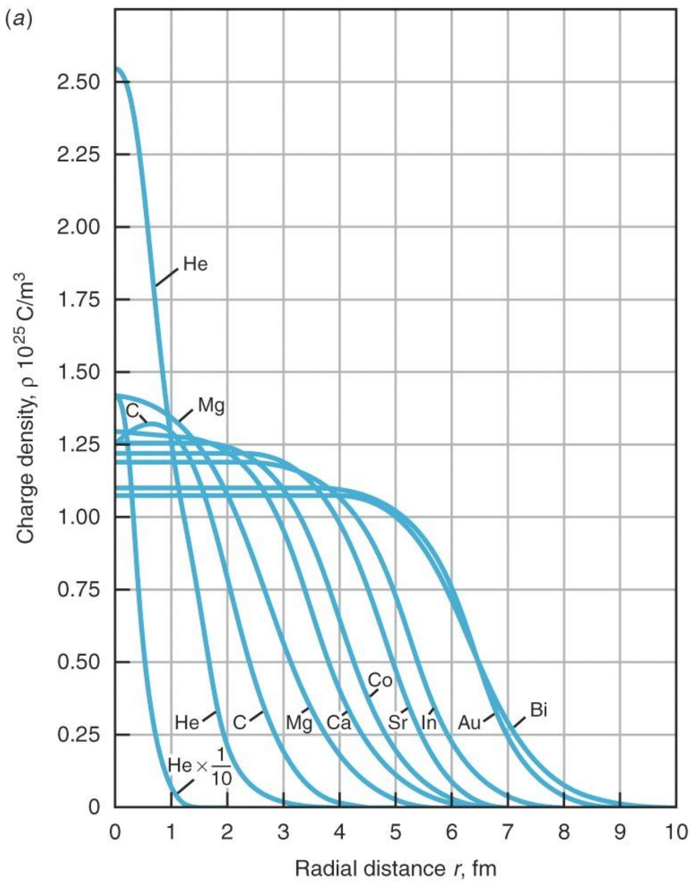
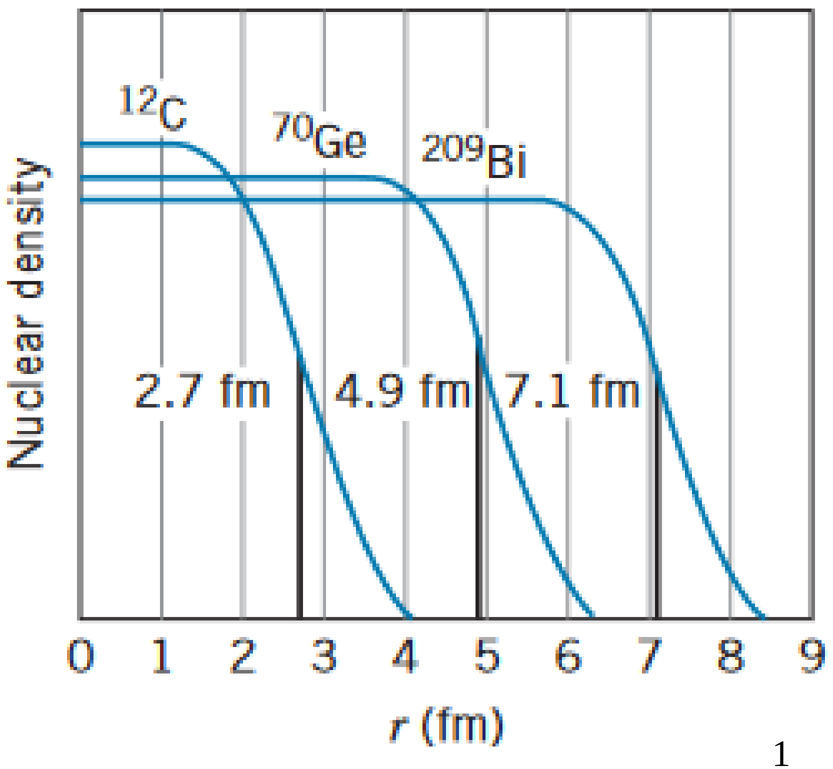
Nuclear Size

Nuclear size has been detected by many different processes; give roughly same answer.

Calculations of charge density vs. r gives curves below.





Question #1

The ^{2}H nucleus (composed of a proton & neutron) is stable. The mass of the ^{2}H nucleus is

(a) greater than the mass of a proton + mass of a neutron

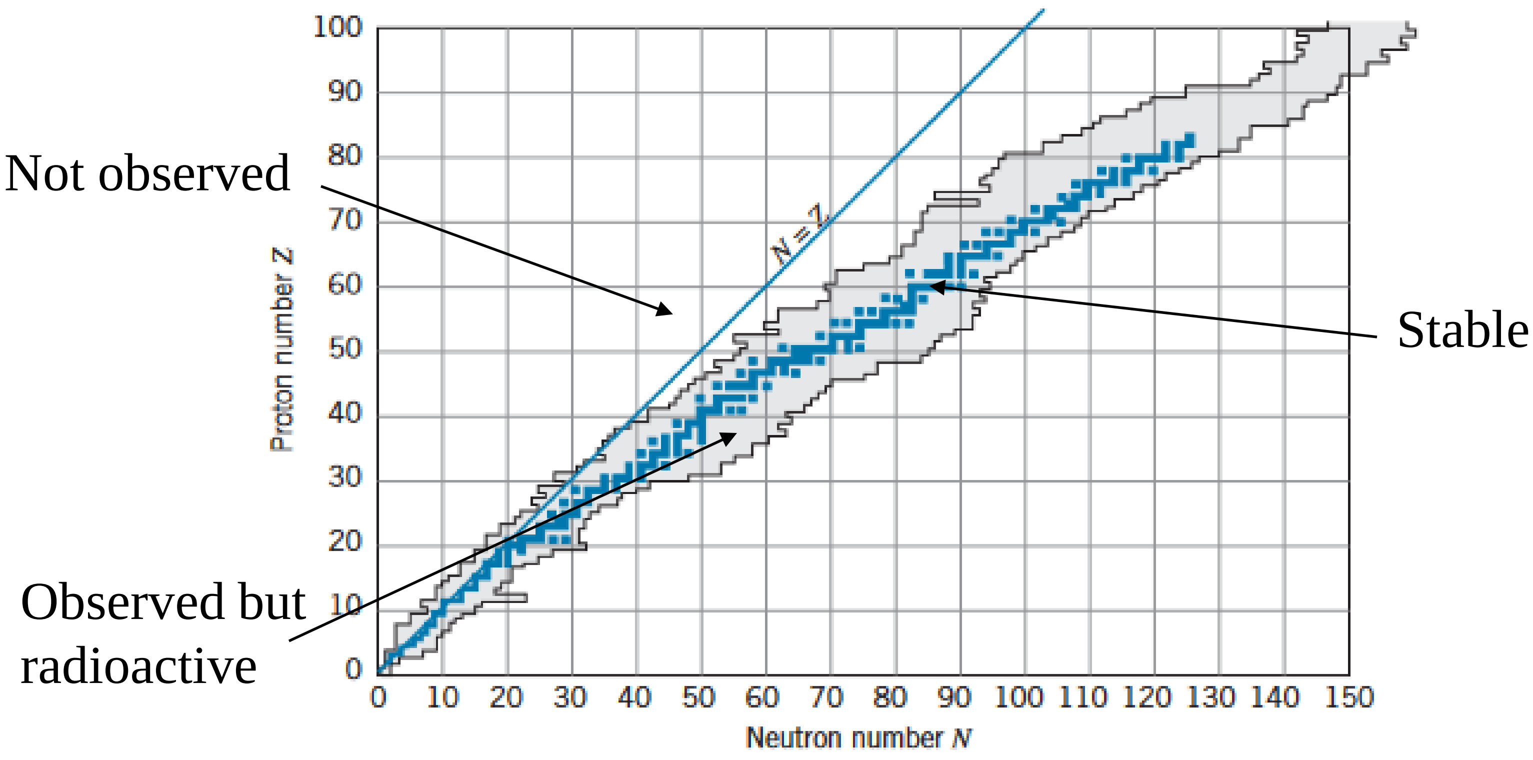
(b) less than the mass of a proton + mass of a neutron

(c) equals the mass of a proton + mass of a neutron

(d) (a-c) but not enough info is given to decide

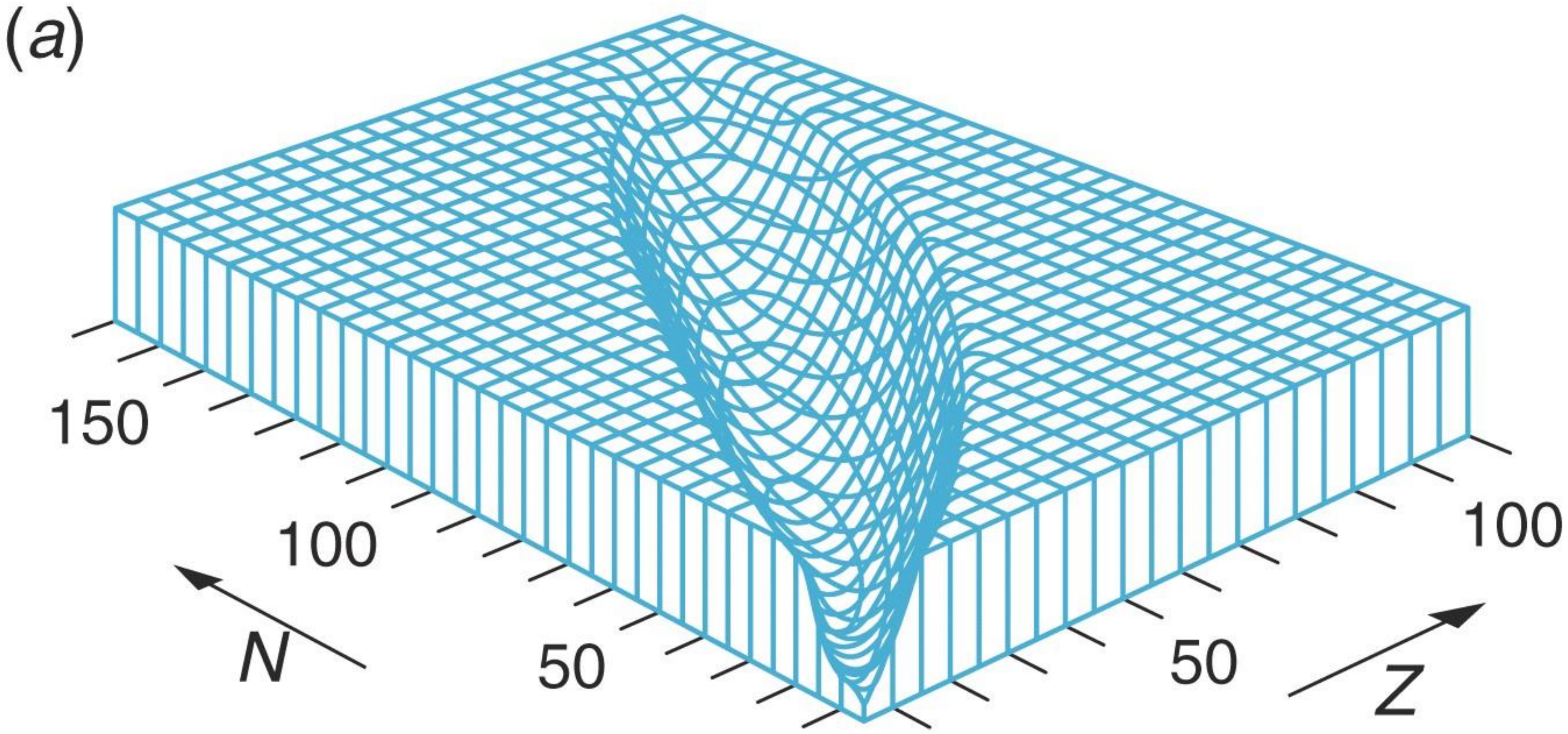
Stable Nuclei

Only a small range of nuclei have been observed.



Valley of Stability

The binding energy decreases rapidly away from the stability line.



Question #2

The number of protons for heavy (Z > 45), stable nuclei

(a) equals the number of neutrons

(b) is greater than the number of neutrons

(c) is less than the number of neutrons

(d) can be (a-c) depending on Z

Question #3

The electrostatic potential energy in nuclei

(a) is negative

(b) increases linearly with the number of protons

(c) increases with the number of neutrons

(d) increases quadratically with the number of protons

Weizsacker Mass Formula

https://www.nuclear-power.com/nuclear-power/fission/weizsaecker-formula-semi-empirical-mass-formula/

$B = [a_V\, A - a_S\, A^{2/3} - a_C\, Z^2\, A^{-1/3} - a_A\, (A - 2\, Z)^2\, A^{-1} + a_5\, A^{-3/4}]\, c^2$

All values are MeV/c^2

a_V	a_S	a_C	a_A	$a_5(e,e)$	$a_5(o,e)$ $a_5(e,o)$	$a_5(o,o)$
15.76	17.81	0.711	23.7	34	0	-34

How Good?

Below is a table of binding energy for isotopes of iron (Fe).

Z,N	Fit	Expt.
26,24	415.9	417.7
26,25	428.9	431.5
26,26	444.6	447.7
26,28	469.6	471.7
26,30	491.3	492.3
26,32	510.1	509.9

Question #4

The ^{14}C nucleus has a half life of 5730 years. You create a ^{14}C nucleus now. What is the probability that it will decay during the next 5730 years?

(a) 1/8

(b) 1/4

(c) 1/2

(d) 1

(e) none of the above

Question #5

The ^{14}C nucleus has a half life of 5730 years. You created a ^{14}C nucleus 5730 years ago; it has survived to today. What is the probability that it will decay during the next 5730 years?

(a) 1/8

(b) 1/4

(c) 1/2

(d) 1

(e) none of the above

Question #6

The ^{14}C nucleus has a half life of 5730 years. You create 64 ^{14}C nucleus now; the nuclei are identical. Roughly how many will not decay during the next 5730 years?

(a) 0

(b) 8

(c) 16

(d) 32

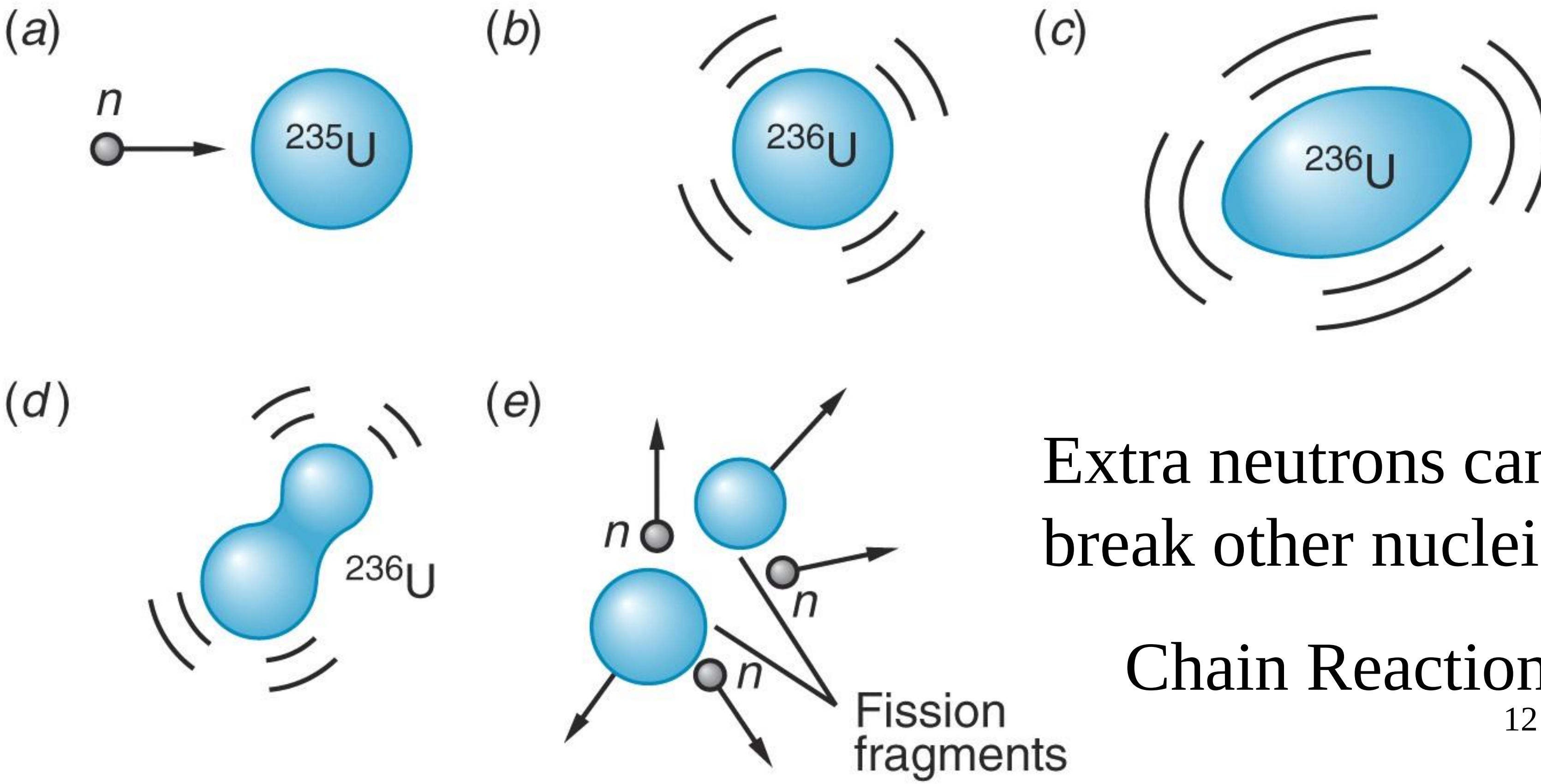
(e) there is a 50% chance that all decayed and a 50% chance that none decayed

Fission Reactions

The heaviest nuclei are just barely stable against electric force breaking nuclei into 2 large pieces + neutrons.

Neutron <u>not</u> charged so doesn't need high energy.

Several years to recognize what was going on.



Extra neutrons can go break other nuclei.

Chain Reaction!

Estimate of energy release

A typical reaction is $^{1}_{0}\text{n} + ^{235}_{92}\text{U} \rightarrow ^{92}_{36}\text{Kr} + ^{142}_{56}\text{Ba} + 2\,^{1}_{0}\text{n}$

Roughly, the fragments start at rest. The two charged fragments are separated by roughly
$R = 1.4$ fm $A^{1/3}$ with $A = 236$.

This gives all energy is PE with roughly
$k\,e^2$ 56 X 36/R = 335 MeV

The actual number is 180 MeV.

Will Reactor Work?

For a working reactor, need to have an average of 1 n out for each n in.

k = reproduction factor = average number of neutrons from each fission that cause a subsequent fission.

Each fission reaction gives > 1 for each n in.
n are lost through the sides of the reactor
n are captured by non-fissioning atoms in the reactor.

Fission cross section is larger for slow n. Moderators (graphite, heavy water) used to slow n.

Because reaction depends on <u>slow</u> neutrons a properly run reactor can be safe.

Fusion Reactions

Energy can be obtained by fusing light nuclei.

$$ {}_{1}^{2}\mathrm{H} + {}_{1}^{3}\mathrm{H} \rightarrow {}_{2}^{4}\mathrm{He} + {}_{0}^{1}\mathrm{n} + 17.6\,\mathrm{MeV} $$

Problem: High T needed to have nuclei approach close enough. **<u>But</u>**…high T gases are hard to hold & need energy to heat the gas. Images from the Joint European Torsatron (JET): http://www.jet.efda.org