MCAT-TEST Q&As

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QUESTION 1

Which one of the following is electron deficient?

A. NH_3

B. PH_3

C. BCl_3

D. PCl_3

Correct Answer: C

QUESTION 2

When glucose is heated with Fehling\\'s solution, the colour of the precipitate obtained is:

A. black.

B. yellow.

C. red.

D. white.

Correct Answer: C

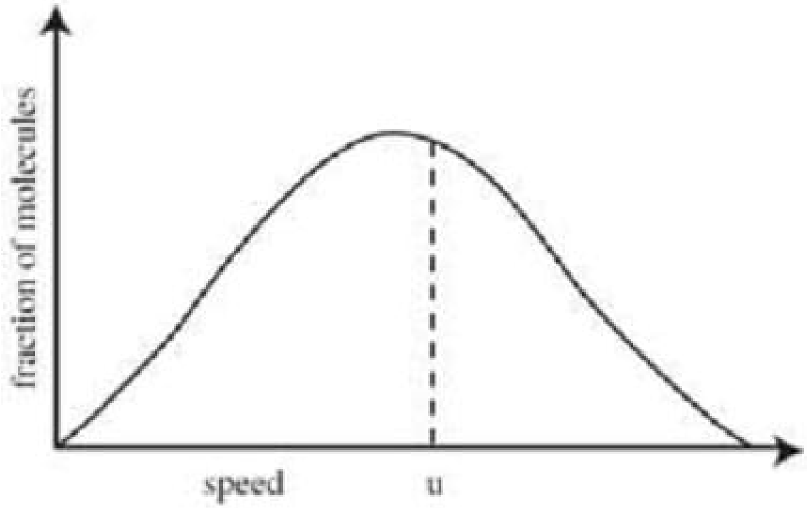
QUESTION 3

The equation of state of an ideal gas is given by the ideal gas law:

$PV = nRT$

where P is the pressure, V is the volume, n is the number of moles of gas, R is the ideal gas constant, and T is the temperature of the gas. The gas particles in a container are constantly moving at various speeds. These speeds are

characterized by the Maxwell shown in the figure below.



If two particles collide, their velocities change. However, if the gas is in thermal equilibrium, the velocity distribution of the gas as a whole will remain unchanged by the collision. The average kinetic energy (E) of a gas particle is given by:

$$E=\left(\frac{1}{2}\right) mu^2$$

Equation 1

where m is the mass of one particle and u is the root mean square speed (rms speed) of the gas particles: where N is the number of gas particles;

$$\text{(i.e., } u = [({v_1}^2 + {v_2}^2 + \cdots {v_n}^2 IN]^{\frac{1}{2}},$$

this is different from the average speed). For an ideal gas, the kinetic energy of all the particles is:

$$E_{total} = \frac{3}{2} nRT$$

Equation 2

where n is the number of moles of gas. Combining these equations gives:

$$u = (3RT/M)^{\frac{1}{2}}$$

Equation 3

where M is the molar mass of the gas particles.

The average distance a particle travels between collisions is known as the mean free path l. Intuitively, the mean free path (mfp) could be expected to be larger for gases at low pressure, since there is a lot of space between particles.

Similarly, the mfp should be larger when the gas particles are small. The following expression for the mfp shows this to be correct.

$$l = \frac{\hat{k}T}{\sqrt{2\pi s^2 P}}$$

Equation 4 In this equation, s is the atomic diameter (typically on the order of 10?), k is the Boltzmann constant, and P is the pressure. In addition to colliding with one another, gas particles also collide with the walls of their container. If the container wall has a pinhole that is small compared to the mfp of the gas, and a pressure differential exists across the wall, the particles will effuse (or escape) through this pinhole without disturbing the Maxwellian distribution of the particles. The rate of effusion can be described by:

$$\frac{\Delta n_{eff}}{\Delta t} = \frac{A(P - P^1)}{\sqrt{2\pi MRT}}$$

Equation 5

Where neff is the number of moles of effusing particles, A is the area of the pinhole, p and p1 are the pressures on the inside and outside of the container wall respectively, and p>p1.

The mean free path of a gas will be longer if the :

A. pressure of the gas is increased.

B. number of gas particles per unit volume is increased.

C. distance between collisions is decreased.

D. pressure of the gas is decreased.

Correct Answer: D

The mean free path of a particle is the average distance the particle can travel before it collides with another gas particle or the wall of the container. The longer the distance that a gas particle travels between collisions, the further apart the individual gas molecules must be. That means that the volume of the gas must increase to increase the distance between collisions. One way to increase the volume is to decrease the pressure of the gas, so D is correct. Choice A is incorrect because an increase in pressure leads to a decrease in the volume and thus a decrease in mean free path as well. Thus the gas particles are closer together and are more likely to collide, decreasing the average distance they travel between collisions. Choice B is incorrect because if the number of particles is increased while the volume remains constant, the likelihood of a collision will also increase. The pressure also increases as the number of particles per unit volume increases. Choice C is incorrect because the mean free path is analogous to the distance between collisions and if this is decreased then the mean free path decreases s well. Basically, choices A, B and C will all decrease the mean free path of a gas, making them all incorrect.

QUESTION 4

There are two opposing theories of light: the particle theory and the wave theory. According to the particle theory, light is composed of a stream of tiny particles that are subject to the same physical laws as other types of elementary particles.

One consequence of this is that light particles should travel in a straight line unless an external force acts on them. According to the wave theory, light is a wave that shares the characteristics of other waves. Among other things, this means

that light waves should interfere with each other under certain conditions.

In support of the wave theory of light, Thomas Young\\'s double slit experiment proves that light does indeed exhibit interference. Figure 1 shows the essential features of the experiment. Parallel rays of monochromatic light pass through two

narrow slits and are projected onto a screen. Constructive interference occurs at certain points on the screen, producing bright areas of maximum light intensity. Between these maxima, destructive interference produces light intensity minima.

The positions of the maxima are given by the equation dsin = n, where d is the distance between the slits, is the angle shown in Figure 1, the integer n specifies the particular maxima, and is the wavelength of the incident light. (Note: sin tan

for small angles.)

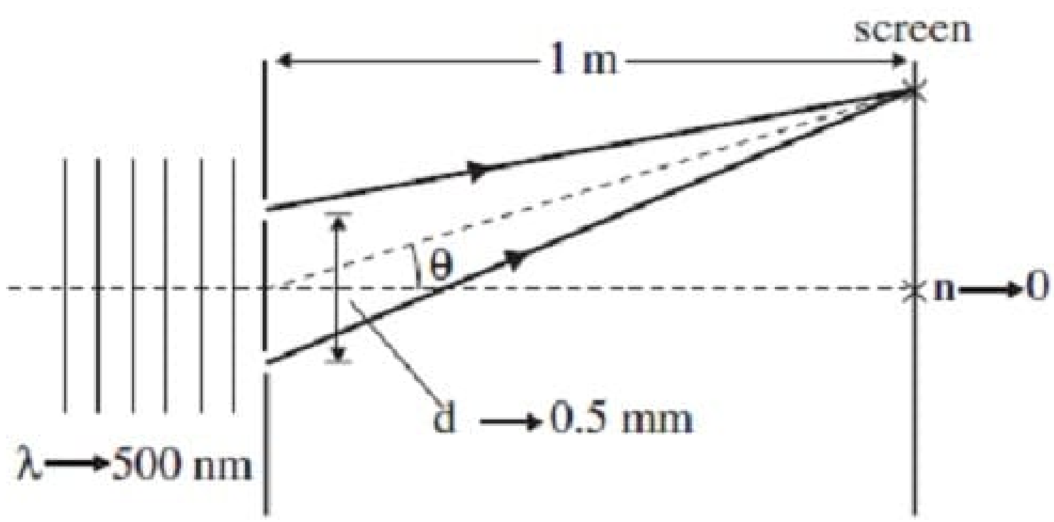


Figure 1

A beam of electrons can also produce an interference pattern. Which one of the following expressions gives a consistent definition of an electron\\'s "wavelength" if it has a total energy given by E? (Note: h = 6.6 ?10-34 J?s is Planck\\'s constant and v is the speed of the electrons.)

A. hvE

B. hE/v

C. hv/E

D. E/hv

Correct Answer: C

The easiest way to solve the problem is to check the units of each of the answers, a process called dimensional analysis. Since wavelength is measured in meters, the correct answer will be in meters as well. First, note that h has the units of

J?s, and v, a speed, has the units of m/s. Then, choice C has the units of hv/E = (J?s)(m/s)/J = m, so it is correct. The other choices are incorrect.

Choice A has the units of hvE = (J?s)(m/s)(J) = J2m. Choice B has =

$$\frac{hE}{v} = \frac{(J \bullet s)(J)}{(m/s)} = \frac{(J \bullet s)(kg \bullet m^2/s^2)}{(m/s)} = (J \bullet kg)m$$

Choice D has the units of E/hv = J/[(J?s)(m/s)] = m-1

Another way to solve the problem is to recall that the photon energy E is given by E = hc/, where c is the speed of light, and is the photon\\'s wavelength. Solving for , we obtain = hc/ E. To find the "wavelength" of an electron, replace the speed of light c with the speed of the electron v, and obtain = hv/E, where E is now the energy of the electron. Again, this is choice C.

QUESTION 5

A student conducts a chemical analysis of the components of a popular soft drink. The beverage label shows that the drink contains carbonated water, phosphoric acid, caffeine, and caramel color, but does not indicate the concentrations of these chemicals.

	Carbonic Acid	Phosphoric Acid
MW	62.03	98.00
mp (°C)	n/a	42.35
K_a	(1) 4.3×10^{-7} (2) 5.61×10^{-11}	(1) 7.52×10^{-4} (2) 6.23×10^{-8} (3) 2.2×10^{-13}
Formula	H_2CO_3	H_3PO_4

Table 1

Dissolved carbon dioxide will react reversibly with water to form carbonic acid. In an attempt to analyze the beverage composition, the student conducts the following experiments on a one liter sample of the beverage.

Experiment 1

The sample is placed in a sealed beaker cooled to 10?C and a vacuum is created in the space above the beverage. The gas pumped from this space is passed through a solution of BaCl2, producing a white precipitate. The process

continues until no more precipitate forms. The precipitate is dried and found to have a mass of 9.5 grams.

Experiment 2

The remaining solution left in the sealed beaker is then titrated with 0.01 M NaOH to give the titration curve shown in Figure 1.

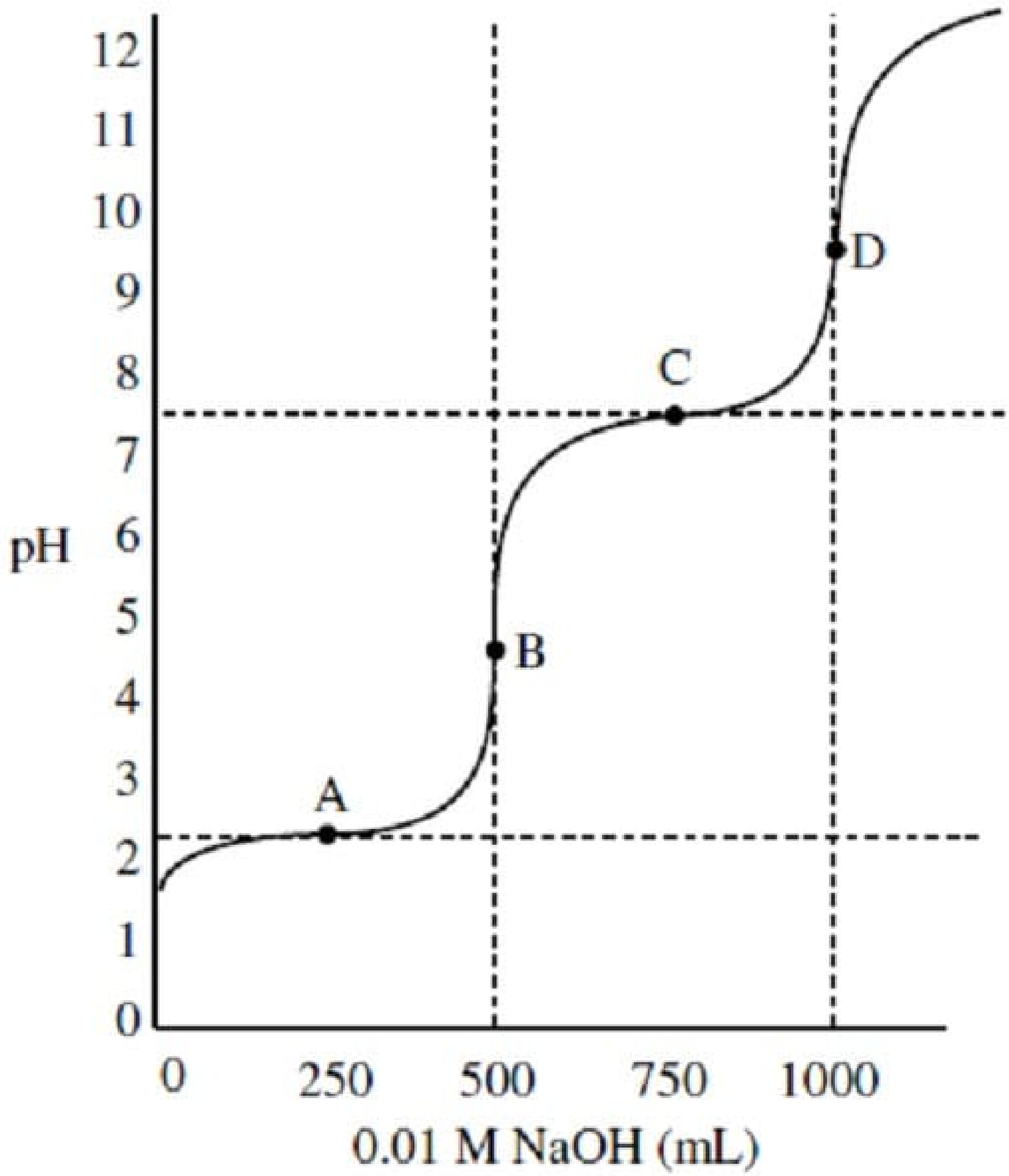


Figure 1

Which region of the graph in Figure 1 provides the best buffering around neutral pH?

A. A

B. B

C. C

D. D

Correct Answer: C

The best buffering occurs in the flat regions of the titration curve where the concentrations of acid and conjugate base are equal. Points A and C are good buffering regions, but point C is the best buffering region around neutral (7) pH.