

ABSTRACTS

Jacobs Science Building
April 27, 2018
11:30am - 3:30pm

Department of Chemistry
University of Kentucky
Lexington, KY 40506

#	Name	Group	#	Name	Group*
3	Cn { u o p C e m e r m a p		43	Clumapaj *La { + O a j m o u f	C
4	E a u u a p f r a C n m a u r k		44	N B e o n e O a r v k p	D
5	E o r d k p C r r a u m k v j		45	O C a { v e O u r k n n o	C
6	L o j p C v v e n a j		46D	C n e z a p f e r N e y m a r m	D
7	L e p p a D k p i j a m		47C	E j r k u v k p e R j k p p u	C
8	C n e z a p f r a F a x k u		48	D e r a p f a S u k l a u	D
9	D r a f { G m m a p		49	G x a p T e e f e r	C
:	M a v e H r a u e r		4D	L a e s u e n { p T j k p e j a r v	
;	O a e M e p k e H r e e m a p		4;	C r e i o r { T u m m e n	C
32	G m k n { H r { m a p		52	D r a f U e a j o r p	D
33	U a r a G a r p e r		53C	E j k a / J u u a p U j e p	C
34	M k m d e r n { G n e a u o p D T { U a p f e r u . a p f L a e s u e n		54	L a p k e e U k m o p	D
35	G n n e p G o u y u		55		D



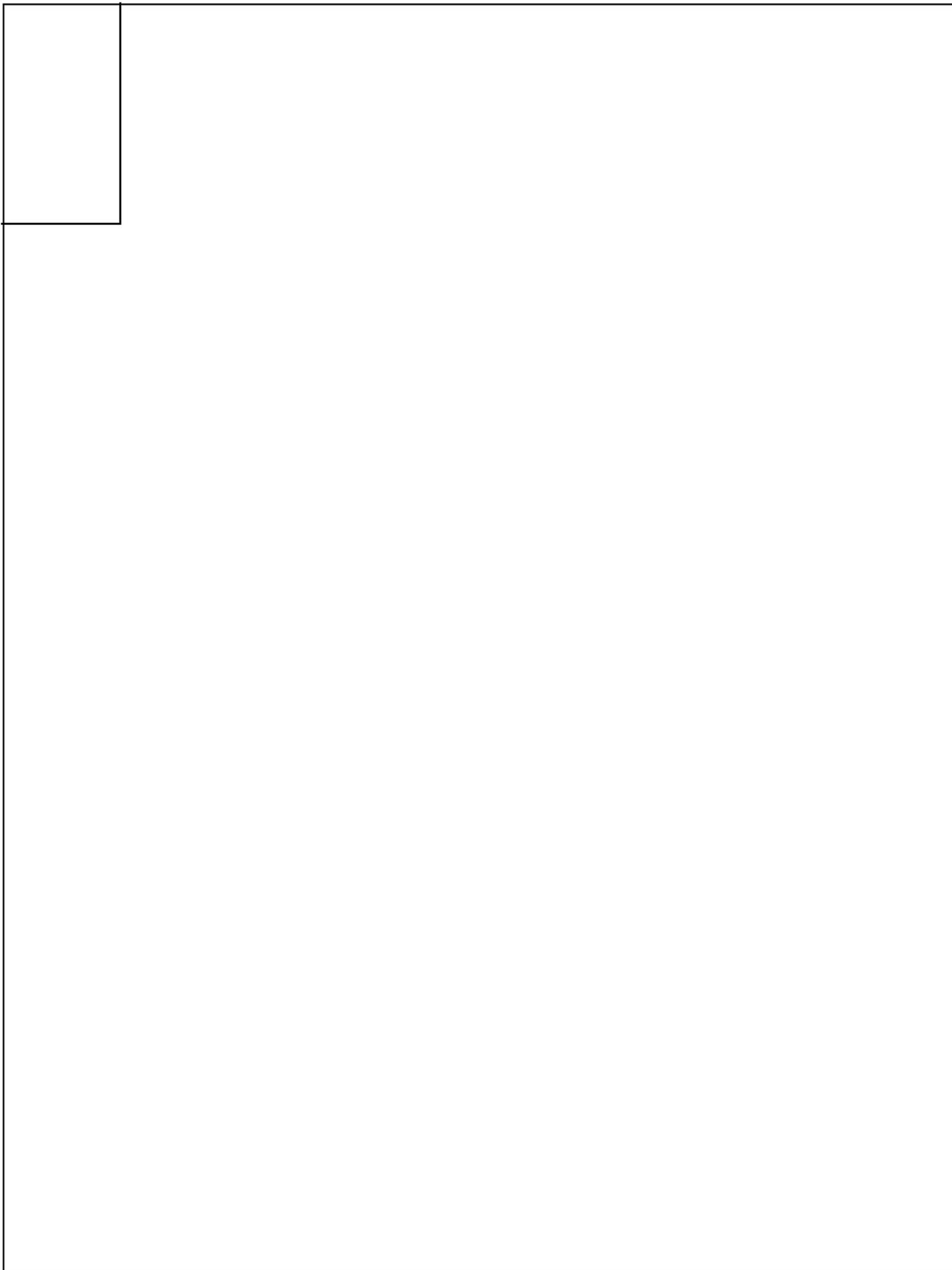
& + \$ 5 \$ & 7 (5 , = \$ 7 , 2 1 2) % 6 1
' 5 8 *

\$ 6 8 * \$ 5 6 8 % 6 7

7+('(6,*1 \$1')\$%5,&\$7,21 2) &20321(176)2
67\$*(723 +,*+ 7+528*+387 7,5) 0,&526&23<
02'8/(

&DVVDQGD \$OPDVUL 6HQLRU &KHPLVWU\ 8QL
&KULV 5LFKDUGV &KHPLVWU\ 8QLYHUVLW\ RI .
-DVRQ 'H5RFXKH\ &KHPLVWU\ 8QLYHUVLW\ RI .

\$EUVUDFW
7RWDO ,QWHUQDO 5HIO



)/8252\$0,'(',5(&7(')/825,1\$7,21 2)
81\$&7,9\$7(' &±+ %21'6

-HQQD %LQJKDP 6HQLRU &KHPLVWU\ ,QGLDQD
%ULDQ *URHQG\NH &KHPLVWU\ ,QGLDQD 8QLYH
6LODV &RRN &KHPLVWU\ ,QGLDQD 8QLYHUVLWV

\$E VWU DFW

2UJDQRIOXRULQH F 2\$A RBXQGRV S A p 0 VE HWV

6<17+(6,6 2) 08/7,&2/25)/825(6&(17 /,*\$1'6
)25 1,&27,1,& \$&(7</&+2/,1(5(&(37256

\$OHIDQGUD 'DYL V HQL,RUG L&QHP 6WDWH 8QLYHU
5LFKDUG)LWFIQG&LIDPL 6WDWH 8QLYHUVLW\

\$EVWUDFW

1LFRWLQLF DFHW\OFKROLQH UHFHFKWDRQMH OQ\$ & K5 VD WH YHL WDRQ W
DFHW\OFKROLQH DQG VHUYH FULW H X D Q WURDQHWPLQ VLRHQ IDQ W KSH
QHUYRXV V\ VWHP D Q G O XIRWHO \$ H Q 5 6 B E D E H H X V L H F R W I R Q L F U H F H S V
DQG FXOWXUH G F H O X R V H 2 X U H G W V O L D D B G G P Q M O X G \$ G D R S K L O L F
DQG WHUPLQDO IOXR D P R I S Q I R Q J H D Y H S U I R H M W R I R U O X R O W L O D E H O L Q
IOXRUHV FHQW PLFURVFRS\ IORZ F\WR

&203\$5,1* '1\$ &21'(16\$7,21 %< 3,6&,1(
3527\$0,1(6

%UDG\ (NPDQ -XQLRU &KHPLVWU\ 8QLYHUVLWY
'DQLHO .LUFKKRII &KHPLVWU\ 8QLYHUVLWY\ RI
-DVRQ 'H5RXFKH\ &KHPLVWU\ 8QLYHUVLWY\ RI .

\$E VWUDFW

3URWDPLQHV DUHFVKSURWDBUQLVQVQD WURVHGDDVHQMK'H\$QSDFN DJL
FKURPDWLQ 3URWDPLGHGXDUQJWXQMFRLRHQHQHWLKHDC\$ LQ VSH
WUDQVFULSWLRQDQDQHLSQDUSRIVYHRRWVRP\$DUVHXVKHVFRRQGHQV DW
GLIIHUHQW SLVFLQHFRPPXUHFHVL DIOQSONWIDRLQIS UFRWDRPLQH V XOID
KHUULQJ DV ZHOUDGHS HRWUDDPLQH HGFKURFFVIDOPRKHVSSHULW\ DQG
SURWDPLQHV ZHUH\DEDD\DPG GXVJQDVSFRQHF WUSR SKQGHQJ HILFL
GLIIHUHQW SURWDPRGQH'V'1\$S UTHFLSXMIDQWLRQ9DVVDSMFWURVFRS
UHVXOWLQJ '1\$ SDFNDJLQJ GHQVLWLQDQCPDQWDFQWYDHYV DVLQCHV
UHVXOWV VKRZQWKZLVGHCHVSLVGH IERQ'V\$V\$RQB\$YHQFDRPLRUFLDOVD
FKORULGH VKRZVWLRLQZKRGGFRP\$GDVIGOWRQFDRRKHIFUDQJ SUP
DQG LVRODWHG VDOPRQ SURWDPLQHLQURP \$DQVADQPVSHULRQXIF
'1\$ DQG WKH LQWHQDQVU\$S\$DXFUNDQV DQDORWHVHJQLRLUFDWKH S

67(5, & 0\$1,38/\$7,21 \$6 \$ 0(&+\$1,60 72 781(
5('8&7,21 327(17,\$/6 2) 60\$// 02/(&8/(6

.DWH)UDVHU -XVQLRUBQ&KHHPLWLW\ RI .HQWXFN\

/(\$ ' & 21 & (175 \$ 7 , 216 , 1 \$ 9 , \$ 1 (* * 6 + (// 6 \$ 1 ' (*
& 217 (176

0DF.HQJLH)UHHPDQ 6HQLRU &KHPLVWU\ 8QLY

\$E VWUDFW

+HDY\ PHWDO SROOXWLRQ LQ WKHL HQYDIQR Q F MSOW VF HQVMDLQX KD
KLJK LQWHUHVW HGVH HHS HVOCH G LHQWR HXKH QHQ WIKUR QPD RI OHD
&KLOGUHQ DJHG VL[\H DUV DQG \RKHQJ US RLVHR QKQJ P R V G \$ X G Q
EH ZDU\ EHFDXVH DW XFDQ EFDXW KIVS UHFG EILYHQKVZHRZJKGV JUR ZWK
&KLFNHQ HJJV DUFIHDR \$ RVHDLG G R Q V X P U S V F D R Q Q G L Q H W K H + \$ Q F H W K H
FKLFNHQ HJJV DQG HJJ FRQWHQWV Q D S H P H V U R V F I S \ E \ W D R W L R Q P Y I F
FRUHHODWLRQ E MWIZO HHQ JOHDGGF WKLW NSORV L W R W W U R D I F L F K H D Y \ U
1R OHDG FRQFHQW \$ G M L R Q V I R P L W J I W H D F K L R O G U R X Q V H U J Z H U
/RFDQO\ VRXUFHG VF KILURNPH QHIOQRZ K S D D I Q H D V G Z R Q K D Q W U D W L R Q
VXSHUPDUNHW G R Q V K H O O V R D O H D G U H R I R U H Y H W B H H H Q Y K U R Q P H Q V
HLWKHU QRW V W H G I Z I E V Q V O H D S R W B E V E L H Q Q L M E O H R W R U H F R Y H U
WKDW PD\ KDYH RFFXUUHG LQ WKH SDVW

81'(567\$1',1* ',))86,21 ,1 32/<0(5 *(/6 :,7+
/((&75267\$7,& ,17(5\$&7,216

(PLO\)U\PDQ 6HQWLRU 8QKYPILUWLW\ RI .HQWXFN\
-DVRQ 'H5RXFKH\ &KHPLVWU\ 8QLYHUVLW\ RI .
-RVHSK 'XNH ,,,8QKYPUVWU\ RI .HQWXFN\
.DQWKL 1XWL &KHPLVWU\ 8QLYHUVLW\ RI .HQW

\$EUVUDFW

%LRORJLFDOK\GJURQHDXVDSIRIOKPIWUHPSROWHZRELNRVSKVLWKDFORSURSHU
NQRZQWR IXOILOOD QXPEHU RI ILRQFOLKGDQWJSIKGLRORNDODDQ
QXWULHQWV SDWKRORQRORORQGXOMVGHIOYRORYRHSORRQXWLRQ DQG
HIIHFWV LW LV UNLQRZQWKDDFQRFQWCHWIXFKRWDK HGFHSRUELDFFWRU
JRYHUQ WKH PRELOLW\ RI SDUWLFOHV LQ ELRJHOV
7UDQVODWLRQDORQWVXDULRGGFRWHHURDEGHFRBUHODRULHRQFVSHFWU
IRU FKDUJHG SURORHDPORQGF\$7072VG\$H DV LZHQ QFKDUFJHWGLRQLF DQ
FKDUJH GH[WUDQ DQGRORQWLRQDQ :SRVORRZUWKDQKLSRUEHG LKQGVIRH
KLJKO\ DV\PPHWULF ZLWK GLIIXVLROUROVZDHWLEFODQWEXDFHWBR
WKDW WKH ILOWHULQJ FDSDELOXWLRQ WRKOLJHFWLUMQHVKLWLYW
IUDFWLRQV RI RSRVWILWDFOLRQDVULMBSHDSHLDG RIRWVKHUSQUWLFOH
LV IRXQG EHWZHHQRHSHWILFFDOWSDQGLFWLRQV

0(\$685(0(17 2) &+(0,&\$/ 6+,)7 7(16256 \$1' -
&283/,1* ,1 62',80 /(\$' 0,;(' 35<23+263+\$7(
*/\$66(6

6DUD *DUQHU 6HQLRU &KHPLVWU\ %HUHD &RO
'U -D\ %DOWLVE/MUWHU%H&KHP &ROOHJH

\$ & \$7,21 (;&+\$1*(/6'23+\$6((;75\$&7,21
35272&2/)25 7+(,62/\$7,21 \$1' \$1\$/<6,6 2)
\$/. \$/2,'6 ,1 32,621)52*6

.LPEHUO\ *OHDVRQ -XQLRU &KHPLVWU\ 8QLYH
5\DQ 6DQGHUV &KHPLVWU\ ,QGLDQD 6WDWH 8Q
1LFKRODV \$QGUHDVHQ &KHPLVWU\ ,QGLDQD 6V
.DPHURQ %HOO &KHPLVWU\ ,QGLDQD 6WDWH 8
-DFTXHOLQH 6PLW,QGLDQD 6WDWH 8QLYHUVLW\

\$1 ,19(67,*\$7,21 ,172 7+()\$&7256 7+\$7 \$))(
32/<0(5,=\$7,21 2) \$1 (;7(51\$/ 67,08/,
5(63216,9(0\$7(5,\$/

0DGLV\Q +D\HV)UHVKPDQ &KHPLVWU\ 1RUWKH
0HJDQ /DQJ %LRQRJHQWRFWKH8QLYHUVLV\
&KDUOLVD 'DQLHUVW&KHQLVWQWXRN\ 8QLYHUVLV

\$EUVUDFW

7KH JRDO RI WKLV VWRGHG MLHDS RQ ZRZGHU VWUDQG W FURVV OLC
DIIHFW WKH VWUXRWSRQ\ DQGL EHWYD\KDFORQDMKHO '0\$(0\$ SRO
WKLW IDFWRUV WXDKQ\ DWKHLRLEBQWVHV LGLHQWILUWX VRI SRURJHG
DQG WKH WHPSHRQ\RXWKID CSR QXPHU\KDDVIRHG ZWBH LFDGQ WKH EH
FRQGLWLRQV 7KLSZDDVGLRQJHF ERWQVWLNQNHV VXFK'S DQG
'0\$(0\$ DW GLIIHUHQWQRQRQWKHQUDG QIVQRIFYDDVLRQJVSRQWHRQV
KH[DQRO RFDQRO RU GRGHFDQDOWKKH PLZVWUH EDWVIRHQD
UDQJLQJ IURP GHQGHVW&HRQVWWRKHURWVWQWVJKW KRXUV
WKDW WKH FURW RQFHQWUWVWHRQV D DRGXQJGURRH PRVW LG
FRPELQHG ZLWK DQRSRURSHQSDKRGDJDQGHVE&HQGHLDVWLVKD ZDV
GLVFRYHU\ IXUWKHRQ H\SHFDLXFGHQWLSRHOV HUKHIDVQROE ZL @DWEE

,03\$&7 2) 3\$5.,1621 ',6(\$6(21 7+(0725 3\$7
86,1* \$ 3,1. .12&.287 5\$7 02'(/

\$17, 7(6 \$'7 ,03529,1* 7+(6<17+(6,6

:LOOLDP -DFNVRQ ,,, 6HQLRU &KHPLVWU\ 8QLY

*\$6 3+\$6(63(&75\$ 2) 0*2 02/(&8/(6 \$ 3266,
&211(&7,21)520 *\$6 3+\$6(02/(&8/(6 72 3/\$
)250\$7,21

.DWKHULQH .ORVND -XQLRU &KHPLVWU\ 8QLYH
5\DQ)RUWHQEHHU\ &KHPLVWU\ 8QLYHUVLW\ RI

\$EUVUDFW

\$ PRUH ILQH WXQRGLQH WSKRDCQ HRW ISUKP DQ JSWIRJLRSQVDQXW DU\ GL
URYLEUDWLRQDOVPRORHREOEUYDSVSEWUPRQSDDOVLPKOHDFXOHV LQV
EXW XOWLPDWHDDWDOHVRUJHDDLVFHGBPBHFXQGDWISGDZKHVQVJUDLQV
PROHFXOHV IRUP QJJDWR\$LLFVRDQGRVQFJRVLVRQLQ DVWU

7+,2/\$7(&203281'6 : ,7+ &\$'0,80 0(5&85< \$1
/(\$'

\$PEHU /HZLV 6HQLRU &KHPLVWU\ 8QLYHUVLW\
'DYL G \$WZRRG &KHPLVWU\ 8QLYHUVLW\ RI .HQ

\$EVWUDFW

0(\$% 0HUFDSWR W&R PPHWIFD[SFDUEPRQOO HEWIK]QRFDDQDQR @ S
PHWK\O HVWHU V D QDDVORWUHUDQVHGLYDH1V R OEXLWLR QHWUR D'SWRHWK\
WR ELQG ZLWK VGRJQJ PDHGVLOXP L RHFODKXUFDDQ EHOIHXQ @ W LQ SROO
SULQFLSOH ZDVWKR RFOUDHMMH LQH WBSHGL RV RECHOUJLEDZOHVQIJIBUWIX
W P•H A0° @tPH A0° Å sDQ\ @ P@OXW\$€4FrÐRÀp#Àð0p» E€0 QG0@ À

PLWGWC W \ @ P@OXW\$€4FR0\KZDV WR WHU D

°\$0€@0°ð€0Àa"= ,WK'ZDWWC

6 < 17 + (6, 6 2) & + (/ \$ 7, 1 * %, 6 1 + (7 (5 2 & < & / , &
& \$ 5 % (1 (& 2 0 3 / (; (6 2) 5 8 , , \$ 6 3 2 7 (1 7, \$ /
\$ 1 7, & \$ 1 & (5 \$ * (1 7 6

- X P D Q D K - D \ 0 D K P R X H P L V W Q L R U Q & K H U V L W \ R I .

\$ E V W U D F W

1 K H W H U R F \ F O L F V F D U E H Q E V T X L W R X V F I K Q F R L U J M Q R B M M D V O R W K H L U
S U R S H U W L H V * O D J H U D Q G F R Z R U N D H L Q H I G R U X I R E R Q D X V H G L S K U L B
O L J K W D F W L Y D W H G W D Q I W Q L E D D Q H F W K R D P N E R V Z Q H D V S I K R W R G X E S \
↑ E L S \ U L G \ O L W U B I G H D W H R Q X S E Z W Y H I O D H S S I W R K S B L D W J K W L Q Z K
F U R V V O L Q N L Q J Q E I D G L Y D L Q H W D J H \ R M D O X H N Q R D O W Q U B I D Q Z O D V E L G L J L +
Z L O O E H S R V V L E O Q L X R F J R I Q S I Q H D W M \ B I W K H F D L E V H I Q U R F 1 + & ↑ V D V
R U G H U W R L Q F V W H D V O H G F W I D Y Q G V O U R S G Q D Y L L V R L E O T H K E L U Q D F S L R B H R Q
& N & & G L 1 + & P H @ > 3) @ Q G @ Z L W E K L \$ V B L G V O R L Q 5 X 0) O S H B G P V H Q H
G L 1 + & P H E S \ @ > L @ P 7 K R F S O X M I G H Q P W Q V L V F U D W E G W G D D Q L Q F U H
E O H O L J K W L U

62/927+(50\$//< 352'8&(')('23(' &\$5%21
1\$12'276 6+2: %,2 ,0\$*,1* 327(17,\$/ : ,7+
7(03(5\$785('(3(1'(17 3+272/80,1(6&(1&(

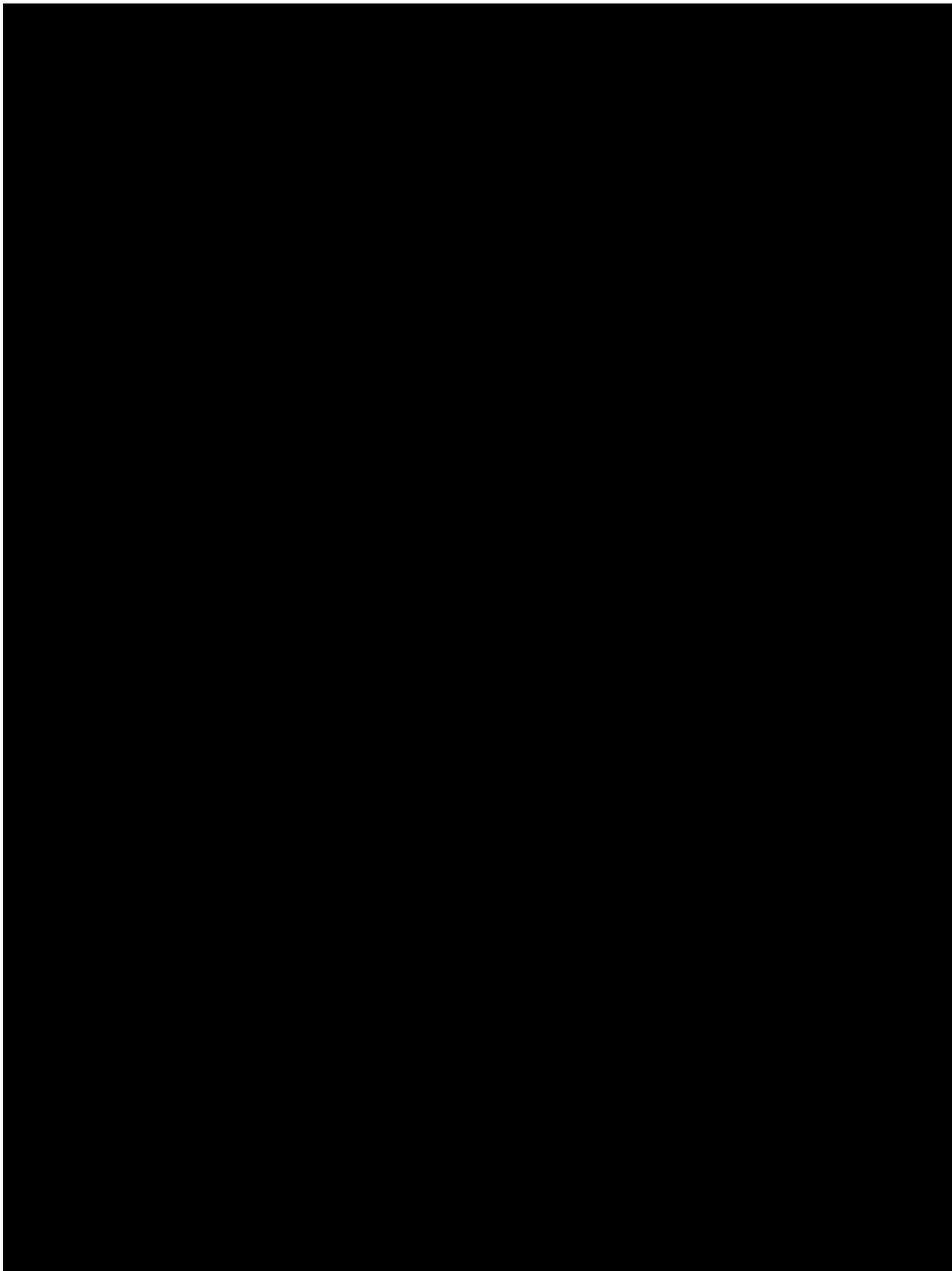
\$OHIDQGHU 1HZPDUN 6HQLRU &KHPLVWU\ 8QL
7LP 3LOODU /LWVOH &KHPLVWU\ 8QLYHUVLW\
'RR <RXQJ .LP &RUUKRVSRIQSDLQW \$XQWQ IRY HUKVLPW\
.HQWXFN\

\$EVWUDFW

7KH HPHUJHQFH RI FDUERQ QDQRGRQV QDQR'RD V M UL QH Z F V Q V V Q
DV &1'V KDYH DGYDQWDJHRXV SK\VLFRFDKUHPLF DODDQOG RSWL EDQ
DOWHUQDWLYHQ WXP LGRWV DLQLE LTR D PDLJ QVR S B WFRFDDW DQG
DGGLWLRQ WKHVH &FWLRQYFRORZ SKRDLF DOU H QLU WQH L R FRP
PDNHV WKHP D SURPLVLQJ PDWHULDQHQ ,QD Q B W H F K R W R M U H C
K\GURWKHUPDO WUHDLVQ W Q W S U H S R G S H P U R Q H S U K R G X G H G I O X R U H
\LHOG 7KH SUHVH Q S O R V X G W X I H P R S W L F D O S S B S S H U W L H R P E R Y L
HWK\OHQHGLDPLQH WK GRXJHQ G H Q W P S H R Q D Y W K H S P D L F D Q U S U R S H
&1' ZHUH SUREHGYWKLURXJKV SHFWURSKRIVORR F H W S W F D Q G V O R S U H
QDWXUH RI WKHWSWIRQ F W S B Q H O H P H Q H 1 F K D Q G Z W Z U L J H G E \) R X U
ip€ p0€ UÀ€†70P €p0b€0` p`0°KV•p`0Àđ0@ppQI` `DO8` 0RXW HUO€

6<67(0\$7,& ,19(67,*\$7,,272 7+(%21',1*
(/(&7521,& 6758&785(' \$1' 5(\$&7,9,7< 2) 0(7
62)7 '2125 &203/(;(6

&KULVWLQH 3KLSSWU>XQURDUV&QMPQLD 8QLYHUV
-HVVLH %URZQ &KHPLVWU\ 7UDQV\OYDQLD 8QL



(), & , (1 7 ' (\$ & 7 , 9 \$ 7 , 2 1 2) (/ (& 7 5 2 1 , & \$ // <

81'(567\$1',1* 7+(52/(2)527\$0,1(',68/),'(%21'6 21 '1\$ &21'(16\$7,21 ,1 0\$00\$/,\$1 63(5 18&/(),

-DFTXHO\Q 5KLQHK ~~DUWW~~ ~~GH~~ ~~ORLY~~ ~~HUK~~ ~~HLW~~ \ RI .HQV
'DQLHO .LUFKKRII &KHPLVWU\ 8QLYHUVLW\ \ RI
-DVRQ 'H5RXFKH\ &KHPLVWU\ 8QLYHUVLW\ \ RI .

\$EVWUDFW

6KRUW DUJLQLQ ~~Q~~ ~~HLG~~ ~~KS~~ ~~SB~~ ~~R~~ ~~W~~ ~~D~~ ~~F~~ ~~L~~ ~~Q~~ ~~M~~ ~~F~~ ~~U~~ ~~V~~ ~~G~~ ~~D~~ ~~D~~ ~~V~~ ~~H~~ ~~Q~~ ~~M~~ ~~K~~ ~~H~~ ~~S~~ ~~Q~~ ~~S~~ ~~I~~ ~~D~~ ~~E~~ ~~N~~ ~~D~~ ~~J~~ ~~L~~ ~~Q~~
VSHUP FHOOV 3URWDPLQHV DUH VQGFRIQVGHJGGHG WUKHQSDWSH ~~H~~ ~~W~~ ~~E~~
WUDQVFULSWLR ~~Q~~ ~~D~~ ~~O~~ ~~O~~ ~~D~~ ~~W~~ ~~E~~ ~~D~~ ~~F~~ ~~M~~ ~~L~~ ~~J~~ ~~H~~ ~~D~~ ~~I~~ ~~R~~ ~~S~~ ~~C~~ ~~H~~ ~~E~~ ~~W~~ ~~H~~ ~~W~~ ~~R~~ ~~E~~ ~~V~~ ~~H~~ ~~X~~ ~~V~~ ~~K~~ ~~R~~ ~~W~~ ~~L~~ ~~D~~ ~~Q~~ ~~P~~ ~~D~~ ~~P~~ ~~F~~
DQG KXPDQV DOVR FRQWDLQ PXQQWLSOHD ~~R~~ ~~G~~ ~~V~~ ~~L~~ ~~Q~~ ~~M~~ ~~C~~ ~~H~~ ~~S~~ ~~U~~ ~~R~~ ~~W~~ ~~D~~ ~~P~~ ~~L~~ ~~Q~~ ~~H~~ ~~V~~ ~~D~~ ~~U~~ ~~H~~ ~~V~~ ~~E~~ ~~H~~ ~~H~~ ~~Q~~ ~~F~~ ~~\~~ ~~V~~ ~~W~~ ~~H~~
GXULQJ WKH IL ~~Q~~ ~~D~~ ~~O~~ ~~P~~ ~~D~~ ~~W~~ ~~X~~ ~~U~~ ~~H~~ ~~W~~ ~~R~~ ~~R~~ ~~Q~~ ~~S~~ ~~Q~~ ~~V~~ ~~K~~ ~~R~~ ~~Z~~ ~~Q~~ ~~V~~ ~~M~~ ~~D~~ ~~M~~ ~~V~~ ~~H~~ ~~E~~ ~~H~~ ~~H~~ ~~Q~~ ~~F~~ ~~\~~ ~~V~~ ~~W~~ ~~H~~
DQG LQWUDPROBER ~~Q~~ ~~D~~ ~~V~~ ~~U~~ ~~W~~ ~~R~~ ~~L~~ ~~V~~ ~~X~~ ~~O~~ ~~R~~ ~~L~~ ~~D~~ ~~X~~ ~~F~~ ~~O~~ ~~M~~ ~~X~~ ~~T~~ ~~X~~ ~~H~~ ~~K~~ ~~I~~ ~~H~~ ~~V~~ ~~S~~ ~~I~~ ~~L~~ ~~E~~ ~~\~~ ~~W~~ ~~W~~ ~~H~~ ~~L~~ ~~Q~~ ~~H~~ ~~U~~ ~~H~~
RWKHU VSHFLHV VXFK DV ILVK 5HRZ ~~G~~ ~~V~~ ~~Z~~ ~~R~~ ~~K~~ ~~D~~ ~~N~~ ~~E~~ ~~R~~ ~~W~~ ~~E~~ ~~H~~ ~~W~~ ~~S~~ ~~R~~ ~~M~~ ~~F~~ ~~I~~ ~~G~~ ~~H~~
GLVXOILGH ERQGV XOWLPDWHO\ ~~O~~ ~~H~~ ~~D~~ ~~X~~ ~~G~~ ~~V~~ ~~H~~ ~~W~~ ~~R~~ ~~V~~ ~~G~~ ~~O~~ ~~F~~ ~~R~~ ~~V~~ ~~K~~ ~~O~~ ~~H~~ ~~Q~~ ~~E~~ ~~D~~ ~~W~~ ~~L~~ ~~O~~ ~~Q~~
VWUXFWXUH LV ~~D~~ ~~S~~ ~~H~~ ~~U~~ ~~R~~ ~~S~~ ~~F~~ ~~U~~ ~~R~~ ~~W~~ ~~D~~ ~~P~~ ~~L~~ ~~Q~~ ~~H~~ ~~V~~ ~~R~~ ~~V~~ ~~S~~ ~~E~~ ~~L~~ ~~R~~ ~~Z~~ ~~H~~ ~~K~~ ~~O~~ ~~D~~ ~~P~~ ~~H~~ ~~K~~ ~~O~~ ~~X~~ ~~I~~ ~~G~~ ~~W~~ ~~K~~ ~~K~~ ~~H~~ ~~U~~ ~~F~~
SURWDPLQH GLVX ~~O~~ ~~I~~ ~~L~~ ~~G~~ ~~H~~ ~~E~~ ~~R~~ ~~V~~ ~~Q~~ ~~G~~ ~~V~~ ~~S~~ ~~H~~ ~~O~~ ~~R~~ ~~E~~ ~~X~~ ~~P~~ ~~K~~ ~~O~~ ~~R~~ ~~X~~ ~~P~~ ~~D~~ ~~W~~ ~~L~~ ~~V~~ ~~Q~~ ~~F~~ ~~M~~ ~~K~~ ~~W~~ ~~P~~ ~~L~~ ~~F~~ ~~U~~ ~~R~~ ~~V~~ ~~F~~
OLFURVFRS\ VWXGKHVGERQKLSUPL ~~R~~ ~~C~~ ~~R~~ ~~V~~ ~~E~~ ~~R~~ ~~Q~~ ~~G~~ ~~U~~ ~~D~~ ~~L~~ ~~S~~ ~~U~~ ~~R~~ ~~D~~ ~~V~~ ~~D~~ ~~P~~ ~~L~~ ~~O~~ ~~L~~ ~~D~~ ~~Q~~ ~~V~~ ~~S~~
GHRQGHQVDWLRQD ~~V~~ ~~L~~ ~~R~~ ~~V~~ ~~C~~ ~~L~~ ~~L~~ ~~F~~ ~~I~~ ~~K~~ ~~V~~ ~~K~~ ~~H~~ ~~K~~ ~~R~~ ~~W~~ ~~H~~ ~~E~~ ~~P~~ ~~E~~ ~~O~~ ~~L~~ ~~H~~ ~~D~~ ~~F~~ ~~R~~ ~~S~~ ~~G~~ ~~H~~ ~~Q~~ ~~V~~ ~~D~~ ~~W~~ ~~L~~ ~~F~~
QXFOHL LV UHPLQ ~~L~~ ~~D~~ ~~F~~ ~~X~~ ~~I~~ ~~R~~ ~~O~~ ~~H~~ ~~R~~ ~~I~~ ~~V~~ ~~K~~ ~~D~~ ~~F~~ ~~V~~ ~~D~~ ~~H~~ ~~D~~ ~~H~~ ~~N~~ ~~H~~ ~~Q~~ ~~E~~ ~~Z~~ ~~O~~ ~~D~~ ~~W~~ ~~R~~ ~~M~~ ~~F~~ ~~R~~ ~~O~~ ~~W~~ ~~L~~ ~~O~~ ~~M~~ ~~K~~ ~~P~~
VSHUP FKURPDWLQK ~~H~~ ~~V~~ ~~S~~ ~~X~~ ~~G~~ ~~I~~ ~~H~~ ~~E~~ ~~F~~ ~~W~~ ~~H~~ ~~R~~ ~~Q~~ ~~V~~ ~~\~~ ~~U~~ ~~A~~ ~~R~~ ~~X~~ ~~F~~ ~~Q~~ ~~U~~ ~~R~~ ~~D~~ ~~J~~ ~~P~~ ~~H~~ ~~G~~ ~~S~~ ~~U~~ ~~R~~ ~~W~~ ~~D~~ ~~P~~
GLVXOILGH ERQGV ~~L~~ ~~K~~ ~~D~~ ~~V~~ ~~H~~ ~~V~~ ~~L~~ ~~P~~ ~~S~~ ~~V~~ ~~L~~ ~~L~~ ~~F~~ ~~J~~ ~~R~~ ~~W~~ ~~D~~ ~~E~~ ~~C~~ ~~W~~ ~~L~~ ~~D~~ ~~O~~ ~~W~~ ~~D~~ ~~Q~~ ~~U~~ ~~R~~ ~~V~~ ~~E~~ ~~R~~ ~~S~~ ~~L~~ ~~O~~ ~~G~~ ~~L~~ ~~S~~ ~~O~~ ~~D~~ ~~H~~ ~~D~~
GDPDJH WR VSHUPDWLF '1\$



,03\$&7 2) 6,08/7\$1(286 '58* 86(21 &<72&+5
3 0(7\$%2/,60 \$1' 67\$%,/,7<

&KLD +VXDQ 6KHQ -XQLRU &KHPLVWU\ 8QLYHU
&DWKHULQH 'HQQLQJ &KHPLVWU\ 8QLYHUVLW\
'DYLG +HLGDU\ &KHPLVWU\ 8QLYHUVLW\ RI .HQ
(GLWK *OD]HU &YKHUPLVWUURI &QWXFN\

\$EVWUDFW

3UHVFULSWLRQ RSLR LQD M R U K I S V G H H F F W H Q W M K E U Q V W G M D Q V K V S
IURP DFFLGHQWD @ U R L Y H U R G I R G U X J \$ R D R M J Q R K V H V L U P X O X O D Q H R X V X V I
1DWLRQDO ,QVWLWXWH RQ 'UXJ \$EXVH
&\WRFKURPH 3 V &H V P R D U W H O H S J U H V I Q Q W D U Q I W K M S R L Q Y H L E O H I R
GHJUDGDWLRQ \DV DRS SPURGLPDWHRQMH @ Q R V Q K &<B D U I R H W P H W D E R O
WKH VWXG\ RI &<3V LV HVVHQWLDO Q Q B U Q G I U P X J O G W L Y G L O X R J S I P Q W M U D
DUH XVLQJ 3 %0 UDKXP D P R &H O P R I W D E R D L Q P G R H [Q L L F R P W L W K R U S K
&<3 V 3 %0 LV L V R O S X E L D L H H O V D Q H G D G U R H H G X G R M D V H H \$ D L U W Q H U I F
PDNLQJ FDWDO\WLV: P R K U S R W I K H F V E I Q H D W K D F W R Q K U R Q Q &+H3/ Z L W K F R F
VXEVWUDWHV D F K D Q J H L Q S U R G X F W M F R D M L R H F Q V I P H W E H E S O H L Y H
GH[WURPHWKRUSK R D I Q O M K Z H O S U R E G X F R N G S L H H Z L O T K G E H H V C R H W S I U R G O E
RI QLFRWLQH DQG GHH [ZVLORP W W K R U S K O D W L R Q P E L Q V I R Q J K L J K S U
FKURPDWRJUDSK\ +3/& DQG J D V F K U R & D W R J H U Z S O P D O V R V S H F
WKHVH GUXJV LPSDFW HQ]\PH VWDEWLKH W O R E D I D W P W S X C F V H S S W R Z
3UHOLPLQDU\ UHVXOWV KDYH VKRZHQ W R D S K I D Q F O P E R Q D Q H R P C H V
GUDVWLFDOO\ GHFUHDVHG

5\$0\$1 %\$6(' ,0\$* ,1*)&5-\$5\$&7(5,=,1* 6,/9(5
1\$123\$57,&/ (0,1(5\$/ ,17(5\$&7,216

-DQLFH 6LNRQ 6HQLRU &KHPLVWU\ :ULJKW 6W
6HWK %ULWWOH &KHPLVWU\ :ULJKW 6WDWH 8Q
'DQLHO)RRVH &KHPLVWU\ :ULJKW 6WDWH 8QLY
.HYLQ 2 1HLO &KHPLVWU\ :ULJKW 6WDWH 8QLY
-DVPLQH -RKQVRQ &KHPLVWU\ :ULJKW 6WDWH
\$GDP 6WDKOHU &KHPLVWU\ :ULJKW 6WDWH 8QL
-RKQ 5\DQ &KHPLVWU\ :ULJKW 6WDWH 8QLYHUV
6WHYHQ +LJJLQV &KHPLVWU\ :ULJKW 6WDWH 8
,RDQD 6LJHPRUH &KHPLVWU\ :ULJKW 6WDWH 8C

\$E VWUDFW

'(16,7<)81&7,21\$/ 7+(25< ,19(67,*\$7,216 2)
2372(/(&7521,& 3523(57,(6 2) 25*\$1,&
&+52023+25(6)25 /,*+7 (0,77,1* \$33/,&\$7,2

:LOOLDP 6PLWK 6HQLRU &KHPLVWU\ 8QLYHUVL
6HDQ 5\QR &KHPLVWU\ 8QLYHUVLW\ RI .HQWXF
&KDG 5LVNR &KHPLVWU\ 8QLYHUVLW\ RI .HQW

\$EUVUDFW

2UJDQLF HOHF WKURYL EPHDWRU DFD O O PUL F VHDG L QG QWVWUHL VFR RS
ZLWK WHFKQRORJLHV ZKHUH WUDGLQRVLR QEDOXVQRU JHDULF ZHIPR E
IXQFWLRQDO WKHURH')GH SHQGGLHW'WWR'H)TS ORQJHO WKH HOHF WUR
FKDUDFWHULVWL KWRRP OS KFRQHMV JQVWVMB DFUOL BK W QHPL WFWLQJ DSS
ZH KDYH IRFXVHG RQF QZRVFKURP R SAKRQHR O E DEU P B Q HULDOV WK
KRVWV LQ OLJKW HPLWWLQJ GLR SWXUHQ QV K DMLVGHQR E Q WUDDOH
7KH ')7 DQG 7')7 UHDXWRPL SWIRY LVG OVK B PVDWLQML E Q K LQO HFWU
RSWLFDO UHVSRLQW SURKLELSQRNDHF B O VDE R V DWKLRKH ZLWW W\ QW
WR QHZ GHVLJQ BODWRODV PDWHULDOV

5(\$&7,9,7<2) 5('2; \$&7,9(&3 ,5 76'3(1
&\$7\$/<67 2±+ %21' \$&7,9\$7,21 2) &\$5%2; </,
\$&,'6

.ULVWHQ 6SRUWLH&OHRP L&R/SUK\R BRU\N HQ\OHW\ RI (
7RGVDSRQ 7KDQDQDWWKDQDFKRQ &KHPLVWU\

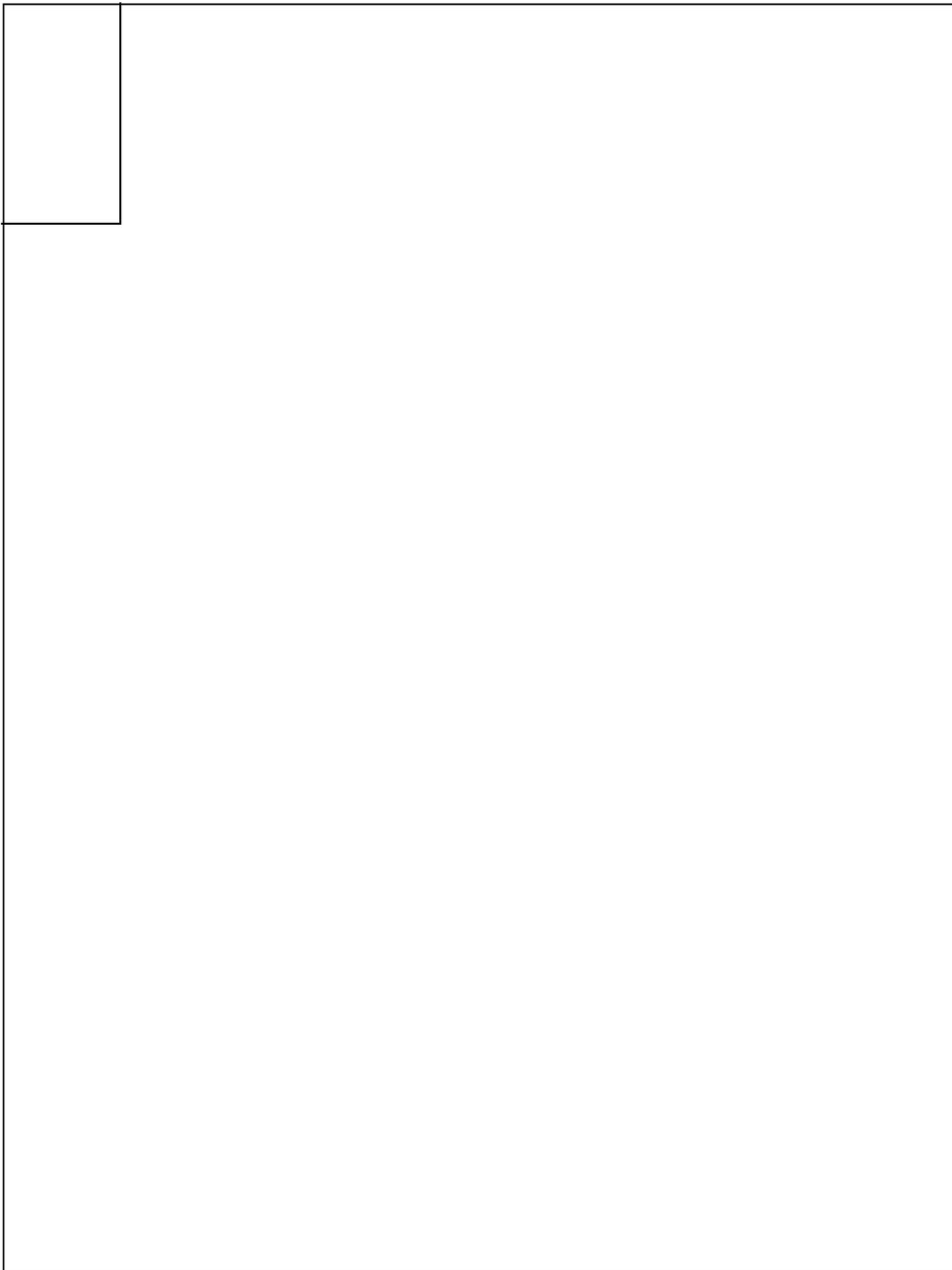
\$EUVUDFW

0HWDO FRPSOH[HV FRQWDLQLQJ UHG R(1DF7WL'Y(H O L7JFVQ G'D W X 6 K
GLSKHQ\OHWK\OHQ HGG GHP RQH V WLDYWHV HMD MR DFWUL D G V H B W D K O G U R J
ZKHUH K\GURJHQ GRQRU DOFRKRO XLOHGHU DRPHVWZEG ERQUG DHFWL
PHWDOODF\FOH LRWHH WPKLGLDWHK DOR SRUD E W LW H X C R V D K W H Y H & S
7V'3(1 FDWDO\VWDZE W\K OYDFUDRXGVDFXFG \$V G E W D R E S D\O H F D F
XQGHUJR 2 + ERQG DHFWUL YDHWIWRHU DFOGRJWRK B KWR3\UHOQ QRYHO &
7V'3(1 + SURGXFW VHZKEK B UKDFWHEJ LJR G FER S1 O B VVZHHG W DV VLQ
GLIUDFWLRQ

&203\$5,1* '1\$ &21'(16\$7,21 \$1' 5(/(\$6(% <
\$&(7</\$7(' \$1' 68&&,1</\$7(' 32/<(7+</(1(, 0,1
3(, '(5,9\$7,9(6

.\OH 6WDUNH\ 6HQLRU &KHPLVWU\ 8QLYHUVLW
-RVHSK 'XNH ,,, 8&KLHPIUWUW\ RI .HQWXFN\
-DVRQ 'H5RXFKH\ &KHPLVWU\ 8QLYHUVLW\ RI .

\$EVWUDFW
3RO\PHULF PDWHULDOV SURYLGR WRW VXSWDYR O/HFDX DRDUG E LIRFU
GHOLYHU\ RI QXF FIDOFOD IDGFN W E WE MRIS E P S D W L B I O O L W \ WR EH F
DGGUHVV ERWK LRV XHUD QG KHIGY S R O Y H W K L O H D E P W O O D W L R Q RU V
SULPDU\ DQG VFRQG Q M K D I L Q H G Z D E H W \ O D W B U G F W R Q D K W L S Q S
RI WKH SRO\PHU E\ Q H X W K H D D R L J Q Q X F F R O J I D Z K H G H Q W U R G X F H V
JZLWWHULRQLF FKDUDFWHU WR WRHUSRIQ \ P G W H U D K F W I D F O W H U H J D
SUHVHQFH RI DFHW\O DQG VXFFLQF DWJURX SEV G K F U M D V H P G D X I G H
GLVVRFLDWHG L Q Z M K H D S P R X Q H V F R I B W E R P S Q M L Q F F R S D U H G WR
3DFNLQJ GHQVLW\ D Z D H V G D I Q V R D I F Q Y H M \$ L X Q G Q J B V P D O O D Q J O H ; U D
6\$;6 2YHUDOO W K K D G W W E H V K Q F H U H D V F W G L Y H W W U B E O E M D B O H W F
DSSURSULDWH EDOH D F E K I E H W L Z O H E Q S P O K L W \ S P O Q E M W U H I D S F W L R Q V
FRPSDUDEOH GHJUHF V R L R Q L P H , P R K R L Z H V W P S I Q U I E H R O K E X I I H U L O
LQWHUDFWLRQV ZLWKKH \$ H W S R O \ P H F U X Q G H H E Q Y H M W W I D W L R L O I L R V
WUDQVIHF WWF H R O D Q E R L W K V R X X P



7+(52/(2) 18&/(\$5 &\$/&,80 0(',\$7(' 75\$16&5,37,21 ,1 ' > \$/5(7,21 ,1 &\$5', \$& 0<2&<7(6

'DULQ 9DXJKDQ 6MQLRUR&KKRDG 6WDWH 8QLYH
'U 3HWH .HNNQHV +XVNH\ &KHPLVWU\ 8QLYHU

\$EVWUDFW

'LVRUJDQLJDWLRQ JKOW KHH JXRODLD MDDKQZRIUN HQV BDKQDIF F YR F
DPRQJ WKH PRVW D \$SDUHQDQJ PRVW \$QRFDQGLPPG RSDVRK\
)UHTXHQWO\ WRQVFRULURHLDQDWH JDZLRPKR FSDIVULHG ZKLFK PRWLY
UHODWLRQV KLSV EHVWZM KEXO7H VFRULURHLDQDWH WRGRLDQGHG R[FLWD
FRQWUDFWLRQ FRXSOLQJ

,Q WKLW VWXG\ KHH H KVDHODWV DQGL JPDVQ FRIHQZLQJF KHYHORSV LQ
+,3 UDWV

6HFRQG ZH LQYHVWR JZKWH KWKDHOHLQDHE \$SDUQF DWSHGRMCH WKH DFWL
UHPRGHOLQJ JHQZLVWRKRWGKLV W7U QEIXWZURVZK E QKURJEWKLR QGLQWOX
FDOFLQHXULQ &D GSHHQGHQW DFWLYLW\

2XU GDWD VXJJHVO\ QWKD D 7SUHMRDQWHFQGF3 QHDXUL QWKD L7JQ QHZV
KLJKHU GLDVWROV FH&DLQOR D GDSW H FEFSSWRUP HPHGLDWHG &D U
\$OWRJHWKHU WKH VUHIO QVLE QW KLSVS QVWZ FHKQOPKDF GWWKH XSFUR
DFWLYDWH UHPRDGMQLPQSO SDDWHG LQ FDUGLDF IDLOXUH

7+,2%\$5%,785,&\$&,'7(67)255\$7(6\$1'/(9
6\$785\$7('0212816\$785\$7('\$1'
32/<816\$785\$7('',(7\$5<75,*/<&(5,'(2;,'\$7,2

\$QQD 9HUODQGHU V6UHQZRDQ&KQYDQ LD 8QLYHUV

\$E VWU DFW

7KH VWUXFWXUH DQW\VDLXGUDGHLVZLWKLOH WKKQFRGLRQV ZHOO
RI R[LGDWLRQ 2GDXQZHUHFRLQURFRPHSDERQGLW DQWQWU DWHG
DFLG IURPDG OOLF V DPSLDF0 WOOO QGDWXUDWDG O5\$EDQQ

\$ & 7, 9 \$ 7, 21 / (9 (/ 6 2) 0 7 2 5 3 \$ 7 + : \$ < 2 9 (5 7 0 (3, 1. . 2 5 \$ 7 0 2 ' (/ 2) 3 \$ 5., 1 6 2 1 ', 6 (\$ 6 (

(U L F 9 R J W 6 H Q L R & J Q L & Y K H U P L L W M U R I . H Q W X F N \ ' \$ O O D Q % X W W H U I L H O G & K H P L V W U \ 8 Q L Y H U V L

\$ E V W U D F W

3 D U N L Q V R Q G L V H D W H L Y L W G I H X H U R V G H J W K O W E D W W R K I D G H D F W K I R I G R S D
W K H V X E V W D Q W I R D W K J U D H F K G O O F O R M D G U R V G L S U R F E Y D H O F C F M D Q
H Y H Q W X D O O \ F D X E C H P R J Q Z K M L B H 1 S U N Q R X W I R X W D V P B G U H D W P R G H O
G L V H D V H 7 K H 3, 1. U J H Q U R F R I G L H Q V N B Q D A H H U Y H K D W R S P I D R D N U G D P I D J H
P L W R F K R Q G U L D I R W J G H Q H U D G D N Q L R F O M H V C K I R I X H V W W R I O F W K W D O V L Y R C O R I
S U R W H L Q V L Q W K H K H P 7 2 7 5 2 \$ S D W K Z K Z D \ 7 L R U H W D Q M P B O H L V P S W K H U R
L Q D X W R S K D J \ D Q G L Q K H K O I E O W L Y H D M H V S D O R O F H L C O M Y L R Z I H W K I L V R S D V K X
U D W L R R I S K R V S K R U K I O U W O B O H W G R S U R Q Y B I W B U S P Z I Q I H G Z E A W K H L Q W H
W K H : H V W H U Q % O R S U L P Z K U L F R K Z M K R O H X U W W B L I J H O G G R O X R U K R Z W K H O
Y D U \ D W G L I I H U L Q J 2 D U D W V W Z H U B I, V. D F R X U L F V H G D O G W H Z I R J K W P R Q W
0 \$ 3 / & % D Q G , 5 6 Z I S U H R W W K I H Q W K V K I H G Z \$ H O J W O B H F W R H L D W H W I K I R Z
L Q F U H D V H L Q D F W H L Y D Z A R L B Q G E H R V Z U H F R B O W W % H F D O P L S O % D O U G H O L S G Y R O
D X W R S K D J \ V R L W W P K N H I R O V O R Z / H V W W K B O O P H 7 K H Q H H U D O F Z H S U B W H J C
G H F U H D V H L Q W K O V D E F H W L Z H D H Q R A K I O H F O P S O I G V R P O R O M G E \ D Q
D F W L Y D W L R I O H O H W K O W I E H D C G H L J K W V P B O V K W E D P S S O H G A G D S K R Q
I R O O R Z V W K H V D R H U W W B R S U D R W W H U A V R O E X W L L W P I H D O W Y W K D W W K I
L Q F U H D V H L Q D E M W Z B W Q R V Q K O H I R X O S O I G V L Q G P R O K W O V D G H F U H D V
H L J K W P R Q W K V D P S O V H K H O B H U L Y H U K I O X L E J W W Y D O W R E K B E F W W O V G R M L
P 7 2 5 S D W K Z D \ Y D U \ 3, 1 W K. 2 J H D W Q P R O H R O F G I L Y B I D N H Q V K H P 7 2 5 S D
E H H Q V K R Z Q W R E H \$ O Y K H U L F D F U V G Y D S I B W K I H Q V R V W D K H W R K E M Z I K O F D V
3 D U N L Q V R Q G L V H D V H , W L V D O V R R K U S I R O W K M L R Q G S E M W K Z H M O W L R H D
W K L V L V W K H F U W K H W W Q R O O H I X J W G R K R A S K H X G L O A H O N B I G D W R D E H W