Answer Key: Let It Glow

Pre-lab Questions

1) \( \nu = 9.49 \times 10^7 \text{ Hz} = 9.49 \times 10^7 / \text{s} \) 
\( c = \lambda \nu \) 
\( c = 3.0 \times 10^8 \text{ m/s} = \lambda (9.49 \times 10^7 / \text{s}) \) 
\( \lambda = 3.16 \text{ m} \)

2) \( \lambda = 5.6 \times 10^{-7} \text{ m} \) 
\( c = \lambda \nu \) 
\( c = 3 \times 10^8 \text{ m/s} = 5.6 \times 10^{-7} \text{ m} (\nu) \) 
\( \nu = 5.4 \times 10^{14} / \text{s} = 5.4 \times 10^{14} \text{ Hz} \)

3) \( E = 1.6 \times 10^{-12} \text{ J} \) 
\( E = h \nu \) 
\( 1.6 \times 10^{-12} \text{ J} = 6.626 \times 10^{-34} \text{ J} \cdot \text{s} (\nu) \) 
\( h = 6.626 \times 10^{-34} \text{ J} \cdot \text{s} \) 
\( \nu = 2.4 \times 10^{21} / \text{s} = 2.4 \times 10^{21} \text{ Hz} \)

4) \( E = ? \) 
\( c = \lambda \nu \) 
\( c = 3 \times 10^8 \text{ m/s} = 1.5 \times 10^{-4} \text{ m} (\nu) \) 
\( \nu = 2.0 \times 10^{12} / \text{s} \)

5) At an atomic level, electrons are excited when UV energy is absorbed from the black light. When the electrons fall back down, photons of light at a lower energy and longer wavelength are given off as visible light. This light shows up instantaneously and disappears when the black light is turned off.

Observations

<table>
<thead>
<tr>
<th>Items Observed</th>
<th>Observations &amp; Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>List each specific item observed under the heading for each Part of the lab.</td>
<td>Student answers will vary. Sample answers given below.</td>
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Part I: Teacher-provided samples

Scorpion was so cool! It glowed blue under the black light but was normal brown color under visible light. Vitamin tablets had an eerie yellow-green glow under the black light but looked brown and boring under visible light.

Part II: Approved student-provided samples

White Lego bricks I brought from home glowed nicely but neon hairpiece that I had did not glow as I expected. Also, $10 bill had a glowing orange strip in it.

Part III: Marker vs highlighter

Yellow ink on “yellow marker” card was not glowing; it showed up as dark against the glowing white background of the index card

Yellow ink on “yellow highlighter” card was glowing pink against the glowing white background of the index card

Is it yellow ink and its interaction with white index card or just different types of yellow ink in highlighter versus marker? I wrote on my hand to see that yellow highlighter still glowed and yellow marker did not.
**Part IV: Different color highlighters**

My blue and green highlighter markers did not glow, but my friend’s green highlighter, which was a different brand than mine, did glow. Yellow and orange highlighters glowed the brightest and pink did glow, but not as brightly. (Student answers will vary based on brand of highlighters used.)

**Part V: Different white samples**

White samples of painted wood and square of leather did not glow in the black UV light, but the cotton ball and the white plastic did glow a purple color.

*Student answers to questions following table for Observations will vary.*

**Calculations**

1. 

\[
\begin{align*}
320 \text{ nm} &= 3.20 \times 10^{-7} \text{ m} = \lambda_1 \\
400 \text{ nm} &= 4.00 \times 10^{-7} \text{ m} = \lambda_2 \\
c &= \lambda v \\
3 \times 10^8 \text{ m/s} &= (3.20 \times 10^{-7} \text{ m}) v \\
v_1 &= 9.38 \times 10^{14} /s = 9.38 \times 10^{14} \text{ Hz} \\
\text{frequency range of } 7.50 \times 10^{14} \text{ Hz to } 9.38 \times 10^{14} \text{ Hz} \\
400 \text{ nm} &= 4.00 \times 10^{-7} \text{ m} = \lambda_2 \\
3 \times 10^8 \text{ m/s} &= (4.00 \times 10^{-7} \text{ m}) v \\
v_2 &= 7.50 \times 10^{14} /s = 7.50 \times 10^{14} \text{ Hz} \\
E &= h v \\
E &= 6.626 \times 10^{-34} \text{ J} \cdot \text{s} (9.38 \times 10^{14} /s) \\
E &= 6.22 \times 10^{-19} \text{ J} \\
E &= 6.626 \times 10^{-34} \text{ J} \cdot \text{s} (7.50 \times 10^{14} /s) \\
E &= 4.97 \times 10^{-19} \text{ J}
\end{align*}
\]

**Analysis**

1. Atoms in the fluorescing compound of the yellow highlighter ink absorb UV energy and the electrons jump up to a higher energy level. When the electrons fall back down, some of the energy is converted into vibrational energy, so the remaining longer wavelength, lower energy light is given off in the visible part of the spectrum. For the regular yellow marker ink, the electrons in its atoms are absorbing and emitting energy of the same wavelength of visible light.

2. Yes. If the blue highlighter does not glow, its ink must not contain the chemical compound (or enough of the chemical compound) that will allow its atoms to absorb UV light and then emit light in the visible range. It is not fluorescent like the highlighter ink from the yellow (and orange and pink and green) highlighter.

3. There must be some differences in the amount or type of dye used in the inks of different highlighters because colors of different brands appear to glow differently under the black light and some colors like blue don’t seem to glow in certain brands while others glow more. (Students may answer this question differently if you used only one brand of highlighter.)

4. All of the samples appeared white under visible light, but they did not all glow with the same bright purple glow. It appears that the composition of the material (and the atoms of the compounds/elements making up that material) affects the fluorescence because white cotton ball and white paper glowed while the white paint on the metal and white leather did not glow. (Student examples in answer will differ based on samples used for Part V.)
Extension

1. PPG’s glow-in-the-dark tools were specially designed to phosphoresce after a flashlight beam passed over them, so technician would only have to shine a flashlight around the work area and then the tool should glow in the dark.
2. Fluorescence occurs immediately when exposed to a black light and fluorescent items do not continue to glow when that energy source is removed. Phosphorescent items store up their energy and continue to glow after the energy source is removed.
3. Tools for those who work in the dark or dark areas like miners, scuba divers, plumbers, car mechanics, etc
4. Possible fluorescence applications: fluorescence microscopy for biological samples, UV lights in forensic investigations, fluorescence spectroscopy with organic molecules, leak detection in HVAC systems or pipes using UV light and a fluorescent dye, UV-C light used in disinfecting and sterilizing

Assessment Key

1. A
2. A
3. B
4. C
5. B
6. A
7. D
8. E
9. \[E = \frac{h \nu}{c} = \frac{6.626 \times 10^{-34} \text{ J} \cdot \text{s}}{3 \times 10^8 \text{ m/s}} = 1.00 \times 10^{-10} \text{ m} (\nu)\]
   \[v = 3.00 \times 10^{18} /\text{s}\]
   \[E = 6.626 \times 10^{-34} \text{ J} \cdot \text{s} (3.00 \times 10^{18} /\text{s})\]
   \[E = 1.99 \times 10^{-15} \text{ J}\]
10. The t-shirt is made of cotton which glows purply white under the black light, especially after being laundered with detergent containing phosphorus. But the pants are made of leather which will not glow. The color white is not what determines the clothing’s appearance under the black light. It is the composition of the material and how its atoms react to the visible and UV light in a black light that determines fluorescence.

   Some highlighters contain ink that will glow under a black light while other highlighters do not. It depends on the composition of the ink; this ink composition can vary by brand and it definitely varies by color.

   At an atomic level, electrons are excited when UV energy is absorbed from the black light. When the electrons fall back down, photons of light at a lower energy and longer wavelength are given off as visible light.

11. Friend’s Batman shirt contains both fluorescent and phosphorescent compounds in the dye used to make the shirt. The phosphorescent dye compounds give off a glow in a darkened room after being exposed to light.

   At a particulate level the phosphorescence works as the atoms/molecules are take in energy from visible light and jump to an excited state. When the electrons fall back down, photons of light are emitted at a delay so the light can be seen even after the light source is removed.

   White shirt with highlighter drawings was no longer glowing because UV light source was no longer available to cause fluorescence.