

## FYbUhc 'HUd]U'nY][ h'bYi Y'@]YVY. : f]gWXYf K ]bX'bUWX 'XYf'HfYbbi b[

 $\label{eq:final_state} FYbUhc `HUd]U `ghY``h `gY]bY `bYi Y': fYi bX]b `@Yg`m`K ]]b_Y`g`j cfž bUWXXYa `Yf`g]WX `j cb `5bXfYU `7cfXYfc `[ YhfYbbh`\Uh"`K Yf`]gh g]Y3$ 

# FYbUhc 'HUd]U'i bX'X]Y' < YfUi gZcfXYfi b[YbdYfgÒb`]WXYf'JYfÀbXYfi b[Yb

8]Y'K Y`h'XYg'Gdcfhg'i bX'XYf'² ZZYbh`]W\\_Y]h'nY][ h'g]W\'\Ài Z][']b
Y]bYa '[ `Ubnj c``Yb'@]W\hž'XcW\'XU\]bhYf'j YfVYf[ Yb'g]W\'cZh
\_ca d`Yl Y'a YbgW\`]W\Y'; YgW\]W\hYb"8Yf'dYfi Ub]gW\Y
: i » VU``gd]Y`Yf'F YbUhc'HUd]U'\Uh'\_Øfn`]W\'GW\`U[ nY]`Yb'[ Ya UW\hž
]bXYa 'Yf'gY]b'bYi Yg'@]YVYg`YVYb'bUW\'XYf'HfYbbi b['j cb'gY]bYf
: fUi ž'5bXfYU'7cfXYfcž'dfAgYbh]Yfh Y]bY'G]hi Uh]cbž'X]Y'ØVYf'X]Y
V`c» Y'HfYbbi b['\]bUi g[Y\h'i bX'h]YZYfY'9]bV`]W\_Y']b'X]Y
<YfUi gZcfXYfi b[Yb'i bX'8mbUa ]\_Yb'Y]bYg'ÒZZYbh`]W\Yb'@YVYbg
V]YhYh"

#### 8]Y bYi Y 6Yn]Y\i b[

BUWX 'gY]bYf'cZ]n]Y``Yb'9f\_`Àfi b['ØVYf'X]Y'HfYbbi b['Ua'&) "'\$b]ž X]Y'X]Y'6YYbX][ib['Y]bYf'`Ub['À\f][Yb'6Yn]Y\ib['bUWX'-'\$U\fYb 9\Y'ibX'%' '[YaY]bgUaYb'\$U\fYb'aUf\_]YfhYž'kifXY'FYbUhc HUd]U'YfghaU`g'a]h'gY]bYf'bYiYb'DUfhbYf]bž'@Yg`m'K]]b\_Y`gž [YgY\Yb"'8]YgY''1 b[Y':fUi ž'X]Y'6Yf]WXhYb'ni Zc`[Y'Ui g'<cbXifUg ghUaahž'VYn]Y\h']\fY'Y][YbY''2 ZZYbh`]WX\_Y]h'XifWX'X]Y [YaY]bgUaYb'GcW]U'!AYX]U!Dcghgž']b'XYbYb'g]Y']\fY'NibY][ib[cZZYb'nY][h'''6YgcbXYfg'\YfjcfghYWXYbX']gh'Y]bY'kibXYfjc``Y; YVifhghU[gVchgWXUZh'Ub'HUd]U.'':Y`]n'W'ad`YUlcgž'Uacf"'BibWUXYYg'XY'gYf'hUb'Öb]Wcž'hUb'hÖ"'HY'Uac"

## $8Yf^DfY]g^XYf^2ZZYbh^]WX_Y]h$

 $8 ]Y'A O[`]WX_Y]h'j cb'GdY_i `Uh]cbYb'i bX'OZZYbh`]WXYa `&hYfYggY']ghYb'ghAbX][Yf'6Y[`Y]hYf'j cb'dfca ]bYbhYb'DYfgOb`]WX_Y]hYb''8]Y HfYbbi b['j cb'HUd]U'i bX'7cfXYfcž'X]Y']b'XYf'^2 ZZYbh`]WX_Y]hYa ]h XYa '9bh\Ø``Yb'Y]bYg'i bY\Y`]WXYb'?]bXYg']b'JYfV]bXi b['[YVfUWXh ki fXYž'\Uh'b]WXh'bi f'5i gk]f_i b[Yb'Ui Z']\fY': Ua]`]Ybž'gcbXYfb Ui WX'Ui Z']\fY'?Uff]YfYb''Ni a]bXYgh'7cfXYfc'\A`h'g]WX']b']\fYf Fc``Y'U`g'6`c[[Yf]b'i bX'&bZi YbWYf]b']b'gcn]U`Yb'BYhnk Yf_Yb'i bX []Vh'XUa]h'9]bV`]W_Y']b']\fYb'bYi Yb'@YVYbgk Y[Z'XYf'Ui Z GY`VghghAbX][_Y]h'i bX'dYfgOb`]WXYa 'K UWXghi a 'UVn]Y`h''$ 

### 8]Y Fc``Y j cb GcWJU`A YX]U

9]b 6`]W\_Ui ZXYb  $\Rightarrow$ ghU[ fUa !5WWci bh'j cb @Yg`m'K ]]b\_Y`g`nY][ h Y]b df]j UhYgž YXcWX a ]h Gcf[ ZU`h'\_i fUh]YfhYg'6]`X U\_hi Y```\Uh'g]Y bi f'' '%: c``ck Yf'i bX XYf'5WWci bh']gh'df]j Uh''  $\Rightarrow$  fY'[ Yk À\`hYb N]hUhY'i bX D\fUgYbž'k ]Y HU\_Y']h YUgm ii bX 9bhfY'hUbhc'fi ]Xc gca cg'a Ög]WU ž'j Yf`Y]\Yb']\fYa 'DfcZ]`Y]bY'dYfgÒb`]WXY'BchY'i bX gdfYWXYb'ZØf'Y]bY''A b[ Y': fUi ž'X]Y'a ]h 6YXUWXh'ØVYf']\f'@YVYb i bX']\fY'?i bXgWXUZh'bUWXXYb\_h''  $\Rightarrow$  fY'gdcfUX]gWXYb' $\Rightarrow$ bhYfU\_h]cbYb a ]h XYf'A i g]\_gnYbY'\UVYb'g]Y'b]WXh'ni 'Y]bYf'\Ui dhVYfi Z`]WXYb ?Øbgh`Yf]b'[ Ya UWXhž'UVYf'Yg']gh'Yfg]WXh']WXž'XUgg'g]Y': fYi XY'Ua \_fYUh]j Yb'5i gXfi W\_`\Uh''

#### 9]bYgWk]Yf][YJYf[Ub[YbY]h

8]Y '6Yn]Y\i b[ 'nk ]gW\Yb 'F Yb Uhc 'HUd]U'i bX '5bXfYU'7cfXYfc k Uf 'gW\cb']a a Yf'j cf' < YfUi gZcfXYfi b[ Yb'b]W\h'[ YZY]hž ]bgVYgcbXYfY']b '5bVYhfUW\h'XYf'9bh\Ø``i b[ Yb'ØVYf'HUd]U g i bY\Y`]W\Yg'?]bXžXUg'Ui g'Y]bYf'ZfØ\YfYb'6Yn]Y\i b[ 'YbhghUbXYb k Uf"8]YgY'I a gh\AbXY'ZØ\fhYb'ni 'GdUbbi b[ Yb'i bX'gW\`]Y»`]W\'ni f YbX[ Ø`h][ Yb'HfYbbi b[ ž'X]Y'j cf'k Yb][ Yb'A cbUhYb'cZZ]n]Y`` VY\_Ubbh'[ Y[ YVYb'k i fXY"'HUd]U'\Uh'\_`Uf'[ YghY``hž'XUgg'gY]b 5i [ Yba Yf\_'bi b'Ui Z'XYa 'K c\`Yf[ Y\Yb'gY]bYf'HcW\hYf'`]Y[ h'i bX XUgg'Yf'\_Y]bY'k Y]hYfYb'9f\_`\Afi b[ Yb'ni 'gY]bYf'DYfgcb'UV[ YVYb a OW\hY Y]bY'6]hhY'i a 'Df]j Uhgd\\AfYž'X]Y']b'XYf'\Yi h][ Yb'NY]h'cZh

#### 

8]Y '9bhk ]W\_`i b[Yb'i a 'X]Y': Ua ]`]Y 'HUd]U'k YfXYb'k Y]hYf\]b'j cb XYb'A YX]Yb'j YfZc`[hž'k Ug'X]Y 'Bchk YbX][\_Y]h'i bhYfghfY]Wkhž'ØVYf X]Y'<YfUi gZcfXYfi b[Yb'XYg'ÒZZYbh`]WkYb'@YVYbg'bUWkni XYb\_Ybž [YfUXY']a '<]bV`]W\_'Ui Z'X]Y'dYfgÒb`]WkY'\DhY[f]hÀh'i bX'XYb FYgdY\_h'j cf'df]j UhYghYb'5b[Y`Y[Yb\Y]hYb"

8 Y hU]`g

6 Y gi W Y b 'G ] Y 'i b g 'U i Z 'X ] Y ! b U W f ] W h Y b "b Y h