PARTICLES, STARS AND NUCLEI **PROBLEM SHEET 3**

NUCLEAR MODELS

1. The two light nuclei ${}^{11}_{5}B$ and ${}^{11}_{6}C$ are a pair of *mirror nuclei*: the number of protons in one equals the number of neutrons in the other. The binding energy of the nuclei ${}^{11}_{5}B$ and ${}^{11}_{6}C$ are 76.205 MeV and 73.443 MeV respectively. Assuming that the difference is due entirely to Coulomb effects and that the proton charge is uniformly distributed through a sphere of radius R_c (identical for both nuclei), find R_c. This was an early way of estimating the size of the nucleus.

[3.44 fm]

2. Use the semi-empirical mass formula to predict which of the following nuclei you would expect to be β-stable:

$${}^{183}_{73}Ta \qquad {}^{183}_{74}W$$

given that $(m_n - m_p - m_e)\,c^2 = 0.8$ MeV.

3. Which of the following nuclei would you expect to be β-stable?

$${}^{190}_{78}Pt \qquad {}^{190}_{76}Os \qquad {}^{190}_{74}W.$$

4. Verify that if the most stable isobar has a neutron to proton ratio given by

$$\frac{N}{Z} = 1 + \frac{dA^{2/3}}{2s}$$

then the binding energy per nucleon (neglecting the pairing term) is given by

$$\frac{B}{A} = a - \frac{b}{A^{1/3}} - \frac{sdA^{2/3}}{4s + dA^{2/3}}\ .$$

5. The lowest few energy levels in the shell model are

$$1s_{1/2} \quad 1p_{3/2} \quad 1p_{1/2} \quad 1d_{5/2} \quad 2s_{1/2} \quad 1d_{3/2}\ .$$

How many nucleons can be accommodated in each level? Predict the spins of the following nuclei:

${}^{4}_{2}He$ ${}^{17}_{8}O$ ${}^{35}_{17}Cl$ ${}^{15}_{7}N$ ${}^{11}_{5}B$ and ${}^{11}_{5}B^{*}$(in the first excited state).