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5.111 Principles of Chemical Science
Fall 2008

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Selected biology-related questions from problem sets for lectures 1-9

Review of fundamentals

A.

Lisinopril, sold under the brand names of Prinivil® (Merck) or Zestril® (AstraZeneca), is a small molecule drug used to treat high blood pressure and heart failure. It works by inhibiting the production of angiotensin, a signaling molecule found in the blood that causes vasoconstriction (narrowing of blood vessels) and increased blood pressure. Lisinopril has a mass percentage composition of 62.2% carbon, 7.7% hydrogen, and 10.4% nitrogen, with the balance being oxygen. What is the empirical formula of lisinopril?

B.

Through a process called cellular respiration (or oxidative metabolism), your body converts energy stored in the molecular bonds of sugars (such as glucose) into a form of energy that can be used directly by your cells. The reaction for the oxidative metabolism of glucose is



In order for your body to oxidize 350. g of glucose, what mass of molecular oxygen (O_2) is required in the reaction?

The Quantum World

C.

Research in the Bawendi lab at MIT focuses on the synthesis and application of quantum dots, fluorescent semiconductor crystals. The green quantum dot depicted in the lecture #3 notes emits photons with a wavelength of 535 nm. Calculate the frequency of the photons emitted.

D.

Carotenoids are a class of molecules found in organisms that undergo photosynthesis. These organic molecules facilitate increased energy production by enabling absorption of blue light. Calculate the energy in 1 mole of 455 nm (blue) light.

E.

Fluorescent molecules (known as fluorophores) are widely used by chemists and biologists to study sub-cellular molecules, including proteins, DNA, and RNA. In the most straightforward applications, fluorophores are appended to a bio-molecule of interest and used to image the bio-molecule's cellular location. The fluorescence imaging process involves the excitation of a fluorophore with a photon of energy, resulting in a brief (1-10 ns) excited state that is followed by the release of a photon with a second, lower energy.

Imagine that you are studying a protein involved in tumor metastasis (spreading). Based on previous studies, you hypothesize that the protein localizes to the nucleus in tumor cells. To determine the sub-cellular location of your protein, you label it with a fluorophore that can be excited by light in the range of 620. to 674 nm.

The lab's fluorescent microscope is currently set up with a He-Ne laser for excitation. The laser produces a beam of light with a per-photon energy of 3.14×10^{-19} J and an intensity of 13 W (J/s).

- (a) Calculate the wavelength of the light emitted by the He-Ne laser.
- (b) Does the He-Ne laser beam have an appropriate energy to excite your fluorophore (does it fall within the excitation range)?
- (c) Calculate the number of photons emitted by the laser per second.

F.

Proton therapy is a form of radiation therapy used to shrink tumors by aiming high-energy protons (H^+ atoms) at cancerous cells and thereby damaging DNA and promoting cell death. The large relative mass of hydrogen ions in comparison to x-rays results in minimal scattering in the tissue, meaning less damage to healthy tissue surrounding a target tumor. If a proton accelerator produces a beam of protons ($m_w = 1.008$ g/mol) with an average speed of 2.11×10^7 m/s, what is the wavelength of the protons?