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| *Indicate the answer choice that best completes the statement or answers the question.* |

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| 1. What is p*K*a of a buffer solution (pH = 5.05) containing 0.2 M sodium acetate and 0.1 M acetic acid?

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| --- | --- | --- |
|   | a.  | 4.75 |
|   | b.  | 0.2 |
|   | c.  | 0.3 |
|   | d.  | 4.45 |
|   | e.  | 1.58 |

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| 2. What is FALSE regarding the laws of thermodynamics?

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|   | a.  | Energy can be neither created nor destroyed. |
|   | b.  | The local decrease in enthalpy will increase the entropy of the surroundings. |
|   | c.  | Heat is a manifestation of the kinetic energy associated with the random motion of molecules. |
|   | d.  | Within chemical systems, potential energy is related to the likelihood that atoms will store energy in some form. |
|   | e.  | Ordered structures can be formed within a system only if the entropy of the surroundings will proportionally increase. |

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| 3. What gives proteins such a dominant role in biochemistry?

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|   | a.  | rigidity of the peptide backbone |
|   | b.  | ability to act as a blueprint |
|   | c.  | ability to self-replicate |
|   | d.  | ability to spontaneously fold into complex three-dimensional structures |
|   | e.  | usage of 40 different building blocks |

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| 4. Which statement about DNA is INCORRECT?

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|   | a.  | The most fundamental role of DNA is to encode the sequences of proteins. |
|   | b.  | The genetic code is the set of rules that links the DNA sequence to the encoded protein sequence. |
|   | c.  | Gene is the fundamental unit of hereditary information. |
|   | d.  | The control regions account for only a small portion of the human genome. |
|   | e.  | There are about 100,000 protein-coding genes in the human genome. |

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| 5. Which statement about the microbiome is CORRECT?

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| --- | --- | --- |
|   | a.  | There are about 10 times more human cells than microbial cells in the body. |
|   | b.  | The human microbiome does not play a role in obesity. |
|   | c.  | The microbiome present on a body remains constant throughout a human life. |
|   | d.  | The microbiome present on different body surfaces is largely distinct. |
|   | e.  | Many species of the human microbiome have been grown in cultures. |

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| 6. Which component of DNA bases is the most susceptible to hydroxide ions?

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|   | a.  | proton of N-1 atom of guanine base |
|   | b.  | proton of O atom of guanine base |
|   | c.  | proton of N-3 atom of thymine base |
|   | d.  | proton of O atom of adenine base |
|   | e.  | proton of N-1 atom of adenine base |

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| 7. What is a p*K*a value in an acid–base reaction?

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| --- | --- | --- |
|   | a.  | the equilibrium constant for proton dissociation |
|   | b.  | concentration of hydrogen ions in the solution |
|   | c.  | a quantitative measure of the strength of an acid in the solution |
|   | d.  | the equilibrium constant for the dissociation of water |
|   | e.  | concentration of hydroxide ions in the solution |

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| 8. What is the number of hydrogen bonds formed between A and T nucleotides?

|  |  |  |
| --- | --- | --- |
|   | a.  | 1 |
|   | b.  | 2 |
|   | c.  | 3 |
|   | d.  | 4 |
|   | e.  | 5 |

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| 9. Why are free interactions of water molecules in bulk water more favorable than more ordered interactions with nonpolar compounds?

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|   | a.  | The total entropy in such interactions increases because the Gibbs free energy is positive. |
|   | b.  | The total entropy in such interactions decreases because the Gibbs free energy is negative. |
|   | c.  | The enthalpy of the ordered state is lower than the enthalpy of the bulk state. |
|   | d.  | The total entropy in such interactions increases because the Gibbs free energy is negative. |
|   | e.  | The total entropy in such interactions decreases because the Gibbs free energy is positive. |

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| 10. What makes water a versatile solvent?

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|   | a.  | stabilization of large molecular complexes |
|   | b.  | ease of breaking different bonds |
|   | c.  | irreversible breakage of different bonds |
|   | d.  | simultaneous formation of a large number of hydrogen bonds |
|   | e.  | stabilization by large molecular complexes |

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| 11. What are the primary chemical components present in a phosphate buffer at pH = 7.4?

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| --- | --- | --- |
|   | a.  | H3PO4 and PO43– |
|   | b.  | H2PO4– and PO43– |
|   | c.  | HPO42– and PO43– |
|   | d.  | H2PO4– and HPO42– |
|   | e.  | H3PO4 and HPO42– |

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| 12. Which set of nutrients corresponds to a healthy diet (based on the nutritional value, in descending order)?

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|   | a.  | protein, carbohydrates, fats, vitamins and minerals |
|   | b.  | carbohydrates, fats, proteins, vitamins and minerals |
|   | c.  | grains, fats, proteins, vitamins and minerals |
|   | d.  | vitamins and minerals, carbohydrates, fats, proteins |
|   | e.  | carbohydrates, dairy, proteins, vitamins and minerals |

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| 13. Which statement about DNA structure is INCORRECT?

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|   | a.  | It is a branched polymer with a flexible backbone. |
|   | b.  | The DNA backbone is built of repeating sugar–phosphate units. |
|   | c.  | Each DNA strand has directionality due to identical orientation of the sugar–phosphate units. |
|   | d.  | Each sugar is connected to two phosphate groups through different linkages. |
|   | e.  | Its structure is a double helix composed of two intertwined strands. |

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| 14. If a particular reaction has a negative Δ*G*, is it likely to occur?

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| --- | --- | --- |
|   | a.  | Not unless energy is added to the system. |
|   | b.  | Yes, if it is coupled with another reaction. |
|   | c.  | Yes, it is spontaneous. |
|   | d.  | No, it is not spontaneous. |
|   | e.  | Yes, as long as the temperature increases. |

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| 15. If the whole chain is used in a nonoverlapping frame, how many amino acids are defined by the DNA sequence ATGTTTGGACTA?

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| --- | --- | --- |
|   | a.  | 2 |
|   | b.  | 3 |
|   | c.  | 4 |
|   | d.  | 6 |
|   | e.  | 12 |

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| 16. What is the direct consequence of the bent shape of a water molecule?

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|   | a.  | Water is highly cohesive. |
|   | b.  | Distribution of charge is asymmetric. |
|   | c.  | Hydrogen atoms possess a net negative charge. |
|   | d.  | The oxygen atom possesses a net positive charge. |
|   | e.  | The water molecule is able to form hydrogen bonds. |

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| 17. Using the Henderson–Hasselbalch equation, calculate the pH of a buffer solution made from 0.20 M CH3COOH and 0.05 M CH3COO– that has p*K*a = 4.7.

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| --- | --- | --- |
|   | a.  | 5.3 |
|   | b.  | 4.1 |
|   | c.  | 2.5 |
|   | d.  | 0.4 |
|   | e.  | 5.0 |

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| 18. Which of the following is a hydrogen bond donor?

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| --- | --- | --- |
|   | a.  | the N in H- - -N—HD |
|   | b.  | the S in S—H- - -O |
|   | c.  | the O and P in P—O- - -H |
|   | d.  | the H in O—H- - -O |
|   | e.  | the O in O—H- - -NN |

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| 19. What is the reason for the existence of the hydrophobic effect?

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|   | a.  | the tendency of water molecules to make a bond with hydrophobic proteins |
|   | b.  | the tendency of polar molecules to self-associate in the presence of an aqueous solution |
|   | c.  | the tendency of nonpolar molecules to self-associate in the presence of an aqueous solution |
|   | d.  | the inability of charged molecules to dissolve in water |
|   | e.  | the property of nucleic acids to dissolve in water |

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| 20. What is the CORRECT description of human migrations as supported by DNA sequence comparisons?

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| --- | --- | --- |
|   | a.  | Modern human beings originated in Africa about 50,000 years ago  migrated first to Asia  then to Europe, Australia, and North and South America about 12,500–19,000 years ago. |
|   | b.  | Modern human beings originated in Africa about 150,000 years ago  migrated first to Europe  then about 46,000 years ago to Asia, Australia, and North and South America. |
|   | c.  | Modern human beings originated in Australia about 150,000 years ago  migrated first to Asia  then to Africa, Europe, and North and South America. |
|   | d.  | Modern human beings originated in Africa about 150,000 years ago  migrated first to Asia  then to Europe, Australia, and North and South America about 12,500–19,000 years ago. |
|   | e.  | Modern human beings originated in Africa about 100,000 years ago  migrated first to Asia  then to Europe, Australia about 40,000 years ago, and North and South America. |

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| 21. What is the energy of an ionic interaction?

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| --- | --- | --- |
|   | a.  | the product of a proportionality constant and charges of two atoms divided by the product of the dielectric constant and the distance between atoms |
|   | b.  | the product of the dielectric constant and a sum of two charges divided by the product of the proportionality constant and the distance between charges |
|   | c.  | the product of the dielectric constant and the distance between atoms divided by the product of the proportionality constant and charges of two atoms |
|   | d.  | the product of the dielectric constant and two charges subtracted from the product of the proportionality constant and the distance between charges |
|   | e.  | the difference between the proportionality constant and charges of two atoms multiplied by the dielectric constant |

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| 22. What are molecules A and B called, if molecule A is large and transforms into a low-molecular-weight molecule B?

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| --- | --- | --- |
|   | a.  | A and B are both biological macromolecules. |
|   | b.  | A and B are both metabolites. |
|   | c.  | A is a biological macromolecule and B is a metabolite. |
|   | d.  | A is a metabolite and B is a biological macromolecule. |
|   | e.  | A is a protein and B is deoxyribonucleic acid. |

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| 23. What is the [A–]:[HA] ratio when a weak acid is in a solution one pH unit below its p*K*a?

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| --- | --- | --- |
|   | a.  | 1:1 |
|   | b.  | 1:10 |
|   | c.  | 10:1 |
|   | d.  | 2:1 |
|   | e.  | 1:2 |

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| 24. The structure of DNA described by Watson and Crick includes:

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|   | a.  | a triple helix. |
|   | b.  | a triple helix composed of three intertwined strands. |
|   | c.  | base pairs that are stacked on the inside of the double helix. |
|   | d.  | a sugar-phosphate backbone that lies on the inside of the helix. |
|   | e.  | base pairs that are stacked on the outside of the triple helix. |

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| 25. What is the number of hydrogen bonds formed between G and C nucleotides?

|  |  |  |
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|   | a.  | 1 |
|   | b.  | 2 |
|   | c.  | 3 |
|   | d.  | 4 |
|   | e.  | 5 |

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| 26. Order the type of interactions by the bond strength in descending value.

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|   | a.  | hydrogen bonds, covalent bonds, van der Waals interactions |
|   | b.  | covalent bonds, van der Waals interactions, hydrogen bonds |
|   | c.  | van der Waals interactions, covalent bonds, hydrogen bonds |
|   | d.  | covalent bonds, hydrogen bonds, van der Waals interactions |
|   | e.  | hydrophobic interactions, hydrogen bonds, electrostatic interactions |

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| 27. Which studies helped to reveal neural circuits and biochemical pathways that are important related to behavioral aspects?

|  |  |  |
| --- | --- | --- |
|   | a.  | studies of developed world diseases |
|   | b.  | studies in comparative genomics |
|   | c.  | studies of drug addiction |
|   | d.  | studies of environmental chemicals |
|   | e.  | studies of predispositions |

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| 28. When did life on Earth begin and when did human beings emerge, respectively?

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| --- | --- | --- |
|   | a.  | 3 billion years ago and 1 billion years ago |
|   | b.  | 3.5 billion years ago and 0.5 billion years ago |
|   | c.  | 3.5 billion years ago and 0.2 billion years ago |
|   | d.  | 3.5 billion years ago and less than 0.1 billion years ago |
|   | e.  | 3.5 billion years ago and 0.1 billion years ago |

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| 29. Which statement about nonpolar interactions in the formation of the DNA double helix is INCORRECT?

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| --- | --- | --- |
|   | a.  | Van der Waals interactions are nearly optimal in a double-helical structure. |
|   | b.  | Nonpolar surfaces of the bases are moved into contact with each other due to a more complete base stacking. |
|   | c.  | Nucleotide bases tend to stack even in single-stranded DNA molecules. |
|   | d.  | The separation distance of the planes of adjacent bases needs to be adjusted for the favorable van der Waals contacts. |
|   | e.  | Surface complementarity maximizes the formation of hydrogen bonds and van der Waals interactions while minimizing the nonpolar surface area exposed to the aqueous environment. |

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| 30. Which statement about ionic interactions in the formation of the DNA double helix is CORRECT?

|  |  |  |
| --- | --- | --- |
|   | a.  | Separation of negatively charged phosphate groups with distances greater than 10 Å prevents unfavorable interactions. |
|   | b.  | Only favorable ionic interactions take place when two strands of DNA come together. |
|   | c.  | Ionic interactions cause the formation of the double helix. |
|   | d.  | Disposition of negatively charged phosphate groups with distances greater than 10 Å provides only favorable interactions. |
|   | e.  | Some unfavorable ionic interactions take place when two strands of DNA come together. |

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| 31. What principle is comparative genomics based on?

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| --- | --- | --- |
|   | a.  | Biological polymers are evolutionary and functionally related in all living organisms. |
|   | b.  | There is a link between evolution and biochemistry. |
|   | c.  | DNA can be isolated from previously known organisms. |
|   | d.  | Biological polymers are greatly variable between single-celled and multicellular organisms. |
|   | e.  | The sequence variation between remotely related individuals is quite substantial compared to differences in populations. |

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| 32. What are the main paths of the tree of life?

|  |  |  |
| --- | --- | --- |
|   | a.  | eukarya and prokarya |
|   | b.  | eukarya and archea |
|   | c.  | bacteria, prokarya, eukarya, and archea |
|   | d.  | bacteria and eukarya |
|   | e.  | bacteria, eukarya, and archea |

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| 33. What did Watson and Crick suggest to be significant about the base-pairing found in the DNA helix?

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| --- | --- | --- |
|   | a.  | It allowed the DNA to twist in a helix. |
|   | b.  | The DNA could be circular. |
|   | c.  | It was a good base for the mechanism of copying genetic information. |
|   | d.  | Only one of the strands could act as a template. |
|   | e.  | The DNA sequence was determined by the sequence of RNA. |

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| 34. Which statement about noncovalent bonds is CORRECT?

|  |  |  |
| --- | --- | --- |
|   | a.  | Five fundamental noncovalent bonds differ in their geometry, strength, and specificity. |
|   | b.  | In the strongest hydrogen bonds, all their components lie along a straight line. |
|   | c.  | The transient asymmetry in the electronic charge distribution of one atom can induce a complementary asymmetry in the neighboring atoms due to hydrophobic interactions. |
|   | d.  | The release of water from more ordered structures is unfavorable. |
|   | e.  | Very strong repulsive forces become dominant at distances greater than the van der Waals contact distance. |

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| 35. The heat content of a system is called:

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| --- | --- | --- |
|   | a.  | entropy. |
|   | b.  | enthalpy. |
|   | c.  | kinetic energy. |
|   | d.  | potential enthalpy. |
|   | e.  | kinetic entropy. |

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| 36. What is the concentration of hydrogen ions in a urine sample that has a pH of 6?

|  |  |  |
| --- | --- | --- |
|   | a.  | 10–6 M |
|   | b.  | 10–8 M |
|   | c.  | 106 M |
|   | d.  | 10–14 M |
|   | e.  | 6 M |

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| 37. Which statement about acid–base relations is CORRECT?

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| --- | --- | --- |
|   | a.  | If [H+] is higher than 10–3, pH is above 3. |
|   | b.  | If [OH–] is 10–9, pH is 7. |
|   | c.  | If [H+] is lower than 10–9, pH is below 9. |
|   | d.  | If [OH–] is higher than 10–3, pH is below 3. |
|   | e.  | If [OH–] is 10–7, pH is 7. |

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| 38. What is the average difference in the genome sequence between each pair of individuals?

|  |  |  |
| --- | --- | --- |
|   | a.  | 1 different base per 200 bases |
|   | b.  | 1 different base per 20 bases |
|   | c.  | 1 different base per 100 bases |
|   | d.  | 1 different base per 1000 bases |
|   | e.  | 1 different base per 2000 bases |

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| 39. Which statement about covalent bonds is INCORRECT?

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|   | a.  | A covalent bond is formed by the sharing of a pair of electrons between adjacent atoms. |
|   | b.  | If more than one electron pair is shared, then a covalent bond becomes stronger. |
|   | c.  | Existence of several resonance structures of nearly equal energies decreases stability of a compound. |
|   | d.  | Some molecules possess several patterns of covalent bonding. |
|   | e.  | The key properties of a bond are length and energy. |

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| 40. A proton exists in a solution as:

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|   | a.  | H+. |
|   | b.  | a water molecule. |
|   | c.  | a deprotonated water molecule. |
|   | d.  | a hydronium ion. |
|   | e.  | H2O+. |

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| 41. By which factor will the 1 M buffer sodium acetate (p*K*a = 4.75) increase the amount of acid required to produce a drop of pH from 7.4 to 7.3 in comparison with pure water where a respective change in [H+] is equal to 1 × 10–8 M?

|  |  |  |
| --- | --- | --- |
|   | a.  | 5,600 |
|   | b.  | 60 |
|   | c.  | 60,000 |
|   | d.  | 1 |
|   | e.  | 600 |

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| 42. Which animal metabolic process is highly similar to the plant process of capturing and converting light energy?

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|   | a.  | capturing energy released from acid dissociation |
|   | b.  | capturing energy released from DNA double helix formation |
|   | c.  | capturing energy released from resisting the change in pH |
|   | d.  | capturing energy released from glucose breakdown |
|   | e.  | capturing energy released from the breakage of noncovalent bonds |

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| 43. Which statement about genetic variations is CORRECT?

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|   | a.  | Predisposition inevitably results in the onset of a disease. |
|   | b.  | Only a few genetic variations are connected to some ailments. |
|   | c.  | Several genetic variations are required to cause a disease. |
|   | d.  | The average difference between two people within one ethnic group is lower than the difference between the averages of two different ethnic groups. |
|   | e.  | A particular variation can lead to a predisposition to the development of a particular disease rather than to its inevitable development. |

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| 44. What is the concentration of hydroxide ions [OH–] in an aqueous solution with pH 9?

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|   | a.  | 10–9 M |
|   | b.  | 10–14 M |
|   | c.  | 105 M |
|   | d.  | 9 M |
|   | e.  | 10–5 M |

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| 45. Which statement about biological diversity is FALSE?

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|   | a.  | The plant kingdom includes species as relatively simple as algae and as complex as sequoias. |
|   | b.  | No species can live in seemingly hostile environments such as hot springs and glaciers. |
|   | c.  | Animal kingdom species range from nearly microscopic to very large. |
|   | d.  | Organisms such as protozoa, yeast, and bacteria are present with great diversity in water and soil. |
|   | e.  | Microscopic organisms can live on or within larger organisms. |

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| 46. How was the fact that formation of the double helix does not violate the second law of thermodynamics experimentally confirmed?

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|   | a.  | in a water bath monitoring the change in entropy to check whether it remains constant |
|   | b.  | in a water bath monitoring the change in heat to sustain a constant temperature in the bath |
|   | c.  | in a water bath monitoring the change in entropy to sustain a constant temperature in the bath |
|   | d.  | in a water bath monitoring the free energy to sustain constant heat content in the bath |
|   | e.  | in a water bath monitoring the change in heat to sustain constant Gibbs energy in the bath |

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| 47. Why does a spontaneous chemical process always increase the entropy of the universe?

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|   | a.  | The system entropy will increase if and only if the entropy of surroundings is greater than the ratio of the heat transferred to the surroundings and their temperature. |
|   | b.  | The total entropy will increase if and only if the product of temperature and the change in system entropy is lower than zero. |
|   | c.  | The total entropy will increase if and only if the change in enthalpy is lower than zero. |
|   | d.  | The system enthalpy will increase only when the change in temperature is greater than zero. |
|   | e.  | The total entropy will increase if and only if the entropy of a system is greater than the ratio of the heat transferred to surroundings and their temperature. |

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| 48. Which statement is INCORRECT if the buffer capacity is not consumed upon addition of a strong acid to the solution?

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|   | a.  | There are more protonated forms of the buffer compound than deprotonated ones. |
|   | b.  | When hydrogen ions are added to this buffer solution they remain free. |
|   | c.  | The pH differs from the p*K*a value of the buffer's base component. |
|   | d.  | There are more deprotonated forms of the buffer compound than protonated ones. |
|   | e.  | Such a buffer is not actually a buffer and cannot mitigate the pH changes. |

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| 49. Which statement about the role of hydrogen bonds in DNA double helix formation is INCORRECT?

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|   | a.  | The hydrophobic effect contributes to the favorability of base stacking. |
|   | b.  | Hydrogen bonds contribute greatly to the overall process of double helix formation. |
|   | c.  | There are more hydrogen bonds with water than bonds between the bases in single-stranded DNA. |
|   | d.  | When two single strands come together, hydrogen bonds with water are broken and new hydrogen bonds between the bases of two DNA strands are formed. |
|   | e.  | Hydrogen bonds contribute greatly to the specificity of bases binding. |

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| 50. Consider the conventional description of bonds in a Fischer projection. What is the CORRECT statement about the bonds in a Fischer projection?

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|   | a.  | Horizontal bonds project behind the page away from the viewer. |
|   | b.  | A solid wedge with the broad end away from the carbon atom denotes a bond coming away from the viewer. |
|   | c.  | The bonds to the central atom are represented by lines from that atom to the substituents. |
|   | d.  | Vertical bonds project behind the page away from the viewer. |
|   | e.  | A dashed wedge with its broad end at the carbon atom represents a bond going toward the viewer. |

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**Answer Key**

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| 1. a |

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| 2. d |

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| 3. d |

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| --- |
| 4. e |

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| --- |
| 5. d |

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| --- |
| 6. a |

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| --- |
| 7. c |

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| --- |
| 8. b |

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| --- |
| 9. d |

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| --- |
| 10. d |

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| --- |
| 11. d |

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| 12. b |

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| --- |
| 13. a |

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| --- |
| 14. c |

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| --- |
| 15. c |

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| --- |
| 16. b |

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| --- |
| 17. b |

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| --- |
| 18. d |

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| --- |
| 19. c |

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| --- |
| 20. d |

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| --- |
| 21. a |

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| --- |
| 22. c |

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| --- |
| 23. b |

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| --- |
| 24. c |

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| --- |
| 25. c |

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| --- |
| 26. d |

|  |
| --- |
| 27. c |

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| --- |
| 28. d |

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| --- |
| 29. d |

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| --- |
| 30. e |

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| --- |
| 31. a |

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| --- |
| 32. e |

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| --- |
| 33. c |

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| --- |
| 34. b |

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| --- |
| 35. b |

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| --- |
| 36. a |

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| --- |
| 37. e |

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| --- |
| 38. a |

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| --- |
| 39. c |

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| --- |
| 40. d |

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| --- |
| 41. c |

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| --- |
| 42. d |

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| --- |
| 43. e |

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| --- |
| 44. e |

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| --- |
| 45. b |

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| --- |
| 46. b |

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| --- |
| 47. e |

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| --- |
| 48. d |

|  |
| --- |
| 49. b |

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| --- |
| 50. d |