Fission

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Course	HL IB Physics
Section	Nuclear & Quantum Physics
Topic	Fission
Difficulty	Medium

To be used by all students preparing for HL IB Physics
Students of other boards may also find this useful

1

The correct answer is **D** because:

- Osmium-190 is the lightest and most stable of these isotopes, all of which are beyond the peak of stability on the binding energy per nucleon curve which occurs around Iron-56 approximately;
  - Therefore, since it is the most stable, it has the least potential to be broken into smaller, more stable components by fission and release greater amounts of energy
  - Generally the more massive the isotope, the more energy it has to release in fission reactions

A is incorrect as Uranium-235 is a large and highly fissionable isotope that is used in many nuclear reactors as fuel for their fission reactions. Since it is larger and less stable than Osmium-190, it is more readily able to release energy via fission reactions.

B is incorrect asThorium-231 is fissionable isotope that is used in less commonly in nuclear reactors as fuel for their fission reactions. As is the case with Uranium-235, Thorium-231 is more mass and less stable than Osmium-190, it is more readily able to release energy via fission reactions.

C is incorrect as Radon-222 is fissionable isotope that occurs as a tasteless, odourless gas that contributes strongly to background radiation. While not used in nuclear reactors, it is larger and less stable than Osmium-190, it is likely to be more readily able to release energy via fission reactions.

2

The correct answer is **C** because:

- When a large nucleus undergoes fission it breaks into two (or more) smaller nuclei and releases energy
- This energy comes from some of the mass of the original nucleus
- Therefore, the combined mass of the daughter nuclei is less than the mass of the original nucleus
  - Hence, option **C** is the only correct statement

A is incorrect as the daughter nucleus/nuclei will have a **smaller** nucleon number than the original nucleus as it has split.

B is incorrect as energy is **released** during nuclear fission, not absorbed.

D is incorrect as the **joining** together of two nuclei to form a larger nucleus is nuclear **fusion**, not nuclear fission.

3

The correct answer is **A** because:

- The purpose of a control rod is to absorb neutrons
  - Ideal control atoms can absorb excess neutrons, slowing down the rate of nuclear reactions, without undergoing fission themselves
- Therefore, boron and cadmium are ideal substances for controlling as they are good absorbers of neutrons
  - This eliminates options **C** & **D**
- The purpose of a moderator is to slow down neutrons
  - Ideal moderator atoms do not absorb neutrons themselves but are able to absorb large amounts of energy from them
  - This is useful because the neutrons can be slowed down sufficiently to encourage fission to take place
- Therefore, water and graphite (carbon) are ideal substances for moderating as they are poor absorbers of neutrons
  - Hence, option **A** is correct

B & **C** are incorrect as cadmium, like boron, is non-fissionable so it is suitable for use as a control rod, but not suitable for moderating as it would absorb neutrons instead of absorbing the energy from them

C & **D** are incorrect as graphite is a form of carbon and is commonly used in moderating, not controlling. Control rods need to be able to absorb excess neutrons, whereas graphite is able to absorb the energy from neutrons but not the neutrons themselves

4

The correct answer is **C** because:

- The decay constant λ is related to the half-life τ of radioactive isotopes by the equation $\lambda = \frac{\ln 2}{\tau}$
- High-level radioactive waste is extremely dangerous because it stays radioactive for thousands of years
  - In other words, the half-life of high-level waste is very long
  - Therefore, since $\lambda \propto \frac{1}{\tau}$, the decay constant is very small
- Therefore, **C** is the incorrect statement

A is correct as thick concrete is able to absorb radiation emitted from radioactive isotopes, so is useful for shielding from harmful effects

B is correct as nuclear power produces no polluting gases. It does, however, produce radioactive waste, which is a challenge to dispose of and store safely

D is correct as nuclear power requires far less fuel, because uranium provides much more energy per kg than fossil fuels like coal

5

The correct answer is **B** because:

- Chain reactions can be started when neutrons from fission reactions go on to initiate further fission reactions
- We know that more neutrons are released in each of the fission reactions
    - So, statement I is **correct**

- To sustain a chain reaction, each fission reaction must go on to cause **at least** one more fission reaction
- Since 2 or 3 neutrons may be released per fission reaction, it is not required that every neutron goes on to initiate another reaction
- As long as the rate of neutron loss = the rate of neutron creation, a chain reaction may be sustained
    - Therefore, statement II is **not** correct

- The neutrons released during fission will have very high speeds and energies
- These neutrons must be slowed to become thermal neutrons - this is the role of the moderator
    - Therefore, statement III is **correct**