1 Introduction to Nuclear Reactions

In this Investigation, you will play the Nuclear Reactions Game. Read the introduction in your Investigation book.

2 Playing Nuclear Reactions

Read about the game in your Investigation book.

3 Scoring points

Read how points are scored in your Investigation book.

4 Miscellaneous rules

Miscellaneous rules are found in your Investigation book.

5 Applying what you learned

a. There are two basic kinds of nuclear reactions, fission and fusion. Fission splits heavy elements up into lighter elements. Fusion combines lighter elements to make heavier elements. Both can release energy, depending on which elements are involved. What element do you get when you fuse lithium-six and boron-11 together? It is stable or radioactive?

____

____

b. Write down a nuclear reaction using only two elements that would allow you to build fluorine-19 starting with boron-10.

____

____

c. Suppose you split a uranium-238 atom. If you have to break it into two pieces, name two elements that could be formed. Be sure that your two elements use up all the neutrons and protons in the uranium. Are either of your two elements stable or is one (or both) radioactive?

____

____

____

____

18.3 The Periodic Table of Elements

Question: What does atomic structure have to do with the periodic table?

In this Investigation, you will:

1. Learn about nuclear reactions.
2. Learn how the different elements of the periodic table were formed.

This Investigation is a game for two to four players called Nuclear Reactions. In order to win, you will need to become quick to figure out which nuclear reactions will make real atoms. The game is similar to the processes by which the elements of the periodic table were created inside stars. At the center of a star, nuclear reactions combine atoms to make new elements. We believe all the elements of the periodic table heavier than lithium were created inside stars through nuclear reactions. The process gives off a huge amount of energy and that is why the sun shines. The energy from nuclear reactions in the sun is what makes life on Earth possible.

Notice that the elements of the periodic table are arranged by **atomic number**, from lowest to highest. The atomic number is equal to the number of protons in the nucleus of an atom. The atomic number also indicates the number of electrons an atom has. Each element has a unique atomic number.

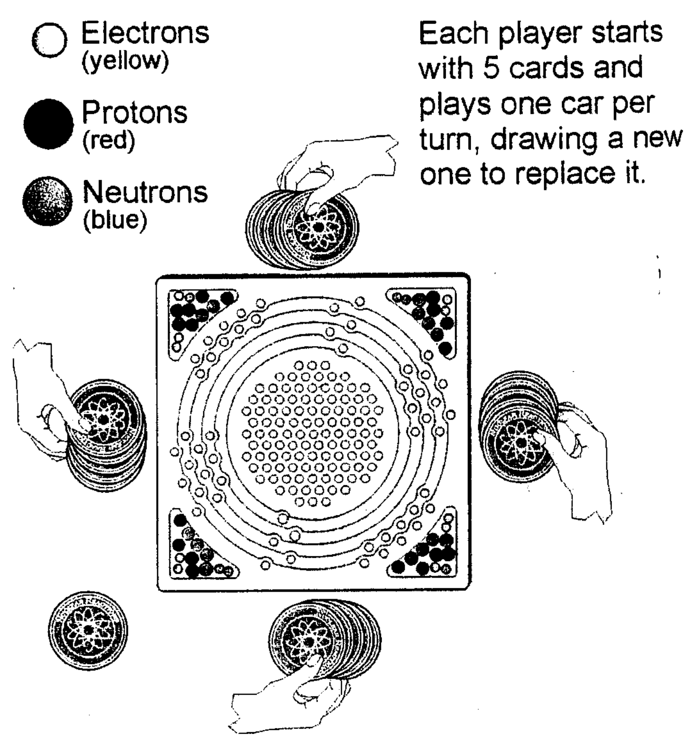
Isotopes are atoms with the same number of protons, but different numbers of neutrons. Isotopes are the same element, but have a different **mass number**. The mass number indicates how many protons and neutrons are in the nucleus of the isotope. The periodic table below shows the mass numbers of the stable isotopes of each element.

1 Introduction to Nuclear Reactions

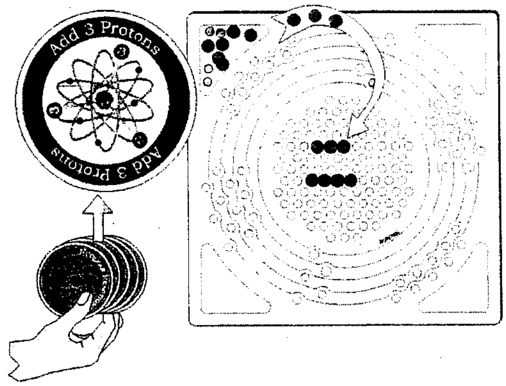
If you were to add one, two or four extra neutrons to lithium-7 you would have created lithium-8, lithium-9, and lithium-11, respectively. Each of these isotopes of lithium is **radioactive**. These means that the atomic force in the nucleus (called **strong nuclear force**) is not strong enough to hold these atoms together. The nuclei of these atoms fly apart.

The goal of Nuclear Reactions is to earn points by creating atoms that are stable (not radioactive) and neutrally charged (not ions). Remember that **ions** are atoms that have different numbers of protons and electrons so they have a charge.

Each player starts with 8 protons, 8 electrons, and 8 neutrons in their pocket of the Atomic Building Game board. The game will last for about a half-hour. The first player to 20 points wins.



2 Playing Nuclear Reactions



To begin play, each player is dealt five cards from the deck of Nuclear Reactions cards. These are held and not shown to anyone else.

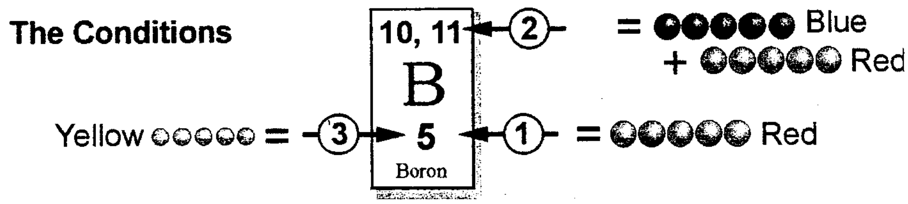
Players take turns, choosing which card to play each turn, and adding or subtracting particles from the atom as instructed on the card. For example, playing an "Add 2 Electrons" card would mean you place two yellow marbles in the atom.

Sub-atomic particles that are added or subtracted from the atom must come from, or be placed in your own pocket. You may not play a card for which you do not have the right marbles. For example, a player with only 2 protons left cannot play an "Add 3 Protons" card.

Each time you play a card, draw a new card from the deck so you always have five cards. Played cards can be shuffled and re-used as needed

3 Scoring points

1. The number of points scored depends how many of the conditions below are satisfied by the atom you create. You can 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.



Condition #1: The number of protons (red marbles) matches the atomic number.
Condition #2: The number of protons (red marbles) plus the number of neutrons (blue marbles) equals one of the correct mass numbers for the element of Rule #1. This creates a stable nucleus.
Condition #3: The number of electrons (yellow marbles) equals the number of protons (red marbles). This creates a neutral atom.

You score 1 point if your move creates or leaves a stable nucleus. For example, you score 1 point by adding a neutron to a nucleus with 6 protons and 5 neutrons. Adding a neutron makes a carbon 12 nucleus, which is stable. The next player can also score a point by adding another neutron, making carbon 13. Points cannot be scored for making a stable nucleus by adding or subtracting electrons, because electrons do not live in the nucleus! To get the nucleus right you need to satisfy conditions #1 and #2.

You score 1 point for adding or taking electrons or protons from the atom if your 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. Getting the electrons and protons to balance satisfies condition #3.

You score 3 points (the best move) when you add or take particles from the atom and your move creates a perfect, 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. You get 3 points if your turn makes an atom that meets all 3 conditions.

4 Miscellaneous rules

Taking a turn

When it is your turn you must either

1. Play a card and add or subtract marbles from the atom.
2. Trade in your cards for a new set of five.

Trading in cards

You may trade in all your cards at any time by forfeiting a turn. You have to trade all your cards in at once. Shuffle the deck before taking new cards.

Using the periodic table

All players should be allowed to use the special periodic table of the elements (on the next page) in the course of the game.

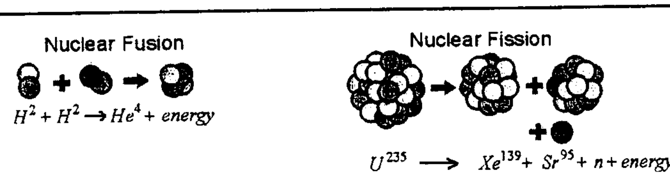
The marble bank

You may choose to play two versions of the marble bank.

Version 1: Players may take marbles from the bank at any time so they have enough to play the game.

Version 2: Players must lose a turn to draw marbles from the bank, and may draw no more than 5 total marbles (of any colors) in one turn.

5 Applying what you learned



a. There are two basic kinds of nuclear reactions, fission and fusion. Fission splits heavy elements up into lighter elements. Fusion combines lighter elements to make heavier elements. Both can release energy, depending on which elements are involved. What element do you get when you fuse lithium six and boron 11 together? It is stable or radioactive?

b. Write down a nuclear reaction using only two elements that would allow you to build Fluorine 19 starting with Boron 10.

c. Suppose you split a uranium 238 atom. If you have to break it into two pieces, name two elements that could be formed. Be sure that your two elements use up all the neutrons and protons in the uranium. Are either of your two elements stable or is one (or both) radioactive?

Periodic Table of the Elements

with Atomic Numbers and Mass Numbers of Stable Isotopes

Key

6, 7 Li 3 Lithium

- 6, 7 — Mass Numbers of Stable Isotopes
- Li — Element Symbol
- 3 — Atomic Number
- Lithium — Element Name

1, 2 H 1 Hydrogen																	3, 4 He 2 Helium
6, 7 Li 3 Lithium	9 Be 4 Beryllium											10, 11 B 5 Boron	12, 13 C 6 Carbon	14, 15 N 7 Nitrogen	16, 17, 18 O 8 Oxygen	19 F 9 Fluorine	20, 21, 22 Ne 10 Neon
23 Na 11 Sodium	24, 25, 26 Mg 12 Magnesium											27 Al 13 Aluminum	28, 29, 30 Si 14 Silicon	31 P 15 Phosphorus	32, 33, 34, 36 S 16 Sulfur	35,37 Cl 17 Chlorine	36,38,40 Ar 18 Argon
39, 41 K 19 Potassium	40,42,43, 44,46,48 Ca 20 Calcium	45 Sc 21 Scandium	46,47,48, 49,50 Ti 22 Titanium	51 V 23 Vanadium	50,52,53, 54 Cr 24 Chromium	55 Mn 25 Manganese	54,56,57, 58 Fe 26 Iron	59 Co 27 Cobalt	58,60,61, 62,64 Ni 28 Nickel	63,65 Cu 29 Copper	64,66,67, 68, 70 Zn 30 Zinc	69,71 Ga 31 Gallium	70,72,73, 74,76 Ge 32 Germanium	75 As 33 Arsenic	74,76,77, 78,80,82 Se 34 Selenium	79,81 Br 35 Bromine	78,80,82, 83,84,86 Kr 36 Krypton
85 Rb 37 Rubidium	84,86,87, 88 Sr 38 Strontium	89 Y 39 Yttrium	90,91,92, 94,96 Zr 40 Zirconium	93 Nb 41 Niobium	92, 94-100 Mo 42 Molybdenum	none Tc 43 Technetium	96,104, 98-103 Ru 44 Ruthenium	104 Rh 45 Rhodium	102,108,11 0104-106 Pd 46 Palladium	107,109 Ag 47 Silver	106,108,114, 110-112,116 Cd 48 Cadmium	113 In 49 Indium	112,114-120, 122,124 Sn 50 Tin	121 Sb 51 Antimony	120,122,128, 124-126,130 Te 52 Tellurium	127 I 53 Iodine	124,126,134, 128-132,136 Xe 54 Xenon
133 Cs 55 Cesium	130,132, 134-138 Ba 56 Barium		174, 176-180 Hf 72 Hafnium	180,181 Ta 73 Tantalum	180,182,183, 184,186 W 74 Tungsten	185 Re 75 Rhenium	184,192, 186-190 Os 76 Osmium	191,193 Ir 77 Iridium	192,198, 194-196 Pt 78 Platinum	197 Au 79 Gold	196,204, 198-202 Hg 80 Mercury	203, 205 Tl 81 Thallium	204, 206-208 Pb 82 Lead	209 Bi 83 Bismuth	none Po 84 Polonium	none At 85 Astatine	none Rn 86 Radon
none Fr 87 Francium	none Ra 88 Radium		none Rf 104 Rutherfordium	none Db 105 Dubnium	none Sg 106 Seaborgium	none Bh 107 Bohrium	none Hs 108 Hassium	none Mt 109 Meitnerium									

139 La 57 Lanthanum	136, 138, 140 Ce 58 Cerium	141 Pr 59 Praseodymium	142,143,145, 146,148,150 Nd 60 Neodymium	none Pm 61 Promethium	144,152,154, 148,149,150 Sm 62 Samarium	151, 153 Eu 63 Europium	152, 160, 154-158 Gd 64 Gadolinium	159 Tb 65 Terbium	156, 158, 160-164 Dy 66 Dysprosium	165 Ho 67 Holmium	162,164,166, 167,168,170 Er 68 Erbium	169 Tm 69 Thulium	168, 176, 170-174 Yb 70 Ytterbium	175 Lu 71 Lutecium
none Ac 89 Actinium	none Th 90 Thorium	none Pa 91 Protactinium	none U 92 Uranium	none Np 93 Neptunium	none Pu 94 Plutonium	none Am 95 Americium	none Cm 96 Curium	none Bk 97 Berkelium	none Cf 98 Californium	none Es 99 Einsteinium	none Fm 100 Fermium	none Md 101 Mendelevium	none No 102 Nobelium	none Lr 103 Lawrencium