PHYS-309(2) (Kaldon-21722) **Name** ____
WMU - Winter 2000
Final Exam - 2×000,000 points **Check-Out:** ☐ **Q** ☐ **X3** ☐ **X2r** ☐ **CA-1** ☐ **CA-2** ☐ **CA-3**

6/22/1999•Rev.2-4/2000

State Any Assumptions You Need To Make – Show All Work – Circle Any Final Answers
Use Your Time Wisely – Work on What You Can – Be Sure to Write Down Equations
Feel Free to Ask Any Questions

For all problems, use $c = 2.998 \times 10^{8}$ *m/s;* $h = 6.626 \times 10^{-34}$ *J·s;* $\hbar = 1.055 \times 10^{-34}$ *J·s.*

Dit-dit-dit-DIT-DIT-dit-dit! News Flash! Hot Off the Press! (50,000 points)

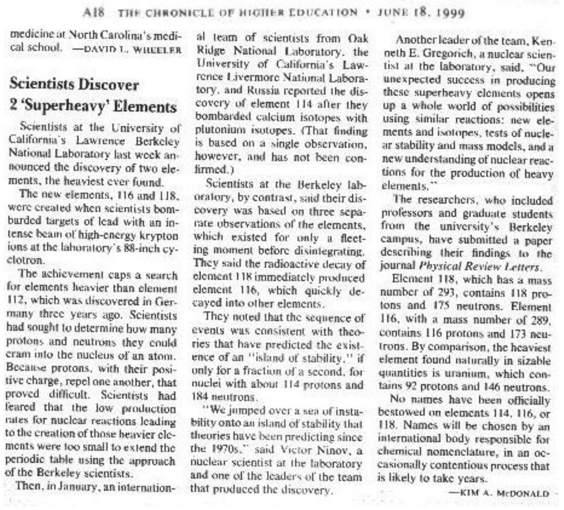
1.) According to *The Chronicle of Higher Education* (June 18, 1999, p. A18), "Scientists at (Berkeley) last week announced the discovery of two elements, the heaviest ever found. The new elements, 116 and 118, were created when scientists bombarded targets of lead with an intense beam of high-energy krypton ions at the laboratory's 88-inch cyclotron. The achievement caps a search for elements heavier than element 112, which was discovered in Germany three years ago. Scientists have sought to determine how many protons and neutrons they could cram into the nucleus of an atom." The IUPAC names should be Ununhexium (Uuh) for 116 and Ununoctium (Uuo) for 118. (a) If *Uuo* didn't immediately decay into *Uuh*, but lasted long enough to form an atom, write down the *complete* electronic configuration ($1s^2$…) for the ground state of *Uuo*.

(b) Element 118 has 175 neutrons and element 116 has 173. Write down the correct symbol for these two elements, as in ${}^{40}_{20}Ca$ for Calcium-40.

(c) When the Berkeley scientists made their atoms of *Uuo*, they (the atoms, not the scientists) immediately decayed into element *Uuh*. Write down the nuclear equation, using all the appropriate symbols and using the correct decay mode(s). My guess is that the *Uuh* formed would be in a nuclear excited state (Uuh^*), so "for full marks", as the British would say, you should take this fact into consideration in some manner.

(d) That one Element 114 event we've seen before was made by bombarding Ca isotopes with Pu isotopes. Identify the isotope of Element 114 (*Uuq, Ununquadium*) that would be created by using the most common isotopes of calcium and plutonium.

(e) Element 118 was made by bombarding lead nuclei with krypton ions. Show that the nuclear reaction isn't from the most common isotopes, as taken from the Periodic Table: ${}^{207}_{82}Pb + {}^{84}_{36}Kr$. Then use *Appendix B* to make a good guess as to what the most likely reaction is – assuming that the *Uuo* itself is made directly.



A18 THE CHRONICLE OF HIGHER EDUCATION • JUNE 18, 1999

medicine at North Carolina's medical school. —DAVID L. WHEELER

Scientists Discover 2 'Superheavy' Elements

Scientists at the University of California's Lawrence Berkeley National Laboratory last week announced the discovery of two elements, the heaviest ever found.

The new elements, 116 and 118, were created when scientists bombarded targets of lead with an intense beam of high-energy krypton ions at the laboratory's 88-inch cyclotron.

The achievement caps a search for elements heavier than element 112, which was discovered in Germany three years ago. Scientists had sought to determine how many protons and neutrons they could cram into the nucleus of an atom. Because protons, with their positive charge, repel one another, that proved difficult. Scientists had feared that the low production rates for nuclear reactions leading to the creation of those heavier elements were too small to extend the periodic table using the approach of the Berkeley scientists.

Then, in January, an international team of scientists from Oak Ridge National Laboratory, the University of California's Lawrence Livermore National Laboratory, and Russia reported the discovery of element 114 after they bombarded calcium isotopes with plutonium isotopes. (That finding is based on a single observation, however, and has not been confirmed.)

Scientists at the Berkeley laboratory, by contrast, said their discovery was based on three separate observations of the elements, which existed for only a fleeting moment before disintegrating. They said the radioactive decay of element 118 immediately produced element 116, which quickly decayed into other elements.

They noted that the sequence of events was consistent with theories that have predicted the existence of an "island of stability," if only for a fraction of a second, for nuclei with about 114 protons and 184 neutrons.

"We jumped over a sea of instability onto an island of stability that theories have been predicting since the 1970s," said Victor Ninov, a nuclear scientist at the laboratory and one of the leaders of the team that produced the discovery.

Another leader of the team, Kenneth E. Gregorich, a nuclear scientist at the laboratory, said, "Our unexpected success in producing these superheavy elements opens up a whole world of possibilities using similar reactions: new elements and isotopes, tests of nuclear stability and mass models, and a new understanding of nuclear reactions for the production of heavy elements."

The researchers, who included professors and graduate students from the university's Berkeley campus, have submitted a paper describing their findings to the journal *Physical Review Letters*.

Element 118, which has a mass number of 293, contains 118 protons and 175 neutrons. Element 116, with a mass number of 289, contains 116 protons and 173 neutrons. By comparison, the heaviest element found naturally in sizable quantities is uranium, which contains 92 protons and 146 neutrons.

No names have been officially bestowed on elements 114, 116, or 118. Names will be chosen by an international body responsible for chemical nomenclature, in an occasionally contentious process that is likely to take years.

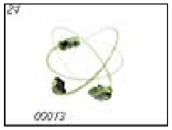
—KIM A. McDONALD

"Scientists Discover a New Element: Turbonium" – VW ADVERTISEMENT (50,000 points)

2.) A new set of VW commercials for the Turbo New Beetle claims that there is a new element called *Turbonium*. The 2833.00 in the Periodic Table entry for *Trb* refers to the 2833.00 lb. weight of the car – mass of 1287.73 kg. The Turbo New Beetles in the commercial are orbiting about some sort of nucleus with a radius of 10.00 Å.[1] (a) Assuming that Turbonium follows as much of the Laws of Physics as a silly television commercial possibly can, use the equation for the radius r_n that we developed for the Bohr hydrogen atom. Replace Ze^2 with $q_{VW}{}^2$, and find the identical charge q_{VW} of the Turbo New Beetle and whatever the nucleus of this "atom" is. Assume that the radius 10.00 Å is the ground state radius, r_1.

(b) Find the Energy, E_1, of the ground state of Turbonium, using your new values for the charge.

(c) Following the lead of our Bohr atom, the kinetic energy of the Turbo New Beetles in the ground state of Turbonium should be K = - E_1. What is the speed, v, of the Turbo New Beetle?



(d) Find the deBroglie wavelength of a Turbo New Beetle in the ground state of Turbonium.

(e) Use the Heisenberg Uncertainty Principle to find Δx, using the momentum of the Turbo New Beetle as Δp, and find Δt, using the kinetic energy as ΔE.

Drivers wanted.

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[1] As originally written, we tried r = 10.00 m and that doesn't work on most calculators.

Relatives: In-Laws At The Speed of Light (50,000 points)

3.) Theodore Benson's Rules of Relativistic Engagement for Interstellar Warfare, © 2287 A.D. discusses the difficulties of dealing with starships traveling near the speed of light. Imagine you are on an outpost effectively at rest on the surface of a planet. A starship (mass = 25,000,000 kg) full of Really Bad Nasty Aliens (RBNA's) is detected approaching your outpost at 90% the speed of light, at a distance of one million miles (1.60×10^6 km = 1.60×10^9 m). (a) How much time will it take for the RBNA's to travel that distance and get to you from *your* point of view and from the *alien's* point of view?

(b) You fire your self-defense lasers the moment you first see the aliens. Of course, what you *saw* was the light from when the RBNA's were a million miles away. While the photons of light traveled that distance to get to your eyes, the RBNA's were still moving at 90% the speed of light. So how far away were the RBNA's actually, at the moment you detected the light from a million miles away?

(c) Unfortunately, even if you hit the starship, the wreck still has its kinetic energy. Find the relativistic K.E. of the RBNA ship. Compare this energy to the energy released in a nuclear bomb: 1 ton TNT = 4.5×10^9 J ; the *Hiroshima* ^{235}U bomb ≈ 13 kilotons TNT = 5.85×10^{13} J. *You don't want to be underneath when it hits!*

(d) For the RBNA's to get their starship up to 90% the speed of light, it is necessary to do work equal to the final K.E. If this ship is powered by D-T fusion (deuterium-tritium fusion: ${}^2_1H + {}^3_1H \rightarrow {}^4_2He + {}^1_0n + 17.59\,MeV$), how many of these 17.59 MeV fusions does it take to create this energy?[2] (e) Each mole of these fusions (N_A = 6.02×10^{23}) uses up 5 grams of D-T (0.00503 kg). What is the mass of the *fuel*? How does it compare to the mass of the ship?

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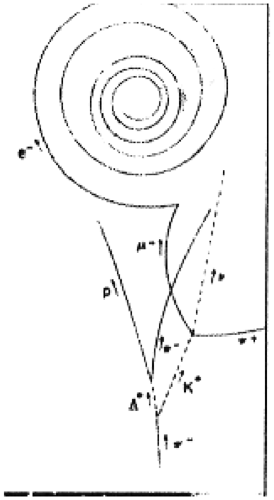
[2] If you can't find the answer to (c), calculate the classical K.E. = ½mv².

Barnum & Bailey's Circus and Particle Zoo (50,000 points)

4.) The bubble-chamber event shown in Serway M&M Figure 15.4 breaks down to the following chain of reactions:

$$p+\pi^- \rightarrow \Lambda^0 + \mathrm{K}^0 \rightarrow \left(p+\pi^-\right)+\left(\mu^-+\pi^++\overline{\nu}_\mu\right)\rightarrow\left(p+\pi^-\right)+\left(e^-+\overline{\nu}_e+\nu_\mu\right)+\left(\pi^++\overline{\nu}_\mu\right)$$

Using the information in Serway M&M Table 15.2, which is reproduced on the next page… (a) Verify that all Baryon, Lepton and Strangeness numbers, as well as charge, are conserved.

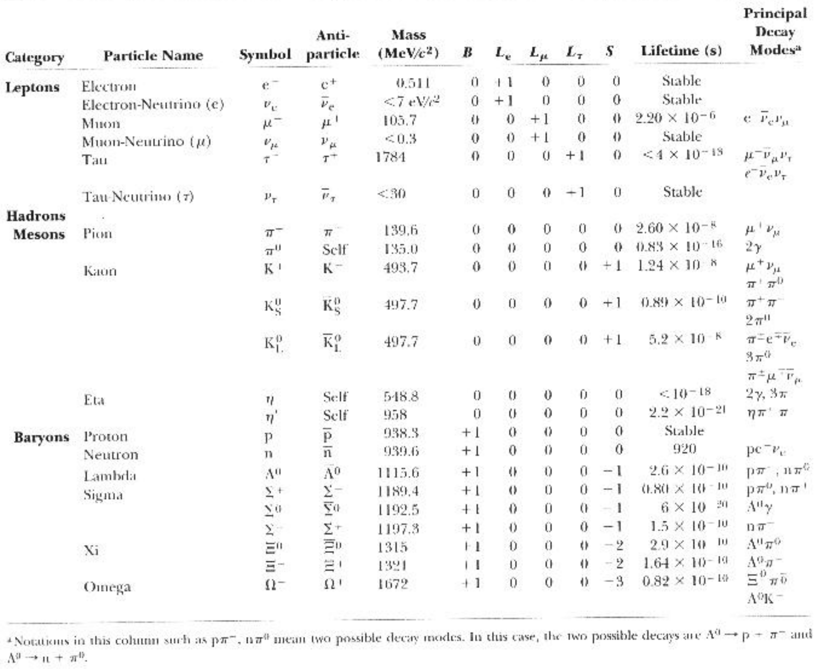


(b) Add up the masses (MeV/c²) for each grouping. Estimate how much kinetic energy (MeV) that the proton + pion-minus must have, ignoring any kinetic energy that the particles at the end might have.

(c) Make a rough estimate of the *time* it takes for all this to happen.

(d) If the incoming proton were to have a kinetic energy of 500. MeV, is this proton relativistic? *It shouldn't matter whether you do the calculation using SI units or MeV, c, and MeV/c² for energy, speed of light, mass. In SI units, 1 MeV = 1.602×10^{-13} J and m$_p$ = 1.673 × 10^{-27} kg.*

Table 15.2 Some Particles and Their Properties



Category	Particle Name	Symbol	Anti-particle	Mass (MeV/c²)	B	L_e	L_μ	L_τ	S	Lifetime (s)	Principal Decay Modes[a]
Leptons	Electron	e^-	e^+	0.511	0	+1	0	0	0	Stable	
	Electron-Neutrino (e)	ν_e	$\overline{\nu}_e$	<7 eV/c²	0	+1	0	0	0	Stable	
	Muon	μ^-	μ^+	105.7	0	0	+1	0	0	2.20×10^{-6}	$e^-\overline{\nu}_e\nu_\mu$
	Muon-Neutrino (μ)	ν_μ	ν_μ	<0.3	0	0	+1	0	0	Stable	
	Tau	τ^-	τ^+	1784	0	0	0	+1	0	$<4 \times 10^{-13}$	$\mu^-\overline{\nu}_\mu\nu_\tau$ $e^-\overline{\nu}_e\nu_\tau$
	Tau-Neutrino (τ)	ν_τ	$\overline{\nu}_\tau$	<30	0	0	0	+1	0	Stable	
Hadrons											
Mesons	Pion	π^-	π^-	139.6	0	0	0	0	0	2.60×10^{-8}	$\mu^+\nu_\mu$
		π^0	Self	135.0	0	0	0	0	0	0.83×10^{-16}	2γ
	Kaon	K^+	K^-	493.7	0	0	0	0	+1	1.24×10^{-8}	$\mu^+\nu_\mu$ $\pi^+\pi^0$
		K^0_S	$\overline{K}^0_S$	497.7	0	0	0	0	+1	0.89×10^{-10}	$\pi^+\pi^-$ $2\pi^0$
		K^0_L	$\overline{K}^0_L$	497.7	0	0	0	0	+1	5.2×10^{-8}	$\pi^\pm e^\mp\overline{\nu}_e$ $3\pi^0$ $\pi^\pm\mu^\mp\overline{\nu}_\mu$
	Eta	η	Self	548.8	0	0	0	0	0	$<10^{-18}$	2γ, 3π
		η'	Self	958	0	0	0	0	0	2.2×10^{-21}	$\eta\pi^+\pi^-$
Baryons	Proton	p	$\overline{p}$	938.3	+1	0	0	0	0	Stable	
	Neutron	n	$\overline{n}$	939.6	+1	0	0	0	0	920	$pe^-\overline{\nu}_e$
	Lambda	Λ^0	$\overline{\Lambda}^0$	1115.6	+1	0	0	0	−1	2.6×10^{-10}	$p\pi^-$; $n\pi^0$
	Sigma	Σ^+	Σ^-	1189.4	+1	0	0	0	−1	0.80×10^{-10}	$p\pi^0$, $n\pi^+$
		Σ^0	$\overline{\Sigma}^0$	1192.5	+1	0	0	0	−1	6×10^{-20}	$\Lambda^0\gamma$
		Σ^-	Σ^+	1197.3	+1	0	0	0	−1	1.5×10^{-10}	$n\pi^-$
	Xi	Ξ^0	$\overline{\Xi}^0$	1315	+1	0	0	0	−2	2.9×10^{-10}	$\Lambda^0\pi^0$
		Ξ^-	Ξ^+	1321	+1	0	0	0	−2	1.64×10^{-10}	$\Lambda^0\pi^-$
	Omega	Ω^-	Ω^+	1672	+1	0	0	0	−3	0.82×10^{-10}	$\Xi^0\pi^-$ Λ^0K^-

[a] Notations in this column such as $p\pi^-$, $n\pi^0$ mean two possible decay modes. In this case, the two possible decays are $\Lambda^0 \rightarrow p + \pi^-$ and $\Lambda^0 \rightarrow n + \pi^0$.