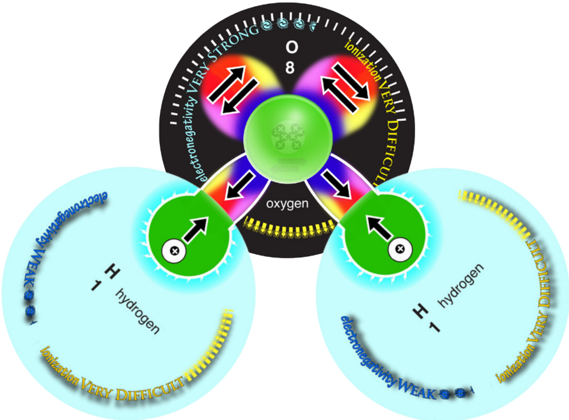
JOURNEY TO NEON®

CHEMISTRY GAME SERIES

ELECTRONIMOES©

Circular Atom Cards



Match the electron arrows to play chemical bonding games

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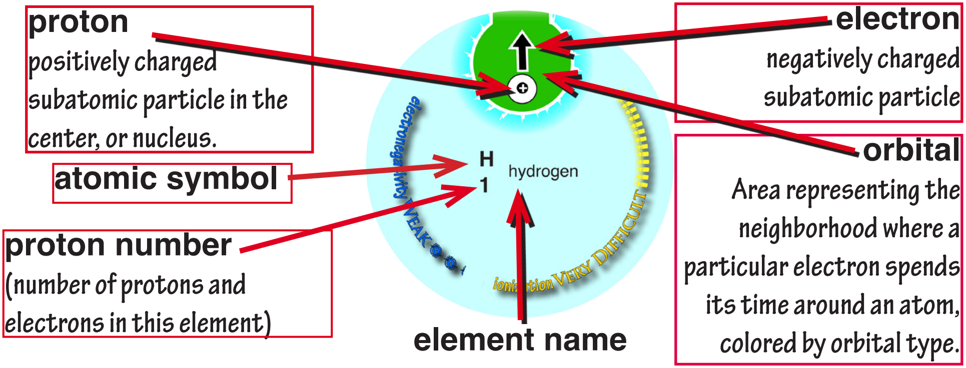
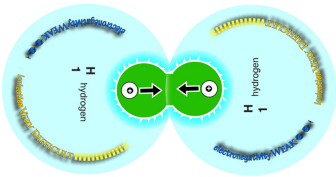
www.electronimoes.com

ELECTRONIMOES©

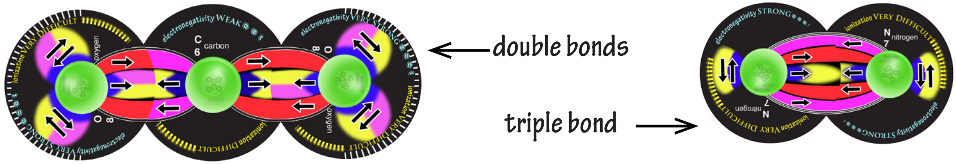
This double deck of round cards is all about atoms and bonding them together to make molecules. The games described in this booklet could be played by the young and curious or more advanced chemistry enthusiasts. They range from simple ones, with similarities to dominoes and Old Maid, to more advanced games which explore properties of the elements. For all the games, it is helpful to know the basics about an atom. These two pages show how to match up the cards, and the anatomy of an atom as it appears on a card:



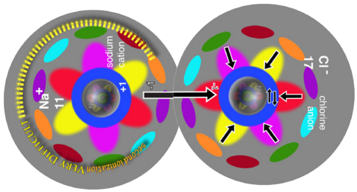
Hydrogen is one of the 18 **elements** represented in this deck. An **element** is an atom with a particular number of protons and an equal number of electrons. You could make the molecule H_2 (two hydrogens bonded together) by overlapping two hydrogen cards. When two atoms share a pair of electrons like this, they are said to be joined together by a **single bond**. Any time you see a white outline around the atoms on two cards, they are a match.



When two atoms share **two** pairs of electrons, it is called a **double bond**. When **three** pairs of electrons are shared between two atoms, it is called a **triple** bond. Look for the lines in the red box to help you match up the cards.



When a card says "cation", it matches with a card that says "anion". These atoms are not sharing electrons equally. The cation may be thought of as losing an electron to the anion. The arrow end from the "cation" card must be matched with the arrow head on the "anion" card.



When you play the more advanced games which explore such concepts as *ionization energy* and *electronegativity*, look for more information on these concepts, the colors and symbolism in the cards in the **appendix**.

Game One

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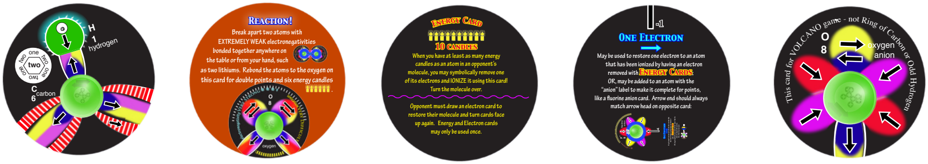
Object of the game: Collect the most points while connecting the atom cards into molecular creations in the center of the table.

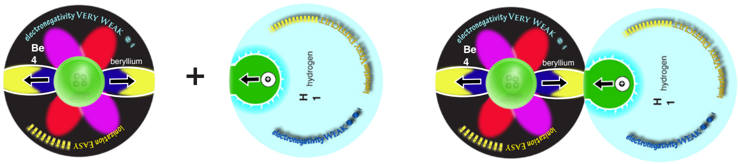
Certain cards will not be used for this game and should first be removed from the deck, or discarded as you go along and replaced with a new card from the pile. These are the special cards, left to right; benzene ring cards, Reaction Cards, Energy Cards, Electron Cards, and Volcano Game cards).

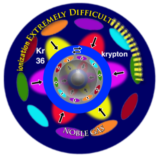


1. Shuffle the cards and deal out 14 cards to each player. Draw lots or player to the right of the dealer goes first. Take turns going first if you play more than one game. Flip one card over from the top of the deck and put it in the center.

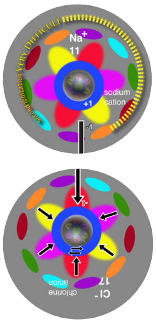
2. If it is your turn, look at your hand and see if you can "bond" any of your atoms to the atom in the center of the table. If a beryllium is

turned over, for example, you could place a hydrogen on it.





If the card is a noble gas, you will notice that it can not make any bonds. Take this card, put it in your winnings pile, and flip over a new card from the top of the deck.



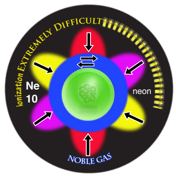
If the displayed card says "cation" on it, and you have a card in your hand that says "anion", this is a bonding match. The same is true if the displayed card is an "anion" and you have a "cation" card. If you do not have a card to match the cation or anion card, you may flip over a **second** card from the top of the pile. There will now be **two** cards face up. If the second card happens to be a match to the anion or cation, you may bond them together. If the second card is yet another cation or anion, but is not a match to the first, you may flip over a **third** card. This is the only situation where three cards as three separate molecules would be face up; two anion (or cation) cards and one atom of another type.

3. If you are not able to bond an atom to any card showing, and it was

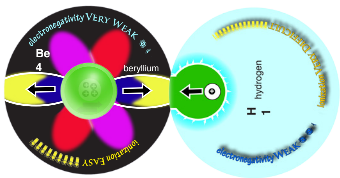
not a noble gas, you must draw from the pile until you can bond something to a card that is face up in the center.

4. Once you have bonded an atom, drawn a noble gas, or drawn a cation or anion card that was a bonding match for the displayed card in the center of the table, record your score for the round. **If the players are younger, they may skip scoring as they go along and simply count their winnings pile at the end, subtracting the number of cards left in their hand.**

5. If you are keeping score of your points, score as follows:

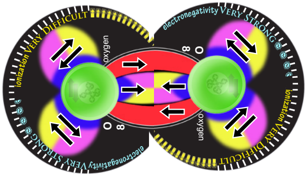


- If you picked up a noble gas, you get the number of points equal to the proton number on that card. Neon, for example, is worth ten points. Record your points and keep this noble gas in your winnings pile. If you have any other noble gasses in your hand, you may record their points and put them in your winnings pile, but you must draw a replacement card for each noble gas that was in your hand.

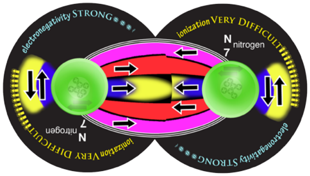


- If you bonded two atoms together, such as a hydrogen onto the beryllium in the example, or a cation to an anion, you add up the proton numbers of the two atoms which you bonded together. Beryllium bonded to hydrogen would be worth 5 points.

- If the two atoms are sharing two pairs of electrons (four arrows), this is called a double bond and is worth double points. For example, if there was an oxygen ready to make a double bond face up, and you bonded another oxygen to it, you would get (8 + 8) x 2 = 32 points. Triple bonds are worth triple points.



O_2 double points



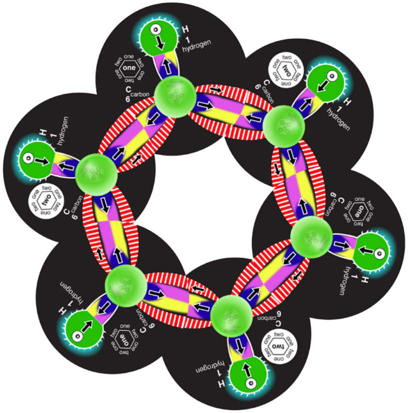
N_2 triple points

6. If you complete a molecule, and so no more atoms may be bonded to it, you may take **all** the atoms in this molecule for your winnings pile. The O_2 and N_2 molecules on the right are complete. Turn over a new card from the deck for the next player.

7. There should now be at least one card face up in the center, and play passes to the right, starting from step 2 again. If you draw a noble gas, record your points, put it in your winnings pile, and draw another card. This is the end of your turn.

8. After a player runs out of cards, the game is over when all players have had their turn for this round (the one who starts last ends last). All players count the number of cards in their winnings pile and add this number to their total points. Subtract the proton numbers of the cards left in your hand. The player with the most points wins!

Game Two
Ring of Carbon



Objective: Be the one to make the most points in **complete** molecules either before any player completes a benzene ring with the special benzene ring cards, or all the cards in the deck have been played.

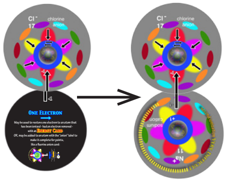
Rules for play

1. Shuffle and deal ten cards.

2. All players lay down as many **complete** molecules (all electrons must be part of a pair; no open bonds) as they can with the cards in their hand. If you have a ring card, you **may** lay it down in front of you **incomplete**. Two different kinds of cards are required to make a benzene ring. The cards with the white circle must alternate with the cards that have only a white hexagon, as shown above.

3. All players then draw enough cards to have ten cards again. Players take turns, starting with the dealer. On your turn, put down all the complete molecules you can make in front of you. Then use any special cards you have (Energy Cards, Electron Cards, or Reaction Cards, described in the next section), with the following rules:

- You **may not** ionize the benzene cards of other players with Energy Cards.
- Unwanted benzene ring cards are kept in your hand, or placed in the middle of the table up for grabs.
- Card trading is optional.
- Cooperation among players to complete a ring (thus ending the game and splitting the benzene ring points between them) is optional.
- No player may rearrange the molecules they have already laid out without using a Reaction Card, *unless you have laid down an anion along with an Electron Card, and draw a molecule that fits with your anion (a cation card). You may pick the Electron Card back up and swap it for your new cation.*

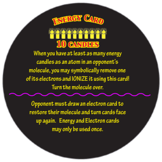


4. When all players have completed a round, start again by first picking enough cards to have ten once again. Play starts with the person to the right of the last person to start. If a player has a complete benzene ring, or all players are not able to draw enough cards to give themselves at least **eight** total cards, the game is over (even if no one has yet made a complete benzene ring).
5. If the game is over, add up the proton numbers in your complete molecules, including your benzene ring IF it is complete. No points for noble gasses or molecules that are still ionized. Deduct points for cards still in your hand or unfinished molecules in front of you. The following molecules are worth DOUBLE points!

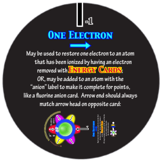
H_2O (water)	**CO_2** (carbon dioxide)	**CH_4** (methane*)
NH_3 (ammonia)	**O_2** (oxygen gas)	**C_2H_2** (ethyne*)
NaCl (sodium chloride, or table salt)	**N_2** (nitrogen gas)	**C_2H_4** (ethene*)

* = IUPAC name, International Union of Pure Applied Chemistry.

The Special Cards: There are five cards which are not atom cards: the Energy Card, the Electron Card, and three Reaction Cards.

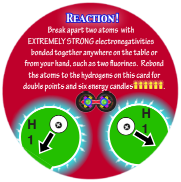


The Energy Card is used to "ionize" an atom by removing one of its electrons. If you have enough total energy candles  to match the number of candles on an opponent's atom card, turn over the molecule containing this atom to symbolize that one of its atoms has been ionized. This molecule is no longer worth any points. Discard this used Energy Card. You may not ionize benzene ring cards.



The Electron Card may be used to restore an ionized molecule that had an electron "removed" with the Energy Card. Flip the cards in this "ionized" molecule face up again. Discard this Electron Card.

The Electron Card may also be combined with an "anion" card and put down for points. If you draw a "cation" card, you may replace the Electron Card with the cation card. Discard or keep the Electron Card.

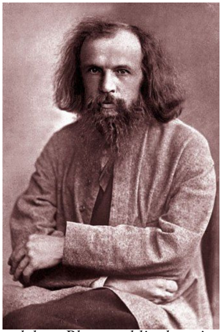


There are three Reaction Cards. The one with the hydrogens on it may be used if you or an opponent has a molecule containing two atoms bonded together which have two "Extremely Strong" electronegativities. You may also use this card if you have two such atoms in your hand. The electronegativity of each atom is printed on the cards using blue symbols on a scale from 1 to 4.5, where 1 is least electronegative. The more electronegative an atom is, the more able it is to attract electrons to itself. A molecule of two fluorines, for example, is very reactive in part because both atoms are so electronegative. They each want the shared pair of electrons in this bond for themselves.

The Reaction Card with oxygen on it is used with two molecules that have "Extremely Weak" electronegativities bonded together anywhere on the table or in your hand.

The deep yellow Reaction Card allows you to break any molecule in half and "react" the pieces with atoms from your hand. If you break an opponent's molecule, you must make two new complete molecules without rearranging the atoms in the original molecule halves. Give one of the products (one new complete molecule) to the owner and keep one for yourself. If it is your own molecule, you may make two complete molecule products, or one larger molecule product by inserting atoms between the two halves. See the card for an example.

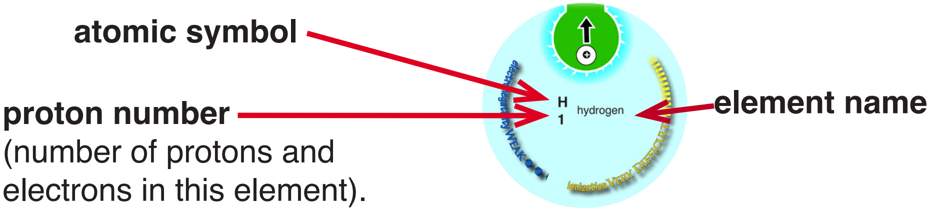
Game Three - The Mendeleev Mindgame



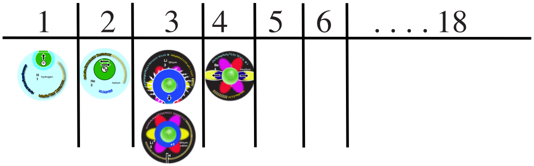
Mendeleev Photo public domain courtesy of the world wide web.

If you look at the cards, you will see that some atoms are able to form more bonds than others. Some have more yellow candles in a ring around the outside, representing how hard it is to remove an electron from the outside of this atom, called the "ionization energy". Some have a greater "electronegativity", the ability of an element to attract more electrons to itself. All of this affects the properties of an element, such as how reactive it is and how many bonds it will make to other atoms. The first person to group atoms by their properties into a table was Dmitri Ivanovich Mendeleev. The Periodic Table of the Elements we use today is based on Mendeleev's table.

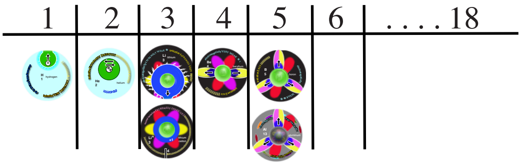
1) You can play this by yourself or players/teams can compete using their own decks. In this game, you will first group the cards in columns by their **proton number.**

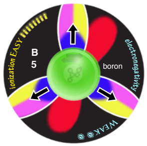


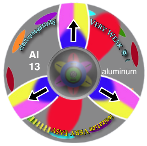
For example, hydrogen would go in the first column, helium in the second, etc. Set duplicate, special, and Volcano Game cards aside. You will only need one of each card.



2) When you have all the atom cards laid out, move any cards that look similar to other cards into the column of the element with the lowest proton number. Boron and aluminum look very similar, even though they have different numbers of protons and electrons. They can both make three bonds, and the colors of their orbitals are the same - blue, magenta and yellow. Aluminum would be moved to column five under boron.

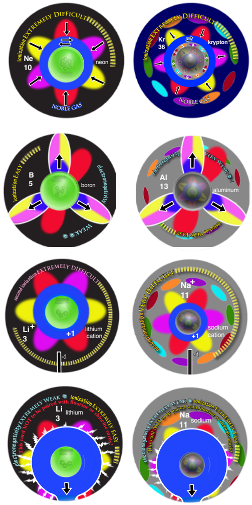






3) When you have all your columns arranged, see how many of your columns contain the same atoms as the columns in the Periodic Table on the back page of this manual, based on Mendeleev's first table. How close did you come to thinking like the great Mendeleev? Use this portion of the deck to play **Concentration** and **Odd Hydrogen**, described next.

Game Four - Odd Hydrogen



Object of Odd Hydrogen: try to escape being the player left with the hydrogen card, the element that does not "fit" neatly into a category.

Using the smaller deck you made playing **Mendeleev Mindgame**, (leaving out duplicates and special cards), shuffle well and deal out all the cards. It is more fun with three or more players. Find all the "pairs"; elements which are in the same row of the periodic table and can make the same number of bonds (like the examples on the right) in your hand. ***Note the similarity of their orbital colors***.

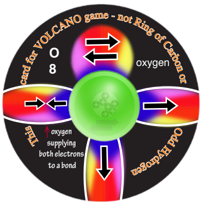
Place your pairs in front of you. First player picks a card from the player to the right without looking at their hand, then discards any new pairs. Continue counter clockwise until all cards are paired up and the only card left in the loser's hand is **Odd Hydrogen**!

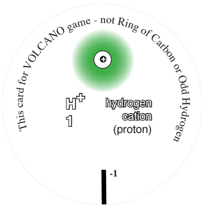
You can play the memory game **Concentration** using the same set of cards as you used to play **Odd Hydrogen**. Shuffle and arrange all cards face down in neat rows. Take turns flipping over two cards. If you find a matching "pair"as above, keep it. If not, turn the cards back over. The player who finds the most pairs wins.

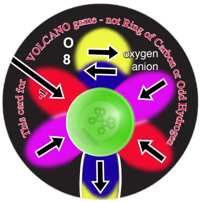
GAME/ACTIVITY FIVE - VOLCANO!

There are three extra cards in the deck that are useful for talking about acids and bases. This is a more advanced chemistry concept, but that shouldn't stop you from using the cards to make all the molecules in that favorite science project with baking soda and vinegar - the volcano! Use the **Electronimoes©** Volcano poster as your guide. A picture of it is on the next page.

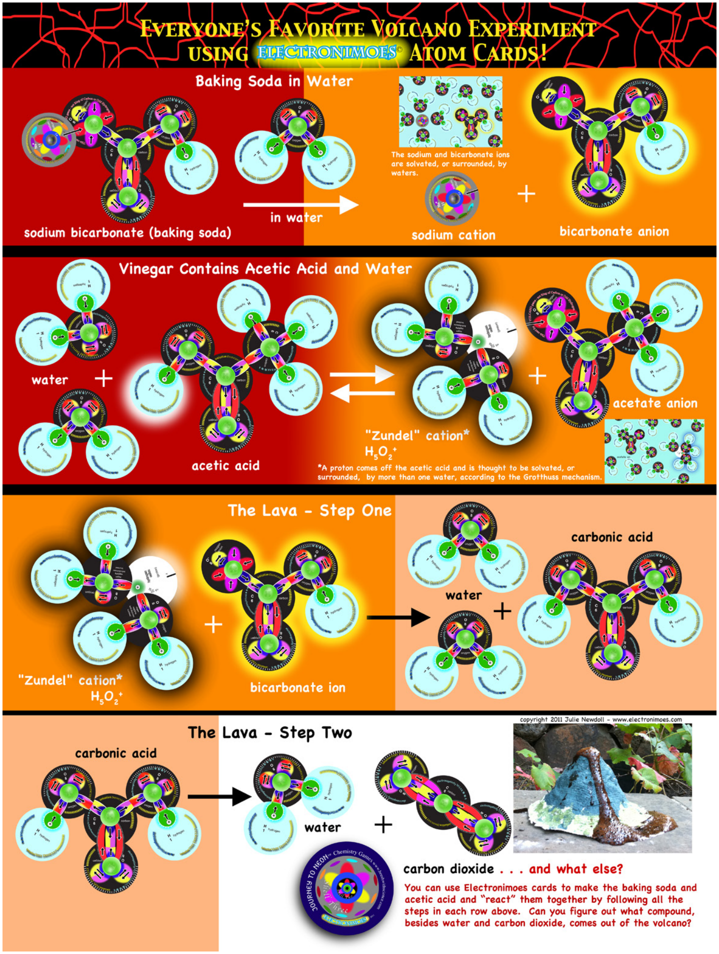
1) Using the cards, make the molecules in the first row - **Baking Soda in Water** - on the LEFT side of the arrow in the red area. These are the "reactants". Then, rearrange these cards to make the "products", or molecules on the right side of the arrow. You may need to swap some cards for others in the deck. Save these products.
2) Next make the products in row two - the **Vinegar** section.
3) Use the products you made in (1) and (2), to carry out the two steps in the "Lava" rows by moving the cards around for each step. There is a product missing in the white box, which also comes out of the volcano in addition to the carbon dioxide and water. What is it?







You will need these three special cards to do the "volcano" reaction.


Everyone's Favorite Volcano Experiment
using Electronimoes© Atom Cards!
Baking Soda in Water
sodium bicarbonate (baking soda)
in water
The sodium and bicarbonate ions are solvated, or surrounded, by waters.
sodium cation
+
bicarbonate anion
Vinegar Contains Acetic Acid and Water
water
+
acetic acid
"Zundel" cation*
$H_5O_2^+$
+
acetate anion
*A proton comes off the acetic acid and is thought to be solvated, or surrounded, by more than one water, according to the Grotthuss mechanism.
The Lava - Step One
"Zundel" cation*
$H_5O_2^+$
+
bicarbonate ion
water
+
carbonic acid
The Lava - Step Two
carbonic acid
water
+
carbon dioxide . . . and what else?
copyright 2011 Julie Newdoll - www.electronimoes.com
You can use Electronimoes cards to make the baking soda and acetic acid and "react" them together by following all the steps in each row above. Can you figure out what compound, besides water and carbon dioxide, comes out of the volcano?

Appendix A

A bit about Atoms

The world is made

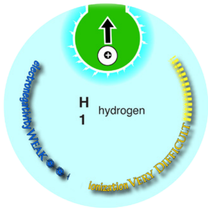
of atoms.

Atoms are very small.

There are about 5 x 10^{21}, or 5,000,000,000,000,000,000,000 atoms in one drop of water. Everything around you is made of atoms - you are made of atoms.

Atoms are small, but they are made of *even smaller* particles. In the center, they have a nucleus which you can think of like the yolk of an egg. Inside the nucleus are neutrons and protons. Outside the nucleus, in the "white" part of the egg, are electrons. Like magnets, the protons are attracted to the electrons, which helps keep the atom from flying apart.

In this deck, and all JOURNEY TO NEON® games, electrons are represented by arrows. Electrons can be thought of as tiny spinning tornadoes of energy. Protons are represented by "plus" signs. Atoms have other kinds of subatomic particles as well, such as neutrons, but they are not represented in the cards.

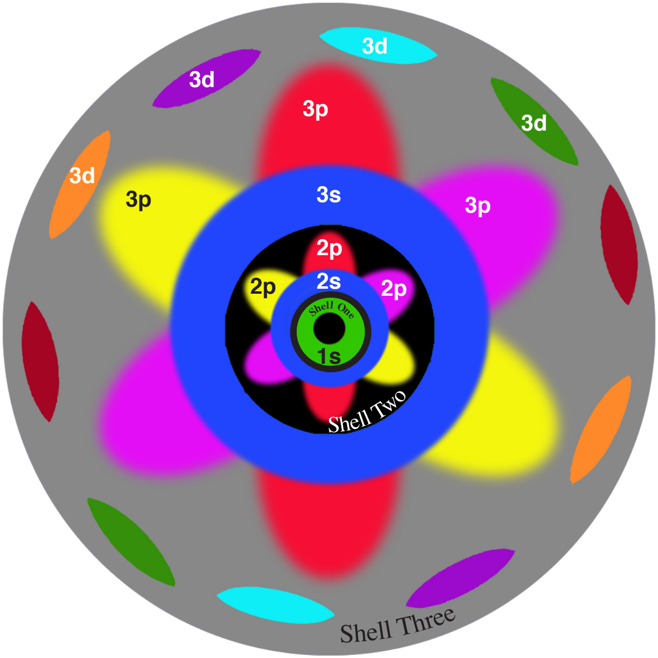


Appendix B
What do the Colors Mean?

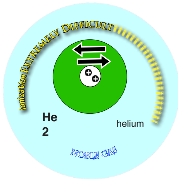
The images on these cards are symbolic representations to help understand bonding and orbitals. They are based on a model which uses orbitals and the hybridization of orbitals created by Linus Pauling (1). You may have noticed that the lines match up when a bond is made, or two halves of an arrow match, but the colors inside the lines do not always match up. This is because the colors indicate what kind of an orbital an electron is in, but orbitals do not have to be arranged the same way for both atoms to make a bond.

The next two pages explain the colors which are used in the cards. In reality, the orbital homes for the electrons do not have a particular color. Atoms and their orbitals are much too small to be seen individually by a microscope, although there are some special types of microscopes which can begin to see fuzzy, general shapes of atoms and molecules.

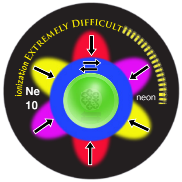
(1) Linus Pauling (March 1932). "The nature of the chemical bond. III. The transition from one extreme bond type to another.". Journal of the American Chemical Society. Retrieved 2008-02-29.



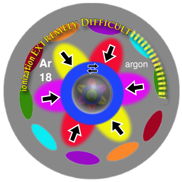
Above is the key to the colors in the cards. In the center, labeled "Shell One", is the lowest energy level in an atom. Cards with a pale blue background have all their electrons in Shell One. You can think of orbitals as homes for electrons. Each shell is like an exclusive neighborhood, allowing only electrons from its own orbital homes to reside there. Shell



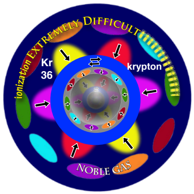
One has just one orbital, called 1s by chemists. It is thought to be spherical, and is the color green in the cards. Each orbital can only hold up to TWO electrons!



Once Shell One is full, a transparent green dome is placed over this orbital. Elements lithium through neon all have a green dome protecting these two electrons in the cards, like neon here. The rest of the electrons in lithium through neon are in Shell Two. Elements with their outermost electrons in Shell Two have **black** backgrounds in the cards. The outermost electrons are the ones that an atom can use to make bonds, and they are called the **valence electrons**. Shell Two has four different orbitals; a 2s orbital (blue in the cards), and three 2p orbitals (magenta, red and yellow in the cards).

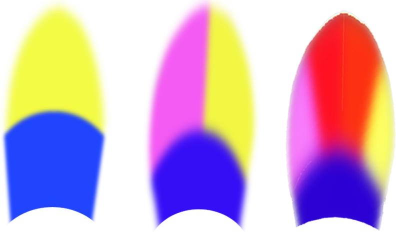


When Shell Two is full, a grey dome is placed over these electrons. Elements sodium through argon have grey domes in the center, like argon. The outermost electrons in these elements are in Shell Three. Elements with their outermost electrons in Shell Three have grey backgrounds in the cards. In addition to a 3s (blue) and three 3p (magenta, red and yellow) orbitals, there are five pairs of d orbitals in Shell Three. Each colored pair of d orbitals may also hold two electrons. The only card which uses d orbitals is krypton, included to make two pairs of noble



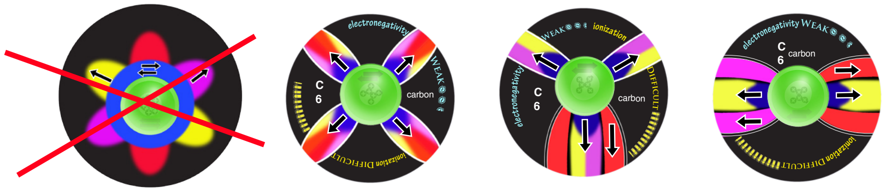
gasses for the game **Old Hydrogen** and **Concentration** on page 14.

Sometimes orbitals are merged together to form hybrid orbitals. These are represented using the colors of the orbitals which merged to form them. An orbital that is blue and yellow, for example, is a mix of the s orbital and one of the p orbitals in a particular shell. It is called an sp orbital by chemists. A hybrid orbital can still hold only up to TWO electrons!



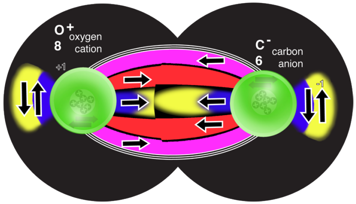
Left to right: sp, sp2, and sp3 hybrid orbitals. S orbitals are blue in all but Shell One in the cards (the 1s orbital is green), p orbitals are magenta, yellow and red.

Orbitals are a way to explain why some elements can bond to different numbers of atoms. Look at the ways carbon arranges its orbitals, in order to be able to bond to two, three or four atoms. If carbon did not hybridize its orbitals together, it would behave as though it could only make two bonds, like the image on the left.



Where is the carbon triple bond card?

Carbon can also bond to just one atom, but there is no card in the deck for this. Carbon would have a lone pair, like nitrogen, and would carry a charge. This is a more complex situation best saved for an advanced deck. Carbon monoxide, CO, is an example of carbon bonding to one atom. Here is one way to represent it.



This deck represents only the first 18 elements, and not every possible arrangement of orbitals are included for all 18 atoms. Sulfur, for example, can bond to six atoms! The arrangement of orbitals in this case is not always agreed upon by all chemists. Special cases like this have been left for another deck.

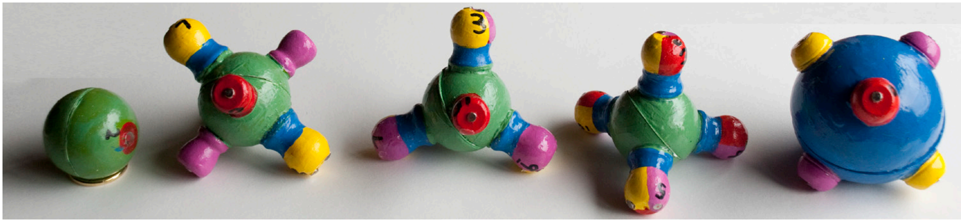
About the Candles

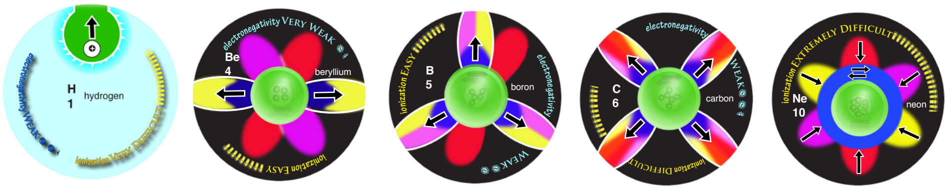
One candle represents 100 kilojoules. One joule is one newton of force applied for one meter. One newton is the force required to accelerate a mass of one kilogram at a rate of one meter per second squared. Ionization energy can be expressed in kilojoules per mole. One mole is the number of atoms in 12 grams of carbon-12 (carbon with 6 protons, 6 electrons and 6 neutrons.)

[redacted]

Atoms are not Flat!

Here are some three dimensional model toys from the JOURNEY TO NEON® game series. Directly below each model is a card which corresponds to it. This gives you a very approximate idea of the shapes of the orbitals and the geometry of the atoms. The orbitals that house electrons are not all spheres! Orbitals and hybrid orbitals come in a variety of shapes. They have been painted in the models using the same color scheme as the cards. Electrons are like spinning tornados of energy, and they can be anywhere in their orbital, like a droplet in a specially shaped cloud.





Periodic Table of the Elements for **Odd Hydrogen** Game

Source public domain courtesy of the world wide web.

Group → / ↓Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	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
5	37 Rb	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
6	55 Cs	56 Ba		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
7	87 Fr	88 Ra		104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 UUb	113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo
Lanthanides				57 La	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
Actinides				89 Ac	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

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