

# Training for Educators

## Quantum Chemistry

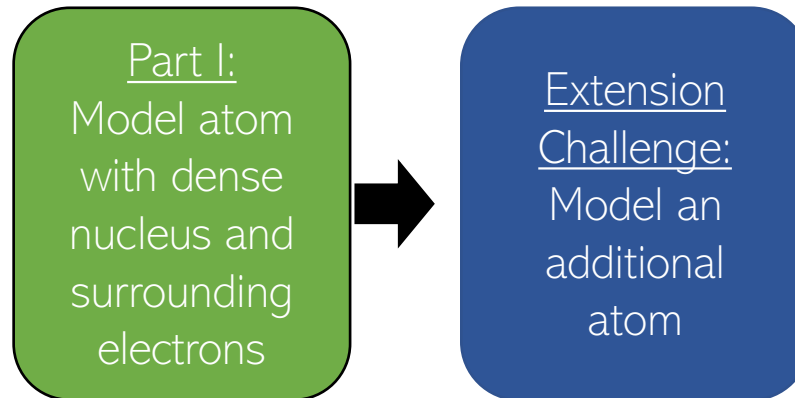
Primary Level

Ages 5-11

# Purpose of the lab

- The purpose of this lab kit is to enable students to understand atoms through theory and demonstration. The manual introduces the students to atomic models.
- The main takeaway is:
  - The Rutherford atomic model has a dense nucleus, with electrons surrounding the nucleus, and contains a lot of empty space.

# Summary of experiments



There is 1 activity and 1 extension challenge.

# Supplies list

- Spherical-like candies of three colors (or compressed foil balls of three colors)
- Toothpicks
- Dark string (or pipe cleaners)
- Marker

# Safety considerations

Before the students begin the laboratory, please take into consideration the following safety concerns:

- Students should not eat or taste items during experiments.

# Setting up your space

- Gather your supplies and separate by experiment(s) on your table.
- These are our recommendations:
  - Each student should have a pencil or pen.

Groups of 2-4 students can be given the following supplies:

- Spherical-like candies of three colors (at least 8 per group) (or compressed foil/paper balls of three colors)
- Several toothpicks
- Length of dark string (approx. ~0.5 m) (or ~4-5 pipe cleaners)
- Paper (at least 2 pieces)

The class can share the following supplies:

- Marker

# Part I. Candy Atomic Models

- Set-up:
  - Each group of 2-4 students gets spherical-like candies of three colors (at least 8 each), toothpicks, dark string, and paper.
- Procedure:
  - Students should join together candies of two colors in a dense ball and use two lengths of string to make concentric circles around the nucleus. Students should then place candies of the third color on the inner and outer circles of string.
- Results:
  - Students will see that they have created a Rutherford model of the atom. If the students use 8 of each candy, they will have modelled the oxygen atom.

The takeaway is that the Rutherford atomic model has a dense nucleus, with electrons surrounding the nucleus, and the atom contains a lot of empty space.

# Part I. Candy Atomic Models



Example of candy atom model

# Extension challenge

- Students are asked to create another atom of a different element. It is recommended they choose an atom in the first two rows of the periodic table.
- Questions to ask the students (encourage students to browse the periodic table)
  - What atom did you choose to model?
  - How many protons and neutrons do you need?
  - How many electrons do you need? Where will they go in your two orbitals?

# Appendix

**PERIODIC TABLE**  
**Atomic Properties of the Elements**

**NIST**  
National Institute of  
Standards and Technology  
U.S. Department of Commerce

**Frequently used fundamental physical constants**  
For the most accurate values of these and other constants, visit [physics.nist.gov/constants](http://physics.nist.gov/constants)  
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 *c* 299 792 458 m s<sup>-1</sup> (exact)  
Planck constant *h* 6.626 07 × 10<sup>-34</sup> J s (*h* = *h*/2π)  
elementary charge *e* 1.602 177 × 10<sup>-19</sup> C  
electron mass *m<sub>e</sub>* 9.109 38 × 10<sup>-31</sup> kg  
*m<sub>e</sub>c<sup>2</sup>* 0.510 999 MeV  
proton mass *m<sub>p</sub>* 1.672 622 × 10<sup>-27</sup> kg  
*α* 1/137.035 999  
Rydberg constant *R<sub>∞</sub>* 10 973 731.569 m<sup>-1</sup>  
*R<sub>∞</sub>c* 3.289 841 960 × 10<sup>15</sup> Hz  
*R<sub>∞</sub>hc* 13.605 69 eV  
Boltzmann constant *k* 1.380 6 × 10<sup>-23</sup> J K<sup>-1</sup>

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

Legend:  
■ Solids  
■ Liquids  
■ Gases  
■ Artificially Prepared

Group 1 IA	PERIODIC TABLE																18 VIIIA				
1 <sup>1</sup> H Hydrogen 1.008 1s																	2 <sup>2</sup> He Helium 4.002602 1s <sup>2</sup>				
2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIII	9	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA					
3 <sup>3</sup> Li Lithium 6.94 1s <sup>2</sup> 2s 5.3917	4 <sup>4</sup> Be Beryllium 9.0121831 1s <sup>2</sup> 2s <sup>2</sup> 9.3227	5 <sup>11</sup> Na Sodium 22.98976928 [Ne]3s <sup>1</sup> 5.1391	6 <sup>12</sup> Mg Magnesium 24.305 [Ne]3s <sup>2</sup> 7.6462	7 <sup>19</sup> K Potassium 39.0983 [Ar]4s 4.3407	8 <sup>20</sup> Ca Calcium 40.078 [Ar]4s <sup>2</sup> 6.1132	9 <sup>21</sup> Sc Scandium 44.955908 [Ar]3d <sup>1</sup> 4s <sup>2</sup> 6.8281	10 <sup>22</sup> Ti Titanium 47.867 [Ar]3d <sup>2</sup> 4s <sup>2</sup> 6.8281	11 <sup>23</sup> V Vanadium 50.9415 [Ar]3d <sup>3</sup> 4s <sup>2</sup> 6.8281	12 <sup>24</sup> Cr Chromium 51.9961 [Ar]3d <sup>5</sup> 4s 7.4340	13 <sup>25</sup> Mn Manganese 54.938044 [Ar]3d <sup>5</sup> 4s <sup>2</sup> 7.9025	14 <sup>26</sup> Fe Iron 55.845 [Ar]3d <sup>6</sup> 4s <sup>2</sup> 7.8810	15 <sup>27</sup> Co Cobalt 58.933194 [Ar]3d <sup>7</sup> 4s <sup>2</sup> 7.6399	16 <sup>28</sup> Ni Nickel 58.9332 [Ar]3d <sup>8</sup> 4s <sup>2</sup> 7.6399	17 <sup>29</sup> Cu Copper 63.546 [Ar]3d <sup>10</sup> 4s 7.7264	18 <sup>30</sup> Zn Zinc 65.38 [Ar]3d <sup>10</sup> 4s <sup>2</sup> 9.3942	19 <sup>31</sup> Ga Gallium 69.723 [Ar]3d <sup>10</sup> 4s <sup>2</sup> 4p 5.9993	20 <sup>32</sup> Ge Germanium 72.630 [Ar]3d <sup>10</sup> 4s <sup>2</sup> 4p 7.8994	21 <sup>33</sup> As Arsenic 74.921595 [Ar]3d <sup>10</sup> 4s <sup>2</sup> 4p 9.7886	22 <sup>34</sup> Se Selenium 78.971 [Ar]3d <sup>10</sup> 4s <sup>2</sup> 4p 9.7524	23 <sup>35</sup> Br Bromine 79.904 [Ar]3d <sup>10</sup> 4s <sup>2</sup> 4p 11.8138	24 <sup>36</sup> Kr Krypton 83.798 [Ar]3d <sup>10</sup> 4s <sup>2</sup> 4p 13.9996
4 <sup>37</sup> Rb Rubidium 85.4678 [Kr]5s 4.1771	5 <sup>38</sup> Sr Strontium 87.62 [Kr]5s <sup>2</sup> 5.6949	6 <sup>39</sup> Y Yttrium 88.90584 [Kr]4d <sup>1</sup> 5s <sup>2</sup> 6.2173	7 <sup>40</sup> Zr Zirconium 91.224 [Kr]4d <sup>2</sup> 5s 6.8339	8 <sup>41</sup> Nb Niobium 92.90637 [Kr]4d <sup>4</sup> 5s 6.8339	9 <sup>42</sup> Mo Molybdenum 95.96 [Kr]4d <sup>5</sup> 5s 7.1194	10 <sup>43</sup> Tc Technetium (98) [Kr]4d <sup>5</sup> 5s 7.1194	11 <sup>44</sup> Ru Ruthenium 101.07 [Kr]4d <sup>7</sup> 5s 7.4595	12 <sup>45</sup> Rh Rhodium 102.90550 [Kr]4d <sup>8</sup> 5s 7.4595	13 <sup>46</sup> Pd Palladium 106.42 [Kr]4d <sup>10</sup> 8.3969	14 <sup>47</sup> Ag Silver 107.8682 [Kr]4d <sup>10</sup> 5s 7.3762	15 <sup>48</sup> Cd Cadmium 112.414 [Kr]4d <sup>10</sup> 5s 5.2654	16 <sup>49</sup> In Indium 114.818 [Kr]4d <sup>10</sup> 5s <sup>2</sup> 5p 5.2654	17 <sup>50</sup> Sn Tin 118.710 [Kr]4d <sup>10</sup> 5s <sup>2</sup> 5p 7.2439	18 <sup>51</sup> Sb Antimony 121.760 [Kr]4d <sup>10</sup> 5s <sup>2</sup> 5p 6.6284	19 <sup>52</sup> Te Tellurium 127.60 [Kr]4d <sup>10</sup> 5s <sup>2</sup> 5p 9.0007	20 <sup>53</sup> I Iodine 126.90447 [Kr]4d <sup>10</sup> 5s <sup>2</sup> 5p 10.4513	21 <sup>54</sup> Xe Xenon 131.293 [Kr]4d <sup>10</sup> 5s <sup>2</sup> 5p 12.1298				
5 <sup>55</sup> Cs Cesium 132.9054520 [Xe]6s 3.8939	6 <sup>56</sup> Ba Barium 137.327 [Xe]6s <sup>2</sup> 5.2117	7 <sup>72</sup> Hf Hafnium 178.49 [Xe]4f <sup>14</sup> 5d <sup>2</sup> 6s <sup>2</sup> 6.8251	8 <sup>73</sup> Ta Tantalum 180.94788 [Xe]4f <sup>14</sup> 5d <sup>3</sup> 6s <sup>2</sup> 7.5496	9 <sup>74</sup> W Tungsten 183.84 [Xe]4f <sup>14</sup> 5d <sup>4</sup> 6s <sup>2</sup> 7.8640	10 <sup>75</sup> Re Rhenium 186.207 [Xe]4f <sup>14</sup> 5d <sup>5</sup> 6s <sup>2</sup> 7.8335	11 <sup>76</sup> Os Osmium 190.23 [Xe]4f <sup>14</sup> 5d <sup>6</sup> 6s <sup>2</sup> 8.4382	12 <sup>77</sup> Ir Iridium 192.227 [Xe]4f <sup>14</sup> 5d <sup>7</sup> 6s <sup>2</sup> 8.9670	13 <sup>78</sup> Pt Platinum 195.084 [Xe]4f <sup>14</sup> 5d <sup>9</sup> 6s <sup>1</sup> 8.9588	14 <sup>79</sup> Au Gold 196.966569 [Xe]4f <sup>14</sup> 5d <sup>10</sup> 6s <sup>1</sup> 9.2256	15 <sup>80</sup> Hg Mercury 200.592 [Xe]4f <sup>14</sup> 5d <sup>10</sup> 6s <sup>2</sup> 10.4375	16 <sup>81</sup> Tl Thallium 204.38 [Hg]6p 6.1083	17 <sup>82</sup> Pb Lead 207.2 [Hg]6p 7.4167	18 <sup>83</sup> Bi Bismuth 208.98040 [Hg]6p 7.2855	19 <sup>84</sup> Po Polonium (209) [Hg]6p 8.414	20 <sup>85</sup> At Astatine (210) [Hg]6p 9.31751	21 <sup>86</sup> Rn Radon (222) [Hg]6p 10.7485					
6 <sup>87</sup> Fr Francium (223) [Rn]7s 4.0727	7 <sup>88</sup> Ra Radium (226) [Rn]7s <sup>2</sup> 5.2764	8 <sup>104</sup> Rf Rutherfordium (261) [Rn]5f <sup>14</sup> 6d <sup>2</sup> 7s <sup>2</sup> 6.01	9 <sup>105</sup> Db Dubnium (268) [Rn]5f <sup>14</sup> 6d <sup>3</sup> 7s <sup>2</sup> 6.8	10 <sup>106</sup> Sg Seaborgium (271) [Rn]5f <sup>14</sup> 6d <sup>4</sup> 7s <sup>2</sup> 7.8	11 <sup>107</sup> Bh Bohrium (272) [Rn]5f <sup>14</sup> 6d <sup>5</sup> 7s <sup>2</sup> 7.7	12 <sup>108</sup> Hs Hassium (270) [Rn]5f <sup>14</sup> 6d <sup>6</sup> 7s <sup>2</sup> 7.8	13 <sup>109</sup> Mt Meitnerium (276) [Rn]5f <sup>14</sup> 6d <sup>7</sup> 7s <sup>2</sup> 7.8	14 <sup>110</sup> Ds Darmstadtium (281) [Rn]5f <sup>14</sup> 6d <sup>8</sup> 7s <sup>2</sup> 7.8	15 <sup>111</sup> Rg Roentgenium (280) [Rn]5f <sup>14</sup> 6d <sup>9</sup> 7s <sup>2</sup> 7.8	16 <sup>112</sup> Cn Copernicium (285) [Rn]5f <sup>14</sup> 6d <sup>10</sup> 7s <sup>2</sup> 7.8	17 <sup>113</sup> Uut Ununtrium (284) [Rn]5f <sup>14</sup> 6d <sup>10</sup> 7s <sup>2</sup> 7p 7.8	18 <sup>114</sup> Fl Flerovium (289) [Rn]5f <sup>14</sup> 6d <sup>10</sup> 7s <sup>2</sup> 7p 7.8	19 <sup>115</sup> Uup Ununpentium (293) [Rn]5f <sup>14</sup> 6d <sup>10</sup> 7s <sup>2</sup> 7p 7.8	20 <sup>116</sup> Lv Livermorium (293) [Rn]5f <sup>14</sup> 6d <sup>10</sup> 7s <sup>2</sup> 7p 7.8	21 <sup>117</sup> Uus Ununseptium (294) [Rn]5f <sup>14</sup> 6d <sup>10</sup> 7s <sup>2</sup> 7p 7.8	22 <sup>118</sup> Uuo Ununoctium (294) [Rn]5f <sup>14</sup> 6d <sup>10</sup> 7s <sup>2</sup> 7p 7.8					
7 <sup>57</sup> La Lanthanum 138.90547 [Xe]5d <sup>1</sup> 6s <sup>2</sup> 5.5769	8 <sup>58</sup> Ce Cerium 140.116 [Xe]4f <sup>1</sup> 5d <sup>1</sup> 6s <sup>2</sup> 5.5386	9 <sup>59</sup> Pr Praseodymium 140.907 [Xe]4f <sup>3</sup> 6s <sup>2</sup> 5.473	10 <sup>60</sup> Nd Neodymium 144.242 [Xe]4f <sup>4</sup> 6s <sup>2</sup> 5.5250	11 <sup>61</sup> Pm Promethium (145) [Xe]4f <sup>5</sup> 6s <sup>2</sup> 5.582	12 <sup>62</sup> Sm Samarium 150.36 [Xe]4f <sup>6</sup> 6s <sup>2</sup> 6.1498	13 <sup>63</sup> Eu Europium 151.964 [Xe]4f <sup>7</sup> 6s <sup>2</sup> 6.2015	14 <sup>64</sup> Gd Gadolinium 157.25 [Xe]4f <sup>7</sup> 6s <sup>2</sup> 6.1498	15 <sup>65</sup> Tb Terbium 158.92535 [Xe]4f <sup>9</sup> 6s <sup>2</sup> 5.9391	16 <sup>66</sup> Dy Dysprosium 162.500 [Xe]4f <sup>10</sup> 6s <sup>2</sup> 6.0215	17 <sup>67</sup> Ho Holmium 164.93033 [Xe]4f <sup>11</sup> 6s <sup>2</sup> 6.1077	18 <sup>68</sup> Er Erbium 167.259 [Xe]4f <sup>12</sup> 6s <sup>2</sup> 6.1843	19 <sup>69</sup> Tm Thulium 168.93422 [Xe]4f <sup>13</sup> 6s <sup>2</sup> 6.2452	20 <sup>70</sup> Yb Ytterbium 173.054 [Xe]4f <sup>14</sup> 6s <sup>2</sup> 6.2529	21 <sup>71</sup> Lu Lutetium 174.967 [Xe]4f <sup>14</sup> 6s <sup>2</sup> 6.2529							
8 <sup>89</sup> Ac Actinium (227) [Rn]6d <sup>1</sup> 7s <sup>2</sup> 5.3802	9 <sup>90</sup> Th Thorium 232.0377 [Rn]6d <sup>2</sup> 7s <sup>2</sup> 6.3067	10 <sup>91</sup> Pa Protactinium 231.03688 [Rn]5f <sup>2</sup> 6d <sup>1</sup> 7s <sup>2</sup> 5.89	11 <sup>92</sup> U Uranium 238.02891 [Rn]5f <sup>3</sup> 6d <sup>1</sup> 7s <sup>2</sup> 6.1941	12 <sup>93</sup> Np Neptunium (237) [Rn]5f <sup>4</sup> 6d <sup>1</sup> 7s <sup>2</sup> 6.2655	13 <sup>94</sup> Pu Plutonium (244) [Rn]5f <sup>6</sup> 7s <sup>2</sup> 6.2658	14 <sup>95</sup> Am Americium (243) [Rn]5f <sup>7</sup> 7s <sup>2</sup> 5.9914	15 <sup>96</sup> Cm Curium (247) [Rn]5f <sup>8</sup> 7s <sup>2</sup> 6.1978	16 <sup>97</sup> Bk Berkelium (247) [Rn]5f <sup>9</sup> 7s <sup>2</sup> 6.1978	17 <sup>98</sup> Cf Californium (251) [Rn]5f <sup>10</sup> 7s <sup>2</sup> 6.2817	18 <sup>99</sup> Es Einsteinium (252) [Rn]5f <sup>11</sup> 7s <sup>2</sup> 6.3676	19 <sup>100</sup> Fm Fermium (257) [Rn]5f <sup>12</sup> 7s <sup>2</sup> 6.50	20 <sup>101</sup> Md Mendelevium (258) [Rn]5f <sup>13</sup> 7s <sup>2</sup> 6.58	21 <sup>102</sup> No Nobelium (259) [Rn]5f <sup>14</sup> 7s <sup>2</sup> 6.85	22 <sup>103</sup> Lr Lawrencium (262) [Rn]5f <sup>14</sup> 7s <sup>2</sup> 7p 4.90							

<sup>1</sup>Based upon <sup>12</sup>C. ( ) indicates the mass number of the longest-lived isotope. <sup>\*</sup>LUPAC conventional atomic weights; standard atomic weights for these elements are expressed in intervals; see [lupac.org](http://lupac.org) for an explanation and values.

For a description of the data, visit [physics.nist.gov/data](http://physics.nist.gov/data)  
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