Solutions

Original-task marking: M1 method, A1 accuracy, B1 reasoning.

2.1 Spontaneous: the nucleus splits by itself, no incoming particle; induced: an absorbed neutron triggers the split.

2.2 To slow fast neutrons to thermal speeds by collisions; slow neutrons are far more likely to cause further U-235 fissions.

2.3 Any two: they are radioactive; neutron-rich, undergoing further beta decay; intensely ionizing with long half-lives; generate decay heat.

2.4 Absorb neutrons to control – hold or damp – the reaction rate.

3.1 Three neutrons: $+\,3\,{}^{1}_{0}n$; A: $236 = 141 + 92 + 3$ and Z: $92 = 56 + 36$ balance; at least one of the three can trigger the next fission, so the reaction can sustain – and if more than one does, grow.

3.2 $E = 0.21 \times 931.5 = 196$ MeV ≈ 200 MeV; in joules: $196 \times 1.6 \times 10^{-13} = 3.1 \times 10^{-11}$ J.

3.3 The fragments inherit uranium's neutron-to-proton ratio while sitting at medium mass numbers, where stability demands fewer neutrons – they are neutron-rich and beta-decay repeatedly; long-term option: after years of cooled pool storage, seal the waste in corrosion-resistant containers inside deep geological repositories, stable for the tens of thousands of years the longest half-lives demand.

3.4 Fissions per second $= P/E = (2.0 \times 10^{9})/(2.8 \times 10^{-11}) = 7.1 \times 10^{19}$ s^{-1}; per day: $\times 86400 = 6.2 \times 10^{24}$ fissions; mass $= 6.2 \times 10^{24} \times 3.9 \times 10^{-25} = 2.4$ kg.