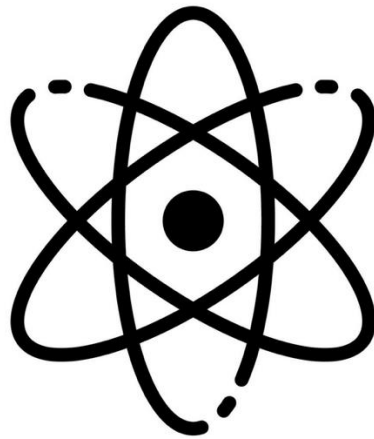


RADIO ACTIVITIES OF THE MUSEE CURIE

A game conceived by Claude Charvy.



*To better understand the mysteries of
atoms and radioactivity*

 musée**CURIE**

RADIO ACTIVITIES OF THE MUSEE CURIE

Presentation

What is an atom? What is it made of? What is radioactivity?

"**Radio-Activities of the Musée Curie**" feature 5 activities designed with the aim of discovering and explaining radioactivity in a fun and educational way.

Inspired by card and board games, "**Radio-Activities of the Musée Curie**" help us understand that the name of the chemical elements is linked to the number of protons that make up the nuclei of atoms, that some atoms are radioactive, and that they can transform into other atoms by emitting alpha and/or beta rays (gamma radiation is not covered).

With these games you can explore these scientific notions in successive stages, and also discover the history of natural and artificial radioactivity: the elements discovered by Marie and Pierre Curie in 1898 (Polonium and Radium) and the radioactive family of Uranium-238 or Nitrogen-13, which were artificially produced by Frédéric and Irène Joliot-Curie in 1934.

You can have fun playing with the nuclei of atoms, protons, and neutrons!

Description

In this manual, you will find:

- The rules of the 5 activities:
 - Activity 1: Match the number of protons to its chemical element p3
 - Activity 2: Find the nucleus name p4
 - Activity 3: Beta radioactivity p5-6
 - Activity 4: Alpha radioactivity p7
 - Activity 5: The radioactive family of Uranium-238 p8-9
- Explanatory guides on:
 - Atoms, Nuclei and the Periodic Table (Activities 1 and 2) p10-11
 - Radioactivity (Activities 3, 4, and 5) P12-13
 - The radioactive family of uranium (Activity 5) p14-15
- Game printing rules p16

You will need the following materials to complete the activities:

- A periodic table
- A printed game kit

Each activity is independent and can be completed separately.

RADIO-ACTIVITY 1:

Match the number of protons to its chemical element

First, the presenter gives a presentation on atoms and nuclei. See the explanatory guide "Atoms, Nuclei and the Periodic Table" p 10-11.

Objective: To make it clear that a chemical element is defined by the number of protons contained in its nucleus.

Materials:

- 1 periodic table
- Activity 1 Game Kit:
 - 12 cards with the Symbols and the names of the Chemical Elements
 - Level 1: H, He, B, C, N, O, F, Ca, Fe, Cu, Ag and Au
 - Level 2: Hg, Pb, Bi, Po, At, Rn, Fr, Ra, Ac, Th, Pa, U
 - 12 labels with the number of protons
 - Level 1: 1, 2, 5, 6, 7, 8, 9, 20, 26, 29, 47, 79
 - Level 2: 80, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92

Setup:

- The cards with the elements are shuffled and turned over (blank side up).
- The labels with the number of protons are laid out (number of protons on top).

How to play:

The game can be played alone or in teams of 2 players who take turns.

- Draw a card with a chemical element.
- Use the periodic table to find the label with the right number of protons.
- Place the label on top of the chemical element card.
- The game is over when all the cards/labels have been matched.

Variant:

- The player places all the element cards in front of them face up, and the labels are placed in a canvas bag
- Player randomly draws a label with a number of protons and matches the corresponding chemical element with it using the periodic table

RADIO-ACTIVITY 2:

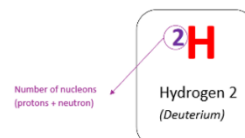
Find the name of a nuclei

First, the presenter gives a presentation on atoms and nuclei. See the explanatory guide "Atoms, Nuclei and the Periodic Table" p 10-11.

Objective: To understand how the atoms are named, then deduce the number of protons and neutrons contained in the nuclei.

Materials:

- 1 periodic table
- Activity 2 Game Kit:
 - 16 cards with the Symbols, the names of the chemical elements, and the number of nucleons
 - Level 1: ${}^1_1\text{H}$, ${}^2_1\text{H}$, ${}^2_2\text{He}$, ${}^{11}_5\text{B}$, ${}^{12}_5\text{B}$, ${}^{11}_6\text{C}$, ${}^{12}_6\text{C}$, ${}^{13}_6\text{C}$, ${}^{14}_6\text{C}$, ${}^{12}_7\text{Na}$, ${}^{13}_7\text{Na}$, ${}^{14}_7\text{Na}$, ${}^{15}_7\text{Na}$, ${}^{14}_8\text{O}$
 - Level 2: ${}^{206}_{82}\text{Pb}$, ${}^{210}_{82}\text{Pb}$, ${}^{210}_{84}\text{Po}$, ${}^{214}_{84}\text{Po}$, ${}^{218}_{84}\text{Po}$, ${}^{226}_{88}\text{Ra}$, ${}^{222}_{86}\text{Rn}$, ${}^{232}_{90}\text{Th}$, ${}^{234}_{90}\text{Th}$, ${}^{234}_{92}\text{U}$, ${}^{235}_{92}\text{U}$, ${}^{238}_{92}\text{U}$
 - 18 Dominoes: "number of protons/number of neutrons"
 - Level 1: 1p/0n, 1p/1 n, 1p/2n, 2p/2n, 5p/6n, 5p/7n, 5p/8n, 6p/5n, 6p/6n, 6p/7n, 6p/8n, 7p/5 n, 7p/6n, 7p/7n, 7p/8n, 8p/5n, 7p/6n, 8p/7n
 - Level 2: 82p/124n, 82p/128n, 84p/126 n, 84p/130n, 84p/134n, 86p/136n, 88p/138n, 90p/142n, 90p/144n, 92p/142n, 92p/143n, 92p/146n



Setup:

- The cards with the elements are shuffled and turned over (blank side up).
- The dominoes are laid out (number of protons and neutrons facing up)

How to play:

The game can be played alone or in teams of 2 players who take turns.

- Draw a card with a chemical element.
- Use the periodic table to find the domino with the right number of protons and neutrons.
 - E.g.: the C13 card will be matched with the domino: 6 protons/7 neutrons
- Place the domino on top of the chemical element card.
- The game is over when all the cards/dominoes have been matched.

Variant:

- The player places all the element cards in front of them face up, and the dominoes are placed in a canvas bag
- Player randomly draws a domino with a number of protons and neutrons and then matches the corresponding chemical element with it using the periodic table



RADIO-ACTIVITY 3:

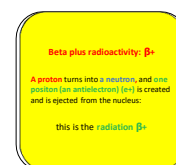
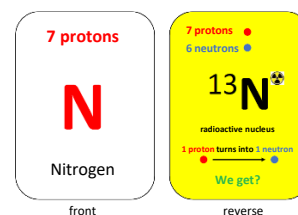
Beta radioactivity

First, the presenter gives a presentation on radioactivity. See the explanatory guide "Radioactivity" p 12-13.

Objective: To understand radioactivity, isotopes, and the "transmutation of the elements". In this game we will limit ourselves to β radioactivity.

Materials:

- 1 periodic table
- Board 1: " B, C, N, O, F" (or a periodic table)
- Board 2 of the game (where we will arrange the cards during the game)
- Two-color red/blue tokens
- Activity 3 Game Kit:
 - 24 nucleus cards:
 - Front: number of protons, symbol, and name of the corresponding chemical element.
 - Back: characteristic of the isotope (number of protons/neutrons) and its stability
 - 9 emitted radiation cards:
 - Beta Radioactivity +
 - Beta Radioactivity -
 - Two-color tokens:
 - Red side: represents the protons 
 - Blue side: represents the neutrons 



Setup:

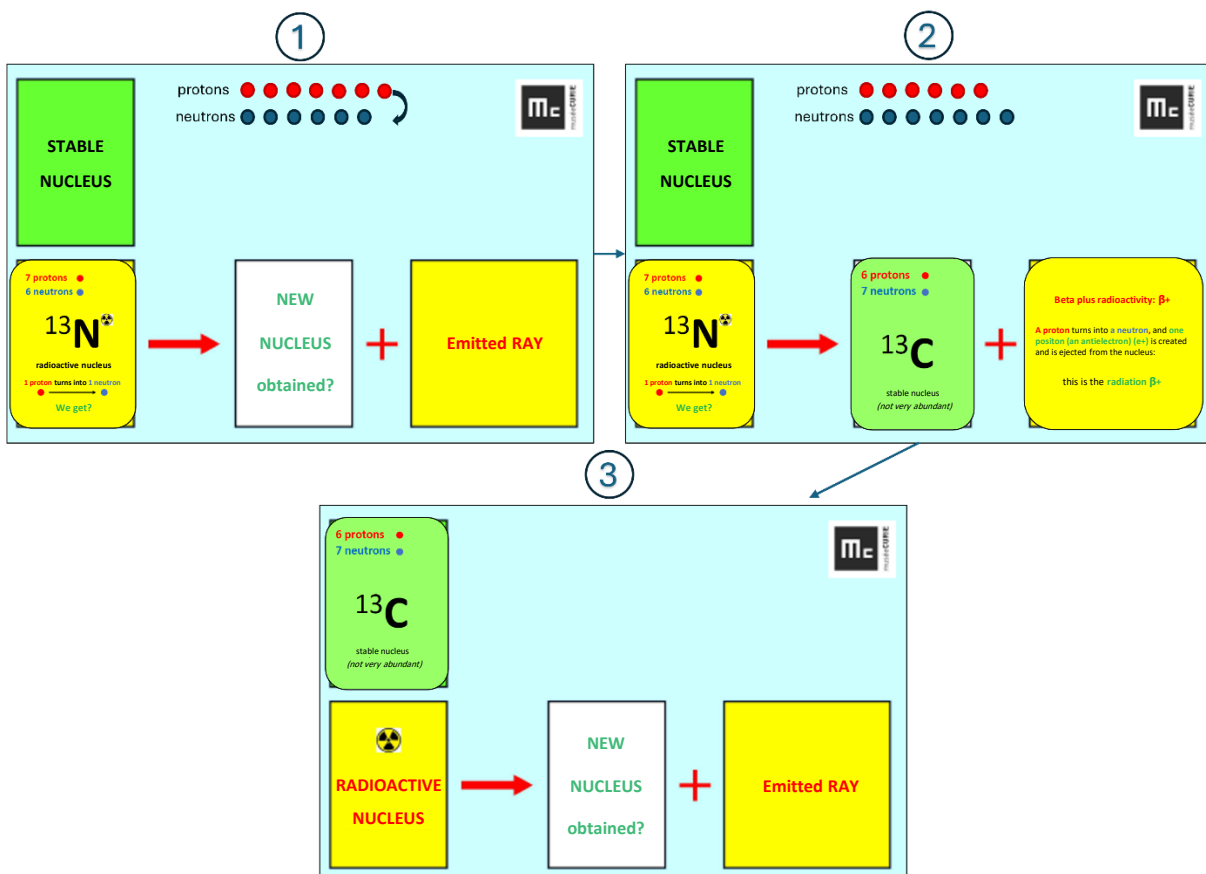
- On board 1 ("Family B, C, N, O, F") the cards by family are placed on each of the corresponding family squares (front of the cards on top)
 - The 4 Bore cards on the Bore square of board 1
 - The 6 Carbon cards on the Carbon square of board 1
 - The 6 Nitrogen cards on the Nitrogen square of board 1
 - The 6 Oxygen cards on the Oxygen square of board 1
 - The 2 Fluorine cards on the Fluorine square of board 1
- Put the two-color tokens in a small jar
- Arrange the emitted radiation cards next to each other

How to play:

The game can be played alone or in teams of 2 players who take turns.

We recommend playing with all the cards of the same family so as to fully understand beta radioactivity. The discovery of artificial radioactivity can be mentioned (N13).

- Draw a card from one of these families and place it on board 2 following the instructions on the card:
 - If the nucleus is stable (green card back) place the card on the "Stable Nucleus" square
 - The game is over, draw another card
 - If the nucleus is radioactive, place your card on the "Radioactive Nucleus" square
 - Continue playing the game
- If the nucleus is radioactive:
 - Follow the instructions to find the new nucleus obtained during the transmutation
 - To understand the transmutation, use colored tokens: one line with the blue tokens (neutrons) and another with the red tokens (protons)
 - Find the corresponding card among the isotopes and place it in the "New nucleus obtained" square
 - Find the emitted ray card:
 - Beta ray plus (β^+): When 1 proton turns into 1 neutron, it emits a positron (antielectron: e^+) and a neutrino (ν)
 - Beta radius less (β^-): When 1 neutron turns into 1 proton, it emits an electron (e^-) and an anti-neutrino ($\bar{\nu}$)



RADIO-ACTIVITY 4:

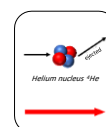
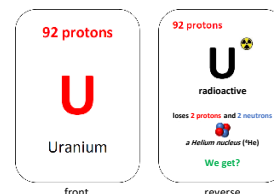
Alpha radioactivity

First, the presenter gives a presentation on radioactivity. See the explanatory guide "Radioactivity" p 12-13.

Objective: To understand radioactivity, isotopes, and the "transmutation of the elements". In this game we will limit ourselves to alpha radioactivity.

Materials:

- 1 periodic table
- Activity 4 Game Kit:
 - 11 nucleus cards (82 to 92 protons):
 - Front: number of protons, symbol, and name of the corresponding chemical element.
 - Back: cards contain information relating exclusively to alpha decays
 - 9 emitted radiation: cards alpha radioactivity



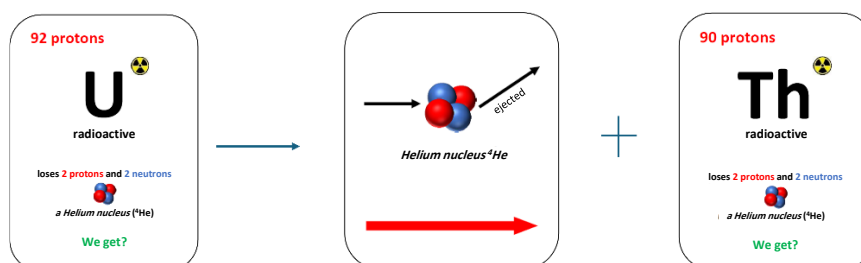
Setup:

- Lay out the 11 cards face down, arranging them in ascending order (number of protons from 82 to 92).

How to play:

The game can be played alone or in teams of 2 players who take turns. At the end of the game, the presenter can talk about radioactive families.

- Flip over the Uranium card with the 92 protons
- Follow the instructions provided on the back of the card
 - Take an emitted radiation card and place it next to the turned-over card
 - Find the new element obtained as a result of the alpha decay
- The game is over when the player comes across a card that reads: **stable**



RADIO-ACTIVITY 5:

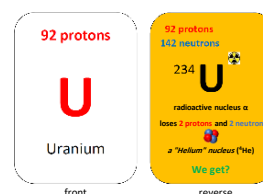
The radioactive family of Uranium (238)

First, the presenter gives a presentation on radioactivity. See the explanatory guide "Radioactivity" p 12-13.

Objective: To discover the radioactive family of Uranium-238 (U238) and to understand how radium (226), radon (222), and polonium nuclei (218, 214 and 210) are formed thanks to successive beta or alpha decays.

Materials:

- 1 periodic table
- Board 2 of the game (*where we will arrange the cards*)
- Activity 5 Game Kit:
 - 36 nuclei cards
 - 7 lead nuclei (Pb 206; 207; 208; 210; 211; 212; 214)
 - 4 cards with 83 protons = 4 Bismuth nuclei (Bi 209; 210; 212; 214)
 - 4 cards with 84 protons = 4 Polonium nuclei (Po 210; 214; 216; 218)
 - 1 card with 85 protons = 1 Astatine nuclei (At 210)
 - 4 cards with 86 protons = 4 Radon nuclei (Rn 218; 219; 220; 222)
 - 1 card with 87 protons = 1 Francium nucleus (Fr 223)
 - 4 cards with 88 protons = 4 Radium nuclei (Ra 223; 224; 226; 228)
 - 2 cards with 89 protons = 2 Actinium nuclei (Ac 227; 228)
 - 4 cards with 90 protons = 4 Thorium nuclei (Th 230; 231; 232; 234)
 - 2 cards with 91 protons = 2 Protactinium nuclei (Pa 231; 234)
 - 3 cards with 92 protons = 3 Uranium nuclei (U 234; 235; 238)
 - Emitted radiation cards
 - Beta plus (β^+) radioactivity (a card with yellow background on the back)
 - Beta minus (β^-) radioactivity (a card with yellow background on the back)
 - Alpha (α) radioactivity (a card with orange background on the back)



Setup:

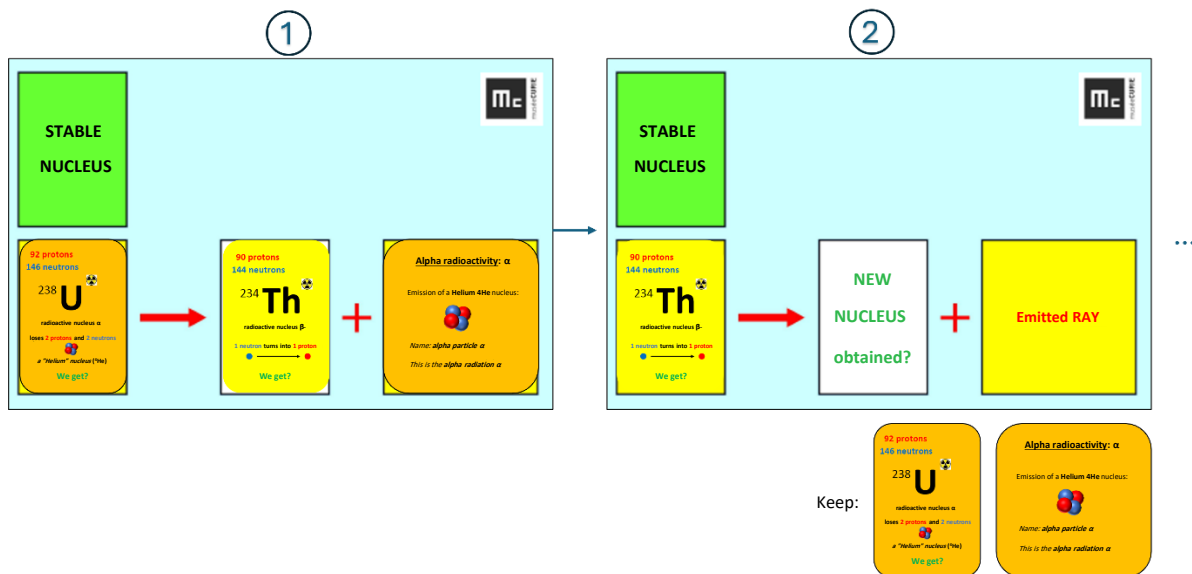
- Group the cards by chemical element, front side

How to play:

The game can be played alone or in teams of 2 players who take turns. At the end of the game, the presenter can talk about the radioactive families in detail. See the explanatory guide "The radioactive family of uranium" p 14-15.

- Turn over the Uranium card with 92 protons and place it on Board 2 on the "Radioactive nucleus" square
- Follow the instructions provided on the back of the card
 - Find the new element obtained in one of the chemical element piles (check the number of protons and neutrons on the back) and put it on Board 2
 - Match the emitted ray

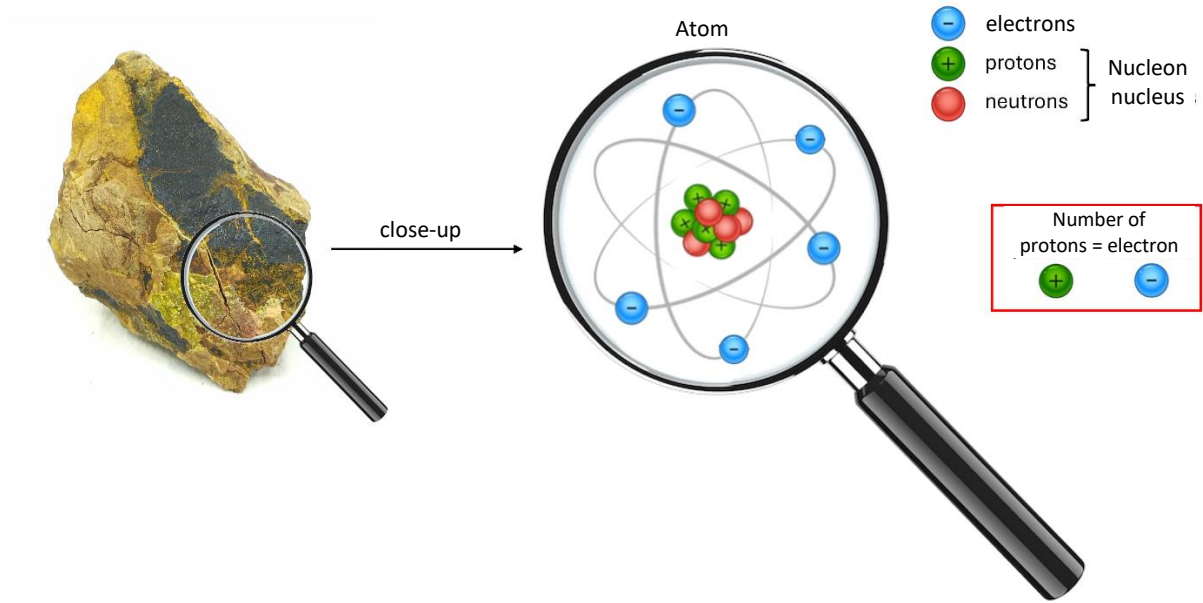
- Place on Board 2 in the corresponding square the new nucleus card, as well as the card with the ray emitted during this decay
- Then remove from the board:
 - The original Uranium nuclei (238) card and keep it in front of you
 - The emitted ray card and keep it
- Move the card with the newly obtained nuclei to the left on the board square
 - On the "Stable Nucleus" square if the nucleus obtained is stable
 - On the "Radioactive Nucleus" square if the nucleus obtained is radioactive
 - In this case, continue playing the game
- The game is over when the player gets a new nucleus that is stable (Pb206)



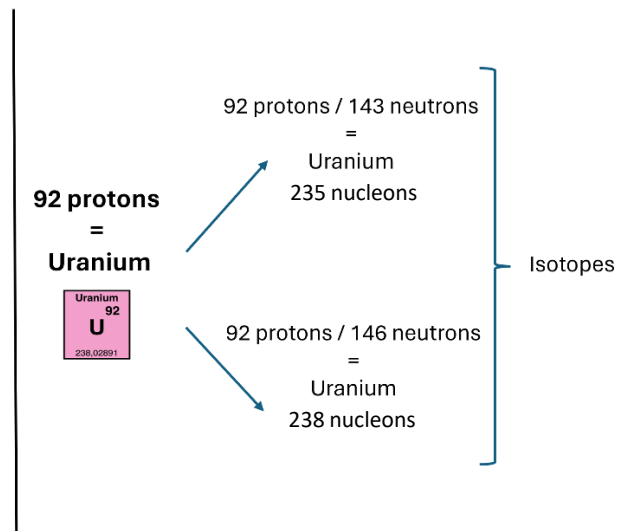
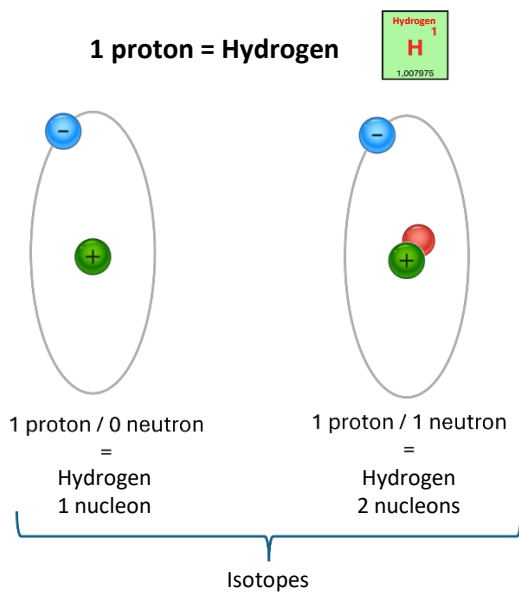
EXPLANATORY GUIDES

Atoms, Nuclei and the Periodic Table



Everything is made up of atoms! They are tiny - for example, a human hair is a million atoms thick.



The number of protons = the atom's identity card



The Periodic Table

-  Rows (= period): ascending order of the number of protons (atomic number)
-  Columns (= group): similar properties of atoms

Periodic table of chemical elements

Name of the element (gas, liquid or solid at 0°C and 101.3 kPa)
 Atomic number
 Chemical symbol
 Relative atomic mass [or that of the most stable isotope]
 Source: CIAAW "Atomic Weights 2013" + Rev. 2015

Hydrogen 1 H 1.00794																	Helium 2 He 4.002602
Lithium 3 Li 6.939	Beryllium 4 Be 9.0121831											Boron 5 B 10.811	Carbon 6 C 12.0107	Nitrogen 7 N 14.006432	Oxygen 8 O 15.9994	Fluorine 9 F 18.9984032	Neon 10 Ne 20.1797
Sodium 11 Na 22.98976928	Magnesium 12 Mg 24.305											Aluminum 13 Al 26.9815385	Silicon 14 Si 28.085	Phosphorus 15 P 30.97376200	Sulfur 16 S 32.065	Chlorine 17 Cl 35.453	Argon 18 Ar 39.948
Potassium 19 K 39.0983	Calcium 20 Ca 40.078	Scandium 21 Sc 44.955908	Titanium 22 Ti 47.867	Vanadium 23 V 50.9415	Chromium 24 Cr 51.9961	Manganese 25 Mn 54.938044	Iron 26 Fe 55.845	Cobalt 27 Co 58.933194	Nickel 28 Ni 58.6934	Copper 29 Cu 63.546	Zinc 30 Zn 65.38	Gallium 31 Ga 69.723	Germanium 32 Ge 72.630	Arsenic 33 As 74.921595	Selenium 34 Se 78.971	Bromine 35 Br 79.904	Krypton 36 Kr 83.798
Rubidium 37 Rb 85.4678	Strontium 38 Sr 87.62	Yttrium 39 Y 88.90584	Zirconium 40 Zr 91.224	Niobium 41 Nb 92.90637	Molybdenum 42 Mo 95.95	Technetium 43 Tc [98]	Ruthenium 44 Ru 101.07	Rhodium 45 Rh 102.90550	Palladium 46 Pd 106.42	Silver 47 Ag 107.8682	Cadmium 48 Cd 112.414	Indium 49 In 114.818	Tin 50 Sn 118.710	Antimony 51 Sb 121.760	Tellurium 52 Te 127.60	Iodine 53 I 126.90447	Xenon 54 Xe 131.293
Cesium 55 Cs 132.905451	Barium 56 Ba 137.327	Lanthanides 57-71	Hafnium 72 Hf 178.49	Tantalum 73 Ta 180.94788	Tungsten 74 W 183.84	Rhenium 75 Re 186.207	Osmium 76 Os 190.23	Iridium 77 Ir 192.222	Platinum 78 Pt 195.084	Gold 79 Au 196.966569	Mercury 80 Hg 200.592	Thallium 81 Tl 204.3835	Lead 82 Pb 207.2	Bismuth 83 Bi 208.98040	Polonium 84 Po [209]	Astatine 85 At [210]	Radon 86 Rn [222]
Francium 87 Fr [223]	Radium 88 Ra [226]	Actinides 89-103	Rutherfordium 104 Rf [261]	Dubnium 105 Db [268]	Seaborgium 106 Sg [266]	Bohrium 107 Bh [270]	Hassium 108 Hs [277]	Mttenium 109 Mt [276]	Darmstadtium 110 Ds [281]	Roentgenium 111 Rg [282]	Copernicium 112 Cn [285]	Nihonium 113 Nh [284]	Flerovium 114 Fl [289]	Moscovium 115 Mc [288]	Livermorium 116 Lv [293]	Tennesseium 117 Ts [294]	Oganeson 118 Og [294]
			Lanthanum 57 La 138.90547	Cerium 58 Ce 140.116	Praseodymium 59 Pr 140.90766	Neodymium 60 Nd 144.242	Promethium 61 Pm [145]	Samarium 62 Sm 150.36	Europium 63 Eu 151.964	Gadolinium 64 Gd 157.25	Terbium 65 Tb 158.92535	Dysprosium 66 Dy 162.500	Holmium 67 Ho 164.93033	Erbium 68 Er 167.259	Thulium 69 Tm 168.93422	Ytterbium 70 Yb 173.045	Lutetium 71 Lu 174.9668
			Actinium 89 Ac [227]	Thorium 90 Th 232.0377	Protactinium 91 Pa 231.03688	Uranium 92 U 238.02891	Neptunium 93 Np [237]	Plutonium 94 Pu [244]	Americium 95 Am [243]	Curium 96 Cm [247]	Berkelium 97 Bk [247]	Californium 98 Cf [251]	Einsteinium 99 Es [252]	Fermium 100 Fm [257]	Mendelevium 101 Md [258]	Nobelium 102 No [259]	Lawrencium 103 Lr [260]

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Metals										Non-metals							
Alkaline	Alkaline earth	Lanthanides	Actinides	Transition metals	Poor metals	Metalloids	Other non-metals	Halogens	Noble gases	Not classified	Primordial	Decay of other elements	Synthetic				

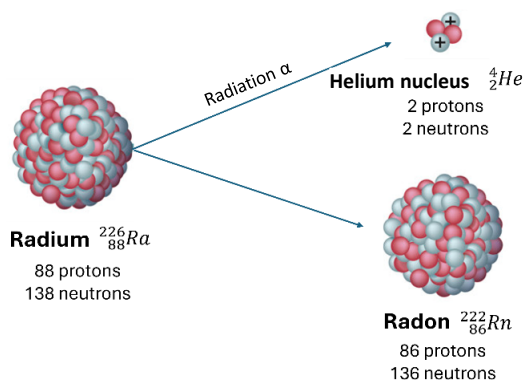
Radioactivity

When atoms contain too many nucleons, or when there is too great an imbalance between the number of protons and neutrons, the force that holds the nucleus together is no longer sufficient. The atoms then tend to reorganize themselves to become stable - this is referred to as radioactivity.

When this happens, the nuclei decay and emit particles and energy in the form of radiation. 3 types of radiation can occur: alpha α , beta β , and gamma γ .

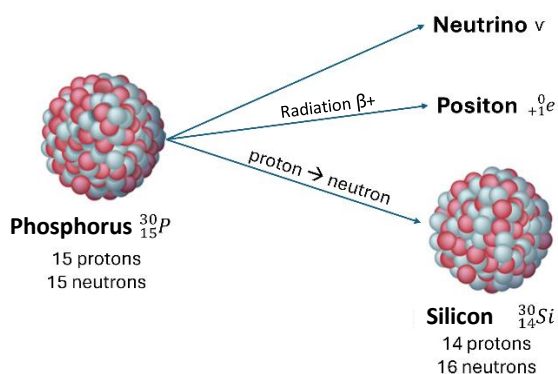
Radioactivity α

Ejection of a helium nucleus



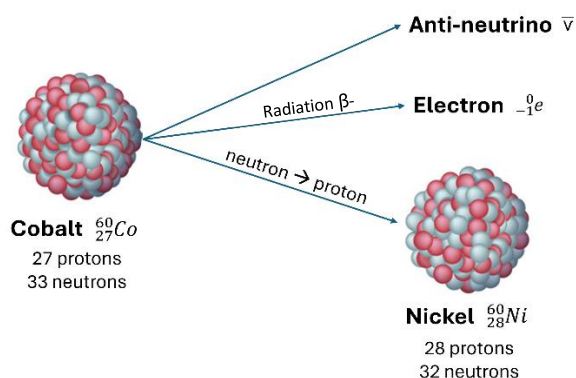
Radioactivity β^+

Transformation of 1 proton into 1 neutron



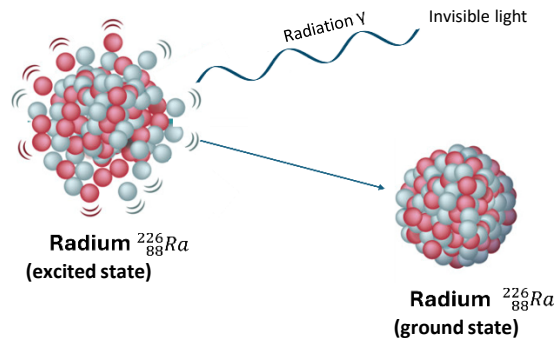
Radioactivity β^-

Transformation of 1 neutron into 1 proton

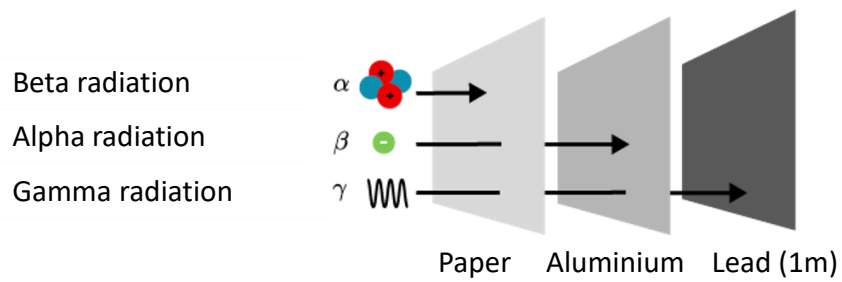


Radioactivity γ

De-excitation by electro-magnetic rays

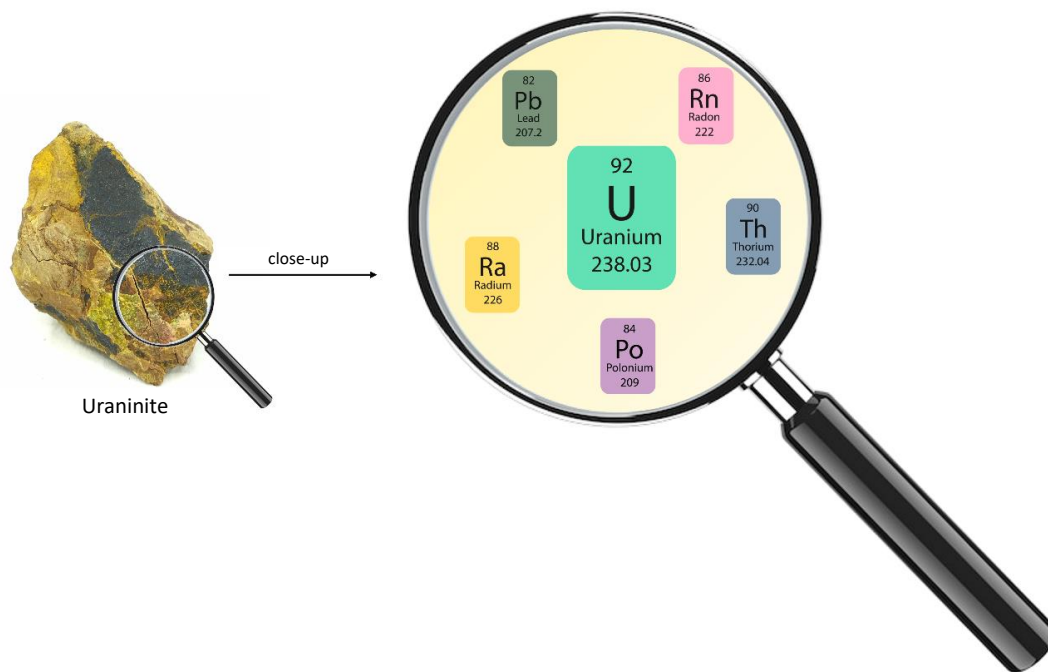


Depending on the type of rays, different types of protection are required:



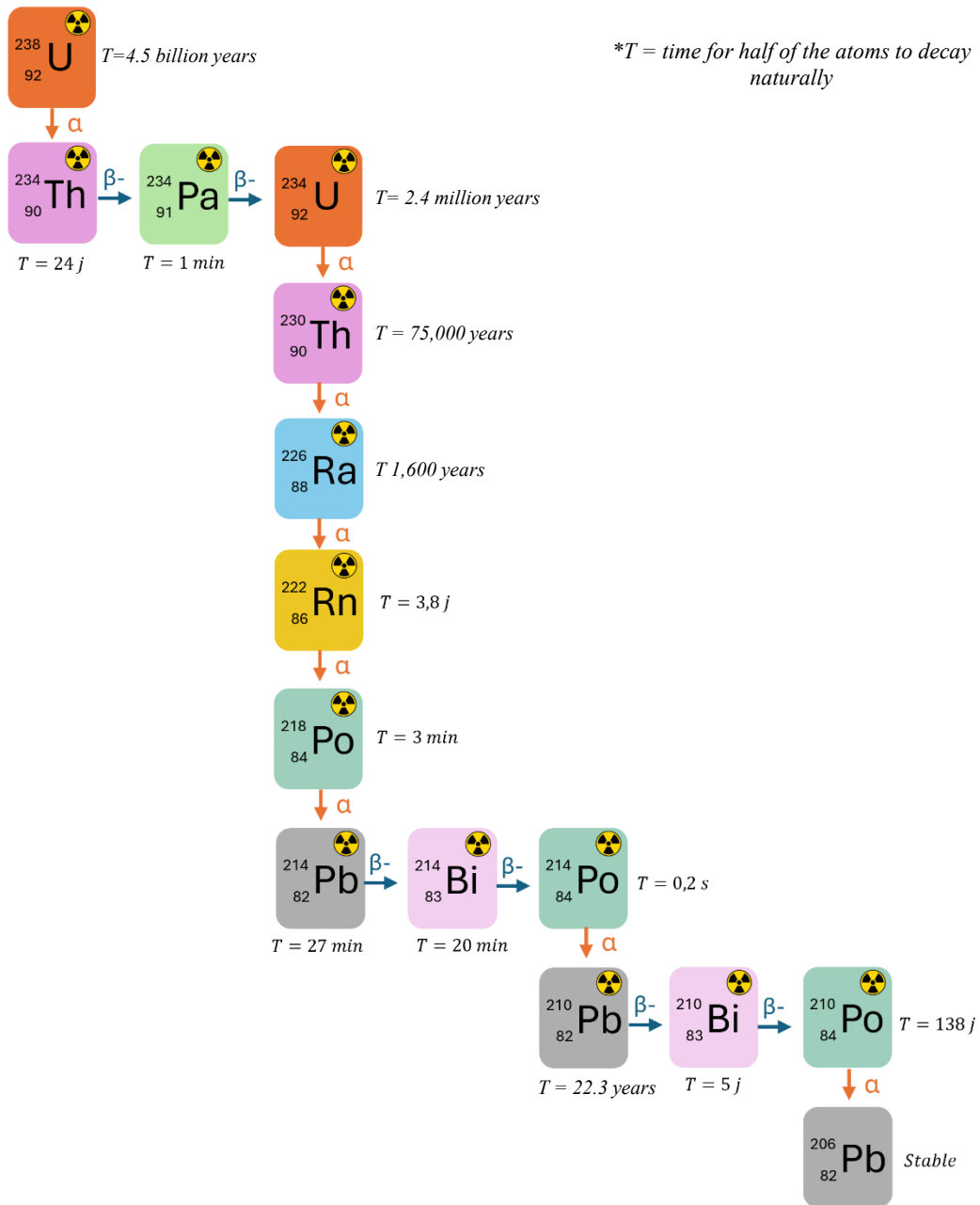
The Radioactive Family of Uranium

In uranium ores, such as pitchblende, there are many other highly radioactive atoms, such as radium and polonium, discovered in 1898 by Marie and Pierre Curie.



In fact, uranium decays into a radioactive atom, which in its turn decays into a radioactive atom until it forms a stable atom - this is called the radioactive family of uranium. Radium and polonium are part of this family, which is why they are found in uranium ores.

The more radioactive the atoms, the faster they decay.



Impression of the game

For the printing of these cards and other elements, here is a summary of the specifications:

1. Types of Materials:

- **Activity Cards:** Cardstock similar to playing cards.
- **Boards and Sheets:** Laminated sheets.

2. Double-sided Printing:

- The cards for Activities 1 and 2, as well as some solo cards from Activity 4, will not initially be printed double-sided.
- To make these cards easier to identify, we've added a colored back design.

3. Back Design Colors:

- Activity 1 - Easy Version: Light blue, RGB (R: 180, G: 243, B: 254).
- Activity 1 - Difficult Version: Dark blue, RGB (R: 75, G: 71, B: 239).
- Activity 2 - Easy Version: Pink, RGB (R: 250, G: 172, B: 244).
- Activity 2 - Difficult Version: Purple, RGB (R: 177, G: 14, B: 190).
- Activity 4 - Solo Card 7x10: White, RGB (R: 255, G: 255, B: 255).

4. Final Formats and Quantities:

- Game Set: 51 A4 sheets printed double-sided.
- Boards: 3 A3 boards printed single-sided.
- Table: 1 A4 table printed single-sided.
- Sheets: 8 A4 sheets printed double-sided.

These specifications will ensure a clear and organized printing of the game components.