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QUESTION 1

Due to ever-increasing paranoia about the transmission of hepatitis and AIDS via blood transfusions and the frequent difficulty of procuring matching blood donors for patients, researchers have been working at a feverish pace to produce disease-free and easy-to-use blood substitutes. The difficulty most synthetic blood researches have had is in formulating a substance that combines qualities of sterility, high capacity for carrying oxygen to body tissues, and versatility within the human body. Three major substitute technologies have been developed to date; each has certain advantages and shortcomings.

"Red blood," the first of the blood substitute technologies, is derived from hemoglobin which has been recycled from old, dead, or worn-out red blood cells and modified so that it can carry oxygen outside the red blood cell. Hemoglobin, a complex protein, is the blood\\'s natural oxygen carrier and is attractive to scientists for use in synthetic blood because of its oxygen-carrying capacity. However, hemoglobin can sometimes constitute a two-fold threat to humans when it is extracted from the red blood cell and introduced to the body in its naked form. First, hemoglobin molecules are rarely sterile and often remain contaminated by viruses to which they were exposed in the cell. Second, naked hemoglobin is extremely dangerous to the kidneys, causing blood flow at these organs to shut down and leading, ultimately, to renal failure. Additional problems arise from the fact that hemoglobin is adapted to operate optimally within the intricate environment of the red blood cell. Stripped of the protection of the cell, the hemoglobin molecule tends to suffer breakdown within several hours. Although modification has produced more durable hemoglobin molecules which do not cause renal failure, undesired side effects continue to plague patients and hinder the development of hemoglobin-based blood substitutes.

Another synthetic blood alternative, "white blood," is dependent on laboratory synthesized chemicals called perfluorocarbons (PFCs). Unlike blood, PFCs are clear oil like liquids, yet they are capable of absorbing quantities of oxygen up to 50% of their volume, enough of an oxygen carrying potential for oxygen-dependent organisms to survive submerged in the liquid for hours by "breathing" it. Although PFCs imitate real blood by effectively absorbing oxygen, scientists are primarily interested in them as constituents of blood substitutes because they are inherently safer to use than hemoglobin-based substitutes. PFCs do not interact with any chemicals in the body and can be manufactured in near-perfect sterility. The primary pitfall of PFCs is in their tendency to form globules in plasma that can block circulation. Dissolving PFCs in solution can mitigate globulation; however, this procedure also seriously curtails the PFCs\\' oxygen capacity.

The final and perhaps most ambitious attempt to form a blood substitute involves the synthesis of a modified version of human hemoglobin by genetically-altered bacteria. Fortunately, this synthetic hemoglobin seems to closely mimic the qualities of sterility, and durability outside the cellular environment, and the oxygen-carrying efficiency of blood. Furthermore, researchers have found that if modified hemoglobin genes are added to bacterial DNA, the bacteria will produce the desired product in copious quantities. This procedure is extremely challenging, however, because it requires the isolation of the human gene for the production of hemoglobin, and the modification of the gene to express a molecule that works without support from a living cell.

While all the above technologies have serious drawbacks and difficulties, work to perfect an ideal blood substitute continues. Scientists hope that in the near future safe synthetic blood transfusions may ease blood shortages and resolve the unavailability of various blood types.

The author mentions all of the following as weaknesses of synthetic bloods EXCEPT:

- A. naked hemoglobin can cause renal failure in humans.
- B. "red blood" can transmit viruses to a recipient.
- C. genetic engineering can be extremely difficult.
- D. "white blood" has a low oxygen-carrying potential.

Correct Answer: D



This is a detail question that requires you to identify the answer choice which is not a weakness of synthetic bloods. Choices (A) and (B) mention that naked hemoglobin can cause renal failure in humans and that "red blood\\'\\' can transmit viruses to a recipient. These facts are expressed in the second paragraph, which addresses red blood and the problems associated with it. The second half of that paragraph states that naked hemoglobin, the basis of "red blood", can constitute a two-fold threat to the human body as it can transmit viruses and is extremely dangerous to the kidneys, causing blood flow at these organs to shut down and results in renal failure. Choice (C) mentions that genetic engineering can be extremely difficult. Paragraph 4 is all about modified hemoglobin derived from genetically-altered bacteria. Its last sentence emphasizes the challenges associated with the to isolation and modification the human hemoglobin gene. Although, in theory, genetic engineering can produce near-ideal synthetic blood, you can infer that a drawback of this process is the complexity of these procedures. So choice (C) is also a weakness, and therefore does not complete this question stem. Choice (D) mentions that "white blood" has a low oxygen-carrying potential. Were this true, it certainly would be a weakness, as one of the chief criteria of synthetic blood is that it mimic blood in its high oxygen-carrying capacity. However, this statement is not true. The third paragraph, regarding "white blood,\\\\\ notes that PFCs, a primary component of "white blood", have high oxygen-carrying capacities. The second and third sentences of this paragraph state that PFCs are capable of absorbing quantities of oxygen up to 50% of their volume and imitate real blood by effectively absorbing oxygen. From this we can infer that "white blood\\'\\' is capable of transporting oxygen well. This contradicts choice (D). Since the passage never suggests that "white blood" has a low oxygen-carrying potential, choice (D) does not represent a weakness of synthetic blood and is the correct answer.

QUESTION 2

A continuous spectrum of light, sometimes called blackbody radiation, is emitted from a region of the Sun called the photosphere. Although the continuous spectrum contains light of all wavelengths, the intensity of the emitted light is much greater at some wavelengths than at others. The relationship between the most intense wavelength of blackbody radiation and the temperature of the emitting body is given by Wien\\'s law, $? = 2.9 \times 106 / T$, where ? is the wavelength in nanometers and T is the temperature in kelvins.

As the blackbody radiation from the Sun passes through the cooler gases in the Sun\\'s atmosphere, some of the photons are absorbed by the atoms in these gases. A photon will be absorbed if it has just enough energy to excite an electron from a lower energy state to a higher one. The absorbed photon will have an energy equal to the energy difference between these two states. The energy of a photon is given by E = hf = hc/? where $h = 6.63 \times 10-34$ J•s, Planck\\'s constant, and $c = 3 \times 108$ m/s, the speed of light in a vacuum.

The Sun is composed primarily of hydrogen. Electron transitions in the hydrogen atom from energy state n = 2 to higher energy states are listed below along with the energy of the absorbed photon:

Final Energy State Energy (x 10-19 J) n = 3

3.02 n = 4 4.08 n = 5 4.57 n = 6 4.84 n = ? 5.44

If the temperature of the Sun\\'s photosphere is 5800 K, what wavelength of radiation does the Sun emit with the



greatest	intensity?
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A. 2 nm
B. 50 nm
C. 500 nm
D. 4,500 nm
Correct Answer: C

QUESTION 3

Every atomic orbital contains plus and minus regions, defined by the value of the quantum mechanical function for electron density. When orbitals from different atoms overlap to form bonds, an equal number of new molecular orbitals results. These are of two types: or bonding orbitals, formed by overlap between orbital regions with the same sign, and antibonding * or * orbitals, formed by overlap between regions with opposite signs. Bonding orbitals have lower energy than their component atomic orbitals, and antibonding orbitals have higher energy. The electron pairs reside in the lower-energy bonding orbitals; the higher-energy, less stable orbitals remain empty when the molecule is in its ground state. A benzene ring has six unhybridized pz orbitals (one from each carbon atom), which together from six molecular orbitals, each one delocalized over the entire ring. Of the possible orbital structures for benzene, the one with the lowest energy has the plus region of all six p orbital functions on one side of the ring. The six electrons occupying the orbitals fill the three most stable molecular orbitals, leaving the other three empty. Molecular orbitals are filled from the lowest to the highest energy level. The number of bonds between atoms is determined by the number of filled bonding orbitals minus the number of filled antibonding orbitals; each antibonding orbitals; each antibonding orbital cancels out a filled bonding orbital. For a diatomic molecule, orbitals in the n = 2 energy level are filled as follows:

 $\sigma_{2s}, \sigma_{2s}^*, \sigma_{2s}^2, \sigma_{2pz}^2, \pi_{2px}^2$ and π_{2py}^2

*2px

p_z

(equal in energy), and * (equal in energy), *2 . (The designation of the three p orbitals as , , and are interchangeable.) Absorption of a photon can raise an electron to a higher-energy molecular orbital. The excited electron does not immediately change its spin, which is opposite to that of the electron with which it was previously paired. This singlet state is relatively unstable: the molecule may interact with another molecule, or fluoresce and return to its ground state. Alternatively, there may be a change in spin direction somewhere in the system; the molecule then enters the so-called triplet state, which generally has lower energy. The molecule now cannot return quickly to its ground state, since the excited electron no longer has a partner of opposite spin with which to pair. It also cannot return to the singlet state, because the singlet has greater energy. Consequently, the triplet state, which has two unpaired electrons in separate orbitals, is long-lived by atomic standards, with a lifetime that may be ten seconds or more. During this period, the molecule is highly reactive.

The quantum number that distinguishes the px orbital from the py orbital is called the:



- A. azimuthal quantum number.
- B. magnetic quantum number.
- C. principal quantum number.
- D. spin quantum number.

Correct Answer: B

This is straightforward question relying on your knowledge of quantum numbers. The first quantum number, n, is called the principal quantum number and determines which principal energy level the electron is in, n = 1, n = 2 etc. This does not help specify between the px and py orbital, thus it is not the answer we are looking for. The second quantum number is the azimuthal number designated by I. This determines the subshell s, p, d or f. The azimuthal quantum number, and it does not help us distinguish the px orbital from the py orbital, so we can rule choice A out. The third quantum number, the magnetic quantum number specifies the particular orbitals within a subshell and is given by ml. Each of these orbitals can hold two electrons. There\\'s only one orbital in an s subshell, in a p subshell there are three, in a d subshell there are five, and in an f subshell there are seven. The three p orbital, so choice B is the correct answer. The fourth quantum number, known as ms, tells us whether the electron has a plus or minus spin. Each orbital when filled contains two electrons of opposite spins. Thus it is choice B, the magnetic quantum number, ml, that distinguishes the x, y, and z orbitals of the p subshell.

QUESTION 4

Light traveling from air into a new medium is refracted away from the normal. This medium might be:

A. glass.

B. water.

C. steel.

D. a vacuum.

Correct Answer: D

The question is about refraction, which is the process that bends light as it travels from one medium into another. Snell\\'s law n1sin 1 = n2 sin 2 describes this process, where n1 and n2 are the indices of refraction of the two media, and 1 and 2 are the angles that the light rays make with the normal to the interface between the two media. This law predicts that light traveling into a medium with a higher index of refraction will be refracted towards the normal. Light traveling into a medium with a lower index of refraction will be refracted away from the normal. In the question, the light is refracted away from the normal, so the new medium must have an index of refraction lower than air. The vacuum has the lowest index of refraction possible, n = 1, so choice D is correct.

Steel is opaque, so light will not travel through it at all. The steel surface will absorb or reflect light, not refract it, so choice C is wrong. Water and glass both have indices of refraction that are higher than air, so both choices A and B are wrong. Note that even if you did not remember whether higher indices cause refraction towards or away from the normal, you could have eliminated choices A and B because they both would bend the light in the same direction, and both cannot be right.

QUESTION 5



Hypoxia refers to a physiological condition in which the body lacks sufficient oxygen for normal cellular functioning. Prolonged hypoxia generally leads to an inhibition of mental capacity and a reduction in the work capacity of muscle. Severe cases of hypoxia can lead to coma or even death. Depending on the cause, hypoxia can be classified into four general types:

Hypoxic hypoxia is a type of hypoxia that occurs when the partial pressure of oxygen in the blood is too low. For example, climbers at high altitude, where the air contains less oxygen, might experience hypoxic hypoxia because the partial pressure of oxygen in the air inhaled is very low, leading to insufficient partial pressure of oxygen in the blood.

Anemic hypoxia describes a diminished ability of the blood to transport oxygen. Several factors can influence the oxygen-carrying capacity of the blood. Primary causes of anemic hypoxia include a lower than normal number of functional erythrocytes or an insufficient quantity of hemoglobin, the oxygen- carrying molecules of the blood. Abnormal hemoglobin can also decrease the blood\\'s capacity to carry oxygen and lead to anemic hypoxia.

Ischemic hypoxia is caused by a decreased delivery of blood to the tissues. Localized circulatory deficiencies, such as blood clots, and global circulatory deficiencies, such as heart failure, decrease the delivery of blood to the tissues, and can therefore cause ischemic hypoxia.

Histotoxic hypoxia results from the inability of cells to utilize the oxygen available in the blood. Causes of histotoxic hypoxia include the poisoning of cellular enzymes involved in aerobic respiration, as well as the decreased metabolic capacity of the oxidative enzymes due to vitamin deficiency. Cyanide poisoning causes histotoxic hypoxia by blocking the action of cytochrome oxidase in the electron transport chain so that tissues cannot use oxygen even though it is available.

Cigarette smoking causes emphysema, a condition in which the net surface area of the lungs is greatly decreased leading to a decrease in the diffusing capacity of the lungs.

Emphysema leads to which type of hypoxia?

- A. Hypoxic hypoxia
- B. Anemic hypoxia
- C. Ischemic hypoxia
- D. Histotoxic hypoxia

Correct Answer: A

The passage states that hypoxic hypoxia is caused by any factor that leads to a decreased plasma pO2. Since emphysema decreases the diffusing capacity of the lungs, less oxygen will diffuse into the blood, leading to a lower pO2. Choice B is incorrect because anemic hypoxia is caused by a decreased oxygen carrying capacity of the blood. Emphysema affects the amount of oxygen in the blood, not the ability of the blood to carry oxygen. Choice C is incorrect because ischemic hypoxia is caused by a decreased delivery of blood to the tissues. Emphysema has no effect on blood circulation. Choice D is incorrect because histotoxic hypoxia is caused by the inability of the tissues to utilize oxygen. Emphysema does not affect the ability of the tissues to use oxygen.

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