PHY100 — Recitation #7

1) Determine the nuclear product remaining after:

- a) β^- decay of ^{211}Pb
- b) α decay of ^{247}Cm
- c) γ decay of ^{131}I

2) Which is safer overall: a coal power plant or a nuclear power plant?

What do you mean by “safe”?

What are all the factors that you should consider?

3) Sometimes radioactive isotopes decay to other isotopes that are also radioactive... which decay to other isotopes that are radioactive, etc... This is called a “decay series”. Here is the beginning of one such series:

$${}^{238}\mathrm{U} \xrightarrow[\alpha]{} \mathrm{A} \xrightarrow[\beta]{} \mathrm{B} \xrightarrow[\gamma]{} \mathrm{C} \xrightarrow[\alpha]{} \mathrm{D}$$

What are nuclei A, B, C, D? (Give Z, A and symbol)

4) A small sample of charcoal from an archeological site is measured to have 64 times less ^{14}C than living material. How long ago was the wood burnt? $T_{1/2}$ (^{14}C) = 5730 years.

Radiation such as α, β, and γ rays are potentially harmful to living things because these particles can ionize (rip apart) the molecules in human tissue, killing cells and causing long-term DNA damage. If the radiation dose is high enough the cell damage can kill the living thing. If the damage is not that severe, the DNA damage can lead to cancer and/or birth defects many years later.

Only particles that are charged can cause ionizing damage as they pass through tissue. The larger the electrical charge of the ionizing radiation, the heavier is the ionizing damage and the shorter the range of the radiation in the material. γ rays pass harmlessly through materials except when they pair-produce into an electron-positron pair: $\gamma \rightarrow e^- + e^+$ The positron (e^+) is the anti-particle of the electron: it shares all its characteristics, except its charge is +1, instead of -1.

So γ rays have a long penetration power, but eventually they interact with matter and decay into an electron-positron pair.

α particles can be stopped by a sheet of paper

β particles can be stopped by the outer layers of the skin

γ rays can pass through living tissue and other materials, they are stopped by a thick layer of lead.

5) If I told you that you had to spend the night sleeping in a bed laced with an α source, a β source, or a γ source... which would you choose? Why? Assume all sources would have the same half-life.

6) Suppose you had three stupid friends:

Friend 1 drinks a glass of water laced with an α source

Friend 2 drinks a glass of water laced with a β source

Friend 3 drinks a glass of water laced with a γ source

Assume similar half-lifes for the materials in the drinks. Which friend should you be most worried about? Why?

In quantum mechanics we usually cannot predict the outcome of a single measurement, but we can often predict the correct average of many measurements.

DO THESE TWO EXCERSISES IN GROUPS OF 2 TO 4

7) One person (the experimentalist) should toss a die 48 times keeping track of the values on top face of the die for each toss. A different person (the oracle) should move where they cannot see the die being thrown and they should predict the value seen for each of the 48 throws and record their predictions.

a) How often does the oracle correctly predict what the experimentalist measures?

b) How often would you expect the oracle to get it right just due to random luck?

c) Does it matter whether the predictions are made after each throw, or all 48 in advance?

d) How much variation is there among all the oracles in your section in terms of the number of correct predictions they make?

e) What is the average value of all the measurements made by the experimentalists?

f) What would you expect to find for the average value of all 48 measurements?

8) Throw two dice sequentially 50 times. If the 1st die comes up as a one or a two, record the value of the second die. Compare the distribution and average values of your measurements with what you observed in the previous exercise. What do you see from this comparison?

Now repeat the exercise... but instead of throwing the second die, take as your measured value the number on the bottom face of the first die (remember only take those where the 1st die comes up one or two). Compare the distribution and average of your measurements with what you saw earlier.

Can you explain the difference you see?

How might this situation be similar to what is meant by “quantum entanglement”?

Key:

element name
atomic number
symbol
atomic weight (mean relative mass)

hydrogen 1 **H** 1.0079																		helium 2 **He** 4.0026
lithium 3 **Li** 6.941	beryllium 4 **Be** 9.0122												boron 5 **B** 10.811	carbon 6 **C** 12.011	nitrogen 7 **N** 14.007	oxygen 8 **O** 15.999	fluorine 9 **F** 18.998	neon 10 **Ne** 20.180
sodium 11 **Na** 22.990	magnesium 12 **Mg** 24.305												aluminium 13 **Al** 26.982	silicon 14 **Si** 28.086	phosphorus 15 **P** 30.974	sulfur 16 **S** 32.065	chlorine 17 **Cl** 35.453	argon 18 **Ar** 39.948
potassium 19 **K** 39.098	calcium 20 **Ca** 40.078		scandium 21 **Sc** 44.956	titanium 22 **Ti** 47.867	vanadium 23 **V** 50.942	chromium 24 **Cr** 51.996	manganese 25 **Mn** 54.938	iron 26 **Fe** 55.845	cobalt 27 **Co** 58.933	nickel 28 **Ni** 58.693	copper 29 **Cu** 63.546	zinc 30 **Zn** 65.39	gallium 31 **Ga** 69.723	germanium 32 **Ge** 72.61	arsenic 33 **As** 74.922	selenium 34 **Se** 78.96	bromine 35 **Br** 79.904	krypton 36 **Kr** 83.80
rubidium 37 **Rb** 85.468	strontium 38 **Sr** 87.62		yttrium 39 **Y** 88.906	zirconium 40 **Zr** 91.224	niobium 41 **Nb** 92.906	molybdenum 42 **Mo** 95.94	technetium 43 **Tc** [98]	ruthenium 44 **Ru** 101.07	rhodium 45 **Rh** 102.91	palladium 46 **Pd** 106.42	silver 47 **Ag** 107.87	cadmium 48 **Cd** 112.41	indium 49 **In** 114.82	tin 50 **Sn** 118.71	antimony 51 **Sb** 121.76	tellurium 52 **Te** 127.60	iodine 53 **I** 126.90	xenon 54 **Xe** 131.29
caesium 55 **Cs** 132.91	barium 56 **Ba** 137.33	57-70 *	lutetium 71 **Lu** 174.97	hafnium 72 **Hf** 178.49	tantalum 73 **Ta** 180.95	tungsten 74 **W** 183.84	rhenium 75 **Re** 186.21	osmium 76 **Os** 190.23	iridium 77 **Ir** 192.22	platinum 78 **Pt** 195.08	gold 79 **Au** 196.97	mercury 80 **Hg** 200.59	thallium 81 **Tl** 204.38	lead 82 **Pb** 207.2	bismuth 83 **Bi** 208.98	polonium 84 **Po** [209]	astatine 85 **At** [210]	radon 86 **Rn** [222]
francium 87 **Fr** [223]	radium 88 **Ra** [226]	89-102 **	lawrencium 103 **Lr** [262]	rutherfordium 104 **Rf** [261]	dubnium 105 **Db** [262]	seaborgium 106 **Sg** [266]	bohrium 107 **Bh** [264]	hassium 108 **Hs** [269]	meitnerium 109 **Mt** [268]	ununnilium 110 **Uun** [271]	unununium 111 **Uuu** [272]	ununbium 112 **Uub** [277]		ununquadium 114 **Uuq** [289]				

*lanthanoids	lanthanum 57 **La** 138.91	cerium 58 **Ce** 140.12	praseodymium 59 **Pr** 140.91	neodymium 60 **Nd** 144.24	promethium 61 **Pm** [145]	samarium 62 **Sm** 150.36	europium 63 **Eu** 151.96	gadolinium 64 **Gd** 157.25	terbium 65 **Tb** 158.93	dysprosium 66 **Dy** 162.50	holmium 67 **Ho** 164.93	erbium 68 **Er** 167.26	thulium 69 **Tm** 168.93	ytterbium 70 **Yb** 173.04
**actinoids	actinium 89 **Ac** [227]	thorium 90 **Th** 232.04	protactinium 91 **Pa** 231.04	uranium 92 **U** 238.03	neptunium 93 **Np** [237]	plutonium 94 **Pu** [244]	americium 95 **Am** [243]	curium 96 **Cm** [247]	berkelium 97 **Bk** [247]	californium 98 **Cf** [251]	einsteinium 99 **Es** [252]	fermium 100 **Fm** [257]	mendelevium 101 **Md** [258]	nobelium 102 **No** [259]