NPA Homework solutions 1

08/10/10

1) The neon isotope Ne_{11} has Z=10, N=11 and therefore A=21 [2]

2) From the lecture notes and the result of the Hofstadter experiment the nuclear mass density is measured to be ~2 x 10^{17} Kg m^{-3}. Assuming the neutron star is a giant nucleus, i.e. has the same density, then the mass of
$1cm^3 = 0.01^3\ m^3 = 10^{-6}\ m^3$ is simply 2 x 10^{17} x 10^{-6} = 2 x 10^{11} Kg (!) [2]

No marks awarded if you needed to look up the mass/size of a neutron star since you didn't read the question properly. Answers within a factor of ~4 are acceptable.

3) 17.999160 u = 17.999160 x 931.502 MeV/c^2
= 16766.25 MeV/c^2 [2]

The sum of nucleon masses = 8 x 938.280 + 10 x 939.573 = 16901.97 MeV/c^2
[2]

The difference of 135.72 MeV/c^2 is equivalent to about 15% of a neutron mass, or about 1% of the complete nuclear mass [0]

The mass is converted to binding energy to keep the nucleus together and is manifested in the field that keeps the nucleus bound (i.e. the strong nuclear force). [4]

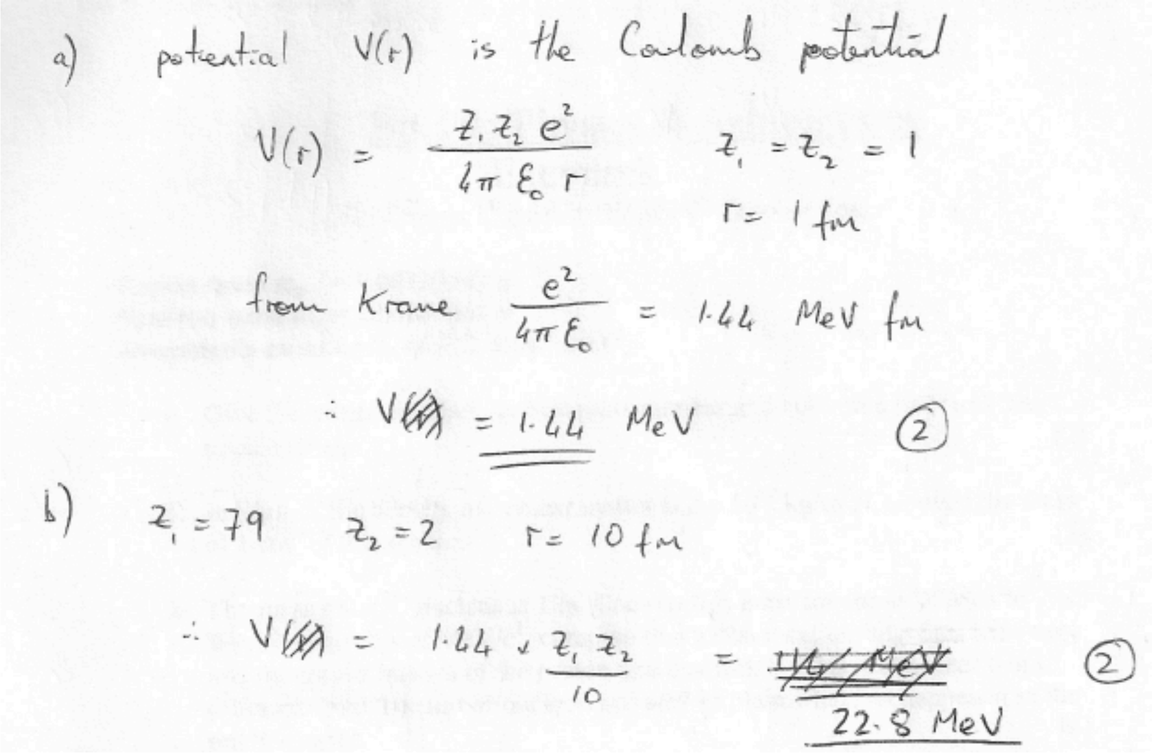
a) Mass difference per nucleon = 135.72 MeV/c^2 / 18 = 7.54 MeV/c^2 [1]
Thus mass difference for ^{235}U is 7.54 x 235 = 1771.9 MeV/c^2 [1]
No marks if units are incorrect!

b) The mass difference can be expressed as an energy by multiplying by c^2
1771.9 MeV/c^2 x c^2 = 1771.9 MeV [2]

c) 10% of this energy is 177.2 MeV
1 mole has Avogadro's number of nuclei, N_A
Total molar energy release = N_A x 177.2 MeV = 1.1 x 10^{26} MeV [4]

d) In Joules: = 1.1 x 10^{26} x 1.6 x 10^{-19} x 10^{-6} J = 1.8 x 10^{13} J/mol [2]
This is compares to 1.3 x 10^{6} J/mol from ethanol, i.e. 10^{7} difference!

4)



a) potential V(r) is the Coulomb potential

$$V(r) = \frac{Z_1 Z_2 e^2}{4\pi \varepsilon_0 r} \qquad Z_1 = Z_2 = 1$$

$$r = 1\ \text{fm}$$

from Krane $\frac{e^2}{4\pi\varepsilon_0} = 1.44\ \text{MeV fm}$

$$\therefore V = \underline{\underline{1.44\ \text{MeV}}} \qquad ②$$

b) $Z_1 = 79 \qquad Z_2 = 2 \qquad r = 10\ \text{fm}$

$$\therefore V = 1.44 \times \frac{Z_1 Z_2}{10} = \underline{22.8\ \text{MeV}} \qquad ②$$

~~[illegible] MeV~~

5) Of course, there is no difference in decay rates, they are all the same! [2]

To convince yourselves you can compare the typical energy of nuclear processes (~ 1-10 MeV) to :

a) the typical thermal kinetic energy of gases at std temp/pressure
b) as above but for, lets say, factor 100 higher pressure
c) as above but for, lets say, factor 100 higher temperature
d) the gravitational potential energy between two nuclei with surfaces touching, or even the gravitational potential between a nucleus at Earth's surface and the Earth itself.

All of these energies are far below the ~ MeV scale. We will see later that nuclear reactions can only occur when sufficient energy is supplied to cause a transition from from nuclear state to another, for example an excitation of a nucleon to a higher energy level (just like for atomic electrons). If insufficient energy is supplied then the transition is less likely to occur.

6) I forgot that the answer is actually given in the lecture notes! In general the time over which a radio-isotope can be used for dating is no more than about 10 half-lives since over this period the number of active nuclei will have reduced to 0.01% $= (½)^{10}$ of their original number making detection difficult unless the sample is very large. Thus the answer is about 50,000 years or any number within ~ factor 2. [2]

^{41}Ar is unsuitable for several reasons:

   a) the half life is far too short! It is around 100 mins only. [2]
   b) Ar is inert (noble gas) and so is not readily taken up by biological organisms. [2]