ANSWER KEY.

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3.11 Spectroscopy and the Electromagnetic Spectrum

AP Chemistry | ANSWER KEY

Answer each question. When asked to justify, name the type of transition and connect it to the energy of the photon.

1. Rank these four types of electromagnetic radiation from **longest** to **shortest** wavelength: X-ray, radio, visible, infrared.

(a) Write your ranking.

(b) Which of the four has the highest energy per photon? Explain how you know.

(a) radio > infrared > visible > X-ray

(b) X-ray. It has the shortest wavelength, so it has the highest frequency and the most energy per photon.

2. For each type of radiation, state the change it causes in a molecule that absorbs it.

(a) microwave

(b) infrared

(c) ultraviolet

(a) Microwave: the rotational energy increases (the molecule rotates faster).

(b) Infrared: the vibrational energy increases (bonds stretch, compress, or bend with more energy).

(c) Ultraviolet: an electron moves to a higher energy level (electronic transition).

3. A blue photon has a wavelength of 450 nm. A red photon has a wavelength of 650 nm.

(a) Which photon has the higher frequency?

(b) Which photon carries more energy? Justify your answer.

(a) The blue (450 nm) photon.

(b) The blue photon. All light travels at the same speed, so the shorter wavelength means a higher frequency, and a higher frequency means more energy per photon.

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4. A molecule absorbs a photon. Afterward, its bonds stretch and compress with more energy, but its rotational and electronic energy have not changed. Which region of the electromagnetic spectrum did the photon most likely come from? Explain.

Infrared. Only the vibrational energy level changed, and vibrational transitions are caused by infrared photons. A microwave photon would only change the rotation, and a UV or visible photon would cause an electronic transition.

5. A student claims that the infrared light from a heat lamp moves electrons in CO_2 molecules to higher energy levels. Do you agree or disagree? Justify your answer.

Disagree. Infrared photons only have enough energy to change the vibrational energy of CO_2. Electronic energy gaps are much larger, so exciting electrons requires higher-energy UV or visible photons.

6. A solution of copper(II) sulfate looks blue because it absorbs orange and red light.

(a) What type of transition happens when the solution absorbs visible light?

(b) Why is a photon absorbed only when its energy matches a gap between two energy levels (ΔE)? What happens to a photon that does not match any gap?

(c) Rank the energy gaps for rotational, vibrational, and electronic transitions from smallest to largest.

(a) An electronic transition: an electron moves to a higher energy level.

(b) A particle can only have certain energy levels, so it can only gain an amount of energy equal to a gap between two levels. A photon that does not match a gap is not absorbed; it passes through the sample.

(c) rotational < vibrational < electronic

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