H133: 1094 Session 6 KEY

Write your name and answers on this sheet and hand it in at the end.
After the indicated time, move on to the next activity, even if you are not finished!

1. Group Warm-Up Problems [10 minutes]

a. Do Q12T.7 and Q13T.1. [Give brief explanations.]

Q12T.7: Ⓑ $\vec{F} = q\vec{v}\times\vec{B}$ so since $\vec{v}\times\vec{B}$ is to the right, the quanton must have a negative charge, so beta (e^-) particles.

Q13T.1: Ⓓ The process $\nu + n \rightarrow e^- + p^+$ leaves A the same and increases Z by 1. So 17→18, which means $^{37}_{18}Ar$ is the product. Different chemistry since different Z.

b. In your body, are there more neutrons or protons? More protons or electrons? Explain.

many of the most common elements, like oxygen, carbon, and nitrogen have N=Z in their most common isotopes so no winner. There are heavy elements with N>Z but they appear in trace amounts. The tiebreaker is hydrogen, which implies a significant dominance of protons. To a very good approximation, your body has no net charge, so protons ≐ electrons.

c. Do Q13T.5 and Q13T.6. [Give brief explanations.]

Q13T.5: Ⓒ Higher Z, same A. Less binding, so from electrostatic energy.

Q13T.6: Ⓒ Higher A, same Z. Less binding, so from asymmetry term.

2. Q14.5: Decay Rates [10 minutes]

a. Consider problem Q14T.7. First, what is the "half-life" (see page 256) in this case? What is the answer to the problem? [BONUS: Using (Q14.31) and (Q14.29), how many undecayed nuclei are there at t = 30 minutes?] Half-life is 1h. So after additional hours:

t	#
0	6.4
1	3.2
2	1.6
3	0.8
4	0.4

$\times 10^{20} \Rightarrow 4\times10^{19}$ Ⓒ

From (Q14.31), $\lambda = \frac{\ln 2}{t_{1/2}}$ and from Q14.29

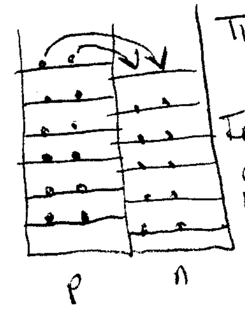
$$N(t=\tfrac{1}{2}h) = 6.4\times10^{20} \times e^{-\frac{\ln 2}{1\,h}\frac{1}{2}h} = \boxed{4.5\times10^{20} \text{ nuclei}}$$

b. Do problem Q14T.9. (Hint: After how much time would you expect the relative abundance to be one-half of that in living tissue?)

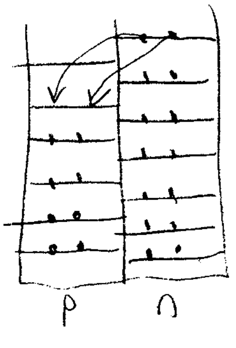
$t_{1/2} \doteq 6000$ y. So two times this leaves the ratio 1/4 to that of living tissue. ⇒ Ⓒ.

3. Beta Decay Physics [15 minutes]

a. Both ^{22}Mg and ^{22}O are unstable. Predict how they will decay until they reach a stable nucleus (using the "box" model of the nucleus). Note what particles (e.g., electron) are emitted.



Two electron capture decays, $p^+ + e^- \Rightarrow n + \nu$ keeps A at 22 and so $^{22}_{12}Mg \rightarrow {}^{22}_{11}Na \rightarrow {}^{22}_{10}Ne$ as in the diagram.
In principle could have proton β^+ decay from ^{22}Mg, but not enough energy available.
Neutron β^- decays $n \rightarrow p^+ + e^- + \bar{\nu}$ take $^{22}_{8}O \rightarrow {}^{22}_{9}F \rightarrow {}^{22}_{10}Ne$.
Both require $m_i > m_f$.



b. Check your predictions: go to http://www.physics.ohio-state.edu/~ntg/H133/h133_applets.php and follow the "Beta Decay" link. Try to account for incorrect predictions.

It works!

c. Do problem Q13S.5. Use $e_b(A,Z) = a_I - a_S A^{-1/3} - a_C Z^2 A^{-4/3} - a_A (A-2Z)^2/A^2$.

Increasing Z and not N changes both Z and A.
Z ↑ means more Coulomb repulsion so $e_b \downarrow$.
If Z=N initially, Z ↑ means greater asymmetry so $e_b \downarrow$
A ↑ means fewer (relatively) nucleons at surface, so $e_b \uparrow$.

d. A radioactive nucleus can emit a position, e^+. This corresponds to a proton in the nucleus being converted to a neutron. The mass of a neutron, however, is greater than that of a proton. How then can positron emission occur?

If the change in nuclear masses is enough to make up the difference, this process can occur.

e. Z changes in beta decay processes but A is constant. Explain how to find, for a given A, an expression for the most stable Z. (Note: How do you account for the neutron weighing more than the proton?) As explained in section Q14.1, use the binding energy formula to find the minimum value of the nucleus's atomic rest energy. Equation (Q14.9) is the result.

4. Rutherford Scattering [10 minutes]

Start up the PhET applet "Rutherford Scattering". The simulation is of the famous experiment of Geiger and Marsden, in which they scattered alpha particles from nuclei. At the time, physicists didn't know for sure where the protons in the atom were located (neutrons weren't discovered until 1932). Two models were the "Rutherford Atom" and the "Plum Pudding Atom". In the latter, protons were spread evenly through the volume of the atom, rather than being concentrated in a small volume (the nucleus).

a. What is the force that deflects the alpha particles?

Coulomb repulsion between protons in alpha particle and nucleus.

b. Look at both the Plum Pudding and Rutherford atoms models. *Select "show traces" for each.* What should observers in the laboratory measure to distinguish the models? (Remember that they don't see into the atoms!)

Measure the distribution in angle of scattered particles. Only the Rutherford atom model predicts large-angle deflections.

c. Why are there no large deflections in the plum pudding model (the simulation won't show *any* deflections)?

With the charge spread out, there are not large enough electromagnetic forces to deflect the alphas (net force is small).

d. List two adjustments you can make in the simulation to make the alphas in the Rutherford Atom approach closer to the nucleus. [BONUS (do this if you have time at the end): Determine quantitatively the maximum energy for the alpha particle in the simulation.]

Change the alpha energy or decrease the number of protons in the target.