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Multiple Choices: Choose the **one** alternative that best completes the statement or answers the question. (2.5 points for each question)

1. At a particular temperature, the half-life of a zero-order reaction is 32 min. How long will it take for the reactant concentration to be depleted by a factor of 16?

   (A) 128 min (B) 480 min (C) 160 min (D) 60 min (E) 96 min

2. A 100.0-mL sample of the triprotic weak acid H_3A (0.200 *M*) is titrated with 0.200 *M* NaOH. Besides water and sodium ions, what are the major species after 180.0 mL of 0.200 *M* NaOH is added in the titration?

   (A) H_2A^-
   (B) HA^{2-}
   (C) HA^{2-}, A^{3-}
   (D) H_2A^-, HA^{2-}
   (E) A^{3-}

3. Which of the following statements is correct?

   (A) As long as the disorder of the surroundings is increasing, a process will be spontaneous.
   (B) For any process, ΔS_{surr} and ΔS_{sys} have opposite signs.
   (C) If $\Delta S_{surr} = -\Delta S_{sys}$, the process is at equilibrium.
   (D) ΔH^o is zero for a chemical reaction at constant temperature.
   (E) none of these

4. Which of the following ions will be expected to have the most negative heat of hydration, ΔH_{hydr}?

   (A) Cs^+ (B) Na^+ (C) Ca^{2+} (D) F^- (E) Ba^{2+}

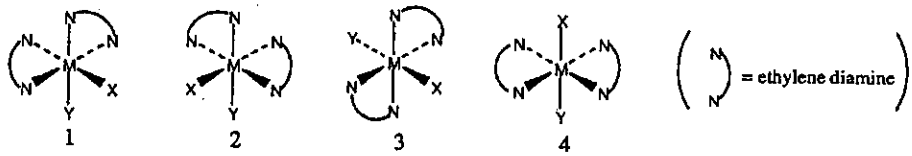
5. Which of the following properties is *not* a state function?

   (A) Internal energy (*E*)
   (B) Entropy (*S*)
   (C) Pressure (*P*)
   (D) Gibb's free energy (*G*)
   (E) Heat (*q*)

6. Among these 8 molecules: CH_4, XeF_4, $CHCl_3$, BF_3, CS_2, PH_3, BrF_5, SCl_2, how many molecules are polar?

   (A) 4 (B) 5 (C) 6 (D) 3 (E) 2

7. Consider the following octahedral complex structures, each involving ethylenediamine and two different monodentate ligands, X and Y.



   1 2 3 4

   Which one of the following statements about these structures is *incorrect*?

   (A) Structures 1 and 2 are optical isomers.
   (B) Structures 1 and 3 are optical isomers.
   (C) Structures 1 and 3 are different complexes.
   (D) Structures 1 and 4 are geometrical isomers.
   (E) Structures 3 and 4 are the same complex.

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8. Which of the following has the smallest radius?

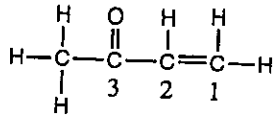
(A) Se^{2-} (B) Br^- (C) Kr (D) Rb^+ (E) Sr^{2+}

9. How many of the following molecules have all of their atoms in the same plane?

$H_2C=CH_2$ F_2O H_2CO NH_3 CO_2 $BeCl_2$ H_2O_2

(A) 3 (B) 4 (C) 5 (D) 6 (E) 7

10. Consider the following Lewis structure. (Lone pairs are not drawn in.)



Which statement about the molecule is *incorrect*?

(A) There are 10 σ and 2 π bonds.
(B) Oxygen is sp^3 hybridized.
(C) C-2 is sp^2 hybridized with bond angles of 120°.
(D) This molecule contains 28 valence electrons.
(E) There are some H–C–H bond angles of about 109° in the molecule.

11. Consider the molecular-orbital energy-level diagrams for O_2 and NO. Which of the following is correct?

I. Both molecules are paramagnetic.
II. The bond strength of O_2 is greater than the bond strength of NO.
III. NO is an example of a homonuclear diatomic molecule.
IV. The ionization energy of NO is smaller than the ionization energy of NO^+.

(A) I only (B) I and II (C) I and IV (D) II and III (E) I, II, and IV

12. Which of the following properties are mainly due to hydrogen bonding?

I. Ethanol is miscible with water
II. Glycerol is highly viscous
III. NaCl is soluble in water
IV. AsH_3 has a higher boiling point than PH_3
V. The formation of α-helices in proteins
VI. The density of ice is smaller than water

(A) I, II, V, VI (B) I, II, III, VI (C) II, IV, V, VI (D) I, V, VI
(E) II, III, VI

13. Which of the following compounds will form an acidic solution upon dissolving in water?

(a) P_4O_{10} (b) Na_2S (c) NaH_2PO_4 (d) $AlCl_3$ (e) $FeCl_3$

(A) a, c, d, e
(B) a, c, e
(C) a, d, e
(D) b, c, d, e
(E) a, c, d

14. In basic solution, Se^{2-} and SO_3^{2-} ions react spontaneously:

$2\ Se^{2-}(aq) + 2\ SO_3^{2-}(aq) + 3\ H_2O(l) \rightarrow 2\ Se(s) + 6\ OH^-(aq) + S_2O_3^{2-}(aq)$ $E°_{cell} = 0.35$ V

If $E°_{sulfite}$ is -0.57 V, what is $E°_{selenium}$?

(A) -0.92 V (B) -0.22 V (C) 0.92 V (D) 0.22 V
(E) None of these choices is correct.

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15. Select the gas with the highest average kinetic energy per mole at 300 K.

(A) O_2 (B) CO_2 (C) H_2O (D) H_2 (E) All have the same average kinetic energy.

16. Arrange the following gases in order of increasing rate of effusion: C_2H_6, Ar, HCl, PH_3

(A) $Ar < HCl < PH_3 < C_2H_6$
(B) $C_2H_6 < PH_3 < HCl < Ar$
(C) $Ar < PH_3 < C_2H_6 < HCl$
(D) $C_2H_6 < HCl < PH_3 < Ar$
(E) $Ar < PH_3 < HCl < C_2H_6$

17. A voltaic cell consists of an Au/Au^{3+} electrode ($E°$ = 1.50 V) and a Cu/Cu^{2+} electrode ($E°$ = 0.34 V). Which $[Au^{3+}]$ will generate the largest E_{cell} if $[Cu^{2+}]$ = 1.20 *M* at 25 °C.

(A) 1.20 *M* (B) 2.00 *M* (C) 0.50 *M* (D) 0.10 *M* (E) 1.00 *M*

18. The Clausius-Clapeyron equation is used in calculations of

(A) melting and freezing points.
(B) vapor pressures of liquids.
(C) osmotic pressures of solutions.
(D) heats of vaporization at different temperatures.
(E) crystal structure.

19. Which of the following atoms should have the smallest polarizability?

(A) Si (B) S (C) Te (D) Bi (E) Br

20. Which of the following statements concerning a face-centered cubic unit cell and the corresponding lattice, made up of identical atoms, is *incorrect*?

(A) Each atom is surrounded by12 nearest atoms.
(B) The packing in this lattice is more efficient than for a body-centered cubic system.
(C) If the atoms have radius *r*, then the length of the cube edge is $2\sqrt{2}r$.
(D) There are four atoms per unit cell in this type of packing.
(E) The packing efficiency in this lattice is larger than hexagonal close packing.

21. The chlor-alkali process produces chlorine, $Cl_2(g)$, in large quantities. What other industrially important substances are produced in this process?

(A) $Na(s)$, $H_2(g)$
(B) $H_2(g)$, $O_2(g)$
(C) $Hg(l)$, $NaCl(s)$
(D) $Na(s)$, $O_2(g)$
(E) $NaOH(aq)$, $H_2(g)$

22. When PCl_5 solidifies it forms PCl_4^+ cations and PCl_6^- anions. According to valence bond theory, what hybrid orbitals are used by phosphorus in the PCl_4^+ cations?

(A) *sp* (B) sp^2 (C) sp^3 (D) sp^3d (E) sp^3d^2

23. Who was the first scientist to propose that an object could emit only certain amounts of energy?

(A) Planck
(B) Einstein
(C) Bohr
(D) Rydberg
(E) de Broglie

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24. The orientation in space of an atomic orbital is associated with
(A) the principal quantum number (n).
(B) the angular momentum quantum number (l).
(C) the magnetic quantum number (m_l).
(D) the spin quantum number (m_s).
(E) the magnetic and spin quantum numbers together.

25. Select the compound with the lowest (i.e., least negative) lattice energy.
(A) CsBr(s) (B) NaCl(s) (C) SrO(s) (D) CaO(s) (E) KBr(s)

26. The melting points of metals are only moderately high because
(A) metallic bonding is weak.
(B) metals have fewer bonding electrons than non-metals.
(C) metals also have relatively low boiling points.
(D) the melting process does not break the metallic bonds.
(E) metals prefer to be bonded to non-metals.

27. In the $COCl_2$ molecule, carbon is the central atom. Based on the best Lewis structure for $COCl_2$, what is the formal charge on carbon?
(A) 0 (B) +1 (C) -1 (D) +2 (E) -2

28. What is the molecular shape of XeO_2F_2 as predicted by the VSEPR theory?
(A) square planar (B) tetrahedral (C) square pyramidal (D) see-saw
(E) octahedral

29. Which of the following aqueous solutions should demonstrate the most ideal behavior?
(A) 0.1 M K_2SO_4 (B) 0.1 M $CaCl_2$ (C) 3.0 M LiF (D) 0.1 M $MgSO_4$
(E) 0.1 M NaCl

30. If a solute dissolves in an endothermic process, then which of the following statement is correct?
(A) Hydrogen bonds must exist between solvent and solute.
(B) Strong ion-dipole forces must exist in the solution.
(C) The solute must be a gas.
(D) The entropy of the solution is immaterial.
(E) The entropy of the solution must be greater than that of its pure components.

31. Aniline ($C_6H_5NH_2$) is a stronger base than 3-chloroaniline ($ClC_6H_5NH_2$). Which of the following statement can best explain this fact?
(A) The anion of aniline is less stable.
(B) 3-Chloroaniline is an acid.
(C) The chlorine acts like an OH group when it dissolves in water.
(D) The chlorine atom withdraws electron density from the NH_2 group.
(E) Neither of these two molecules is a base.

32. Which of the following statements is ***incorrect*** about the corrosion of iron?
(A) The component of rust is $Fe_2O_3 \cdot nH_2O$
(B) In the process, H_2 is produced.
(C) In the presence of H^+, Fe will be corroded rapidly.
(D) Adding phenolphthalein to the cathode region, the color will turn pink.
(E) The process usually requires H_2O, and O_2 is reduced.

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33. For the compound $[Co(en)_2Cl_2]Cl$, which of the following statement is *incorrect*?

(A) The oxidation number of the central metal ion is +3.
(B) The coordination number of the metal ion is 4.
(C) One mole of $[Co(en)_2Cl_2]Cl$ will form two moles of ions when it is dissolved in water.
(D) One mole of AgCl(s) will precipitate when one mole of compound is dissolved in water and treated with $AgNO_3$.
(E) None of the above statements.

34. Consider the following reaction and data measured at 25 °C:

$$2\ A(g) + B_2(g) \rightarrow 2\ C(g)$$

Initial [A] (*M*)	Initial [B_2] (*M*)	Initial rate (*M*/sec)
0.10	0.10	0.18
0.10	0.20	0.36
0.20	0.20	1.45

When 1 mol of A and 1 mol of B_2 are added into a 1-L flask, the initial consuming rate of A ($d[A]/dt$) is x *M*/sec. The instantaneous consuming rate of B_2 ($d[B_2]/dt$) is y *M*/sec when 0.6 mol of B_2 is remained in the flask. Assuming the reaction proceeds only from left to right, what is the x/y ratio?

(A) 41.7 (B) 5.21 (C) 8.33 (D) 83.3 (E) 16.7

35. Which of the following complexes will absorb the longest wavelength of light?

(A) $[Cr(H_2O)_6]^{3+}$ (B) $[Cr(NH_3)_6]^{3+}$ (C) $[Cr(NO_2)_6]^{3-}$ (D) $[CrCl_6]^{3-}$ (E) $[Cr(CN)_6]^{3-}$

36. Which of the following species has the smallest bond order?

(A) F_2^+ (B) O_2^{2-} (C) B_2^+ (D) N_2^- (E) C_2^{2+}

37. Which of the following materials is put into a nuclear reactor to slow the chain reaction?

(A) control rods (B) moderators (C) heavy water (D) reflectors (E) chlorine

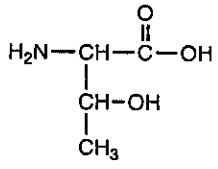
38. Iodine-131, $t_{1/2}$ = 8.0 days, is used in diagnosis and treatment of thyroid gland diseases. If a laboratory sample of iodine-131 initially emits 9.95×10^{18} β particles per day, how long will it take for the activity to drop to 6.22×10^{17} β particles per day? ($ln\ 2 = 0.693$)

(A) 48 days (B) 32 days (C) 16 days (D) 128 days (E) 2 days

39. Which of the following statements about $[Ni(NH_3)_6]^{2+}$ and $[Pt(NH_3)_4]^{2+}$ complex ions is *incorrect*?

(A) Both metal ions are d^8 species.
(B) The crystal field splitting energy (Δ) is different for these two complex ions.
(C) $[Ni(NH_3)_6]^{2+}$ is octahedral and paramagnetic.
(D) $[Pt(NH_3)_4]^{2+}$ is square planar and paramagnetic.
(E) According to valence bond theory, the dsp^2 hybrid orbitals are used in $[Pt(NH_3)_4]^{2+}$.

40. Threonine is one of the naturally coded amino acids and its structure is shown as follows,



How many chiral centers in threonine?

(A) 0 (B) 1 (C) 2 (D) 3 (E) 4