ANSWER KEY. Work and answers are shown in bold italic.

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Beer-Lambert Law

AP Chemistry | Topic 3.13 | ANSWER KEY

Answer each question in the space provided. Show your work with units and correct significant figures.
Beer-Lambert law: A = εbc

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1. Identify each variable in the Beer-Lambert law and give its units. Write *none* if it has no units.

Symbol	What it represents	Units
A	***absorbance***	***none (unitless)***
ε	***molar absorptivity (how strongly the substance absorbs at that wavelength)***	***M^{-1} cm^{-1}***
b	***path length (width of the cuvette the light passes through)***	***cm***
c	***concentration of the absorbing species***	***M (mol L^{-1})***

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2. A solution of a colored compound has an absorbance of **0.40** in a 1.00 cm cuvette. Predict the new absorbance for each change. Make each change separately, starting from the original solution.

(a) The concentration is doubled.

A = 0.80. A is directly proportional to c, so A doubles.

(b) A 0.500 cm cuvette is used instead.

A = 0.20. Half the path length gives half the absorbance.

(c) 10.0 mL of the solution is diluted to 40.0 mL.

A = 0.10. c is 1/4 as large (10.0/40.0), so 0.40/4.

(d) Describe the relationship between A and c. On a graph of A versus c, what quantity equals the slope?

A and c are directly proportional: the graph is a straight line through the origin. The slope equals εb (molar absorptivity × path length).

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3. Potassium permanganate, $KMnO_4$, has a molar absorptivity of 2.40×10^3 M^{-1} cm^{-1} at 525 nm. Calculate the absorbance of a 1.50×10^{-4} M $KMnO_4$ solution in a 1.00 cm cuvette.

$A = \varepsilon bc = (2.40 \times 10^3\ M^{-1}\ cm^{-1})(1.00\ cm)(1.50 \times 10^{-4}\ M)$
$A = 0.360$ (no units)

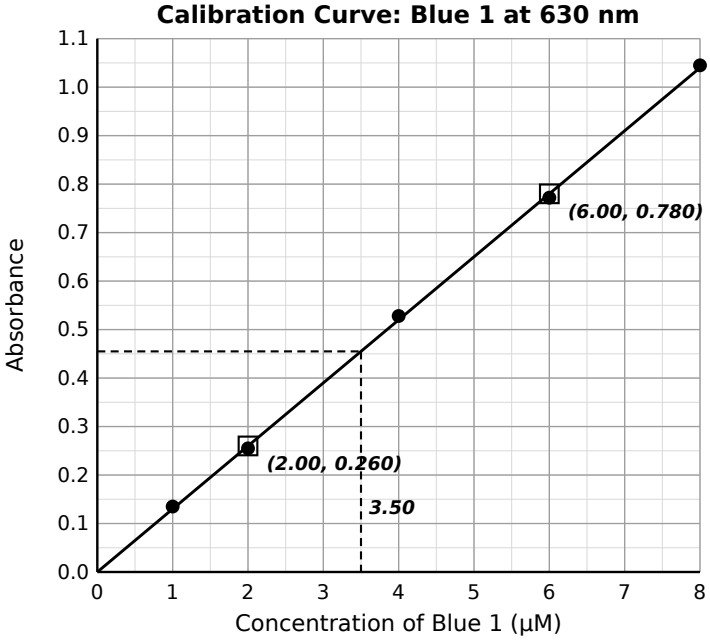
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4. Red 40 dye has a molar absorptivity of 2.50×10^4 M^{-1} cm^{-1} at 504 nm. A sample of fruit punch has an absorbance of 0.520 at 504 nm in a 1.00 cm cuvette. Calculate the concentration of Red 40 in the punch.

$c = A / \varepsilon b = 0.520 / [(2.50 \times 10^4\ M^{-1}\ cm^{-1})(1.00\ cm)]$
$c = 2.08 \times 10^{-5}$ M

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5. A student makes standard solutions of Blue 1 dye and measures the absorbance of each at 630 nm in a 1.00 cm cuvette. The data and best-fit line are graphed below. (1 μM = 1×10^{-6} M)



(a) Use two points on the best-fit line (not data points) to find the slope. Then determine ε for Blue 1. Include units.

slope = (0.780 − 0.260) / (6.00 − 2.00) μM
= 0.130 μM^{-1} = 1.30 × 10^5 M^{-1}
slope = εb, so ε = slope / 1.00 cm
ε = 1.30 × 10^5 M^{-1} cm^{-1}

(b) A sports drink sample has an absorbance of 0.455. Determine the concentration of Blue 1 in the drink, in M.

From the graph, A = 0.455 at 3.50 μM.
Check: c = 0.455 / (1.30 × 10^5)(1.00)
c = 3.50 × 10^{-6} M

(c) A second drink gives an absorbance of 1.62. Explain why the student should dilute this sample and remeasure instead of extending the line to find its concentration.

1.62 is above the highest standard (1.045), so the line has not been shown to stay linear there, and very little light reaches the detector, making the reading less reliable. Dilute by a known factor so A falls within the standards, then multiply the result by the dilution factor.

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6. For each error, state whether the measured absorbance of the drink sample would be **too high** or **too low**, and whether the calculated concentration would be too high or too low. Explain.

(a) The student leaves fingerprints on the clear sides of the cuvette holding the drink sample.

Absorbance too high. The fingerprints absorb and scatter light, so less light reaches the detector and the extra absorbance is blamed on the dye. Calculated concentration too high.

(b) The student rinses the cuvette with distilled water but not with the drink sample, so water droplets remain inside when the sample is added.

Absorbance too low. The water dilutes the sample, so fewer dye particles are in the light path. Calculated concentration too low.

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