Chapter 4 **Fission and fusion**

Module 4.2 **Chain reactions and nuclear reactors**

Evaluation and Analysis 4.2.1 **Data analysis:** Critical mass **Total marks 20**

Imagine that a particular sample of fissile material is manufactured only in 1 cm cubes. Each cubic centimetre of this material generates 6×10^6 neutrons each second; all of which are capable of going on to cause further fission should they meet another fissile atom. It is a property of this material that each square centimetre of surface area allows up to 3×10^6 of these neutrons to exit the cube every second, therefore these neutrons will not cause further fission. Hence, the quantity of material (in cm^3), and the surface area together determine whether a sample of this material is subcritical, critical or supercritical.

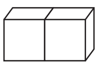
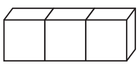
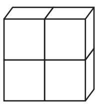
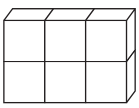
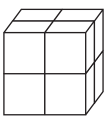
- A critical mass is defined as one in which a chain reaction can be sustained.
- A subcritical mass is defined as one in which a chain reaction cannot be sustained.
- A supercritical mass is defined as one in which a chain reaction will increase in rate.

Questions

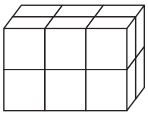
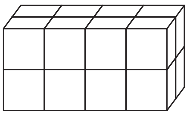
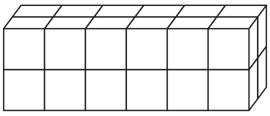
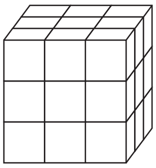
1 What is the net number of neutrons escaping from a single (1 cm^3) cube? (1 mark)

2 A chain reaction is sustained if there are fewer atoms escaping than there are atoms being produced. Is a single cube able to sustain a chain reaction? (2 marks)

3 When two or more cubes are joined together to make a cuboid, the following data were obtained. Complete the following table, using your calculations of surface area and the information given above. (5 marks)

Number of cubes used	**Total volume (cm^3)**	**Total surface area (cm^2)**	**No. of neutrons produced ($\times 10^6$)**	**No. of neutrons escaping ($\times 10^6$)**	**Critical?**
2 	2		12		
3 	3	14			
4 		16		48	
6 	6			66	
8 					

 ISBN 978 1 4860 2222 9

Number of cubes used	Total volume (cm^3)	Total surface area (cm^2)	No. of neutrons produced ($\times 10^6$)	No. of neutrons escaping ($\times 10^6$)	Critical?
12 					
16 					
24 					
27 					
30 (3 × 1 × 10)		86			
36 (3 × 2 × 6)	36	72			

4 Which of the combinations shown in the table would be ‘critical’? (2 marks)

5 Are any of the combinations shown in the table adequate as the final configuration of a nuclear fission bomb? (1 mark)

6 Look just at the arrangements that have a surface area of 4 cm^3 at one end. What difference always occurs between the number of neutrons produced and the number escaping? (1 mark)

7 With the help of calculations, explain why it is impossible for a rectangular prism of cross-sectional area 4 cm^2 and length n cm to sustain a chain reaction? (2 marks)

8 Write a formula for the number of neutrons produced in an n cm × n cm cube every second. (2 marks)

9 Write a formula for the number of neutrons escaping from an n cm × n cm cube every second. (1 mark)

10 Show that the smallest cube that will form a supercritical mass is 3 cm × 3 cm × 3 cm. Use calculations incorporating your answers to questions **8** and **9** to support your answer. (3 marks)