

# **IT'S ELEMENTAL**

**THE HIDDEN CHEMISTRY  
IN EVERYTHING**

**KATE BIBERDORF**





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It's Elemental: The Hidden Chemistry in Everything

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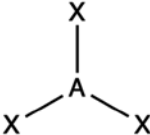
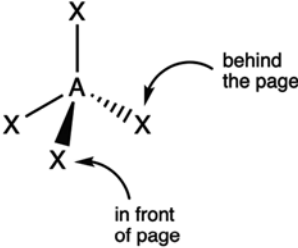
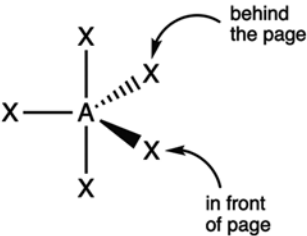
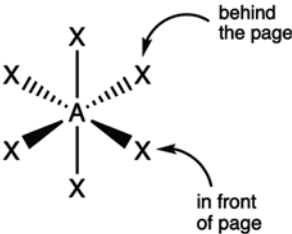
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# 2

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## **ALL ABOUT THE SHAPE**

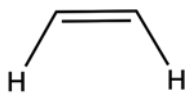
Atoms in Space

| FORMULA | SHAPE                | STRUCTURE   |
|---------|----------------------|---|
| $AX_2$  | Linear               | $X-A-X$   |
| $AX_3$  | Trigonal Planar      |    |
| $AX_4$  | Tetrahedral          |    |
| $AX_5$  | Trigonal Bipyramidal |   |
| $AX_6$  | Octahedral           |  |

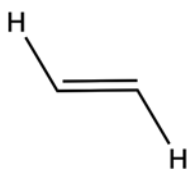
## ORIENTATION





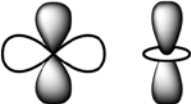



## STRUCTURE

cis



trans

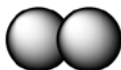


| ORBITAL  | SHAPE(S)  | COMBINED ORBITALS   |
|----------|---|---|
| <i>s</i> |  |  |
| <i>p</i> |  |  |
| <i>d</i> |  |  |
| <i>f</i> |  |  |

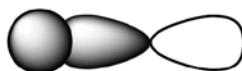
## ORBITAL

## COMBINED ORBITALS

*s-s*  
head-on overlap



*s-p*  
head-on overlap



*p-p*  
head-on overlap



*p-p*  
side-on overlap



# 3

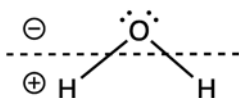
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## **LET'S GET PHYSICAL**

Solids, Liquids, and Gases



There are two different ways that the electrons can distribute themselves across a molecule, giving us polar and nonpolar molecules. If the molecule can be split in half symmetrically, then it is considered to be a *polar* molecule. This means that electrons are not perfectly distributed across a molecule. Instead, there is a positive side and a negative side—just like a standard magnet.



Let's look more closely at how the electrons are distributed in water. Like I mentioned earlier, the oxygen in water carries a partially negative charge. Therefore, both hydrogens carry partially positive charges. This is true for every single water molecule on Earth. The oxygen is always partially negative and the hydrogens are always partially positive. In these situations, we can actually divide the molecule in half to give us one positive side and one negative side, creating poles on the molecule.

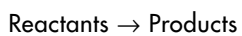
# 4

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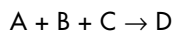
## **BONDS ARE MEANT TO BE BROKEN**

Chemical Reactions

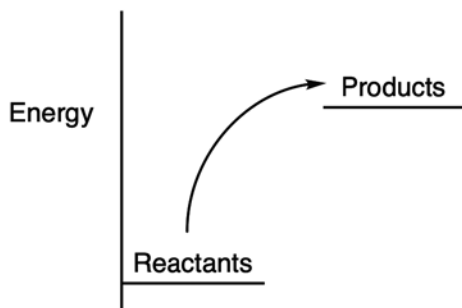
A generic chemical equation looks like this:



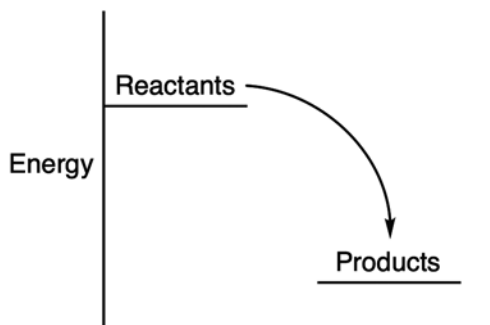
Or like this:



If more energy is put into the reaction than released, then the total energy for the reaction is positive. The energy changes are defined as *endothermic*.



When the new bonds are stronger than the original bonds, the reaction is *exothermic*. Energy is released because the reactants start at higher energy than the products.



# Periodic Table of Elements

|                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |
|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| 1A<br>1            |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    | 8A<br>18           |                    |                    |                    |                    |                    |
| 1<br>H<br>1.008    | 2A<br>2            |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    | 3A<br>13           | 4A<br>14           | 5A<br>15           | 6A<br>16           | 7A<br>17           | 2<br>He<br>4.003   |
| 3<br>Li<br>6.941   | 4<br>Be<br>9.012   |                    |                    |                    |                    |                    |                    |                    |                    |                    |                    | 5<br>B<br>10.81    | 6<br>C<br>12.01    | 7<br>N<br>14.01    | 8<br>O<br>16.00    | 9<br>F<br>19.00    | 10<br>Ne<br>20.18  |
| 11<br>Na<br>22.99  | 12<br>Mg<br>24.31  | 3B<br>3            | 4B<br>4            | 5B<br>5            | 6B<br>6            | 7B<br>7            | 8B<br>8            | 8B<br>9            | 8B<br>10           | 1B<br>11           | 2B<br>12           | 13<br>Al<br>26.98  | 14<br>Si<br>28.09  | 15<br>P<br>30.97   | 16<br>S<br>32.07   | 17<br>Cl<br>35.45  | 18<br>Ar<br>39.95  |
| 19<br>K<br>39.10   | 20<br>Ca<br>40.08  | 21<br>Sc<br>44.96  | 22<br>Ti<br>47.87  | 23<br>V<br>50.94   | 24<br>Cr<br>52.00  | 25<br>Mn<br>54.94  | 26<br>Fe<br>55.85  | 27<br>Co<br>58.93  | 28<br>Ni<br>58.69  | 29<br>Cu<br>63.55  | 30<br>Zn<br>65.38  | 31<br>Ga<br>69.72  | 32<br>Ge<br>72.64  | 33<br>As<br>74.92  | 34<br>Se<br>78.96  | 35<br>Br<br>79.90  | 36<br>Kr<br>83.80  |
| 37<br>Rb<br>85.47  | 38<br>Sr<br>87.62  | 39<br>Y<br>88.91   | 40<br>Zr<br>91.22  | 41<br>Nb<br>92.91  | 42<br>Mo<br>95.94  | 43<br>Tc<br>(98)   | 44<br>Ru<br>101.07 | 45<br>Rh<br>102.91 | 46<br>Pd<br>106.42 | 47<br>Ag<br>107.87 | 48<br>Cd<br>112.41 | 49<br>In<br>114.82 | 50<br>Sn<br>118.71 | 51<br>Sb<br>121.76 | 52<br>Te<br>127.60 | 53<br>I<br>126.90  | 54<br>Xe<br>131.29 |
| 55<br>Cs<br>132.91 | 56<br>Ba<br>137.33 | 57<br>La<br>138.91 | 72<br>Hf<br>178.49 | 73<br>Ta<br>180.95 | 74<br>W<br>183.84  | 75<br>Re<br>186.21 | 76<br>Os<br>190.23 | 77<br>Ir<br>192.22 | 78<br>Pt<br>195.08 | 79<br>Au<br>196.97 | 80<br>Hg<br>200.59 | 81<br>Tl<br>204.38 | 82<br>Pb<br>207.20 | 83<br>Bi<br>208.98 | 84<br>Po<br>(209)  | 85<br>At<br>(210)  | 86<br>Rn<br>(222)  |
| 87<br>Fr<br>(223)  | 88<br>Ra<br>(226)  | 89<br>Ac<br>(227)  | 104<br>Rf<br>(261) | 105<br>Db<br>(262) | 106<br>Sg<br>(266) | 107<br>Bh<br>(264) | 108<br>Hs<br>(277) | 109<br>Mt<br>(268) | 110<br>Ds<br>(281) | 111<br>Rg<br>(281) | 112<br>Cn<br>(285) | 113<br>Nh<br>(286) | 114<br>Fl<br>(289) | 115<br>Mc<br>(289) | 116<br>Lv<br>(293) | 117<br>Ts<br>(293) | 118<br>Og<br>(294) |

|                           |                           |                           |                          |                           |                           |                           |                           |                           |                           |                           |                           |                           |                           |
|---------------------------|---------------------------|---------------------------|--------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|
| 58<br><b>Ce</b><br>140.12 | 59<br><b>Pr</b><br>140.91 | 60<br><b>Nd</b><br>144.24 | 61<br><b>Pm</b><br>(145) | 62<br><b>Sm</b><br>150.36 | 63<br><b>Eu</b><br>151.96 | 64<br><b>Gd</b><br>157.25 | 65<br><b>Tb</b><br>158.93 | 66<br><b>Dy</b><br>162.50 | 67<br><b>Ho</b><br>164.93 | 68<br><b>Er</b><br>167.26 | 69<br><b>Tm</b><br>168.93 | 70<br><b>Yb</b><br>173.04 | 71<br><b>Lu</b><br>174.97 |
| 90<br><b>Th</b><br>232.04 | 91<br><b>Pa</b><br>231.04 | 92<br><b>U</b><br>238.03  | 93<br><b>Np</b><br>(237) | 94<br><b>Pu</b><br>(244)  | 95<br><b>Am</b><br>(243)  | 96<br><b>Cm</b><br>(247)  | 97<br><b>Bk</b><br>(247)  | 98<br><b>Cf</b><br>(251)  | 99<br><b>Es</b><br>(252)  | 100<br><b>Fm</b><br>(257) | 101<br><b>Md</b><br>(258) | 102<br><b>No</b><br>(259) | 103<br><b>Lr</b><br>(262) |

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# GLOSSARY

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**Acid:** a molecule with a pH lower than 7

**Aerobic:** a reaction that needs oxygen to occur

**Alcohol:** molecules (usually hydrocarbons) that contain an oxygen-hydrogen covalent bond

**Amino acids:** molecules that contain only carbon, hydrogen, nitrogen, and oxygen, atoms that are necessary for human life

**Anaerobic:** a process that occurs without the presence of oxygen

**Anion:** a negatively charged atom

**Aromatic:** molecules that are fragrant in nature

**Atom:** the fundamental building block of matter (contains protons, neutrons, and electrons)

**Atomic mass:** the sum of the protons and weighted average of neutrons in an atom

**Atomic number:** the number of protons in an atom

**Base:** a molecule with a pH greater than 7

**Bond:** a chemical interaction between two atoms (usually by sharing or transferring electrons)

**Carbohydrates:** the sugar and starch molecules in our foods

**Catalyst:** a molecule that provides an alternate pathway for a chemical reaction (and usually increases the rate of reaction)

**Cation:** a positively charged atom

**Cis:** the orientation that occurs when both functional groups are on the same side of the molecule

**Covalent bond:** an interaction that occurs when two atoms share electrons

**Density:** the relative mass occupied by a substance in a specific volume

**Dipole-dipole:** IMFs that occur between two polar molecules

**Dispersion forces:** IMFs that occur between two nonpolar molecules

**Electrolytes:** ionic species (or salts)

**Electromagnetic radiation:** electromagnetic waves that propagate through space in the form of radio, microwave, infrared, visible, ultraviolet, X-ray, and gamma radiation

**Electron:** a negatively charged particle located outside of the nucleus of an atom

**Electronegativity:** a measure of how attracted one atom's electrons are to another atom's nucleus



**Element:** a collection of atoms with the same number of protons (and physical/chemical properties)

**Endothermic:** a process that absorbs energy (becomes colder)

**Enzymes:** naturally occurring molecules that act like catalysts to cause a chemical reaction (often within the human body)

**Exothermic:** a process that releases energy (becomes warmer)

**Fatty acids:** a long molecule that has a nonpolar end (hydrocarbons) and a polar end (a carboxylic acid)

**Functional groups:** one part of the molecule that greatly affects the chemical reactivity of the entire molecule

**Glucose:** a monosaccharide (sugar) with the molecular formula  $C_6H_{12}O_6$

**Hormone:** a molecule that carries “messages” from one place to another in the body

**Hydrocarbon:** a molecule that contains only hydrogen and carbon atoms

**Hydrogen bonding:** IMFs that occur between two molecules that each contain covalent bonds between hydrogen and either nitrogen, oxygen, or fluorine atoms

**Hydrophobic:** a nonpolar molecule that repels water

**Intermolecular forces (IMFs):** attractions that occur between molecules

**Intramolecular forces:** attractions within the molecule (usually bonds between atoms)

**Ion:** a charged atom (it can be positive or negative)

**Ionic bond:** an interaction that occurs when one atom transfers electrons to another atom

**Isotopes:** two or more elements that have the same number of protons, but a different number of neutrons

**Macroscopic:** something that can be observed with the human eye (without special instruments)

**Mass number:** the number of protons and neutrons in an atom

**Microscopic:** something that cannot be observed with the human eye (without special instruments)

**Molecule:** a substance that contains two or more atoms

**Neutron:** a neutrally charged particle located in the nucleus of an atom

**Nonpolar:** a molecule (or bond) that has an even distribution of electrons

**Nucleus:** the center of the atom (contains protons and neutrons)

**Peptide:** a molecule made of two or more amino acids

**Polar:** a molecule (or bond) that has an uneven distribution of electrons

**Polymer:** large molecules of repeating units

**Polypeptides:** the protein molecules in our foods

**Proton:** a positively charged particle located in the nucleus of an atom

**Thermal energy:** kinetic energy in the form of heat

**Trans:** the orientation that occurs when both functional groups are on the opposite side of the molecule

**Triglycerides:** the molecules in fats and oils in our foods

**Valence electron:** electrons in the outer layer of the atom

**Vaporization:** the phase change that occurs when a liquid changes into a gas