

The Atom

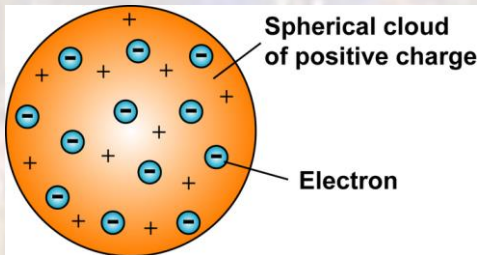
Last updated 2/4/22

These concepts have been greatly simplified

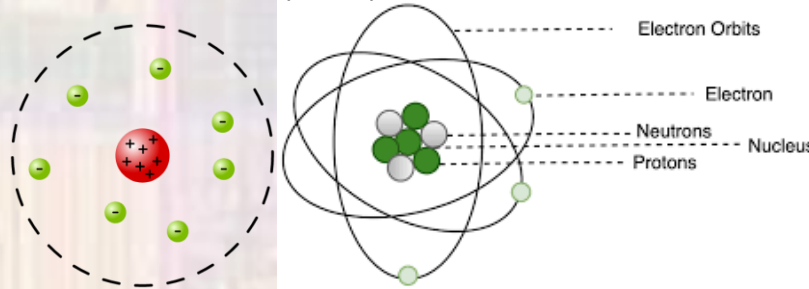
The Atom

- Our understanding of atomic structure has changed over time

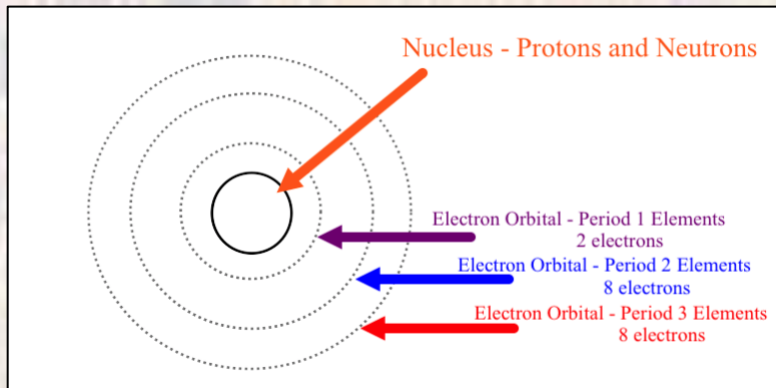
Thomson (1897) – Plum Pudding



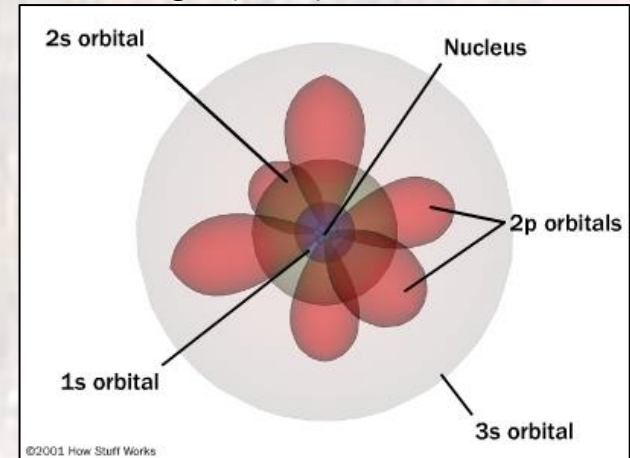
Rutherford (1909) – Distinct nucleus



Bohr (1913) – Electron Orbitals



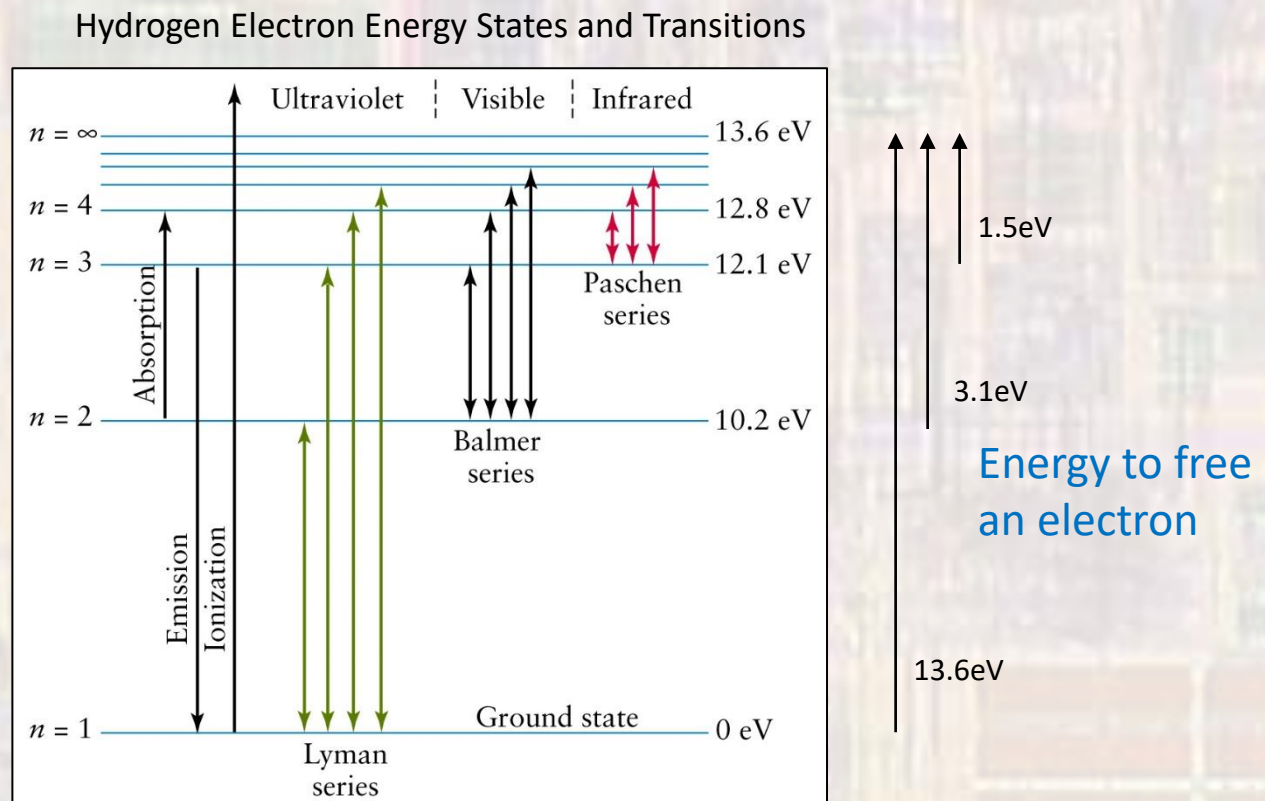
Schrödinger (1926) – Electron Clouds



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The Atom

- Electrons are only allowed to occupy specific energy levels (states)



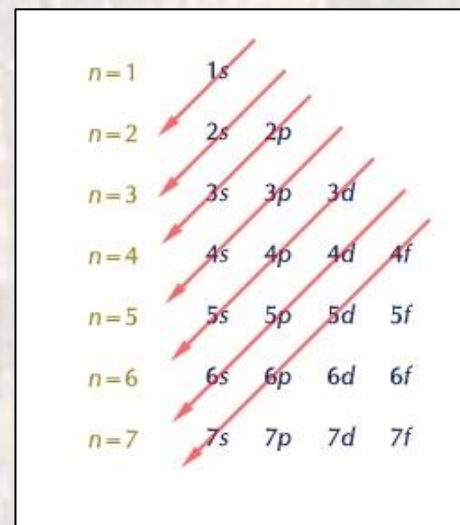
The Atom

- Electron configurations
 - As the atomic number increases, more electrons are associated with the atom
 - These electrons occupy specific energy levels

Energy levels and # of electrons / level

| Energy Level (n) | Sublevels in main energy level (n sublevels) | Number of orbitals per sublevel | Number of Electrons per sublevel | Number of electrons per main energy level ($2n^2$) |
|------------------|--|---------------------------------|----------------------------------|--|
| 1 | s | 1 | 2 | 2 |
| 2 | s | 1 | 2 | 8 |
| | p | 3 | 6 | |
| 3 | s | 1 | 2 | 18 |
| | p | 3 | 6 | |
| | d | 5 | 10 | |
| 4 | s | 1 | 2 | 32 |
| | p | 3 | 6 | |
| | d | 5 | 10 | |
| | f | 7 | 14 | |

Energy level fill order



All electrons at a given level are filled before filling the next level

The Atom

- Electron configurations

Electron Configurations in the Periodic Table

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|----------------|----------|--|-----------|-----------|-----------|-----------|-----------|-----------|----------|-----------|-----------|-----------|-----------------|----------|----------|----------|----------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------------|----------|----------|---------|----------|----------|----------|----------|----------|----------|----------|-----------|-----------|-----------|-----------------|
| 1 H 1s | | | | | | | | | | | | | | | | | 2 He 1s | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 Li 2s | 4 Be | | | | | | | | | | | 5 B | 6 C | 7 N | 8 O | 9 F | 10 Ne 2p | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 11 Na 3s | 12 Mg | | | | | | | | | | | 13 Al | 14 Si | 15 P | 16 S | 17 Cl | 18 Ar 3p | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 19 K 4s | 20 Ca | 21 Sc | 22 Ti | 23 V | 24 Cr | 25 Mn | 26 Fe | 27 Co | 28 Ni | 29 Cu | 30 Zn | 31 Ga | 32 Ge | 33 As | 34 Se | 35 Br | 36 Kr 4p | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 37 Rb 5s | 38 Sr | 39 Y | 40 Zr | 41 Nb | 42 Mo | 43 Tc | 44 Ru | 45 Rh | 46 Pd | 47 Ag | 48 Cd | 49 In | 50 Sn | 51 Sb | 52 Te | 53 I | 54 Xe 5p | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 55 Cs 6s | 56 Ba | 57 La | 72 Hf | 73 Ta | 74 W | 75 Re | 76 Os | 77 Ir | 78 Pt | 79 Au | 80 Hg | 81 Tl | 82 Pb | 83 Bi | 84 Po | 85 At | 86 Rn 6p | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 87 Fr 7s | 88 Ra | 89 Ac | 104 Rf | 105 Db | 106 Sg | 107 Bh | 108 Hs | 109 Mt | 110 | 111 | 112 | 113 | 114 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | <table border="1" style="width: 100%; text-align: center;"> <tbody> <tr> <td>58 Ce</td> <td>59 Pr</td> <td>60 Nd</td> <td>61 Pm</td> <td>62 Sm</td> <td>63 Eu</td> <td>64 Gd</td> <td>65 Tb</td> <td>66 Dy</td> <td>67 Ho</td> <td>68 Er</td> <td>69 Tm</td> <td>70 Yb</td> <td>71 Lu 4f</td> </tr> <tr> <td>90 Th</td> <td>91 Pa</td> <td>92 U</td> <td>93 Np</td> <td>94 Pu</td> <td>95 Am</td> <td>96 Cm</td> <td>97 Bk</td> <td>98 Cf</td> <td>99 Es</td> <td>100 Fm</td> <td>101 Md</td> <td>102 No</td> <td>103 Lr 5f</td> </tr> </tbody> </table> | | | | | | | | | | | | | | | 58 Ce | 59 Pr | 60 Nd | 61 Pm | 62 Sm | 63 Eu | 64 Gd | 65 Tb | 66 Dy | 67 Ho | 68 Er | 69 Tm | 70 Yb | 71 Lu 4f | 90 Th | 91 Pa | 92 U | 93 Np | 94 Pu | 95 Am | 96 Cm | 97 Bk | 98 Cf | 99 Es | 100 Fm | 101 Md | 102 No | 103 Lr 5f |
| 58 Ce | 59 Pr | 60 Nd | 61 Pm | 62 Sm | 63 Eu | 64 Gd | 65 Tb | 66 Dy | 67 Ho | 68 Er | 69 Tm | 70 Yb | 71 Lu 4f | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 90 Th | 91 Pa | 92 U | 93 Np | 94 Pu | 95 Am | 96 Cm | 97 Bk | 98 Cf | 99 Es | 100 Fm | 101 Md | 102 No | 103 Lr 5f | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

by: Sarah Faizi

The Atom

- Valence Electrons
 - Electrons in the outer “shell” of the atom
 - Easiest electrons to free from the atom

Valence Electrons in Each Group

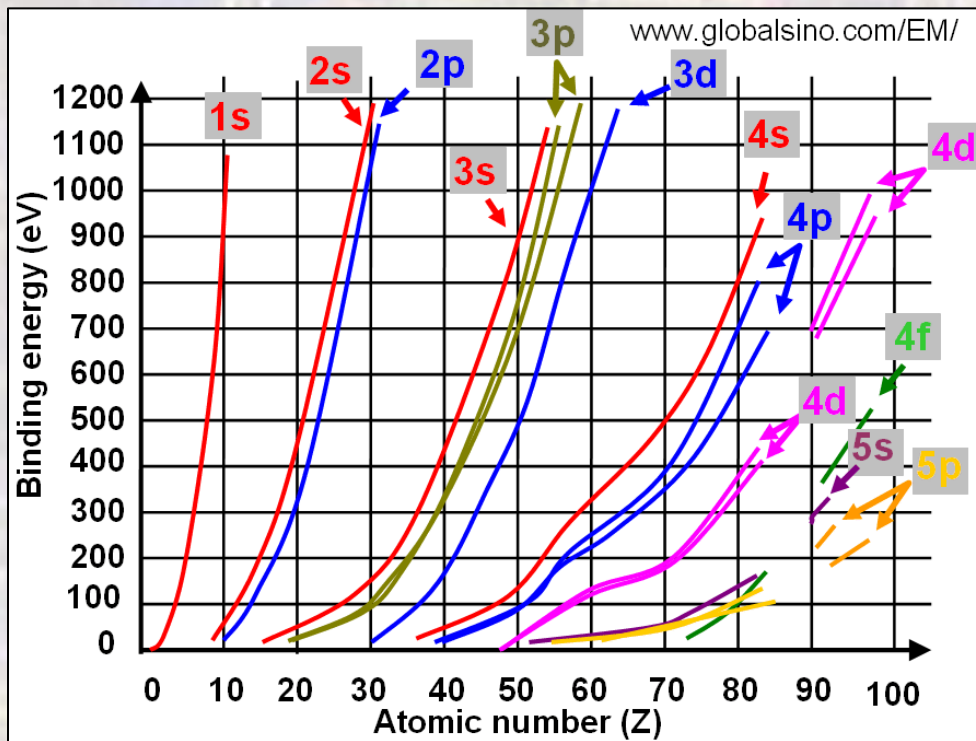
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|----------|----------|--|--|--|--|--|--|--|--|--|----------|----------|----------|----------|----------|----------|--|--|--|--|--|----------|
| 1 | | | | | | | | | | | | | | | | | | | | | | 2 |
| 1 | 2 | | | | | | | | | | 3 | 4 | 5 | 6 | 7 | 8 | | | | | | 8 |
| 1 | 2 | | | | | | | | | | 3 | 4 | 5 | 6 | 7 | 8 | | | | | | 8 |
| 1 | 2 | | | | | | | | | | 3 | 4 | 5 | 6 | 7 | 8 | | | | | | 8 |
| 1 | 2 | | | | | | | | | | 3 | 4 | 5 | 6 | 7 | 8 | | | | | | 8 |
| 1 | 2 | | | | | | | | | | 3 | 4 | 5 | 6 | | | | | | | | |

These are complicated

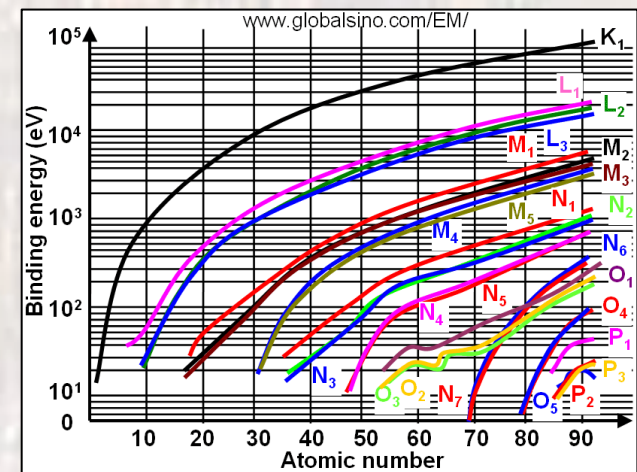
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| | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | |

The Atom

- Binding Energy
 - Energy required to free an electron from an atom
 - Once a shell is “protected” the binding energy goes up fast



| Conversion ^{[2],[3]} | | | | | |
|-------------------------------|-----|-----|-----|-------------------|----------------|
| Quantum numbers | | | | Atomic notation | X-ray notation |
| n | l | s | j | | |
| 1 | 0 | 1/2 | 1/2 | 1S _{1/2} | K ₁ |
| 2 | 0 | 1/2 | 1/2 | 2S _{1/2} | L ₁ |
| 2 | 1 | 1/2 | 1/2 | 2P _{1/2} | L ₂ |
| 2 | 1 | 3/2 | 3/2 | 2P _{3/2} | L ₃ |
| 3 | 0 | 1/2 | 1/2 | 3S _{1/2} | M ₁ |
| 3 | 1 | 1/2 | 1/2 | 3P _{1/2} | M ₂ |
| 3 | 1 | 3/2 | 3/2 | 3P _{3/2} | M ₃ |
| 3 | 2 | 1/2 | 3/2 | 3D _{3/2} | M ₄ |
| 3 | 2 | 5/2 | 5/2 | 3D _{5/2} | M ₅ |



The Atom

- A few atoms of interest

Silicon

Symbol: Si
Atomic number: 14
Atomic mass: 28.0855 au
Electron Config: $1s^2 2s^2 2p^6 3s^2 3p^2$ [Ne] $3s^2 3p^2$
Valence Electrons: 4, (4 empty spots)

8 possible
states / atom

Boron

Symbol: B
Atomic number: 5
Atomic mass: 10.811 au
Electron Config: $1s^2 2s^2 2p^1$ [He] $2s^2 2p^1$
Valence Electrons: 3, (1 empty spot)

Phosphorus

Symbol: P
Atomic number: 15
Atomic mass: 30.974 au
Electron Config: $1s^2 2s^2 2p^6 3s^2 3p^3$ [Ne] $3s^2 3p^3$
Valence Electrons: 5, (3 empty spots)