BASE-LiNE Earth

Basics of isotope fractionation and its use for proxy – reconstruction of past environmental and climate change?

UNIT 1

Definition Isotope

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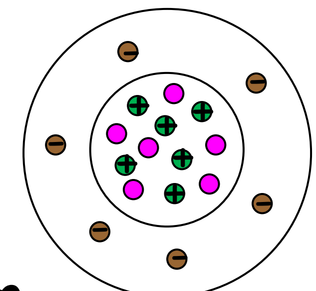
Definition

- Greek "isos (ίσος) " means **equal** & "topos" (τόπος) means **site or place**
- Isotopes of an element have nuclei with the same number of protons (atomic number Z) but different numbers of neutrons

6 protons (6^+) + 6 neutrons (n) } 12

6 protons (6+), 6 electrons (6^-) → 6

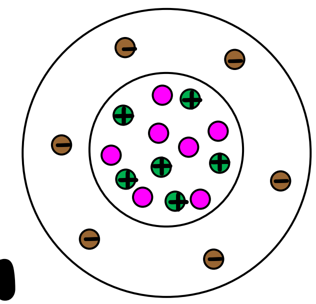
$^{12}_{6}C$



6 protons (6^+) + 7 neutrons (n) } 13

6 protons (6+), -6 electrons (6^-) → 6

$^{13}_{6}C$



Isotopes have different masses and different nuclear properties!!!!!!

Definition Isotope

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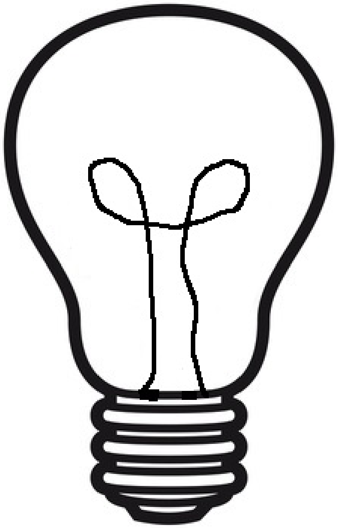
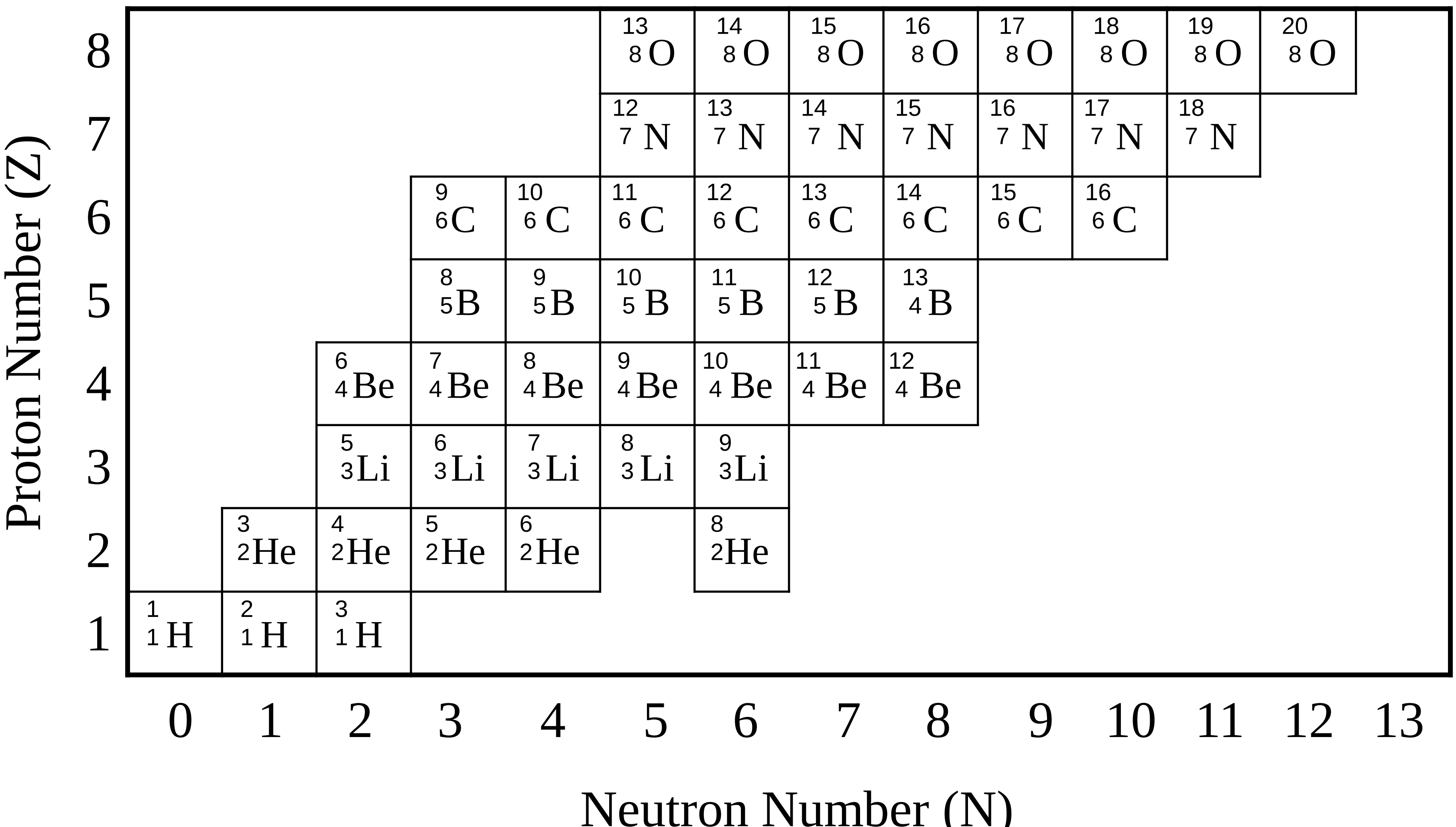


1. The **atomic number** (Z) is the total number of **protons** in a nucleus
2. A proton is a subatomic particle with a positive charge
3. The number of protons in an atom defines the element
4. A **neutron** (N) is a subatomic particle with **zero charge**, which changes mass but NOT chemical properties
5. The **mass number** (A) is the total number of protons **and** neutrons in a nucleus ($A = N + Z$)
6. **Isotopes** are two or more atoms with the same atomic number but different numbers of neutrons, and different **mass numbers**

The Nuclide Chart

Shows nuclides (often called "isotopes") arranged with increasing atomic numbers from left to right and increasing neutron numbers from top to buttom



The Nuclide Chart

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Each square represents a nuclide, an isotope specific atom

Atomic number = Z (Protons) Atomic mass = Z + N (Protons + Neutrons)

Proton Number (Z)	0	1	2	3	4	5	6	7	8	9	10	11	12	13
8						${}^{13}_{8}\mathrm{O}$	${}^{14}_{8}\mathrm{O}$	${}^{15}_{8}\mathrm{O}$	${}^{16}_{8}\mathrm{O}$	${}^{17}_{8}\mathrm{O}$	${}^{18}_{8}\mathrm{O}$	${}^{19}_{8}\mathrm{O}$	${}^{20}_{8}\mathrm{O}$	
7						${}^{12}_{7}\mathrm{N}$	${}^{13}_{7}\mathrm{N}$	${}^{14}_{7}\mathrm{N}$	${}^{15}_{7}\mathrm{N}$	${}^{16}_{7}\mathrm{N}$	${}^{17}_{7}\mathrm{N}$	${}^{18}_{7}\mathrm{N}$		
6				${}^{9}_{6}\mathrm{C}$	${}^{10}_{6}\mathrm{C}$	${}^{11}_{6}\mathrm{C}$	${}^{12}_{6}\mathrm{C}$	${}^{13}_{6}\mathrm{C}$	${}^{14}_{6}\mathrm{C}$	${}^{15}_{6}\mathrm{C}$	${}^{16}_{6}\mathrm{C}$			
5				${}^{8}_{5}\mathrm{B}$	${}^{9}_{5}\mathrm{B}$	${}^{10}_{5}\mathrm{B}$	${}^{11}_{5}\mathrm{B}$	${}^{12}_{5}\mathrm{B}$	${}^{13}_{4}\mathrm{B}$					
4			${}^{6}_{4}\mathrm{Be}$	${}^{7}_{4}\mathrm{Be}$	${}^{8}_{4}\mathrm{Be}$	${}^{9}_{4}\mathrm{Be}$	${}^{10}_{4}\mathrm{Be}$	${}^{11}_{4}\mathrm{Be}$	${}^{12}_{4}\mathrm{Be}$					
3			${}^{5}_{3}\mathrm{Li}$	${}^{6}_{3}\mathrm{Li}$	${}^{7}_{3}\mathrm{Li}$	${}^{8}_{3}\mathrm{Li}$	${}^{9}_{3}\mathrm{Li}$							
2		${}^{3}_{2}\mathrm{He}$	${}^{4}_{2}\mathrm{He}$	${}^{5}_{2}\mathrm{He}$	${}^{6}_{2}\mathrm{He}$		${}^{8}_{2}\mathrm{He}$							
1	${}^{1}_{1}\mathrm{H}$	${}^{2}_{1}\mathrm{H}$	${}^{3}_{1}\mathrm{H}$											

Neutron Number (N)

The Nuclide Chart

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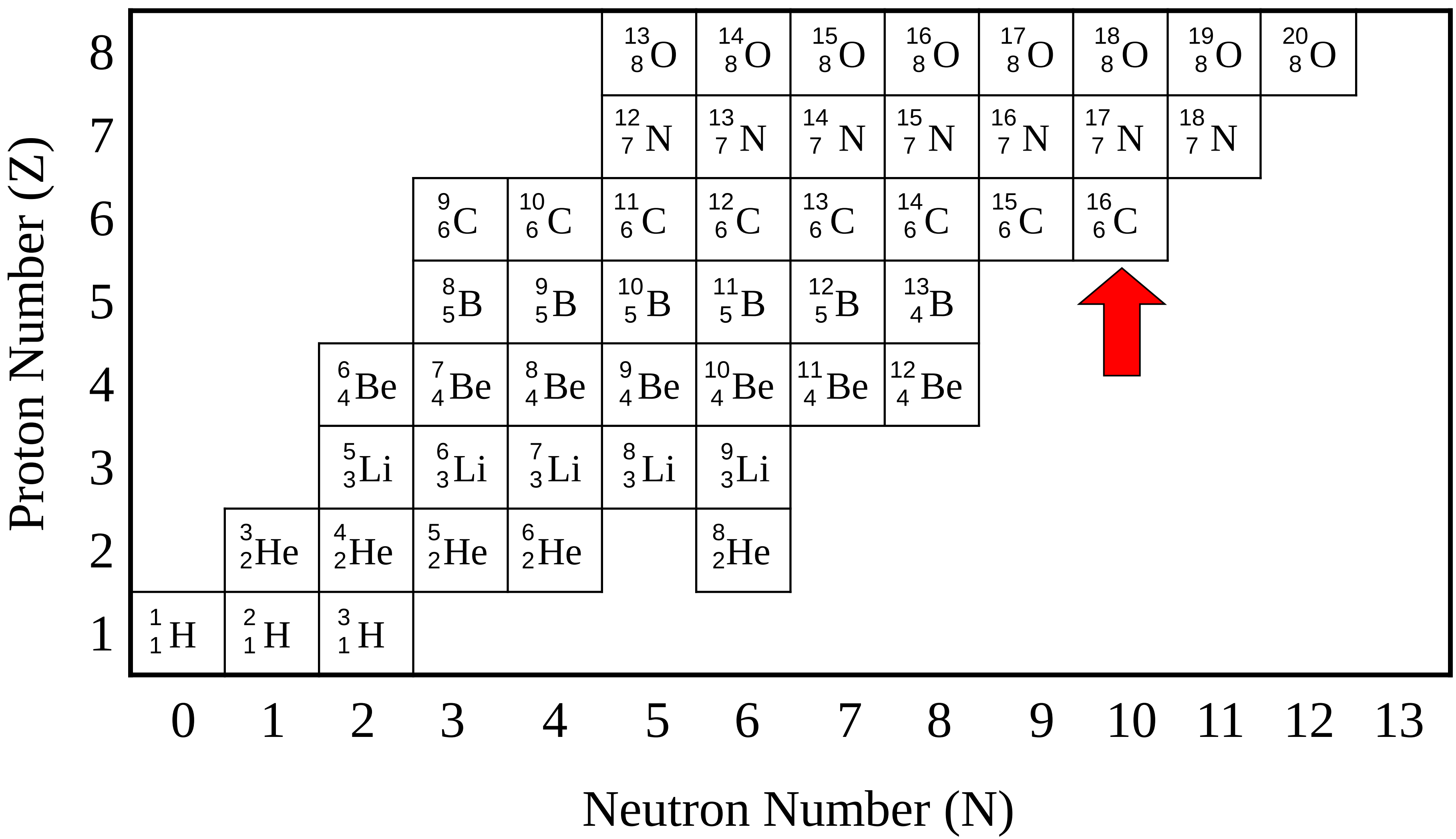
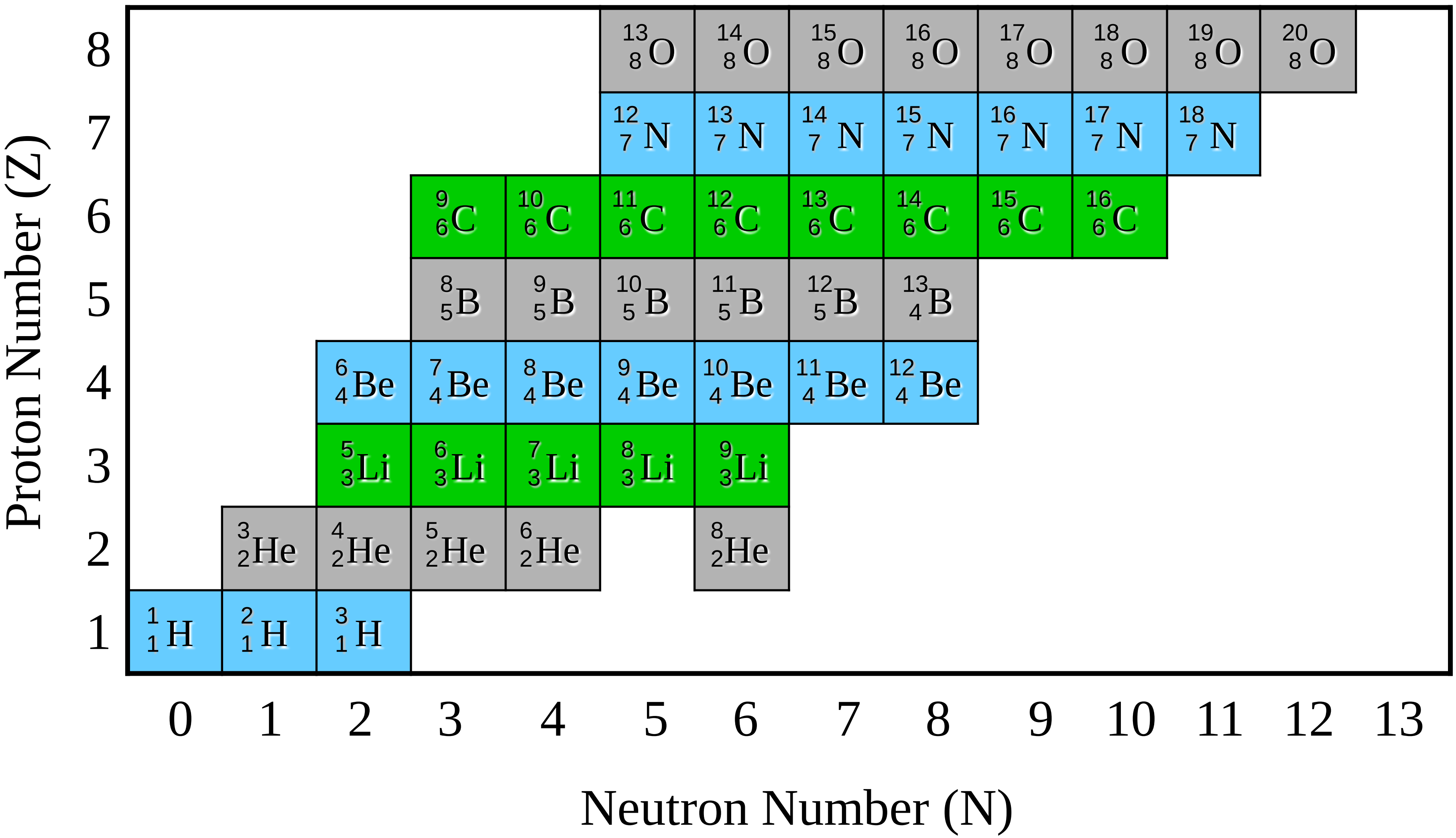
Atomic number = Z (Protons)   Atomic mass = Z + N (Protons + Neutrons)



The Nuclide Chart

Each row represents nuclides that are isotopes: they share a common number of protons (Z) but differ in their number of neutrons (N).



The Nuclide Chart

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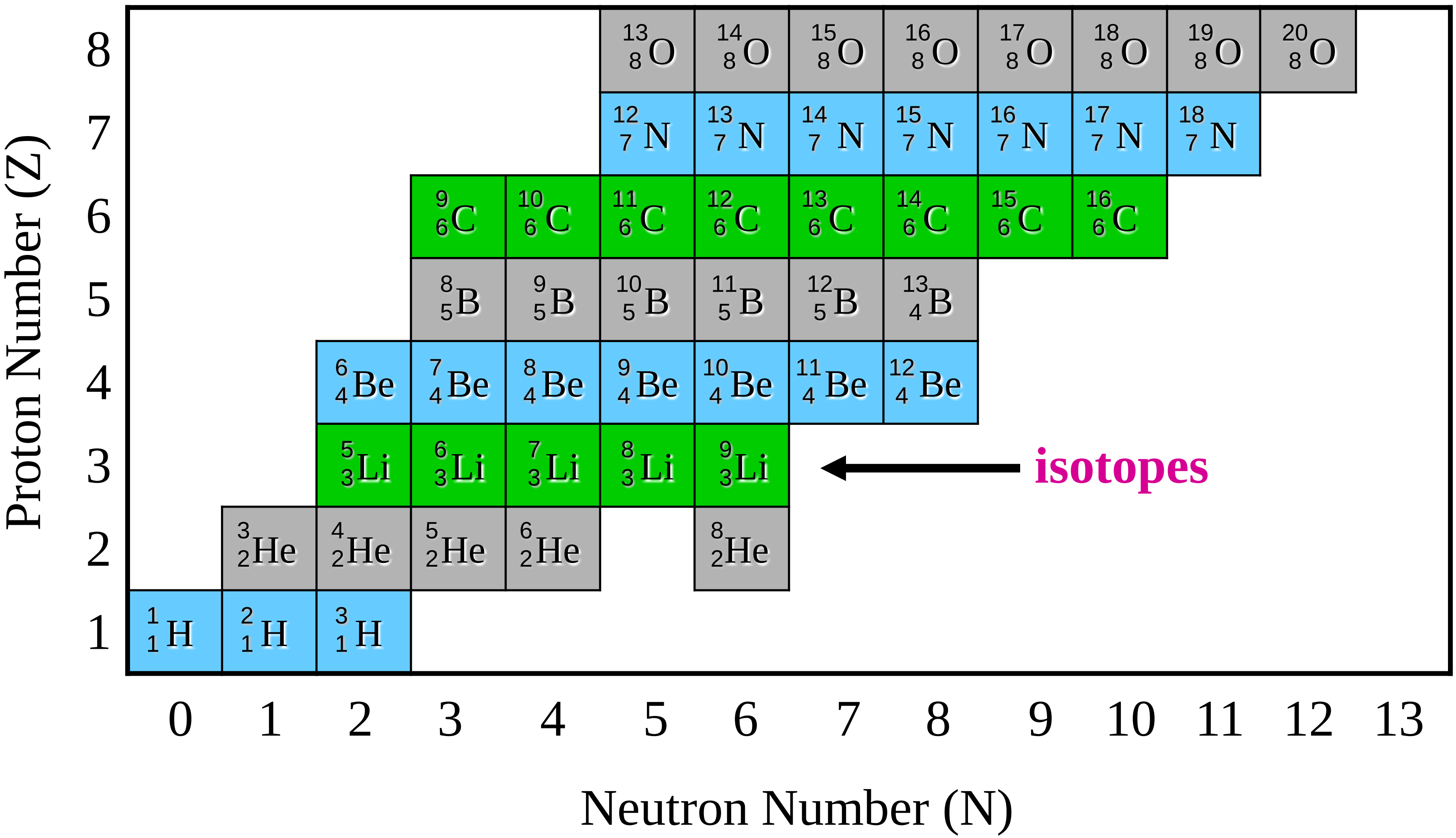

The Nuclide Chart

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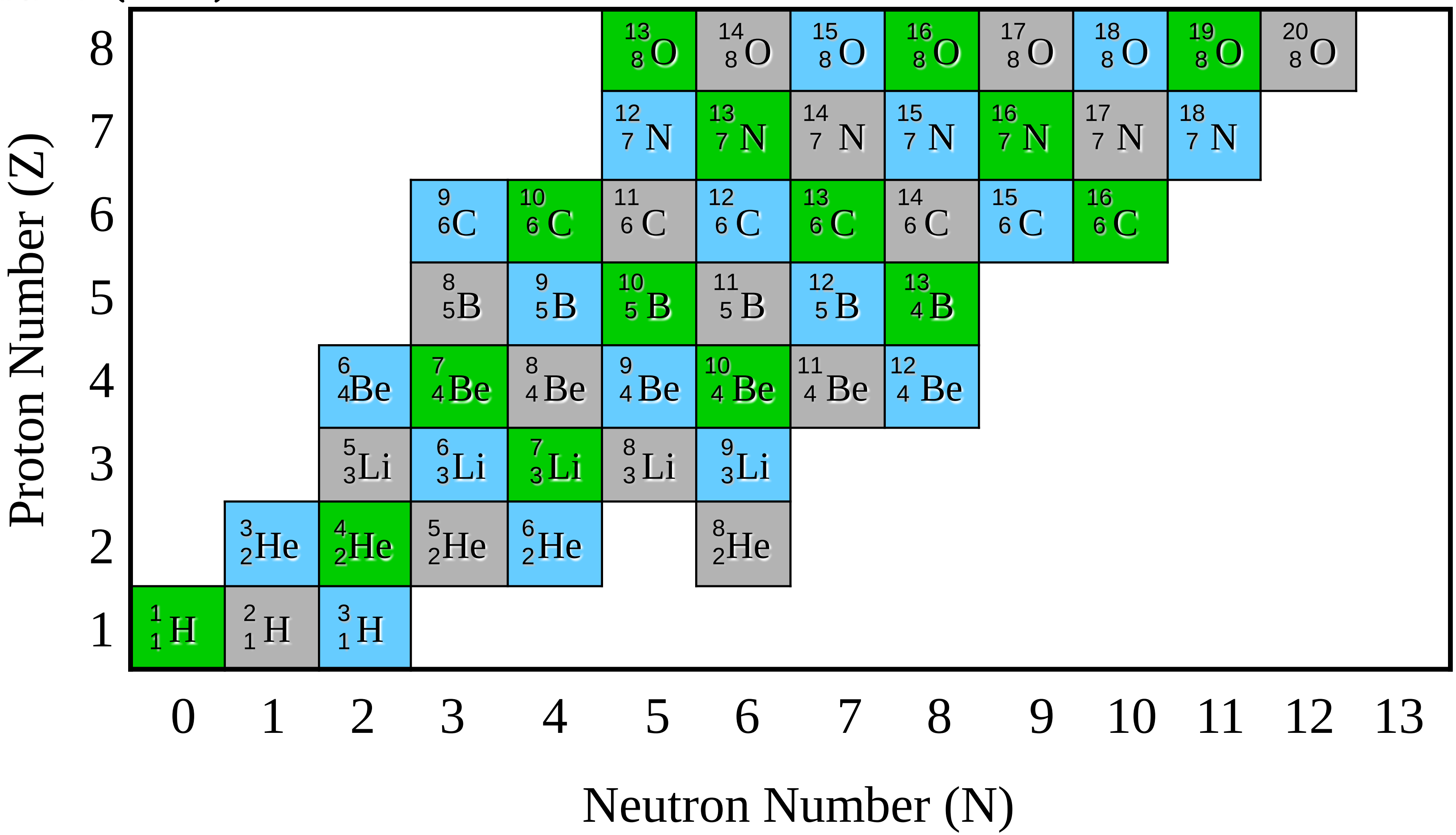
Each row represents nuclides that are isobars: they share a common atomic weight/mass number (N + Z).



The Nuclide Chart

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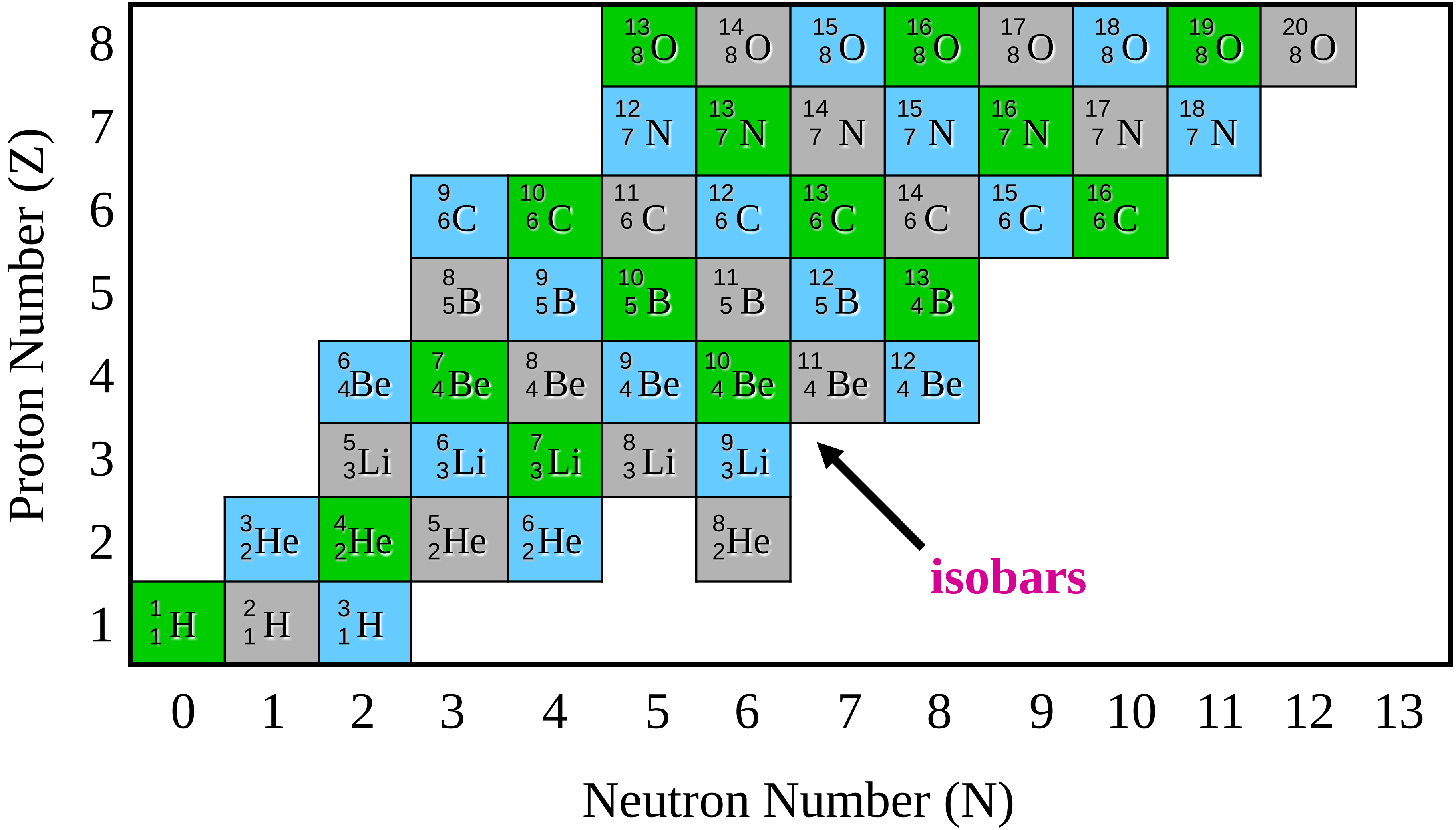
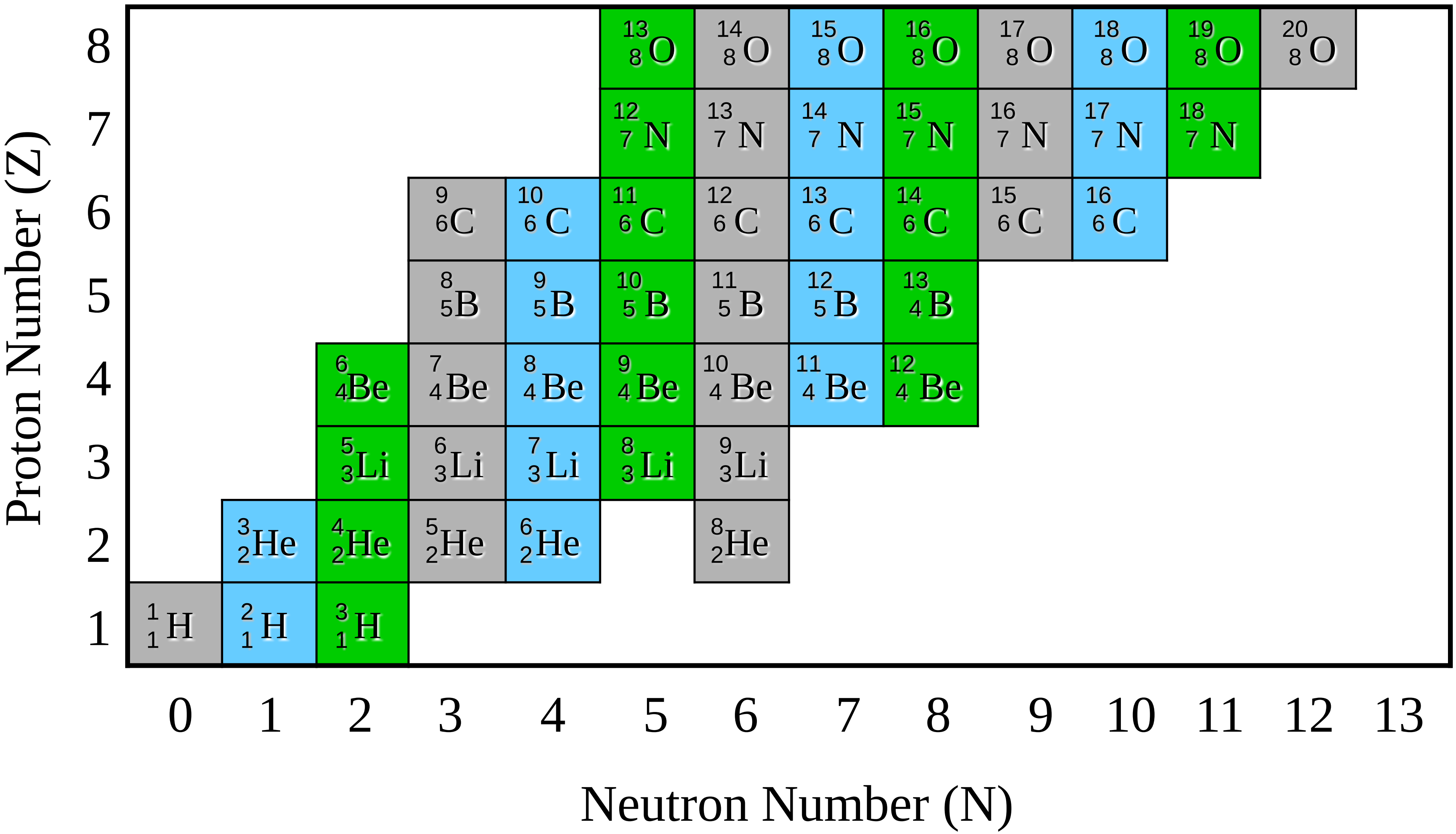


The Nuclide Chart

Each row represents nuclides that are isotones: they share a common number of neutrons (N).



The Nuclide Chart

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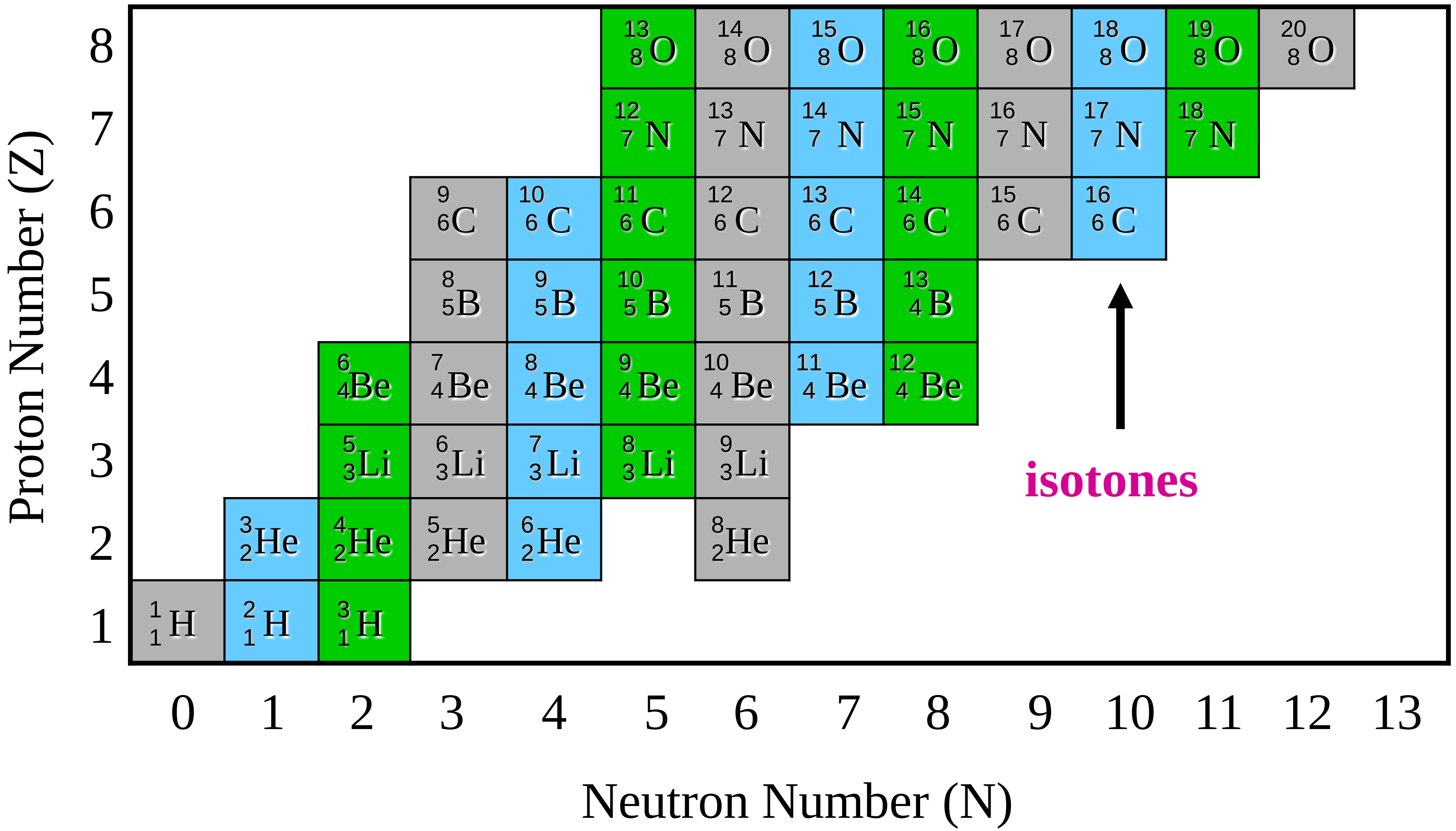
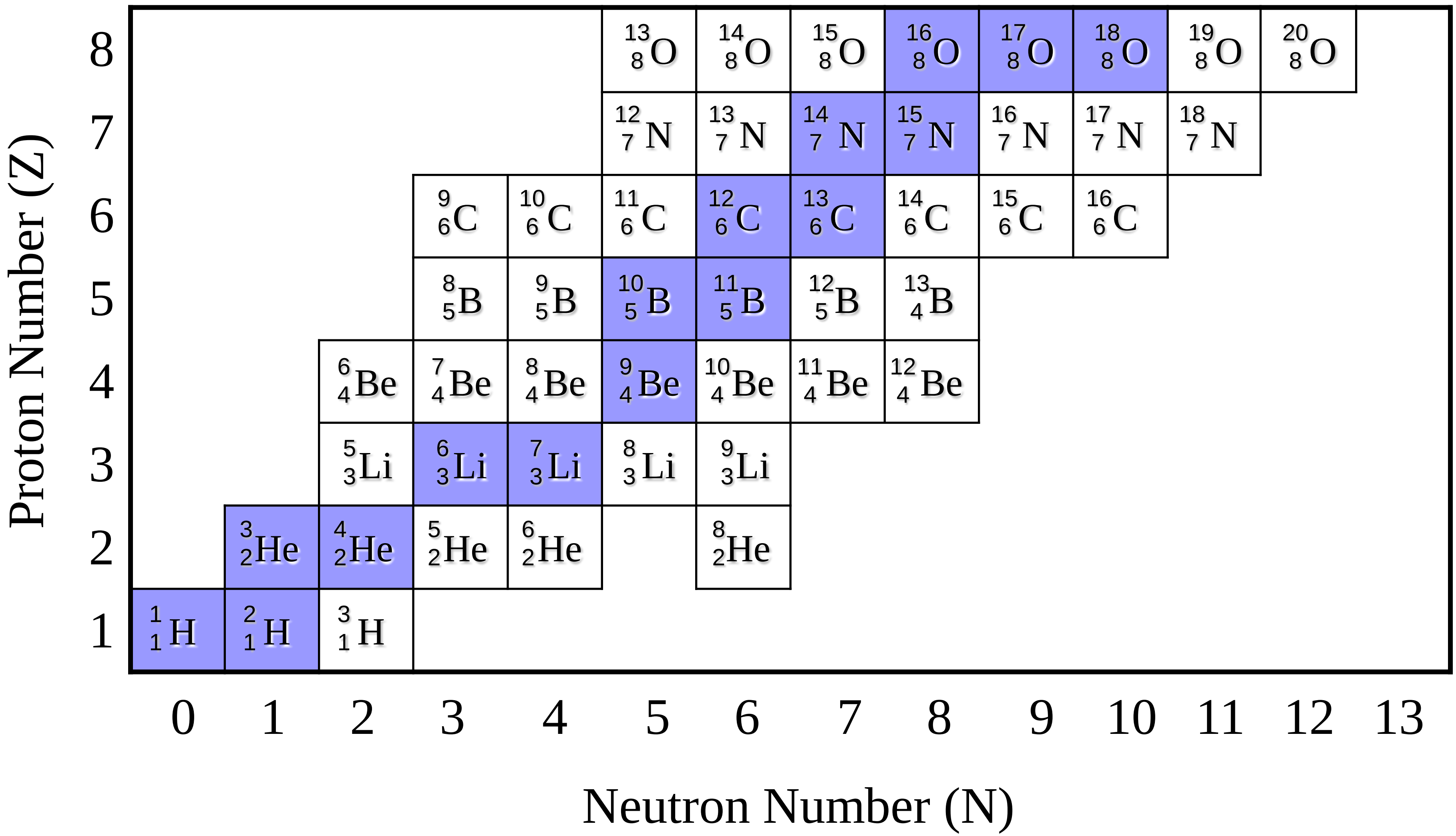
Each row represents nuclides that are isotones: they share a common number of neutrons (N).



The Nuclide Chart

The shaded squares are stable and the un-shaded squares are unstable or radioactive nuclides.



The Nuclide Chart

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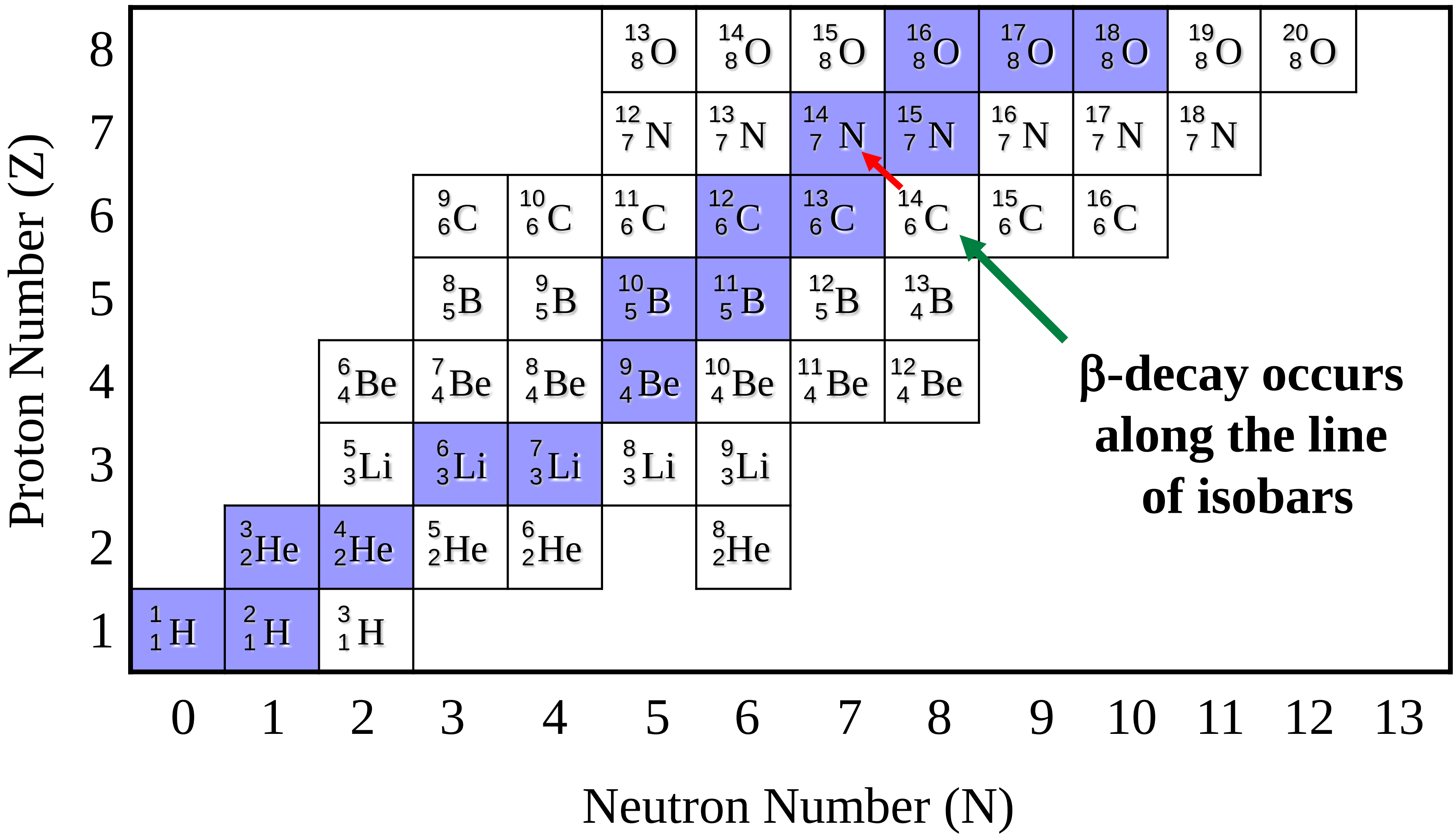

Isotope Definition Characterization

1. Stable Isotopes

A certain amount of a stable isotope in a given closed geological archive will **not change as a function of time**.
The ratio of stable isotopes will not change throughout time as long as there is no external forcing. Examples: $^{18}O/^{16}O$, $^{44}Ca/^{42}Ca$, etc.

2. Radioactive Isotopes

Radioactive isotope is a nuclei of an atom having same chemical formula and atomic number but different mass number. Radioactive isotopes are defined as an artificially or naturally occurring isotope of an element which has high number of neutrons. A certain amount of a radioactive isotope in a given closed geological archive will **decline as a function of time**. Isotope ratios including a radioactive one will change throughout time. Examples: ^{238}U, ^{3}H, ^{131}J, ^{14}C etc.

Isotope Definition Characterization

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3. Radiogenic Isotopes

A **radiogenic isotope** is a nuclide that is produced by a process of radioactive decay. A **non-radioactive** isotope of which the amount in a closed geological archive is **increasing as a function of time** through the decay of a radioactive mother nuclide is called **radiogenic**. A radiogenic isotope ratio is **increasing as a function of time**. Examples: ^{206}Pb, ^{40}Ar, ^{87}Sr etc.

4. Cosmogenic Isotopes

Are very rare isotopes and are produced when cosmic rays collide with atmospheric molecules at high speed. Examples: ^{10}Be, ^{26}Al, ^{36}Cl, ^{21}Ne etc.

5. Extinct Isotopes

Are isotopes formed by nucleosynthesis **before the formation of the Solar System**, about 4.6 billion years ago whose half-lives were too short to have lasted through the formation of the solar system. Examples: ^{244}Pu, ^{247}Cm, ^{53}Mn, ^{129}J etc.

Isotope ratios may vary due to chemical and physical processes:

- e.g due to chemical reactions and type of bonding,
- changes of external chemical conditions like pH, temperature and chemcial composition of the solution,
- diffusion,
- radiation,
- etc.

Given a isotope ratios changes as a function of external processes like pH temperature, salinity etc. measurement of isotope ratios may be applied to reconstruct environmental conditions in the present and past.

- $^{11}B/^{10}B$ ratios may be applied to reconstruct pH in seawater
- $^{18}O/^{16}O$ are applied to reconstruct temperature and evaporation
- $^{230}Th/^{234}U$ ratios are applied for age dating of carbonates
- $^{87}Sr/^{86}Sr$ ratios measured in carbonates reflect the balance between hydrothermal input and continental input of Sr from the continent
- etc.

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