Part 1: Calculating mass defect and binding energy

Large quantities of energy are released during chain reactions and fission when nuclei are destabilised and eventually split into smaller fragments. Fusion is another process that takes place at a nuclear level that also produces large amounts of energy. In fact quantities are so large that fusion reactions are yet to be harnessed for commercial energy generation on a large scale.

Fusion involves joining two relatively light nuclei to form a heavier nucleus. The larger binding energy of reaction products compared with reactants results in production of energy. The equation below shows a typical fusion reaction.

$${}^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{1}H + {}^{1}_{0}n$$

Two atoms of hydrogen-2 (deuterium) combine to produce hydrogen-3 (tritium), a neutron and energy.

Extremely high temperatures are necessary for two positively-charged nuclei to overcome the potential barrier caused by the electric force and come close enough to fuse. Such a temperature is found in the Sun, where fusion reactions produce energy that is radiated to Earth.

The quantity of energy produced in a fusion reaction can be calculated in a similar way to that used in fission reactions.

1. Using the equation above for fusion of two atoms of deuterium, calculate mass defect and energy released in MeV. The table below contains masses of atoms and particles involved, expressed in unified mass units (u) where 1 u = 931 MeV.

mass of deuterium	2.014 102 u
mass of tritium	3.016 049 u
mass of a neutron	1.008 665 u
mass of an electron	0.000 549 u

Calculate mass of the reactants (two deuterium atoms):

mass of reactants = ... x 2 = ... u

Calculate mass of products (one tritium atom and one neutron):

mass of products = ...+ ....= .... u

Calculate mass defect (mass of reactants – mass of products):

mass defect = ...- ....= .... u

Now use the conversion factor of 1 u = 931 MeV to convert mass into energy:

energy released in fusion reaction =................................. x 931 = ... MeV

2. The following reaction produces thermal energy in the Sun.

$${}^{3}_{2}\mathrm{He} + {}^{3}_{2}\mathrm{He} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H}$$

Use the following data to calculate energy produced in this reaction (note: electron masses are not included).

mass of a helium-3 nucleus	3.014 933 u
mass of a helium-4 nucleus	4.001 504 u
mass of a hydrogen-1 nucleus (proton)	1.007 276 u

3. Fission of uranium-235 to form Ba-144 and Kr-90 releases about 200 MeV per atom. How does this compare with energy produced by fusion of two atoms of deuterium (see question 1)? Which do you consider to be the most efficient energy producer? Explain your answer.

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Part 2: Nuclear fusion

The fact sheet, *The ITER project*, outlines a major international research program to develop technologies for generation of power using fusion reactions.

4. Using the fact sheet, books and other sources of information, complete the table below to compare energy production in the Sun and an ITER-like fusion reactor.

	THE SUN	ITER REACTOR
FUEL		
TEMPERATURE		
CONFINEMENT MECHANISM		
REACTION EQUATIONS		

5. What are some potential advantages and disadvantages of fusion power compared with fission?

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6. The Wikipedia article, ITER (http://en.wikipedia.org/wiki/ITER), contains arguments for and against the ITER project. Summarise and comment on these arguments. The ITER project web site (http://www.iter.org) contains additional information you may need.

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