***Supporting Information***

**2D-HELS MS Seq: A general LC-MS-based method for direct and *de novo* sequencing of RNA mixtures with different nucleotide modifications**

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**Figure S1.** 2D-HELS MS sequencing of 5 mixed RNA strands simultaneously using a biotin tag to label the 3´-ends. Original tR was displayed without any normalization.

**Table S1.** LC-MS analysis of 3´-biotin-labeled RNA #1 after streptavidin-aided bead separation followed by subsequent chemical degradation (3´-labeled ladder components of RNA #1, referring to the top curve in Figure 1c).

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Theoretical** | | | | **Extracted data file after LC/MS analysis** | | | | **Error** |
| **Fragments** | **Theoretical mass** | **Base mass** | **Base** | **MFE mass** | **tR** | **Volume** | **Quality Score** | **ppm** |
| 19 | 6781.0733 | 305.0413 | C | 6781.0413 | 9.752 | 16819442 | 100 | 4.72 |
| 18 | 6476.0320 | 345.0474 | G | 6475.9924 | 9.717 | 247965 | 84 | 6.11 |
| 17 | 6130.9846 | 305.0413 | C | 6130.9398 | 9.662 | 178841 | 80 | 7.31 |
| 16 | 5825.9433 | 329.0525 | A | 5825.9037 | 9.782 | 510096 | 80 | 6.80 |
| 15 | 5496.8908 | 306.0253 | U | 5496.8566 | 9.383 | 262486 | 99 | 6.22 |
| 14 | 5190.8655 | 305.0413 | C | 5190.8364 | 9.241 | 349988 | 100 | 5.61 |
| 13 | 4885.8242 | 306.0253 | U | 4885.7908 | 9.135 | 356118 | 100 | 6.84 |
| 12 | 4579.7989 | 345.0475 | G | 4579.7738 | 9.109 | 386687 | 100 | 5.48 |
| 11 | 4234.7514 | 329.0525 | A | 4234.7271 | 9.145 | 305380 | 100 | 5.74 |
| 10 | 3905.6989 | 305.0413 | C | 3905.6749 | 8.575 | 145505 | 96 | 6.14 |
| 9 | 3600.6576 | 306.0253 | U | 3600.6373 | 8.420 | 195308 | 100 | 5.64 |
| 8 | 3294.6323 | 345.0474 | G | 3294.6165 | 8.370 | 125991 | 100 | 4.80 |
| 7 | 2949.5849 | 329.0525 | A | 2949.5716 | 8.339 | 106993 | 100 | 4.51 |
| 6 | 2620.5324 | 305.0413 | C | 2620.5193 | 7.492 | 90629 | 100 | 5.00 |
| 5 | 2315.4911 | 305.0413 | C | 2315.4814 | 7.299 | 163692 | 100 | 4.19 |
| 4 | 2010.4498 | 329.0525 | A | 2010.4388 | 7.625 | 279963 | 100 | 5.47 |
| 3 | 1681.3973 | 329.0525 | A | 1681.3891 | 7.354 | 183827 | 100 | 4.88 |
| 2 | 1352.3448 | 329.0526 | A | 1352.3378 | 7.303 | 135065 | 100 | 5.18 |
| 1 | 1023.2922 | 329.0525 | A | 1023.2859 | 7.219 | 106700 | 100 | 6.16 |

Output sequence: CGCAUCUGACUGACCAAAA

**Table S2.** LC-MS analysis of 3´-biotin-labeled RNA #1 after streptavidin-aided bead separation followed by subsequent chemical degradation (5´-unlabeled ladder components of RNA #1, referring to the bottom curve in Figure 1c).

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Theoretical** | | | | **Extracted data file after LC/MS analysis** | | | | **Error** |
| **Fragments** | **Theoretical mass** | **Base mass** | **Base** | **MFE mass** | **tR** | **Volume** | **Quality Score** | **ppm** |
| 19 | 6024.8778 | 249.0862 | A | 6024.8483 | 7.664 | 14325731 | 100 | 4.90 |
| 18 | 5775.7916 | 329.0525 | A | 5775.7522 | 7.701 | 457844 | 87 | 6.82 |
| 17 | 5446.7391 | 329.0525 | A | 5446.6965 | 7.411 | 417145 | 100 | 7.82 |
| 16 | 5117.6866 | 329.0525 | A | 5117.6572 | 7.105 | 490290 | 100 | 5.74 |
| 15 | 4788.6341 | 305.0413 | C | 4788.6060 | 6.685 | 728135 | 100 | 5.87 |
| 14 | 4483.5928 | 305.0413 | C | 4483.5657 | 6.428 | 481770 | 100 | 6.04 |
| 13 | 4178.5515 | 329.0525 | A | 4178.5286 | 6.183 | 297514 | 100 | 5.48 |
| 12 | 3849.4990 | 345.0475 | G | 3849.4787 | 5.653 | 518403 | 100 | 5.27 |
| 11 | 3504.4515 | 306.0253 | U | 3504.4331 | 5.238 | 614494 | 100 | 5.25 |
| 10 | 3198.4262 | 305.0413 | C | 3198.4106 | 4.785 | 524613 | 99 | 4.88 |
| 9 | 2893.3849 | 329.0525 | A | 2893.3714 | 4.341 | 373933 | 100 | 4.67 |
| 8 | 2564.3324 | 345.0474 | G | 2564.3219 | 3.458 | 509219 | 100 | 4.09 |
| 7 | 2219.2850 | 306.0253 | U | 2219.2752 | 2.840 | 579139 | 100 | 4.42 |
| 6 | 1913.2597 | 305.0413 | C | 1913.2521 | 2.081 | 466058 | 100 | 3.97 |
| 5 | 1608.2184 | 306.0253 | U | 1608.2123 | 1.375 | 372038 | 80 | 3.79 |
| 4 | 1302.1931 | 329.0525 | A | 1302.1878 | 0.925 | 240613 | 100 | 4.07 |
| 3 | 973.1406 | 305.0413 | C | 973.1367 | 0.765 | 208989 | 100 | 4.01 |
| 2 | 668.0993 | 345.0474 | G | 668.0955 | 0.652 | 26061 | 100 | 5.69 |
| 1 | 323.0519 | 305.0413 | C | NA\* | NA | NA | NA | NA |

\* NA: Not Analyzed. The 350 Da threshold was set to minimize background ions from the elution buffers. Thus, the masses which are smaller than 350 Da were not detected.

Output sequence: CGCAUCUGACUGACCAAAA

**Table S3.** LC-MS analysis of 5´-biotin-labeled RNA #1 (5´-labeled ladder components of RNA #1, referring to the bottom ladder curve in black in Figure 1d).

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Theoretical** | | | | **Extracted data file after LC/MS analysis** | | | | **Error** |
| **Fragments** | **Theoretical mass** | **Base mass** | **Base** | **MFE mass** | **tR** | **Volume** | **Quality Score** | **ppm** |
| 19 | 6600.0415 | 249.0862 | A | 6600.0153 | 10.113 | 1468018 | 100 | 3.97 |
| 18 | 6350.9553 | 329.0525 | A | 6350.9006 | 10.094 | 139388 | 80 | 8.61 |
| 17 | 6021.9028 | 329.0525 | A | 6021.8665 | 9.957 | 152155 | 80 | 6.03 |
| 16 | 5692.8503 | 329.0525 | A | 5692.8225 | 9.806 | 122377 | 84 | 4.88 |
| 15 | 5363.7978 | 305.0413 | C | 5363.7567 | 9.594 | 255396 | 100 | 7.66 |
| 14 | 5058.7565 | 305.0413 | C | 5058.7320 | 9.508 | 169499 | 80 | 4.84 |
| 13 | 4753.7152 | 329.0525 | A | 4753.6944 | 9.449 | 121869 | 96 | 4.38 |
| 12 | 4424.6627 | 345.0475 | G | 4424.6389 | 9.204 | 222046 | 100 | 5.38 |
| 11 | 4079.6152 | 306.0253 | U | 4079.5902 | 9.067 | 296271 | 100 | 6.13 |
| 10 | 3773.5899 | 305.0413 | C | 3773.5679 | 8.937 | 249085 | 100 | 5.83 |
| 9 | 3468.5486 | 329.0525 | A | 3468.5308 | 8.838 | 185624 | 100 | 5.13 |
| 8 | 3139.4961 | 345.0474 | G | 3139.4834 | 8.507 | 319911 | 100 | 4.05 |
| 7 | 2794.4487 | 306.0253 | U | 2794.4360 | 8.288 | 380189 | 100 | 4.54 |
| 6 | 2488.4234 | 305.0413 | C | 2488.4134 | 8.073 | 317954 | 100 | 4.02 |
| 5 | 2183.3821 | 306.0253 | U | 2183.3725 | 7.863 | 305479 | 100 | 4.40 |
| 4 | 1877.3568 | 329.0525 | A | 1877.3489 | 7.642 | 222446 | 100 | 4.21 |
| 3 | 1548.3043 | 305.0413 | C | 1548.2982 | 7.088 | 361254 | 100 | 3.94 |
| 2 | 1243.2630 | 345.0474 | G | 1243.2575 | 6.798 | 162972 | 100 | 4.42 |
| 1 | 898.2156 | 305.0413 | C | 898.2105 | 6.880 | 88421 | 100 | 5.68 |

Output sequence: CGCAUCUGACUGACCAAAA

**Table S4.** LC-MS analysis of 5´-biotin-labeled RNA #2 (5´-labeled ladder components of RNA #2, referring to the top ladder curve in red in Figure 1d).

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Theoretical** | | | | **Extracted data file after LC/MS analysis** | | | | **Error** |
| **Fragments** | **Theoretical mass** | **Base mass** | **Base** | **MFE mass** | **tR** | **Volume** | **Quality Score** | **ppm** |
| 20 | 6898.0505 | 225.0750 | C | 6898.0210 | 10.014 | 3995416 | 100 | 4.28 |
| 19 | 6672.9755 | 345.0474 | G | 6673.4755 | 10.115 | 92706 | 80 | -74.9 |
| 18 | 6327.9281 | 305.0413 | C | 6327.8894 | 10.117 | 108088 | 80 | 6.12 |
| 17 | 6022.8868 | 329.0525 | A | 6022.8313 | 10.104 | 133027 | 100 | 9.21 |
| 16 | 5693.8343 | 306.0253 | U | 5693.7870 | 9.920 | 68281 | 80 | 8.31 |
| 15 | 5387.8090 | 305.0413 | C | 5387.7785 | 9.850 | 167081 | 80 | 5.66 |
| 14 | 5082.7677 | 306.0253 | U | 5082.7314 | 9.784 | 170198 | 100 | 7.14 |
| 13 | 4776.7424 | 345.0474 | G | 4776.7210 | 9.695 | 114657 | 99 | 4.48 |
| 12 | 4431.6950 | 329.0526 | A | 4431.6685 | 9.629 | 143358 | 92 | 5.98 |
| 11 | 4102.6424 | 305.0412 | C | 4102.6199 | 9.367 | 245033 | 100 | 5.48 |
| 10 | 3797.6012 | 306.0253 | U | 3797.5819 | 9.264 | 184127 | 100 | 5.08 |
| 9 | 3491.5759 | 345.0475 | G | 3491.5567 | 9.131 | 91691 | 100 | 5.50 |
| 8 | 3146.5284 | 329.0525 | A | 3146.5054 | 9.028 | 187937 | 100 | 7.31 |
| 7 | 2817.4759 | 305.0413 | C | 2817.4633 | 8.675 | 288050 | 100 | 4.47 |
| 6 | 2512.4346 | 305.0413 | C | 2512.4233 | 8.509 | 138698 | 100 | 4.50 |
| 5 | 2207.3933 | 305.0413 | C | 2207.3835 | 8.335 | 192998 | 100 | 4.44 |
| 4 | 1902.3520 | 345.0474 | G | 1902.3433 | 8.161 | 149466 | 100 | 4.57 |
| 3 | 1557.3046 | 329.0525 | A | 1557.2976 | 8.042 | 133349 | 100 | 4.49 |
| 2 | 1228.2521 | 306.0253 | U | 1228.2455 | 7.618 | 188828 | 100 | 5.37 |
| 1 | 922.2268 | 329.0525 | A | 922.2213 | 7.434 | 86674 | 100 | 5.96 |

Output sequence: AUAGCCCAGUCAGUCUACGC

**Table S5.** LC-MS analysis of a 1 ψ-containing RNA #6 (ψ unconverted ladder components in the 5´ ladder of RNA #6, referring to the bottom ladder curve in black in Figure 2b).

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Theoretical** | | | | **Extracted data file after LC/MS analysis** | | | | **Error** |
| **Fragments** | **Theoretical mass** | **Base mass** | **Base** | **MFE mass** | **tR** | **Volume** | **Quality Score** | **ppm** |
| 20 | 6345.9028 | 265.0811 | G | 6345.9217 | 11.736 | 41088112 | 100 | -2.98 |
| 19 | 6080.8217 | 329.0525 | A | 6080.8255 | 11.769 | 2582596 | 100 | -0.62 |
| 18 | 5751.7692 | 345.0474 | G | 5751.7749 | 11.496 | 2169051 | 100 | -0.99 |
| 17 | 5406.7218 | 306.0253 | U | 5406.7209 | 11.315 | 2126771 | 100 | 0.17 |
| 16 | 5100.6965 | 319.057 | m5C | 5100.6941 | 11.167 | 1149416 | 100 | 0.47 |
| 15 | 4781.6395 | 329.0525 | A | 4781.6402 | 10.970 | 2692877 | 100 | -0.15 |
| 14 | 4452.5870 | 306.0253 | U | 4452.5866 | 10.566 | 5448251 | 100 | 0.09 |
| 13 | 4146.5617 | 306.0253 | U | 4146.5603 | 10.343 | 4115258 | 100 | 0.34 |
| 12 | 3840.5364 | 329.0526 | A | 3840.5352 | 10.141 | 2038738 | 100 | 0.31 |
| 11 | 3511.4838 | 305.0413 | C | 3511.4836 | 9.610 | 1167942 | 100 | 0.06 |
| 10 | 3206.4425 | 305.0412 | C | 3206.4401 | 9.331 | 3422282 | 100 | 0.75 |
| 9 | 2901.4013 | 329.0526 | A | 2901.3988 | 9.067 | 2391922 | 100 | 0.86 |
| 8 | 2572.3487 | 306.0253 | Unconverted ψ | 2572.3468 | 8.328 | 4952174 | 100 | 0.74 |
| 7 | 2266.3234 | 306.0253 | U | 2266.3215 | 7.944 | 4534905 | 100 | 0.84 |
| 6 | 1960.2981 | 345.0474 | G | 1960.2956 | 7.360 | 3437270 | 100 | 1.28 |
| 5 | 1615.2507 | 305.0413 | C | 1615.2481 | 6.693 | 4151449 | 100 | 1.61 |
| 4 | 1310.2094 | 305.0413 | C | 1310.2062 | 5.915 | 1289241 | 87 | 2.44 |
| 3 | 1005.1681 | 329.0525 | A | 1005.1655 | 4.416 | 913589 | 100 | 2.59 |
| 2 | 676.1156 | 329.0525 | A | 676.1140 | 3.321 | 748977 | 100 | 2.37 |
| 1 | 347.0631 | 329.0525 | A | NA\* | NA | NA | NA | NA |

\* NA: Not Analyzed. The 350 Da threshold was set to minimize background ions from the elution buffers. Thus, the masses which are smaller than 350 Da were not detected.

Output sequence: AAACCGUψACCAUUAm5CUGAG

**Table S6.** LC-MS analysis of a 1 ψ-containing RNA #6 (ladder components with CMC-converted ψ in the 5´ ladder of RNA #6, referring to the top ladder curve in red in Figure 2b)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Theoretical** | | | | **Extracted data file after LC/MS analysis** | | | | **Error** |
| **Fragments** | **Theoretical mass** | **Base mass** | **Base** | **MFE mass** | **tR** | **Volume** | **Quality Score** | **ppm** |
| 20 | 6597.1025 | 265.0811 | G | 6597.1125 | 13.985 | 60627484 | 100 | -1.52 |
| 19 | 6332.0214 | 329.0525 | A | 6332.0201 | 13.979 | 1541470 | 100 | 0.21 |
| 18 | 6002.9689 | 345.0474 | G | 6002.9756 | 13.816 | 2147847 | 89 | -1.12 |
| 17 | 5657.9215 | 306.0253 | U | 5657.9243 | 13.742 | 2608610 | 100 | -0.49 |
| 16 | 5351.8962 | 319.057 | m5C | 5351.8960 | 13.695 | 2110248 | 100 | 0.04 |
| 15 | 5032.8392 | 329.0525 | A | 5032.8400 | 13.633 | 1907945 | 100 | -0.16 |
| 14 | 4703.7867 | 306.0253 | U | 4703.7861 | 13.394 | 4110706 | 88 | 0.13 |
| 13 | 4397.7614 | 306.0253 | U | 4397.7599 | 13.320 | 2867370 | 100 | 0.34 |
| 12 | 4091.7361 | 329.0526 | A | 4091.7361 | 13.283 | 1855682 | 100 | 0.00 |
| 11 | 3762.6835 | 305.0413 | C | 3762.6830 | 12.962 | 2817838 | 100 | 0.13 |
| 10 | 3457.6422 | 305.0412 | C | 3457.6396 | 12.878 | 1149319 | 100 | 0.75 |
| 9 | 3152.6010 | 329.0526 | A | 3152.5974 | 12.934 | 746862 | 100 | 1.14 |
| 8 | 2823.5485 | 557.2251 | Converted ψ | 2823.5455 | 12.380 | 2149383 | 100 | 1.06 |
| 7 | 2266.3234 | 306.0253 | U | 2266.3213 | 7.944 | 4767282 | 100 | 0.93 |
| 6 | 1960.2981 | 345.0474 | G | 1960.2956 | 7.360 | 3433416 | 100 | 1.28 |
| 5 | 1615.2507 | 305.0413 | C | 1615.2481 | 6.694 | 4174772 | 100 | 1.61 |
| 4 | 1310.2094 | 305.0413 | C | 1310.2071 | 5.917 | 806139 | 87 | 1.76 |
| 3 | 1005.1681 | 329.0525 | A | 1005.1655 | 4.416 | 913589 | 100 | 2.59 |
| 2 | 676.1156 | 329.0525 | A | 676.1140 | 3.321 | 743305 | 100 | 2.37 |
| 1 | 347.0631 | 329.0525 | A | NA\* | NA | NA | NA | NA |

\* NA: Not Analyzed. The 350 Da threshold was set to minimize background ions from the elution buffers. Thus, the masses which are smaller than 350 Da were not detected.

Output sequence: AAACCGUψACCAUUAm5CUGAG

**Table S7.** LC-MS analysis of 3´-biotin-labeled RNA #1, showing its ladder components (referring to the ladder curve in black in Figure 3).

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Theoretical** | | | | **Extracted data file after LC/MS analysis** | | | | **Error** |
| **Fragments** | **Theoretical mass** | **Base mass** | **Base** | **MFE mass** | **tR** | **Volume** | **Quality Score** | **ppm** |
| 19 | 6781.0733 | 305.0413 | C | 6781.0426 | 9.576 | 35286012 | 100 | 4.53 |
| 18 | 6476.0320 | 345.0474 | G | 6475.9985 | 9.535 | 23351 | 60 | 5.17 |
| 17 | 6130.9846 | 305.0413 | C | 6130.9933 | 9.473 | 50125 | 90 | -1.42 |
| 16 | 5825.9433 | 329.0525 | A | 5825.9244 | 9.634 | 55880 | 80 | 3.24 |
| 15 | 5496.8908 | 306.0253 | U | 5496.8590 | 9.218 | 633795 | 80 | 5.79 |
| 14 | 5190.8655 | 305.0413 | C | 5190.8470 | 9.078 | 849742 | 100 | 3.56 |
| 13 | 4885.8242 | 306.0253 | U | 4885.7976 | 8.976 | 1193120 | 100 | 5.44 |
| 12 | 4579.7989 | 345.0475 | G | 4579.7742 | 8.951 | 1191558 | 100 | 5.39 |
| 11 | 4234.7514 | 329.0525 | A | 4234.7340 | 8.989 | 1196633 | 100 | 4.11 |
| 10 | 3905.6989 | 305.0413 | C | 3905.6808 | 8.420 | 729180 | 100 | 4.63 |
| 9 | 3600.6576 | 306.0253 | U | 3600.6382 | 8.275 | 605689 | 100 | 5.39 |
| 8 | 3294.6323 | 345.0474 | G | 3294.6179 | 8.229 | 935654 | 100 | 4.37 |
| 7 | 2949.5849 | 329.0525 | A | 2949.5713 | 8.210 | 903559 | 100 | 4.61 |
| 6 | 2620.5324 | 305.0413 | C | 2620.5217 | 7.376 | 587699 | 100 | 4.08 |
| 5 | 2315.4911 | 305.0413 | C | 2315.4825 | 7.191 | 700118 | 100 | 3.71 |
| 4 | 2010.4498 | 329.0525 | A | 2010.4378 | 7.527 | 1052796 | 100 | 5.97 |
| 3 | 1681.3973 | 329.0525 | A | 1681.3901 | 7.273 | 714971 | 100 | 4.28 |
| 2 | 1352.3448 | 329.0526 | A | 1352.3387 | 7.230 | 447072 | 100 | 4.51 |
| 1 | 1023.2922 | 329.0525 | A | 1023.2881 | 7.148 | 736463 | 100 | 4.01 |

Output sequence: CGCAUCUGACUGACCAAAA

**Table S8.** LC-MS analysis of 3´-biotin-labeled RNA #2, showing its ladder components (referring to the ladder curve in red in Figure 3).

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Theoretical** | | | | **Extracted data file after LC/MS analysis** | | | | **Error** |
| **Fragments** | **Theoretical mass** | **Base mass** | **Base** | **MFE mass** | **tR** | **Volume** | **Quality Score** | **ppm** |
| 20 | 7079.0823 | 329.2088 | A | 7079.0513 | 9.529 | 34343980 | 100 | 4.38 |
| 19 | 6750.0298 | 306.1667 | U | 6749.9875 | 9.259 | 170073 | 78 | 6.27 |
| 18 | 6444.0045 | 329.2088 | A | 6443.9653 | 9.344 | 934361 | 97 | 6.08 |
| 17 | 6114.9519 | 345.2077 | G | 6114.9082 | 9.000 | 176482 | 94 | 7.15 |
| 16 | 5769.9045 | 305.1828 | C | 5769.8590 | 8.867 | 537259 | 80 | 7.89 |
| 15 | 5464.8632 | 305.1828 | C | 5464.8338 | 8.733 | 381043 | 100 | 5.38 |
| 14 | 5159.8219 | 305.1827 | C | 5159.7998 | 8.619 | 939572 | 99 | 4.28 |
| 13 | 4854.7806 | 329.2088 | A | 4854.7556 | 8.734 | 1104050 | 100 | 5.15 |
| 12 | 4525.7281 | 345.2078 | G | 4525.7027 | 8.273 | 799528 | 100 | 5.61 |
| 11 | 4180.6807 | 306.1667 | U | 4180.6575 | 8.047 | 727253 | 100 | 5.55 |
| 10 | 3874.6554 | 305.1828 | C | 3874.6361 | 7.836 | 1007297 | 100 | 4.98 |
| 9 | 3569.6141 | 329.2087 | A | 3569.5985 | 7.960 | 1323892 | 100 | 4.37 |
| 8 | 3240.5616 | 345.2078 | G | 3240.5458 | 7.328 | 854305 | 100 | 4.88 |
| 7 | 2895.5141 | 306.1668 | U | 2895.5009 | 6.991 | 838944 | 100 | 4.56 |
| 6 | 2589.4888 | 305.1827 | C | 2589.4785 | 6.639 | 1076014 | 100 | 3.98 |
| 5 | 2284.4476 | 306.1668 | U | 2284.4388 | 6.433 | 1085561 | 100 | 3.85 |
| 4 | 1978.4223 | 329.2088 | A | 1978.4152 | 6.298 | 1224106 | 100 | 3.59 |
| 3 | 1649.3697 | 305.1827 | C | 1649.3632 | 5.150 | 443067 | 100 | 3.94 |
| 2 | 1344.3284 | 345.2078 | G | 1344.3229 | 5.115 | 530069 | 100 | 4.09 |
| 1 | 999.2810 | 305.1827 | C | 999.2764 | 5.258 | 300175 | 100 | 4.60 |

Output sequence: AUAGCCCAGUCAGUCUACGC

**Table S9.** LC-MS analysis of 3´-biotin-labeled RNA #3, showing its ladder components (referring to the ladder curve in green in Figure 3).

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Theoretical** | | | | **Extracted data file after LC/MS analysis** | | | | **Error** |
| **Fragments** | **Theoretical mass** | **Base mass** | **Base** | **MFE mass** | **tR** | **Volume** | **Quality Score** | **ppm** |
| 20 | 7088.0826 | 329.0525 | A | 7088.0479 | 9.902 | 18422776 | 100 | 4.90 |
| 19 | 6759.0301 | 329.0525 | A | 6758.9878 | 9.816 | 342458 | 82 | 6.26 |
| 18 | 6429.9776 | 329.0525 | A | 6429.9401 | 9.553 | 297978 | 100 | 5.83 |
| 17 | 6100.9251 | 305.0413 | C | 6100.8860 | 9.162 | 176200 | 80 | 6.41 |
| 16 | 5795.8838 | 305.0413 | C | 5795.8502 | 9.059 | 325811 | 100 | 5.80 |
| 15 | 5490.8425 | 345.0475 | G | 5490.8084 | 9.029 | 561379 | 99 | 6.21 |
| 14 | 5145.7950 | 306.0253 | U | 5145.7640 | 8.927 | 543764 | 100 | 6.02 |
| 13 | 4839.7697 | 306.0253 | U | 4839.7382 | 8.852 | 751511 | 100 | 6.51 |
| 12 | 4533.7444 | 329.0525 | A | 4533.7170 | 8.857 | 916467 | 100 | 6.04 |
| 11 | 4204.6919 | 305.0413 | C | 4204.6726 | 8.273 | 363029 | 100 | 4.59 |
| 10 | 3899.6506 | 305.0413 | C | 3899.6323 | 8.164 | 664338 | 100 | 4.69 |
| 9 | 3594.6093 | 329.0525 | A | 3594.5912 | 8.300 | 1247513 | 100 | 5.04 |
| 8 | 3265.5568 | 306.0253 | U | 3265.5400 | 7.653 | 597972 | 100 | 5.14 |
| 7 | 2959.5315 | 306.0253 | U | 2959.5186 | 7.464 | 985122 | 100 | 4.36 |
| 6 | 2653.5062 | 329.0525 | A | 2653.4963 | 7.431 | 1500526 | 100 | 3.73 |
| 5 | 2324.4537 | 305.0413 | C | 2324.4444 | 6.486 | 663475 | 100 | 4.00 |
| 4 | 2019.4124 | 306.0253 | U | 2019.4039 | 6.101 | 752760 | 100 | 4.21 |
| 3 | 1713.3871 | 345.0474 | G | 1713.3811 | 5.973 | 1299628 | 100 | 3.50 |
| 2 | 1368.3397 | 329.0525 | A | 1368.3335 | 6.144 | 379728 | 100 | 4.53 |
| 1 | 1039.2872 | 345.0474 | G | 1039.2820 | 5.644 | 273139 | 100 | 5.00 |

Output sequence: AAACCGUUACCAUUACUGAG

**Table S10.** LC-MS analysis of 3´-biotin-labeled RNA #4, showing its ladder components (referring to the ladder curve in pink in Figure 3).

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Theoretical** | | | | **Extracted data file after LC/MS analysis** | | | | **Error** |
| **Fragments** | **Theoretical mass** | **Base mass** | **Base** | **MFE mass** | **tR** | **Volume** | **Quality Score** | **ppm** |
| 20 | 6954.9836 | 345.0475 | G | 6954.9478 | 9.243 | 16978916 | 100 | 5.15 |
| 19 | 6609.9361 | 305.0412 | C | 6609.8899 | 9.131 | 184784 | 80 | 6.99 |
| 18 | 6304.8949 | 345.0475 | G | 6304.8568 | 9.109 | 510790 | 80 | 6.04 |
| 17 | 5959.8474 | 306.0253 | U | 5959.7956 | 9.056 | 393186 | 90 | 8.69 |
| 16 | 5653.8221 | 329.0525 | A | 5653.7838 | 9.059 | 830821 | 100 | 6.77 |
| 15 | 5324.7696 | 305.0413 | C | 5324.7319 | 8.701 | 496925 | 98 | 7.08 |
| 14 | 5019.7283 | 329.0525 | A | 5019.6982 | 8.848 | 1059427 | 100 | 6.00 |
| 13 | 4690.6758 | 306.0253 | U | 4690.6470 | 8.345 | 581020 | 82 | 6.14 |
| 12 | 4384.6505 | 305.0413 | C | 4384.6245 | 8.185 | 852527 | 100 | 5.93 |
| 11 | 4079.6092 | 306.0253 | U | 4079.5872 | 8.071 | 872930 | 100 | 5.39 |
| 10 | 3773.5839 | 306.0253 | U | 3773.5632 | 7.884 | 880358 | 100 | 5.49 |
| 9 | 3467.5586 | 305.0413 | C | 3467.5339 | 7.639 | 168485 | 97 | 7.12 |
| 8 | 3162.5173 | 305.0413 | C | 3162.4881 | 7.411 | 503294 | 100 | 9.23 |
| 7 | 2857.4760 | 305.0413 | C | 2857.4625 | 7.156 | 851140 | 100 | 4.72 |
| 6 | 2552.4347 | 305.0412 | C | 2552.4231 | 6.920 | 1065610 | 100 | 4.54 |
| 5 | 2247.3935 | 306.0253 | U | 2247.3838 | 6.690 | 1189236 | 100 | 4.32 |
| 4 | 1941.3682 | 306.0253 | U | 1941.3605 | 6.350 | 1445336 | 100 | 3.97 |
| 3 | 1635.3429 | 306.0254 | U | 1635.3384 | 6.009 | 22256 | 85 | 2.75 |
| 2 | 1329.3175 | 329.0525 | A | 1329.3120 | 6.598 | 1296266 | 100 | 4.14 |
| 1 | 1000.2650 | 306.0253 | U | 1000.2606 | 5.604 | 422194 | 100 | 4.40 |

Output sequence: GCGUACAUCUUCCCCUUUAU

**Table S11.** LC-MS analysis of 3´-biotin-labeled RNA #5, showing its ladder components (referring to the ladder curve in light blue in Figure 3).

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Theoretical** | | | | **Extracted data file after LC/MS analysis** | | | | **Error** |
| **Fragments** | **Theoretical mass** | **Base mass** | **Base** | **MFE mass** | **tR** | **Volume** | **Quality Score** | **ppm** |
| 21 | 7522.1050 | 345.0475 | G | 7522.0681 | 9.519 | 21361914 | 100 | 4.91 |
| 20 | 7177.0575 | 305.0413 | C | 7176.9933 | 9.405 | 68800 | 60 | 8.95 |
| 19 | 6872.0162 | 345.0474 | G | 6871.9775 | 9.363 | 252280 | 88 | 5.63 |
| 18 | 6526.9688 | 345.0474 | G | 6526.9161 | 9.345 | 403291 | 100 | 8.07 |
| 17 | 6181.9214 | 329.0526 | A | 6181.8847 | 9.425 | 1246921 | 100 | 5.94 |
| 16 | 5852.8688 | 306.0253 | U | 5852.8226 | 9.054 | 263228 | 92 | 7.89 |
| 15 | 5546.8435 | 306.0253 | U | 5546.8116 | 8.935 | 1204009 | 100 | 5.75 |
| 14 | 5240.8182 | 306.0253 | U | 5240.7914 | 8.839 | 944494 | 100 | 5.11 |
| 13 | 4934.7929 | 329.0525 | A | 4934.7693 | 8.917 | 796848 | 100 | 4.78 |
| 12 | 4605.7404 | 345.0474 | G | 4605.7119 | 8.465 | 673185 | 100 | 6.19 |
| 11 | 4260.6930 | 305.0413 | C | 4260.6681 | 8.290 | 729523 | 100 | 5.84 |
| 10 | 3955.6517 | 306.0253 | U | 3955.6308 | 8.107 | 803678 | 100 | 5.28 |
| 9 | 3649.6264 | 305.0413 | C | 3649.6084 | 7.894 | 1056834 | 100 | 4.93 |
| 8 | 3344.5851 | 329.0525 | A | 3344.5687 | 7.990 | 1336987 | 100 | 4.90 |
| 7 | 3015.5326 | 345.0474 | G | 3015.5131 | 7.343 | 882742 | 100 | 6.47 |
| 6 | 2670.4852 | 306.0253 | U | 2670.4731 | 6.959 | 659989 | 100 | 4.53 |
| 5 | 2364.4599 | 306.0253 | U | 2364.4502 | 6.560 | 845446 | 100 | 4.10 |
| 4 | 2058.4346 | 345.0475 | G | 2058.4278 | 6.256 | 752026 | 100 | 3.30 |
| 3 | 1713.3871 | 345.0474 | G | 1713.3811 | 5.973 | 1299628 | 100 | 3.50 |
| 2 | 1368.3397 | 345.0475 | G | 1368.3335 | 6.144 | 379728 | 100 | 4.53 |
| 1 | 1023.2922 | 329.0525 | A | 1023.2881 | 7.148 | 736463 | 100 | 4.01 |

Output sequence: GCGGAUUUAGCUCAGUUGGGA