

step 2

$$[Cr(N\text{-}t\text{-}Bu)(terpy)]^{2+} + PMe_3 \overset{K}{\longleftrightarrow} [Cr(N\text{-}t\text{-}Bu)(terpy)(PMe_3)]^{2+}$$

$$[Cr(N\text{-}t\text{-}Bu)(terpy)(PMe_3)]^{2+} + PMe_3 \xrightarrow{k'} Cr(II) + t\text{-}BuN{=}PMe_3$$

Electrochemistry. To understand the thermodynamic driving force governing the imido transfer reaction of **1**, we determined the formal potentials of diimido−Cr^{VI} complexes by cyclic voltammetry. The cyclic voltammogram of **1** shown in Figure 3 consists of a reversible couple at −0.74 V and an irreversible wave at −1.45 V vs ferrocenium−ferrocene. The former couple is attributed to the metal-centered Cr(VI)/Cr(V) reduction, which as far as we are aware, is the first observation of reversible Cr(VI)/Cr(V) couple. The Cr(VI)/Cr(V) formal potential for cationic **1** is considerably less anodic than those for the neutral diimido−Cr^{VI} analogs. For example, $[Cr(N\text{-}t\text{-}Bu)_2Cl_2]$ is reduced irreversibly at ca. −2.0 V. The irreversibility of reduction of $[Cr(N\text{-}t\text{-}Bu)_2Cl_2]$ is possibly due to instability of the reduced bis(imido)−Cr(V) species. To this end, we also prepared the sterically encumbered diaryloxo complex $[Cr(N\text{-}t\text{-}Bu)_2(OAr)_2]$ (**3**, Ar = 2,6-diisopropylphenyl) that should be kinetically stable with respect to reduction. **3** is an air-stable compound and shows no reactions with phosphines. The cyclic voltamogram of **3** in acetontrile displays a reversible couple at −1.2 V, ascribable to the metal-centered Cr(VI)/Cr(V) reduction. It seems that the less negative formal potential for cationic **1** provides the driving force for its high reactivity in imido transfer with phosphines.

In summary, we have successfully isolated a dicationic bis(imido)−Cr(VI) complex that is more reactive toward imido transfer than its neutral analogs. By judicious choice of coligands and fine-tuning the formal potential, we believe that highly oxidizing imido complexes should undergo nitrogen atom transfer reactions toward other kinds of organic substrates such as hydrocarbons.

Acknowledgment. The financial support from The Hong Kong University of Science and Technology, The University of Hong Kong, The City University of Hong Kong, and The Hong Kong Research Grants Council is gratefully acknowledged.

Supporting Information Available: Listings of crystal data (Table S1), complete bond distances (Table S2) and angles (Table S3), atomic coordinates with isotropic thermal parameters (Table S4), and anisotropic displacement parameters (Table S5) (8 pages). Ordering information is given on any current masthead page.

IC941451L