

$$\text{Mean} \Rightarrow \bar{x} = \frac{\sum x_i}{n}$$

standard deviation  $\Rightarrow$

$$s = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}}$$

Confidence interval:  $\mu = \bar{x} \pm \frac{ts}{\sqrt{n}}$

$$\% e = \frac{e}{\bar{x}} \cdot 100$$

$$\pm t = (\bar{x} - \mu) \left( \frac{\sqrt{n}}{s} \right) \quad \text{CASE 1}$$

$$t = \frac{|\bar{x}_1 - \bar{x}_2|}{s_{\text{pooled}}} \sqrt{\frac{n_1 n_2}{n_1 + n_2}}$$

$$s_{\text{pooled}} = \sqrt{\frac{s_1^2(n_1-1) + s_2^2(n_2-1)}{n_1 + n_2 - 2}}$$

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$$t = \frac{\bar{d}}{s_d} \sqrt{n}$$

$$s_d = \sqrt{\frac{\sum (d_i - \bar{d})^2}{n-1}}$$

$$Q = \frac{\text{gap}}{\text{range}}$$

$$F = \frac{s_1^2}{s_2^2}$$

$$e_f = \sqrt{\sum_{i=1}^n e_i^2}$$

$$\% e_f = \sqrt{\sum_{i=1}^n \% e_i^2}$$

$$\frac{\text{concentration ratio (x/s) in unknown}}{\text{concentration ratio in standard mixture}} = \frac{\text{signal ratio (x/s) in unknown}}{\text{signal ratio in standard mixture}}$$

$$\frac{[X]_i}{[X]_f + [S]_f} = \frac{[I]_x}{[I]_{x+s}}$$

INTERNAL STANDARD

$$\frac{[x]}{[is]} \cdot F = \frac{I_x}{I_{is}}$$

$$A = \log_{10}(P_0/P) = -\log_{10} T$$

Grating Equation:  $n\lambda = d(\sin\theta - \sin\phi)$

$$A = \varepsilon b C \quad C = \lambda v,$$

$$E = h\nu$$

$$E = (-2.178 \times 10^{-18} \text{ J}) \cdot (z^2/n^2)$$

$$N = \frac{16 t_r^2}{w^2} \text{ or } \frac{5.55 t_r^2}{w_{1/2}^2}$$

$$R = \frac{\Delta t_r}{w_{av}}$$

**TABLE 3-1** Summary of rules for propagation of uncertainty

| Function              | Uncertainty                                | Function <sup>a</sup> | Uncertainty <sup>b</sup>                                               |
|-----------------------|--------------------------------------------|-----------------------|------------------------------------------------------------------------|
| $y = x_1 + x_2$       | $e_y = \sqrt{e_{x_1}^2 + e_{x_2}^2}$       | $y = x^a$             | $\%e_y = a\%e_x$                                                       |
| $y = x_1 - x_2$       | $e_y = \sqrt{e_{x_1}^2 + e_{x_2}^2}$       | $y = \log x$          | $e_y = \frac{1}{\ln 10} \frac{e_x}{x} \approx 0.434\,29 \frac{e_x}{x}$ |
| $y = x_1 \cdot x_2$   | $\%e_y = \sqrt{\%e_{x_1}^2 + \%e_{x_2}^2}$ | $y = \ln x$           | $e_y = \frac{e_x}{x}$                                                  |
| $y = \frac{x_1}{x_2}$ | $\%e_y = \sqrt{\%e_{x_1}^2 + \%e_{x_2}^2}$ | $y = 10^x$            | $\frac{e_y}{y} = (\ln 10)e_x \approx 2.302\,6 e_x$                     |
|                       |                                            | $y = e^x$             | $\frac{e_y}{y} = e_x$                                                  |

a.  $x$  represents a variable and  $a$  represents a constant that has no uncertainty.

b.  $e_x/x$  is the relative error in  $x$  and  $\%e_x$  is  $100 \times e_x/x$ .

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general: 
$$e_f = \sqrt{\sum_i \left(\frac{\partial f}{\partial x_i}\right)^2 \cdot e_i^2}$$

**TABLE 4-2** Values of Student's  $t$

| Degrees of freedom | Confidence level (%) |       |        |        |        |         |         |
|--------------------|----------------------|-------|--------|--------|--------|---------|---------|
|                    | 50                   | 90    | 95     | 98     | 99     | 99.5    | 99.9    |
| 1                  | 1.000                | 6.314 | 12.706 | 31.821 | 63.656 | 127.321 | 636.578 |
| 2                  | 0.816                | 2.920 | 4.303  | 6.965  | 9.925  | 14.089  | 31.598  |
| 3                  | 0.765                | 2.353 | 3.182  | 4.541  | 5.841  | 7.453   | 12.924  |
| 4                  | 0.741                | 2.132 | 2.776  | 3.747  | 4.604  | 5.598   | 8.610   |
| 5                  | 0.727                | 2.015 | 2.571  | 3.365  | 4.032  | 4.773   | 6.869   |
| 6                  | 0.718                | 1.943 | 2.447  | 3.143  | 3.707  | 4.317   | 5.959   |
| 7                  | 0.711                | 1.895 | 2.365  | 2.998  | 3.500  | 4.029   | 5.408   |
| 8                  | 0.706                | 1.860 | 2.306  | 2.896  | 3.355  | 3.832   | 5.041   |
| 9                  | 0.703                | 1.833 | 2.262  | 2.821  | 3.250  | 3.690   | 4.781   |
| 10                 | 0.700                | 1.812 | 2.228  | 2.764  | 3.169  | 3.581   | 4.587   |
| 15                 | 0.691                | 1.753 | 2.131  | 2.602  | 2.947  | 3.252   | 4.073   |
| 20                 | 0.687                | 1.725 | 2.086  | 2.528  | 2.845  | 3.153   | 3.850   |
| 25                 | 0.684                | 1.708 | 2.060  | 2.485  | 2.787  | 3.078   | 3.725   |
| 30                 | 0.683                | 1.697 | 2.042  | 2.457  | 2.750  | 3.030   | 3.646   |
| 40                 | 0.681                | 1.684 | 2.021  | 2.423  | 2.704  | 2.971   | 3.551   |
| 60                 | 0.679                | 1.671 | 2.000  | 2.390  | 2.660  | 2.915   | 3.460   |
| 120                | 0.677                | 1.658 | 1.980  | 2.358  | 2.617  | 2.860   | 3.373   |
| $\infty$           | 0.674                | 1.645 | 1.960  | 2.326  | 2.576  | 2.807   | 3.291   |

In calculating confidence intervals,  $\sigma$  may be substituted for  $s$  in Equation 4-6 if you have a great deal of experience with a particular method and have therefore determined its "true" population standard deviation. If  $\sigma$  is used instead of  $s$ , the value of  $t$  to use in Equation 4-6 comes from the bottom row of Table 4-2.

Values of  $t$  in this table apply to two-tailed tests illustrated in Figure 4-9a. The 95% confidence level specifies the regions containing 2.5% of the area in each wing of the curve. For a one-tailed test, we use values of  $t$  listed for 90% confidence. Each wing outside of  $t$  for 90% confidence contains 5% of the area of the curve.

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**TABLE 4-5 Critical values of  $G$  for rejection of outlier**

| Number of observations | $G$<br>(95% confidence) |
|------------------------|-------------------------|
| 4                      | 1.463                   |
| 5                      | 1.672                   |
| 6                      | 1.822                   |
| 7                      | 1.938                   |
| 8                      | 2.032                   |
| 9                      | 2.110                   |
| 10                     | 2.176                   |
| 11                     | 2.234                   |
| 12                     | 2.285                   |
| 15                     | 2.409                   |
| 20                     | 2.557                   |

$$G_{CAL} = \frac{|out - \bar{x}|}{s}$$

$G_{calculated} = |questionable\ value - mean|/s$ . If  $G_{calculated} > G_{table}$ , the value in question can be rejected with 95% confidence. Values in this table are for a one-tailed test, as recommended by ASTM.

SOURCE: ASTM E 178-02 Standard Practice for Dealing with Outlying Observations, <http://webstore.ansi.org>; F. E. Grubbs and G. Beck, *Technometrics* **1972**, 14, 847.

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# Periodic Table

|                                         |                                            |                                           |                                            |                                             |                                       |                                             |                                               |                                                      |                                        |                                              |                                                |                                              |                                          |                                            |                                              |                                                    |                                                   |                                          |                                               |                                            |                                      |                                            |                                           |                                            |                                               |                                               |                                                   |                                             |                                            |                                           |                                          |                                         |                                        |                                                 |                                                  |                                        |                                           |                                         |                                              |                                          |                                                    |                                           |                                            |                                            |                                           |                                             |                                         |                                                |                                         |                                            |                                          |                                               |                                           |                                          |                                          |                                             |                                         |                                         |                                         |                                          |                                      |                                         |                                          |                                        |                                        |                                  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| 1<br>1<br>1.00794 ± 7<br>Hydrogen<br>+1 | 2<br>4<br>9.012 182 ± 3<br>Beryllium<br>+2 | 3<br>11<br>22.989 770 ± 2<br>Sodium<br>+1 | 4<br>12<br>24.305 0 ± 6<br>Magnesium<br>+2 | 5<br>21<br>44.955 910 ± 8<br>Scandium<br>+3 | 6<br>22<br>47.867<br>Titanium<br>+4,3 | 7<br>23<br>50.941 5<br>Vanadium<br>+5,4,3,2 | 8<br>24<br>51.996 1 ± 6<br>Chromium<br>+6,3,2 | 9<br>25<br>54.938 049 ± 9<br>Manganese<br>+7,6,4,2,3 | 10<br>26<br>55.845 ± 2<br>Iron<br>+2,3 | 11<br>27<br>58.933 200 ± 9<br>Cobalt<br>+2,3 | 12<br>28<br>58.933 200 ± 9<br>Nickel<br>+2,3,4 | 13<br>29<br>58.933 200 ± 9<br>Copper<br>+2,3 | 14<br>30<br>58.933 200 ± 9<br>Zinc<br>+2 | 15<br>31<br>68.932 74 ± 2<br>Gallium<br>+3 | 16<br>32<br>72.64 ± 1<br>Germanium<br>+4,3,2 | 17<br>33<br>74.921 60 ± 2<br>Arsenic<br>+3,5,4,3,2 | 18<br>34<br>75.939 38 ± 2<br>Selenium<br>+6,4,3,2 | 19<br>35<br>78.96<br>Bromine<br>+5,4,3,2 | 20<br>36<br>79.904 ± 1<br>Krypton<br>+6,4,2,1 | 21<br>37<br>85.467 8 ± 3<br>Rubidium<br>+1 | 22<br>38<br>87.62<br>Strontium<br>+2 | 23<br>39<br>88.905 85 ± 2<br>Yttrium<br>+3 | 24<br>40<br>91.224 ± 2<br>Zirconium<br>+4 | 25<br>41<br>92.906 38 ± 2<br>Niobium<br>+5 | 26<br>42<br>95.94<br>Molybdenum<br>+6,5,4,3,2 | 27<br>43<br>98.906 25 ± 2<br>Technetium<br>+7 | 28<br>44<br>101.07 ± 2<br>Ruthenium<br>+8,6,4,2,1 | 29<br>45<br>102.905 50 ± 2<br>Rhodium<br>+9 | 30<br>46<br>106.42 ± 1<br>Palladium<br>+10 | 31<br>47<br>107.868 2 ± 2<br>Silver<br>+1 | 32<br>48<br>112.411 ± 2<br>Cadmium<br>+2 | 33<br>49<br>114.904 ± 1<br>Indium<br>+3 | 34<br>50<br>118.710 ± 2<br>Tin<br>+4,2 | 35<br>51<br>121.757 ± 2<br>Antimony<br>+5,3,3,2 | 36<br>52<br>127.759 ± 2<br>Tellurium<br>+6,4,3,2 | 37<br>53<br>127.60 ± 1<br>Iodine<br>+7 | 38<br>54<br>132.905 45 ± 2<br>Xenon<br>+8 | 39<br>55<br>137.327 ± 7<br>Barium<br>+2 | 40<br>56<br>138.905 5 ± 2<br>Lanthanum<br>+3 | 41<br>57<br>140.12 ± 1<br>Cerium<br>+3,4 | 42<br>58<br>140.907 65 ± 2<br>Praseodymium<br>+3,4 | 43<br>59<br>144.24 ± 3<br>Neodymium<br>+3 | 44<br>60<br>147.07 ± 2<br>Promethium<br>+3 | 45<br>61<br>150.36 ± 3<br>Samarium<br>+3,2 | 46<br>62<br>150.919 ± 2<br>Europium<br>+3 | 47<br>63<br>151.964 ± 2<br>Gadolinium<br>+3 | 48<br>64<br>157.25 ± 1<br>Terbium<br>+3 | 49<br>65<br>158.925 32 ± 2<br>Dysprosium<br>+3 | 50<br>66<br>162.50 ± 1<br>Holmium<br>+3 | 51<br>67<br>164.930 32 ± 2<br>Erbium<br>+3 | 52<br>68<br>167.259 ± 1<br>Thulium<br>+3 | 53<br>69<br>168.930 32 ± 2<br>Ytterbium<br>+3 | 54<br>70<br>173.054 ± 1<br>Lutetium<br>+3 | 55<br>71<br>175.047 ± 1<br>Hafnium<br>+4 | 56<br>72<br>178.49 ± 2<br>Tantalum<br>+5 | 57<br>73<br>180.947 9 ± 2<br>Tungsten<br>+6 | 58<br>74<br>183.84 ± 1<br>Rhenium<br>+7 | 59<br>75<br>186.207 ± 1<br>Osmium<br>+8 | 60<br>76<br>190.23 ± 3<br>Iridium<br>+9 | 61<br>77<br>192.22 ± 1<br>Platinum<br>+6 | 62<br>78<br>195.08 ± 1<br>Gold<br>+3 | 63<br>79<br>197.03 ± 1<br>Mercury<br>+2 | 64<br>80<br>200.59 ± 1<br>Thallium<br>+3 | 65<br>81<br>204.38 ± 1<br>Lead<br>+4,2 | 66<br>82<br>207.2 ± 1<br>Bismuth<br>+3 | 67<br>83<br>208.980 4 ± 1<br>Polonium<br>+4,2 | 68<br>84<br>209<br>Astatine<br>+5,3,3,2 | 69<br>85<br>210<br>Radon<br>+6 | 70<br>86<br>222<br>Radium<br>+2 | 71<br>87<br>223<br>Actinium<br>+3 | 72<br>88<br>226<br>Rutherfordium<br>+4 | 73<br>89<br>227<br>Dubnium<br>+5 | 74<br>90<br>228<br>Seaborgium<br>+6 | 75<br>91<br>229<br>Bohrium<br>+7 | 76<br>92<br>230<br>Hassium<br>+8 | 77<br>93<br>231<br>Meitnerium<br>+9 | 78<br>94<br>232<br>Darmstadtium<br>+10 | 79<br>95<br>233<br>Roentgenium<br>+11 | 80<br>96<br>234<br>Copernicium<br>+12 | 81<br>97<br>235<br>Darmstadtium<br>+13 | 82<br>98<br>236<br>Tennessine<br>+14 | 83<br>99<br>237<br>Oganesson<br>+15 | 84<br>100<br>238<br>Ununennium<br>+16 | 85<br>101<br>239<br>Unbinilium<br>+17 | 86<br>102<br>240<br>Untrium<br>+18 | 87<br>103<br>241<br>Unquadium<br>+19 | 88<br>104<br>242<br>Unpentium<br>+20 | 89<br>105<br>243<br>Unsextium<br>+21 | 90<br>106<br>244<br>Unseptium<br>+22 | 91<br>107<br>245<br>Unoctium<br>+23 | 92<br>108<br>246<br>Unnennium<br>+24 | 93<br>109<br>247<br>Unnilium<br>+25 | 94<br>110<br>248<br>Ununium<br>+26 | 95<br>111<br>249<br>Unbium<br>+27 | 96<br>112<br>250<br>Untrium<br>+28 | 97<br>113<br>251<br>Unquadium<br>+29 | 98<br>114<br>252<br>Unpentium<br>+30 | 99<br>115<br>253<br>Unsextium<br>+31 | 100<br>116<br>254<br>Unseptium<br>+32 | 101<br>117<br>255<br>Unoctium<br>+33 | 102<br>118<br>256<br>Unnennium<br>+34 | 103<br>119<br>257<br>Unnilium<br>+35 | 104<br>120<br>258<br>Ununium<br>+36 | 105<br>121<br>259<br>Unbium<br>+37 | 106<br>122<br>260<br>Untrium<br>+38 | 107<br>123<br>261<br>Unquadium<br>+39 | 108<br>124<br>262<br>Unpentium<br>+40 | 109<br>125<br>263<br>Unsextium<br>+41 | 110<br>126<br>264<br>Unseptium<br>+42 | 111<br>127<br>265<br>Unoctium<br>+43 | 112<br>128<br>266<br>Unnennium<br>+44 | 113<br>129<br>267<br>Unnilium<br>+45 | 114<br>130<br>268<br>Ununium<br>+46 | 115<br>131<br>269<br>Unbium<br>+47 | 116<br>132<br>270<br>Untrium<br>+48 | 117<br>133<br>271<br>Unquadium<br>+49 | 118<br>134<br>272<br>Unpentium<br>+50 | 119<br>135<br>273<br>Unsextium<br>+51 | 120<br>136<br>274<br>Unseptium<br>+52 | 121<br>137<br>275<br>Unoctium<br>+53 | 122<br>138<br>276<br>Unnennium<br>+54 | 123<br>139<br>277<br>Unnilium<br>+55 | 124<br>140<br>278<br>Ununium<br>+56 | 125<br>141<br>279<br>Unbium<br>+57 | 126<br>142<br>280<br>Untrium<br>+58 | 127<br>143<br>281<br>Unquadium<br>+59 | 128<br>144<br>282<br>Unpentium<br>+60 | 129<br>145<br>283<br>Unsextium<br>+61 | 130<br>146<br>284<br>Unseptium<br>+62 | 131<br>147<br>285<br>Unoctium<br>+63 | 132<br>148<br>286<br>Unnennium<br>+64 | 133<br>149<br>287<br>Unnilium<br>+65 | 134<br>150<br>288<br>Ununium<br>+66 | 135<br>151<br>289<br>Unbium<br>+67 | 136<br>152<br>290<br>Untrium<br>+68 | 137<br>153<br>291<br>Unquadium<br>+69 | 138<br>154<br>292<br>Unpentium<br>+70 | 139<br>155<br>293<br>Unsextium<br>+71 | 140<br>156<br>294<br>Unseptium<br>+72 | 141<br>157<br>295<br>Unoctium<br>+73 | 142<br>158<br>296<br>Unnennium<br>+74 | 143<br>159<br>297<br>Unnilium<br>+75 | 144<br>160<br>298<br>Ununium<br>+76 | 145<br>161<br>299<br>Unbium<br>+77 | 146<br>162<br>300<br>Untrium<br>+78 | 147<br>163<br>301<br>Unquadium<br>+79 | 148<br>164<br>302<br>Unpentium<br>+80 | 149<br>165<br>303<br>Unsextium<br>+81 | 150<br>166<br>304<br>Unseptium<br>+82 | 151<br>167<br>305<br>Unoctium<br>+83 | 152<br>168<br>306<br>Unnennium<br>+84 | 153<br>169<br>307<br>Unnilium<br>+85 | 154<br>170<br>308<br>Ununium<br>+86 | 155<br>171<br>309<br>Unbium<br>+87 | 156<br>172<br>310<br>Untrium<br>+88 | 157<br>173<br>311<br>Unquadium<br>+89 | 158<br>174<br>312<br>Unpentium<br>+90 | 159<br>175<br>313<br>Unsextium<br>+91 | 160<br>176<br>314<br>Unseptium<br>+92 | 161<br>177<br>315<br>Unoctium<br>+93 | 162<br>178<br>316<br>Unnennium<br>+94 | 163<br>179<br>317<br>Unnilium<br>+95 | 164<br>180<br>318<br>Ununium<br>+96 | 165<br>181<br>319<br>Unbium<br>+97 | 166<br>182<br>320<br>Untrium<br>+98 | 167<br>183<br>321<br>Unquadium<br>+99 | 168<br>184<br>322<br>Unpentium<br>+100 | 169<br>185<br>323<br>Unsextium<br>+101 | 170<br>186<br>324<br>Unseptium<br>+102 | 171<br>187<br>325<br>Unoctium<br>+103 | 172<br>188<br>326<br>Unnennium<br>+104 | 173<br>189<br>327<br>Unnilium<br>+105 | 174<br>190<br>328<br>Ununium<br>+106 | 175<br>191<br>329<br>Unbium<br>+107 | 176<br>192<br>330<br>Untrium<br>+108 | 177<br>193<br>331<br>Unquadium<br>+109 | 178<br>194<br>332<br>Unpentium<br>+110 | 179<br>195<br>333<br>Unsextium<br>+111 | 180<br>196<br>334<br>Unseptium<br>+112 | 181<br>197<br>335<br>Unoctium<br>+113 | 182<br>198<br>336<br>Unnennium<br>+114 | 183<br>199<br>337<br>Unnilium<br>+115 | 184<br>200<br>338<br>Ununium<br>+116 | 185<br>201<br>339<br>Unbium<br>+117 | 186<br>202<br>340<br>Untrium<br>+118 | 187<br>203<br>341<br>Unquadium<br>+119 | 188<br>204<br>342<br>Unpentium<br>+120 | 189<br>205<br>343<br>Unsextium<br>+121 | 190<br>206<br>344<br>Unseptium<br>+122 | 191<br>207<br>345<br>Unoctium<br>+123 | 192<br>208<br>346<br>Unnennium<br>+124 | 193<br>209<br>347<br>Unnilium<br>+125 | 194<br>210<br>348<br>Ununium<br>+126 | 195<br>211<br>349<br>Unbium<br>+127 | 196<br>212<br>350<br>Untrium<br>+128 | 197<br>213<br>351<br>Unquadium<br>+129 | 198<br>214<br>352<br>Unpentium<br>+130 | 199<br>215<br>353<br>Unsextium<br>+131 | 200<br>216<br>354<br>Unseptium<br>+132 | 201<br>217<br>355<br>Unoctium<br>+133 | 202<br>218<br>356<br>Unnennium<br>+134 | 203<br>219<br>357<br>Unnilium<br>+135 | 204<br>220<br>358<br>Ununium<br>+136 | 205<br>221<br>359<br>Unbium<br>+137 | 206<br>222<br>360<br>Untrium<br>+138 | 207<br>223<br>361<br>Unquadium<br>+139 | 208<br>224<br>362<br>Unpentium<br>+140 | 209<br>225<br>363<br>Unsextium<br>+141 | 210<br>226<br>364<br>Unseptium<br>+142 | 211<br>227<br>365<br>Unoctium<br>+143 | 212<br>228<br>366<br>Unnennium<br>+144 | 213<br>229<br>367<br>Unnilium<br>+145 | 214<br>230<br>368<br>Ununium<br>+146 | 215<br>231<br>369<br>Unbium<br>+147 | 216<br>232<br>370<br>Untrium<br>+148 | 217<br>233<br>371<br>Unquadium<br>+149 | 218<br>234<br>372<br>Unpentium<br>+150 | 219<br>235<br>373<br>Unsextium<br>+151 | 220<br>236<br>374<br>Unseptium<br>+152 | 221<br>237<br>375<br>Unoctium<br>+153 | 222<br>238<br>376<br>Unnennium<br>+154 | 223<br>239<br>377<br>Unnilium<br>+155 | 224<br>240<br>378<br>Ununium<br>+156 | 225<br>241<br>379<br>Unbium<br>+157 | 226<br>242<br>380<br>Untrium<br>+158 | 227<br>243<br>381<br>Unquadium<br>+159 | 228<br>244<br>382<br>Unpentium<br>+160 | 229<br>245<br>383<br>Unsextium<br>+161 | 230<br>246<br>384<br>Unseptium<br>+162 | 231<br>247<br>385<br>Unoctium<br>+163 | 232<br>248<br>386<br>Unnennium<br>+164 | 233<br>249<br>387<br>Unnilium<br>+165 | 234<br>250<br>388<br>Ununium<br>+166 | 235<br>251<br>389<br>Unbium<br>+167 | 236<br>252<br>390<br>Untrium<br>+168 | 237<br>253<br>391<br>Unquadium<br>+169 | 238<br>254<br>392<br>Unpentium<br>+170 | 239<br>255<br>393<br>Unsextium<br>+171 | 240<br>256<br>394<br>Unseptium<br>+172 | 241<br>257<br>395<br>Unoctium<br>+173 | 242<br>258<br>396<br>Unnennium<br>+174 | 243<br>259<br>397<br>Unnilium<br>+175 | 244<br>260<br>398<br>Ununium<br>+176 | 245<br>261<br>399<br>Unbium<br>+177 | 246<br>262<br>400<br>Untrium<br>+178 | 247<br>263<br>401<br>Unquadium<br>+179 | 248<br>264<br>402<br>Unpentium<br>+180 | 249<br>265<br>403<br>Unsextium<br>+181 | 250<br>266<br>404<br>Unseptium<br>+182 | 251<br>267<br>405<br>Unoctium<br>+183 | 252<br>268<br>406<br>Unnennium<br>+184 | 253<br>269<br>407<br>Unnilium<br>+185 | 254<br>270<br>408<br>Ununium<br>+186 | 255<br>271<br>409<br>Unbium<br>+187 | 256<br>272<br>410<br>Untrium<br>+188 | 257<br>273<br>411<br>Unquadium<br>+189 | 258<br>274<br>412<br>Unpentium<br>+190 | 259<br>275<br>413<br>Unsextium<br>+191 | 260<br>276<br>414<br>Unseptium<br>+192 | 261<br>277<br>415<br>Unoctium<br>+193 | 262<br>278<br>416<br>Unnennium<br>+194 | 263<br>279<br>417<br>Unnilium<br>+195 | 264<br>280<br>418<br>Ununium<br>+196 | 265<br>281<br>419<br>Unbium<br>+197 | 266<br>282<br>420<br>Untrium<br>+198 | 267<br>283<br>421<br>Unquadium<br>+199 | 268<br>284<br>422<br>Unpentium<br>+200 | 269<br>285<br>423<br>Unsextium<br>+201 | 270<br>286<br>424<br>Unseptium<br>+202 | 271<br>287<br>425<br>Unoctium<br>+203 | 272<br>288<br>426<br>Unnennium<br>+204 | 273<br>289<br>427<br>Unnilium<br>+205 | 274<br>290<br>428<br>Ununium<br>+206 | 275<br>291<br>429<br>Unbium<br>+207 | 276<br>292<br>430<br>Untrium<br>+208 | 277<br>293<br>431<br>Unquadium<br>+209 | 278<br>294<br>432<br>Unpentium<br>+210 | 279<br>295<br>433<br>Unsextium<br>+211 | 280<br>296<br>434<br>Unseptium<br>+212 | 281<br>297<br>435<br>Unoctium<br>+213 | 282<br>298<br>436<br>Unnennium<br>+214 | 283<br>299<br>437<br>Unnilium<br>+215 | 284<br>300<br>438<br>Ununium<br>+216 | 285<br>301<br>439<br>Unbium<br>+217 | 286<br>302<br>440<br>Untrium<br>+218 | 287<br>303<br>441<br>Unquadium<br>+219 | 288<br>304<br>442<br>Unpentium<br>+220 | 289<br>305<br>443<br>Unsextium<br>+221 | 290<br>306<br>444<br>Unseptium<br>+222 | 291<br>307<br>445<br>Unoctium<br>+223 | 292<br>308<br>446<br>Unnennium<br>+224 | 293<br>309<br>447<br>Unnilium<br>+225 | 294<br>310<br>448<br>Ununium<br>+226 | 295<br>311<br>449<br>Unbium<br>+227 | 296<br>312<br>450<br>Untrium<br>+228 | 297<br>313<br>451<br>Unquadium<br>+229 | 298<br>314<br>452<br>Unpentium<br>+230 | 299<br>315<br>453<br>Unsextium<br>+231 | 300<br>316<br>454<br>Unseptium<br>+232 | 301<br>317<br>455<br>Unoctium<br>+233 | 302<br>318<br>456<br>Unnennium<br>+234 | 303<br>319<br>457<br>Unnilium<br>+235 | 304<br>320<br>458<br>Ununium<br>+236 | 305<br>321<br>459<br>Unbium<br>+237 | 306<br>322<br>460<br>Untrium<br>+238 | 307<br>323<br>461<br>Unquadium<br>+239 | 308<br>324<br>462<br>Unpentium<br>+240 | 309<br>325<br>463<br>Unsextium<br>+241 | 310<br>326<br>464<br>Unseptium<br>+242 | 311<br>327<br>465<br>Unoctium<br>+243 | 312<br>328<br>466<br>Unnennium<br>+244 | 313<br>329<br>467<br>Unnilium<br>+245 | 314<br>330<br>468<br>Ununium<br>+246 | 315<br>331<br>469<br>Unbium<br>+247 | 316<br>332<br>470<br>Untrium<br>+248 | 317<br>333<br>471<br>Unquadium<br>+249 | 318<br>334<br>472<br>Unpentium<br>+250 | 319<br>335<br>473<br>Unsextium<br>+251 | 320<br>336<br>474<br>Unseptium<br>+252 | 321<br>337<br>475<br>Unoctium<br>+253 | 322<br>338<br>476<br>Unnennium<br>+254 | 323<br>339<br>477<br>Unnilium<br>+255 | 324<br>340<br>478<br>Ununium<br>+256 | 325<br>341<br>479<br>Unbium<br>+257 | 326<br>342<br>480<br>Untrium<br>+258 | 327<br>343<br>481<br>Unquadium<br>+259 | 328<br>344<br>482<br>Unpentium<br>+260 | 329<br>345<br>483<br>Unsextium<br>+261 | 330<br>346<br>484<br>Unseptium<br>+262 | 331<br>347<br>485<br>Unoctium<br>+263 | 332<br>348<br>486<br>Unnennium<br>+264 | 333<br>349<br>487<br>Unnilium<br>+265 | 334<br>350<br>488<br>Ununium<br>+266 | 335<br>351<br>489<br>Unbium<br>+267 | 336<br>352<br>490<br>Untrium<br>+268 | 337<br>353<br>491<br>Unquadium<br>+269 | 338<br>354<br>492<br>Unpentium<br>+270 | 339<br>355<br>493<br>Unsextium<br>+271 | 340<br>356<br>494<br>Unseptium<br>+272 | 341<br>357<br>495<br>Unoctium<br>+273 | 342<br>358<br>496<br>Unnennium<br>+274 | 343<br>359<br>497<br>Unnilium<br>+275 | 344<br>360<br>498<br>Ununium<br>+276 | 345<br>361<br>499<br>Unbium<br>+277 | 346<br>362<br>500<br>Untrium<br>+278 | 347<br>363<br>501<br>Unquadium<br>+279 | 348<br>364<br>502<br>Unpentium<br>+280 | 349<br>365<br>503<br>Unsextium<br>+281 | 350<br>366<br>504<br>Unseptium<br>+282 | 351<br>367<br>505<br>Unoctium<br>+283 | 352<br>368<br>506<br>Unnennium<br>+284 | 353<br>369<br>507<br>Unnilium<br>+285 | 354<br>370<br>508<br>Ununium<br>+286 | 355<br>371<br>509<br>Unbium<br>+287 | 356<br>372<br>510<br>Untrium<br>+288 | 357<br>373<br>511<br>Unquadium<br>+289 | 358<br>374<br>512<br>Unpentium<br>+290 | 359<br>375<br>513<br>Unsextium<br>+291 | 360<br>376<br>514<br>Unseptium<br>+292 | 361<br>377<br>515<br>Unoctium<br>+293 | 362<br>378<br>516<br>Unnennium<br>+294 | 363<br>379<br>517<br>Unnilium<br>+295 | 364<br>380<br>518<br>Ununium<br>+296 | 365<br>381<br>519<br>Unbium<br>+297 | 366<br>382<br>520<br>Untrium<br>+298 | 367<br>383<br>521<br>Unquadium<br>+299 | 368<br>384<br>522<br>Unpentium<br>+300 | 369<br>385<br>523<br>Unsextium<br>+301 | 370<br>386<br>524<br>Unseptium<br>+302 | 371<br>387<br>525<br>Unoctium<br>+303 | 372<br>388<br>526<br>Unnennium<br>+304 | 373<br>389<br>527<br>Unnilium<br>+305 | 374<br>390<br>528<br>Ununium<br>+306 | 375<br>391<br>529<br>Unbium<br>+307 | 376<br>392<br>530<br>Untrium<br>+308 | 377<br>393<br>531<br>Unquadium<br>+309 | 378<br>394<br>532<br>Unpentium<br>+310 | 379<br>395<br>533<br>Unsextium<br>+311 | 380<br>396<br>534<br>Unseptium<br>+312 | 381<br>397<br>535<br>Unoctium<br>+313 | 382<br>398<br>536<br>Unnennium<br>+314 | 383<br>399<br>537<br>Unnilium<br>+315 | 384<br>400<br>538<br>Ununium<br>+316 | 385<br>401<br>539<br>Unbium<br>+317 | 386<br>402<br>540<br>Untrium<br>+318 | 387<br>403<br>541<br>Unquadium<br>+319 | 388<br>404<br>542<br>Unpentium<br>+320 | 389<br>405<br>543<br>Unsextium<br>+321 | 390<br>406<br>544<br>Unseptium<br>+322 | 391<br>407<br>545<br>Unoctium<br>+323 | 392<br>408<br>546<br>Unnennium<br>+324 | 393<br>409<br>547<br>Unnilium<br>+325 | 394<br>410<br>548<br>Ununium<br>+326 | 395<br>411<br>549<br>Unbium<br>+327 | 396<br>412<br>550<br>Untrium<br>+328 | 397<br>413<br>551<br>Unquadium<br>+329 | 398<br>414<br>552<br>Unpentium<br>+330 | 399<br>415<br>553<br>Unsextium<br>+331 | 400<br>416<br>554<br>Unseptium<br>+332 | 401<br>417<br>555<br>Unoctium<br>+333 | 402<br>418<br>556<br>Unnennium<br>+334 | 403<br>419<br>557<br>Unnilium<br>+335 | 404<br>420<br>558<br>Ununium<br>+336 | 405<br>421<br>559<br>Unbium<br>+337 | 406<br>422<br>560<br>Untrium<br>+338 | 407<br>423<br>561<br>Unquadium<br>+339 | 408<br>424<br>562<br>Unpentium<br>+340 | 409<br>425<br>563<br>Unsextium<br>+341 | 410<br>426<br>564<br>Unseptium<br>+342 | 411<br>427<br>565<br>Unoctium<br>+343 | 412<br>428<br>566<br>Unnennium<br>+344 | 413<br>429<br>567<br>Unnilium<br>+345 | 414<br>430<br>568<br>Ununium<br>+346 | 415<br>431<br>569<br>Unbium<br>+347 | 416<br>432<br>570<br>Untrium<br>+348 | 417<br>433<br>571<br>Unquadium<br>+349 | 418<br>43 |
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|--------------------------------------------------------------------|---------------------------------------------------------------------|--------------------------------------------------------------------|---------------------------------------------------------------------|----------------------------------------------------------------|---------------------------------------------------------------------|-------------------------------------------------------------------|----------------------------------------------------------------|
| 64<br>3539<br>1585<br>7.89<br><b>Gd</b><br>Gadolinium<br>157.25 ±3 | 65<br>3496<br>1630<br>8.27<br><b>Tb</b><br>Terbium<br>158.925 34 ±2 | 66<br>2835<br>1682<br>8.54<br><b>Dy</b><br>Dysprosium<br>162.50 ±3 | 67<br>2968<br>1743<br>8.80<br><b>Ho</b><br>Holmium<br>164.930 32 ±2 | 68<br>3136<br>1795<br>9.05<br><b>Er</b><br>Erbium<br>167.26 ±3 | 69<br>2220<br>1818<br>9.33<br><b>Tm</b><br>Thulium<br>168.934 21 ±2 | 70<br>1467<br>1097<br>6.98<br><b>Yb</b><br>Ytterbium<br>173.04 ±3 | 71<br>3668<br>1936<br>9.84<br><b>Lu</b><br>Lutetium<br>174.967 |
| 96<br>1340<br>13.51<br><b>Cm</b><br>Curium<br>(247)                | 97<br><b>Bk</b><br>Berkelium<br>(247)                               | 98<br>900<br><b>Cf</b><br>Californium<br>(251)                     | 99<br><b>Es</b><br>Einsteinium<br>(254)                             | 100<br><b>Fm</b><br>Fermium<br>(257)                           | 101<br><b>Md</b><br>Mendelevium<br>(260)                            | 102<br><b>No</b><br>Nobelium<br>(259)                             | 103<br><b>Lr</b><br>Lawrencium<br>(262)                        |