

Question 36**(17 marks)**

A scientist was given the task of investigating the concentration of dissolved heavy metals in abandoned open-cut mines that had filled with water to create small freshwater dams.

Using a map, the scientist identified 180 locations containing abandoned open-cut mines that had become freshwater dams. The scientist decided to randomly select locations to take water samples. The procedure for water sampling at each location was as follows:

1. Take two samples using separate 100.0 mL bottles at a water depth of 0.50 m.
2. Acidify each sample with a few drops of nitric acid solution to minimise heavy metal precipitation.
3. Wait eight hours before measuring heavy metal concentration.
4. Calculate the average concentration of a range of heavy metals, using two samples per location.

- (a) Outline the difference between random and systematic errors. Give an example of each that might be encountered in this investigation. (4 marks)

Water samples were collected from 59 of the 180 possible locations.

- (b) (i) Calculate the sample size as a percentage of the testable locations. (1 mark)

- (ii) Propose **two** reasons why samples were not collected from all locations. (2 marks)

One: _____

Two: _____

- (iii) Predict the effect of using a smaller sample size on the reliability of the overall results. Justify your answer. (2 marks)

Once the samples had been analysed, the scientist found that a particular sampling location had a high concentration of cadmium(II) ions. The dam from which the sample came is now used as a water source for leisure activities and irrigation of surrounding food crops.

Cadmium is known to be harmful to human health. Authorities are concerned that the cadmium could be consumed accidentally by humans at that water source or they could be exposed to cadmium from crops irrigated by the dam.

After further investigation, the scientist determined that the freshwater dam had:

- a volume of 1.123×10^9 L
- an average cadmium(II) ion concentration of 0.5310 mg L^{-1} with an error margin of $\pm 0.09100 \text{ mg L}^{-1}$.

To remove the cadmium(II) ions, phosphate ions can be added to immobilise the cadmium as an insoluble precipitate. The scientist proposes that sodium phosphate, $\text{Na}_3\text{PO}_4(\text{s})$, be used to remove the cadmium(II) ions.

- (c) Calculate the minimum mass of sodium phosphate needed to remove all the cadmium(II) ions from the water. Give your final answer to the appropriate number of significant figures. Assume that there are no species other than cadmium(II) ions present in the dam that will react with the phosphate ions. (8 marks)
