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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.

According to the passage, how much oxygen can be absorbed by a 300 cc sample of PFC?

A. 50 cc

B. 100 cc

C. 150 cc D. 300 cc

Correct Answer: C

This is an application question which requires you to apply information from the passage to solve a problem. The passage mentions that PFCs are capable of absorbing quantities of oxygen up to 50% of their volume. Applying this information, then, a 300 cc sample of PFC can absorb up to 150 cc, 50% of 300 cc. The correct answer, then, is choice (C), 150 cc.

QUESTION 2

Sugars are carbohydrates, that is, molecules usually with the empirical formula C(H2O), and structural formulas made up of polyhydroxy aldehydes or ketones. Because of their polyfunctional nature, sugars can undergo a wide variety of

transformations upon treatment with acids, bases, or heat, and upon reaction with other simple reagents and enzymes. While many sugars occur in nature and are thus readily available, the synthesis and modification of simple sugars is a

necessary step in studies of enzymatic processes.

Higher sugars can be synthesized from the simple carbohydrate D-glyceraldehyde with the following procedure:

D-glyceraldehyde (Compound A) is reacted with HCN to produce a cyanohydrin (Compound B). Compound B is then treated with hydrogen gas and a modified palladium catalyst (similar to the Lindlar reagent) to give Compound C.

Compound C is hydrolyzed to give the higher sugars in Mixture D. This reaction is summarized in Figure 1. Mixture D contains two compounds, which can be separated by crystallization. Two doublets near 9.5 (, ppm) are observed in the 1H

NMR spectrum of mixture D, with each doublet corresponding to one of the two products present in the mixture. IR spectroscopy shows broad absorptions for both products around 3300 cm?.

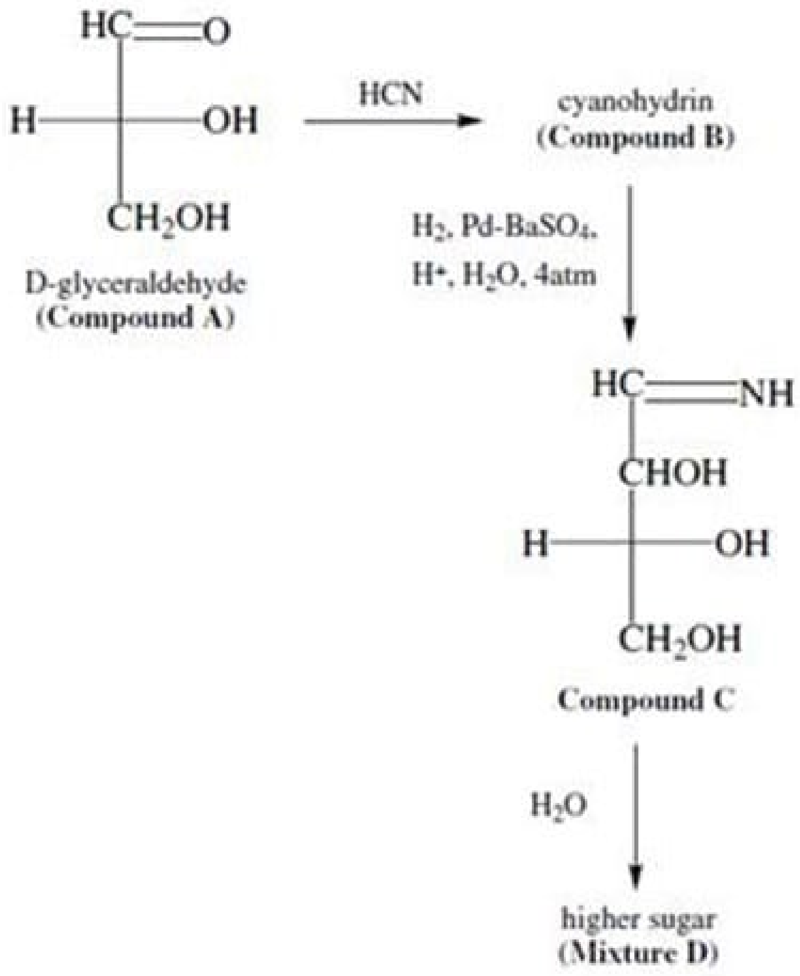


Figure 1 Synthesis of higher sugar

The hydroxyl groups of carbohydrates can also participate in reactions. For example, D-glyceraldehyde can react with chloromethane under basic conditions to yield a completely methylated product. This SN2 reaction is shown in Figure 2.

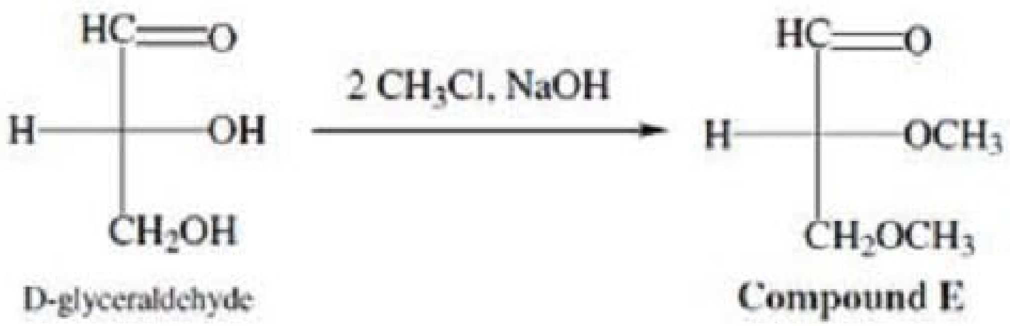
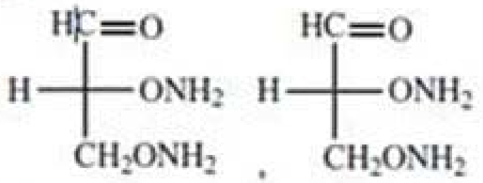


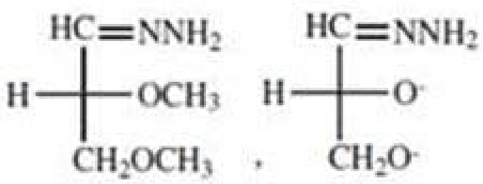
Figure 2 Methylation of D-glyceraldehyde

What are the missing compounds, respectively, in the following reaction?

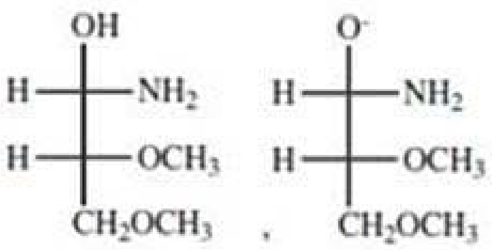
A.



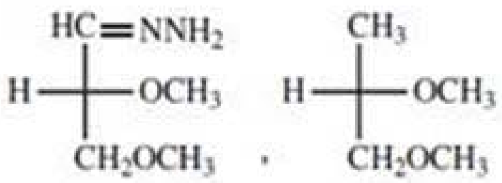
B.



C.



D.



A. Option A

B. Option B

C. Option C

D. Option D

Correct Answer: D

This reaction is called the Wolff-Kishner Reduction and reduces a carbonyl group to the corresponding alkane. The first step, reaction with hydrazine, leads to the formation of a hydrazone. The second step occurs in basic solution and leads

to the evolution of nitrogen gas and the formation of the corresponding hydrocarbon.

Choice A is incorrect because the indicated structures do not form. Choice B is incorrect because ethers do not form alkoxides under basic conditions. Ethers are relatively unreactive.

Choice C is incorrect because hydrazine reacts with a carbonyl to form hydrazone. This is a condensation reaction, not an addition reaction, and the addition product shown would not form.

QUESTION 3

Tetrodotoxin, the extremely potent poison produced by the puffer (fugu) fish, binds tightly to Na+ channels and blocks the flow of Na+ ions but does not affect K+ or Cl- channels. Tetrodotoxin directly blocks which phase of action potential propagation?

A. Depolarization

B. Repolarization

C. Hyperpolarization

D. Saltatory conduction

Correct Answer: A

An action potential begins with the opening of voltage gated sodium channels that allow sodium to flow into the axon, depolarizing the cell. This is followed by opening of potassium channels that allow potassium to flow out of the cell,

repolarizing it. Blocking the sodium channels would block depolarization. Choice B is incorrect because repolarization is achieved primarily by opening potassium channels. Choice C is incorrect because hyperpolarization is also due primarily

to the flux of potassium ions out of the axon.

Choice D is incorrect because saltatory conduction refers to conduction between nodes of Ranvier in myelinated fibers.

QUESTION 4

Fireworks have been used for centuries in celebrations around the world. One of the primary components of these devices, black powder, was developed by the Chinese over a thousand years ago and is still used today as a propellant and explosive. Black powder is composed of potassium nitrate (KNO3), charcoal (primarily C) and sulfur (S8) in a 75:15:10 ratio by weight. It is very stable if kept dry but can easily be ignited by a spark or burning fuse to undergo the following reaction:

$$2KNO_3 + 3C + S \rightarrow N_2 + 3CO_2 + K_2S$$

Reaction 1 The basic firework is shown in Figure 1. Fireworks rely on a particular kind of combustion in which oxygen is supplied by oxidizing agents included in the pyrotechnic mixture. When ignited, the solid propellant begins to liquefy and vaporize allowing the fuel and oxidizing agents to interact more intimately leading to rapid expansion of gases. Delay fuses time the ignition of the other compartments to occur when the shell is high above ground.

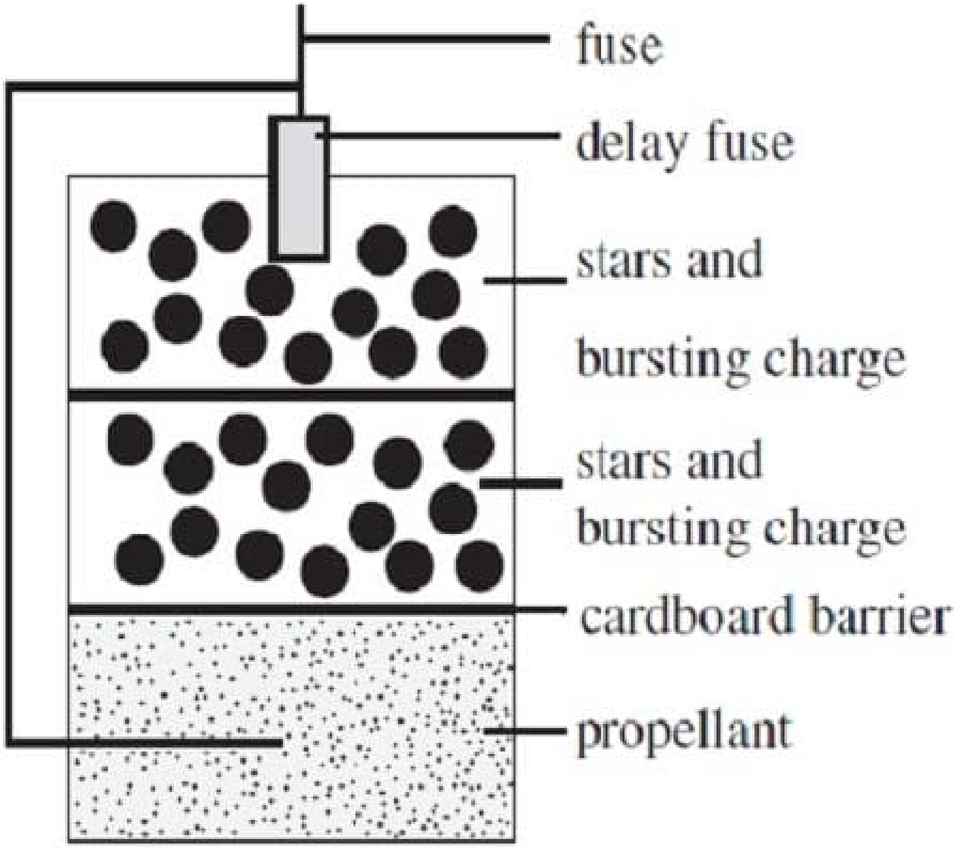


Figure 1

The light generating units of the firework are called stars and are dispersed and ignited by the bursting charge in each compartment. The intense colors of modern fireworks are generated by molecular emitters. For example, barium chloride emits green light (510?30 nm) and strontium chloride emits vibrant red light (605?50 nm). Many of the molecular emitters are unstable at room temperature and so cannot be placed directly into the firework. Instead, they are synthesized in the flame of the pyrotechnic reaction and exist for a short time before decomposing. The flame temperature must be carefully adjusted so that these emitters do not decompose too rapidly.

$(h = 6.63 \times 10^{-34} \text{J} \cdot \text{s}, c = 3.0 \times 10^{8} ms^{-1})$

The molar ratio of N to C to S in black powder is approximately:

A. 75:125:35

B. 85:10:210

C. 75:15:10

D. 100:20:7

Correct Answer: A

The passage gives the composition by weight of black powder as 75:15:10, potassium nitrate:charcoal: S8. Let\\'s assume we have 100 grams of black powder, composed of 75 grams of potassium nitrate, 15 grams of charcoal, and 10 grams of S8. First, we must determine the mass of one mole of each of the materials from the periodic table:

$$KNO_3: 39.1 + 14 + 3(16 = 101.1\frac{grams}{mol})$$

$$C: 12\frac{grams}{mol}$$

$$S_8: 8(32) = 256\frac{grams}{mol}$$

Now we can determine how many moles of each material is present by dividing the mass by the mass per mole:

$$\text{moles of } KNO_3 = \frac{75}{101} \approx 0.75 \text{ mol N}$$

$$\text{moles of C} = \frac{15}{12} \approx 1.25 \text{ mol C}$$

$$\text{moles of } S_8 = \frac{10}{256} \approx 0.04 \text{ mol} = 8(.04) = 0.32 \text{ mol S}$$

Therefore, our mole ratio is 0.75:1.25:0.32, or 75:125:32.

QUESTION 5

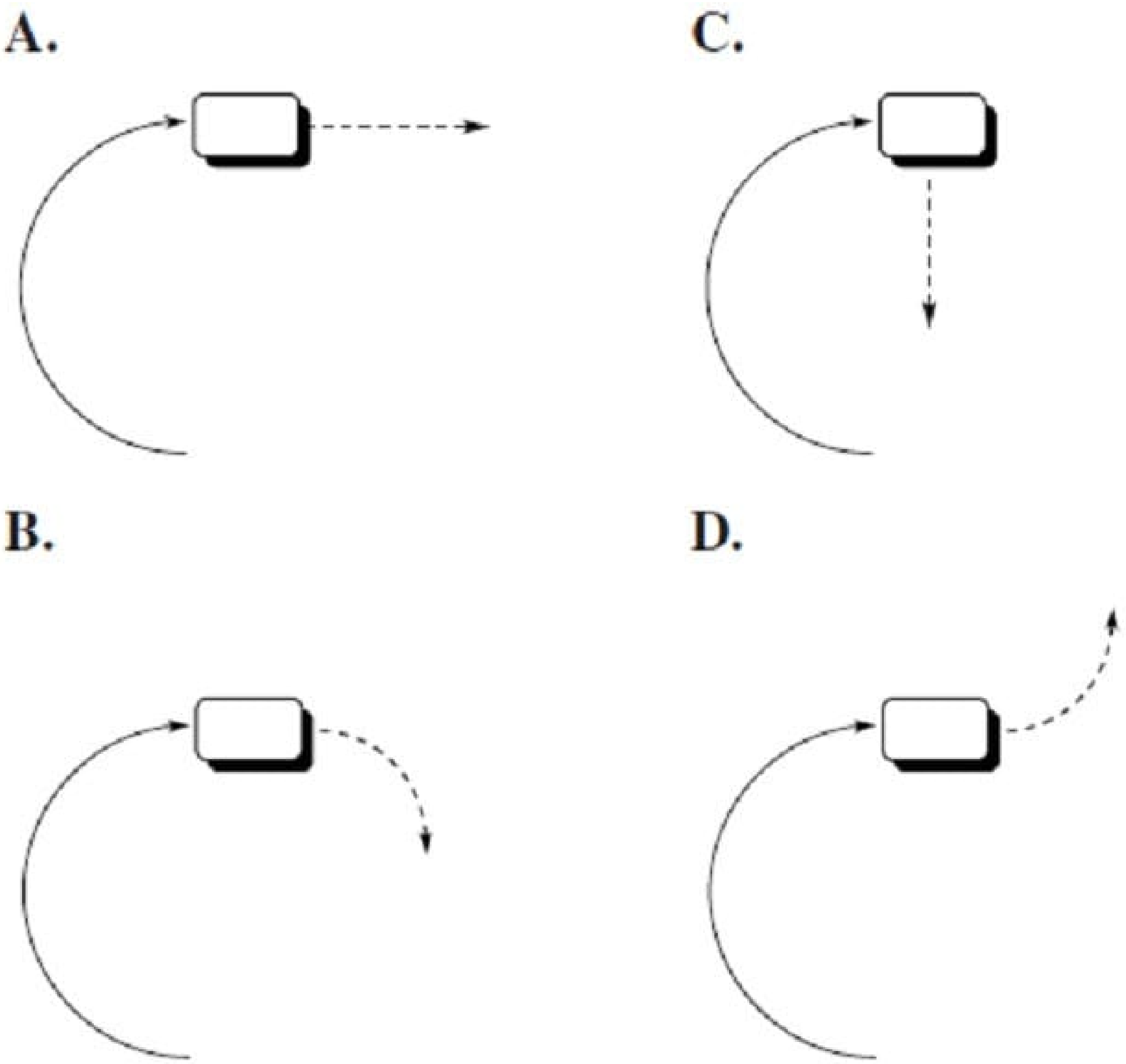
A hovercraft is a versatile vehicle capable of traveling over land, water, or any other essentially flat surface. The hovercraft consists of a body or hull onto which a rotor (lift fan) is mounted. The lift fan provides the vertical lift by propelling air into an area beneath the hovercraft called the skirt. The pocket of air in the skirt supports the moving hovercraft and reduces the friction between the vehicle and the ground to almost zero. As such, there is no contact between the hovercraft and the ground.

A second fan, which generates a horizontal thrust, propels the hovercraft forward. Rudders which direct the airflow from this second fan are used by the pilot to control the movement of the hovercraft. The horizontal movement of the

$$(1 \text{ atm} = 1.01 \times 10^5 \text{ Pa} = 1.01 \times 10^5 \text{ N/m}^2)$$

hovercraft is opposed by air resistance which generates aerodynamic drag.

The horizontal thrust fan of a hovercraft traveling across a frozen lake in a large circle suddenly fails. Which of the following best describes the path of the hovercraft (as one looks down from above) immediately following thrust fan shutoff?



A. Option A

B. Option B

C. Option C

D. Option D

Correct Answer: A

When the thrust fan is shut off, there will no longer be a centripetal force to sustain the hovercraft in its circular motion. Thus, it will proceed in a straight line tangent to its path at the moment the fan is turned off.Choice B is incorrect because a force (centripetal force) is required to cause an object to move in a circle. No such force is being applied to the hovercraft after the thrust fan is shut off.Choice C is incorrect. This arrow indicates the direction of a centripetal force required to keep an object moving in a circle. This would be the force generated by the thrust fan before it is shut off.Choice D is incorrect because a force directed out of the circle would be required to cause the hovercraft to follow this path. No such force exists in this scenario.