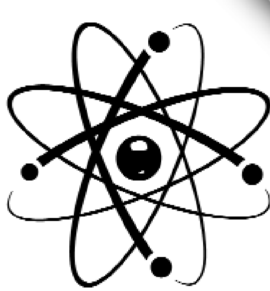
Atomic Structure and the Atom Building Game

cpo science

Games for Learning about the Structure of the Atom



ATOMIC STRUCTURE AND THE ATOM BUILDING GAME

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Thank you for purchasing the CPO Science Atom Building Game.

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INTRODUCTION: THREE GAMES OF ATOMIC STRUCTURE

The three atomic structure games reveal the inner workings of the atom and demonstrate the principles behind the periodic table of the elements, lasers, nuclear reactions, radioactivity, and many other fascinating phenomena. They are also challenging and lots of fun!

ATOMIC CHALLENGE

In this game players use the colorful marbles to simulate electrons, protons, and neutrons as they build and identify different atoms. The objective is to be the first player to use all your marbles. A game for 2-8 players that will be enjoyed from ages 8-adult

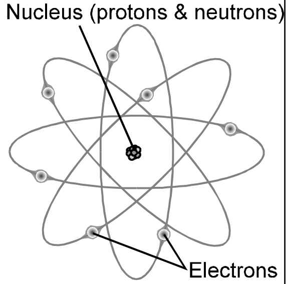
NUCLEAR REACTIONS

In this more advanced game, players score points by building neutral atoms, stable nuclei, and complete atoms that are both neutral and stable. The NUCLEAR REACTIONS cards create a strategic challenge as players try to build their way up the Periodic Table of the Elements.

PHOTONS & LASERS

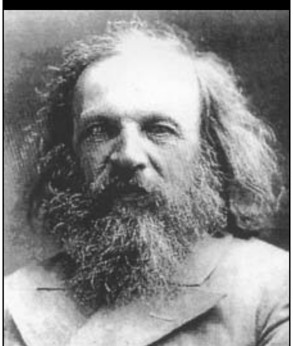
This unique game teaches players how light is emitted and absorbed by atoms. The object of the game is to score points by playing cards and moving electrons up and down energy levels. Pump cards build the atom up to excited states, ready for scoring. Laser cards allow players to strategically move electrons down, scoring points and simulating the emission of light from a real atom.

THE DISCOVERY OF THE ATOM



The atom has a tiny dense nucleus of protons and neutrons surrounded by a cloud of electrons.

1869

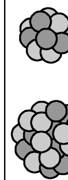


At the age of 35 Dmitri Mendeleev publishes the first version of the Periodic Table of the Elements in which the elements are grouped by common chemical properties. There are gaps in the resulting patterns which lead Mendeleev to predict the existence of three new elements, gallium, scandium, and germanium which are subsequently discovered in 1875, 1879, and 1885.

From the mystical researches of medieval alchemists to the high technology competition to discover new materials, the quest to understand the nature of matter has been a central theme in the evolution of science and technology. The discovery of the structure of the atom makes one of the greatest international detective stories in history. The clues were elusive and often contradictory. The solution elegantly unified physics and chemistry.

Atoms are the tiny building blocks from which matter is made. The various kinds of matter we find around us, such as iron or oxygen, are made from different kinds of atoms. Atoms themselves are made of three basic particles; **electrons, protons,** and **neutrons.** The protons and neutrons are concentrated in a tiny space at the center of the atom called the **nucleus.**

The **atomic number** is the number of protons in the nucleus and determines what **element** an atom is. The different elements are made from atoms with different numbers of protons. For example, all atoms of the element oxygen have eight protons in the nucleus. Conversely, any atom with eight protons is an atom of oxygen. Iron is a different element, iron atoms have twenty six protons in the nucleus.



Atoms of different elements have different numbers of protons in the nucleus.

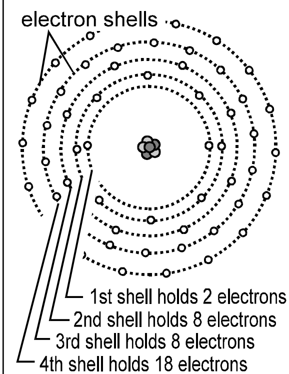
1897

J.J. Thompson discovers the electron and explains Crooke’s mysterious “cathode rays” as streams of electrons. He later proposes the first serious model of the atom, often called the “plum pudding” model in which electrons are embedded like raisins in a “pudding” of positive charge. Thompson is awarded the 1906 Nobel Prize for the discovery of the electron.

The neutron, the other particle that lives in the nucleus, acts like a kind of nuclear glue that keeps the nucleus together. This is necessary because protons all have positive electric charge and two positive charges repel each other. If the nucleus does not have enough neutrons (or too many) it can become **unstable.** Unstable nuclei are **radioactive,** which means they break down into other nuclei by emitting particles. A stable nucleus with more than two protons needs at least one neutron per proton.

The atomic **mass number** is the total number of particles in the nucleus, protons plus neutrons. Atoms of one element (same number of protons) with different numbers of neutrons are called **isotopes**. Isotopes of a given element have the same atomic number but different mass numbers. For example, there are three natural isotopes of oxygen. All three have eight protons in the nucleus while oxygen sixteen (O^{16}) has 8 neutrons, oxygen seventeen (O^{17}) has 9 neutrons, and oxygen eighteen (O^{18}) has 10 neutrons.

The Bohr Model of the Atom



1898

Marie Curie coins the word radioactivity to describe peculiar behavior of new elements she and her husband, Pierre have discovered. The Curies share the 1903 Nobel Prize for the discovery of radioactivity, Marie is awarded a second Nobel Prize in 1911 for discovering the elements radium and polonium.

1909

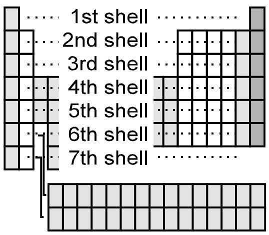
Ernest Rutherford, deduces the existence the atomic nucleus from alpha particle scattering experiments performed with Hans Geiger and Ernest Marsden. Rutherford's laboratory becomes the center of atomic and nuclear research. Rutherford discovers the proton a few years later in 1914.

1913

A 28 year old physicist named Neils Bohr publishes the theory of electron shells that leads to quantum mechanics and the modern theory of the atom. Considered the "father of quantum mechanics", Bohr is awarded the 1922 Nobel Prize in physics for his discovery of the structure of the atom.

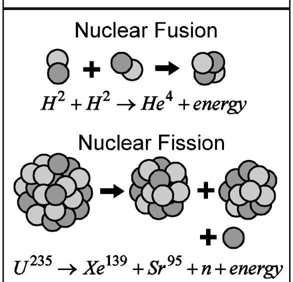
Also in 1913 a talented young physicist named Henry Moseley, then 26, performs a series of x-ray experiments from which he deduces the atomic number and is the first to correctly sequence the elements on the Periodic Table. Tragically, Moseley is killed in action only two years later at Gallipoli, Turkey during World War 1.

The Rows of the Periodic Table Correspond to the First 7 Electron Shells



1932

James Chadwick discovers the neutron at the renowned Cavendish Laboratory. The neutron is the last of the three primary constituents of the atom to be discovered.



Nuclear Reactions

The last of the three sub-atomic particles, the **electron** is by far the lightest of the three and has a negative electric charge, equal and opposite to the proton. Electrons are attracted to the positive charge of the nucleus but are prevented from falling into the nucleus by the laws of quantum mechanics. **Quantum mechanics** is the branch of physics that describes the sub-microscopic world inside the atom. Electrons inhabit the space around the nucleus in a system of fixed orbits called **electron shells**. Each shell also represents an **energy level**, with the lowest shells having the lowest energy. Just as objects tend to roll downhill, electrons tend to settle into the lowest shells.

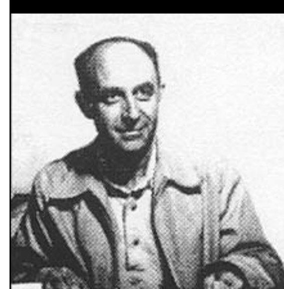
Each electron shell is composed of a number of discrete **energy states**, also known as electron **orbitals**. The shells and energy states are represented by the arrangement and number of pockets on each tier of the Atomic Structure board. Each energy state in a real atom, like the individual pockets on the board, can hold only one electron.

A complete **neutral** atom has the same number of electrons as protons. Each electron has a charge of -1 and each proton has a charge of +1. When the number of electrons equals the number of protons the total charge of the atom is zero (neutral). Since positive and negative charges attract each other, atoms prefer to be neutral. **Ions** are atoms that have different numbers of electrons and protons. Ions have net electric charge and exist naturally under certain circumstances, like in a lightning bolt or in chemical compounds. For example, neutral oxygen has eight electrons to balance its eight protons. An oxygen ion might have only seven electrons, leaving a net charge of +1.

1938

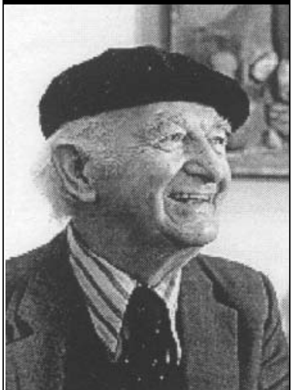
In 1938 Austrian physicist Lise Meitner narrowly escapes Hitler to reach Bohr's laboratory in Sweden. She brings with her evidence for unusual radioactive behavior of uranium that leads to the discovery of nuclear fission.

1942



Enrico Fermi ushers in the nuclear age by creating the first man-made nuclear chain reaction in a laboratory under Stagg Field at the University of Chicago as part of the famous Manhattan Project.

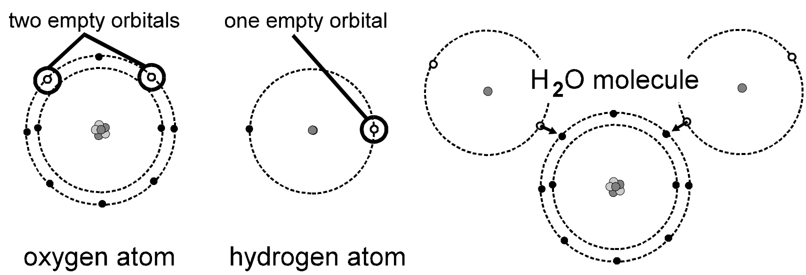
1939



Linus Pauling publishes his landmark book describing how Bohr's atom and the electron shell model explains chemical bonding in terms of sharing electrons between atoms in a molecule. Like Newton's *Principia,* Pauling's *The Nature of the Chemical Bond, and Structure of Molecules and Crystals* immediately becomes a classic work, providing the long sought explanation for the structure of the Periodic Table. A brilliant scientist and passionate advocate for peace, Linus Pauling was the first man to be awarded an unshared Nobel Prize twice. He received the 1954 Nobel Prize in chemistry and the 1962 Nobel Prize for Peace.

Most common materials are not pure elements, but are **compounds** of elements. For example, water (H_2O) is a compound of the elements hydrogen and oxygen. Just as atoms are the smallest units of elements, a **molecule** is the smallest unit of a compound. A molecule is held together by **chemical bonds** between the constituent atoms. For example, two hydrogen atoms and one oxygen atom are bonded to make a single water molecule (H_2O). The periodic table groups elements according to how they bond with other elements to form compounds. Understanding bonding and the interactions between atoms is the essence of **chemistry.**

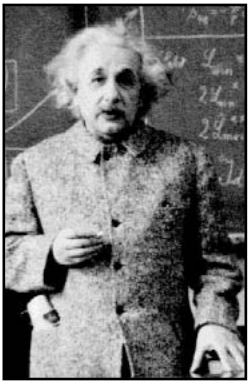
Atoms bond by sharing electrons. Atoms bond into molecules so that each atom in the molecule can have an electron structure with filled or empty shells. Energetically, completely filled or empty shells are preferred states for atoms. By knowing the electron structure, we can predict which atoms will bond with which, and the relative proportions of atoms in a molecule.



As an example, why are there two hydrogen atoms and only one oxygen atom in a water molecule (H_2O)? Hydrogen has only one electron. Oxygen has eight electrons, enough to fill the first shell (2) and fill six out of the eight slots in the second shell. If one oxygen atom takes an electron from each of two hydrogen atoms the molecule satisfies all the rules for forming chemical bonds. The oxygen has 10 electrons, its 8 plus one each from the two hydrogens. Ten electrons perfectly fill the first and second shells. The hydrogen atoms each have zero electrons, giving each only empty shells, also favored states. The water molecule has a total of ten (positive) protons and ten (negative) electrons, making it electrically neutral.

In the simplest interpretation, the shared electrons create the chemical bond through the attraction of positive and negative charges. Within the water molecule, the oxygen atom acts like an ion with a charge of -2 from the two shared electrons. The two hydrogen atoms have likewise become ions, each with a charge of +1 since they each lost an electron. The electrically neutral molecule is held together by the attraction between the oppositely charged ions.

A Brief Chronology of Lasers



It was in 1917 that Albert Einstein proposed the idea that atoms could be stimulated to emit radiation. This concept describes an excitation (or stimulation) of the atom and its subsequent release of energy - as a *photon*. Einstein's proposal forms the conceptual basis for laser technology.

Many scientists made contibutions predicated on Einstein's "*stimulated emission of radiation*" - the underlying phenomenon of laser technology. A few key events in the development of the laser are outlined here:

1951 - The first device to apply the idea of stimulated emission is invented. The device was named after the process it is based upon, namely *MASER* (an acronym for **M**icrowave **A**mplification by **S**timulated **E**mission of **R**adiation). Credited as independent inventors of the first MASER are Joseph Weber (at the University of Maryland) and the pair of Alexander Prokhorov & Nikolai G Basov (from Lebedev Laboratories in Moscow). The MASER, as its name suggests, was used to amplify microwaves. The technology, found an early application in microwave communication systems.

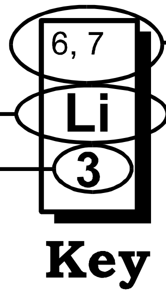
1958 - Arthur L. Schawlow (a researcher at Bell Labs) and Charles H. Townes (a professor at Columbia University) publish a landmark paper in *Physical Review* called *Infrared and Optical Masers*. Expanding upon their work dealing with the MASERs, the paper discussed how the MASER process could be applied to electromagnetic waves (i.e., light) of higher frequencies. In other words, they showed how a device could produce stimulated emissions of *infrared, visible,* and *ultraviolet light* - in addition to microwaves. Coining the term "optical MASER" for the device, the paper was the basis for the construction of the LASER, as it would come to be known, with *light* replacing *microwave* in the original acronym. Both men would later receive the Nobel Prize in Physics (Townes in 1964, and Schawlow in 1981) for their work in MASER and LASER research and technology.

1960 - Based on the foundation work of Townes and Schawlow, Theodore Maiman of Hughes Aircraft Research Labs uses a synthetic ruby rod and flash lamp *pumping* agent to construct the first device to successfully produce laser light. Atoms in the ruby rod are excited by the pumping agent. As the atoms return to their ground state, energy is released in the form of a photon. Maiman is generally considered the inventor of the LASER.

Interestingly, Gordon Gould, a graduate student at Columbia University coined the term LASER in his notebooks in 1957, along with a basic design for the device. He did not apply for a patent until 1959 since he believed he first needed a working model for the patent office. The patent office was already considering the optical MASER design of Townes and Schawlow at the time, which was awarded the very next year (1960), along with Maiman's patent for his working device. In 1977, after almost 20 years of litigation, Gould was finally awarded several patents concerning his work, based upon his writings from 1957 - key pages of which were notarized by a candy store owner.

READING THE PERIODIC TABLE

The periodic table of the elements is used for two of the three games presented in this guide. Players should be familiar with the meaning of the different numbers and symbols listed in the periodic table.



Element Symbol

Atomic Number

The **atomic number** is the number of protons in the nucleus. The atomic number determines what **element** the atom is. All atoms of a given element have the same atomic number. For example, all atoms of Lithium (Li) have 3 protons in the nucleus.

Mass Number

The **mass number** is the total number of particles (protons plus neutrons) in the nucleus. Atoms with the same number of protons but different mass numbers are called **isotopes.** These numbers are the mass numbers of the **stable isotopes**. Stable isotopes are not radioactive. For example, lithium has two stable isotopes, Li^6 with three protons and three neutrons, and Li^7 with three protons and four neutrons.

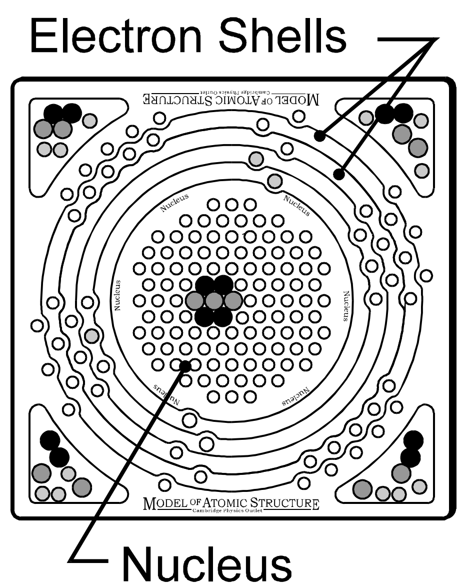
THE LANGUAGE OF ATOMS AND ISOTOPES

$${}_3Li^7 \text{ or } Li^7$$

The expression above refers to the isotope of lithium having three protons, four neutrons and a mass number of seven. You read this as “lithium seven".

ELECTRONS AND NEUTRAL ATOMS

A neutral atom has the same number of electrons as protons. Each electron has a charge of -1 and each proton has a charge of +1. When the number of electrons equals the number of protons the total charge of the atom is zero (neutral). Since positive and negative charges attract each other, atoms prefer to be neutral. Ions are atoms that have different numbers of electrons and protons. Ions have net electric charge and exist naturally under certain circumstances, like in a lightning bolt or in compounds.



The Atomic Structure board set up as an atom of lithium seven with three protons and four neutrons in the nucleus, and a total of three electrons in the first and second shells.

ATOMIC CHALLENGE

A game for 2 - 8 players

This is the simplest game, and a good one to start with. Everyone learns how to read the periodic table and the meaning of the atomic number and mass number.

The game starts by dividing the marbles evenly among all players. Yellow marbles represent electrons, red marbles are protons, and blue marbles are neutrons. All players should use as reference the periodic table that is provided with the game - for convenience, two copies of the periodic table are included with the Atom Building Game.

The object of the game is to play all your marbles by adding them to the atom and correctly identifying what atom has been made. The first player to run out of marbles wins.

The game is started with the board clear of marbles. Each player takes turns adding 5 or less of their marbles to the atom. An example of a 1st move could be to build hydrogen-1 by adding one proton and one electron to the empty board. The player must add the marbles according to the rules for building atoms:

(1) Protons and neutrons go in the nucleus.

(2) Electrons go in the electron levels (shells).

(3) The electrons should be placed in the lowest energy levels with one energy level filled before filling the next energy level.

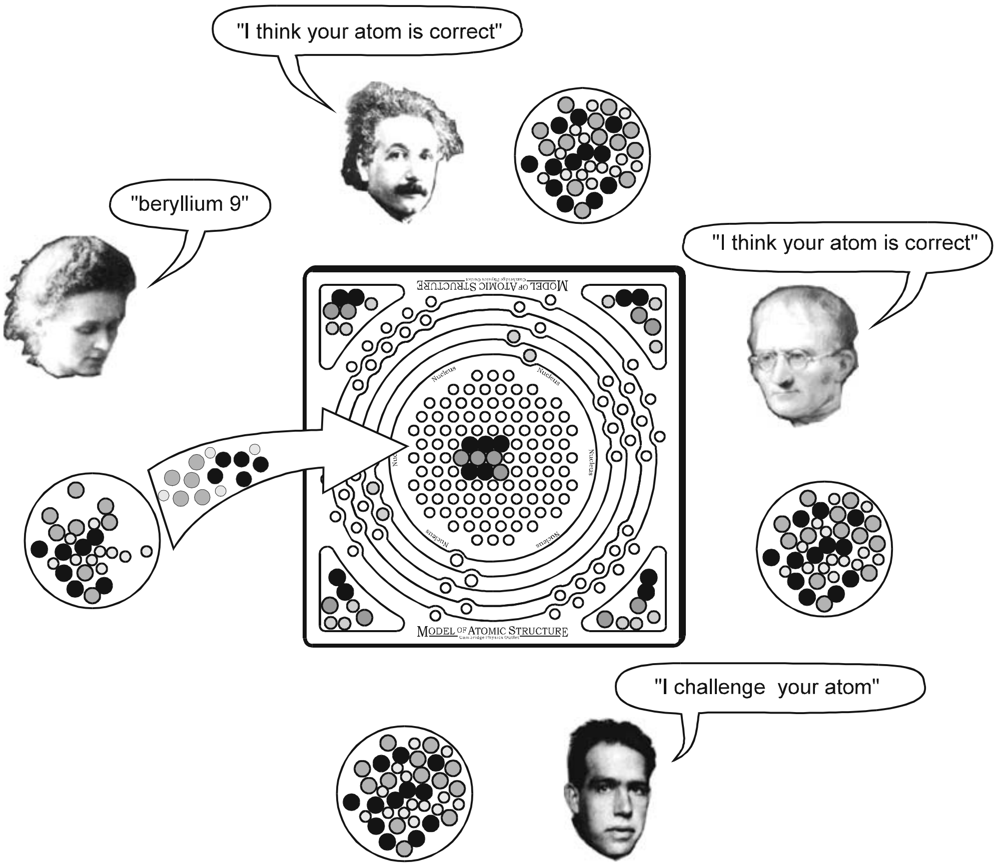
For this game, it does not matter which orbital* on a given energy level is filled first, as long as all orbitals on one energy level are filled before starting the next higher energy level.

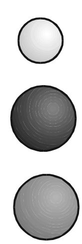
The player then announces what atom has been made. The player must correctly identify the **element,** the **mass number**, and the **charge** of the atom. For example, A player may add three marbles and say "carbon thirteen, plus 2". If there are 6 red marbles, 7 blue marbles, and 4 yellow marbles on the board, the player would be correct and play continues to the next player on the right.

Once a player states what the atom is, each of the other players must take turns either saying “I think your atom is correct” or “I challenge your atom.” If no one challenges, play continues to the next player on the right.

*Orbitals are explained in greater detail in the Curriculum Resource Guide for the Atom Building Game (part number 492-2250).

If an atom is challenged the periodic table should be carefully consulted by all players to see whether the atom is correct or not. If the atom has been incorrectly **built** or **identified,** then the offending player must take **all the marbles on the board**. The next player on the right then takes a turn.





Electrons
(Yellow Marbles)

Neutrons
(Blue Marbles)

Protons
(Red Marbles)

NUCLEAR REACTIONS

A game for 2 - 4 players

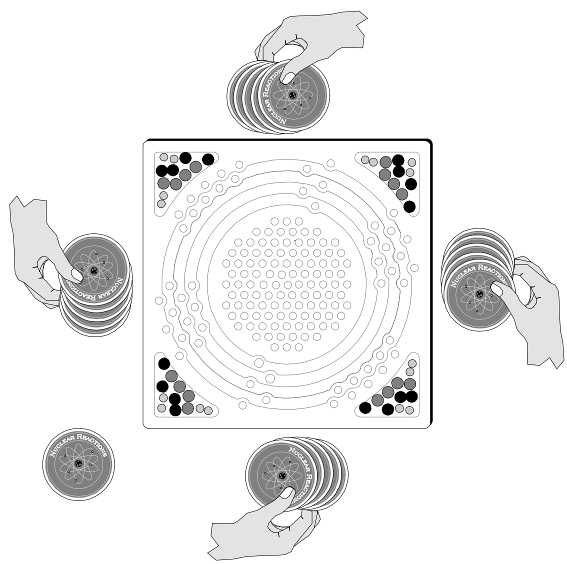
In this game players learn about the elements, the constitution and structure of the atom, stable and unstable isotopes, atomic number and atomic mass. Considerable strategy can be involved. The game is played with marbles and the NUCLEAR REACTIONS cards. The objective of the game is to score points by creating **stable**, **neutral**, or **stable and neutral** atoms.

STARTING THE GAME

Each player starts with the same number of each kind of sub-atomic particle in their pocket of the Atomic Building Game board. The table below gives the recommended starting number of particles (per player) for different (individual) winning scores. A winning score of 20 makes for about a half hour game.

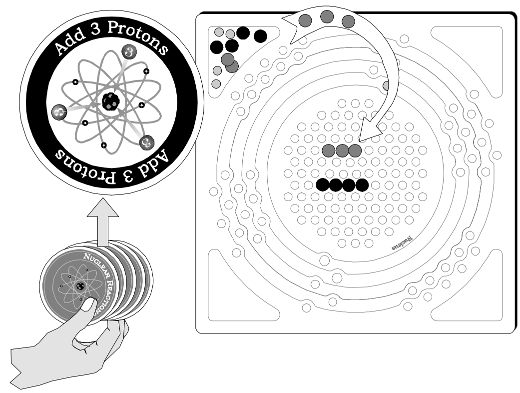
The deck of *NUCLEAR REACTIONS* cards are shuffled and each player is dealt a hand of five cards which are held and not shown to any other player.

Each player starts with five ***NUCLEAR REACTIONS*** cards and 8 of each kind of particle: electrons, protons, and neutrons.



Winning score (individual)	**15**	**20**	**25**	**30**	**35**	**40**
Number of electrons	7	8	9	11	13	15
Number of protons	7	8	9	11	13	15
Number of neutrons	7	8	9	11	13	15

Players take turns playing cards and marbles trying to build stable nuclei, neutral atoms, or (the best score) atoms which are stable and neutral.



PLAY

Players take turns playing **one card per turn** and adding or subtracting particles from the atom as instructed on the card played. For example, playing an "Add 2 Electrons" card would mean placing two yellow marbles in the atom.

Each player draws a new card from the deck after each play to maintain a five card hand. If necessary the played cards can be re-shuffled and re-used.

Particles added or subtracted from the atom must be played from, or to, a players own pocket of particles. **Players may not play cards for which they do not have sufficient particles** to make the specified move. For example, a player with only 2 protons left cannot play an “Add 3 Protons” card.

The first player to reach **20 points wins**. Agreeing to play to 15 points makes a faster game. Choosing a higher winning score makes a longer game.

TEAM PLAY

With four players it is possible to play in teams. Players opposite each other belong to the same team. Play and set-up are the same as for individual players, but teammates can try to set each other up for three point plays. **Players on the same team are not allowed to disclose their cards to their teammate**. Team play should go to twice the individual score, for example a winning score of 40 is recommended when starting with 8 of each marble.

Scoring Points (nuclear reactions)

Points are scored depending on the constitution of the atom which is formed by each player's turn. Players should use the periodic table to determine strategy and points. In particular it is useful to know which cards to play to get to stable isotopes, neutral atoms, or stable and neutral atoms.

A player scores **1 point** for adding or taking particles **from the nucleus** if the move creates or leaves a **stable nucleus.** For example, a player would score 1 point by adding a proton to a nucleus with 6 protons and 5 neutrons because adding the proton makes a carbon 12 nucleus, which is stable. The next player can also score a point if they can add a neutron, making carbon 13. *Points cannot be scored for making a stable nucleus by adding or subtracting electrons.*

A player also scores **1 point** for adding or taking electrons or protons from the atom if the move creates or leaves a **neutral atom**. A neutral atom has the same number of electrons and protons. Because neutrons have no charge, points cannot be scored for neutrality by adding or subtracting neutrons.

A player scores **3 points** (the best move) when they add or take particles from the atom and the move creates or leaves a **complete stable and neutral** atom. Both adding and subtracting can leave stable, neutral atoms. For example, taking a neutron from a stable, neutral carbon 13 atom leaves a stable neutral carbon 12 atom, scoring 3 points.

Miscellaneous Rules

A player may trade in their entire hand, forfeiting a turn if they can prove, by showing all players their hand, that they do not have the particles to play any of their five cards. Otherwise, cards must be played, one per turn whether or not it is of strategic advantage to expend marbles.

All players should be allowed to use the periodic table of the elements provided in the course of the game. It is advisable to make a photocopy of the back cover of this booklet for each player to use for reference.

Card Count

Each Nuclear Reactions deck should contain 48 cards, "E" refers to electrons, "P" to protons, and "N" to neutrons. (6)+1E, (4)+2E, (2)+3E, (6)+1P, (4)+2P, (2)+3P, (8)+1N, (4)+2N, (2)+3N, (2)-1E, (4)-1P, (2)-1N, (2)-2N.

PHOTONS AND LASERS

A game for 2 - 4 players

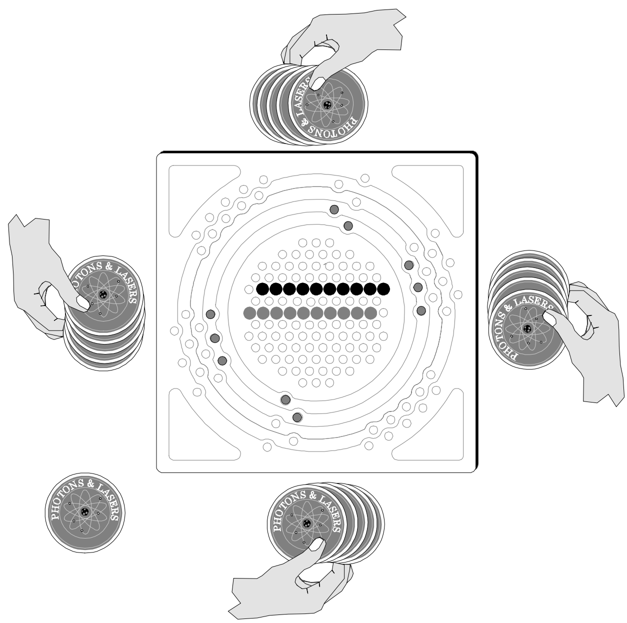
The Photons and Lasers game teaches players about how light is absorbed and emitted from atoms. The objective of the game is to score points by stimulating excited electrons to laser, emitting photons of light. Players play **pump** cards to excite the atom by moving electrons up energy levels. Players score points by playing **laser** cards and moving electrons back down energy levels.

STARTING THE GAME

To begin, the atom should be set up for a specific element. Neon-20 is a good choice with 10 each of protons, neutrons, and electrons. The electrons should all start in the lowest possible levels, i.e. the **ground state** of the atom. For neon this would put two electrons in the first level and eight in the second level. The atom does not gain or lose particles during the game. Play consists of moving electrons up and down energy levels, the nucleus remains unchanged.

The game may be started with any element, provided all the electrons are in the ground state. Starting with different elements changes the strategy considerably.

This game uses the deck of PHOTONS & LASERS cards. The cards are shuffled and each player is dealt a hand of five cards which are held and not shown to any other player. Players will use the marbles on the board at the beginning of the game. Additional marbles are not required or needed.



The atom starts with neon-20 with all its electrons in the lowest possible places (ground state).

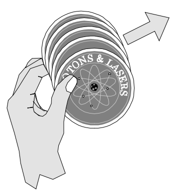
Each player gets five cards.

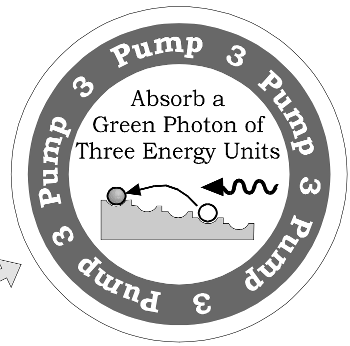
PLAY

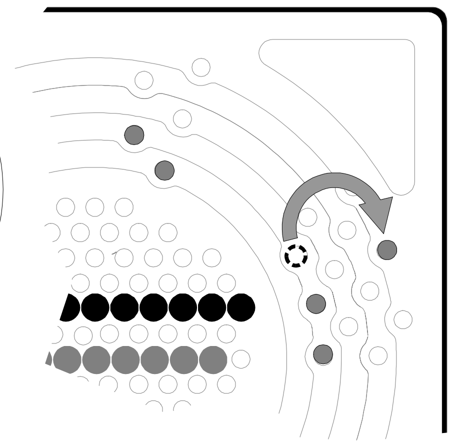
Players take turns playing **one card per turn** and moving electrons up and down energy levels as instructed on the card played.

Each player draws a new card from the deck after each play to maintain a five card hand. If necessary the played cards can be re-shuffled and re-used.

A **pump** card allows the player to move **one electron** up the specified number of energy levels.







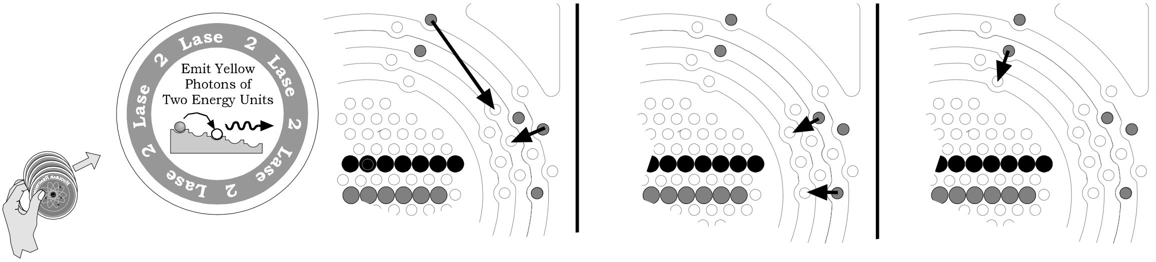
Pump cards represent photons of light **absorbed** by the atom. An absorbed photon raises a **single electron** the number of energy levels corresponding to the energy (color) of the photon. For example, playing a "Pump 2" card would allow the player to move one electron up two steps. **No points are scored by pump cards**, but the atom is raised to **excited states** which can later be used to earn points by playing Laser cards. An excited state is a configuration of the atom where one or more electrons can be moved down one or more energy levels.

Laser cards represent photons that stimulate the atom to emit light matching the energy (color) of the stimulating photon. Playing a laser card allows the player to move as many electrons as possible **down** the number of energy levels specified on the card, scoring points for each electron moved.

In a given turn electrons may be moved from **one level only** and **only to unfilled states** in the appropriate lower level.

For example, playing a "Laser 2" card allows the player to move as many electrons as possible from one level to a level two steps lower. If there were 2 electrons on level 4 and two empty spaces on level 2, the player could move both electrons from level 4 to level 2.

Three possible ways to play a “Laser 2” card



2 electrons moved from level 5 to level 3, scoring 4 points

2 electrons moved from level 4 to level 2, scoring 4 points

1 electron moved from level 3 to level 1, scoring 2 points

Scoring

Players score by playing laser cards when the atom is in an excited state.

The points scored are equal to the number of electrons moved multiplied by the number of levels moved. For example, if a player moves three electrons down two levels by playing a "Laser 2" card, two points are scored for each electron, making a total of six points.

Electrons may only be moved down to empty orbitals.

Laser cards may not be divided. For example, a “Laser 4” card may be used to move electrons down four levels only. A “Laser 4” may **not** be used to move two electrons two levels each.

The first player to reach the agreed upon winning score wins the game.

Card count

Each Photons & Lasers deck should contain 48 cards, (14) “Pump 1”, (8) “Pump 2”, (6) “Pump 3”, (4) “Pump 4” , (8) “Laser 1”, (4) “Laser 2”, (2) “Laser 3”, and (2) “Laser 4” cards.

Strategy

Having many excited electrons on one level creates a large scoring opportunity for another player.

Only two electrons can be moved with the valuable “Laser 4” card since there are only two energy states in the first energy level.

SPECIAL NOTE: ON THE SE VERSION OF THE ATOM BUILDING GAME

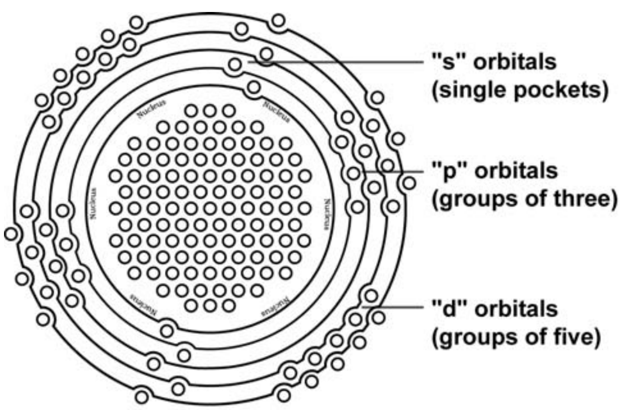
Like our original Atom Building Game, The Atom Building Game SE (special edition) comes with marbles that represent protons, neutrons and electrons, a laminated periodic table, and game cards. The special features of The Atom Building Game SE include its durable, thermoformed plastic atomic structure board, and clear labeling of the energy levels and electron orbitals represented on the board.

The description of the game board below includes information about electron orbitals and energy levels that you will want to share with your students.

A description of the Atom Building Game SE game board:

The Atom Building Game SE board illustrates five of the possible seven energy levels and three kinds of electron orbitals that are found in atoms. The energy levels surround the center of the board (the nucleus). The orbitals are labeled and represented by the pockets for the marbles at each energy level. You will notice that the pockets for the marbles in these energy levels are either single or in groups of three or five.

s orbitals: The single pockets represent **s** orbitals. Two electrons are associated with an **s** orbital for a given energy level. This is why two single pockets are always across from each other on the game board.

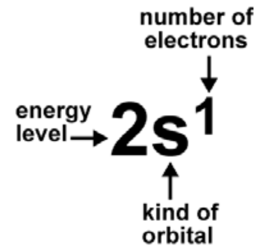


p orbitals: The pockets that are in groups of three represent **p** orbitals. Six electrons fill the **p** orbitals for a given energy level. This is why there are two sets of three pockets to represent the p orbitals for an energy level. The pockets represent three p orbitals that hold two electrons each.

d orbitals: The pockets that are in groups of five represent **d** orbitals. Ten electrons fill **d** orbitals for a given energy level. This is why there are two sets of five pockets to represent the **d** orbitals for a given energy level. The pockets represent five d orbitals that hold two electrons each.

f orbitals: The **f** orbitals are not featured on the Atom Building Game SE game board.

The labels for the electron orbitals on the game board include the energy level number and the kind of orbital. The order in which electrons fill all seven energy levels (1 - 7) and all electron orbitals (s, p, d and f) is listed in Table 1. This order (going from left to right) is called an electron configuration.



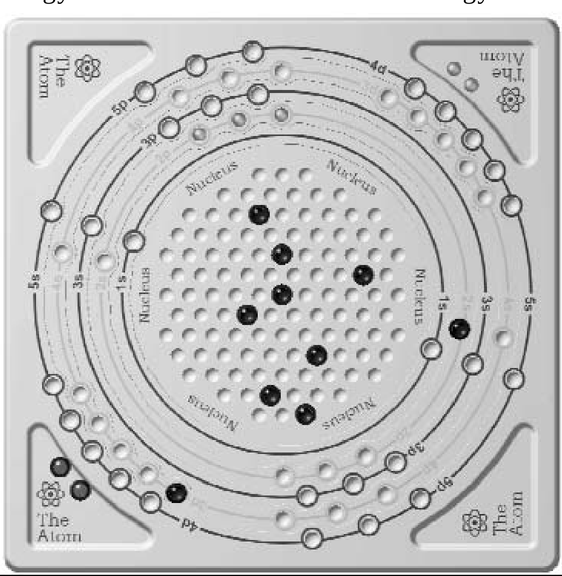
Using only electrons (yellow marbles) in the energy levels to represent an atom, all atoms from hydrogen to xenon can be built using The Atom Building Game SE.

Using protons (red marbles), neutrons (blue marbles), and electrons (yellow marbles), atoms from hydrogen to silver-109 may be built on the board.

Table: The order in which electrons fill energy levels

These energy levels are represented on the Atom Building Game board					Not represented on Atom Building Game board	
Lowest energy	>	>	>	>	>	Highest energy
1	2	3	4	5	6	7
$1s^2$	$2s^2 2p^6$	$3s^2 3p^6$	$4s^2 3d^{10} 4p^6$	$5s^2 4d^{10} 5p^6$	$6s^2 4f^{14} 5d^{10} 6p^6$	$7s^2 5f^{14} 6d^{10} 7p^6$

NOTE: In the 4th, 5th, 6th and 7th energy levels, you will notice orbitals with numbers from a lower energy level. For example, the 4s and 4p orbitals, and the 3d orbital are all in the 4th energy level. This is because the energy level of the 3d electrons overlaps with the energy levels for electrons in the 4th energy level. Also, the 4s orbital is filled before the 3d orbital. This is because the 4s orbital has a lower energy than the 3d orbital.



PERIODIC TABLE OF THE ELEMENTS 1 TO 54

Key

Element Symbol: Mo
Atomic Number: 42
Stable Mass Numbers: 92, 94-100

1,2 **H** 1																	3,4 **He** 2
6,7 **Li** 3	9 **Be** 4											10,11 **B** 5	12,13 **C** 6	14,15 **N** 7	16-18 **O** 8	19 **F** 9	20-22 **Ne** 10
23 **Na** 11	24-26 **Mg** 12											27 **Al** 13	28-30 **Si** 14	31 **P** 15	32-34, 36 **S** 16	35,37 **Cl** 17	36,38, 40 **Ar** 18
39,41 **K** 19	40,42-44,46, 48 **Ca** 20	45 **Sc** 21	46-50 **Ti** 22	51 **V** 23	50, 52-54 **Cr** 24	55 **Mn** 25	54,56-58 **Fe** 26	59 **Co** 27	58,60-62,64 **Ni** 28	63,65 **Cu** 29	64,66-68,70 **Zn** 30	69,71 **Ga** 31	70,72-74,76 **Ge** 32	75 **As** 33	74,76-78,80, 82 **Se** 34	79,81 **Br** 35	78,80, 82-84, 86 **Kr** 36
85 **Rb** 37	84, 86-88 **Sr** 38	89 **Y** 39	90-92, 94,96 **Zr** 40	93 **Nb** 41	92, 94-100 **Mo** 42	none **Tc** 43	96,98-103,104 **Ru** 44	103 **Rh** 45	102,104-106,108, 110 **Pd** 46	107,109 **Ag** 47	106,108, 110-112, 114,116 **Cd** 48	113 **In** 49	112,114-120,122, 124 **Sn** 50	121 **Sb** 51	120,122, 124-126, 128,130 **Te** 52	127 **I** 53	124,126, 128-132, 134,136 **Xe** 54