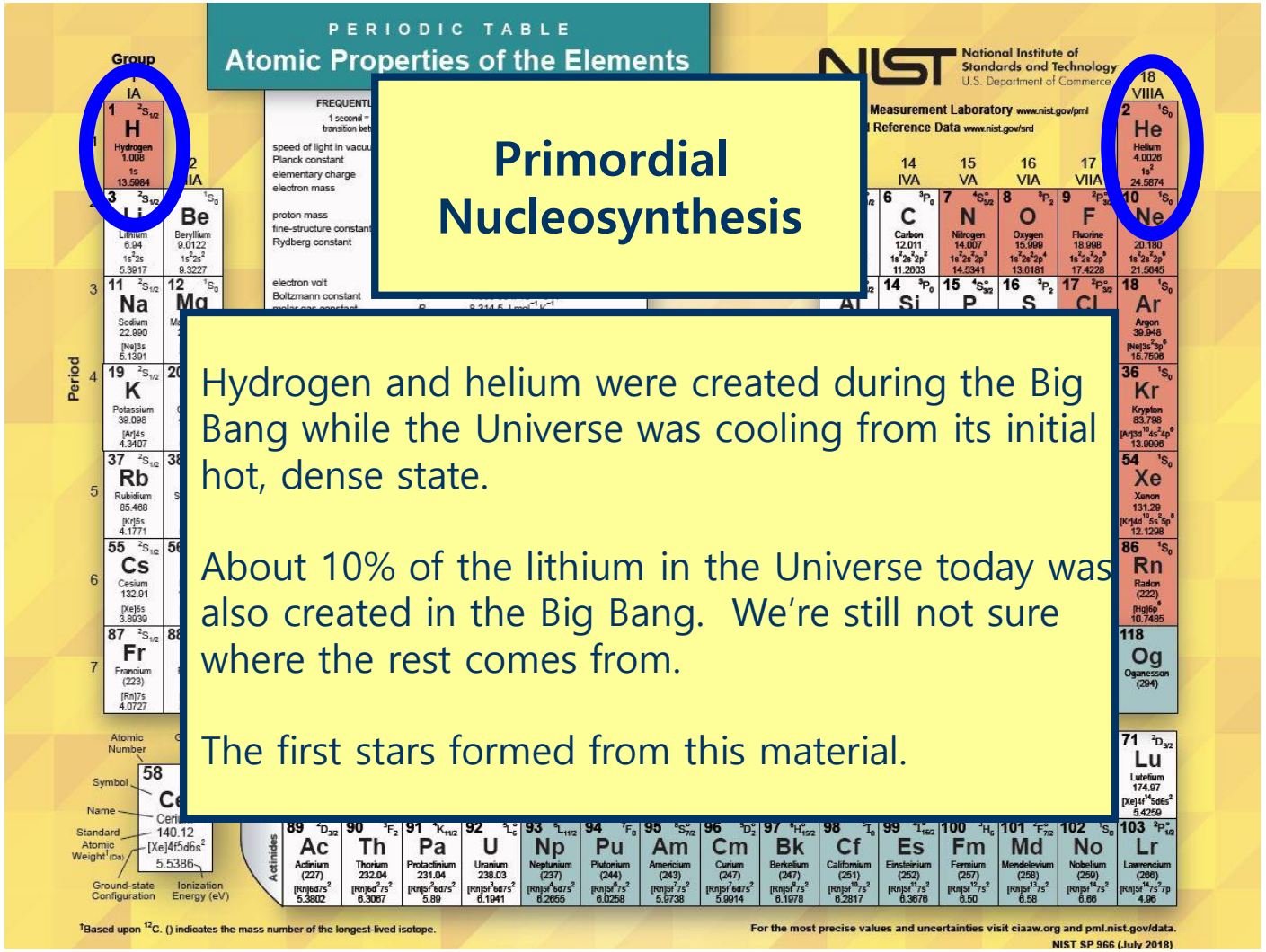
물질은 어디에서 왔을까?

- 수소 (hydrogen), 헬륨 (helium)
  - 대폭발 (Big Bang)에 의해 생성



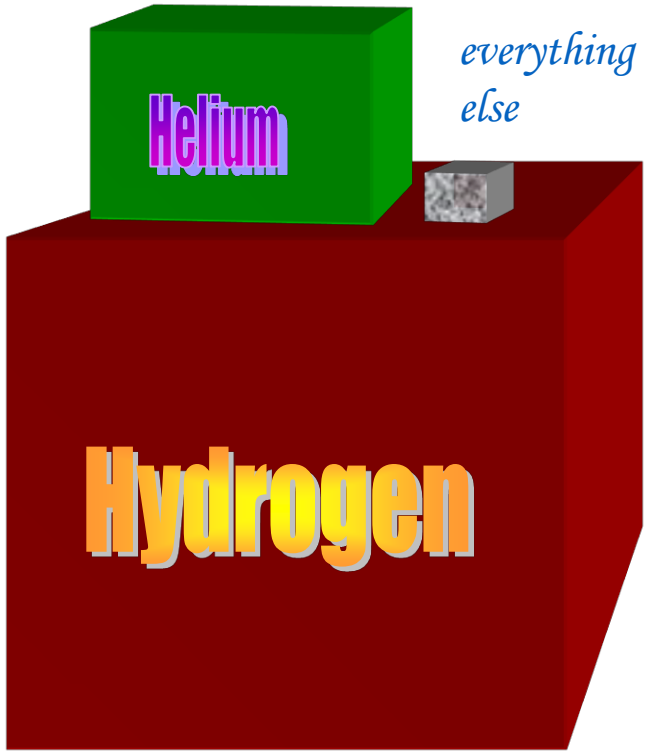
- 수소, 헬륨 이외의 다른 원자들의 탄생

• 별의 구성 성분

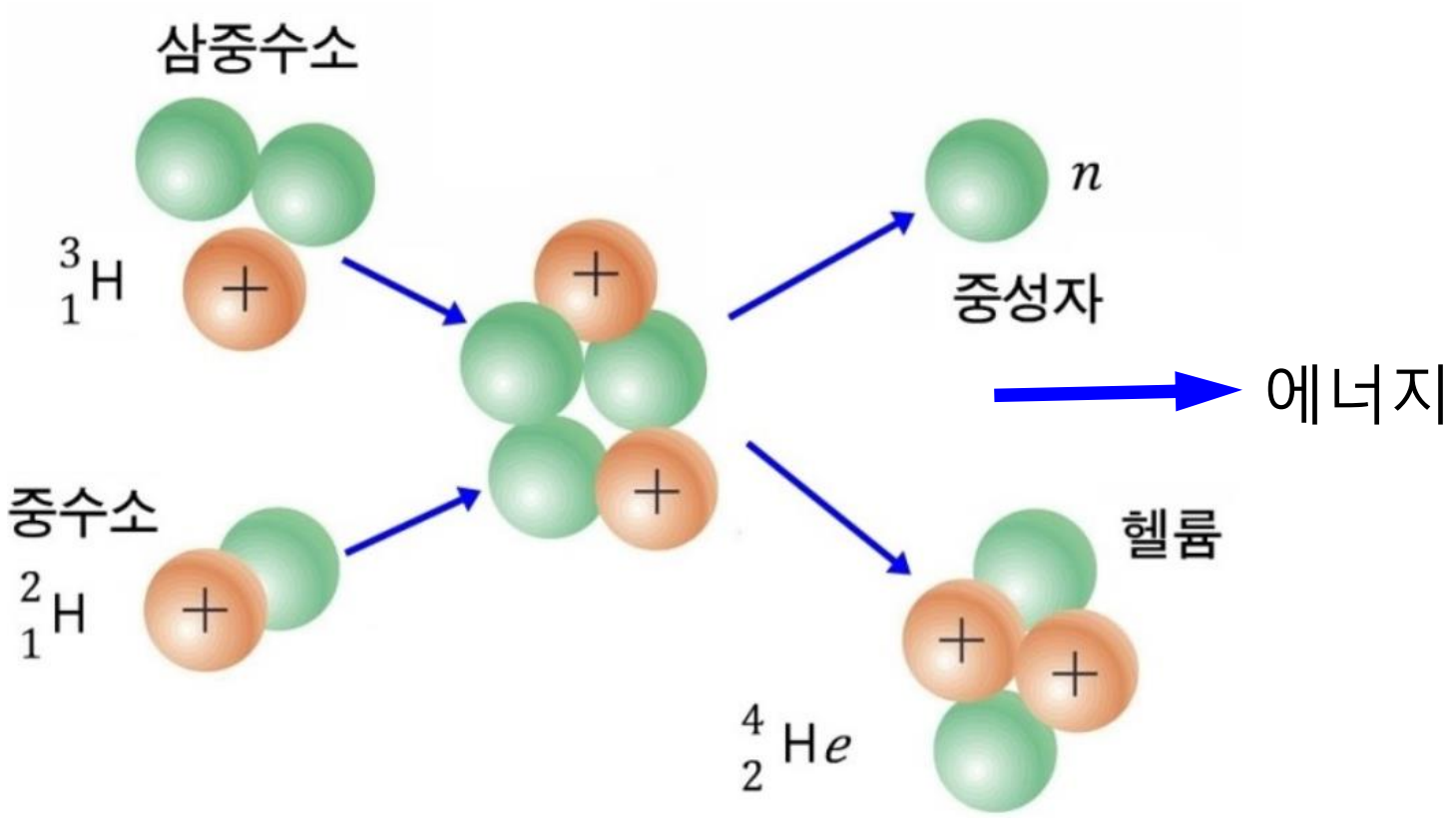
90% hydrogen atoms

10% helium atoms

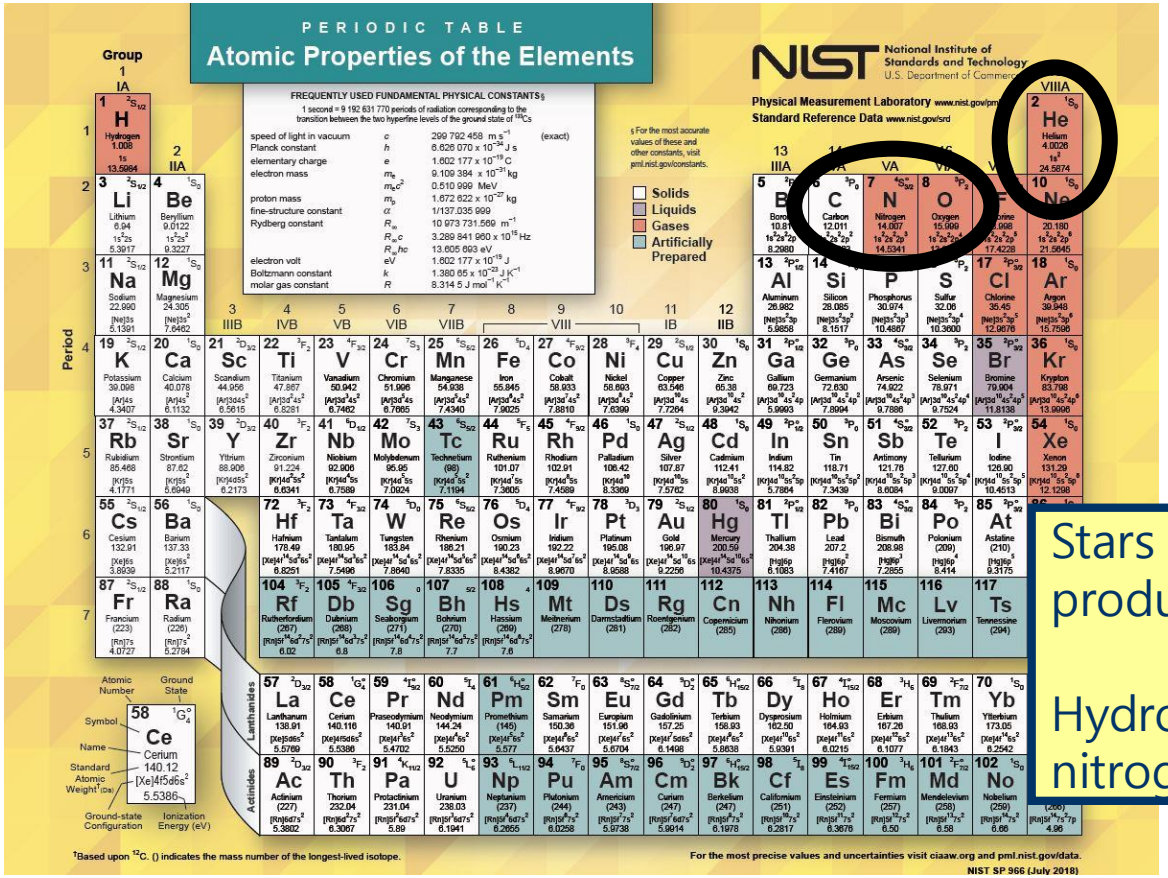
Less than 1%
everything else
(and everything else is made in stars!)



- 태양의 핵융합 (nuclear fusion)



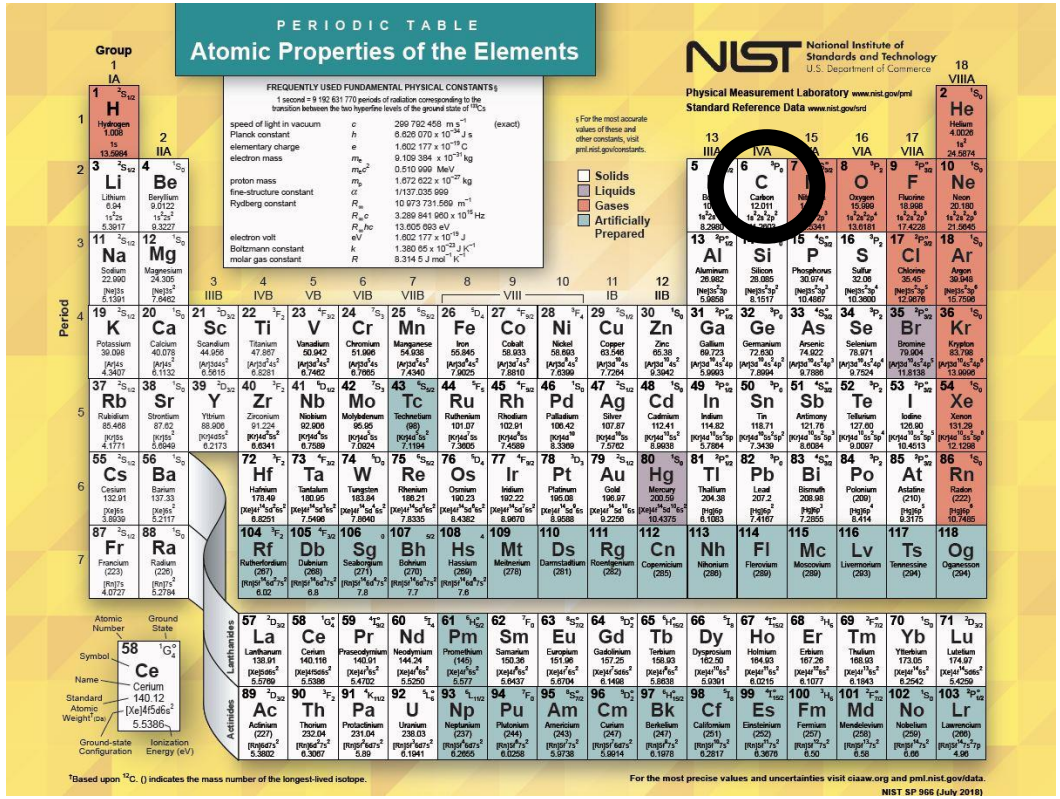
- Hydrogen burning



Stars burn hydrogen in their interiors to produce helium.

Hydrogen burning also rearranges carbon, nitrogen, and oxygen.

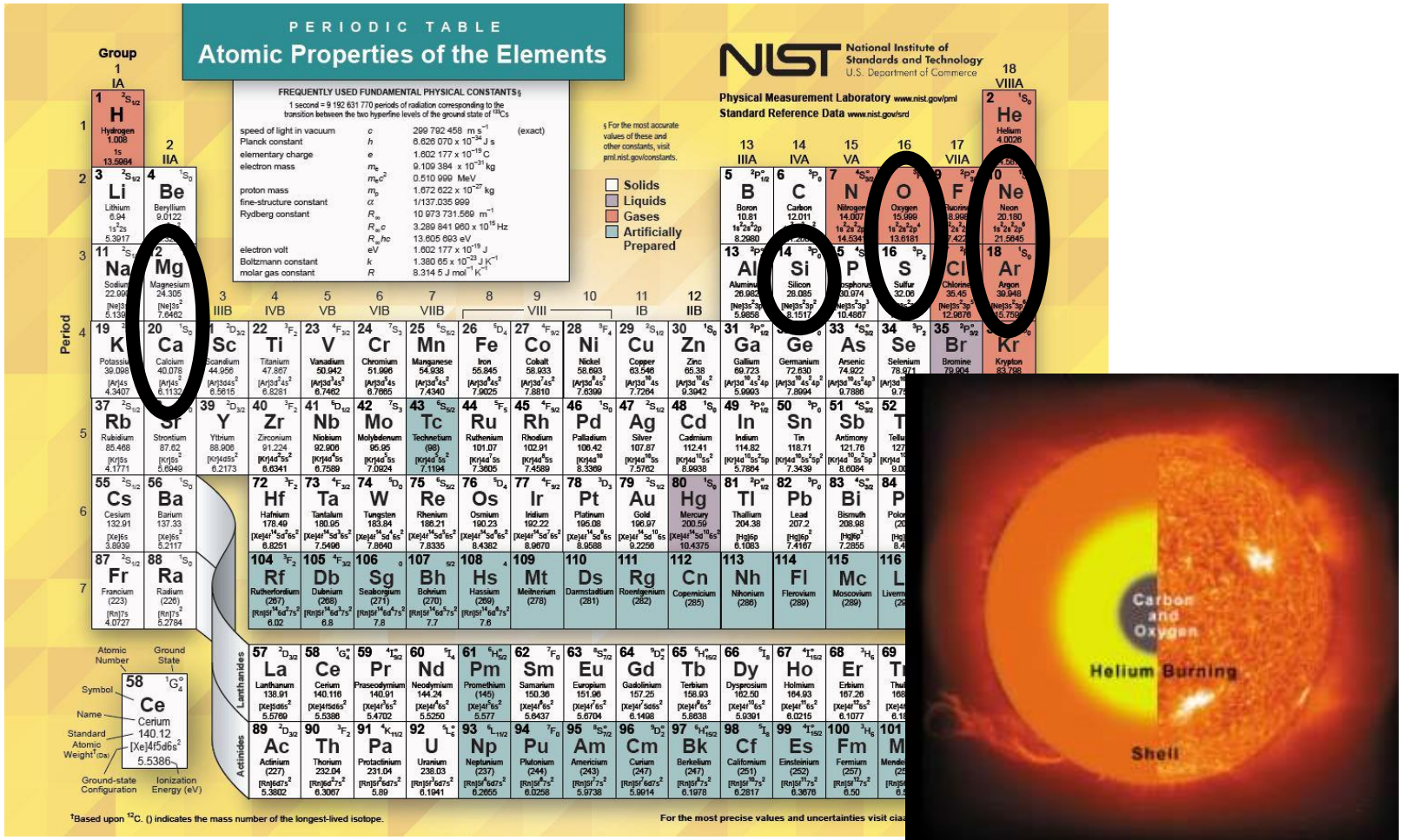
- Helium burning



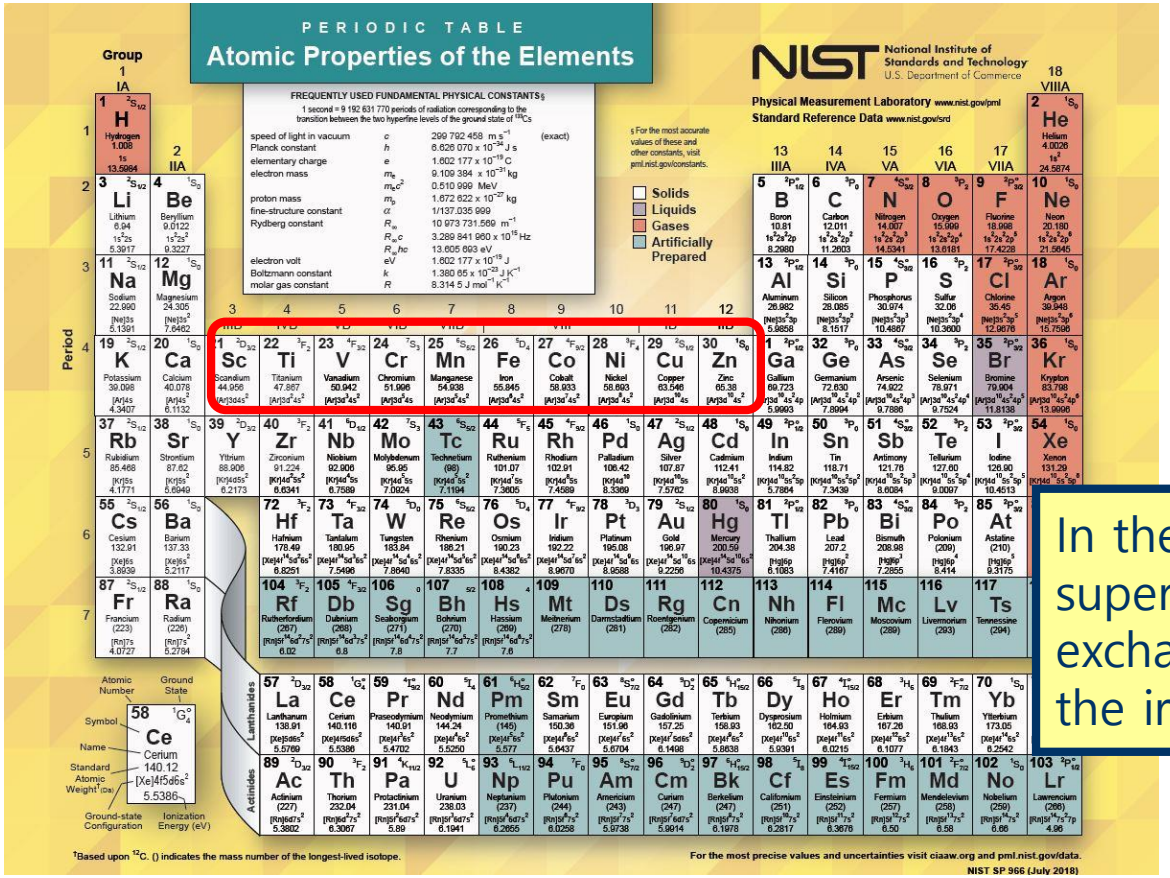
$$3\left({}^{4}He\right) \rightarrow {}^{12}C + energy$$

Three helium atoms combine to form carbon

- Massive Stars (large stars)
  - Hydrogen → helium → carbon
  - 내부 온도가 높음 : carbon → ‘alpha’ elements (magnesium, etc.)

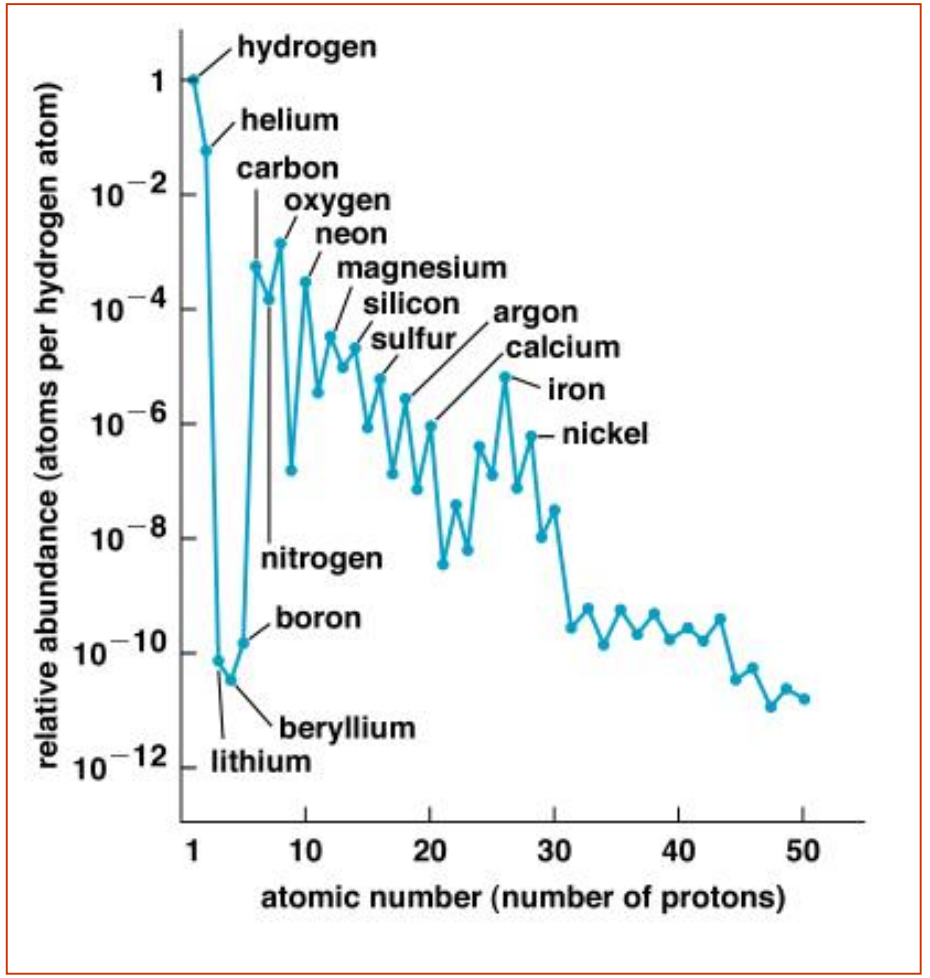


- Massive stars (supernova explosions 이전)
  - Protons과 neutrons이 서로 교환 가능 → iron peak metals (transition metals)생성



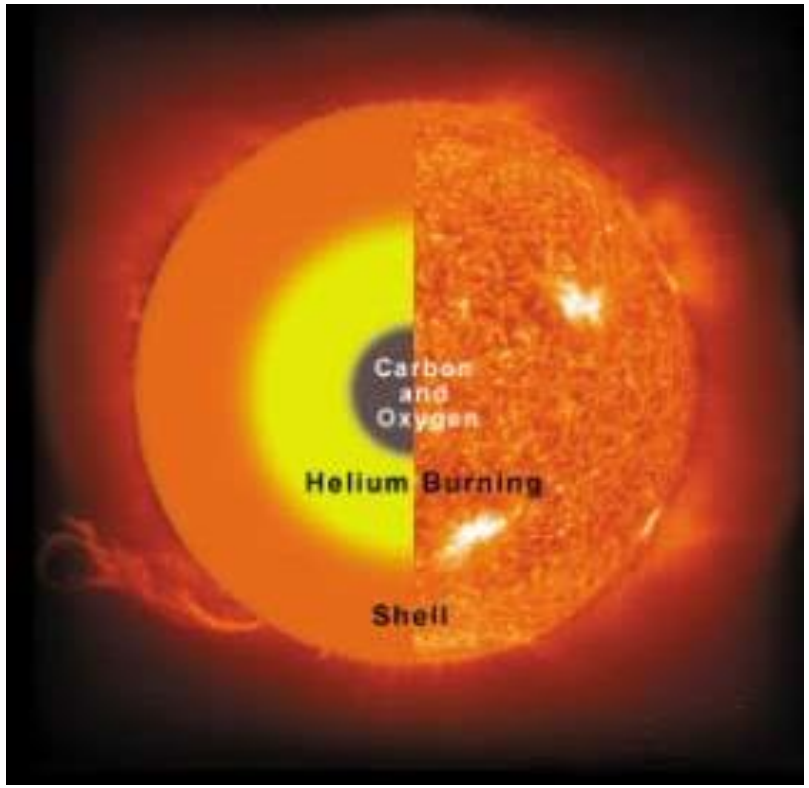
In the cores of massive stars just before supernova explosions, atomic nuclei exchange protons and neutrons to form the iron peak metals.

- 원소들의 개수분포 비율
  - 수소 원자의 개수를 1로 놓는다.
  - Odd-even effect



- 정리
  - Hydrogen
    - from big bang nucleosynthesis
  - Hellium
    - from big bang and from hydrogen burning
  - Nitrogen
    - from CNO cycle
  - Carbon, Oygengen
    - from helium burning
  - Light elements (Neon, Magnesium, Calcium)
    - from carbon and oxygen burning
  - Iron metals
    - from the final burning

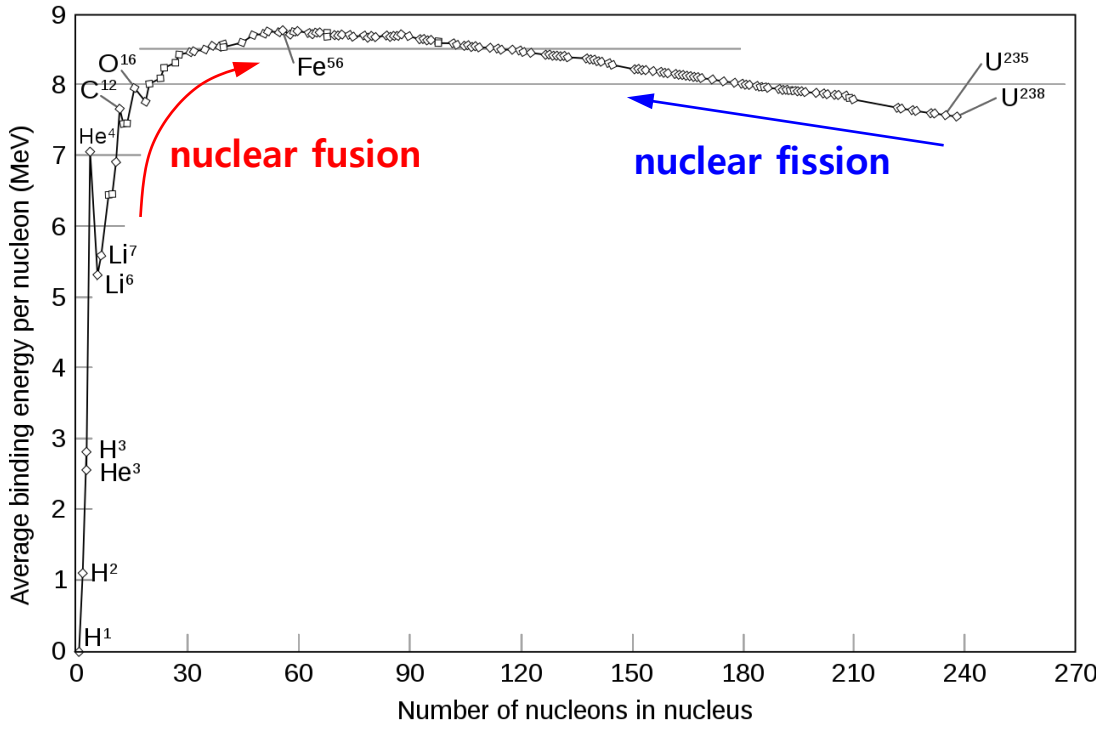
Making Elements Up to Iron



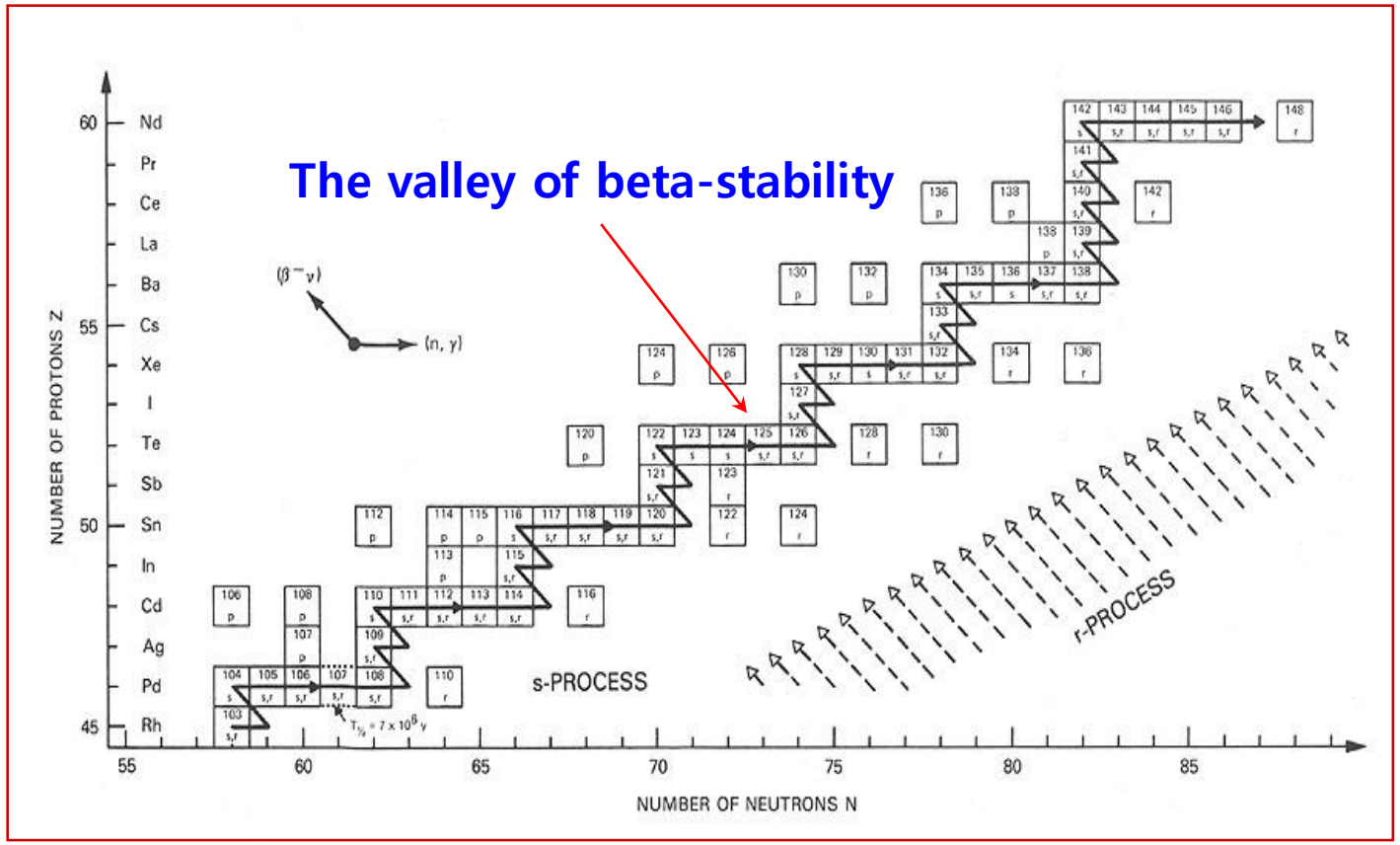
- 핵자의 결합 에너지 nuclear binding energy
  - 수평축 : 원자의 질량수 A
  - 수직축 : 핵자의 결합에너지

  - 핵융합 nuclear fusion
    - 예) K-STAR

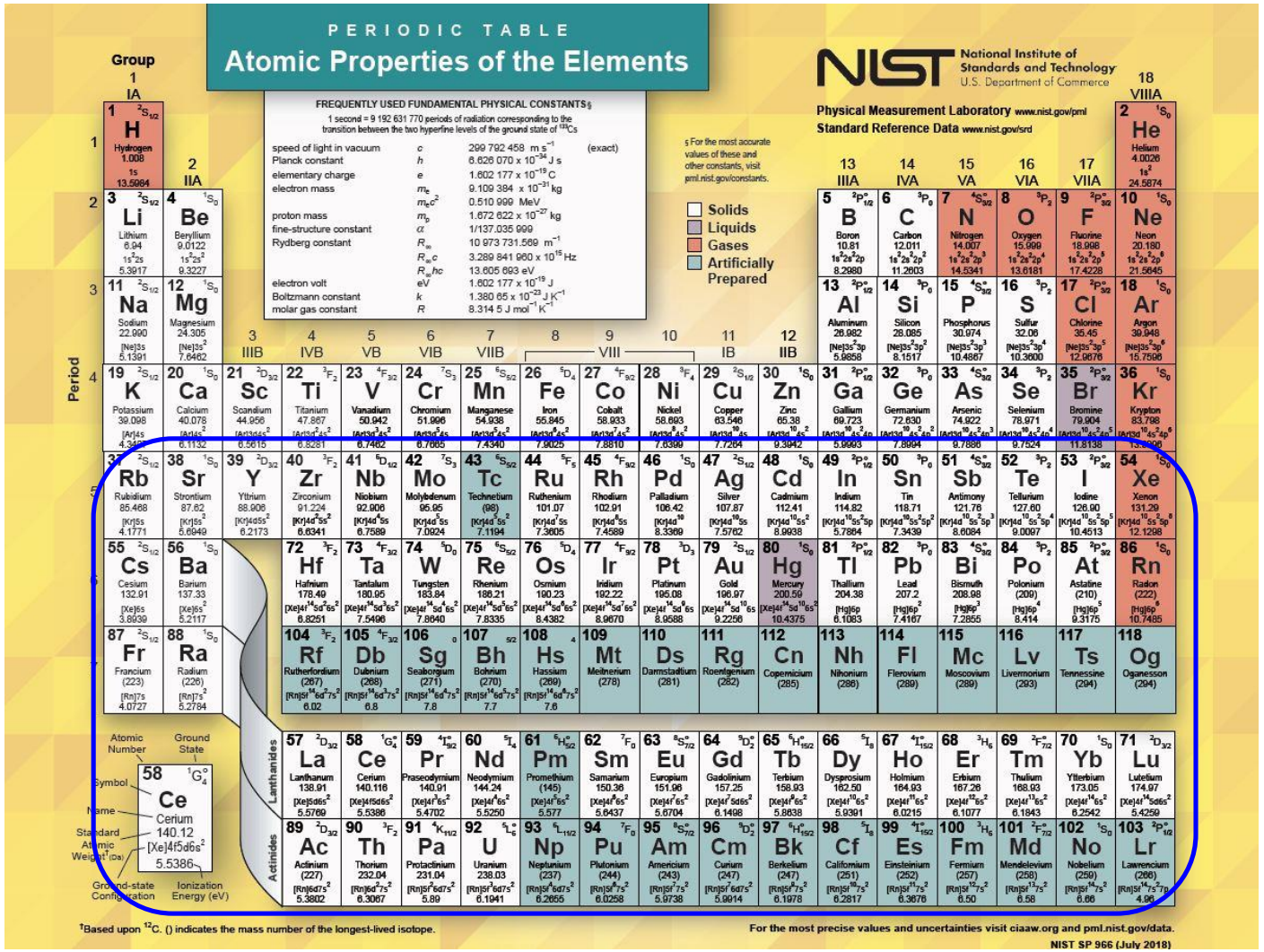
  - 핵분열 nuclear fission
    - 예) 핵폭탄, 원자력발전



- 철 Fe 보다 무거운 원자 생성
  - Ion peak metals에 중성자 포획 (neutron capture)
  - $_{26}Fe + neutron + energy \rightarrow {}_{26}Fe + proton \rightarrow {}_{27}Co$
  - …



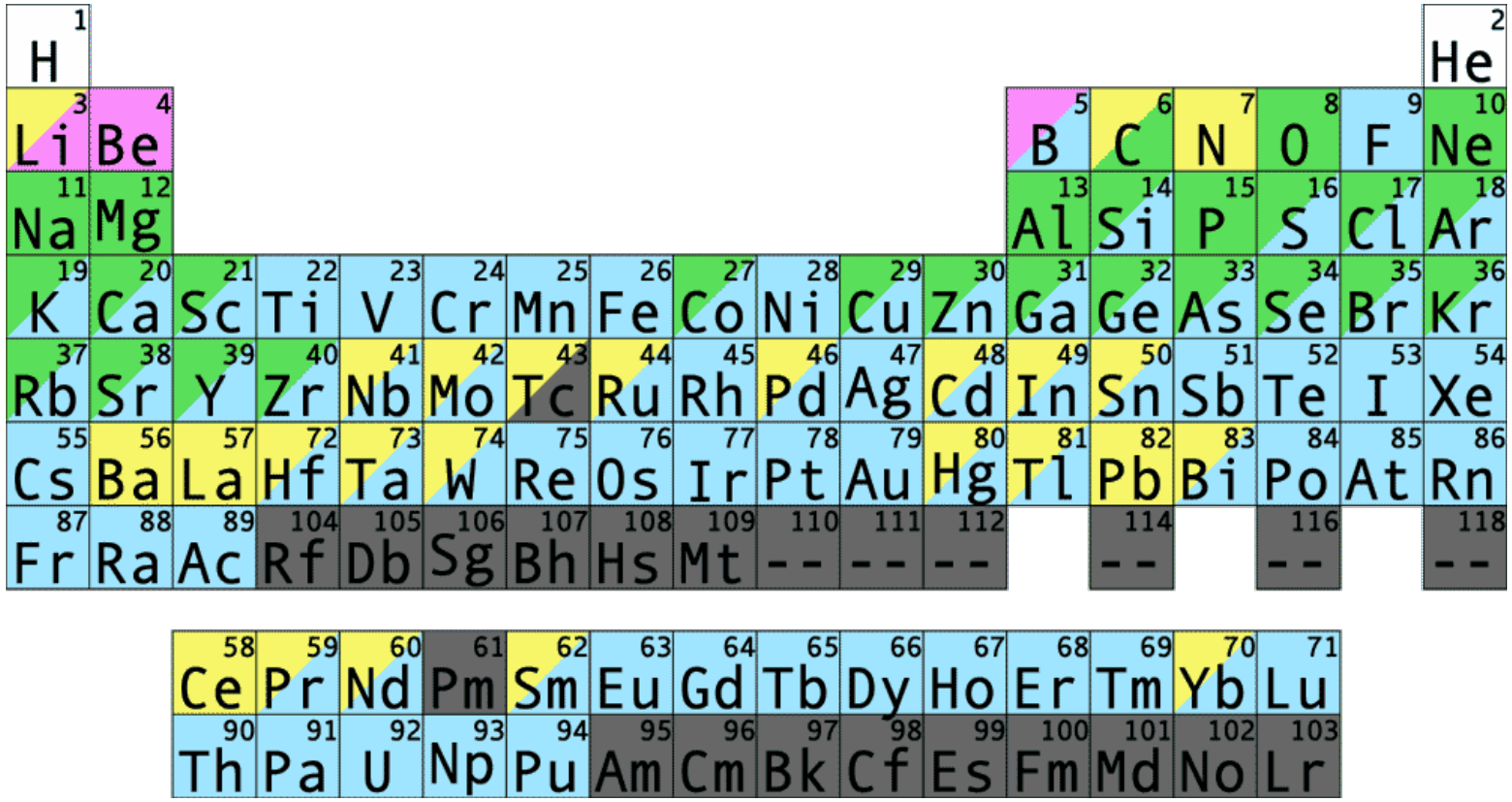
- 중성자 포획에 의해 만들어지는 무거운 원자



Heavy Metals

All heavier elements are formed when iron peak elements capture neutrons

- 주기율표의 원자 생성 분류



White - Big Bang
Pink - Cosmic Rays
Yellow - Small Stars
Green - Large Stars
Blue - Supernovae

- Your Cosmic Origin