MCAT-TEST Q&As

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QUESTION 1

The Earth\\'s atmosphere reaches hundreds of kilometers above the surface of the planet. The lowest layer, the troposphere, extends from the ground to a height of approximately 12 km. Air pressure within the troposphere decreases with height above the ground, accompanied by a parallel trend in air density. The decrease in density has important consequences for the dissipation of air pollution from industrial smoke stacks. The gas from the stack is typically hotter and less dense than the surrounding air and rises. As a parcel of hot air rises, it expands approximately adiabatically doing work on the surrounding air. This results in a decrease in both its temperature and its density.

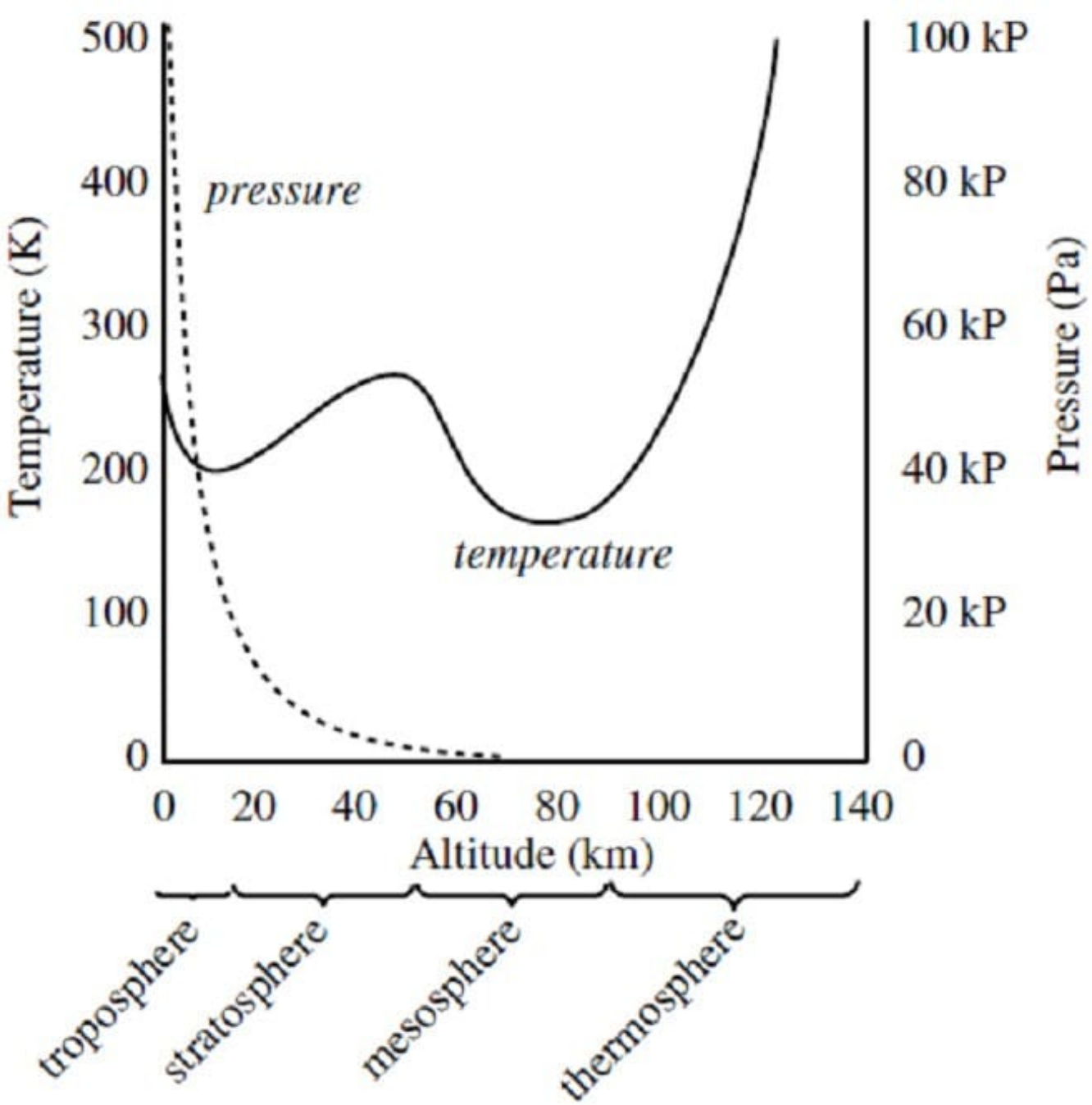


Figure 1 A smoke stack functions to expel gaseous waste products from a chemical process. It is also an important means of removing heat from a reaction mixture. The heat corresponding to a change in temperature of a gas at

constant pressure is

$$Q = nC_p\Delta T$$

Q

given by , where is the heat added to the gas, n is the number of moles of gas, is the molar heat capacity of a particular gas at constant pressure, and T is the change in temperature. At atmospheric pressure, the

H_2

molar heat capacity for steam, O (g) is approximately four times that of air.

C_p

At constant pressure, the ratio between the volume expansion of a mole of gas with a high to that of a mole of gas with a low for a given heat input will be:

A. greater than 1.

B. less than 1.

C. equal to 1.

D. cannot be determined.

Correct Answer: B

$$Q = nC_p\Delta T$$

The passage provides the equation . A gas with a high Cp will have a smaller change in temperature for a given Q than a gas with a low Cp. Change in temperature is directly proportional to change in volume (at constant pressure). Charles\\' Law describes this relationship:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

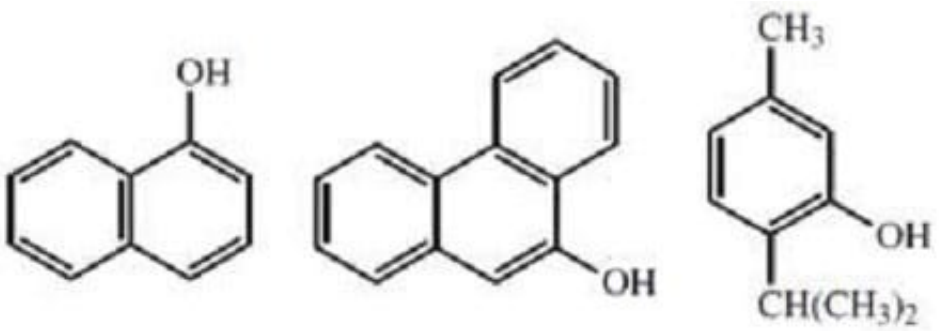
Thus, the gas with the high Cp will expand less than a gas with a low Cp and the ratio of this expansion will be less than 1.

$$\frac{expansion\ of\ high\ C_p}{expansion\ of\ low\ C_p} < 1$$

QUESTION 2

Compounds containing a hydroxyl group attached to a benzene ring are called phenols. Derivatives of phenols, such as

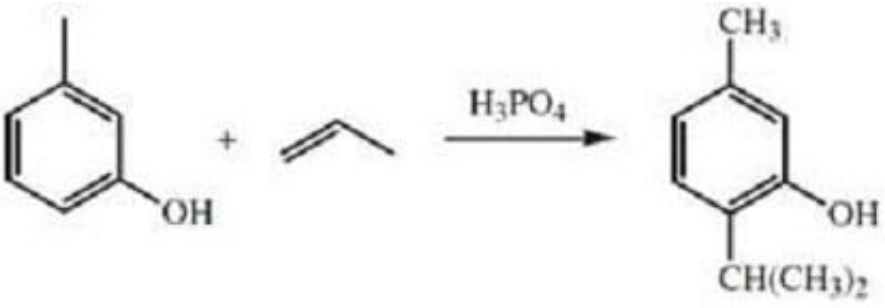
naphthols and phenanthrols, have chemical properties similar to those of phenols, as do most of the many naturally-occurring substituted phenols. Like other alcohols, phenols have higher boiling points than hydrocarbons of similar molecular weight. Like carboxylic acids, phenols are more acidic than their alcohol counterparts. Phenols undergo a number of different reactions; both their hydroxyl groups and their benzene rings are highly reactive. A number of chemical tests can be used to distinguish phenols from alcohols and carboxylic acids.



naphthol phenanthrol thymol

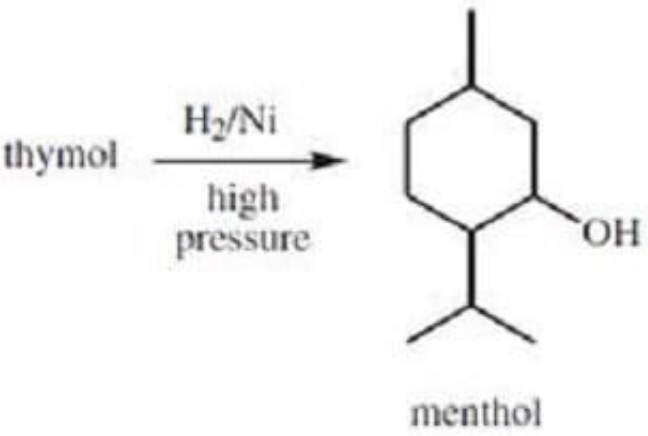
Thymol, a naturally occurring phenol, is an effective disinfectant that is obtained from thyme oil. Thymol can also be synthesized from m-cresol, as shown in Reaction A below. Thymol can then be converted to menthol, another naturally-occurring organic compound; this conversion is shown in Reaction B.

Reaction A



m-cresol thymol

Reaction B



menthol

Reaction A is an example of:

A. a free radical substitution.

B. an electrophilic aromatic substitution.

C. an electrophilic addition.

D. a nucleophilic aromatic substitution.

Correct Answer: B

Reaction A is an electrophilic aromatic substitution reaction, in which thymol is formed from meta-cresol. Both the methyl and hydroxyl substituents in meta-cresol are ortho-para directing activators. However, hydroxyl is the more powerful of the two and if you look at reaction A you can see that substitution occurs ortho to the hydroxyl group. However, we are not too concerned about substituent effects but rather the mechanism of the reaction, so let\\'s briefly review what happens. Initially, phosphoric acid abstracts an electron from propene creating a secondary carbocation. This carbocation then acts as an electrophile and adds to the electron rich benzene ring, ortho to the hydroxyl group. This results in the formation of an arenium ion and aromaticity is regained by loss of a proton, generating thymol. Therefore, this mechanism is electrophilic aromatic substitution -- making choice B the correct answer. From this mechanism, it should be pretty easy to eliminate the other answer choices. Choice C is wrong, because although the carbocation adds to the ring, a proton is lost in order to regain aromaticity. Therefore, this is an example of substitution NOT addition. Choice D is wrong because the carbocation which adds to the ring is acting as an electrophile, not a nucleophile. Remember that benzene is electron rich, and the substituents on meta- cresol enhance this, so there is no way that meta-cresol could be susceptible to nucleophilic attack. Finally, choice A -- free radical substitution -- is also wrong. There is nothing in reaction A to suggest that free radicals are formed and phosphoric acid will not induce radical formation.

QUESTION 3

Although we know more about so-called Neanderthal men than about any other early population, their exact relation to present-day human beings remains unclear. Long considered sub-human, Neanderthals are now known to have been fully human. They walked erect, used fire, and made a variety of tools. They lived partly in the open and partly in caves. The Neanderthals are even thought to have been the first humans to bury their dead, a practice which has been interpreted as demonstrating the capacity for religious and abstract thought. The first monograph on Neanderthal anatomy, published by Marcelling Boule in 1913, presented a somewhat misleading picture. Boule took the Neanderthals\\' lowvaulted cranium and prominent brow ridges, their heavy musculature, and the apparent overdevelopment of certain joints as evidence of a prehuman physical appearance. In postulating for the Neanderthal such "primitive" characteristics as a stooping, bent-kneed posture, a rolling gait, and a forward-hanging head, Boule was a victim of the rudimentary state of anatomical science. Modern anthropologists recognize the Neanderthal bone structure as that of a creature whose bodily orientation and capacities were very similar to those of present-day human beings. The differences in the size and shape of the limbs, shoulder blades, and other body parts are simply adaptations which were necessary to handle the Neanderthal\\'s far more massive musculature. Current taxonomy considers the Neanderthals to have been fully human and thus designates them not as a separate species, Homo neanderthalensis, but as a subspecies of Homo sapiens: Homo sapiens neanderthalensis. The rise of the Neanderthals occurred over some 100,000 years -- a sufficient period to account for evolution of the specifically Neanderthal characteristics through free interbreeding over a broad geographical range. Fossil evidence suggests that the Neanderthals inhabited a vast area from Europe through the Middle East and into Central Asia from approximately 100,000 years ago until 35,000 years ago. Then, within a brief period of five to ten thousand years, they disappeared. Modern human, not found in Europe prior to about 33,000 years ago, thenceforth became the sole inhabitants of the region. Anthropologists do not believe that the Neanderthals evolved into modern human beings. Despite the similarities between Neanderthal and modern human anatomy, the differences are great enough that, among a population as broad-ranging as the Neanderthals, such an evolution could not have taken place in a period of only ten thousand years. Furthermore, no fossils of types intermediate between Neanderthals and moderns have been found. A major alternative hypothesis, advanced by E. Trinkaus and W.W. Howells, is that of localized evolution. Within a geographically concentrated

population, free interbreeding could have produced far more pronounced genetic effects within a shorter time. Thus modern human could have evolved relatively quickly, either from Neanderthals or from some other ancestral type, in isolation from the main Neanderthal population. These humans may have migrated throughout the Neanderthal areas, where they displaced or absorbed the original inhabitants. One hypothesis suggests that these "modern" humans immigrated to Europe from the Middle East. No satisfactory explanation of why modern human beings replaced the Neanderthals has yet been found. Some have speculated that the modern humans wiped out the Neanderthals in warfare; however, there exists no archeological evidence of a hostile encounter. It has also been suggested that the Neanderthals failed to adapt to the onset of the last Ice Age; yet their thick bodies should have been heat-conserving and thus well-adapted to extreme cold. Finally, it is possible that the improved tools and hunting implements of the late Neanderthal period made the powerful Neanderthal physique less of an advantage than it had been previously. At the same time, the Neanderthals\\' need for a heavy diet to sustain this physique put them at a disadvantage compared to the less massive moderns. If this was the case, then it was improvements in human culture -- including some introduced by the Neanderthals themselves -- that made the Neanderthal obsolete.

According to the passage, the latest that any Neanderthal might have existed was:

A. 100,000 years ago.

B. 35,000 years ago.

C. 33,000 years ago.

D. 25,000 years ago.

Correct Answer: D

According to the third paragraph, Neanderthals inhabited a vast area from 100,000 to 35,000 years ago and then disappeared within a period of five to ten thousand years. If they actually took the whole 10,000 years to disappear, that means the latest any Neanderthal could have existed was 25,000 years ago (Choice D).

QUESTION 4

The polymerase chain reaction (PCR) is a powerful biological tool that allows the rapid amplification of any fragment of DNA without purification. In PCR, DNA primers are made to flank the specific DNA sequence to be amplified. These primers are then extended to the end of the DNA molecule with the use of a heat- resistant DNA polymerase. The newly synthesized DNA strand is then used as the template to undergo another round of replication.

The 1st step in PCR is the melting of the target DNA into 2 single strands by heating the reaction mixture to approximately 94 oC, and then rapidly cooling the mixture to allow annealing of the DNA primers to their specific locations. Once the primer has annealed, the temperature is elevated to 72 oC to allow optimal activity of the DNA polymerase. The polymerase will continue to add nucleotides until the entire complimentary strand of the template is completed at which point the cycle is repeated (Figure 1)

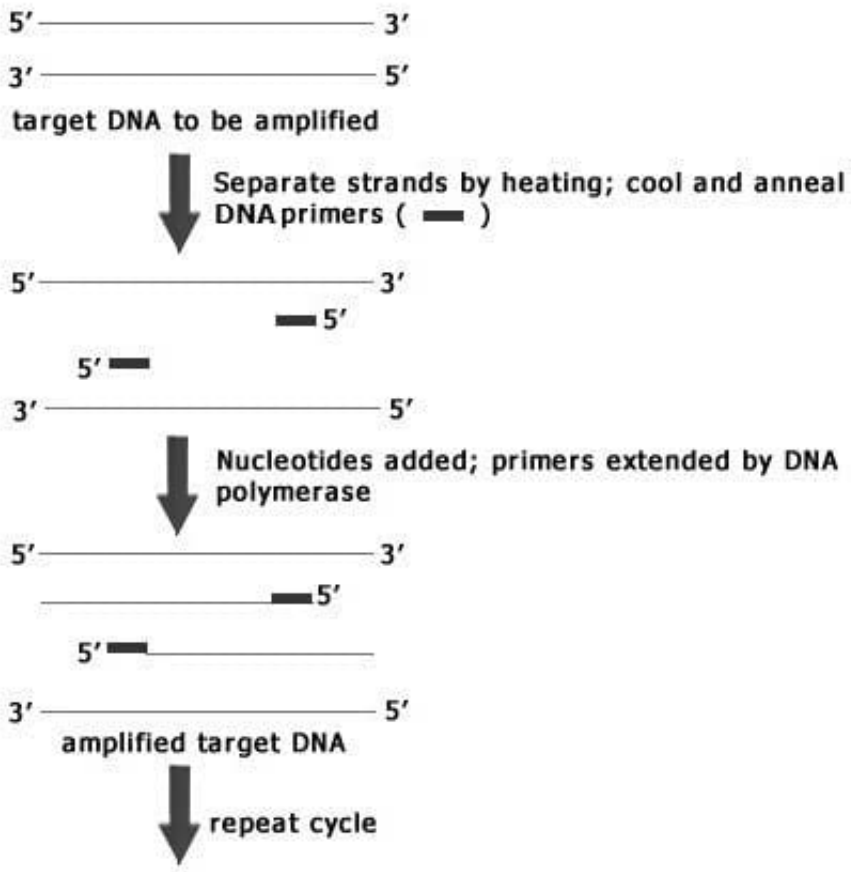


Figure 1

One of the uses of PCR is sex determination, which requires amplification of intron 1 of the amelogenin gene. This gene found on the X-Y homologous chromosomes has a 184 base pair deletion on the Y homologue. Therefore, by amplifying intron 1 females can be distinguished from males by the fact that males will have 2 different sizes of the amplified DNA while females will only have 1 unique fragment size.

Which of the following statements could be used to correctly describe the overall polymerase chain reaction?

A. It is an anabolic reaction that breaks down new DNA strands.

B. It is an anabolic reaction that synthesizes new DNA strands.

C. It is a catabolic reaction that breaks down new DNA strands.

D. It is a catabolic reaction that synthesizes new DNA strands.

Correct Answer: B

This question requires knowledge of the definition of anabolism and catabolism. A catabolic reaction involves the breakdown of macromolecules, whereas an anabolic reaction involves the synthesis of macromolecules from individual building blocks. PCR entails the synthesis (amplification) of a new DNA strand using a DNA template and free nucleotides, therefore, it is an anabolic reaction that synthesizes new DNA strands.

QUESTION 5

The frequency of second\\'s pendulum is:

A. 2 Hertz

B. 0.5 Hertz

C. 1 Hertz

D. 0.25 Hertz

Correct Answer: B