

## **Investigating the effect of different light intensities on water weed** **[Online Simulation]**

### **Research question**

Is there a change (decrease / increase) in oxygen ( $O_2$ ) production (number of bubbles) of water weed with changing light intensities?

### **Variables**

**Independent variable** – the light intensity (varying from a scale of 1 – 10, unknown units)

**Dependent variable** - The number of bubbles produced over a known period of time ( $O_2$  production)

### **Control variables**

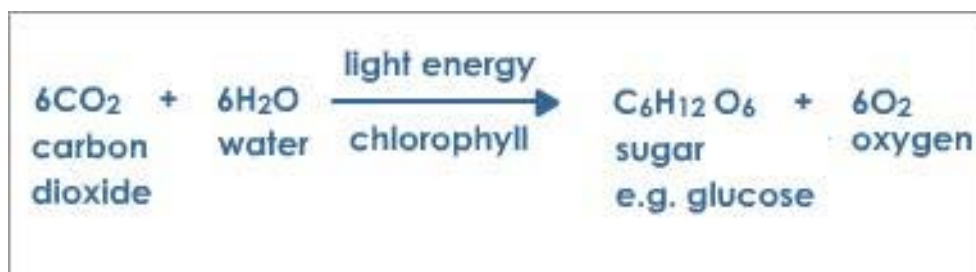
### **How is it being controlled?**

|                                    |                                                                                                                                                                                                                                                                                                                                                                                      |
|------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Type and age of water weed         | The water weed used in this experiment was unknown. It could not be controlled and it was assumed that it was healthy and would give consistent results.                                                                                                                                                                                                                             |
| Weight (amount) of pond weed       | This could not be controlled. It was assumed that the experiment provided the optimum amount for best results.                                                                                                                                                                                                                                                                       |
| Temperature of the $CO_2$ solution | This was unknown and could not be controlled. It was assumed that the temperature remained constant and was at an optimum level.                                                                                                                                                                                                                                                     |
| Time of bubble collection          | This should always be the same and of a reasonable length to provide stat data, A time of 30 seconds was pre-programmed into the simulation. The speed could be at normal time or x 5 so the faster simulation speed was used to quicken data collection. It was assumed that this did not influence the results given. The results could be doubled up to 1 minute (see evaluation) |

|                                |                                                                                                                                                                                                                                                                                                                             |
|--------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| External light intensities     | These could not be controlled and no data was provided. It was assumed that the simulation was carried out in dark conditions to provide optimum results.                                                                                                                                                                   |
| Sodium carbonate concentration | This could be controlled using an arbitrary scale of 1 – 10. The simulation gave no indication of the solution composition or Molarity so it was assumed that CO <sub>2</sub> was in excess. The level used in this experiment was 10 to ensure that the CO <sub>2</sub> was in excess and would not influence the results. |
| Temperature of the room        | This was unknown and could not be controlled. It was assumed that it was optimum for the experiment.                                                                                                                                                                                                                        |
| Size of bubbles                | From observations during the simulation these appeared to be of a regular size and were released from the plant at regular intervals.                                                                                                                                                                                       |

Aquatic plants can be used to demonstrate oxygen evolution in the process of photosynthesis. In theory, when an aquatic plant is placed in a solution containing a source of carbon dioxide [CO<sub>2</sub>], in the presence of light of appropriate intensity, the plant will photosynthesise and produce bubbles of oxygen-containing gas. These bubbles can be counted and the rate of bubbling can serve as an indication of the rate of photosynthesis. When the light intensity is increased, the rate of bubble production should increase. Decrease the light intensity and the rate of bubbling should decrease. Remove the light source altogether, or move in to a distance beyond which the energy levels are too small for photosynthesis, and the bubbling should cease.

The equation for photosynthesis is



Light is essential for photosynthesis. Green plant cells that are placed in the dark will not photosynthesise. An increase in light intensity will produce an increase in the rate of photosynthesis until a level of light intensity is reached [normally 38% - (1)]

above which the rate does not increase because the light saturation point has been reached and another factor (CO<sub>2</sub> concentration or temperature) is limiting.

In this experiment, the light intensity is changed, by decreasing the light intensity. The rate of photosynthesis should decrease and therefore the amount of oxygen bubbles should decrease.

### Hypothesis

**I think that if the light intensity is very low, then the number of bubbles of oxygen produced will also be very low, because the plant obtains light energy from photons being absorbed by pigments in photosystems, and this energy is what drives the photosynthetic process. At low light intensity, water will not undergo photolysis and therefore will not produce O<sub>2</sub> as a byproduct. As the light intensity increases, more electrons are energised in the reaction centre of the Photosystem, and so more photolysis occurs to replace the high energy electron, thus releasing more oxygen which can be detected as more bubbles.**

**At the highest light intensities it is possible that the number of bubbles will plateau, as photosynthesis can be limited by several factors: light intensity, temperature, and carbon dioxide concentration. The rate of photosynthesis is unlikely to continue increasing even with high light intensities because e.g. carbon dioxide concentrations may not be optimal.**

Photosynthesis also requires CO<sub>2</sub> to be present and the simulation provides this as a solution of CO<sub>2</sub> of changeable concentration with arbitrary units 1-10.

Photosynthesis is dependent on the CO<sub>2</sub> concentration but this is in excess and will not influence the results. Decreasing CO<sub>2</sub> concentrations could be explored in this simulation.

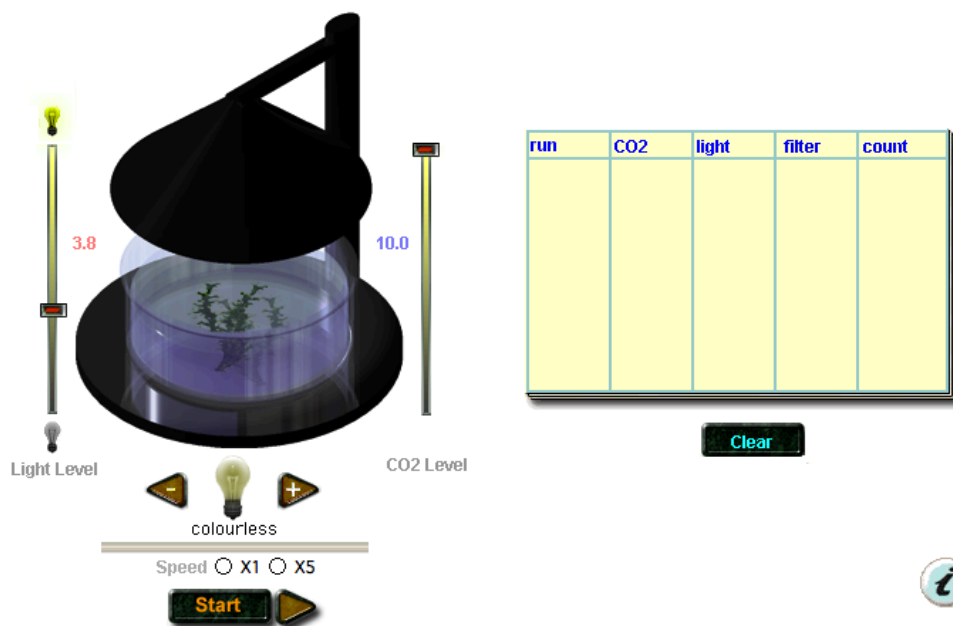
Light is absorbed by chlorophyll during photosynthesis, in the blue/green spectrum. Normal light provides these wavelengths, so using a normal light bulb (white light) without filters is sufficient. The use of coloured light could be explored using this simulation.

### The Simulation program: Water weed

This simulation permits the experimenter to modify light intensity, carbon dioxide levels and the colour of the light.

The screen shot below shows the virtual set up.

#### Water Weed Simulation



<http://www.saddleworth.oldham.sch.uk/science/simulations/waterweed.htm>

### Method

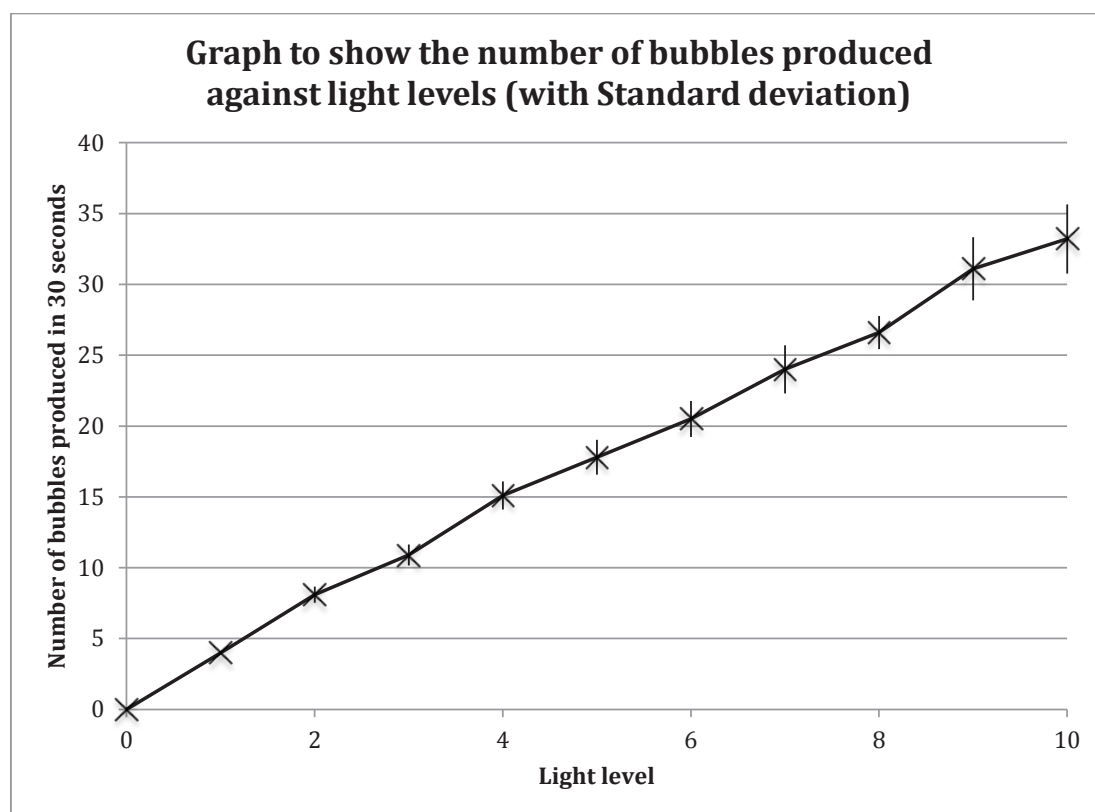
The parameters were set on the simulation as follows:

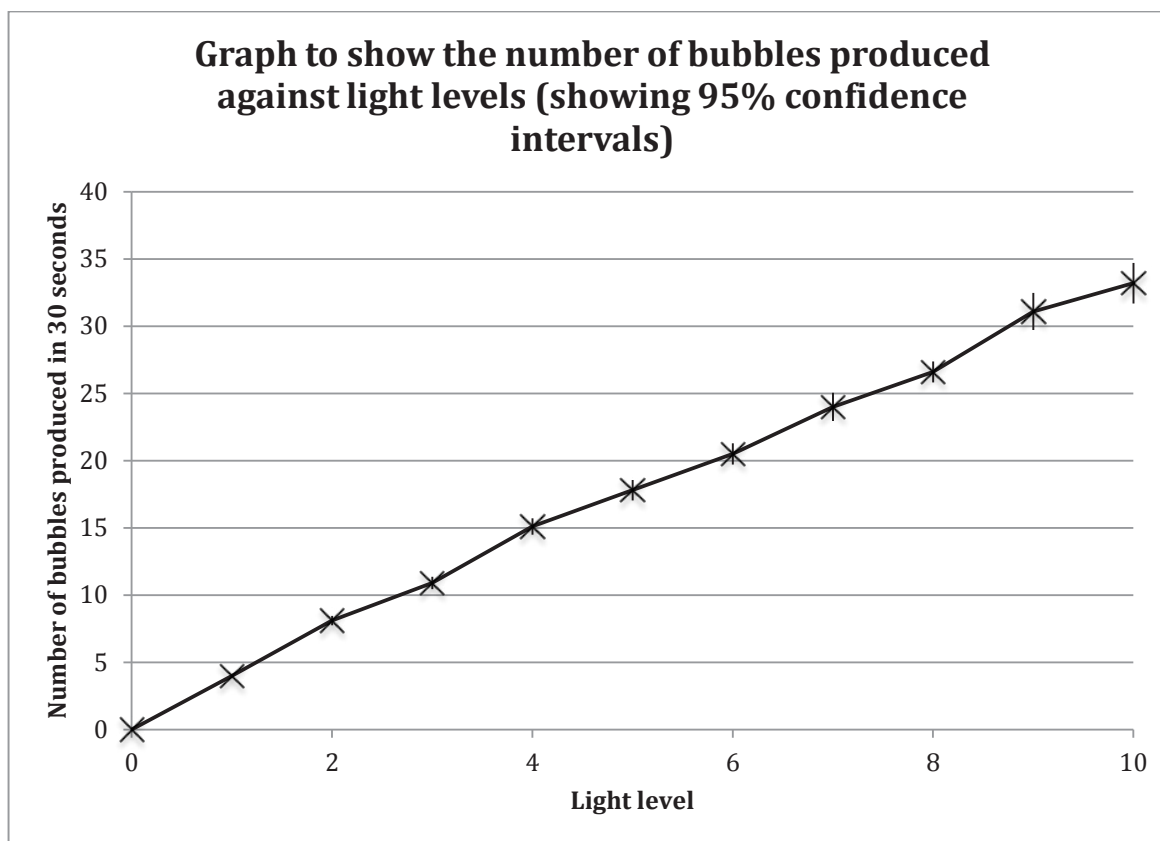
- CO2 level =10
- Light filter white
- Speed x5

Data was collected from light levels 1 -10. 5 repeats were carried out at each light level.

The raw data collected is shown in tables in the appendix

| Light Level (AU) | Number of bubbles produced in 30 seconds (+/-0.05 seconds) |       |       |       |       |       |       |       |       |        |      |        |        |
|------------------|------------------------------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|--------|------|--------|--------|
|                  | Rpt 1                                                      | Rpt 2 | Rpt 3 | Rpt 4 | Rpt 5 | Rpt 6 | Rpt 7 | Rpt 8 | Rpt 9 | Rpt 10 | Mean | St Dev | 95% CL |
| 0                | 0                                                          | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0      | 0.0  | 0.00   | 0      |
| 1                | 4                                                          | 4     | 4     | 4     | 4     | 4     | 4     | 4     | 4     | 4      | 4.0  | 0.00   | 0      |
| 2                | 8                                                          | 8     | 9     | 9     | 8     | 7     | 8     | 8     | 8     | 8      | 8.1  | 0.57   | 0.35   |
| 3                | 11                                                         | 11    | 12    | 10    | 11    | 10    | 12    | 10    | 11    | 11     | 10.9 | 0.74   | 0.46   |
| 4                | 17                                                         | 15    | 14    | 14    | 16    | 15    | 14    | 16    | 15    | 15     | 15.1 | 0.99   | 0.61   |
| 5                | 17                                                         | 20    | 17    | 17    | 17    | 18    | 17    | 17    | 18    | 20     | 17.8 | 1.23   | 0.76   |
| 6                | 19                                                         | 19    | 22    | 21    | 20    | 19    | 20    | 22    | 21    | 22     | 20.5 | 1.27   | 0.79   |
| 7                | 22                                                         | 26    | 26    | 22    | 24    | 23    | 26    | 24    | 25    | 22     | 24.0 | 1.70   | 1.05   |
| 8                | 26                                                         | 27    | 28    | 28    | 27    | 26    | 25    | 28    | 26    | 25     | 26.6 | 1.17   | 0.78   |
| 9                | 33                                                         | 32    | 29    | 32    | 32    | 32    | 33    | 28    | 27    | 33     | 31.1 | 2.23   | 1.38   |
| 10               | 35                                                         | 30    | 31    | 31    | 36    | 36    | 34    | 32    | 36    | 31     | 33.2 | 2.44   | 1.51   |





### **Conclusion**

As the light levels are increased there is an increase in oxygen (bubble) production from photosynthesis of the plant. This result suggests that my hypothesis was correct.

Light levels at unit 10 were approximately twice those at light level 5. This corresponded to levels of photosynthesis at light level 10 being twice that of light level 5. This can also be seen e.g. with the number of bubbles at a light intensity of 4 units being double that seen with a light intensity of 2 units, indicating that there is a direct, positive correlation between light intensity and the number of bubbles produced.

Standard deviation was calculated to determine the reliability of the experiment. Standard deviation shows the spread of the data about the mean, and so the lower the standard deviation, the more reliable the results. It can be seen on the graph that the higher the light level, the greater the standard deviation and 95% confidence limits become, showing that the data becomes less reliable as the light intensity increases. However, at all light intensities the standard deviation was relatively small in comparison with the mean, being at the most less than 8% of the mean value (for light level 2).

The results of this experiment demonstrate the theory that, at low light levels photolysis is not happening much because there are only a small number of photons striking the Photosystem, and therefore not many electrons being excited to a higher energy level. Photolysis is not occurring, water is not being split and therefore no, or few oxygen bubbles are being released by the plant.

As the light increases in intensity, more photons are being absorbed by the pigments and more electrons need replacing in the primary reaction centre of the photosystem, resulting in a higher rate of photolysis and more oxygen bubbles (2).

My hypothesis was only partially correct, as I predicted that at a certain light intensity the number of bubbles would reach a plateau because another factor would be limiting. This did not happen, but this is possibly due to the light saturation point not having been reached in this experiment.

### **Evaluation**

| <b><u>Weaknesses</u></b>                                                                                                                                                                                                                                                                                                                                                                                               | <b><u>Improvements</u></b>                                                                                                                                                                                                                |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| No intermediate values could be assessed                                                                                                                                                                                                                                                                                                                                                                               | The simulation does not allow assessment of any values outside the pre-programmed values. This is an area that could be explored in the laboratory. It would be useful if this could be changed.                                          |
| Maximum light level of simulation did not reach light saturation point, therefore other limiting factors could not be determined.                                                                                                                                                                                                                                                                                      | Unlike a related practical carried out in the laboratory this simulation did not have maximum or minimum light levels that influenced photosynthesis. This could not be controlled and would add more to results if it could be explored. |
| Units of light and CO <sub>2</sub> concentration were in units of 1 -10. There was no indication of how this is related to a laboratory situation and what the solutions and the light levels actually were. These variables cannot be controlled and may not provide sufficient data to comment fully or provide the variation in an experiment that would normally be carried out. No trial runs can be carried out. | Provide more detail about light units, solutions etc. Allow fine adjustments of variables. Provide more information.                                                                                                                      |

### **References**

(1) [www.proprofs.com](http://www.proprofs.com)

(2) 'Steps in Photosynthesis' Clegg, Biology for the Diploma, 2007, Hodder Education

**Appendix Raw Data Produced on 31/1/12 11.16am- 11.33 am**

| Run | CO2 | Light | Filter | Count |
|-----|-----|-------|--------|-------|
| 1   | 10  | 0     | White  | 0     |
| 2   | 10  | 0     | White  | 0     |
| 3   | 10  | 0     | White  | 0     |
| 4   | 10  | 0     | White  | 0     |
| 5   | 10  | 0     | White  | 0     |
| 6   | 10  | 0     | White  | 0     |
| 7   | 10  | 0     | White  | 0     |
| 8   | 10  | 0     | White  | 0     |
| 9   | 10  | 0     | White  | 0     |
| 10  | 10  | 0     | White  | 0     |

| Run | CO2 | Light | Filter | Count |
|-----|-----|-------|--------|-------|
| 1   | 10  | 1     | White  | 4     |
| 2   | 10  | 1     | White  | 4     |
| 3   | 10  | 1     | White  | 4     |
| 4   | 10  | 1     | White  | 4     |
| 5   | 10  | 1     | White  | 4     |
| 6   | 10  | 1     | White  | 4     |
| 7   | 10  | 1     | White  | 4     |
| 8   | 10  | 1     | White  | 4     |
| 9   | 10  | 1     | White  | 4     |
| 10  | 10  | 1     | White  | 4     |

| Run | CO2 | Light | Filter | Count |
|-----|-----|-------|--------|-------|
| 1   | 10  | 2     | White  | 8     |
| 2   | 10  | 2     | White  | 8     |
| 3   | 10  | 2     | White  | 8     |
| 4   | 10  | 2     | White  | 9     |
| 5   | 10  | 2     | White  | 9     |
| 6   | 10  | 2     | White  | 8     |
| 7   | 10  | 2     | White  | 7     |
| 8   | 10  | 2     | White  | 8     |
| 9   | 10  | 2     | White  | 8     |
| 10  | 10  | 2     | White  | 8     |

| Run | CO2 | Light | Filter | Count |
|-----|-----|-------|--------|-------|
| 1   | 10  | 3     | White  | 11    |
| 2   | 10  | 3     | White  | 11    |
| 3   | 10  | 3     | White  | 12    |
| 4   | 10  | 3     | White  | 10    |
| 5   | 10  | 3     | White  | 11    |
| 6   | 10  | 3     | White  | 10    |
| 7   | 10  | 3     | White  | 12    |
| 8   | 10  | 3     | White  | 10    |
| 9   | 10  | 3     | White  | 11    |
| 10  | 10  | 3     | White  | 11    |



| Run | CO2 | Light | Filter | Count |
|-----|-----|-------|--------|-------|
| 1   | 10  | 4     | White  | 17    |
| 2   | 10  | 4     | White  | 15    |
| 3   | 10  | 4     | White  | 14    |
| 4   | 10  | 4     | White  | 14    |
| 5   | 10  | 4     | White  | 16    |
| 6   | 10  | 4     | White  | 15    |
| 7   | 10  | 4     | White  | 14    |
| 8   | 10  | 4     | White  | 16    |
| 9   | 10  | 4     | White  | 15    |
| 10  | 10  | 4     | White  | 15    |

| Run | CO2 | Light | Filter | Count |
|-----|-----|-------|--------|-------|
| 1   | 10  | 5     | White  | 17    |
| 2   | 10  | 5     | White  | 20    |
| 3   | 10  | 5     | White  | 17    |
| 4   | 10  | 5     | White  | 17    |
| 5   | 10  | 5     | White  | 17    |
| 6   | 10  | 5     | White  | 18    |
| 7   | 10  | 5     | White  | 17    |
| 8   | 10  | 5     | White  | 17    |
| 9   | 10  | 5     | White  | 18    |
| 10  | 10  | 5     | White  | 20    |

| Run | CO2 | Light | Filter | Count |
|-----|-----|-------|--------|-------|
| 1   | 10  | 6     | White  | 19    |
| 2   | 10  | 6     | White  | 19    |
| 3   | 10  | 6     | White  | 22    |
| 4   | 10  | 6     | White  | 21    |
| 5   | 10  | 6     | White  | 20    |
| 6   | 10  | 6     | White  | 19    |
| 7   | 10  | 6     | White  | 20    |
| 8   | 10  | 6     | White  | 22    |
| 9   | 10  | 6     | White  | 21    |
| 10  | 10  | 6     | White  | 22    |

| Run | CO2 | Light | Filter | Count |
|-----|-----|-------|--------|-------|
| 1   | 10  | 7     | White  | 26    |
| 2   | 10  | 7     | White  | 26    |
| 3   | 10  | 7     | White  | 22    |
| 4   | 10  | 7     | White  | 24    |
| 5   | 10  | 7     | White  | 23    |
| 6   | 10  | 7     | White  | 26    |
| 7   | 10  | 7     | White  | 24    |
| 8   | 10  | 7     | White  | 25    |
| 9   | 10  | 7     | White  | 22    |
| 10  | 10  | 7     | White  | 22    |

| Run | CO2 | Light | Filter | Count |
|-----|-----|-------|--------|-------|
| 1   | 10  | 8     | White  | 26    |
| 2   | 10  | 8     | White  | 27    |
| 3   | 10  | 8     | White  | 28    |
| 4   | 10  | 8     | White  | 28    |
| 5   | 10  | 8     | White  | 27    |
| 6   | 10  | 8     | White  | 26    |
| 7   | 10  | 8     | White  | 25    |
| 8   | 10  | 8     | White  | 28    |
| 9   | 10  | 8     | White  | 26    |
| 10  | 10  | 8     | White  | 25    |

| Run | CO2 | Light | Filter | Count |
|-----|-----|-------|--------|-------|
| 1   | 10  | 9     | White  | 33    |
| 2   | 10  | 9     | White  | 32    |
| 3   | 10  | 9     | White  | 29    |
| 4   | 10  | 9     | White  | 32    |
| 5   | 10  | 9     | White  | 32    |
| 6   | 10  | 9     | White  | 32    |
| 7   | 10  | 9     | White  | 33    |
| 8   | 10  | 9     | White  | 28    |
| 9   | 10  | 9     | White  | 27    |
| 10  | 10  | 9     | White  | 33    |

| Run | CO2 | Light | Filter | Count |
|-----|-----|-------|--------|-------|
| 1   | 10  | 10    | White  | 35    |
| 2   | 10  | 10    | White  | 30    |
| 3   | 10  | 10    | White  | 31    |
| 4   | 10  | 10    | White  | 31    |
| 5   | 10  | 10    | White  | 36    |
| 6   | 10  | 10    | White  | 36    |
| 7   | 10  | 10    | White  | 34    |
| 8   | 10  | 10    | White  | 32    |
| 9   | 10  | 10    | White  | 36    |
| 10  | 10  | 10    | White  | 31    |