

PHYS-5380

Homework #1 due Wednesday, September 20

e – electron, μ - muon, γ – photon, ν – neutrino, p – proton, τ – tau lepton,

Λ – lambda baryon, π - pion (pi meson), n - neutron

Invariant mass values

$$m(e) = 0.511 \text{ MeV}/c^2, \quad m(\mu) = 105.6 \text{ MeV}/c^2, \quad m(\gamma) = 0, \quad m(\nu) < 10^{-3} \text{ eV},$$

$$m(p) = 938.3 \text{ MeV}/c^2, \quad m(n) = 939.6 \text{ MeV}/c^2$$

$$m(\Lambda) = 1232 \text{ MeV}/c^2, \quad m(\pi^\pm) = 134 \text{ MeV}/c^2, \quad m(\pi^0) = 140 \text{ MeV}/c^2$$

1. a) How many protons are in one kg of lead?
b) How many electrons are in one kg of lead?
c) What is the total negative charge of these electrons in Coulombs?
2. What is the minimum center of mass energy of the proton - proton collision that can result in the following process?

$$p + p \rightarrow p + p + \pi^- + \pi^+ + \pi^- + \pi^+ + \pi^+ + \pi^-$$

3. Which of the following reactions are forbidden by the conservation laws? Explain why. For allowed processes describe the type of interactions responsible. You can use textbooks, slides of past lectures at <http://www.physics.smu.edu/ryszard/5380fa17/> or particle properties listing in Particle Data Tables on the web at <http://pdg.lbl.gov/>

a) $p + p \rightarrow p + p + p + n + \pi^- + \pi^+ + \pi^-$

b) $p \rightarrow e^+ + \gamma$

c) $p + p \rightarrow n + p + K^+ + K^+ + \pi^- + \pi^+ + \pi^-$

- d) cosmic ray proton travelling with energy of 10000 MeV decay in flight

$$p \rightarrow n + e^+ + \nu_e$$

e) $\Lambda^0 \rightarrow p + \pi^0$

f) $e^+ + e^- \rightarrow \mu^+ + \mu^-$

Answers:

If you use atomic mass unit you need to translate them to kg

1. Mass of a lead atom is 3.44×10^{-25} kg

-> number of atoms in 1 kg of lead is $N = 2.907 \times 10^{24}$

Atomic number of lead is 82 – that is the number of protons in a single atom

-> total number of protons is $N \times 82 = 2.3837 \times 10^{26}$

Number of electrons = number of protons

Total electric charge of electrons is

$N \times \text{charge of electron} = N \times 1.6 \times 10^{-19} \text{ C} = 38.1 \times 10^5 \text{ C}$

2. $E_{\text{min}} = 2 m(p) + 6 m(\pi) = 2.681 \text{ GeV}$

3. a) forbidden by baryon number conservation

b) forbidden by baryon number conservation

c) forbidden by strangeness conservation

d) forbidden by energy conservation (consider the rest frame of the proton)

e) forbidden by charge conservation

f) allowed