ExamFitter

examfitter.com · Free AP Chemistry quizzes, revision notes and worksheets

Topic 3.11: Spectroscopy and the Electromagnetic Spectrum

Worksheet · AP Chemistry

UNIT 3 · PROPERTIES OF SUBSTANCES AND MIXTURES

On ExamFitter.com: Topic 3.11 Revision Notes · Topic 3.11 Quiz · Previous Worksheet: Topic 3.10 · Next Worksheet: Topic 3.12 · Unit 3: All Topics · AP Chemistry Home

How to Use This Worksheet

Work in order. Section A checks the ideas: the order of the spectrum, how wavelength, frequency and photon energy move together, and what spectroscopy is. Section B builds the calculations: frequency from wavelength, photon energy, energy ratios and energy per mole of photons. Section C combines identification, absorption and per photon reasoning in exam style.

Every value you need is stated in the question, so each question can be answered from the text alone. Where a calculation needs them, use $c = 3.00 \times 10^{8}$ m/s, $h = 6.626 \times 10^{-34}$ J·s and Avogadro's number $= 6.022 \times 10^{23}$ mol^{-1}. Show the rearrangement you use in every calculation, and convert every wavelength to metres before substituting it.

Do not look at the answer key until you have attempted every question.

© 2026 ExamFitter.com · Free AP Chemistry worksheets

Section A: Recall and Concepts

A1. (a) List the seven regions of the electromagnetic spectrum in order of increasing wavelength. (b) State which region has the highest frequency. (c) State which region has the lowest energy per photon. (d) State the approximate wavelength range of visible light, in nanometres, and name the colours at the two ends of that range. (e) State the two regions that lie immediately on either side of visible light.

A2. (a) Write down the equation linking the speed of light, wavelength and frequency, and state the unit of each quantity. (b) The wavelength of a beam doubles. State what happens to its frequency and to the energy of each of its photons. (c) The frequency of a beam triples. State what happens to its wavelength and to the energy of each of its photons. (d) A red beam and a violet beam travel through a vacuum side by side. State which quantity is identical for the two beams, and name two quantities that differ.

A3. In a diagram of two waves travelling at the same speed, wave P completes 3 full cycles over a distance in which wave Q completes 5 full cycles. (a) State which wave has the shorter wavelength. (b) State which wave has the higher frequency, and give the ratio of the two frequencies, $\nu_Q : \nu_P$. (c) Give the ratio of the photon energies, $E_Q : E_P$. (d) Wave P has a wavelength of 700 nm. Calculate the wavelength of wave Q.

A4. (a) Define spectroscopy. (b) Explain why the set of wavelengths a substance absorbs can be used to identify the substance. (c) A sample absorbs strongly at 600 nm and transmits the rest of white light. State the colour of the light absorbed, and the colour the sample appears. (d) A second sample appears yellow in white light. State the colour it absorbs most strongly.

© 2026 ExamFitter.com · Free AP Chemistry worksheets

A5. For each process or use, name the region of the spectrum responsible. (a) Setting chemical bonds vibrating, used to identify functional groups. (b) Heating food in a kitchen oven appliance. (c) Producing images of bones in a hospital. (d) Killing cancer cells in radiotherapy. (e) Driving photosynthesis in a leaf. (f) Producing tanning and sunburn in skin. (g) Broadcasting television and radio programmes.

Section B: Core Practice

B1. Radiation has a wavelength of 2.50×10^{-7} m. (a) Calculate its frequency. (b) Calculate the energy of one photon of this radiation. (c) Name the region of the spectrum it belongs to.

B2. Radiation has a frequency of 9.0×10^{14} Hz. (a) Calculate its wavelength, in metres. (b) Convert your answer to nanometres. (c) Name the region of the spectrum it belongs to. (d) Calculate the energy of one photon of this radiation.

B3. Two beams have wavelengths of 4.50×10^{-7} m and 7.50×10^{-7} m. (a) Calculate the energy of one photon of the longer wavelength beam. (b) Calculate the energy of one photon of the shorter wavelength beam. (c) State the ratio of the two photon energies, shorter to longer, and explain the ratio using the wavelengths. (d) Name the region, or colour, of each beam.

© 2026 ExamFitter.com · Free AP Chemistry worksheets

B4. A beam of orange light has a wavelength of 6.00×10^{-7} m. (a) Calculate the energy of one photon. (b) Calculate the energy of one mole of these photons, giving your answer in kJ/mol. (c) A student writes the answer to part (b) as 3.31×10^{-19} kJ/mol. State what the student has done wrong.

B5. Three radiations are described as follows. Radiation 1: wavelength 1.0×10^{-5} m. Radiation 2: frequency 5.0×10^{14} Hz. Radiation 3: wavelength 1.0×10^{-9} m. (a) Calculate the wavelength of radiation 2, in nanometres. (b) Name the region each radiation belongs to. (c) Rank the three radiations in order of increasing energy per photon. (d) Calculate the energy of one photon of radiation 3. (e) Calculate how many times more energy one photon of radiation 3 carries than one photon of radiation 1.

B6. Wave A has a wavelength of 600 nm. (a) Calculate the frequency of wave A. (b) Wave B has twice the frequency of wave A. Calculate the wavelength of wave B, in nanometres, and name its region. (c) Calculate the energy of one photon of wave B. (d) State the ratio of the photon energies, $E_B : E_A$.

© 2026 ExamFitter.com · Free AP Chemistry worksheets

Section C: Exam Style

C1. Ultraviolet light of wavelength 3.00×10^{-7} m and visible light of wavelength 6.00×10^{-7} m fall on skin at the same intensity. (a) Calculate the energy of one photon of each type of light. (b) Calculate the energy of one mole of the ultraviolet photons, in kJ/mol. (c) Typical chemical bond energies are a few hundred kJ/mol. Use your answer to part (b) to explain why ultraviolet light can break bonds in molecules in the skin. (d) Explain why the visible light, at the same intensity, does not cause the same damage. (e) At the same intensity, state which beam delivers more photons per second, and by what factor.

C2. Three sources emit radiation. Source P emits at a wavelength of 2.0×10^{-6} m. Source Q emits at a frequency of 1.5×10^{15} Hz. Source R emits at a wavelength of 5.0×10^{-7} m. (a) Calculate the wavelength of the radiation from source Q, in metres. (b) Name the region each source belongs to. (c) Rank the three sources in order of increasing energy per photon. (d) Calculate the energy of one photon from source Q. (e) State which source is absorbed in setting chemical bonds vibrating. (f) State which sources are invisible to the human eye.

C3. A solution absorbs strongly at 450 nm and only weakly at other visible wavelengths. (a) State the colour of the light absorbed at 450 nm. (b) State the colour the solution appears in white light, and explain your answer. (c) Calculate the energy of one photon of the absorbed light. (d) A different solution absorbs strongly at 600 nm instead. State the colour it appears. (e) Explain why recording absorption across the whole visible range identifies a substance more reliably than measuring absorption at a single wavelength.

© 2026 ExamFitter.com · Free AP Chemistry worksheets

Answer Key

A1. (a) Radio, microwave, infrared, visible, ultraviolet, X-ray, gamma. (b) Gamma rays. (c) Radio waves: the longest wavelengths give the lowest frequencies, and E = hν makes those photons the least energetic. (d) About 400 nm to 700 nm: violet at the short wavelength end, red at the long wavelength end. (e) Infrared on the long wavelength side and ultraviolet on the short wavelength side.

A2. (a) c = λν, where c is the speed of light in m/s, λ is wavelength in metres and ν is frequency in Hz (cycles per second). (b) The frequency halves, and the energy of each photon halves: c is fixed so ν falls as λ rises, and E = hν falls with it. (c) The wavelength falls to one third, and the energy of each photon triples. (d) The speed is identical, $c = 3.00 \times 10^{8}$ m/s for both. The wavelength and the frequency differ, and so does the energy per photon.

A3. (a) Wave Q: more cycles in the same distance means each cycle is shorter. (b) Wave Q. Frequency is proportional to the number of cycles in a given distance at fixed speed, so ν_Q : ν_P = 5 : 3. (c) E_Q : E_P = 5 : 3, because photon energy is proportional to frequency through E = hν. (d) Wavelength is inversely proportional to the cycle count, so λ_Q = 700 × 3 ÷ 5 = 420 nm.

A4. (a) Spectroscopy is the study of how electromagnetic radiation interacts with matter, including how matter absorbs, emits and transmits radiation. (b) The wavelengths a substance absorbs are set by its structure, so each substance has a characteristic absorption pattern. Matching a measured pattern against known patterns identifies the substance, the way a fingerprint identifies a person. (c) The light absorbed at 600 nm is orange. The sample appears blue-green, the complementary colour, because the eye sees the wavelengths that are transmitted, with the orange removed. (d) Blue. A yellow appearance means blue light has been absorbed out of the white light falling on the sample.

A5. (a) Infrared. (b) Microwave. (c) X-ray. (d) Gamma. (e) Visible. (f) Ultraviolet. (g) Radio waves: their long wavelengths and low photon energies suit carrying signals over long distances.

B1. (a) $\nu = c/\lambda = (3.00 \times 10^{8}) \div (2.50 \times 10^{-7}) = 1.20 \times 10^{15}$ Hz. (b) $E = h\nu = 6.626 \times 10^{-34} \times 1.20 \times 10^{15} = 7.95 \times 10^{-19}$ J. The same value comes from E = hc/λ. (c) Ultraviolet: 250 nm is shorter than the 400 nm violet edge of visible light.

B2. (a) $\lambda = c/\nu = (3.00 \times 10^{8}) \div (9.0 \times 10^{14}) = 3.33 \times 10^{-7}$ m. (b) 3.33×10^{-7} m ÷ (1×10^{-9} m per nm) = 333 nm. (c) Ultraviolet: 333 nm lies between 10 nm and 400 nm. (d) $E = h\nu = 6.626 \times 10^{-34} \times 9.0 \times 10^{14} = 5.96 \times 10^{-19}$ J. Using E = hc/λ with the wavelength from part (a) gives the same value, as it must.

B3. (a) $E = hc/\lambda = (6.626 \times 10^{-34} \times 3.00 \times 10^{8}) \div (7.50 \times 10^{-7}) = (1.99 \times 10^{-25}) \div (7.50 \times 10^{-7}) = 2.65 \times 10^{-19}$ J. (b) $E = (1.99 \times 10^{-25}) \div (4.50 \times 10^{-7}) = 4.42 \times 10^{-19}$ J. (c) E_short : E_long = 4.42 : 2.65 = 5 : 3. Photon energy is inversely proportional to wavelength, and the wavelengths are in the ratio 750 :

© 2026 ExamFitter.com · Free AP Chemistry worksheets

450 = 5 : 3, so the energies stand in the flipped ratio. (d) The 450 nm beam is visible violet light. The 750 nm beam is infrared, just beyond the red end of the visible range.

B4. (a) $E = hc/\lambda = (1.99 \times 10^{-25}) \div (6.00 \times 10^{-7}) = 3.31 \times 10^{-19}$ J. (b) Per mole: $3.31 \times 10^{-19} \times 6.022 \times 10^{23} = 2.00 \times 10^{5}$ J/mol, which is 2.0×10^{2} kJ/mol. (c) The student has taken the energy of a single photon and simply relabelled it per mole. The multiplication by Avogadro's number was never done, so the value is too small by a factor of about 10^{23}, and its unit is wrong as well.

B5. (a) $\lambda = c/\nu = (3.00 \times 10^{8}) \div (5.0 \times 10^{14}) = 6.0 \times 10^{-7}$ m = 600 nm. (b) Radiation 1 is infrared (10 micrometres). Radiation 2 is visible light (600 nm, orange). Radiation 3 is X-ray (1 nm). (c) Radiation 1, then radiation 2, then radiation 3: the longest wavelength carries the least energy per photon, and the X-ray wavelength of 1 nm is by far the shortest. (d) $E = hc/\lambda = (1.99 \times 10^{-25}) \div (1.0 \times 10^{-9}) = 1.99 \times 10^{-16}$ J. (e) One photon of radiation 1 carries $E = hc/\lambda = (1.99 \times 10^{-25}) \div (1.0 \times 10^{-5}) = 1.99 \times 10^{-20}$ J. The ratio is $(1.99 \times 10^{-16}) \div (1.99 \times 10^{-20}) = 10^{4}$, so each X-ray photon carries ten thousand times the energy of each infrared photon, the inverse of the wavelength ratio of 10^{-5} to 10^{-9}.

B6. (a) $\nu = c/\lambda = (3.00 \times 10^{8}) \div (6.00 \times 10^{-7}) = 5.00 \times 10^{14}$ Hz. (b) Doubling the frequency halves the wavelength: $\lambda_B = 600 \div 2 = 300$ nm. That is ultraviolet. (c) $E = h\nu = 6.626 \times 10^{-34} \times 1.00 \times 10^{15} = 6.63 \times 10^{-19}$ J. (d) $E_B : E_A = 2 : 1$, because the frequency doubled and photon energy is proportional to frequency.

C1. (a) Ultraviolet: $E = hc/\lambda = (1.99 \times 10^{-25}) \div (3.00 \times 10^{-7}) = 6.63 \times 10^{-19}$ J. Visible: $E = (1.99 \times 10^{-25}) \div (6.00 \times 10^{-7}) = 3.31 \times 10^{-19}$ J. (b) $6.63 \times 10^{-19} \times 6.022 \times 10^{23} = 3.99 \times 10^{5}$ J/mol, about 4.0×10^{2} kJ/mol. (c) A mole of ultraviolet photons carries about 400 kJ, the same scale as the energy needed to break a mole of chemical bonds. So a single ultraviolet photon carries enough energy to break a bond in an individual molecule, damaging the molecules of the skin. (d) Each visible photon carries half the energy of an ultraviolet photon, and a mole of them delivers only about 200 kJ, below the scale of bond energies. Bond breaking needs one photon with enough energy; adding more weaker photons raises the total energy delivered but never gives any single photon the energy to break a bond. (e) The visible beam delivers more photons per second, by a factor of 2. Equal intensity means equal total energy per second; each visible photon carries half the energy of an ultraviolet photon, so twice as many visible photons are needed to deliver the same total.

C2. (a) $\lambda = c/\nu = (3.00 \times 10^{8}) \div (1.5 \times 10^{15}) = 2.0 \times 10^{-7}$ m. (b) Source P is infrared (2.0 micrometres). Source Q is ultraviolet (200 nm). Source R is visible light (500 nm, green). (c) P, then R, then Q: energy per photon rises as wavelength falls, and 2.0×10^{-6} m is longer than 5.0×10^{-7} m, which is longer than 2.0×10^{-7} m. (d) $E = h\nu = 6.626 \times 10^{-34} \times 1.5 \times 10^{15} = 9.94 \times 10^{-19}$ J. (e) Source P: infrared photons match the energy gaps between vibrational states of chemical bonds. (f) Sources P and Q: infrared and ultraviolet both lie outside the visible window of about 400 to 700 nm.

C3. (a) Blue: 450 nm sits in the blue part of the visible spectrum. (b) The solution appears yellow. White light with its blue component absorbed leaves the complementary colour, yellow, to reach the eye. (c) $E = hc/\lambda = (1.99 \times 10^{-25}) \div (4.50 \times 10^{-7}) = 4.42 \times 10^{-19}$ J. (d) Blue-green: absorbing orange

© 2026 ExamFitter.com · Free AP Chemistry worksheets

light (600 nm) leaves its complement to be seen. (e) A single wavelength is shared by countless substances, so absorption at one wavelength alone could match many candidates. A full absorption pattern, the set of wavelengths absorbed and their relative strengths, is fixed by the substance's structure and is characteristic of that one substance, which makes the identification reliable.

Continue Revising

Topic 3.11 Revision Notes

Topic 3.11 Quiz

Previous Worksheet: Topic 3.10

Next Worksheet: Topic 3.12

Unit 3: All Topics

AP Chemistry Home

© 2026 ExamFitter.com · Free AP Chemistry worksheets