Table 1. Nuclear spectroscopic data and yields of fission products in the 3.72 MeV neutron-induced fission of 238U

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Nuclide | Half-life | γ-ray  Energy(keV) | γ-ray  abundance (%) | *YR*(%) | *YA* (%) |
| 84Br  85Krm  87Kr  88Kr  91Sr  92Sr  93Y  95Zr  97Zr  99Mo  103Ru  105Ru  105Rh  112Ag  113Ag  115Cdg  115Cdtotal  117Cdm  117Cdg  117Cdtotal | 31.8 min  4.48 h  76.3 min  2.84 h  9.63 h  2.71 h  10.18 h  64.02 d  16.91 h  65.94 h  39.26 d  4.44 h  35.36 h  3.13 h  5.37 h  53.46 h  3.36 h  2.49 h | 1616.2  151.2  304.9  402.6  196.3  749.8  1024.3  1384.9  266.9  756.7  724.3  743.4  140.5  739.5  497.1  724.4  319.1  617.5  298.6  336.2  1066.0  1097.3  273.4 | 6.2  75.0  14.0  49.6  25.9  23.6  33.0  90.0  7.3  54.0  44.2  93.0  89.4  12.13  90.0  47.0  19.2  43.0  10.0  45.9  23.1  26.0  28.0 | 0.743±0.098  0.913±0.033  0.891±0.025  1.494±0.121  1.951±0.064  3.440±0.206  3.755±0.284  3.603±0.261  3.125±0.291  5.016±0.275  5.201±0.248  6.086±0.255  5.418±0.266  5.380±0.168  6.483±0.397  3.211±0.157  3.298±0.196  0.076±0.011  0.052±0.011  .0326±.0054  0.038±0.006\*  .0120±.0022  .0117±.0027  .0185±.0033  .0304±.0038 | 0.743±0.098  0.913±0.033  0.891±0.025  1.494±0.121  1.951±0.065  3.440±0.206  3.755±0.284  3.608±0.262  3.125±0.291  5.016±0.275  5.201±0.248  6.097±0.256  5.418±0.266  5.380±0.168  6.483±0.397  3.217±0.158  3.298±0.196  0.076±0.011  0.052±0.011  .0326±0.0054  0.038±0.006\*  .0304±.0038 |

\*The yields of 115Cdtotal is based on the ratio of 115Cdg/115Cdm =6 from Ref. [64]

Table 1. –continued

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Nuclide | Half-life | γ-ray  Energy(keV) | γ-ray abundance (%) | *YR*(%) | *YA* (%) |
| 127Sb  128Sn  129Sb  131I  132Te  133I  134Te  135I  138Csg  139Ba  140Ba  141Ce  142La  143Ce  144Ce  147Nd  149Nd  151Pm  153Sm | 3.85 d  59.07 min  4.32 h  8.02 d  3.2 d  20.8 h  41.8 min  6.57 h  33.41 min  83.03 min  12.75 d  32.5 d  91.1 min  33.03 h  284.89 d  10.98 d  1.728 h  53.08 h  46.28 h | 687.0  482.3  812.4  364.5  228.1  529.9  566.0  767.2  1131.5  1260.4  1435.8  1009.8  462.8  165.8  537.3  145.4  641.3  293.3  133.5  531.0  211.3  270.2  340.8  103.2 | 37.0  59.0  43.0  81.7  88.0  87.0  18.0  29.5  22.7  28.9  76.3  29.8  30.7  23.7  24.4  48.0  47.0  42.8  11.09  13.1  25.9  10.6  23.0  30.0 | 0.288±0.049  0.417±0.089  0.791±0.048  3.673±0.284  4.749±0.202  6.977±0.287  7.885±0.239  8.004±0.267  5.547±0.259  5.434±0.054  7.015±0.304  6.102±0.242  6.646±0.233  6.537±0.209  5.684±0.291  5.304±0.266  4.233±0.196  4.592±0.297  4.847±0.255  3.211±0.191  1.975±0.157  1.902±0.212  0.999±0.049  0.434±0.082 | 0.288±0.049  0.460±0.098  0.794±0.048  3.673±0.284  4.776±0.203  6.977±0.287  8.515±0.258  8.644±0.288  5.586±0.261  5.472±0.054  7.015±0.304  6.102±0.242  6.646±0.233  6.537±0.209  5.684±0.291  5.304±0.266  4.260±0.197  4.592±0.297  4.847±0.255  3.211±0.191  1.983±0.158  1.911±0.213  0.999±0.049  0.434±0.082 |

*YR* – Cumulative yields, *YA* – Mass yields, 135I – Fission rate monitor.

Table 2. Nuclear spectroscopic data and yields of fission products in the 5.42 MeV neutron-induced fission of 238U

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Nuclide | Half-life | γ-ray  Energy(keV) | γ-ray  abundance (%) | *YR*(%) | *YA* (%) |
| 84Br  85Krm  87Kr  88Kr  91Sr  92Sr  93Y  95Zr  97Zr  99Mo  103Ru  105Ru  105Rh  112Ag  113Ag  115Cdg  115Cdtotal  117Cdm  117Cdg  117Cdtotal | 31.8 min  4.48 h  76.3 min  2.84 h  9.63 h  2.71 h  10.18 h  64.02 d  16.91 h  65.94 h  39.26 d  4.44 h  35.36 h  3.13 h  5.37 h  53.46 h  3.36 h  2.49 h | 1616.2  151.2  304.9  402.6  196.3  749.8  1024.3  1384.9  266.9  756.7  724.3  743.4  140.5  739.5  497.1  724.4  319.1  617.5  298.6  336.2  1066.0  1097.3  273.4 | 6.2  75.0  14.0  49.6  25.9  23.6  33.0  90.0  7.3  54.0  44.2  93.0  89.4  12.13  90.0  47.0  19.2  43.0  10.0  45.9  23.1  26.0  28.0 | 0.755±0.038  0.960±0.031  0.976±0.037  1.611±0.146  2.152±0.269  3.781±0.157  3.967±0.268  3.922±0.241  3.490±0.094  5.615±0.273  5.998±0.331  6.228±0.261  5.235±0.178  5.613±0.262  6.251±0.251  3.893±0.282  3.965±0.231  0.117±0.014  0.094±0.017  0.063±0.016  0.074±0.018\*  0.016±0.005  0.018±0.006  0.042±0.011  0.059±0.013 | 0.755±0.038  0.960±0.031  0.976±0.037  1.619±0.147  2.178±0.273  3.781±0.157  3.967±0.268  3.926±0.241  3.490±0.094  5.615±0.273  5.998±0.331  6.235±0.262  5.235±0.178  5.613±0.262  6.251±0.251  3.913±0.283  3.956±0.231  0.117±0.014  0.094±0.017  0.063±0.016  0.074±0.018\*  0.059±0.013 |

\*The yields of 115Cdtotal is based on the ratio of 115Cdg/115Cdm =6 from Ref. [64]

Table 2. –continued

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Nuclide | Half-life | γ-ray  Energy(keV) | γ-ray abundance (%) | *YR*(%) | *YA* (%) |
| 127Sb  128Sn  129Sb  131I  132Te  133I  134Te  135I  138Csg  139Ba  140Ba  141Ce  142La  143Ce  144Ce  147Nd  149Nd  151Pm  153Sm | 3.85 d  59.07 min  4.32 h  8.02 d  3.2 d  20.8 h  41.8 min  6.57 h  33.41 min  83.03 min  12.75 d  32.5 d  91.1 min  33.03 h  284.89 d  10.98 d  1.728 h  53.08 h  46.28 h | 687.0  482.3  812.4  364.5  228.1  529.9  566.0  767.2  1131.5  1260.4  1435.8  1009.8  462.8  165.8  537.3  145.4  641.3  293.3  133.5  531.0  211.3  270.2  340.8  103.2 | 37.0  59.0  43.0  81.7  88.0  87.0  18.0  29.5  22.7  20.3  76.3  29.8  30.7  23.7  35.4  20.5  47.0  42.8  11.09  13.1  25.9  10.6  23.0  30.0 | 0.362±0.073  0.451±0.067  0.940±0.042  3.141±0.136  4.778±0.115  6.841±0.211  7.135±0.277  7.311±0.171  5.051±0.224  5.248±0.052  6.804±0.226  6.617±0.204  6.436±0.246  6.604±0.273  5.930±0.214  5.355±0.226  4.288±0.089  4.912±0.121  5.211±0.178  3.401±0.199  2.104±0.210  2.159±0.139  0.855±0.042  0.451±0.037 | 0.362±0.073  0.497±0.073  0.942±0.042  3.154±0.136  4.802±0.115  6.841±0.211  7.697±0.299  7.887±0.184  5.085±0.226  5.285±0.052  6.804±0.226  6.617±0.204  6.436±0.246  6.604±0.273  5.930±0.214  5.355±0.226  4.288±0.089  4.912±0.121  5.211±0.178  3.401±0.199  2.112±0.211  2.167±0.140  0.855±0.042  0.451±0.037 |

*YR* – Cumulative yields, *YA* – Mass yields, 135I – Fission rate monitor.

Table 3. Nuclear spectroscopic data and yields of fission products in the 7.75 MeV neutron-induced fission of 238U

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Nuclide | Half-life | γ-ray  Energy(keV) | γ-ray  abundance (%) | *YR*(%) | *YA* (%) |
| 84Br  85Krm  87Kr  88Kr  91Sr  92Sr  93Y  95Zr  97Zr  99Mo  103Ru  105Ru  105Rh  112Ag  113Ag  115Cdg  115Cdtotal  117Cdm  117Cdg  117Cdtotal | 31.8 min  4.48 h  76.3 min  2.84 h  9.63 h  2.71 h  10.18 h  64.02 d  16.91 h  65.94 h  39.26 d  4.44 h  35.36 h  3.13 h  5.37 h  53.46 h  3.36 h  2.49 h | 1616.2  151.2  304.9  402.6  196.3  749.8  1024.3  1384.9  266.9  756.7  724.3  743.4  140.5  739.5  497.1  724.4  319.1  617.5  298.6  336.2  1066.0  1097.3  273.4 | 6.2  75.0  14.0  49.6  25.9  23.6  33.0  90.0  7.3  54.0  44.2  93.0  89.4  12.13  90.0  47.0  19.2  43.0  10.0  45.9  23.1  26.0  28.0 | 0.726±0.043  0.920±0.075  0.956±0.086  1.894±0.156  2.315±0.127  3.950±0.228  4.020±0.171  4.381±0.097  3.954±0.266  5.365±0.188  5.096±0.241  5.962±0.225  5.455±0.221  5.751±0.247  6.151±0.291  3.821±0.059  3.912±0.152  0.289±0.048  0.230±0.043  0.173±0.032  0.202±0.037\*  .0468±.0086  .0425±.0043  0.121±0.018  0.166±0.021 | 0.726±0.043  0.920±0.075  0.956±0.086  1.894±0.156  2.351±0.129  3.950±0.228  4.020±0.171  4.385±0.097  3.954±0.266  5.365±0.188  5.096±0.241  5.968±0.225  5.455±0.221  5.751±0.247  6.151±0.291  3.844±0.059  3.912±0.152  0.289±0.048  0.230±0.043  0.173±0.032  0.202±0.037\*  0.166±0.021 |

\*The yields of 115Cdtotal is based on the ratio of 115Cdg/115Cdm =6 from Ref. [64]

Table 3. –continued

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Nuclide | Half-life | γ-ray  Energy(keV) | γ-ray abundance (%) | *YR*(%) | *YA* (%) |
| 127Sb  128Sn  129Sb  131I  132Te  133I  134Te  135I  138Csg  139Ba  140Ba  141Ce  142La  143Ce  144Ce  147Nd  149Nd  151Pm  153Sm | 3.85 d  59.07 min  4.32 h  8.02 d  3.2 d  20.8 h  41.8 min  6.57 h  33.41 min  83.03 min  12.75 d  32.5 d  91.1 min  33.03 h  284.89 d  10.98 d  1.728 h  53.08 h  46.28 h | 687.0  482.3  812.4  364.5  228.1  529.9  566.0  767.2  1131.5  1260.4  1435.8  1009.8  462.8  165.8  537.3  145.4  641.3  293.3  133.5  531.0  211.3  270.2  340.8  103.2 | 37.0  59.0  43.0  81.7  88.0  87.0  18.0  29.5  22.7  28.9  76.3  29.8  30.7  23.7  24.4  48.0  47.0  42.8  11.09  13.1  25.9  10.6  23.0  30.0 | 0.543±0.027  0.769±0.041  1.238±0.134  3.514±0.102  5.558±0.234  6.818±0.243  7.338±0.255  7.133±0.178  5.012±0.134  5.381±0.053  6.608±0.217  6.724±0.263  6.651±0.209  6.480±0.124  6.011±0.258  5.268±0.214  4.489±0.182  4.660±0.194  4.827±0.204  3.620±0.118  2.133±0.167  2.004±0.150  0.829±0.022  0.473±0.027 | 0.543±0.027  0.807±0.043  1.243±0.135  3.514±0.102  5.585±0.236  6.818±0.243  7.890±0.275  7.670±0.179  5.047±0.135  5.419±0.054  6.608±0.217  6.724±0.263  6.651±0.209  6.480±0.124  6.011±0.258  5.268±0.214  4.525±0.183  4.698±0.195  4.827±0.204  3.620±0.118  2.142±0.168  2.088±0.151  0.829±0.022  0.473±0.027 |

*YR* – Cumulative yields, *YA* – Mass yields, 135I – Fission rate monitor.

Table 4. Nuclear spectroscopic data and yields of fission products in the 10.09 MeV neutron-induced fission of 238U

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Nuclide | Half-life | γ-ray Energy  (keV) | γ-ray abundance (%) | *YR*(%) | *YA* (%) |
| 84Br  85Krm  87Kr  88Kr  91Sr  92Sr  93Y  95Zr  97Zr  99Mo  103Ru  105Ru  105Rh  112Ag  113Ag  115Cdg  115Cdtotal  117Cdm  117Cdg  117Cdtotal | 31.8 min  4.48 h  76.3 min  2.84 h  9.63 h  2.71 h  10.18 h  64.02 d  16.91 h  65.94 h  39.26 d  4.44 h  35.36 h  3.13 h  5.37 h  53.46 h  3.36 h  2.49 h | 1616.2  151.2  304.9  402.6  196.3  749.8  1024.3  1384.9  266.9  756.7  724.3  743.4  140.5  739.5  497.1  724.4  319.1  617.5  298.6  336.2  1066.0  1097.3  273.4 | 6.2  75.0  14.0  49.6  25.9  23.6  33.0  90.0  7.3  54.0  44.2  93.0  89.4  12.13  90.0  47.0  19.2  43.0  10.0  45.9  23.1  26.0  28.0 | 0.825±0.041  1.106±0.079  1.115±0.051  1.932±0.096  2.445±0.196  4.084±0.215  3.908±0.206  4.255±0.188  3.947±0.165  5.637±0.154  5.528±0.182  6.036±0.295  5.205±0.097  5.404±0.102  6.125±0.211  3.532±0.181  3.589±0.148  0.512±0.038  0.403±0.017  0.290±0.034  0.338±0.039\*  0.062±0.010  0.057±0.011  0.220±0.026  0.279±0.028 | 0.825±0.041  1.103±0.079  1.115±0.051  1.934±0.097  2.480±0.199  4.084±0.215  3.908±0.206  4.260±0.188  3.947±0.165  5.637±0.154  5.528±0.182  5.557±0.295  5.205±0.097  5.404±0.102  6.125±0.211  3.539±0.181  3.589±0.148  0.512±0.038  0.404±0.017  0.290±0.034  0.338±0.039\*  0.279±0.063 |

\*The yields of 115Cdtotal is based on the ratio of 115Cdg/115Cdm =6 from Ref. [64]

Table 4. –continued

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Nuclide | Half-life | γ-ray  Energy(keV) | γ-ray abundance (%) | *YR*(%) | *YA* (%) |
| 127Sb  128Sn  129Sb  131I  132Te  133I  134Te  135I  138Csg  139Ba  140Ba  141Ce  142La  143Ce  144Ce  147Nd  149Nd  151Pm  153Sm | 3.85 d  59.07 min  4.32 h  8.02 d  3.2 d  20.8 h  41.8 min  6.57 h  33.41 min  83.03 min  12.75 d  32.5 d  91.1 min  33.03 h  284.89 d  10.98 d  1.728 h  53.08 h  46.28 h | 687.0  482.3  812.4  364.5  228.1  529.9  566.0  767.2  1131.5  1260.4  1435.8  1009.8  462.8  165.8  537.3  145.4  641.3  293.3  133.5  531.0  211.3  270.2  340.8  103.2 | 37.0  59.0  43.0  81.7  88.0  87.0  18.0  29.5  22.7  28.9  76.3  29.8  30.7  23.7  24.4  48.0  47.0  42.8  11.09  13.1  25.9  10.6  23.0  30.0 | 0.774±0.063  0.992±0.119  1.331±0.074  3.418±0.211  5.541±0.232  6.501±0.176  6.838±0.211  6.732±0.296  5.134±0.192  5.688±0.056  6.371±0.148  6.190±0.204  6.161±0.244  5.889±0.344  5.449±0.232  4.863±0.215  4.486±0.085  4.471±0.199  4.641±0.206  3.811±0.279  2.798±0.334  2.821±0.273  0.995±0.037  0.478±0.034 | 0.774±0.063  1.044±0.125  1.335±0.074  3.418±0.211  5.569±0.233  6.501±0.176  7.369±0.226  7.254±0.307  5.170±0.193  5.728±0.057  6.371±0.148  6.190±0.204  6.161±0.244  5.889±0.344  5.449±0.232  4.863±0.215  4.486±0.085  4.471±0.199  4.641±0.206  3.811±0.279  2.809±0.336  2.832±0.274  0.995±0.037  0.478±0.034 |

*YR* – Cumulative yields, *YA* – Mass yields, 135I – Fission rate monitor.

Table.5. Yields of asymmetric (*Ya*) and symmetric (*Ys*) products and *P/V* ratio in neutron-induced fission of 238U.

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*En*(MeV) *E*∗(MeV) *Ya*(%) *Ys*(%) *P/V* ratio Ref.

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1*.*5 5*.*85 8.120 ± 0.400 0.0102 ± 0.0014 796.1 ±116.1 [64]

1*.*5 5*.*85 – 0.0075 ± 0.0008 825.0 [50]

1*.*72 6*.*07 7.830 ± 0.930 – – [68]

2*.*0 6*.*35 7.780 ± 0.370 0.0121 ± 0.0017 643.0 ±95.4 [64]

2*.*0 6*.*35 – 0.0135 ± 0.0014 452.0 [50]

2*.*16 6*.*55 7.510 ± 0.830 – – [68]

3*.*0 7*.*35 – 0.029 ±0.003 238.0 [50]

3*.*0 7*.*35 8.190 ± 0.840 0.034 ±0.006 240.9 ±49.2 [59]

3.72 8.07 7.945 ± 0.267 0.038 ±0.006 209.1±33.7 [A]

3*.*72 8*.*07 7.490 ± 0.790 – – [68]

3*.*9 8*.*25 7.760 ± 0.420 0.034 ±0.005 228.2 ±35.8 [64]

3*.*9 8*.*25 – 0.047 ±0.005 129.0 [50]

4*.*78 9*.*13 6.770 ± 0.700 – – [68]

4*.*8 9*.*15 – 0.068 ±0.007 89.0 [50]

5.42 9.77 7.223 ± 0.277 0.074 ±0.018 97.6 ±24.1 [A]

5*.*5 9*.*85 7.000 ± 0.500 0.077 ±0.011 90.9 ±14.5 [64]

5*.*98 10*.*33 6.290 ± 0.800 – – [68]

6*.*0 10*.*35 6.132 ± 0.699 0.124 ±0.010 49.5 ±6.9 [67]

6*.*9 11*.*25 7.240 ± 0.860 0.134 ±0.018 54.0 ±9.7 [64]

7*.*1 11*.*45 6.839 ± 0.595 0.121 ±0.009 56.5 ±6.5 [67]

7*.*7 12*.*05 7.020 ± 0.430 0.191 ±0.032 36.8 ±6.6 [64]

7*.*75 12*.*1 7.257 ± 0.215 0.202 ±0.037 35.9 ±6.7 [A]

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Table.5. -continued

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8*.*1 12*.*45 6.713 ± 0.665 0.135 ±0.011 49.7 ±6.4 [67]

8.27 12*.*72 7.210 ± 0.430 0.227 ±0.009 31.2 ±1.6 [66]

9*.*1 13*.*45 6.308 ± 0.688 0.191 ±0.016 33.0 ±4.5 [67]

10*.*09 14*.*55 6.785 ± 0.286 0.338 ±0.039 20.1 ±2.5 [A]

11*.*3 15*.*65 6.660 ± 0.260 0.430 ±0.050 15.5 ±1.9 [69]

13*.*0 17*.*35 – 0.570 ±0.070 8.8 [50]

14*.*0 18*.*35 6.500 ± 0.150 0.860±0.090 7.6± 0.8 [52]

14*.*0 18*.*35 -- 0.970±0.150 -- [61]

14*.*1 18*.*45 6.000 ± 0.210 0.950±0.090 6.6± 0.6 [58]

14*.*4 18*.*75 6.340 ± 0.340 0.843 ±0.048 7.5 ±0.6 [62]

14*.*4 18*.*75 -- 0.975 ±0.055 -- [62]

14.7 19.05 6.360 ± 0.450 0.860 ±0.090 7.4 ±0.9 [34]

14*.*7 19*.*05 -- 0.930 ±0.120 -- [34]

14*.*8 19*.*15 6.350 ± 0.300 0.870 ±0.150 7.3± 1.3 [60]

14*.*8 19*.*15 -- 0.950 ±0.070 -- [60]

14*.*9 19*.*25 6.50 ± 0.300 0.985 ±0.039 6.6± 0.4 [67]

14*.*9 19*.*05 -- 0.834 ±0.039 -- [67]

15*.*0 19*.*35 – 0.780 ±0.090 6.5 [50]

16*.*4 20*.*75 – 0.870 ±0.100 5.8 [50]

17*.*7 22*.*05 – 0.740 ±0.090 6.8 [50]

A-Present work

Table 6. Average light mass (<*A*L>), heavy mass (<*A*H>), and average neutron numbers (<*v*>expt

and <*v*>calc) in the neutron -induced fission of 238U.

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En (MeV) E\* (MeV) <AL><AH><ν>expt Ref

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238U(n,f)

1.5 5.85 97.5 139 2.5 [64]

2.0 6.35 97.5 139 2.5 [64]

3.0 7.35 97.46 139 2.54 [59]

3.72 8.07 97.44 138.89 2.67 [A]

3.9 8.25 97.4 138.9 2.7 [64]

5.42 9.77 97.27 138.82 2.91 [A]

5.5 9.85 97.4 138.6 3.0 [64]

6.0 10.35 97.44 138.47 3.09 [63]

6.9 11.51 97.5 138.4 3.1 [64]

7.1 11.45 97.4 138.35 3.25 [63]

7.7 11.05 97.4 138.3 3.3 [64]

7.75 12.1 97.37 138.33 3.31 [A]

8.1 12.45 97.48 138.13 3.39 [63]

8.27 12.72 97.4 138.2 3.4 [66]

9.1 13.45 97.4 138.06 3.6 [63]

10.09 14.55 97.37 138.03 3.6 [A]

11.3 15.65 97.51 137.75 3.74 [69]

14.1 18.45 98.09 136.79 4.12 [61]

14.8 19.15 98.0 136.8 4.2 [60]

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A-Present work