(2) The carbon conundrum. (4)

A) i: Carbon 12 (6 protons, 6 neutrons)

$\Delta m = (6 \times 1.67262 \times 10^{-27} + 6 \times 1.67493 \times 10^{-27}) - 19.9200 \times 10^{-27}$

$= 1.653 \times 10^{-28}$ kg

Total BE $= \Delta m c^2 = 1.653 \times 10^{-28} \times (3.00 \times 10^{8})^2$

$= 1.48776 \times 10^{-11}$

BE/n in eV $= \dfrac{1.4877 \times 10^{-11}}{12 \times 1.6 \times 10^{-19}}$

$= \underline{7.748 \text{ MeV}}$ (Carbon 12)

ii: Carbon 14: (6 protons, 8 neutrons)

$\Delta m = (6 \times 1.67262 \times 10^{-27} + 8 \times 1.67493 \times 10^{-27}) - 23.2454 \times 10^{-27}$

$= 1.8976 \times 10^{-28}$ kg

Total BE: $E = \Delta m c^2 = 1.8976 \times 10^{-28} \times (3 \times 10^{8})^2$

$= 1.7078 \times 10^{-11}$ J

BE/n $= \dfrac{1.7078 \times 10^{-11}}{14 \times 1.6 \times 10^{-19}} = \underline{7.624 \text{ MeV}}$ (Carbon 14)

Carbon 12 is more stable than Carbon 14.

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(1) a) Nuclear fission

b) ① This reaction releases a significant amount of energy which can be harnessed to generate electricity in a power plant. Alternatively it can be very destructive in nuclear weaponry.

② The reaction releases 3 high speed neutrons which can go on to bombard 3 more U-235 nuclei, each of which will release a further 3 neutrons etc. The effect is a chain reaction which increases rapidly if not controlled.

(2) Both fission and fusion reactions release energy as nucleons in daughter nuclei (products) are in a lower energy state than in parent nuclei (reactants)

Fission is when large nuclei decay to form smaller nuclei. This occurs because large nuclei are often unstable and will decay naturally under normal conditions.

Fusion reactions are when small nuclei fuse to form larger nuclei. This will only occur under high pressure and/or temperature (eg in stars) where the nuclei collide with sufficient kinetic energy to overcome the electric force and get sufficiently close for the nuclear force to act between the nucleons.

There is a much greater increase in binding energy per nucleon for fusion reactions than for fission reactions which indicates that the energy released by fusion reactions is significantly greater than for fission reactions given the same mass of parent nuclides.

(3) $^{2}_{1}H + ^{2}_{1}H \longrightarrow ^{4}_{2}He$

a) $\Delta m = 2 \times 3.3433 \times 10^{-27} - 6.64466 \times 10^{-27}$

$= \underline{4.194 \times 10^{-29} \text{ kg}}$

b) $E = \Delta m c^2 = 4.194 \times 10^{-29} \times (3 \times 10^8)^2$

$= 3.7746 \times 10^{-12}$ J

$(= 23.6 \text{ MeV})$

(4) Lithium-6 (3 protons, 3 neutrons)

a) $\Delta m = (3 \times 1.67262 \times 10^{-27} + 3 \times 1.67493 \times 10^{-27})$

$- 9.98835 \times 10^{-27}$

$= 5.43 \times 10^{-29}$ kg

Total Binding Energy $= \Delta m c^2 = 5.43 \times 10^{-29} \times (3 \times 10^8)^2 = 4.887 \times 10^{-12}$ J

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B) Binding energy per nucleon (in eV) $= \dfrac{4.887 \times 10^{-12}}{6 \times 1.6 \times 10^{-19}}$

$= 5.090625$ MeV.

c) Binding energy per nucleon is the amount of energy required to remove a nucleon from the nucleus. The higher the binding energy per nucleon, the more stable a nucleus is because each nucleon is in a lower energy state. ie more energy would be required to free a nucleon from the nucleus.

D). $E = \Delta m c^2$ Δm = mass parent nuclei − mass daughter nuclei.

$= 3.3433 \times 10^{-27} + 5.00784 \times 10^{-27} - 6.64466 \times 10^{-27} - 1.67493 \times 10^{-27}$

$= 3.155 \times 10^{-29}$ kg.

$E = 3.155 \times 10^{-29} \times (3 \times 10^8)^2$

$= \underline{2.8395 \times 10^{-12} \text{ J}}$ $(= 17.7 \text{ MeV})$

E) Fusion reactions involve fusing two small nuclei to form a larger nuclei. Since nuclei contain protons and are positively charged, they naturally repel each other due to the electric force which acts over relatively large distances. In order to fuse, the nuclei must get sufficiently close for the nuclear force to act. The nuclear force only acts over very short distances but is much stronger than the electric force. In order for the nuclei to get close enough, the must have sufficient kinetic energy (and therefore momentum) to overcome the electric force. Nuclei can only have this much kinetic energy at very high temperatures, hence cold fusion is not possible.