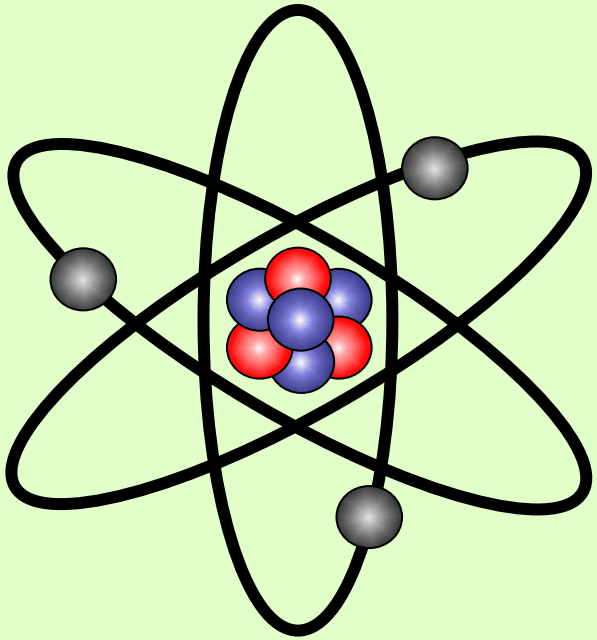
Journey to the Center of the Atom!



Bill Wabbersen

Past-Chairman, American Nuclear Society-Savannah River Section

Education Committee, Citizens for Nuclear Technology Awareness

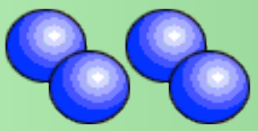
Structure of the Atom

Nucleus

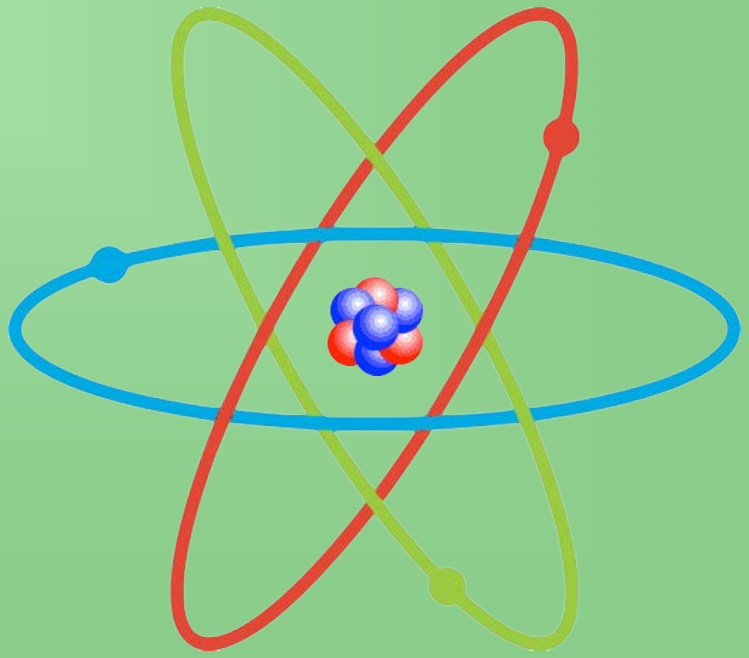
Protons - Charge = +1

Mass = 1 amu
(Atomic Mass Unit)

Neutrons - No Charge

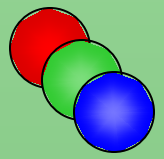


Mass = 1 amu



Electron Cloud

Electrons - Charge = -1



Mass = 1/1836 amu

Periodic Table

Periodic Table of the Elements

ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY

atomic number
atomic weight
14 28.09
Si
Silicon
symbol:
name

black solid
blue liquid
red gas
white synthetically prepared *most stable isotope*

alkali metals
alkaline earth metals
transitional metals
other metals
nonmetals
noble gases

1 1.01 H Hydrogen																	2 4.003 He Helium
3 6.94 Li Lithium	4 9.01 Be Beryllium											5 10.81 B Boron	6 12.01 C Carbon	7 14.01 N Nitrogen	8 15.999 O Oxygen	9 18.998 F Fluorine	10 20.18 Ne Neon
11 22.99 Na Sodium	12 24.31 Mg Magnesium											13 26.98 Al Aluminum	14 28.09 Si Silicon	15 30.97 P Phosphorus	16 32.06 S Sulfur	17 35.45 Cl Chlorine	18 39.95 Ar Argon
19 39.10 K Potassium	20 40.08 Ca Calcium	21 44.96 Sc Scandium	22 47.90 Ti Titanium	23 50.94 V Vanadium	24 51.996 Cr Chromium	25 54.94 Mn Manganese	26 55.85 Fe Iron	27 58.93 Co Cobalt	28 58.70 Ni Nickel	29 63.55 Cu Copper	30 65.37 Zn Zinc	31 69.72 Ga Gallium	32 72.59 Ge Germanium	33 74.92 As Arsenic	34 78.96 Se Selenium	35 79.90 Br Bromine	36 83.80 Kr Krypton
37 85.47 Rb Rubidium	38 87.62 Sr Strontium	39 88.91 Y Yttrium	40 91.22 Zr Zirconium	41 92.91 Nb Niobium	42 95.94 Mo Molybdenum	43 (98) Tc Technetium	44 101.07 Ru Ruthenium	45 102.91 Rh Rhodium	46 106.42 Pd Palladium	47 107.87 Ag Silver	48 112.41 Cd Cadmium	49 114.82 In Indium	50 118.69 Sn Tin	51 121.75 Sb Antimony	52 127.60 Te Tellurium	53 126.90 I Iodine	54 131.30 Xe Xenon
55 132.91 Cs Cesium	56 137.33 Ba Barium	57 138.91 La Lanthanum	72 178.49 Hf Hafnium	73 180.95 Ta Tantalum	74 183.85 W Tungsten	75 186.21 Re Rhenium	76 190.20 Os Osmium	77 192.22 Ir Iridium	78 195.09 Pt Platinum	79 196.97 Au Gold	80 200.59 Hg Mercury	81 204.37 Tl Thallium	82 207.19 Pb Lead	83 208.98 Bi Bismuth	84 (209) Po Polonium	85 (210) At Astatine	86 (222) Rn Radon
87 (223) Fr Francium	88 226.03 Ra Radium	89 227.03 Ac Actinium	104 (261) Rf Rutherfordium	105 (262) Ha Hahnium	106 (266) Sg Seaborgium	107 (262) Ns Nielsbohrium	108 (265) Hs Hassium	109 (266) Mt Meitnerium	110 (271)	111 (272)	112 (277)	(113)	(114)	(115)	(116)	(117)	(118)

Lanthanide series	58 140.12 Ce Cerium	59 140.91 Pr Praseodymium	60 144.24 Nd Neodymium	61 (145) Pm Promethium	62 150.40 Sm Samarium	63 151.96 Eu Europium	64 157.25 Gd Gadolinium	65 158.93 Tb Terbium	66 162.50 Dy Dysprosium	67 164.93 Ho Holmium	68 167.26 Er Erbium	69 168.93 Tm Thulium	70 173.04 Yb Ytterbium	71 174.97 Lu Lutetium
Actinide series	90 232.04 Th Thorium	91 231.04 Pa Protactinium	92 238.03 U Uranium	93 237.05 Np Neptunium	94 (244) Pu Plutonium	95 (243) Am Americium	96 (247) Cm Curium	97 (247) Bk Berkelium	98 (251) Cf Californium	99 (252) Es Einsteinium	100 (257) Fm Fermium	101 (258) Md Mendelevium	102 (259) No Nobelium	103 (262) Lr Lawrencium

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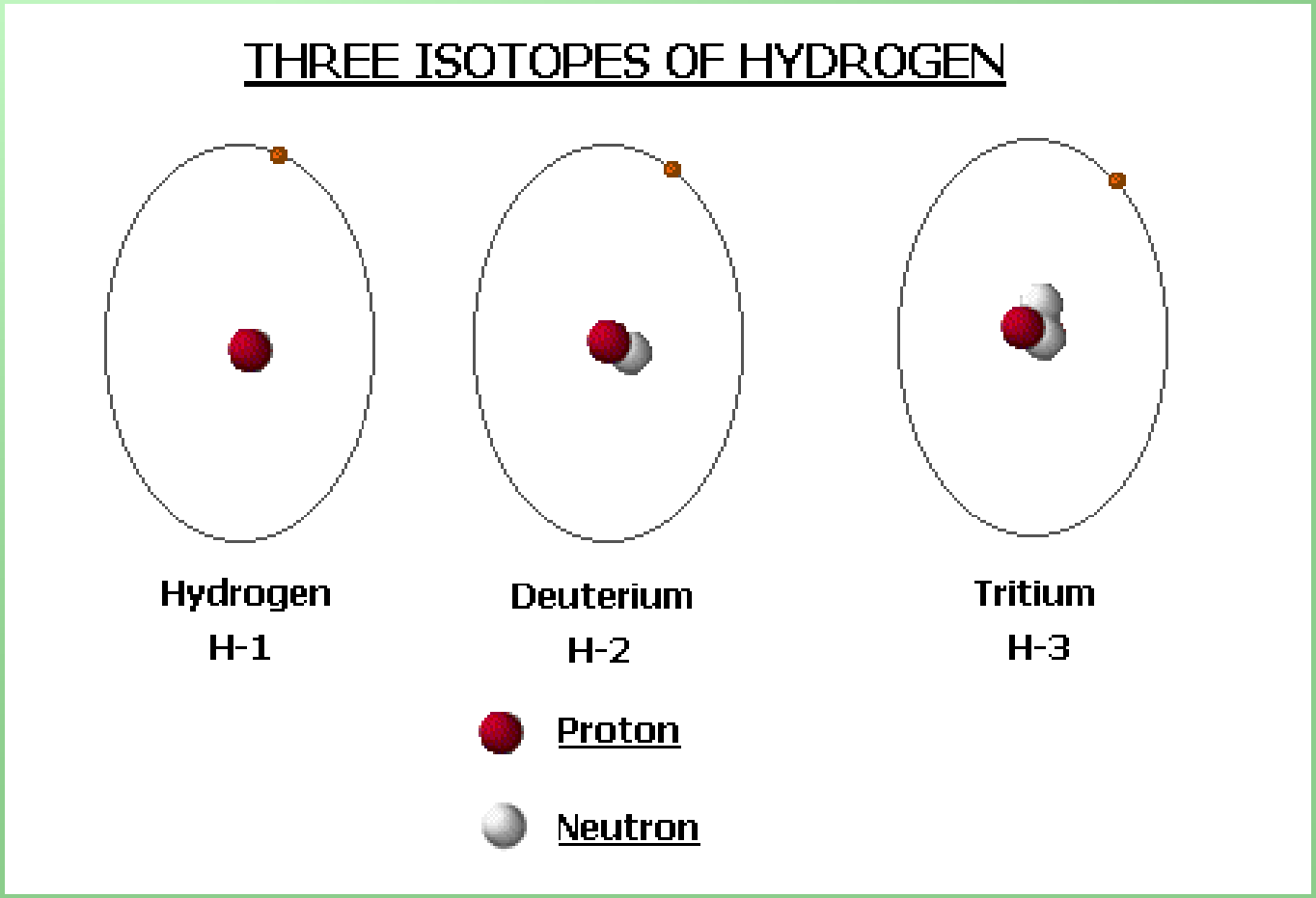
XBD 9603-01001.PDF

Isotopes

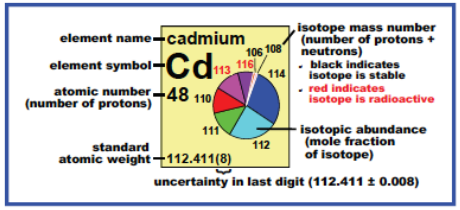

THREE ISOTOPES OF HYDROGEN
Hydrogen
H-1
Deuterium
H-2
Tritium
H-3
Proton
Neutron

IUPAC Periodic Table of the Isotopes

Element Background Color Key

[Standard atomic weights are determined using all stable isotopes and selected radioactive isotopes (having relatively long half-lives and characteristic isotopic abundances) in natural terrestrial substances. Isotopes are considered stable (non-radioactive) if evidence for radioactive decay has not been detected experimentally.]

- Element has two or more isotopes that are used to determine its standard atomic weight. The isotopic abundances and atomic weights vary in natural terrestrial substances. These variations are well known, and the standard atomic weight is given as lower and upper bounds within square brackets, [ ].
- Element has two or more isotopes that are used to determine its standard atomic weight. The isotopic abundances and atomic weights vary in natural terrestrial substances, but upper and lower bounds of the standard atomic weight have not been assigned by IUPAC or the variations may be too small to affect the standard atomic weight value. Thus, the standard atomic weight is given as a single value with an uncertainty that includes both measurement uncertainty and uncertainty due to isotopic abundance variations.
- Element has only one isotope that is used to determine its standard atomic weight. Thus, the standard atomic weight is invariant and is given as a single value with an IUPAC evaluated measurement uncertainty.
- Element has no standard atomic weight because all of its isotopes are radioactive and, in natural terrestrial substances, no isotope occurs with a characteristic isotopic abundance from which a standard atomic weight can be determined.



1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
hydrogen H 1 [1.007 84; 1.008 11]																	helium He 2 4.002 602(2)
lithium Li 3 [6.938; 6.997]	beryllium Be 4 9.012 182(3)											boron B 5 [10.806; 10.821]	carbon C 6 [12.0096; 12.0116]	nitrogen N 7 [14.006 43; 14.007 28]	oxygen O 8 [15.999 03; 15.999 77]	fluorine F 9 18.998 4032(5)	neon Ne 10 20.1797(6)
sodium Na 11 22.989 769 28(2)	magnesium Mg 12 24.3050(6)											aluminium (aluminum) Al 13 26.981 5386(8)	silicon Si 14 [28.084; 28.086]	phosphorus P 15 30.973 762(2)	sulfur S 16 [32.059; 32.076]	chlorine Cl 17 [35.446; 35.457]	argon Ar 18 39.948(1)
potassium K 19 39.0983(1)	calcium Ca 20 40.078(4)	scandium Sc 21 44.955 912(6)	titanium Ti 22 47.867(1)	vanadium V 23 50.9415(1)	chromium Cr 24 51.9961(6)	manganese Mn 25 54.938 045(5)	iron Fe 26 55.845(2)	cobalt Co 27 58.933 195(5)	nickel Ni 28 58.6934(4)	copper Cu 29 63.546(3)	zinc Zn 30 65.38(2)	gallium Ga 31 69.723(1)	germanium Ge 32 72.63(1)	arsenic As 33 74.921 60(2)	selenium Se 34 78.96(3)	bromine Br 35 79.904(1)	krypton Kr 36 83.798(2)
rubidium Rb 37 85.4678(3)	strontium Sr 38 87.62(1)	yttrium Y 39 88.905 85(2)	zirconium Zr 40 91.224(2)	niobium Nb 41 92.906 38(2)	molybdenum Mo 42 95.96(2)	technetium Tc 43	ruthenium Ru 44 101.07(2)	rhodium Rh 45 102.905 50(2)	palladium Pd 46 106.42(1)	silver Ag 47 107.8682(2)	cadmium Cd 48 112.411(8)	indium In 49 114.818(3)	tin Sn 50 118.710(7)	antimony Sb 51 121.760(1)	tellurium Te 52 127.60(3)	iodine I 53 126.904 47(3)	xenon Xe 54 131.293(6)
caesium (cesium) Cs 55 132.905 4519(2)	barium Ba 56 137.327(7)	57 - 71 lanthanoids	hafnium Hf 72 178.49(2)	tantalum Ta 73 180.947 88(2)	tungsten W 74 183.84(1)	rhenium Re 75 186.207(1)	osmium Os 76 190.23(3)	iridium Ir 77 192.217(3)	platinum Pt 78 195.084(3)	gold Au 79 196.966 569(4)	mercury Hg 80 200.59(2)	thallium Tl 81 [204.382; 204.385]	lead Pb 82 207.2(1)	bismuth Bi 83 208.980 40(1)	polonium Po 84	astatine At 85	radon Rn 86
francium Fr 87	radium Ra 88	89 - 103 actinoids	rutherfordium Rf 104	dubnium Db 105	seaborgium Sg 106	bohrium Bh 107	hassium Hs 108	meitnerium Mt 109	darmstadtium Ds 110	roentgenium Rg 111	copernicium Cn 112	ununtrium Uut 113	flerovium Fl 114	ununpentium Uup 115	livermorium Lv 116	ununseptium Uus 117	ununoctium Uuo 118

lanthanum La 57 138.905 47(7)	cerium Ce 58 140.116(1)	praseodymium Pr 59 140.907 65(2)	neodymium Nd 60 144.242(3)	promethium Pm 61	samarium Sm 62 150.36(2)	europium Eu 63 151.964(1)	gadolinium Gd 64 157.25(3)	terbium Tb 65 158.925 35(2)	dysprosium Dy 66 162.500(1)	holmium Ho 67 164.930 32(2)	erbium Er 68 167.259(3)	thulium Tm 69 168.934 21(2)	ytterbium Yb 70 173.054(5)	lutetium Lu 71 174.9668(1)
actinium Ac 89	thorium Th 90 232.038 06(2)	protactinium Pa 91 231.035 88(2)	uranium U 92 238.028 91(3)	neptunium Np 93	plutonium Pu 94	americium Am 95	curium Cm 96	berkelium Bk 97	californium Cf 98	einsteinium Es 99	fermium Fm 100	mendelevium Md 101	nobelium No 102	lawrencium Lr 103

International Union of Pure and Applied Chemistry (IUPAC) Project 2007-038-3-200, "Development of an isotopic periodic table for the educational community"

June 20, 2012 www.ciaaw.org

Standard Nuclear Notation

Mass Number

A = Z + N

(N = # of Neutrons)

Chemical Symbol

$$^{A}_{Z}X$$

Atomic Number

# of Protons

$^{12}_{6}C$	$^{13}_{6}C$	$^{14}_{6}C$	**or**	^{12}C	^{13}C	^{14}C

Let's Practice using Standard Nuclear Notation

How many Protons are in $^{1}_{1}H$?

One

How many Neutrons are in $^{7}_{3}Li$?

Four

How many Protons are in $^{17}_{8}O$?

Eight

How many Neutrons are in $^{1}_{1}H$?

Zero

Mass Number

A = Z + N

(N = # of Neutrons)

Chemical Symbol

$^{A}_{Z}X$

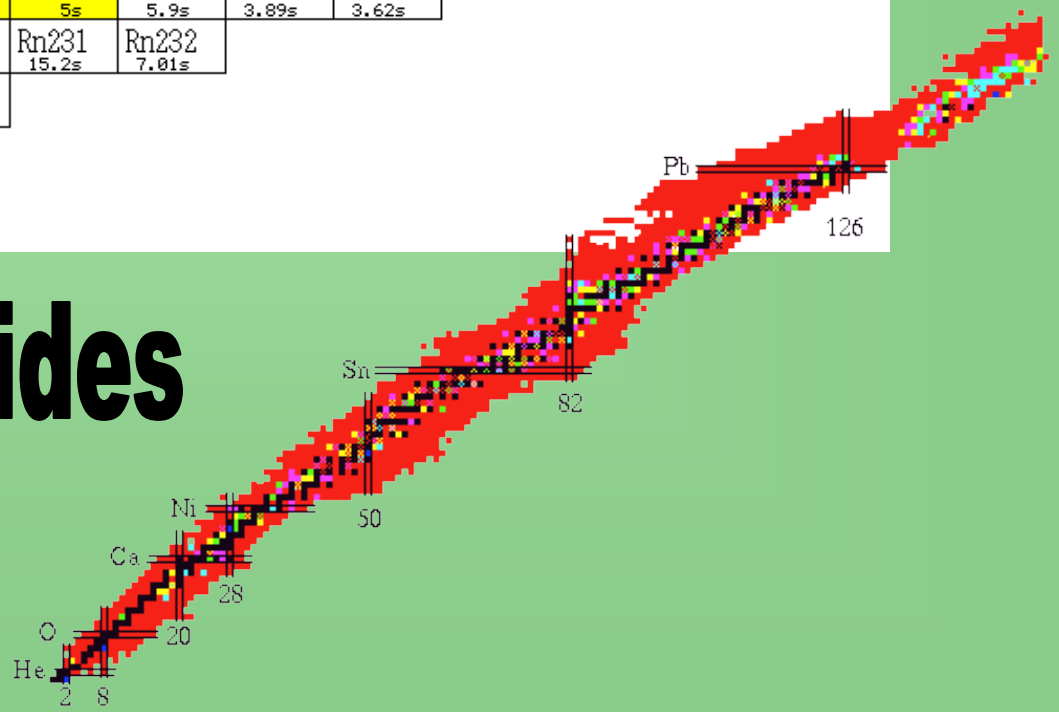
Atomic Number

# of Protons

Building a 3D Periodic Table

99	Es237 4.46s	Es238 4.98s	Es239 7.19s	Es240 9.68s	Es241 8s	Es242 16s	Es243 21s	Es244 37s	Es245 1.1m	Es246 7.7m	Es247 4.55m	Es248 27m	Es249 1.7h	Es250 8.6h	Es251 1.375d
98	Cf236 9.98s	Cf237 2.1s	Cf238 0.021s	Cf239 39s	Cf240 1.06m	Cf241 3.78m	Cf242 3.49m	Cf243 10.7m	Cf244 19.4m	Cf245 46.3m	Cf246 1.487d	Cf247 3.11h	Cf248 333.5d	Cf249 350.6y	Cf250 13.08y
97	Bk235 14.3s	Bk236 22.5s	Bk237 31.9s	Bk238 2.4m	Bk239 1.65m	Bk240 4.8m	Bk241 9.08m	Bk242 7m	Bk243 4.5h	Bk244 4.35h	Bk245 4.94d	Bk246 1.8d	Bk247 1380y	Bk248 9y	Bk249 320d
96	Cm234 49.9s	Cm235 1.29m	Cm236 2.12m	Cm237 3.98m	Cm238 2.4h	Cm239 2.9h	Cm240 27d	Cm241 32.8d	Cm242 162.8d	Cm243 29.1y	Cm244 18.1y	Cm245 8500y	Cm246 4730y	Cm247 1.56e+07y	Cm248 3.4e+05y
95	Am233 1.72m	Am234 2.32m	Am235 15m	Am236 4.4m	Am237 1.217h	Am238 1.633h	Am239 11.9h	Am240 2.117d	Am241 432.2y	Am242 141y	Am243 7370y	Am244 10.1h	Am245 2.05h	Am246 39m	Am247 23m
94	Pu232 34.1m	Pu233 20.9m	Pu234 8.8h	Pu235 25.3m	Pu236 2.858y	Pu237 45.2d	Pu238 87.74y	Pu239 2.41e+04y	Pu240 6564y	Pu241 14.35y	Pu242 3.73e+05y	Pu243 4.956h	Pu244 8.08e+07y	Pu245 10.5h	Pu246 10.84d
93	Np231 48.8m	Np232 14.7m	Np233 36.2m	Np234 4.4d	Np235 1.084y	Np236 1.54e+05y	Np237 2.14e+06y	Np238 2.117d	Np239 2.356d	Np240 1.032h	Np241 13.9m	Np242 5.5m	Np243 1.85m	Np244 2.29m	Np245 1.7m
92	U 230 20.8d	U 231 4.2d	U 232 68.9y	U 233 1.59e+05y	U 234 0.0055	U 235 0.72	U 236 2.34e+07y	U 237 6.75d	U 238 99.2745	U 239 23.45m	U 240 14.1h	U 241 18.4m	U 242 16.8m	U 243 4.54m	U 244 57.9s
91	Pa229 1.5d	Pa230 17.4d	Pa231 3.28e+04y	Pa232 1.31d	Pa233 26.97d	Pa234 6.7h	Pa235 24.5m	Pa236 9.1m	Pa237 8.7m	Pa238 2.3m	Pa239 1.767h	Pa240 26.6s	Pa241 25.7s	Pa242 21.2s	Pa243 12s
90	Th228 1.913y	Th229 7880y	Th230 7.54e+04y	Th231 1.063d	Th232 100	Th233 21.83m	Th234 24.1d	Th235 7.1m	Th236 37.5m	Th237 5m	Th238 9.4m	Th239 41s	Th240 16.4s	Th241 16.7s	Th242 4.54s
89	Ac227 21.77y	Ac228 6.15h	Ac229 1.045h	Ac230 2.033m	Ac231 7.5m	Ac232 1.983m	Ac233 2.417m	Ac234 44s	Ac235 18.1s	Ac236 5.55s	Ac237 9.87s	Ac238 5.01s	Ac239 3.14s	Ac240 3.65s	
88	Ra226 1600y	Ra227 42.2m	Ra228 5.75y	Ra229 4m	Ra230 1.55h	Ra231 1.717m	Ra232 4.167m	Ra233 30s	Ra234 30s	Ra235 13.7s	Ra236 12s	Ra237 7.01s			
87	Fr225 4m	Fr226 49s	Fr227 2.47m	Fr228 39s	Fr229 50.2s	Fr230 19.1s	Fr231 17.5s	Fr232 5s	Fr233 5.9s	Fr234 3.89s	Fr235 3.62s				
86	Rn224 1.783h	Rn225 4.5m	Rn226 7.4m	Rn227 22.5s	Rn228 1.083m	Rn229 25.9s	Rn230 10.6s	Rn231 15.2s	Rn232 7.01s						
85	At223 50s	At224 11.7s	At225 18.5s	At226 11.3s	At227 10.2s	At228 10.7s	At229 7.08s								
84	Po222 2.24m	Po223 1.56m	Po224 49.2s	Po225 33.3s	Po226 8.96s										
83	Bi221 9.48s	Bi222 4.98s	Bi223 5.05s	Bi224 3.91s											

Chart of the Nuclides

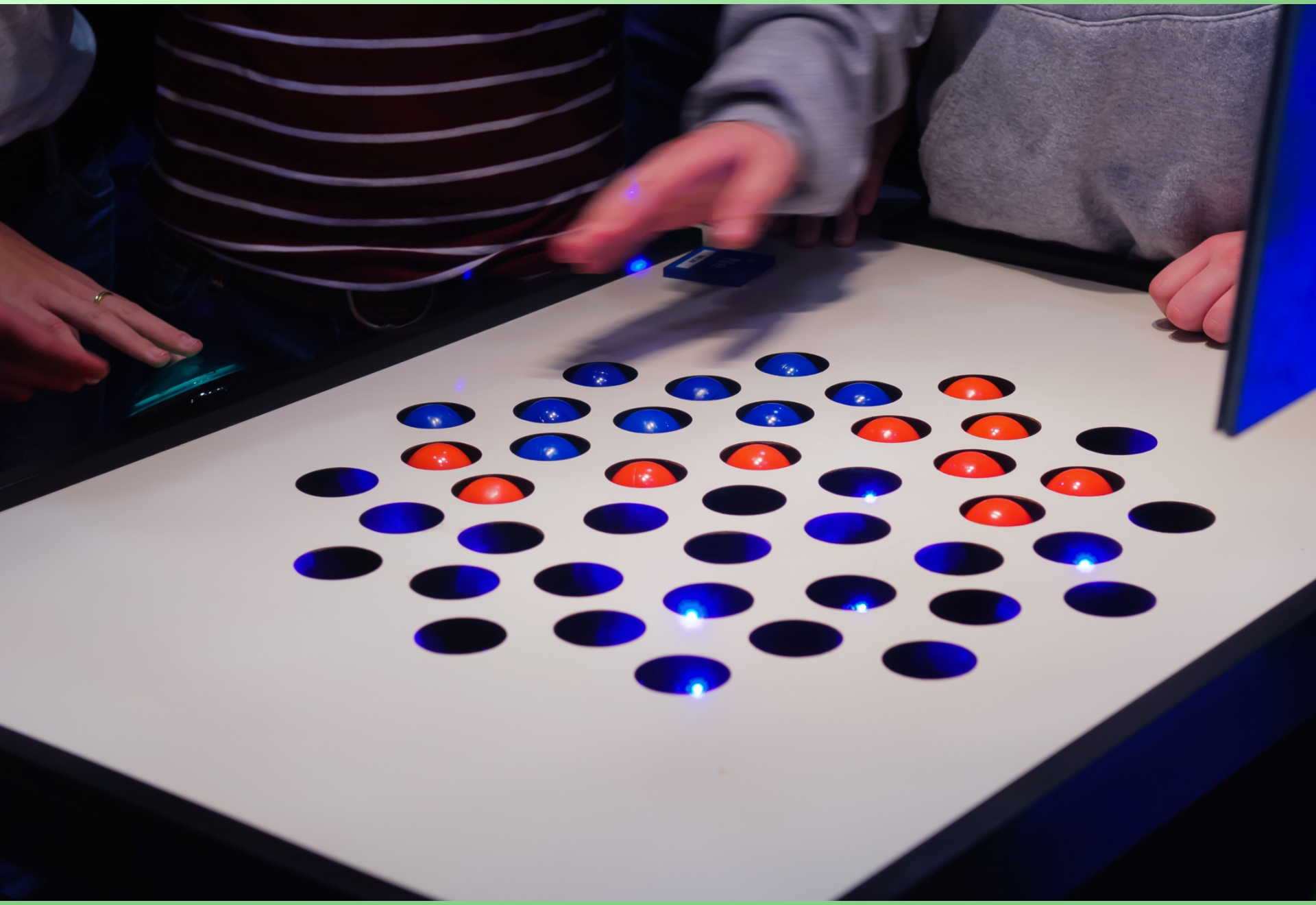


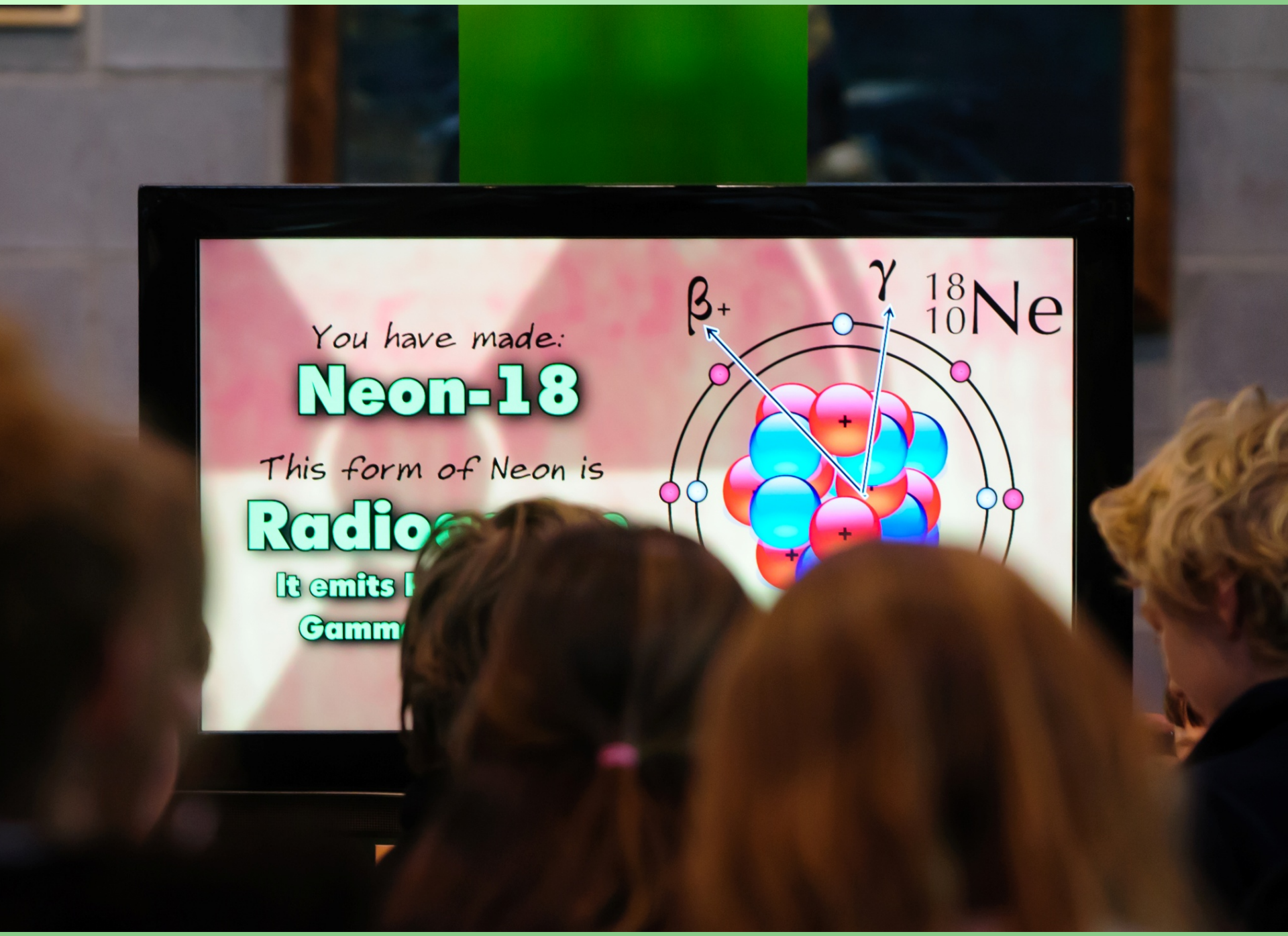
Interactive Nucleus at the Ruth Patrick Science Education Center at the University of South Carolina- Aiken

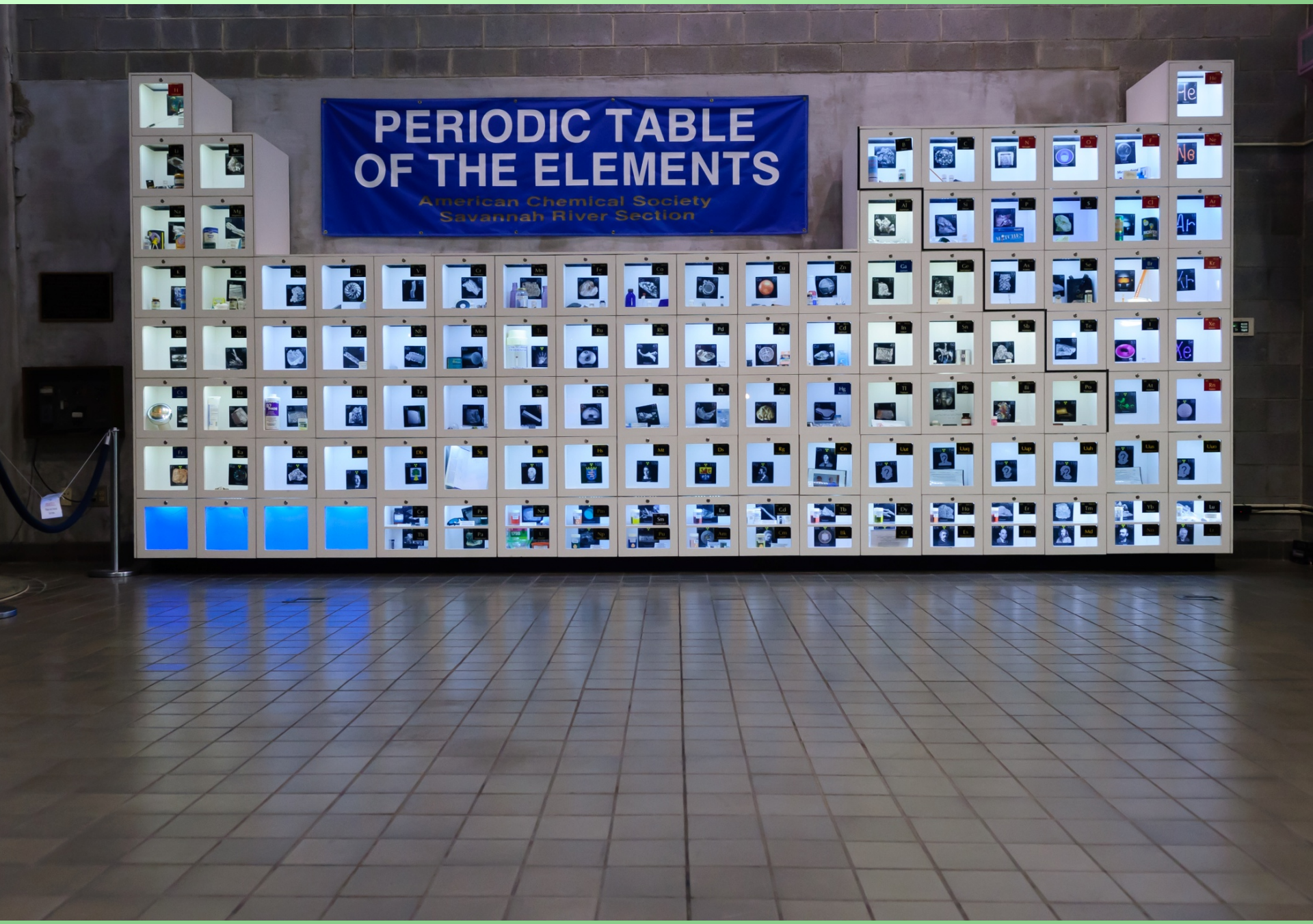

Number of protons
Hydrogen
neutron


19
Ne
10
NEON


MARGRITAVILLE
Net-Up on

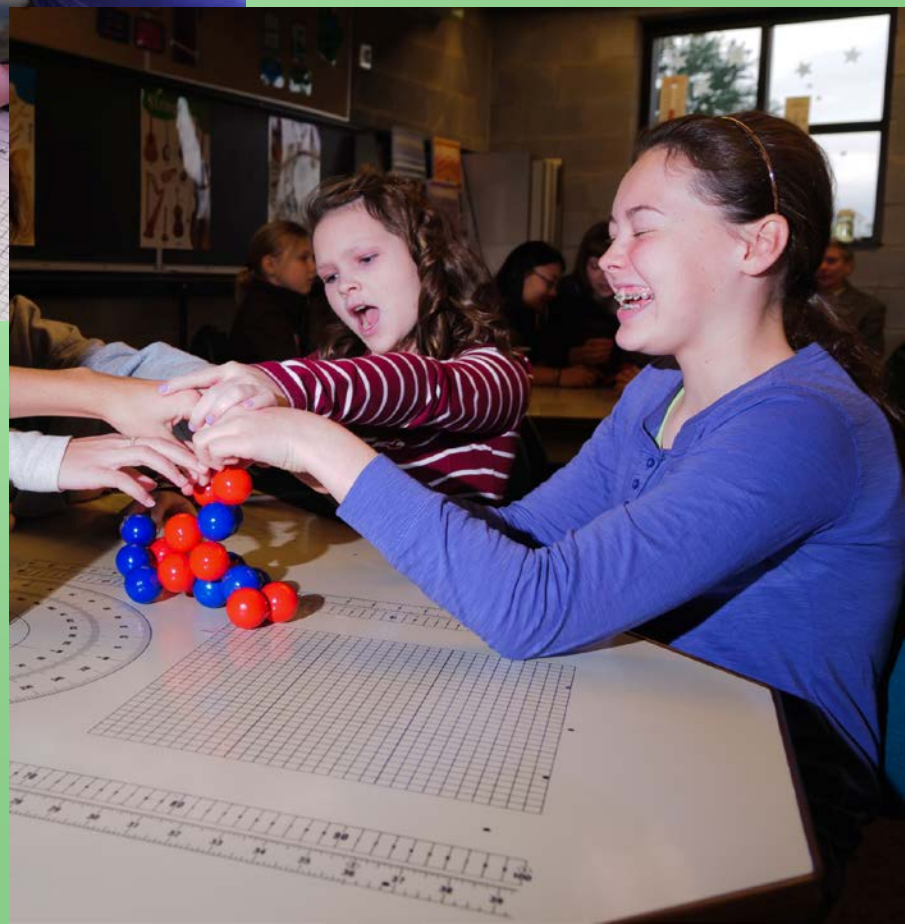



You have made:
Neon-18
This form of Neon is
Radio
It emits
Gamm
β+
γ
18
10
Ne


PERIODIC TABLE
OF THE ELEMENTS
American Chemical Society
Savannah River Section


B
C
N
O
F
Ne
Al
Si
P
S
Cl
Ar
Ga
Ge
As
Se
Br
Kr
In
Sn
Sb
Xe
Tl
Pb
Bi
Uut
Uuq
Uup
Dy
Ho
Er
Cf
Es
Fm


1



Questions?