1 Juglone is a chemical produced by plants in the genus *Juglans*, which includes different species of walnut tree.

Fig. 1.1 shows a black walnut tree.

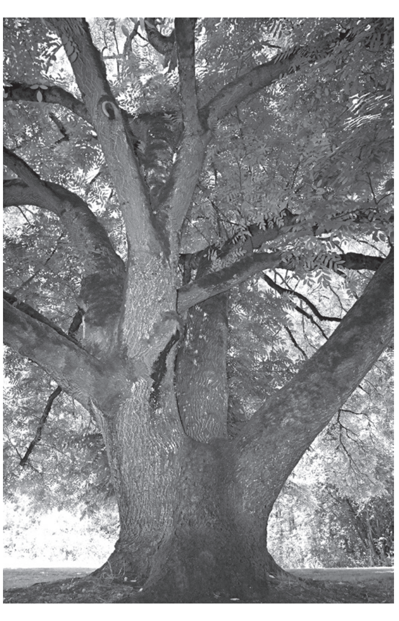

Fig. 1.1

Juglone produced by a black walnut tree can diffuse into the soil surrounding the tree.

Groups of scientists have observed that juglone affects different species of plant growing close to black walnut trees.

Juglone can reduce the percentage of seeds that germinate, delay the start of germination or reduce growth. In some studies, juglone has no effect on germination or growth.

A student planned to investigate the effect of juglone on the cucumber plant, *Cucumis sativus*.

In the investigation, the student:

- placed some damp soil containing juglone in a tray
- added some cucumber seeds to the soil
- placed the container in a suitable environment for germination and growth.

Fig. 1.2 shows cucumber seedlings (young plants) a few days after germination.

Fig. 1.2

The student planned to compare the effect of exposing cucumber seeds to:

- juglone solution with a concentration of 1.0×10^{-3} mol dm^{-3}, which is a concentration that has been measured in soils surrounding black walnut trees
- a control treatment.

The student planned to determine:

- the percentage of cucumber seeds that germinated in soil
- the growth of each cucumber seedling 10 days after the appearance of the seedling above the soil.

(a) Identify the independent variable in this investigation.

.... [1]

(b) Juglone solutions are prepared using a mixture of solvents.

The student was provided with:

- a juglone solution with a concentration of 0.1 mol dm^{-3}
- the mixture of solvents.

Using the solution provided, the student prepared a juglone solution with a volume of 500 cm^3 and a concentration of 1.0×10^{-3} mol dm^{-3}.

The student carried out 1 dilution to prepare the 1.0×10^{-3} mol dm^{-3} solution using measuring cylinders.

(i) State the volumes that the student used to carry out the dilution to produce 500 cm^3 of 1.0×10^{-3} mol dm^{-3} juglone solution.

....

.... [2]

(ii) Outline **one** improvement the student could make to reduce the percentage error while carrying out the dilution.

....

....

.... [1]

(c) **(i)** State a suitable control that the student could use, **and** explain why the student decided to include a control in the investigation.

control ....

....

explanation ....

....

.... [2]

(ii) Describe a method the student could use to investigate the effect of juglone on:

- the percentage of cucumber seeds that germinate
- the growth of each cucumber seedling 10 days after the appearance of the seedling above the soil.

The description of your method should be set out in a logical way and be detailed enough for another person to follow.

....

.... [7]

(d) Another student investigated the effect of juglone on a different species of plant called crimson clover, *Trifolium incarnatum*.

The student recorded the number of days required for germination of:

- 10 seeds treated with a juglone solution with a concentration of 1.0×10^{-3} mol dm^{-3}
- 10 seeds not treated with a juglone solution.

(i) The student used the *t*-test to analyse the results. The *t*-test is appropriate for the number of seeds that were used.

Suggest **two other** reasons why the *t*-test is an appropriate statistical test to use for this investigation.

....

.... [2]

(ii) The null hypothesis for this *t*-test was:

There is no difference between the time taken for seeds to germinate when treated with juglone and the time taken for seeds to germinate when not treated with juglone.

The calculated value of *t* was **2.090**.

The student compared **2.090** to the values in Table 1.1.

Table 1.1

degrees of freedom	probability level (*p*)			
	0.10	**0.05**	**0.01**	**0.001**
17	1.740	2.110	2.898	3.965
18	1.734	2.101	2.878	3.922
19	1.729	2.093	2.861	3.883
20	1.725	2.086	2.845	3.850
21	1.721	2.080	2.831	3.819

Using Table 1.1 and the calculated value of *t* of **2.090**, state **and** explain what the student can conclude about the results.

....

.... [3]

[Total: 18]