For the following multiple choice questions, there is only one correct or best answer. There are 2 points for each question.

1. Which of the following is *not* the correct chemical formula for the compound named?
   (A) $Al(OH)_2$　　aluminum hydroxide　　(B) LiCN　　lithium cyanide
   (C) Fe_2O_3　　Iron(III) oxide　　(D) ZnSe　　zinc selenide
   (E) $Mg(C_2H_3O_2)_2$　　magnesium acetate

2. Which is the correct formula for gold(I) sulfide?
   (A) AuS　　(B) Au_2S　　(C) AuS_2　　(D) Au_2S_3　　(E) Au_2S_2

3. When $NH_3(aq)$ is added to $Cu^{2+}(aq)$, a precipitate initially forms.　What is its formula?
   (A) $Cu(NH_3)_2$　　(B) $Cu(NO_3)_2$　　(C) CuO　　(D) $Cu(NH_3)_2^{2+}$　　(E) $Cu(OH)_2$

4. True or false?　The equation $2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$ is an oxidation-reduction reaction.
   (A) True; the oxygen is reduced and the hydrogen is oxidized.
   (B) True; the carbon is oxidized and the hydrogen is reduced.
   (C) True; the carbon is oxidized and the oxygen is reduced.
   (D) True; the carbon is reduced and the oxygen is oxidized.
   (E) False

5. Consider two samples of helium in separate containers of the same volume.　Sample 1 has an absolute temperature four times that of Sample 2.　Both samples are at the same pressure.　Calculate the ratio $n_1:n_2$.
   (A) 1:1　　(B) 1:2　　(C) 2:1　　(D) 1:4　　(E) 4:1

6. Which of the following statements concerning equilibrium is *not* true?
   (A) A system that is disturbed from an equilibrium condition responds in such a way as to restore equilibrium.
   (B) A system moves spontaneously toward a state of equilibrium.
   (C) Equilibrium in molecular systems is dynamic, with two opposing processes balancing one another.
   (D) The value of the equilibrium constant for a given reaction mixture is the same regardless of the direction from which equilibrium is attained.
   (E) The equilibrium constant is independent of temperature.

7. For the reaction $2H_2(g) + O_2(g) \rightleftharpoons 2H_2O(g)$, what is the relationship between K and K_p at temperature T?
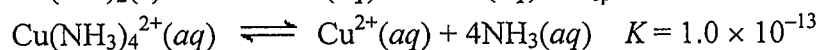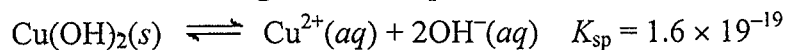   (A) $K = K_p$　　(B) $K = K_p(RT)$　　(C) $K_p = K(RT)$　　(D) $K = K_p(RT)^2$　　(E) $K_p = K(RT)^2$

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8. When the substances in the equation below are at equilibrium at pressure P and temperature T, how can the equilibrium be shifted to favor the products?　$CuO(s) + H_2(g) \rightleftharpoons Cu(s) + H_2O(g)$　Change in enthalpy = –2.0 kJ.
   (A) Decrease the temperature.
   (B) Increase the temperature.
   (C) Add a catalyst.
   (D) Increase the pressure by adding an inert gas such as nitrogen.
   (E) Allow some gas to escape at constant pressure and temperature.

9. The acids $HC_2H_3O_2$ and HF are both weak, but HF is a stronger acid than $HC_2H_3O_2$.　HCl is a strong acid. Order the following according to base strength.
   (A) $C_2H_3O_2^- > F^- > Cl^- > H_2O$
   (B) $Cl^- > F^- > C_2H_3O_2^- > H_2O$
   (C) $C_2H_3O_2^- > F^- > H_2O > Cl^-$
   (D) $F^- > C_2H_3O_2^- > H_2O > Cl^-$
   (E) none of these

10. HOAc　$K_a = 1.8 \times 10^{-5}$　H_2CO_3　$K_{a1} = 4.3 \times 10^{-7}$,　$K_{a2} = 5.6 \times 10^{-11}$
    Which of the following 0.01 M solutions has the highest pH?
    (A) HOAc　　　(B) NaOAc　　　(C) H_2CO_3　　　(D) Na_2CO_3　　　(E) $NaHCO_3$

11. Determine the pH of the following aqueous solution.　Choose your answer from the given pH ranges.　0.5 M NH_4F (pK_b for NH_3 = 4.74, pK_a for HF = 3.14)
    (A) pH 0.00–2.99　　(B) pH 3.00–5.99　　(C) pH 6.00–8.99　　(D) pH 9.00–10.99　　(E) pH 11.00–14.00

12. Which of the following solutions will be the best buffer at a pH of 9.26? (K_a for $HC_2H_3O_2$ is 1.8×10^{-5}; K_b for NH_3 is 1.8×10^{-5}.)
    (A) 0.20 M $HC_2H_3O_2$ and 0.20 M $NaC_2H_3O_2$
    (B) 3.0 M $HC_2H_3O_2$ and 3.0 M NH_4Cl
    (C) 3.0 M $HC_2H_3O_2$ and 3.0 M NH_3
    (D) 0.20 M NH_3 and 0.20 M NH_4Cl
    (E) 3.0 M NH_3 and 3.0 M NH_4Cl

13. A 100.0-mL sample of 0.2 M $(CH_3)_3N$ ($K_b = 5.3 \times 10^{-5}$) is titrated with 0.2 M HCl. What is the pH at the equivalence point?
    (A) 7.0　　(B) 3.1　　(C) 10.4　　(D) 5.4　　(E) 9.5

14. Which of the following compounds has the lowest solubility, in moles per liter, in water?
    (A) CdS　$K_{sp} = 1.0 \times 10^{-28}$　　(B) $Al(OH)_3$　$K_{sp} = 2 \times 10^{-32}$　　(C) $PbSO_4$　$K_{sp} = 1.3 \times 10^{-8}$
    (D) $Sn(OH)_2$　$K_{sp} = 3 \times 10^{-27}$　(E) MgC_2O_4　$K_{sp} = 8.6 \times 10^{-5}$

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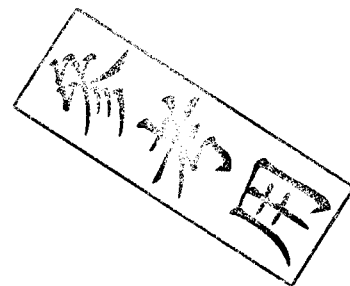
15. Given the following values of equilibrium constants:

$Cu(OH)_2(s) \rightleftharpoons Cu^{2+}(aq) + 2OH^-(aq)$ $K_{sp} = 1.6 \times 19^{-19}$

$Cu(NH_3)_4{}^{2+}(aq) \rightleftharpoons Cu^{2+}(aq) + 4NH_3(aq)$ $K = 1.0 \times 10^{-13}$

What is the value of the equilibrium constant for the following reaction? $Cu(OH)_2(s) + 4NH_3(aq) \rightleftharpoons$ $Cu(NH_3)_4{}^{2+}(aq) + 2OH^-(aq)$

(A) 1.6×10^{-19} (B) 1.6×10^{-6} (C) 6.2×10^{31} (D) 1.6×10^{-32} (E) 1.0×10^{13}

16. Consider the following reaction: $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$ $\Delta H = -198$ kJ   Calculate the energy change associated with 0.334 mole of SO_2 reacting with excess O_2.

(A) -33.1 kJ   (B) -66.1 kJ   (C) -132 kJ   (D) -198 kJ   (E) -424 kJ

17. For the reaction $H_2O(l) \rightarrow H_2O(g)$ at 298 K, 1.0 atm, ΔH is more positive than ΔE by 2.5 kJ/mol.   This quantity of energy can be considered to be

(A) the heat flow required to maintain a constant temperature.

(B) the value of ΔH itself.

(C) the work done in pushing back the atmosphere.

(D) the difference in the H–O bond energy in $H_2O(l)$ compared to $H_2O(g)$.

(E) none of these.

18. Given: $Cu_2O(s) + (1/2)O_2(g) \rightarrow 2CuO(s)$ $\Delta H° = -144$ kJ

$Cu_2O(s) \rightarrow Cu(s) + CuO(s)$ $\Delta H° = +11$ kJ
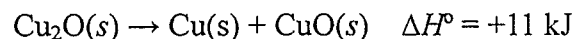
Calculate the standard enthalpy of formation of $CuO(s)$.

(A) -166 kJ   (B) -299 kJ   (C) $+299$ kJ   (D) $+155$ kJ   (E) -155 kJ

19. For which process is ΔS negative?

(A) evaporation of 1 mol of $CCl_4(l)$

(B) mixing 5 mL of ethanol with 25 mL of water

(C) raising the temperature of 100 g of Cu from 275 K to 295 K

(D) compressing 1 mol of Ne at constant temperature from 1.5 atm to 0.5 atm

(E) grinding a large crystal of KCl to powder

20. For the reaction $A + B \rightarrow C + D$, $\Delta H° = +40$ kJ and $\Delta S° = +50$ J/K.   Therefore, the reaction under standard conditions is

(A) spontaneous at temperatures less than 10 K.

(B) spontaneous at temperatures greater than 800 K.

(C) spontaneous only at temperatures between 10 K and 800 K.

(D) spontaneous at all temperatures.

(E) nonspontaneous at all temperatures.

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21. For which of the following processes would $\Delta S°$ be expected to be most positive?

    (A) $O_2(g) + 2H_2(g) \rightarrow 2H_2O(g)$　　　(B) $H_2O(l) \rightarrow H_2O(s)$　　　(C) $N_2O_4(g) \rightarrow 2NO_2(g)$

    (D) $2NH_4NO_3(s) \rightarrow 2N_2(g) + O_2(g) + 4H_2O(g)$　　　(E) $NH_3(g) + HCl(g) \rightarrow NH_4Cl(g)$

22. Which of the following is the best reducing agent?

    $Cl_2 + 2e^- \rightarrow 2Cl^-$　　　$E° = 1.36$ V

    $Mg^{2+} + 2e^- \rightarrow Mg$　　　$E° = -2.37$ V

    $2H^+ + 2e^- \rightarrow H_2$　　　$E° = 0.00$ V

    (A) Cl_2　　　(B) H_2　　　(C) Mg　　　(D) Mg^{2+}　　　(E) Cl^-

23. The standard potential for the reaction $Zn + 2Ag^+ \rightarrow Zn^{2+} + 2Ag$ is 1.56 V.　　Given that the standard reduction potential for $Ag^+ + e^- \rightarrow Ag$ is 0.80 V, determine the standard reduction potential for $Zn^{2+} + 2e^- \rightarrow Zn$.

    (A) −0.76 V　　　(B) 0.04 V　　　(C) 0.76 V　　　(D) 2.36 V　　　(E) none of these

24. The standard reduction potentials are as follows:

    $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$　　　$E° = 1.51$ V

    $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2 Cr^{3+} + 7H_2O$　　　$E° = 1.33$ V

    How many electrons are transferred in the balanced reaction (that is, what will be the value of n in the Nernst equation)?

    (A) 5　　　(B) 6　　　(C) 12　　　(D) 30　　　(E) 36

25. From the following list of observations, choose the one that most clearly supports the conclusion that atoms contain electrons.

    (A) the emission spectrum of hydrogen

    (B) the photoelectric effect

    (C) the scattering of alpha particles by metal foil

    (D) diffraction

    (E) cathode "rays"

26. What is the electron configuration of Cr^{3+}?

    (A) [Ar] $4s^2 3d^1$　　　(B) [Ar] $4s^1 3d^2$　　　(C) [Ar] $3d^3$　　　(D) [Ar] $4s^2 3d^4$　　　(E) none of these

27. An element has the electron configuration [Kr] $4d^{10} 5s^2 5p^2$.　　The element is a(n)

    (A) nonmetal　　　(B) transition metal　　　(C) lanthanide　　　(D) metal　　　(E) chalcogenide

28. Which element listed below has the highest electronegativity?

    (A) K　　　(B) Rb　　　(C) Te　　　(D) I　　　(E) Br

29. The molecule XCl_5^- has a square pyramidal shape.　　Which of the following atoms could be X?

    (A) S　　　(B) Xe　　　(C) O　　　(D) P　　　(E) At least two of these atoms could be X.

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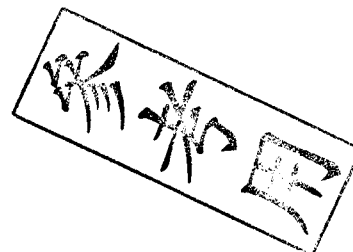
30. Which molecule or ion violates the octet rule?

    (A) H_2O　　(B) I_3^-　　(C) NO_3^-　　(D) PF_3　(E) none of these

31. What is the hybridization of the central atom in PCl_4^+?

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

32. Which of the following statements is correct?

    (A) A triple bond is composed of two σ bonds and one π bond.

    (B) σ bonds result from the head-to-head overlap of atomic orbitals.

    (C) Free rotation may occur about a double bond.

    (D) π bonds have electron density on the internuclear axis.

    (E) More than one of these statements are correct.

33. The configuration $(\sigma_{2s})^2(\sigma_{2s}*)^2(\pi_{2py})^1(\pi_{2px})^1$ is the molecular orbital description for the ground state of which of the following species?

    (A) B_2　　(B) B_2^{2-}　　(C) Li_2^+　　(D) C_2　　(E) Be_2

34. The following data were obtained for the reaction of NO with O_2.　Concentrations are in molecules/cm^3 and rates are in molecules/cm^3·s.

$[NO]_0$	$[O_2]_0$	Initial Rate
1×10^{18}	1×10^{18}	2.0×10^{16}
2×10^{18}	1×10^{18}	8.0×10^{16}
3×10^{18}	1×10^{18}	18.0×10^{16}
1×10^{18}	2×10^{18}	4.0×10^{16}
1×10^{18}	3×10^{18}	6.0×10^{16}

    Which of the following is the correct rate law?

    (A) Rate = $k[NO][O_2]$　　　(B) Rate = $k[NO]^2$　　　(C) Rate = $k[NO][O_2]^2$

    (D) Rate = $k[NO]^2[O_2]$　　(E) Rate = $k[NO]^2[O_2]^2$

35. If the reaction $2HI \rightarrow H_2 + I_2$ is second order, which of the following will yield a linear plot?

    (A) log [HI] vs. time　　(B) [HI] vs. time　　(C) ln [HI] vs. time

    (D) $[HI]^{1/2}$ vs. time　　(E) 1/[HI] vs. time

36. What is the overall order of a reaction with the following rate law?

    Rate = $[A]^2[B]^1[C]^0$

    (A) 0　　(B) 1　　(C) 2　　(D) 3　　(E) 4

37. Which intermolecular force is the strongest?

    (A) dipole-dipole interactions　　(B) hydrogen bonding　　(C) polar covalent bonds

    (D) London dispersion forces　　(E) ionic bonding

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38. In the unit cell of sphalerite, Zn^{2+} ions occupy half the tetrahedral holes in a face-centered cubic lattice of S^{2-} ions. What is the number of formula units of ZnS in the unit cell?
    (A) 2   (B) 3   (C) 4   (D) 6   (E) 8

39. In which of the following processes is energy evolved as heat?
    (A) sublimation   (B) crystallization   (C) melting   (D) vaporization   (E) none of these

40. A lquid-liquid solution is called an ideal solution if
    I. it obeys $PV = nRT$.
    II. it obeys Raoult's law.
    III. solute-solute, solvent-solvent, and solute-solvent interactions are very similar.
    IV. solute-solute, solvent-solvent, and solute-solvent interactions are quite different.
    (A) I, II, III   (B) II, III   (C) I, II, IV   (D) II, IV   (E) I, II

41. Which of the following statements is(are) true?
    (A) The rate of dissolution of a solid in a liquid always increases with increasing temperature.
    (B) The solubility of a solid in a liquid always increases with increasing temperature.
    (C) According to Henry's law, the amount of gas dissolved in a solution is directly proportional to the pressure of the gas above the liquid.
    (D) Two of these statements are true.
    (E) All of these statements are true.

42. A solute added to a solvent raises the boiling point of the solution because
    (A) the solute particles lower the solvent's vapor pressure, thus requiring a higher temperature to cause boiling.
    (B) the temperature to cause boiling must be great enough to boil not only the solvent but also the solute.
    (C) the solute particles raise the solvent's vapor pressure, thus requiring a higher temperature to cause boiling.
    (D) the solute increases the volume of the solution, and an increase in volume requires an increase in the temperature to reach the boiling point (derived from $PV = nRT$).
    (E) Two of the above are correct.

43. In which group are the elements listed in correct order of increasing first ionization energy?
    (A) Na > P > Cl   (B) Cs > Na > K   (C) K > Ca > Ge   (D) Al > Si > P   (E) Cs < Rb < Na

44. Which metal ion has a d^6 electron configuration?
    (A) Mn^{2+} (B) Co^{3+} (C) Ni^{2+} (D) Ti^{2+} (E) Fe^{3+}

45. Which of the following coordination compounds will form a precipitate when treated with an aqueous solution of $AgNO_3$?
    (A) $[Cr(NH_3)_3Cl_3]$ (B) $Na_3[CrCl_6]$ (C) $[Cr(NH_3)_6]Cl_3$ (D) $Na_3[Cr(CN)_6]$ (E) two of these

46. The spectrochemical series is $I^- < Br^- < Cl^- < F^- < OH^- < H_2O < NH_3 < en < NO_2^- < CN^-$ Which of the following complexes will absorb visible radiation of the highest energy (shortest wavelength)?

(A) $[Co(H_2O)_6]^{3+}$　　(B) $[Co(I)_6]^{3-}$　(C) $[Co(OH)_6]^{3-}$　(D) $[Co(en)_3]^{3+}$　(E) $[Co(NH_3)_6]^{3+}$

47. Which of the following processes increases the atomic number by 1?

(A) gamma-ray production　　(B) alpha production　　(C) neutron-particle production

(D) proton production　　　　(E) beta-particle production

48. Vibrational transitions in molecules typically require energies that correspond to the _____ region of the electromagnetic spectrum.

(A) UV　　(B) visible　　(C) IR　　(D) X-ray　　(E) microwave

49. Which of the following is *not* a structural isomer of 1-pentene?

(A) 2-pentene　　　　(B) 1-methyl-cyclobutene　　　　(C) cyclopentane

(D) 2-methyl-2-butene　　(E) 3-methyl-1-butene

50. Identify the type of organic compound shown:

$$CH_3 - \overset{\overset{\textstyle |}{}}{C} = O$$
$$\overset{|}{O}$$
$$\overset{|}{CH_3}$$
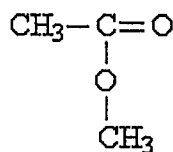
(A) ester　　(B) aldehyde　　(C) amine　　(D) carboxylic acid　　(E) ketone

1																	18
1 H 1.00794	2	B = Solids		Hg = Liquids		Kr = Gases		Pm = Not found in nature				13	14	15	16	17	2 He 4.002602
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.9984032	10 Ne 20.1797
11 Na 22.989770	12 Mg 24.3050	3	4	5	6	7	8	9	10	11	12	13 Al 26.981538	14 Si 28.0855	15 P 30.973761	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.955910	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938049	26 Fe 55.845	27 Co 58.933200	28 Ni 58.6934	29 Cu 63.545	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.92160	34 Se 78.96	35 Br 79.504	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 196.56655	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.90447	54 Xe 131.29
55 Cs 132.90545	56 Ba 137.327	71 Lu 174.967	72 Hf 178.49	73 Ta 180.94.79	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.078	79 Au 196.56655	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.58038	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	103 Lr (262)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 Ds (269)	111 Rg (272)	112 Cn (277)	113 Uut (277)	114 Uuq (277)	115 Uup (277)	116 Uuh (277)		118 Uuo (277)

57 La 138.9055	58 Ce 140.116	59 Pr 140.50765	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.964	64 Gd 157.25	65 Tb 158.92534	66 Dy 162.50	67 Ho 164.93032	68 Er 167.26	69 Tm 168.93421	70 Yb 173.04
89 Ac 232.0381	90 Th 232.0381	91 Pa 231.035888	92 U 238.0289	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)