Periodic Table of the Elements

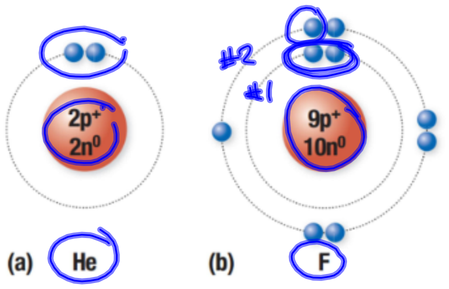
1 IA 1A	2 IIA 2A	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8 VIII 8	9 VIII 8	10 VIII 8	11 IB 1B	12 IIB 2B	13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	18 VIIIA 8A
1 H Hydrogen 1.008																	2 He Helium 4.003
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.811	6 C Carbon 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 32.066	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 47.867	23 V Vanadium 50.942	24 Cr Chromium 51.996	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 72.631	33 As Arsenic 74.922	34 Se Selenium 78.971	35 Br Bromine 79.904	36 Kr Krypton 84.798
37 Rb Rubidium 84.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.95	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.414	49 In Indium 114.818	50 Sn Tin 118.711	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.904	54 Xe Xenon 131.294
55 Cs Cesium 132.905	56 Ba Barium 137.328	57-71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.085	79 Au Gold 196.967	80 Hg Mercury 200.592	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [208.982]	85 At Astatine 209.987	86 Rn Radon 222.018
87 Fr Francium 223.020	88 Ra Radium 226.025	89-103	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [269]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]	113 Uut Ununtrium unknown	114 Fl Flerovium [289]	115 Uup Ununpentium unknown	116 Lv Livermorium [298]	117 Uus Ununseptium unknown	118 Uuo Ununoctium unknown

Lanthanide Series	57 La Lanthanum 138.905	58 Ce Cerium 140.116	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.243	61 Pm Promethium 144.913	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.500	67 Ho Holmium 164.930	68 Er Erbium 167.259	69 Tm Thulium 168.934	70 Yb Ytterbium 173.055	71 Lu Lutetium 174.967
Actinide Series	89 Ac Actinium 227.028	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium 237.048	94 Pu Plutonium 244.064	95 Am Americium 243.061	96 Cm Curium 247.070	97 Bk Berkelium 247.070	98 Cf Californium 251.080	99 Es Einsteinium [254]	100 Fm Fermium 257.095	101 Md Mendelevium 258.1	102 No Nobelium 259.101	103 Lr Lawrencium [262]

SPH3U 7.1 Atoms and Isotopes

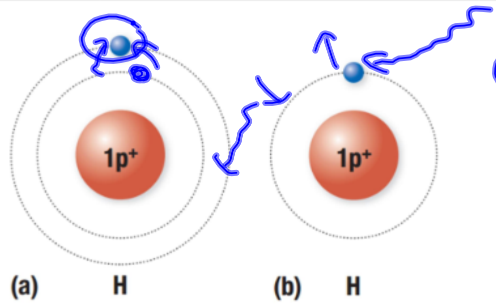
1. **Bohr-Rutherford model of the atom**

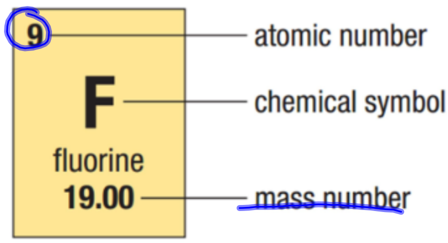
Nucleus:	Centre part, filled with protons and neutrons.	Shells:	energy states of the electrons.



Shell number	Maximum number of electrons
1	2
2	8
3	18
4	32

Excited state:	electrons are at higher-energy states than the ground state.	Atomic number:	# of protons. unique for each element.
		Mass number:	# of protons + # of neutrons.

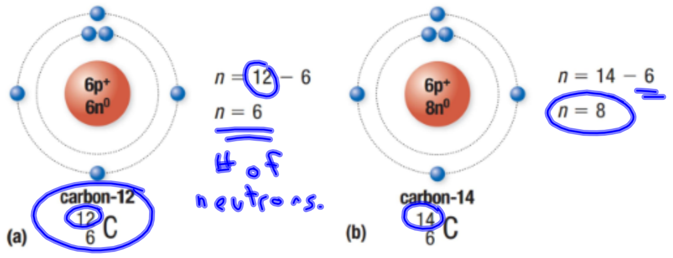




$n^0 = 19 - 9 = 10$

2. Isotopes

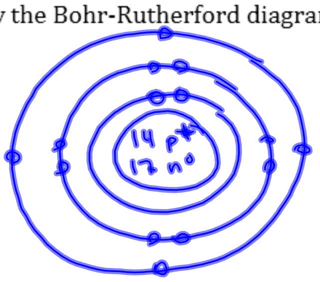
Isotope:	same atomic #, different # of neutrons.



Naturally occurring →

Hydrogen:	1 proton, 1 electron, no neutrons $^{1}_{1}H$
deuterium	$^{2}_{1}H$, has one neutron. } Used to make "Heavy
tritium	$^{3}_{1}H$, has two neutron. } water" (H_2O) ← Canadian nuclear reactors.
Periodic table:	Lists the most commonly occurring isotope.

Draw the Bohr-Rutherford diagram for silicon-31. $^{31}_{14}Si$ → $n^0 = 31 - 14 = 17$.



3. Medical applications of radioisotopes

Radioisotopes:	Unstable isotope that will decay and release radiation.
nuclear medical imaging	inject a radioisotope into a patient and use the radiation to see internal problems.
radionuclide therapy (RNT)	use radiation to target and kill specific structures (tumors)

Homework: page 322: #1-3, 5

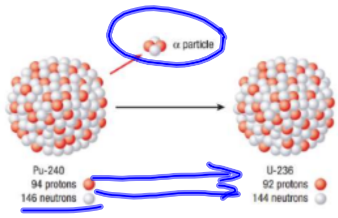
SPH3U 7.2 Radioactive Decay

1. Radioactivity

Radioactivity:	nucleus of an atom spontaneously disintegrates.
stable atom	strong nuclear force > electrostatic force
atomic #	more p^+ → more electrostatic force → less stable.
3 types of decay	① Alpha (α), ② Beta (β), ③ Gamma (γ).

2. Alpha (α) decay

Alpha decay:	nucleus emits an α particle.
α particle	2 protons + 2 neutrons. ${}^{4}_{2}He$
plutonium-240 decay	${}^{240}_{94}Pu \rightarrow {}^{236}_{92}U + {}^{4}_{2}He$.
general alpha decay	${}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He$.
X and Y	X: Parent atom, Y: Daughter atom.



When lead-204 undergoes alpha decay, it produces a stable isotope. Determine the element and its atomic number and mass number. Write the nuclear reaction equation.

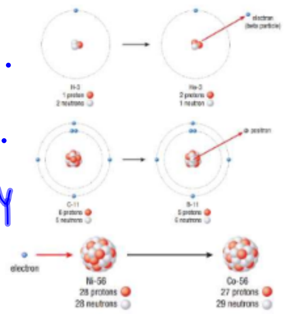
${}^{204}_{82}Pb \rightarrow {}^{204-4}_{82-2}Y + {}^{4}_{2}He$. ${}^{200}_{80}Hg$

Element: Mercury. Atomic #: 80 Mass #: 200.

${}^{204}_{82}Pb \rightarrow {}^{200}_{80}Hg + {}^{4}_{2}He$.

3. Beta (β) decay

Beta decay:	β particle is released or absorbed.
β particle	electron (${}^{0}_{-1}e$) or positron (${}^{0}_{+1}e$)
① Beta-negative decay:	electron emitted. ${}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}e$.
tritium H-3 decay	${}^{3}_{1}H \rightarrow {}^{3}_{2}He + {}^{0}_{-1}e$.
② Beta-positive decay:	positron emitted. ${}^{A}_{Z}X \rightarrow {}^{A}_{Z-1}Y + {}^{0}_{+1}e$.
carbon-11 decay	${}^{11}_{6}C \rightarrow {}^{11}_{5}B + {}^{0}_{+1}e$
③ Electron capture:	electron absorbed. ${}^{A}_{Z}X + {}^{0}_{-1}e \rightarrow {}^{A}_{Z-1}Y$
Ni-56 decay	${}^{56}_{28}Ni + {}^{0}_{-1}e \rightarrow {}^{56}_{27}Co$.



When bismuth-214 undergoes beta-negative decay, it produces a stable isotope. Determine the element and its atomic number and mass number. Write the nuclear reaction.

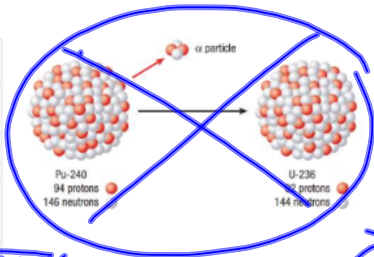
$^{214}_{83}Bi \rightarrow ^{214}_{84}Po + ^{0}_{-1}e$

At #: 84, Mass #: 214, Polonium.

4. Gamma (γ) decay

(*): Excited state.

Gamma decay:	γ ray is released.
γ ray	Light (photon).
He-3 decay	$^{3}_{2}He^{*} \rightarrow ^{3}_{2}He + ^{0}_{0}\gamma$
general gamma decay	$^{A}_{Z}X^{*} \rightarrow ^{A}_{Z}X + ^{0}_{0}\gamma$
excited state	~~an electron is in a higher energy shell.~~ the nucleus has extra energy.



When dysprosium-152 undergoes gamma decay, its nucleus changes from an excited state to a stable state. Write the nuclear reaction equation for this gamma decay.

$^{152}_{66}Dy^{*} \rightarrow ^{152}_{66}Dy + ^{0}_{0}\gamma$

5. Characteristics of radioactive decay

Danger of radiation:	radiation can ionize (strip electrons from) atoms. → can cause burns, tumors, etc.

Decay	Radiation	Electric charge	Penetrating ability
alpha	α particle, $^{4}_{2}He$	+2	penetrate skin or paper; slow.
beta-negative	electron, $^{0}_{-1}e$	−1	penetrate a few sheets of aluminum foil.
beta-positive	positron, $^{0}_{+1}e$	+1	(same as above)
electron capture	gain electron.	—	—
gamma	γ ray, photon, $^{0}_{0}\gamma$	0	penetrate a few cm of lead.

Homework: page 329: #1-3, 5-6

7.3 Half-Life

1. Measuring the rate of radioactive decay processes: Half-life

Half-life: Average time for half of a radioactive substance to decay.

Rate of decay:  Exponential

Mass of a radioactive material: $A = A_0\left(\frac{1}{2}\right)^{\frac{t}{h}}$ (h is half-life)

Neon-19 has a half-life of 17.22 s. What mass of neon-19 will remain from a 100 mg initial sample after 30 s?

G: $h = 17.22\text{ s}$, $A_0 = 100\text{ mg}$, $t = 30\text{ s}$

R: A

E: $A = A_0\left(\frac{1}{2}\right)^{\frac{t}{h}}$

S: $A = (100\text{ mg})\left(\frac{1}{2}\right)^{(30/17.22)} = 29.9\text{ mg} = 30\text{ mg}$

S: ∴ 30 mg remain.

A 100 mg sample of magnesium-27 decays by 7% of its previous mass every minute. Determine its half-life and state the half-life decay equation.

∴ $h \doteq 9.5\text{ min}$

$A = A_0\left(\frac{1}{2}\right)^{t/9.5}$

$93 \times 0.07 = 6.51$

Time (min)	Initial mass (mg)	Final mass (mg)
0	100	100 − 7 = 93
1	93	93 − 6.51 = 86.49
2	86.49	− 6.05 = 80.44
3	80.44	74.81
4	74.81	69.57
5	69.57	64.70
6	64.70	60.17
7	60.17	55.96
8	55.96	52.04
9	52.04	48.40
10	48.40	45.01

$= 80.44 \times 0.93$

2. Applications of half-life: Carbon dating

Half-life of carbon-14: 5730 years

Carbon-14 decay: $^{14}_{6}C \rightarrow ^{14}_{7}N + ^{0}_{-1}e$ (β-negative)

Carbon-14 absorption: CO_2 → Plants → animals → Us
(fixed ratio of C-14 : C-12 while living)

Half-life of aluminum-26: 720 000 years

Aluminum-26 decay: $^{26}_{13}Al \rightarrow ^{26}_{12}Mg + ^{0}_{+1}e$ (β-positive).

⇒ date interstellar rocks (meteorites)

Homework: page 333: #1-4

SPH3U 7.4 Nuclear Fission

1. Mass-energy equivalence

Mass-energy equation:	$E = mc^2$ (Einstein).
c	speed of light, 3.0×10^8 m/s.
Law of conservation of mass-energy:	Mass can transform into energy, and energy into mass. The total mass-energy in a closed system is conserved.

Particle	Mass (kg)	Mass (u)
proton	$1.672\,6014 \times 10^{-27}$	1.007 276
neutron	$1.674\,920 \times 10^{-27}$	1.008 665
electron	$9.109\,56 \times 10^{-31}$	0.000 549

Atomic mass unit (u):	$1\text{ u} = 1.66 \times 10^{-27}$ kg.
Mega-electron volt:	$1\text{ MeV} = 1.602 \times 10^{-13}$ J.

Mass defect: Δm	Difference between the calculated mass of an ~~nucleus~~ atom and its actual mass.
Binding energy:	Amount of energy needed to separate a nucleus.

Determine the mass defect and binding energy of a lithium-7 nucleus, given that its actual atomic mass is 7.016 00 u, and using the particle mass table above.

$^{7}_{3}Li$: $3p^+ + 4n^0 + 3e^-$

$= 3(1.007276) + 4(1.008665) + 3(0.000549) = 7.058135$.

$\Delta m = 7.058135 - 7.01600 = 0.042135$ u.

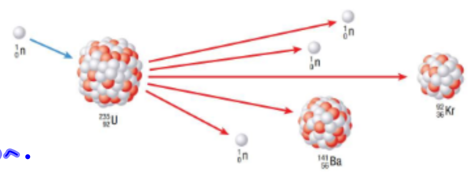
$E = \Delta m c^2 = (0.042135)(3.0 \times 10^8)^2 (1.66 \times 10^{-27} \frac{kg}{u})$

$= 6.29 \times 10^{-12}$ J.

$= (6.29 \times 10^{-12})\left(\frac{1\text{ MeV}}{1.602 \times 10^{-13}\text{ J}}\right) = 39$ MeV.

2. Nuclear fuel

U-235 fission:	$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{92}_{36}Kr + ^{141}_{56}Ba + 3(^{1}_{0}n)$
Chain reaction:	repeated series of reactions where the products of a reaction create a new reaction.



Other nuclear fuels:	Plutonium-239, Thorium-232, Uranium-233.

What is the energy yield of the following fission reaction? Use the given masses below.

$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{140}_{55}Cs + ^{93}_{37}Rb + 3(^{1}_{0}n)$

mass of U (m_U) = 235.044 u
mass of Cs (m_{Cs}) = 139.909 u
mass of Rb (m_{Rb}) = 92.922 u
mass of neutron (m_n) = 1.009 u

$m_U + m_n = m_{Cs} + m_{Rb} + 3m_n + \Delta m$.

$\Delta m = m_U + m_n - (m_{Cs} + m_{Rb} + 3m_n)$

$= 235.044 + 1.009 - 139.909 - 92.922 - 3(1.009)$

$= 0.195\ u$.

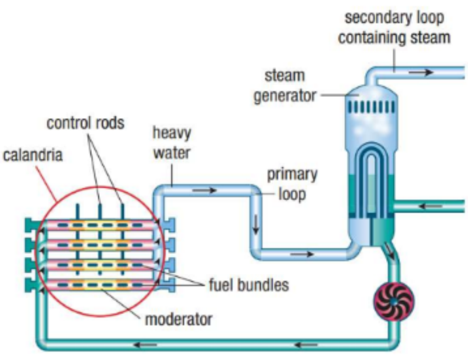
$= (0.195)(1.66\times10^{-27}\ \frac{kg}{u}) = 3.237\times10^{-28}\ kg$

$E = \Delta m c^2 = (3.237\times10^{-28})(3.00\times10^{8})^2 = 2.913\times10^{-11}\ J$

$= 181.9\ MeV$.

3. **CANDU Reactors**

Neutron moderation:	Neutrons are slowed down by heavy water for chain-reaction.
Natural uranium:	99.27% U-238 (not fuel), 0.72% U-235 (radioactive).
Radiation badges:	wear them, they show how much radiation you've been exposed to.
Waste disposal:	very little pollution, but nuclear (radioactive) waste needs to be stored safely for 100s of years.

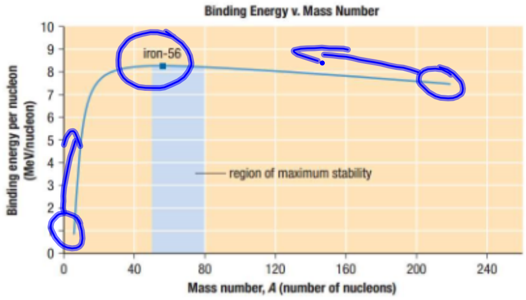


Homework: page 341: #1-4

SPH3U 7.5 Nuclear Fusion

1. Mass-energy equivalence

Heavy nuclei:	want fission to become more stable.
Light nuclei:	want fusion to become more stable.
c^2:	$(3.0\times10^8)^2 = 930\ \frac{MeV}{u}$



Determine the energy released when a deuterium atom (D) fuses with a tritium atom (T) to form helium, according to the nuclear reaction equation below. Use the given masses.

$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n + \text{energy}$

$m_D = 2.014\ 10\ u$ $m_{He} = 4.002\ 60\ u$ $c^2 = 930\ MeV/u$
$m_T = 3.016\ 05\ u$ $m_n = 1.008\ 67\ u$

$\Delta m = m_D + m_T - m_{He} - m_n$
$= 2.01410 + 3.01605 - 4.00260 - 1.00867 = 0.01888\ u.$

$E = \Delta m c^2 = (0.01888)(930\ MeV/u)$
$= 17.56\ MeV.$

2. Controlled nuclear fusion

Proton-proton chain:	$4(^{1}_{1}H) \rightarrow ^{4}_{2}He + 2(^{0}_{+1}e) + \text{energy}$. → happens in the sun.
Production of elements:	stars fuse particles together to create higher elements.
Carbon-nitrogen-oxygen cycle:	$^{12}_{6}C \rightarrow ^{13}_{7}N \rightarrow ^{13}_{6}C \rightarrow ^{14}_{7}N \rightarrow ^{15}_{8}O \rightarrow ^{15}_{7}N \rightarrow ^{12}_{6}C + ^{4}_{2}He$
Magnetic confinement:	in fusion, the substance (plasma) is very hot
The ITER Project:	experimental fusion reactor.

Homework: page 347: #1-3, 5-6