

# PERIODIC TABLE Atomic Properties of the Elements

## FREQUENTLY USED FUNDAMENTAL PHYSICAL CONSTANTS<sup>§</sup>

1 second = 9 192 631 770 periods of radiation corresponding to the transition between the two hyperfine levels of the ground state of <sup>133</sup>Cs

speed of light in vacuum	<i>c</i>	299 792 458 m s <sup>-1</sup>	(exact)
Planck constant	<i>h</i>	6.626 070 15 × 10 <sup>-34</sup> J Hz <sup>-1</sup>	(exact)
elementary charge	<i>e</i>	1.602 176 634 × 10 <sup>-19</sup> C	(exact)
Avogadro constant	<i>N<sub>A</sub></i>	6.022 140 76 × 10 <sup>23</sup> mol <sup>-1</sup>	(exact)
Boltzmann constant	<i>k</i>	1.380 649 × 10 <sup>-23</sup> J K <sup>-1</sup>	(exact)
electron volt	eV	1.602 176 634 × 10 <sup>-19</sup> J	(exact)
electron mass	<i>m<sub>e</sub></i>	9.109 383 70 × 10 <sup>-31</sup> kg	
energy equivalent	<i>m<sub>e</sub>c<sup>2</sup></i>	0.510 998 950 MeV	
proton mass	<i>m<sub>p</sub></i>	1.672 621 924 × 10 <sup>-27</sup> kg	
energy equivalent	<i>m<sub>p</sub>c<sup>2</sup></i>	938.272 088 MeV	
fine-structure constant	<i>α</i>	1/137.035 999	
Rydberg energy	<i>R<sub>∞</sub>hc</i>	13.605 693 1230 eV	
Newtonian constant of gravitation	<i>G</i>	6.674 × 10 <sup>-11</sup> m <sup>3</sup> kg <sup>-1</sup> s <sup>-2</sup>	

<sup>§</sup>For the most accurate values of these and other constants, visit [pml.nist.gov/constants](http://pml.nist.gov/constants).

- Solids
- Liquids
- Gases
- Artificially Prepared

Physical Measurement Laboratory [www.nist.gov/pml](http://www.nist.gov/pml)  
Standard Reference Data [www.nist.gov/srd](http://www.nist.gov/srd)

Group	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIII	9 VIII	10 VIII	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	<b>1</b> <sup>2</sup> S <sub>1/2</sub> <b>H</b> Hydrogen 1.008 1s 13.5984																	<b>2</b> <sup>1</sup> S <sub>0</sub> <b>He</b> Helium 4.0026 1s <sup>2</sup> 24.5874
2	<b>3</b> <sup>2</sup> S <sub>1/2</sub> <b>Li</b> Lithium 6.94 1s <sup>2</sup> 2s 5.3917	<b>4</b> <sup>1</sup> S <sub>0</sub> <b>Be</b> Beryllium 9.0122 1s <sup>2</sup> 2s <sup>2</sup> 9.3227											<b>5</b> <sup>2</sup> P <sub>1/2</sub> <b>B</b> Boron 10.81 1s <sup>2</sup> 2s <sup>2</sup> 2p 8.2980	<b>6</b> <sup>3</sup> P <sub>0</sub> <b>C</b> Carbon 12.011 1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>2</sup> 11.2603	<b>7</b> <sup>4</sup> S <sub>3/2</sub> <b>N</b> Nitrogen 14.007 1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>3</sup> 14.5341	<b>8</b> <sup>3</sup> P <sub>2</sub> <b>O</b> Oxygen 15.999 1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>4</sup> 13.6181	<b>9</b> <sup>2</sup> P <sub>3/2</sub> <b>F</b> Fluorine 18.998 1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>5</sup> 17.4228	<b>10</b> <sup>1</sup> S <sub>0</sub> <b>Ne</b> Neon 20.180 1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 21.5645
3	<b>11</b> <sup>2</sup> S <sub>1/2</sub> <b>Na</b> Sodium 22.990 [Ne]3s 5.1391	<b>12</b> <sup>1</sup> S <sub>0</sub> <b>Mg</b> Magnesium 24.305 [Ne]3s <sup>2</sup> 7.6462											<b>13</b> <sup>2</sup> P <sub>1/2</sub> <b>Al</b> Aluminum 26.982 [Ne]3s <sup>2</sup> 3p 5.9858	<b>14</b> <sup>3</sup> P <sub>0</sub> <b>Si</b> Silicon 28.085 [Ne]3s <sup>2</sup> 3p <sup>2</sup> 8.1517	<b>15</b> <sup>4</sup> S <sub>3/2</sub> <b>P</b> Phosphorus 30.974 [Ne]3s <sup>2</sup> 3p <sup>3</sup> 10.4867	<b>16</b> <sup>3</sup> P <sub>2</sub> <b>S</b> Sulfur 32.06 [Ne]3s <sup>2</sup> 3p <sup>4</sup> 10.3600	<b>17</b> <sup>2</sup> P <sub>3/2</sub> <b>Cl</b> Chlorine 35.45 [Ne]3s <sup>2</sup> 3p <sup>5</sup> 12.9676	<b>18</b> <sup>1</sup> S <sub>0</sub> <b>Ar</b> Argon 39.948 [Ne]3s <sup>2</sup> 3p <sup>6</sup> 15.7596
4	<b>19</b> <sup>2</sup> S <sub>1/2</sub> <b>K</b> Potassium 39.098 [Ar]4s 4.3407	<b>20</b> <sup>1</sup> S <sub>0</sub> <b>Ca</b> Calcium 40.078 [Ar]4s <sup>2</sup> 6.1132	<b>21</b> <sup>2</sup> D <sub>3/2</sub> <b>Sc</b> Scandium 44.956 [Ar]3d <sup>4</sup> 4s <sup>2</sup> 6.5615	<b>22</b> <sup>3</sup> F <sub>2</sub> <b>Ti</b> Titanium 47.867 [Ar]3d <sup>2</sup> 4s <sup>2</sup> 6.8281	<b>23</b> <sup>4</sup> F <sub>3/2</sub> <b>V</b> Vanadium 50.942 [Ar]3d <sup>3</sup> 4s <sup>2</sup> 6.7462	<b>24</b> <sup>7</sup> S <sub>3</sub> <b>Cr</b> Chromium 51.996 [Ar]3d <sup>5</sup> 4s 6.7665	<b>25</b> <sup>6</sup> S <sub>5/2</sub> <b>Mn</b> Manganese 54.938 [Ar]3d <sup>5</sup> 4s <sup>2</sup> 7.4340	<b>26</b> <sup>5</sup> D <sub>4</sub> <b>Fe</b> Iron 55.845 [Ar]3d <sup>6</sup> 4s <sup>2</sup> 7.9025	<b>27</b> <sup>4</sup> F <sub>9/2</sub> <b>Co</b> Cobalt 58.933 [Ar]3d <sup>7</sup> 4s <sup>2</sup> 7.8810	<b>28</b> <sup>3</sup> F <sub>4</sub> <b>Ni</b> Nickel 58.693 [Ar]3d <sup>8</sup> 4s <sup>2</sup> 7.6399	<b>29</b> <sup>2</sup> S <sub>1/2</sub> <b>Cu</b> Copper 63.546 [Ar]3d <sup>10</sup> 4s 7.7264	<b>30</b> <sup>1</sup> S <sub>0</sub> <b>Zn</b> Zinc 65.38 [Ar]3d <sup>10</sup> 4s <sup>2</sup> 9.3942	<b>31</b> <sup>2</sup> P <sub>1/2</sub> <b>Ga</b> Gallium 69.723 [Ar]3d <sup>10</sup> 4s <sup>2</sup> 4p 5.9993	<b>32</b> <sup>3</sup> P <sub>0</sub> <b>Ge</b> Germanium 72.630 [Ar]3d <sup>10</sup> 4s <sup>2</sup> 4p <sup>2</sup> 7.8994	<b>33</b> <sup>4</sup> S <sub>3/2</sub> <b>As</b> Arsenic 74.922 [Ar]3d <sup>10</sup> 4s <sup>2</sup> 4p <sup>3</sup> 9.7886	<b>34</b> <sup>3</sup> P <sub>2</sub> <b>Se</b> Selenium 78.971 [Ar]3d <sup>10</sup> 4s <sup>2</sup> 4p <sup>4</sup> 9.7524	<b>35</b> <sup>2</sup> P <sub>3/2</sub> <b>Br</b> Bromine 79.904 [Ar]3d <sup>10</sup> 4s <sup>2</sup> 4p <sup>5</sup> 11.8138	<b>36</b> <sup>1</sup> S <sub>0</sub> <b>Kr</b> Krypton 83.798 [Ar]3d <sup>10</sup> 4s <sup>2</sup> 4p <sup>6</sup> 13.9996
5	<b>37</b> <sup>2</sup> S <sub>1/2</sub> <b>Rb</b> Rubidium 85.468 [Kr]5s 4.1771	<b>38</b> <sup>1</sup> S <sub>0</sub> <b>Sr</b> Strontium 87.62 [Kr]5s <sup>2</sup> 5.6949	<b>39</b> <sup>2</sup> D <sub>3/2</sub> <b>Y</b> Yttrium 88.906 [Kr]4d <sup>5</sup> 5s <sup>2</sup> 6.2173	<b>40</b> <sup>3</sup> F <sub>2</sub> <b>Zr</b> Zirconium 91.224 [Kr]4d <sup>5</sup> 5s <sup>2</sup> 6.6341	<b>41</b> <sup>6</sup> D <sub>1/2</sub> <b>Nb</b> Niobium 92.906 [Kr]4d <sup>4</sup> 5s 6.7589	<b>42</b> <sup>7</sup> S <sub>3</sub> <b>Mo</b> Molybdenum 95.95 [Kr]4d <sup>5</sup> 5s 7.0924	<b>43</b> <sup>6</sup> S <sub>5/2</sub> <b>Tc</b> Technetium (97) [Kr]4d <sup>5</sup> 5s <sup>2</sup> 7.1194	<b>44</b> <sup>5</sup> F <sub>5</sub> <b>Ru</b> Ruthenium 101.07 [Kr]4d <sup>7</sup> 5s 7.3605	<b>45</b> <sup>4</sup> F <sub>9/2</sub> <b>Rh</b> Rhodium 102.91 [Kr]4d <sup>8</sup> 5s 7.4589	<b>46</b> <sup>1</sup> S <sub>0</sub> <b>Pd</b> Palladium 106.42 [Kr]4d <sup>10</sup> 8.3368	<b>47</b> <sup>2</sup> S <sub>1/2</sub> <b>Ag</b> Silver 107.87 [Kr]4d <sup>10</sup> 5s 7.5762	<b>48</b> <sup>1</sup> S <sub>0</sub> <b>Cd</b> Cadmium 112.41 [Kr]4d <sup>10</sup> 5s <sup>2</sup> 8.9938	<b>49</b> <sup>2</sup> P <sub>1/2</sub> <b>In</b> Indium 114.82 [Kr]4d <sup>10</sup> 5s <sup>2</sup> 5p 7.3439	<b>50</b> <sup>3</sup> P <sub>0</sub> <b>Sn</b> Tin 118.71 [Kr]4d <sup>10</sup> 5s <sup>2</sup> 5p <sup>2</sup> 7.4589	<b>51</b> <sup>4</sup> S <sub>3/2</sub> <b>Sb</b> Antimony 121.76 [Kr]4d <sup>10</sup> 5s <sup>2</sup> 5p <sup>3</sup> 8.6084	<b>52</b> <sup>3</sup> P <sub>2</sub> <b>Te</b> Tellurium 127.60 [Kr]4d <sup>10</sup> 5s <sup>2</sup> 5p <sup>4</sup> 9.0098	<b>53</b> <sup>2</sup> P <sub>3/2</sub> <b>I</b> Iodine 126.90 [Kr]4d <sup>10</sup> 5s <sup>2</sup> 5p <sup>5</sup> 10.4513	<b>54</b> <sup>1</sup> S <sub>0</sub> <b>Xe</b> Xenon 131.29 [Kr]4d <sup>10</sup> 5s <sup>2</sup> 5p <sup>6</sup> 12.1298
6	<b>55</b> <sup>2</sup> S <sub>1/2</sub> <b>Cs</b> Cesium 132.91 [Xe]6s 3.8939	<b>56</b> <sup>1</sup> S <sub>0</sub> <b>Ba</b> Barium 137.33 [Xe]6s <sup>2</sup> 5.2117		<b>72</b> <sup>3</sup> F <sub>2</sub> <b>Hf</b> Hafnium 178.49 [Xe]4f <sup>14</sup> 5d <sup>4</sup> 6s <sup>2</sup> 6.8251	<b>73</b> <sup>4</sup> F <sub>3/2</sub> <b>Ta</b> Tantalum 180.95 [Xe]4f <sup>14</sup> 5d <sup>3</sup> 6s <sup>2</sup> 7.5496	<b>74</b> <sup>5</sup> D <sub>0</sub> <b>W</b> Tungsten 183.84 [Xe]4f <sup>14</sup> 5d <sup>4</sup> 6s <sup>2</sup> 7.8640	<b>75</b> <sup>6</sup> S <sub>5/2</sub> <b>Re</b> Rhenium 186.21 [Xe]4f <sup>14</sup> 5d <sup>5</sup> 6s <sup>2</sup> 7.8335	<b>76</b> <sup>5</sup> D <sub>4</sub> <b>Os</b> Osmium 190.23 [Xe]4f <sup>14</sup> 5d <sup>6</sup> 6s <sup>2</sup> 8.4382	<b>77</b> <sup>4</sup> F <sub>9/2</sub> <b>Ir</b> Iridium 192.22 [Xe]4f <sup>14</sup> 5d <sup>7</sup> 6s <sup>2</sup> 8.9670	<b>78</b> <sup>3</sup> D <sub>3</sub> <b>Pt</b> Platinum 195.08 [Xe]4f <sup>14</sup> 5d <sup>9</sup> 6s <sup>1</sup> 8.9588	<b>79</b> <sup>2</sup> S <sub>1/2</sub> <b>Au</b> Gold 196.97 [Xe]4f <sup>14</sup> 5d <sup>10</sup> 6s <sup>1</sup> 9.2256	<b>80</b> <sup>1</sup> S <sub>0</sub> <b>Hg</b> Mercury 200.59 [Xe]4f <sup>14</sup> 5d <sup>10</sup> 6s <sup>2</sup> 10.4375	<b>81</b> <sup>2</sup> P <sub>1/2</sub> <b>Tl</b> Thallium 204.38 [Hg]6p 6.1083	<b>82</b> <sup>3</sup> P <sub>0</sub> <b>Pb</b> Lead 207.2 [Hg]6p <sup>2</sup> 7.4167	<b>83</b> <sup>4</sup> S <sub>3/2</sub> <b>Bi</b> Bismuth 208.98 [Hg]6p <sup>3</sup> 7.2855	<b>84</b> <sup>3</sup> P <sub>2</sub> <b>Po</b> Polonium (209) [Hg]6p <sup>4</sup> 8.4181	<b>85</b> <sup>2</sup> P <sub>3/2</sub> <b>At</b> Astatine (210) [Hg]6p <sup>5</sup> 9.3175	<b>86</b> <sup>1</sup> S <sub>0</sub> <b>Rn</b> Radon (222) [Hg]6p <sup>6</sup> 10.7485
7	<b>87</b> <sup>2</sup> S <sub>1/2</sub> <b>Fr</b> Francium (223) [Rn]7s 4.0727	<b>88</b> <sup>1</sup> S <sub>0</sub> <b>Ra</b> Radium (226) [Rn]7s <sup>2</sup> 5.2784		<b>104</b> <sup>3</sup> F <sub>2</sub> <b>Rf</b> Rutherfordium (261) [Rn]5f <sup>14</sup> 6d <sup>2</sup> 7s <sup>2</sup> 6.02	<b>105</b> <sup>4</sup> F <sub>3/2</sub> <b>Db</b> Dubnium (268) [Rn]5f <sup>14</sup> 6d <sup>3</sup> 7s <sup>2</sup> 6.8	<b>106</b> <sup>0</sup> <b>Sg</b> Seaborgium (269) [Rn]5f <sup>14</sup> 6d <sup>4</sup> 7s <sup>2</sup> 7.8	<b>107</b> <sup>5/2</sup> <b>Bh</b> Bohrium (270) [Rn]5f <sup>14</sup> 6d <sup>5</sup> 7s <sup>2</sup> 7.7	<b>108</b> <sup>4</sup> <b>Hs</b> Hassium (269) [Rn]5f <sup>14</sup> 6d <sup>6</sup> 7s <sup>2</sup> 7.6	<b>109</b> <sup>0</sup> <b>Mt</b> Meitnerium (278)	<b>110</b> <sup>0</sup> <b>Ds</b> Darmstadtium (281)	<b>111</b> <sup>0</sup> <b>Rg</b> Roentgenium (282)	<b>112</b> <sup>0</sup> <b>Cn</b> Copernicium (285)	<b>113</b> <sup>0</sup> <b>Nh</b> Nihonium (286)	<b>114</b> <sup>0</sup> <b>Fl</b> Flerovium (289)	<b>115</b> <sup>0</sup> <b>Mc</b> Moscovium (289)	<b>116</b> <sup>0</sup> <b>Lv</b> Livermorium (293)	<b>117</b> <sup>0</sup> <b>Ts</b> Tennessine (294)	<b>118</b> <sup>0</sup> <b>Og</b> Oganesson (294)
			<b>57</b> <sup>2</sup> D <sub>3/2</sub> <b>La</b> Lanthanum 138.91 [Xe]5d <sup>6</sup> 6s <sup>2</sup> 5.5769	<b>58</b> <sup>1</sup> G <sub>4</sub> <b>Ce</b> Cerium 140.12 [Xe]4f <sup>1</sup> 5d <sup>1</sup> 6s <sup>2</sup> 5.5386	<b>59</b> <sup>4</sup> 1/2 <b>Pr</b> Praseodymium 140.91 [Xe]4f <sup>3</sup> 6s <sup>2</sup> 5.4702	<b>60</b> <sup>5</sup> 1/2 <b>Nd</b> Neodymium 144.24 [Xe]4f <sup>4</sup> 6s <sup>2</sup> 5.5250	<b>61</b> <sup>6</sup> H <sub>5/2</sub> <b>Pm</b> Promethium (145) [Xe]4f <sup>5</sup> 6s <sup>2</sup> 5.5819	<b>62</b> <sup>7</sup> F <sub>0</sub> <b>Sm</b> Samarium 150.36 [Xe]4f <sup>6</sup> 6s <sup>2</sup> 5.6437	<b>63</b> <sup>8</sup> S <sub>7/2</sub> <b>Eu</b> Europium 151.96 [Xe]4f <sup>7</sup> 6s <sup>2</sup> 5.6704	<b>64</b> <sup>9</sup> D <sub>2</sub> <b>Gd</b> Gadolinium 157.25 [Xe]4f <sup>7</sup> 5d <sup>1</sup> 6s <sup>2</sup> 5.8638	<b>65</b> <sup>6</sup> H <sub>15/2</sub> <b>Tb</b> Terbium 158.93 [Xe]4f <sup>9</sup> 6s <sup>2</sup> 5.9391	<b>66</b> <sup>5</sup> 1/2 <b>Dy</b> Dysprosium 162.50 [Xe]4f <sup>10</sup> 6s <sup>2</sup> 6.0215	<b>67</b> <sup>4</sup> 1/2 <b>Ho</b> Holmium 164.93 [Xe]4f <sup>11</sup> 6s <sup>2</sup> 6.1077	<b>68</b> <sup>3</sup> H <sub>6</sub> <b>Er</b> Erbium 167.26 [Xe]4f <sup>12</sup> 6s <sup>2</sup> 6.1844	<b>69</b> <sup>2</sup> F <sub>7/2</sub> <b>Tm</b> Thulium 168.93 [Xe]4f <sup>13</sup> 6s <sup>2</sup> 6.2542	<b>70</b> <sup>1</sup> S <sub>0</sub> <b>Yb</b> Ytterbium 173.05 [Xe]4f <sup>14</sup> 6s <sup>2</sup> 6.2542	<b>71</b> <sup>2</sup> D <sub>3/2</sub> <b>Lu</b> Lutetium 174.97 [Xe]4f <sup>14</sup> 5d <sup>1</sup> 6s <sup>2</sup> 6.2542	
			<b>89</b> <sup>2</sup> D <sub>3/2</sub> <b>Ac</b> Actinium (227) [Rn]6d <sup>1</sup> 7s <sup>2</sup> 5.3802	<b>90</b> <sup>3</sup> F <sub>2</sub> <b>Th</b> Thorium 232.04 [Rn]6d <sup>2</sup> 7s <sup>2</sup> 6.3067	<b>91</b> <sup>4</sup> K <sub>11/2</sub> <b>Pa</b> Protactinium 231.04 [Rn]5f <sup>1</sup> 6d <sup>1</sup> 7s <sup>2</sup> 5.89	<b>92</b> <sup>5</sup> L <sub>6</sub> <b>U</b> Uranium 238.03 [Rn]5f <sup>3</sup> 6d <sup>1</sup> 7s <sup>2</sup> 6.1941	<b>93</b> <sup>6</sup> L <sub>11/2</sub> <b>Np</b> Neptunium (237) [Rn]5f <sup>4</sup> 6d <sup>1</sup> 7s <sup>2</sup> 6.2655	<b>94</b> <sup>7</sup> F <sub>0</sub> <b>Pu</b> Plutonium (244) [Rn]5f <sup>6</sup> 7s <sup>2</sup> 6.0258	<b>95</b> <sup>8</sup> S <sub>7/2</sub> <b>Am</b> Americium (243) [Rn]5f <sup>7</sup> 7s <sup>2</sup> 5.9738	<b>96</b> <sup>9</sup> D <sub>2</sub> <b>Cm</b> Curium (247) [Rn]5f <sup>8</sup> 6d <sup>1</sup> 7s <sup>2</sup> 5.9914	<b>97</b> <sup>6</sup> H <sub>15/2</sub> <b>Bk</b> Berkelium (247) [Rn]5f <sup>9</sup> 7s <sup>2</sup> 6.1979	<b>98</b> <sup>5</sup> 1/2 <b>Cf</b> Californium (251) [Rn]5f <sup>10</sup> 7s <sup>2</sup> 6.2819	<b>99</b> <sup>4</sup> 1/2 <b>Es</b> Einsteinium (252) [Rn]5f <sup>11</sup> 7s <sup>2</sup> 6.3676	<b>100</b> <sup>3</sup> H <sub>6</sub> <b>Fm</b> Fermium (257) [Rn]5f <sup>12</sup> 7s <sup>2</sup> 6.50	<b>101</b> <sup>2</sup> F <sub>7/2</sub> <b>Md</b> Mendelevium (258) [Rn]5f <sup>13</sup> 7s <sup>2</sup> 6.58	<b>102</b> <sup>1</sup> S <sub>0</sub> <b>No</b> Nobelium (259) [Rn]5f <sup>14</sup> 7s <sup>2</sup> 6.6262	<b>103</b> <sup>2</sup> P <sub>1/2</sub> <b>Lr</b> Lawrencium (260) [Rn]5f <sup>14</sup> 7s <sup>2</sup> 7p 4.96	

Atomic Number: 58  
Ground State: <sup>1</sup>G<sub>4</sub>  
Symbol: Ce  
Name: Cerium  
Standard Atomic Weight: 140.12  
Ground-state Configuration: [Xe]4f<sup>1</sup>5d<sup>1</sup>6s<sup>2</sup>  
Ionization Energy (eV): 5.5386

<sup>†</sup>Based upon <sup>12</sup>C. ( ) indicates the mass number of the longest-lived isotope.

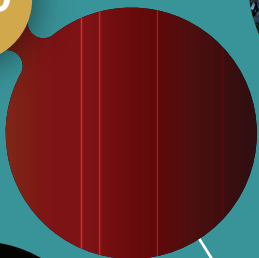
# NISTory of the Periodic Table

## Krypton:

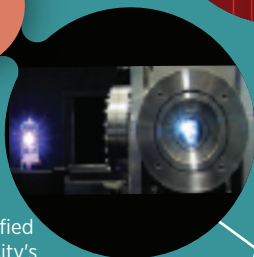
Wavelengths of light from this atom, measured by NIST researchers, defined the official meter until 1983.

Image Credit: Neil Tucker/Wikimedia

1960



1931



## Deuterium:

This rare heavy isotope of hydrogen was concentrated at NIST and then identified by Columbia University's Harold Urey (Nobel Prize 1934). On the left is a deuterium lamp; the light on the right comes from the NIST SURF III Synchrotron Ultraviolet Radiation Facility.

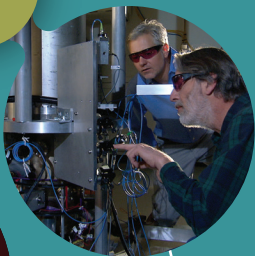
Image Credit: Uwe Arp/NIST

## Cesium:

The frequency of microwave radiation from this atom in atomic clocks such as the NIST-F2 (2014), is used to define the second.

Image Credit: NIST

1967

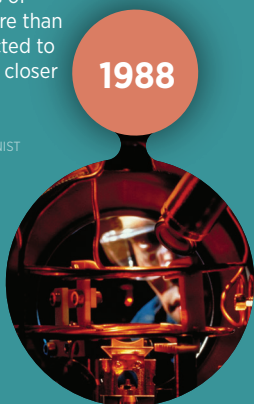


## Sodium:

NIST scientists used lasers to cool a gas of these atoms to more than theoretically expected to temperatures even closer to absolute zero. (Nobel Prize 1997)

Image Credit: H.Mark Helfer/NIST

1988

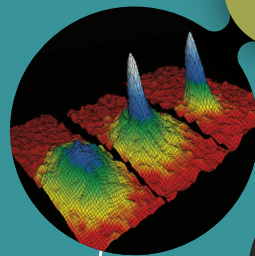


## Rubidium:

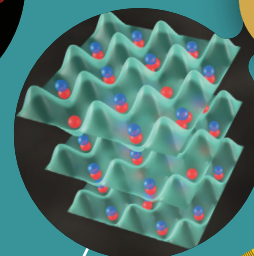
These atoms were used by researchers at JILA (NIST-CU Boulder) to create the first Bose-Einstein condensate (Nobel Prize 2001).

Image Credit: NIST/JILA/CU-Boulder

1995



2008

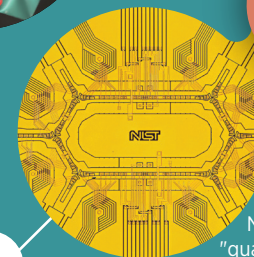


## Potassium and Rubidium:

JILA researchers married these elements into an ultracold gas of molecules and demonstrated striking predictions of quantum physics by hitting the atoms with "rulers of light" known as frequency combs (Nobel Prize 2005) and trapping them in webs of light known as optical lattices.

Image Credit: Steven Burrows and Ye/Jin groups/JILA

2010/2011



## Beryllium and Aluminum:

Individual ions of these atoms were probed in a NIST trap to create "quantum logic" clocks that measured the second more precisely than before and tested Einstein's general theory of relativity. Such quantum manipulations were recognized in the 2012 Nobel Prize.

Image Credit: J. Amini/NIST