

!"#\$%&' () "& %)"&+ , -"%' () ' (. / 01\$2*&)34 5 6 ,71(8,\$%,9(4&
,)\$ / 01\$2*&)34 5 61(8,9(4& : %""* β1-3-4(\$&8"+%) *

GH I ' < ; 5.7:27 , -HB' J67K5*6** *73 < I L H"7K8527K**

(M7A161.12 " : I // #23 ; 52@6A10+ , ; "##2K2 " : ; 52@6A10+ *73) "#28.#0 B7K6722067K , N2F67K O76P20A61+ , Q26R67K % , , ST% , ; 567*)

U2826P23 L81"420 %(, & , % ; 02P6A23 ' "P2@420 %(, & , %

; < "+" , -" M7120*816"7A " : & , (C36/527+ # % , V , WC"D*36*X"#2 (NNY) *73 & , (C36/527+ # % , VC"D*X"#2 (NNL) ?615 βC8+8#"32D1067 (βC ; Y) *02
A1.3623 4+ %HC ') U *73 A12*3+CA1*12 #. "02A82782 @2*A.02@271A , *73 152 A1"6856"@21062A *73 152 *AA"86*16"7 8"7A1*71A *02 2A16@*123\$ M1 6A " : . 73 15*1
152 5+30"/5"468 67120*816"7 6A 152 @*67 306P67K " : 082 : "0 152 : "0@*16"7 " : 678#.A6"7 8"@/#2D2A " : NNY *73 NNL ?615 βC ; Y\$ M7 152 /02A2782 " : *#6/5*168
*8"5" #A (: 0" @ %C/0"/*7" # 1" %C/271*7" #) , NNY *73 NNL 10*7A:20 : 0" @ 152 ; Y 8*P61+ 1" 152 *Z.2".A /5*A2\$ [. 278567K 2D/206@271A " : NNY *73 NNL
4+ 6"3632 : .01520 /0"P2 152 *4"P2 8"78#.A6"7A\$ >52 02A.#1A A.KK2A1 15*1 A1202" 2:281 6A 152 80.86*# : *81"0 1" 152 672D6A12782 " : 7*7"1.42 67 NNY ("0
NNL) βC ; Y A+A12@A\$

=&3 : (+\$ ' : 5>1?@A , ' , & , \$31" , " , & .4#(+&' -&) -& , .4#(+&' -&) -& ,)%' ("+(23 , β1-3-4(\$&8"+%) β

; +8#"32D1067A (; YA) *02 8+8#68 " #6K"A*885*0632A 15*1
5*P2 152 *46#61+ 1" A2#2816P2# 678"0/"0*12 P*06".A 67"OK*768
"0 "OK*768 8"@/1".73A % &]\$ -1.362A "7 " @"#28.#*0 728FC
#*82 "1+ /2 8"@/#2D2A 5*P2 02826P23 67802*A67K 67120A1 67
028271 +2*0A^[v] (]\$ j6 21 *# \$ 02/"0123 15*^[v]] βC ; Y "0 γC ; Y
8*7 : "0@ 7*7"1.42 4+ 678#.367K 152 0"3#6F2 @"#28.#2 , 6\$
2\$ *##CtransC% , C36/527+C% , V , (C52D*106272 (YNH) \$ I KC
4*06* *73 56A 8"?"0F20^[w] (]\$ " : .73 15*1 A"@2 "D*X"#2
@"#28.#2A , A.85 *A & , (C36/527+ # % , VC"D*X"#2 (NNL) , & ,
(C36/525+ # % , V , WC"D*36*X"#2 (NNY) , & C/525+ #C((WC
36/527+ # %) , V , WC"D*36*X"#2 (NQY) *73 & , ((W , W_C
36/527+ # %) , V , WC"D*X"#2 (QQLY) 8" .#3 : "0@ & ' % 467*0+
678#.A6"7 8"@/#2D2A ?615 γC ; Y\$ I 1 56K520 8"782710*16"7 ,
152A2 .761A : "0@ 2D127323 7*7"1.42A\$ >52 : "0@*16"7 " :
152A2 7*7"1.42A 6A 02P20A64#2 ?527 52*167K *73 8"##67K ,
A6@6#*0 1" 152 425*P6"0 " : 12@/20*1.02C32/273271 #6Z.63
80+A1*#A\$ M1 5*A *#A" 4227 : " : .73 15*1 152A2 "D*X"#2A 8*77"1
: "0@ 7*7"1.42 ?615 βC ; Y\$ O/ 1" 7"? , "7# : 6P2 A@*##
@"#28.#2A , 6\$2\$ YNH , NNY , NNL , NQY *73 QQLY 5*P2
4227 02/"0123 1" : "0@ 7*7"1.42 ?615 ; YA\$ >5.A , 61 6A 152C
"02168*##+ 6@/"01*71 1" A1.3+ 152 @285*76A@ " : 152 : "0@*C
16"7 " : 152 7*7"1.42^[^] (]\$ >56A @*+ 52# / A2*08567K : "0
@ "02 A.85 A@*## @"#28.#2A\$

M7 156A / * / 20 , ?2 : 60A1 *6@ *1 A1.3+67K 152 : "0@*16"7
" : 678#.A6"7 8"@/#2D2A 421?227 βC ; Y *73 NNY ("0 NNL)
4+ @2*7A " : %HC ') U @2*A.02@271 , *73 *4A"0/16"7 *73
:#. "02A82782 A/2810*# 128576Z.2A\$ >52 321*6#23 67:"0@*16"7
"7 152 67120*816"7A " : NNY *73 NNL ?615 βC ; Y 3"2A 7"1

2D6A1 67 152 #6120*1.02\$ M7 "0320 1" 2D/#"02 152 02*A"7 ?5+
152 7*7"1.42 8*77"1 42 : "0@23 67 152A2 A+A12@A , ?2 *#A"
? *71 1" A1.3+ 152 67120*816"7 421?227 *#6/5*168 *8"5" #A ,
NNY ("0 NNL) *73 βC ; Y\$ > " 2#.863*12 ?521520 152
1207*0+ 678#.A6"7 8"@/#2D 6A : "0@23 "0 7"1 ?6## 52# / .A 1"
2D/#*67 152 : *81"0A " : 28167K 152 : "0@*16"7 " : 152 7*7"1.42\$
5 C82&+ #D&) "

%\$% U2*K271A *73 67A10.@271A

NNY *73 NNL (I #30685) ?202 850"@*1"K0*/523 4+ *
A6#68* K2# 8"#. @7\$ βC ; Y *73 aM (Q26R67K -5.*7K5.*7
U2*K271 N#*71 , ; 567*) ?202 0280+A1*##6X23 15022 16@2A\$
Y&L (==\$ = b) ?*A / .085*A23 : 0"@ ; *@4063K2 MA"1"/2
] *4"0*1"0+ M78\$, O- I \$ I ## "1520 02*K271A ?202 " : *7*#+16C
8*# K0*32\$

%HC ') U A/2810* ?202 0.7 "7 *7 I UJCW , , A/2810"@C
2120\$ I1 #2*A1 S , , 10*7A6271A ?202 8"##28123 : "0 2*85 %HC
') U A/2810.@\$; 52@68*# A56:1A ?202 2D/02AA23 02*#16P2 1"
*7 *3323 671207*# A1*73*03 " : @215*7" # (δ c V\$W , , d
% , e ^ } S]\$ 14A"0/16"7 *73 : #. "02A82782 A/2810* ?202
028"0323 "7 * -56@*3X. O!CV% , , *73 * H61*856 9CW(, ,
:#. "02A82782 A/2810* /5"1"@2120 , 02A/2816P2#+\$ 9#."02AC
82782 *76A"10"/+ ?*A 028"0323 "7 * -56@*3X. U9C(V , %
/5"1"@2120\$ BD861*16"7 ?*P2#27K15A " : NNY *73 NNL *02
&S , 7@ *73 V%V 7@ , 02A/2816P2#+\$

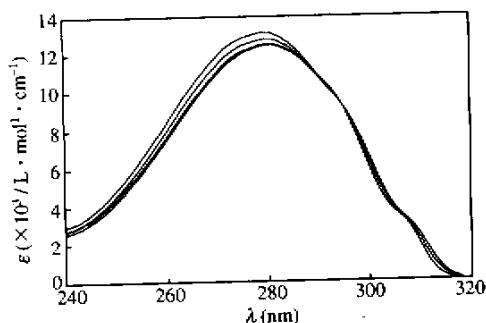
%\$&) 215"3A

!"#\$% &'(")*#& #+ , , - .*/ , , 0 1232 4324.32/ 56
/))* "92:)* :2"9.*#'; <443#43)."2 .: #(*&(7#'=
(:2 +3.\$")#* φ #* :#32 "9.*?>)#&'#\$% &'(")*#& .*/
β=@- 1232 .//2/ "# .A:B +'.&%, .*/ /)'("2/ "# "92 :.3%
1)"9 "3)4'6 /)&'")'2/ 1."23; <' :2.&(32:2*"& 1232 \$.33)2/
#(" ." 3##: "2:423."(32;

2 Results and discussion

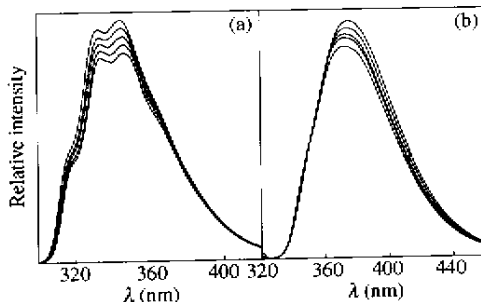
C;> !42\$3.' \$9.3.\$(23)&)"\$&

C;>;> <5"")#* &42\$3. D)8; > &9#1& "92 .5"=
")#* &42\$3. #+ , , -)* "92 &#(')"#& #+ β=@- ." /)+232**
\$#\$2*\$3.)#*& E)"9 "92)*\$32.&2)* "92 β=@- \$#\$2*\$3.=
")#* , "92 .5"")#*)*(2*&)"6 &'89""6 /2\$32.&2& .\$\$#:4.=
)2/ 56.)4&)"\$ 4#)*" .CFG*: ,)*/\$.))*8 "9." , , -
:.6 #3: .*)\$'(&)"#* \$#:4'2H 1)"9 β=@- ;



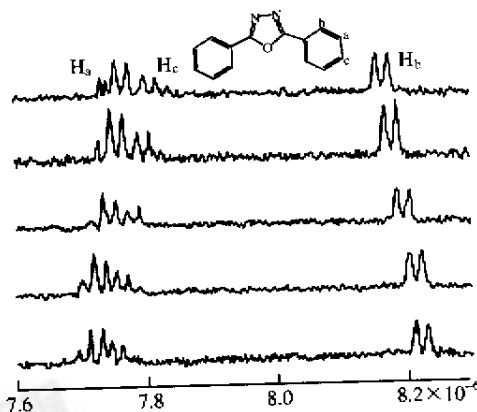
D)8; >; 1J &42\$3. #+ , , - (G;K L>K^{MA} :#'|B)))* β=@- &#(')"#*;
D3#: "#4 "5#""#: : [β=@-]O K, P L>K^{MG}, C L>K^{MQ},
>L>K^{MC} :#'|B;

C;>;C D'(#32&\$2*\$2 &42\$3. D)8; C /24)\$"& +'(#32&=
\$2*\$2 &42\$3. #+ , , - .*/ , , 0 ." /)+232** β=@- \$#\$2*\$2*=
"3.)#*& R" \$.* 52 &22* "9." , , - 2H9)5)"& "1# 42.%& ."
QQQ .*/ QGS*: ,32&42\$)72'6 , .*/ , , 0 9.&#*6 #*2 /)&=
")*\$" 42.% ." QTA*: ; U92 +'(#32&\$2*\$2)*(2*&)"2& #+ , , -
.* / , , 0 .32 32/(2\$/ 56 "92 .//)"#* #+ β=@- , 19)\$9
&9#(' / 32&(" +3#: "92 +'(#32&\$2*\$2 V(2*\$9)*8 :2\$9.*& ;
U92 3#2 #+ "92 *)3#82* 92"23#."#: .& .&6:2'36)*(23=
3(4)*8 2*)"6 9.& 522* 328.3/2/ .& .*) :4#3.*" +.#3)*
"92 V(2*\$9)*8 :2\$9.*& :# "92 :#2\$('2& \$#\$*")*(*)8 92*=
23#."#: 3)*8&F¹;



D)8; C; D'(#32&\$2*\$2 &42\$3. #+ , , - (C;G L>K^{MS} :#'|B)(. .)* /
., 0(G;K L>K^{MQ} :#'|B)(5))* β=@- &#(')"#* ; D3#: "#4 "5#""#: :
[β=@-]O K, G L>K^{MG}, >L>K^{MQ}, G L>K^{MQ}, >L>K^{MC} :#'|B;

C;>;Q >W=XYZ &42\$3. U92 >W=XYZ &42\$3. #+
., , -)* "92 .V(2#(& &#(')"#& #+ β=@-)* -cO ." 7.36)*8
\$#\$2*\$3.)#*& .32 &9#1*)* D)8; Q; U9322 %)/& #+ 96/3#=
82*(W, W₅, W₈))* , , - .32 .'&# &9#1* ;



D)8; Q; >W=XYZ &42\$3. #+ , , - (G;K L>K^{MA} :#'|B))* β=@- &#(=
)"#* ; D3#: "#4 "5#""#: : [β=@-]O K, C L>K^{MG}, P L>K^{MG}, C L>K^{MQ},
G L>K^{MQ} :#'|B;

<\$#\$3/)*8 "# D)8; Q , (4#* "92 .//)"#* #+ β=@- , "92
&8*.' #+ "92 43#""# W₅ & 9)8923=+2'/ &9)"2/ , &9#1)*8 "92
&9)2'/)*8 2+2\$# #+ "92 W₅ 43#""# ; U92 .//)"#* #+ β=@-
'&# 32&(" &) /#1*)2'/ &9)"& #+ W. .*/ W₅ , .*/ "92 &9)"
7.'(2 #+ W₅ & '.3823 "9.* "9." #+ W. ; U92&2)*/\$."2 "9."
."3.\$")#* "# "92 2'2\$3#* #+ @O X 5#* /)* "92 #H.[#2 3)*8
/2\$32.&2& , 19)\$9 32&(" &)*)\$32.&2)* "92 \$9.382 /2*&)"6
#+ @₅ ; U9(& , #*2 \$.* \$#\$*(/2 "9." "92 #H.[#2 3)*8 2*=
"2&)*(*)8 "92)*(23 \$.7)"6 #+ β=@- ; <& . 32&(" , "92 96/3#=
82* 5#* / , +3:2/ 52"122* X ."#: .*/ W_CO :#2\$('2)&
53#%2* ; <"9#(89 X ."#: :)89" +3: 96/3#82* 5#* / 1)"9
—OW 5#* /)*& /2 "92 β=@- \$.7)"6 , "9)& +3\$2)& 27/2*""6
12.%23 "9.* "9.")* 4(32 1."23;

C;C !"#)\$9)#:2'3)2& .*/ .&&#\$.)"#* \$#\$&)."&

!"!# \$%&'()*'+,-./+0 1*2(,3 (,'+ *44+5,'
'/. 6(7.6 +8 99: *,0 '/(.,.) 4*;'(< +8 β=>: ,? . 4+,6(0=
)'/. 8+00+?(,3 6'.A?(6. .B5(C)4#]:

$$99: D >: \xrightleftharpoons{K_{\#}} 9>, \quad (\#)$$

$$9> D >: \xrightleftharpoons{K_1} 9>_1, \quad (!)$$

?/.) . 9> , 9>_1 0.,+', '/. #E# *,0 #E! (,4056(+, 4+ -=
A0.F.6 ,).6A.4'(;.0< , ?/(0. K# *,0 K1 *). '/. *66+4(*'+,
4+,6'*,'6" 1/., '/. 4/.- (4*0 6/(8' 0(6A0*4.-., ' 4*, C.
4*0450*'.0 *44+0)(,3 '+ '/. 8+00+?(,3 .B5*(+, [#]:

$$\Delta = \frac{\Delta_{\#} K_{\#} [> :] + \Delta_{\#1} K_{\#1} [> :]}{\# + K_{\#} [> :] + K_{\#1} [> :]}, \quad (G)$$

?/.) . Δ# *,0 Δ#1).A).6., ' '/. 4/.- (4*0 6/(8' 0(6A0*4.=
-., '6 +8 '/. #E# *,0 #E! (,4056(+, 4+ -A0.F.6 '+ '/*'+ 8
99: (, A5). : ,H ,).6A.4'(;.0< " I, '/(6 6'50< , '/. .B5(=
0(C)(5- 4+,4.,)'*(+, +8 4<40+0.F)(, [> :], 4*, C.).=
A0*4.0 C< ('6 (,('(*0 4+,4.,)'*(+, , [> :], 6(,4. (' (6
-54/ 03.) '/*, '/. 4+,4.,)'*(+, +8 99: "

1/. 8(' C*6.0 +, KB" (G) 4*,+', 3(;. *).*6+, *C0.
) .650" L+ , ? . 4+,6(0.) '/. 8+00+?(,3 '+ 6A.4(*0 4*6.6"

Case 1 " H,0< '/. #E# 4+ -A0.F (6 8+)-.0 , (" . " K1
M J" 1/56 , KB" (G) C.4+-.6

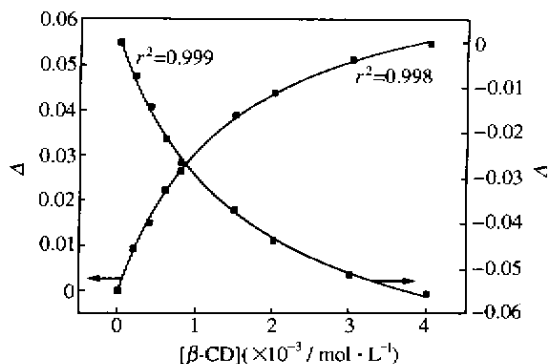
$$\Delta = \frac{\Delta_{\#} K_{\#} [> :]}{\# + K_{\#} [> :]}. \quad (N)$$

Case 2 " H,0< '/. #E! 4+ -A0.F (6 8+)-.0" 1/.,

$$\Delta = \frac{\Delta_{\#1} K_{\#1} [> :]}{\# + K_{\#1} [> :]}. \quad (O)$$

1/. \$P& *,*0<6.6 +8 '/. Δ ;*05.6 +8 Q* *,0 Qc ?('/
[> :] ?.). 4*)(.0 +5' +, '/. C*6(6 +8 KB6" (N) *,0
(O)" H,0< '/. 8(' C*6.0 +, KB" (N) (6).*6+, *C0. (6..
R(3" N) , ?/(4/ (,0(4*'.6 '/*'+ ,0< '/. #E# 4+ -A0.F (6
8+)-.0" 1/. A*)*-.'.) K# (6 .6'(-*'.0 *(ST! U G J)*,0
(S J V U ! O) -+0W#P 8+) Q* *,0 Qc ,).6A.4'(;.0< "

1/. X.,.6=Q(0.C)*,0 0+5C0.).4(A)+4*0 A0+' ?*6
06+ +C'(, .0" H,0< #V Δ ;.)656 #V [> :] .F/(C'6 *
6')*(3/' 0(, . (8(35). ,+' 6/+?,)" 1/(6 85)'/.) 65AA+'6 '/.
#E# -+0.0"



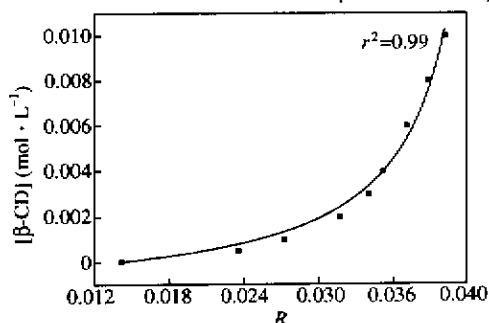
R(3" N" 90+6 +8 '/. 4/.- (4*0 6/(8' (■ Q+ , ● Qc ;.)656 [β=>:] 8+)
99: "

!"! ! R05+).64.,4. *,(6+)+A< -./+06 R(3" !
6/+?6 '/*' '/. *00('(+, +8 β=>: / *6 0('0. .88.4' +, '/. 805=
+).64.,4. (.,.6'(< +8 99: *,0 99H , 6+ (' (6 ,+' 65('*C0.
' + 4*0450*'. '/. *66+4(*'+, 4+,6'*,'6 C< 805+).64.,4. (,=
' .6'(< -./+0" Z6 ? . 2, +? , '/. 0.A.,0.,4. +8 805+).6=
4.,4. *,(6+)+A< R 5A+,)+*(+,*0 0(8856(+, / *6 C.,
56.0 '+ B5*,'(0< A+)'(.=0(3*,0 *66+4(*'+, 4+,6'*, [#J] ,
?/(0. '/(6 -./+0 (6 6.00+ - 56.0 '+ .6'(-*'. '/. *66+4(*=
'(+, 4+,6'*,'6 +8 805+)+A+).=>: 6#H5)).650'6 6/+?
'/*' '/. *,(6+)+A< +8 99: (+) 99H) ?*6 8*0)0< (,805.,4.0
C< '/. *00('(+, +8 β=>: , 6+ (' (6 A+66(C0. '+ .6'(-*'. '/.
66+4('+, 4+,6'*,'6 8+)- 805+).64.,4. *,(6+)+A< -.*=
65).-.,'6"

Z665-. '/*' 805+)+A+). 4*, 8+)- * #E# (,4056(+,
4+ -A0.F ?(' β=>: " 1/. 805+).64.,4. *,(6+)+A< R 4+500
C.).0*'.0 '+ [> :] C< '/. 8+00+?(,3 .B5*(+, [#]:

$$[> :] = \frac{R - R_R}{K_{\#}(R_X - R)}. \quad (S)$$

I, '/. 99: β=>: 6+05'(+, (' ?*6 8+5,0 '/*' '/.
\$P& *,*0<6(6 C*6.0 +, KB" (S) 3*;.).*6+, *C0.).650" "
K# ?*6 .6'(-*'.0 *(OS! U N G) -+0W#P , ?('/* 4+)).0*=
'(+, 4+.88(4., ' r1 M J" V V (R(3" 0)" 1/. ;*05. +8 K# (6 (,
3+00 *3).-., ' ?(' '/. \$%&'()*'+,-./+0 , ?/(4/
6533.6'6 '/. -./+0 +8 805+).64.,4. *,(6+)+A< (6).*6+, =
*C0. " I' ?*6 *60+ 8+5,0 '/*' 99H *,0 β=>: 4+500 8+)- '/.
"



R(3" 0" 90+6 +8 [β=>:] ;.)656 R 8+ 99: "

!"!#\$%&'(#)\$%)*+&,-,.\$/ K! 0(123 4 56) *)&^!8(r^9
0 2:;;, ,<#='>, \$)? (@)A\$):

B? @.(C,,\$>,+)>?, / ?@.? A@,\$?@, # \$?,>.%?#)\$(< ?A)
=',(? (A#?@ βDEF .>, @G/>)+@)C#% # \$ \$.?'>, , ?@, >.?#)<
&\$ K! K! (*)&^!8)]#(,l' .& ?) ?@.?)< ?@, *)&,%'&.> J)&D



it was impossible for β -CD to form the 2