



- Nothing due on Friday
- Test 2 on Friday!!
  - Solar System material (Ch7-14)
  - All review materials posted (with solutions)
  - Equation page updated
  - Email me if you want to reserve one of my few calculators for Friday
- Polling: `rembold-class.ddns.net`

# Review Question!



Our Sun is powered by:

- A. Fusion
- B. Fission
- C. Gravitational Collapse
- D. Solar Power

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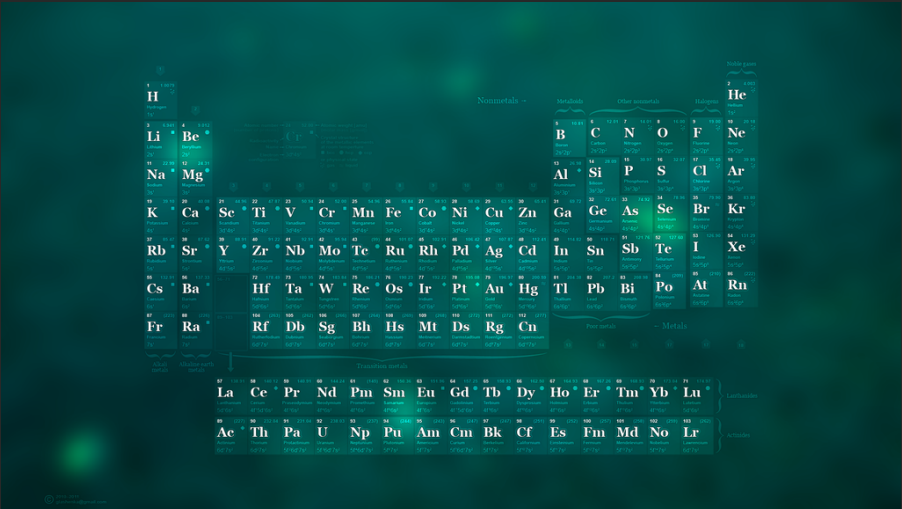
- The interior of the Sun is very dense, very hot, and very Hydrogen
- Packs lots of protons close together and moving real fast
- When protons get close enough:
  - Bang! Fusion happens!
  - Energy is given off!
  - The cycle continues. . .

# The Sun is a Mass...



[https://www.youtube.com/watch?v=me06I9GDM\\_k](https://www.youtube.com/watch?v=me06I9GDM_k)

# Fusion vs Fission: The Periodic Table



# Fusion vs Fission: The Periodic Table



Periodic Table of Elements

**Fusion**

Nonmetals

Metals

Tablet gases

Alkali metals

Alkaline earth metals

Transition metals

Lanthanides

Actinides

Periodic Table of Elements

1 H Hydrogen 1.008

2 He Helium 4.003

3 Li Lithium 6.941

4 Be Beryllium 9.012

5 B Boron 10.811

6 C Carbon 12.011

7 N Nitrogen 14.007

8 O Oxygen 15.999

9 F Fluorine 18.998

10 Ne Neon 20.180

11 Na Sodium 22.990

12 Mg Magnesium 24.305

13 Al Aluminum 26.982

14 Si Silicon 28.086

15 P Phosphorus 30.974

16 S Sulfur 32.065

17 Cl Chlorine 35.453

18 Ar Argon 39.948

19 K Potassium 39.098

20 Ca Calcium 40.078

21 Sc Scandium 44.956

22 Ti Titanium 47.88

23 V Vanadium 50.942

24 Cr Chromium 52.004

25 Mn Manganese 54.938

26 Fe Iron 55.845

27 Co Cobalt 58.933

28 Ni Nickel 58.693

29 Cu Copper 63.546

30 Zn Zinc 65.38

31 Ga Gallium 69.723

32 Ge Germanium 72.64

33 As Arsenic 74.922

34 Se Selenium 78.96

35 Br Bromine 79.904

36 Kr Krypton 83.798

37 Rb Rubidium 85.468

38 Sr Strontium 87.62

39 Y Yttrium 88.906

40 Zr Zirconium 91.224

41 Nb Niobium 92.906

42 Mo Molybdenum 95.94

43 Tc Technetium 98.906

44 Ru Ruthenium 101.07

45 Rh Rhodium 102.91

46 Pd Palladium 106.36

47 Ag Silver 107.87

48 Cd Cadmium 112.41

49 In Indium 114.82

50 Sn Tin 118.71

51 Sb Antimony 121.76

52 Te Tellurium 127.6

53 I Iodine 126.91

54 Xe Xenon 131.29

55 Cs Cesium 132.91

56 Ba Barium 137.33

57 La Lanthanum 138.91

58 Ce Cerium 140.12

59 Pr Praseodymium 140.91

60 Nd Neodymium 144.24

61 Pm Promethium 144.91

62 Sm Samarium 150.36

63 Eu Europium 151.96

64 Gd Gadolinium 157.25

65 Tb Terbium 158.93

66 Dy Dysprosium 162.50

67 Ho Holmium 164.93

68 Er Erbium 167.26

69 Tm Thulium 168.93

70 Yb Ytterbium 173.05

71 Lu Lutetium 174.97

72 Hf Hafnium 178.49

73 Ta Tantalum 180.95

74 W Tungsten 183.84

75 Re Rhenium 186.21

76 Os Osmium 190.23

77 Ir Iridium 192.22

78 Pt Platinum 195.08

79 Au Gold 196.97

80 Hg Mercury 200.59

81 Tl Thallium 204.38

82 Pb Lead 207.2

83 Bi Bismuth 208.98

84 Po Polonium 209

85 At Astatine 210

86 Rn Radon 222

87 Fr Francium 223

88 Ra Radium 226

89 Ac Actinium 227

90 Th Thorium 232.04

91 Pa Protactinium 231.04

92 U Uranium 238.03

93 Np Neptunium 237.05

94 Pu Plutonium 244

95 Am Americium 243

96 Cm Curium 247

97 Bk Berkelium 247

98 Cf Californium 251

99 Es Einsteinium 252

100 Fm Fermium 257

101 Md Mendelevium 258

102 No Nobelium 259

103 Lr Lawrencium 262

# Fusion vs Fission: The Periodic Table

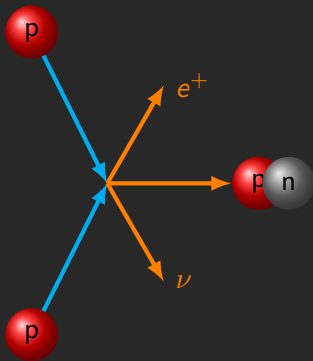


Periodic table of elements showing the distribution of elements across the table, categorized by groups and periods. The table is color-coded to distinguish between different types of elements:

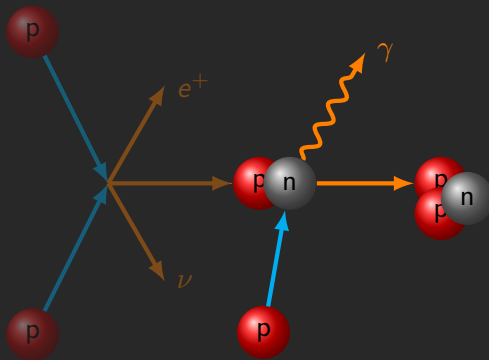
- Nonmetals:** Elements in the top right corner, including Hydrogen (H), Helium (He), Lithium (Li), Beryllium (Be), Boron (B), Carbon (C), Nitrogen (N), Oxygen (O), Fluorine (F), Neon (Ne), Sodium (Na), Magnesium (Mg), Aluminum (Al), Silicon (Si), Phosphorus (P), Sulfur (S), Chlorine (Cl), Argon (Ar), Potassium (K), Calcium (Ca), Scandium (Sc), Titanium (Ti), Vanadium (V), Chromium (Cr), Manganese (Mn), Iron (Fe), Cobalt (Co), Nickel (Ni), Copper (Cu), Zinc (Zn), Gallium (Ga), Germanium (Ge), Arsenic (As), Selenium (Se), Bromine (Br), Krypton (Kr), Rubidium (Rb), Strontium (Sr), Yttrium (Y), Zirconium (Zr), Niobium (Nb), Molybdenum (Mo), Technetium (Tc), Ruthenium (Ru), Rhodium (Rh), Palladium (Pd), Silver (Ag), Cadmium (Cd), Indium (In), Tin (Sn), Antimony (Sb), Tellurium (Te), Iodine (I), Xenon (Xe), Barium (Ba), Lanthanum (La), Cerium (Ce), Praseodymium (Pr), Neodymium (Nd), Promethium (Pm), Samarium (Sm), Europium (Eu), Gadolinium (Gd), Terbium (Tb), Dysprosium (Dy), Holmium (Ho), Erbium (Er), Thulium (Tm), Ytterbium (Yb), and Lutetium (Lu).
- Metals:** Elements in the bottom left and middle left, including Potassium (K), Calcium (Ca), Scandium (Sc), Titanium (Ti), Vanadium (V), Chromium (Cr), Manganese (Mn), Iron (Fe), Cobalt (Co), Nickel (Ni), Copper (Cu), Zinc (Zn), Gallium (Ga), Germanium (Ge), Arsenic (As), Selenium (Se), Bromine (Br), Krypton (Kr), Rubidium (Rb), Strontium (Sr), Yttrium (Y), Zirconium (Zr), Niobium (Nb), Molybdenum (Mo), Technetium (Tc), Ruthenium (Ru), Rhodium (Rh), Palladium (Pd), Silver (Ag), Cadmium (Cd), Indium (In), Tin (Sn), Antimony (Sb), Tellurium (Te), Iodine (I), Xenon (Xe), Barium (Ba), Lanthanum (La), Cerium (Ce), Praseodymium (Pr), Neodymium (Nd), Promethium (Pm), Samarium (Sm), Europium (Eu), Gadolinium (Gd), Terbium (Tb), Dysprosium (Dy), Holmium (Ho), Erbium (Er), Thulium (Tm), Ytterbium (Yb), and Lutetium (Lu).
- Fission:** Elements in the center, including Potassium (K), Calcium (Ca), Scandium (Sc), Titanium (Ti), Vanadium (V), Chromium (Cr), Manganese (Mn), Iron (Fe), Cobalt (Co), Nickel (Ni), Copper (Cu), Zinc (Zn), Gallium (Ga), Germanium (Ge), Arsenic (As), Selenium (Se), Bromine (Br), Krypton (Kr), Rubidium (Rb), Strontium (Sr), Yttrium (Y), Zirconium (Zr), Niobium (Nb), Molybdenum (Mo), Technetium (Tc), Ruthenium (Ru), Rhodium (Rh), Palladium (Pd), Silver (Ag), Cadmium (Cd), Indium (In), Tin (Sn), Antimony (Sb), Tellurium (Te), Iodine (I), Xenon (Xe), Barium (Ba), Lanthanum (La), Cerium (Ce), Praseodymium (Pr), Neodymium (Nd), Promethium (Pm), Samarium (Sm), Europium (Eu), Gadolinium (Gd), Terbium (Tb), Dysprosium (Dy), Holmium (Ho), Erbium (Er), Thulium (Tm), Ytterbium (Yb), and Lutetium (Lu).



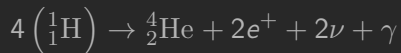
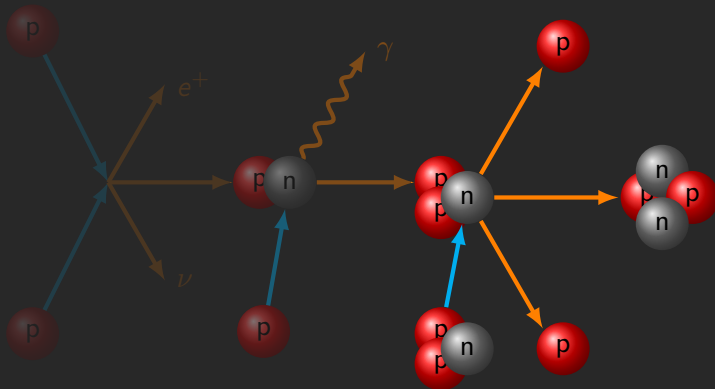
# Powering Your Sun: A 3 Step Process



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# Powering Your Sun: A 3 Step Process



# Taking things slow...



- The full 3 step reaction is actually quite slow!
- First Step:
  - The tricky one
  - Need both to get **really** close AND need the proton to decay into a neutron
  - Takes over a billion years!
- Second Step:
  - Quite fast
  - About 1 second
- Third Step:
  - Slow again, but  $1000\times$  faster than Step 1
  - About a million years
- The sheer number of protons is what maintains such a high energy output!

# The Photon Trail...



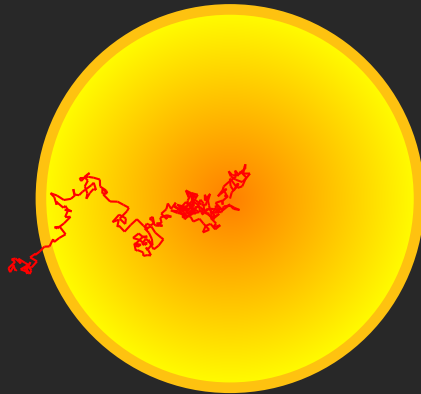
- Our mechanism for fusion releases much of the energy in gamma rays
- But Gamma Rays are not the majority of what we see coming out of the Sun! (Thankfully!)
- Something else must be happening enroute
  - Not much between us and the Sun, so most likely in the Sun itself



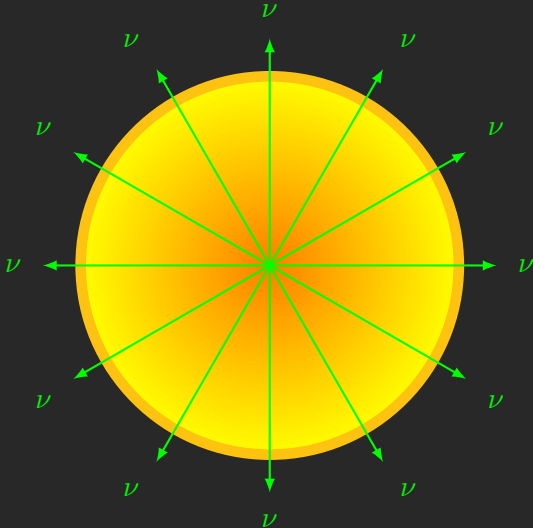
## ... a crooked path



- Gas below photosphere is very dense and ionized
  - Photons interact with charged particles
  - “Scattered” by nuclei and electrons
  - Results in a “random walk” to the surface
- Energy produced in the core thus takes many thousands of years to reach the surface
- The photons we see on Earth tell us about the *photosphere*
- We do *not* get to see into the core



# Nature's Atomic Hermits



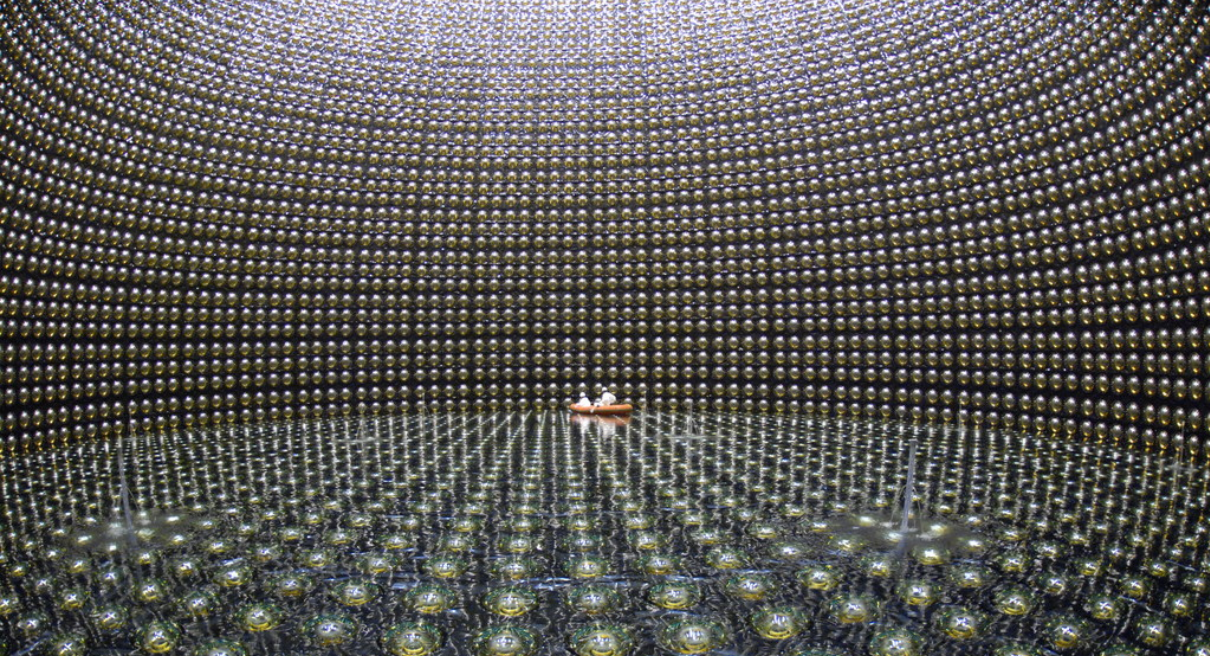
- Neutrinos are notoriously inactive
  - They generally don't interact with anything
- This makes them very tricky to detect
- But they COULD show us the core of the Sun!

# Catch a Neutrino by its tail...



- Find an isolated area
  - Generally underground, away from other radiation
- Build a BIG detector
  - A neutrino interacting is a rare event, the bigger the detector, the better your chances
- Variety of detection methods
  - Checking huge vats of chlorine for traces of argon caused by a neutrino interaction
  - Looking for traces of light from Cherenkov radiation, when a charged particle travels fast than *in that medium*, usually water or ice (Antarctica)

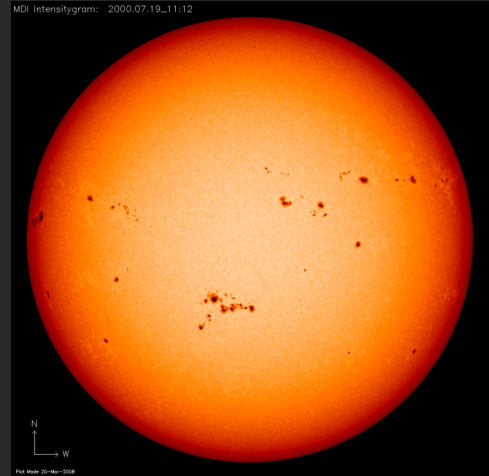


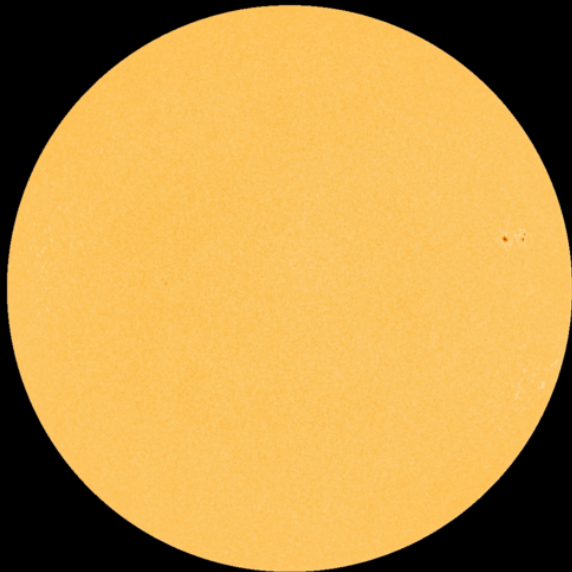


# Can't Change Your Spots (But the Sun can!)

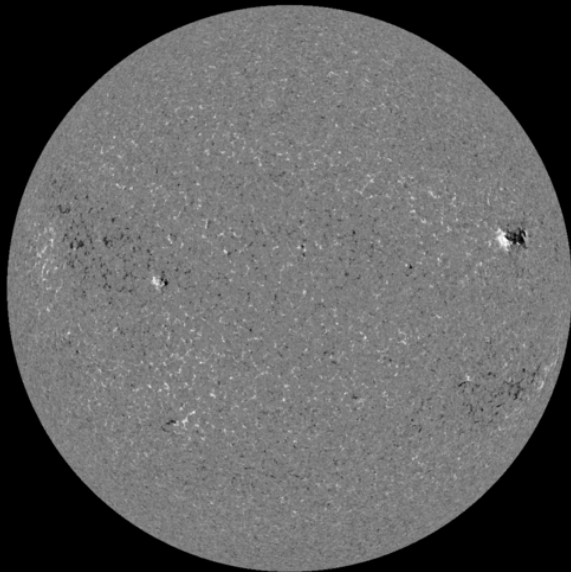


- Sunspots are dark patches on the surface of the photosphere
- Darker because they are cooler ( $\approx 4000$  K)
- Something must keep the cool gas from mixing with the surrounding hotter gas!





500/PMI Quick-Look Continuum: 20161026\_043000

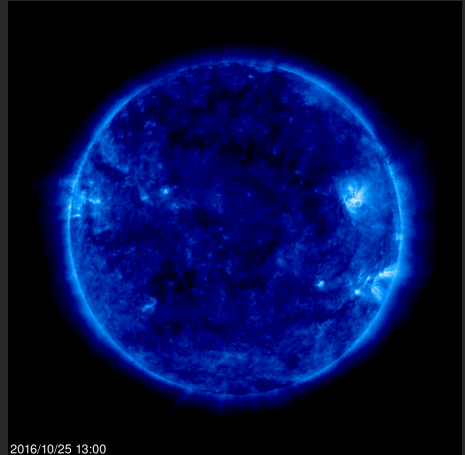


500/PMI Quick-Look Magnetogram: 20161026\_043000

# The Sun's Magnetic Fields



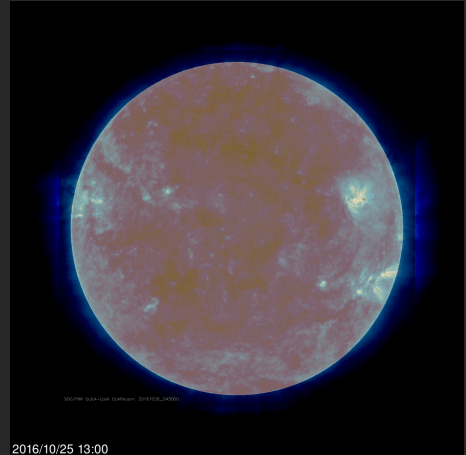
- Sunspots give us a way to see parts of the Sun's magnetic field!
- Often come in pairs, one for each magnetic pole
- Seem to be loops where the magnetic field can connect



# The Sun's Magnetic Fields



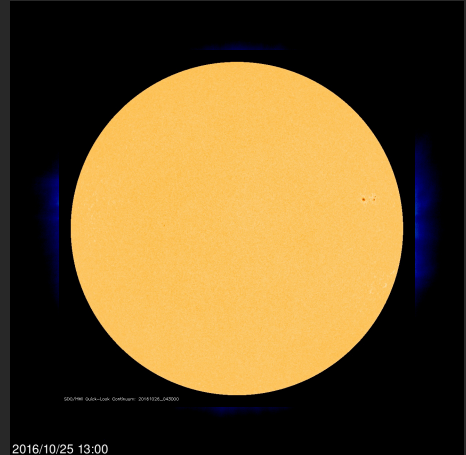
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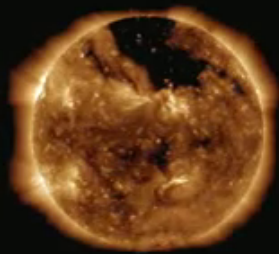
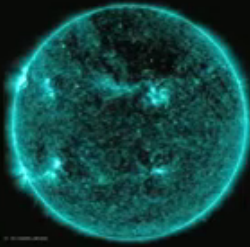


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- Most flares occur near sunspots, implying a connection to the magnetic field
- Unlike the Earth, the equator of the Sun rotates faster than the poles!
  - Think tradewinds on Earth, but the entire Sun is a gas
- Gases tend to drag the magnetic field with them
- Things can get very tangled, and flares are thought to be a way of rearranging magnetic field lines to untangle them







- Communications
- Aurora

