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I. **Multiple choice questions (60%, 2 points for each question)**

1. How do drugs exhibit biological activity?
   (A) They interact with specific enzymes and block or change the shape of the active site of the receptor.
   (B) They stimulate the cells to perform acid-base reactions.
   (C) They hydrolyze the fats and oils in abnormal cells to make metal salts of fatty acids.
   (D) They react with abnormal cells in the body and form Lewis acids by electrophilic aromatic substitution.
   (E) They mimic the action of a specific enzyme, increasing the availability of the receptors.

2. Which type of spectroscopy would be most useful in distinguishing the following pair of compounds?
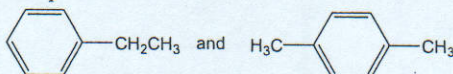
   (A) IR　(B) UV-Vis　(C) NMR　(D) MS　(E) X-ray

3. The mole percent of helium is 0.000524. What is the concentration of helium in parts per million (ppm)?
   (A) 5.24×10^{-2}　(B) 5.24　(C) 5.24×10^{-4}　(D) 5.24×10^{-5}　(E) 5.24×10^{-3}

4. An air pollutant is
   (A) a toxic compound.
   (B) a compound that is soluble in water.
   (C) a compound that cannot be filtered from the air.
   (D) a compound found in air in greater abundance than normally occurs in nature.
   (E) Answers A, B, and C are correct.

5. Conjugated alkenes are composed of π-electrons. What do compounds contain an especially long conjugated systems exhibit?
   (A) The compounds are colored.
   (B) The compounds have a low melting point.
   (C) The compounds undergo elimination reactions.
   (D) The compounds fit specific receptor sites on cell memberanes.
   (E) The compounds are aromatic.

6. Mercury is toxic to the body, in part, because Hg^{2+} interferes with
   (A) oxygen uptake.
   (B) sulfur containing enzymes.
   (C) digestion.
   (D) transport of electrons across the blood-brain barrier.
   (E) antioxidant activity.

7. Which of the following statements is *incorrect*?
   (A) Aluminum is the most abundant metal by mass in the Earth's crust.
   (B) The most useful production of aluminum is the Hall-Heroult process which involves the electrolysis of molten Al_2O_3.
   (C) The energy required to produce aluminum from Al_2O_3 is similar to that required to recycle aluminum cans and packaging.
   (D) The B–H–B bond in diborane, B_2H_6, consists of two electrons shared among three atoms.
   (E) Boric acid, $B(OH)_3$, accepts a hydroxide ion, forming the complex ion $[B(OH)_4]^-$.

8. Why does a synthetic detergent not leave a dirty grayish film on clothes washed in hard water?
   (A) Modern synthetic detergents are linear alkylbenzene sulfonates and therefore are biodegradable.
   (B) Synthetic detergents are designed to precipitate only with M^+ cations.
   (C) Synthetic detergents complex with M^{2+} cations but do not precipitate like soaps.
   (D) Modern hard water is very soft compared to hard water used previously.
   (E) Hard water lacks the M^{2+} cations that cause the dirty grayish film.

9. Arrange the following compounds in the expected order of increasing solubility in water (lowest solubility first, highest solubility last).

LiOH	$Sr(OH)_2$	$Ba(OH)_2$	$Ca(OH)_2$
A	**B**	**C**	**D**

   (A) D, B, C, A　(B) A, D, B, C　(C) A, B, C, D　(D) D, A, B, C　(E) C, D, B, A

10. The half-life of a radioactive nuclide is 14 hours. Without doing calculations, estimate how long would it take for a sample to decay to 12% of its present activity?
   (A) 3 hours   (B) 14 hours   (C) 28 hours   (D) 42 hours   (E) 56 hours

11. The overall cell reaction during discharge of the lead-acid battery is
   $$PbO_{2(s)} + Pb_{(s)} + 2\,H_2SO_{4(aq)} \rightarrow 2\,PbSO_{4(s)} + 2\,H_2O_{(l)}$$
   Which statement is *incorrect*?
   (A) The lead serves as the anodes.
   (B) The PbO_2 electrode would be positive during discharge.
   (C) Upon recharging, the above reaction occurs in revers.
   (D) Upon recharging, the density of the electrolyte will increase.
   (E) Upon recharging, the lead electrode is negative.

12. Which of the following statements correctly identifies the Second Law of Thermodynamics?
   (A) All spontaneous processes increase the entropy of the universe.
   (B) The enthalpy of a pure substance at 0 K is zero.
   (C) The total entropy of the universe is the sum of the entropy of the system and the surroundings.
   (D) The free energy of a reaction at equilibrium is zero.
   (E) The universe of a spontaneous reaction is a nonspontaneous process.

13. "All spontaneous or natural processes result in an increase in entropy." The entropy change referred to in this statement is
   (A) ΔS_{system}.   (B) $\Delta S_{surroundings}$.   (C) $\Delta S_{universe}$.   (D) $\Delta S_{reversible}$.   (E) $\Delta S_{irreversible}$.

14. Which on eof the following processes is not spontaneous and endothermic (at 1 atm)?
   (A) $H_2O_{(l)} \rightarrow H_2O_{(g)}$ at 101 °C
   (B) melting of ice at 10 °C
   (C) sublimation of CO_2 at 25 °C
   (D) dissolving the soluble salt, NH_4NO_3, and the temperature drops
   (E) condensation of water at 99 °C

15. Two salts, **AX** and **BX₂**, having identical Ksp values at a given temperature. We can say
   (A) the salts are more soluble in 0.1 M NaX than in water.
   (B) the molar solubility of **AX** is identical to **BX₂**.
   (C) addition of NaX will not affect the solubilities of the salts.
   (D) the molar solubility of **AX** is greater than that of **BX₂**.
   (E) the molar solubility of **BX₂** is greater than that of **AX**.

16. The reason HI is a stronger acid than HCl is because
   (A) bond dissociation energy decreases as you go down the periodic table.
   (B) electronegativity increases as you go up the periodic table.
   (C) anion radius decreases as you go down the periodic table.
   (D) the difference in electronegativity gets larger as the atoms get farther apart on the periodic table.
   (E) HI is an Arrehnius acid and HCl is not.

17. The equilibrium constant for the following reaction is given. Assuming that the forward and reverse reactions can be written as elementary steps, which statement below is true for this reaction at equilibrium?
   $$A \leftrightarrow B + C \quad K_c = 150$$
   (A) The rate constant for the forward reaction is 150 times greater than that for the reverse reaction.
   (B) The rate constants for the forward and reverse reactions are identical at equilibrium.
   (C) The rate constant for the forward reaction is smaller than that for the reverse reaction.
   (D) The rate constant for the reverse reaction is 150 times greater than that for the forward reaction.
   (E) The rate constants for this reaction cannot be determined based on the equilibrium constant.

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18. Concerning vapor pressures, which of the following is not a correct statement?
    (A) The vapor pressure of a solvent is proportional to the mole fraction of solvent in solution.
    (B) Raoult's Law is applicable to ideal solutions, but often works for dilute nonideal solutions.
    (C) The addition of a non-volatile solute to a solvent lowers the vapor pressure of the solvent.
    (D) The vapor above of a solution containing two volatile components is enriched in the higher boiling component.
    (E) The total vapor pressure of a system is equal to the product of the vapor pressures of the individual components.

19. Which statement is not true regarding colligative properties?
    (A) The magnitude depends on the density of the solute.
    (B) The magnitude depends on whether the solute is an electrolyte or not.
    (C) The magnitude depends on the concentration.
    (D) Raoult's Law describes the vapor pressure above a solution.
    (E) Since the vapor pressure of the solvent is lowered by a nonvolatile solute, the boiling point of the solution is higher.

20. Which of the following is not true in dynamic equilibrium describing a saturated solution?
    (A) Solid crystallizes from solution.
    (B) Rate of dissolving is double the rate of crystallization.
    (C) Concentration of dissolved solute remains constant.
    (D) Quantity of undissolved solute remains constant.
    (E) Solid dissolves into solution.

21. Which statement is _incorrect_?
    (A) When 40.0 mL of ethanol and 60.0 mL of water are mixed, the volume of the mixture is 100.0 mL.
    (B) When ethanol and water are mixed, the solution warms slightly. Therefore, the solution process is exothermic.
    (C) Ideal solutions form when the intermolecular forces of the solvent and solute are similar.
    (D) For an ideal solution, the ΔH of solution is zero.
    (E) When an ionic compound dissolves in water, the positive and negative ions separate from each other.

22. According to VSEPR theory, the shape of ICl_4^- is described as
    (A) Tetrahedral.
    (B) Square planar.
    (C) Square pyramidal.
    (D) Octahedral.
    (E) Trigonal bipyramidal.

23. Which combination of elements would be mostly to form ionic bonds?
    (A) oxygen-fluorine
    (B) sulfur-oxygen
    (C) potassium-bromine
    (D) bromine-iodine
    (E) carbon-chlorine

24. Rank the elements C, O, Na, Al in order of decreasing ionization energy (largest first, etc.)
    (A) C > O > Na > Al
    (B) O > Na > C > Al
    (C) O > C > Al > Na
    (D) Al > Na > O > C
    (E) Na > Al > C > O

25. Which of the followings is not a true statement concerning the energy of orbitals?
    (A) In the hydrogen atom, all subshells of a principal shell are at the same energy level.
    (B) Orbital energies are higher in multielectron atoms than in the hydrogen atom.
    (C) In a multielectron atom, the various subshells of a principal shell are at different energy levels.
    (D) All orbitals within a subshell of a multielectron atom are at the same energy level.
    (E) In high numbered principal shells of a multielectron atom, some subshells of different principal shells have nearly identical energies.

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26. Which one of the following associations of a scientist and a discovery is _incorrect_?
    (A) Albert Einstein – explained photoelectric effect
    (B) Niels Bohr – model of hydrogen
    (C) Ernest Rutherford – nuclear atoms
    (D) Max Planck – quantized energy
    (E) Robert Millikan – electrolysis

27. The assumptions of the kinetic-molecular theory are most likely to be correct under what conditions?
    (A) high temperature and high pressure
    (B) high temperature and low pressure
    (C) low temperature and high pressure
    (D) low temperature and low pressure
    (E) always correct

28. Which of the following species is a weak base in water?
    (A) KOH
    (B) $B(OH)_3$
    (C) NH_3
    (D) CH_3COOH
    (E) $Mg(OH)_2$

29. Which of the followings could be an empirical formula?
    (A) C_2H_6
    (B) $C_6H_{12}O_6$
    (C) C_3H_8
    (D) $C_2H_2Cl_2$
    (E) $C_{60}H_{60}$

30. Which name is _incorrect_?
    (A) CCl_4: carbon tetrachloride
    (B) N_2O_4: dinitrogen tetroxide
    (C) Al_2O_3: dialuminum trioxide
    (D) CS_2: carbon disulfide
    (E) SCl_2: sulfur dichloride

II. **Essay questions (40%)**

1. You have a 2.00-L sample of hot water (95 °C) sitting open in a 25 °C room. Eventually the water cools to 25 °C, whereas the temperature of the room remains unchanged. Prove that this is a spontaneous process. Assume the density of water is 1.00 g/mL over this temperature range and that the heat capacity of water is constant over this temperature range and equal to 75.3 J/K · mol.   (7%)

2. Which member of the following pairs would you expect to be more energetically stable? Justify each choice. (8%)
    (A) $NaBr$ or $NaBr_2$
    (B) ClO_4 or ClO_4^-
    (C) SO_4 or XeO_4
    (D) OF_4 or SeF_4

3. For the following reactions at constant pressure, predict if $\Delta H > \Delta E$, $\Delta H < \Delta E$, or $\Delta H = \Delta E$.   (9%)
    (a) $2\ HF_{(g)} \rightarrow H_{2(g)} + F_{2(g)}$
    (b) $N_{2(g)} + 3\ H_{2(g)} \rightarrow 2\ NH_{3(g)}$
    (c) $4\ NH_{3(g)} + 5\ O_{2(g)} \rightarrow 4\ NO_{(g)} + 6\ H_2O_{(g)}$

4. Consider the ionic solid A_xB_y, which has the unit cell below. The B ions are packed in a cubic arrangement, where each face has this structure:

There is one B in the corner of the cube. The structure can also be described in terms of three parallel planes of

B's of the type shown above. The resulting structure thus contains eight intersecting cubes of B's. The A ions are found in the centers of alternate intersecting cubes (that is, four of every eight cubes have A's in the center). What is the formula of A_xB_y? In the extended structure, how many B's surround each A?　　(8%)

5. Most of substances possess positive standard entropy, except $F^-_{(aq)}$, $OH^-_{(aq)}$, and $S^{2-}_{(aq)}$ ions, which have standard entropy -14, -11, and -15 J/K $\cdot$ mol, respectively. How can $S°$ values be less than zero since the third law of thermodynamic states that the entropy of a perfect crystal at 0 K is zero?　　(8%)

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