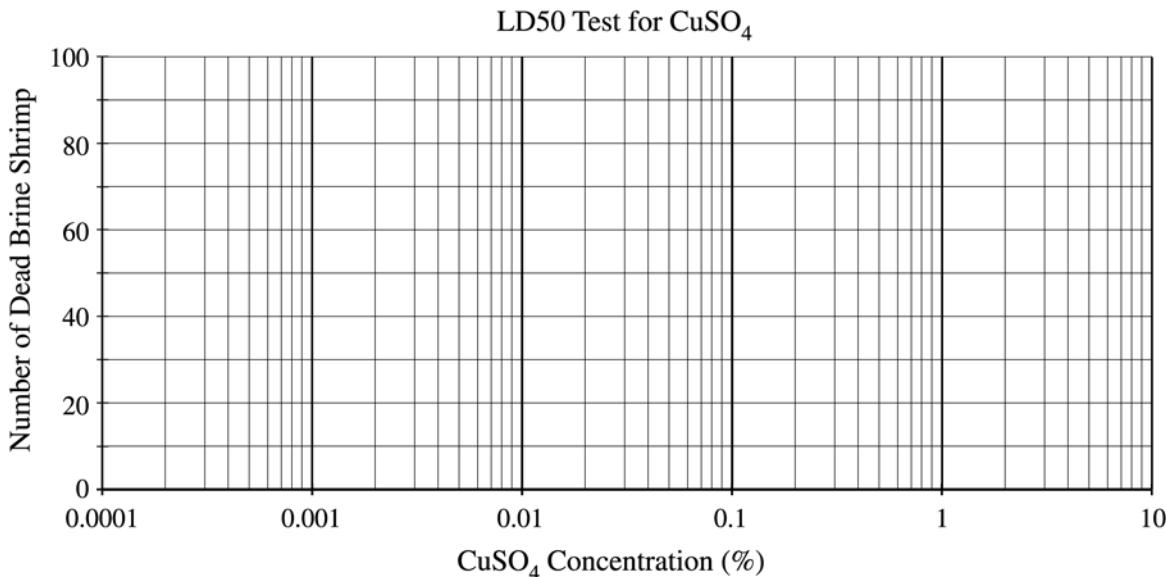


## 2002 AP® ENVIRONMENTAL SCIENCE FREE-RESPONSE QUESTIONS

3. An experiment is performed to test the toxicity of copper sulfate ( $\text{CuSO}_4$ ) using brine shrimp as a test organism. Six different concentrations of  $\text{CuSO}_4$  solution are prepared in separate petri dishes, and 100 brine shrimp are placed in each dish. After 48 hours, the number of brine shrimp that have died is counted and recorded. The results of this experiment are shown in the table below.

| $\text{CuSO}_4$ Concentration (%) | Number of Dead Brine Shrimp |
|-----------------------------------|-----------------------------|
| < 0.0001                          | 10                          |
| 0.001                             | 10                          |
| 0.01                              | 20                          |
| 0.1                               | 55                          |
| 1                                 | 90                          |
| 10                                | 100                         |

- (a) Plot these data on the blank semi-log graph provided below. Draw a smooth curve through the data points to illustrate the overall trend of the data.



- (b) Explain the meaning of the term LD50 (ED50). What is the LD50 concentration of  $\text{CuSO}_4$  for brine shrimp?
- (c) Explain the meaning of the term “threshold level of toxicity”. What is the threshold level of toxicity of  $\text{CuSO}_4$  for brine shrimp? Label this point on the graph.
- (d) Provide one argument for extending these toxicity results to humans and one argument against doing so.

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**Question 3**

**Total Score 10 Points**

- (a) Plot these data on the blank semi-log graph provided below. Draw a smooth curve through the data points to illustrate the overall trend of the data. (*2 points total*)

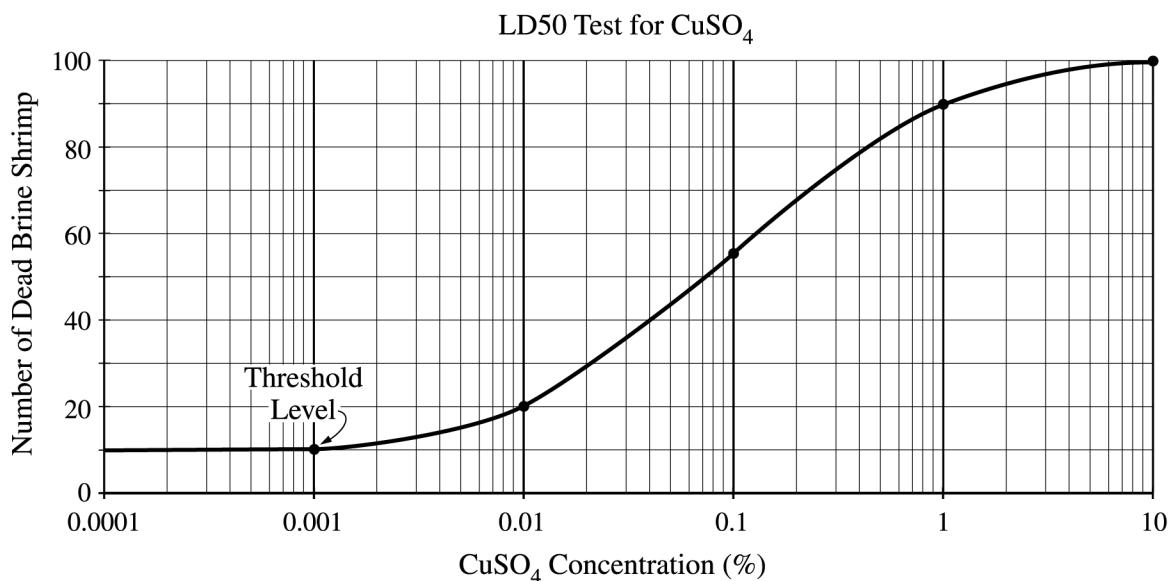
- Plot of data points should be only those points indicated in the data table (see graph below). The only acceptable extra data points must correctly correspond to the student's identification of LD50 and/or threshold level of toxicity. (*1 point*)

**(No data point is included at the beginning of the curve since <0.0001% is technically not a data point though the line of the graph does extend to 0.0001%. However, the students are not penalized for including this as a data point in their graphs.)**

- Student draws a smooth, sigmoid curve (see graph below). (*1 point*)

**No credit is earned:**

- if student draws line of best fit
- if data points are connected with straight segments
- if curved lines dip well below 10 between 0.0001% and 0.001% OR well above 100 between 1% and 10% (not consistent with the data)
- if student draws more than one line
- if the student redraws the graph in the answer section (the directions clearly state that the student is to use "the blank semi-log graph provided below")



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**Question 3 (cont'd.)**

- (b) Explain the meaning of the term LD50 (ED50). What is the LD50 concentration of CuSO<sub>4</sub> for brine shrimp? (2 points)

**Explanation of LD50 (ED50) (1 point)**

LD50 is the amount or dose of a chemical (toxic substance) that kills half the test population (test organisms/specimens).

**OR**

ED50 is the amount or dose of a chemical (toxic substance) that causes an observable or undesirable effect or desired symptom in 50 percent of the test population (test organisms/specimens).

If the word “test” is omitted from the definition, students must clearly indicate that the population has been experimentally exposed to a toxin.

No credit is earned for “kills half the 1) species population, or 2) population of a particular species, or 3) population leading to extinction of the species.”

**Determination of LD50 concentration based on graph (= 0.07 - 0.09%) (1 point)**

Students must read the value from their graph; answer must be consistent with their graph. The answer is given as a range to accommodate the thickness of the student’s pen and the shape of a free-hand smooth curve.

**OR**

If the graph is done incorrectly, the LD50 must be consistent with the graph they have drawn, but not contradictory to the data as presented in the table. This specific value must be >0.01% and <0.1%.

**OR**

If students interpret and indicate the 10 dead brine shrimp as the control (natural mortality), then the test population is 90 brine shrimp; 50 percent of this test population would then be 45 brine shrimp. Therefore, according to the graph, the LD50 concentration is equal to 0.1% (which corresponds to the control (10) plus test (45) = 55 dead brine shrimp).

**No credit is earned:**

- if the value is stated without a plotted graph (no graph plotted, no credit for second part of (b))
- if their answer is not consistent with the line on their graph
- if the student responds “less than 0.1%,” OR “approximately 0.1%,” OR “between 0.01% and 0.1%”

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**Question 3 (cont'd.)**

- (c) Explain the meaning of the term “threshold level of toxicity”. What is the threshold level of toxicity of CuSO<sub>4</sub> for brine shrimp? Label this point on the graph. (*2 points*)

**Explanation of threshold level of toxicity (*1 point*)**

The dose (level) below which no toxic (lethal) effects are observed and/or above which the toxic (lethal) effects are apparent.

**Determination of threshold level of toxicity (*1 point*)**

If students interpret the 10 dead brine shrimp as natural mortality, then 0.001% CuSO<sub>4</sub> is the Threshold Level of Toxicity because there is an observable increase in the death of brine shrimp after that concentration. This point must be correctly located and labeled on their drawn curve or on the horizontal axis.

Since the question is worded in such a way that the students might interpret the directions “Label this point on the graph” as the way to answer this part of the question, the numerical value does not have to be included in the written answer as long as it is correctly labeled on the graph.

A point in the range of 0.001% to 0.002% is acceptable as long as it is consistent with their graph and the point at which their graph upturns.

**OR**

If students do not interpret the 10 dead brine shrimp as natural mortality, then the threshold level is below 0.0001% and therefore they should locate a point to the left of the graph.

**No credit is earned:**

- if written numerical value is given without notation on the graph
- if student’s narrative contradicts or is not consistent with the point plotted
- if a student brackets <0.0001 to 0.001 on the graph; this area is the threshold and not the threshold level, which is an identifiable point as asked for in the question

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**Question 3 (cont'd.)**

- (d) Provide one argument for extending these toxicity results to humans and one argument against doing so.  
*(4 points)*

**Definition of “argument” used: “A coherent series of statements leading from a premise to a conclusion” (Merriam Webster, 2002)**

In their argument, students must include a thesis statement (*1 point*) linked with one supporting detail (*1 point*) within the context of a paragraph. Any of the statements below may be used either as the thesis statement or the supporting detail. In this context, a complete argument is scored 2 points, an incomplete argument is 1 point, and an invalid or no argument is 0 points.

If students begin their argument with “One argument for extending the testing to humans...” or “One argument against extending the testing to humans...,” they have misunderstood the question, which clearly addresses “these toxicity results.”

The FOR portion of the rubric will be used to score their FOR argument and the AGAINST portion of the rubric will be used to score their AGAINST argument.

In actuality their FOR argument would match the AGAINST rubric resulting in 0 points; likewise their AGAINST argument would match the FOR rubric also resulting in 0 points. So students earn 0 points if they have misread or misinterpreted the question.

Additionally, if students discuss “publishing the results” or “informing the public” they have also misunderstood what “extending the results” means and receive no points.

If students do not clearly identify their argument as “for” or “against”, it will be scored in the order of the presentation of the question — the “for” argument first followed by the “against” argument and the rubric will be applied accordingly.

**One argument FOR extending these toxicity results to humans (maximum 2 points)**

Since the copper sulfate (metal ion) was toxic to brine shrimp, it is reasonable to assume that it might be toxic to humans. *(1 point)*

Copper sulfate is a water soluble toxin and humans are susceptible/exposed to water-soluble compounds. *(1 point)*

Since there is evidence of a dose effect in the brine shrimp, there may be a dose effect in humans. *(1 point)*

Since it may be unethical and/or illegal to test on humans or it might result in injury, harm or death to humans, testing must be done on other organisms. *(1 point)*

These dose-response results can be mathematically extrapolated/estimated and applied to humans. *(1 point)*

This was an experiment conducted under laboratory conditions, therefore the results are verifiable. *(1 point)*

No credit is earned for “Brine shrimp and humans are living organisms”.

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**Question 3 (cont'd.)**

**One argument AGAINST extending these toxicity results to humans (maximum 2 points)**

Test animals and humans differ in anatomy, body size, physiology, metabolism, genetics and/or sensitivity, and exposure to toxins. (*1 point for each specified difference*)

Many factors affect the dose-response results — species, sex and age of organism, temperature, synergistic effects, diet, and number of organisms in a cage or container. (*1 point*)

Laboratory conditions do not necessarily reflect actual conditions. (*1 point*)

It is difficult to mathematically predict/estimate these effects on humans. (*1 point*)

Brine shrimp are aquatic organisms and humans are terrestrial. (*1 point*)

A mammalian test population (such as mice or rats) might be more appropriate. (*1 point*)

Dose-response testing only provides data on acute effects and does not address chronic effects. (*1 point*)

The experimental results may not be accurate — sample size too small, only one trial, no control group, error in measurements. (*1 point for each specific inaccuracy*)

Dose-response studies should be conducted on several species before they are applied to humans. (*1 point*)

Just because CuSO<sub>4</sub> is toxic to brine shrimp does not necessarily mean it is toxic to humans. (*1 point*)

Documented historic data/incidences on human exposure to CuSO<sub>4</sub> might provide more reliable information. (*1 point*)

**No credit is earned:**

- **for “humans are more complicated (complex) than brine shrimp”**
- **for “humans are different than brine shrimp”**
- **if the student’s second argument is simply the opposite of the first argument**