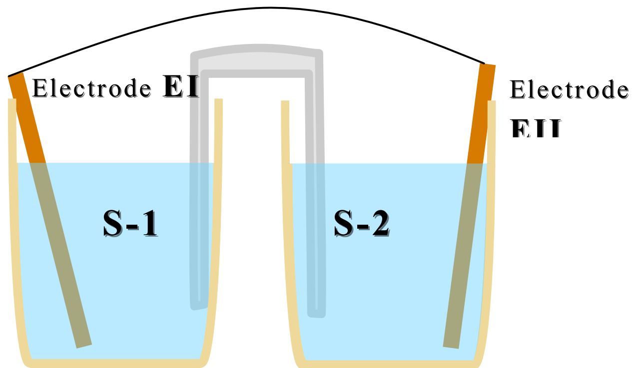
Consider setting up the reaction in separate beakers connected by a salt bridge and wire electrodes as shown below.



1.) Which arrangement of the electrodes and ions would result in electron flow from the left beaker to the right if S-2 has Ag^{+} ions?

	EI	**EII**	**S-1**
A)	Ag	Cu	Cu^{+2}
B)	Ag	Cu	Ag^{+}
C)	Cu	Ag	Cu^{+2}
D)	Cu	Ag	Ag^{+}

E) Cannot be determined.

2.) What direction(s) would ions flow through the salt bridge if electrons flowed from the left beaker to the right? **MARK ALL THAT APPLY.**

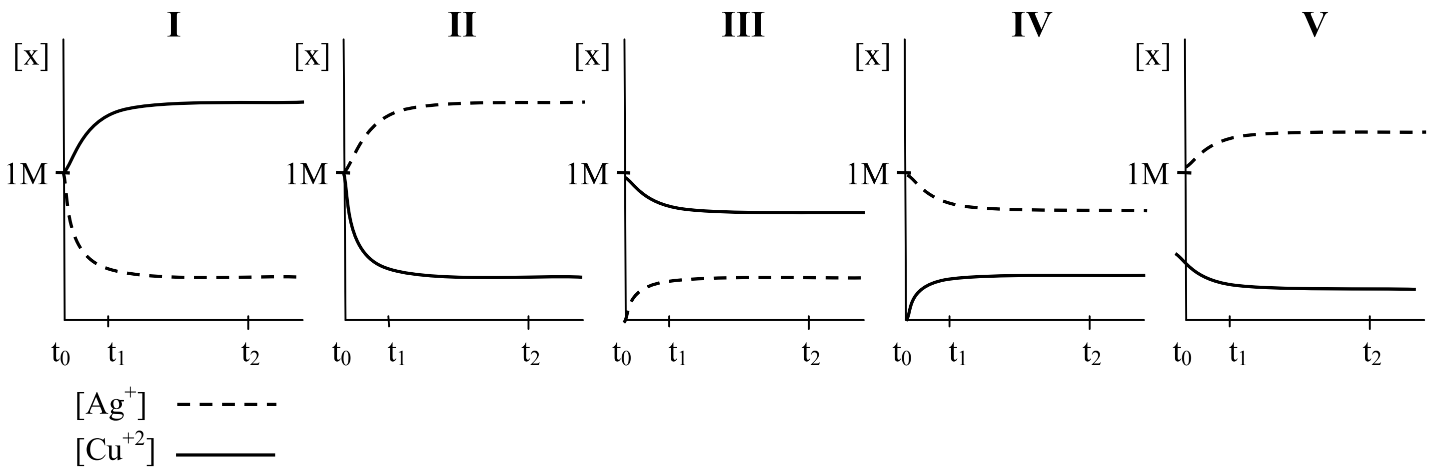
A) Negative ions would flow to the right.
B) Positive ions would flow to the right.
C) Negative ions would flow to the left.
D) Positive ions would flow to the left.
E) Cannot be determined.

3.) Which arrangement of the electrodes and ions results in a reaction in the left beaker only?

	EI	**EII**	**S-I**
A)	Ag	Cu	Cu^{+2}
B)	Ag	Cu	Ag^{+}
C)	Cu	Ag	Cu^{+2}
D)	Cu	Ag	Ag^{+}

E) Cannot be determined.

$$2Ag^{+}\,(aq) + Cu\,(s) \rightarrow 2Ag\,(s) + Cu^{+2}\,(aq)$$



For questions 4-8,consider the plots of concentration vs. time for the silver and copper ion concentrations starting from a variety of initial conditions at 298K in the cell arranged according to the above equation:

4.) Which plot(s) represent non-spontaneous reactions? **MARK ALL THAT APPLY.**

A) I
B) II
C) III
D) IV
E) V

5.) For which plot(s) are the initial product and reactant conditions standard states? **MARK ALL THAT APPLY.**

A) I
B) II
C) III
D) IV
E) V

6.) For the reaction in plot III, what is ΔG at time t_0?

A) $\Delta G > 0$ B) $\Delta G = 0$ **C) $\Delta G < 0$** D) $\Delta G = \Delta G°$ E) none of these

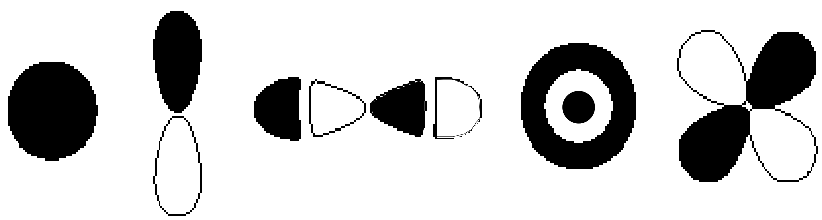
7.) For the reaction in plot III, what is ΔG at time t_2?

A) $\Delta G > 0$ **B) $\Delta G = 0$** C) $\Delta G < 0$ D) $\Delta G = \Delta G°$ E) none of these

8.) Which is true for the reaction in plot I at time t_1?

A) $Q > K$ B) $Q = K$ **C)** $Q < K$ D) $Q = 0$ E) none of these

Consider the atomic orbitals below for questions 9 and 10. Black represents a negative sign to the wave function, white positive.



A B C D E

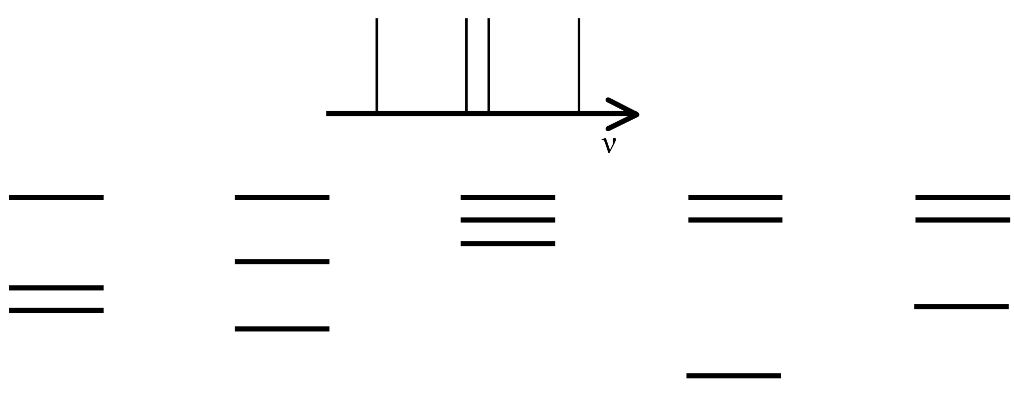
9.) Which has the most angular nodes?

A) A B) B C) C D) D **E) E**

10.) Which would have designation 3p?

A) A B) B **C) C** D) D E) E

11.) To which energy level scheme does the following emission spectrum correspond?



A B C D E

12.) Consider the ***unbalanced*** redox reaction below:

$Cr_2O_7^{2-} + I_2 \rightarrow Cr^{3+} + IO_4^-$

What is the number of electrons transferred in the balanced equation under aqueous acidic conditions?

A) 14
B) 17
C) 42
D) 4
E) 6

13.) Which of the following statements are true?

A) pH of 0.01 M HCl > pH of 0.01 M KOH
B) pH of 0.01 M HF > pH of 0.01 M KBr
C) pH of 0.01 M NH_4Cl > pH of 0.01 M NH_3
D) pH of 0.01 M NaCN > pH of 0.01 M $CaCl_2$

14.) A blue advertising signs emits light with a wavelength of 400 nm. Which relationship is appropriate for directly calculating the frequency of this light?

A) $E = \frac{1}{2} mv^2$
B) $E_n = -(Z^2/n^2) R_\infty$
C) $\lambda = c/\nu$
D) $E = hc/\lambda$
E) $p = h/\lambda$

15.) What is the coefficient for oxygen in the balanced chemical equation for the combustion of the one mole of the hydrocarbon acetylene (C_2H_2) in oxygen (O_2) to produce carbon dioxide (CO_2) and water (H_2O)?

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

16.) What is the bond order of the N-O bond in the nitrate ion?

A) 1 **B) 1 1/3** C) 1 ½ D) 2 E) 2 ½

17.) What is the maximum number of electrons with the same spin quantum number (m_s) for the principle quantum number 3?

A) 4 B) 8 **C) 9** D) 14 E) 19

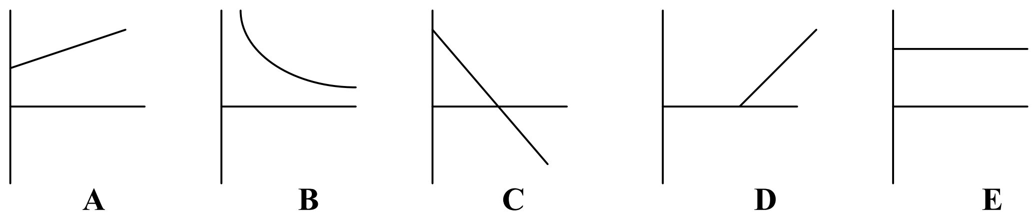
18.) The K_a of formic acid (HCOOH) is 1.80×10^{-4}. What is the pK_b of the conjugate base?

A) 3.75
B) 10.25
C) 7.00
D) 1.80
E) 4.18

19) Novocaine can be used as a local anesthetic, and has a pK_b of 5.00. What is the ratio of novocaine to its conjugate acid if a small amount is added to the blood, which has a pH of approximately 7?

A) 7/5
B) 5/7
C) 1/1
D) 1/100
E) 100/1

For questions 20-23, choose from the following graphs to answer.



20) Which of the graphs is a plot of ln K vs. 1/T for an endothermic reaction where the change in entropy is positive? **C**

21) Which of the graphs is a plot of temperature versus heat added for a liquid that does not include a phase change? **A**

22) Which of the graphs is a plot of kinetic energy vs. frequency of incident light for photoelectrons ejected from sodium? **D**

23) Which of the graphs is a plot of the equilibrium constant vs. initial concentrations of reactants for a chemical reaction of the form $A + B \rightarrow C$? **E**

24) The acid ionization constants are K_{a1} for NH_4^+ and K_{a2} for HAc. What is K for the following reaction?

$$HAc\ (aq) + NH_3\ (aq) \rightleftharpoons Ac^-\ (aq) + NH_4^+\ (aq)$$

A) K_w
B) K_{a2}/ K_{a1}
C) $(K_{a1} K_{a2}) / K_w$
D) K_{a1} / K_{a2}
E) $K_{a1}K_{a2}$

25) Which of the following is the ground state electronic configuration for Tin (Sn)?

A) $[Kr]4s^2 3d^{10} 4p^2$
B) $[Kr]5s^2 5d^{10} 5p^2$
C) $[Kr]5s^2 4d^{10} 5p^3$
D) $[Kr]5s^2 4d^{12} 5p^0$
E) $[Kr]5s^2 4d^{10} 5p^2$

26) Which one of the following is always positive when a spontaneous process occurs?

A) ΔSsystem
B) ΔSsurroundings
C) ΔSuniverse
D) ΔHuniverse
E) ΔHsurroundings

27) For the element bismuth, which ionization will require the least amount of energy?

A) $Bi + \text{energy} \rightarrow Bi^{+} + 1e^-$
B) $Bi^{+} + \text{energy} \rightarrow Bi^{2+} + 1e^-$
C) $Bi^{2+} + \text{energy} \rightarrow Bi^{3+} + 1e^-$
D) $Bi^{3+} + \text{energy} \rightarrow Bi^{4+} + 1e^-$
E) $Bi^{4+} + \text{energy} \rightarrow Bi^{5+} + 1e^-$

28) For an exothermic reaction, K will increase when:

A) reactants are added.
B) products are added.
C) the temperature decreases.
D) the volume decreases.
E) the entropy of the universe increases.

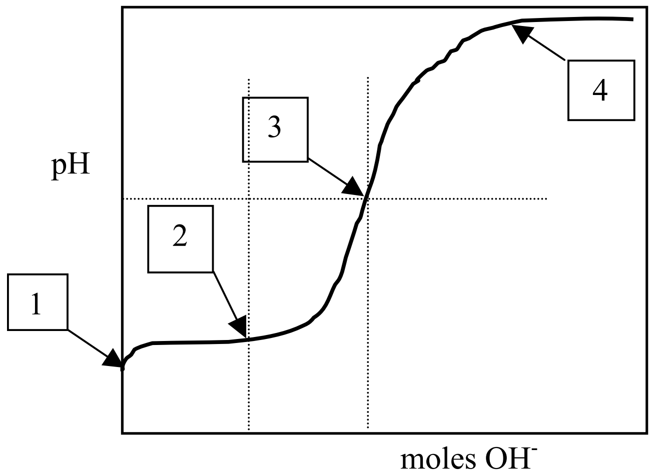
29) Which of the following statements is true?

A. If N/Z ratio is too high, there are too many protons and the nuclide will undergo positron emission or electron capture.
B. If N/Z ratio lies somewhere below 1, the nuclide is stable.
C. If N/Z ratio is too low, there are too many neutrons and the nuclide will undergo beta decay.
D. The valley of stability is the geographic location where many of the known nuclides were first discovered.
E. None of the above is true.

30) An electron in a hydrogen atom is excited to an excited state with n=2. The atom then emits a photon. What is a possible value of n for the electron following the emission?

A) n = 0
B) n = 1
C) n = 2
D) n = 3
E) Can't tell with the given information

A solution of 0.2 M , hydrofluoric acid (HF), was titrated with a strong base. A pH meter was used to monitor the changes during the titration. The Ka for HF is 7.2 x 10^{-4}. Answer **31-34** using the titration curve below.



31) What is the value of the equilibrium constant for the ***titration*** reaction shown here?
HF (aq) + OH^- (aq) $\leftrightarrows$ F^- (aq) + H_2O (l)

A) 7.2 x10^{-4}
B) 1.4 x10^{-11}
C) 1.4 x10^{-14}
D) 7.2 x10^{10}
E) 1.4 x 10^{10}

32) Which of the following is the major species in solution at point marked 1 on the graph?

A) HF
B) OH^-
C) F^-
D) H_3O^+

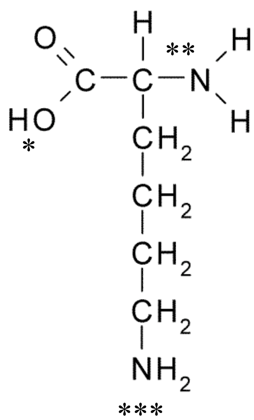
33) Which of the following is/are true at the point marked 2 on the graph? **MARK ALL THAT APPLY.**

A) pH = pKa
B) pH = 7
C) [HF] = [F^-]
D) [OH^-] < 1 M
E) the solution acts as a buffer

34) Which of the following is/are ***false*** at the point marked 3 on the graph? **MARK ALL THAT APPLY.**

A) pH > 7
B) [HF] = [OH^-]
C) moles of added OH^- equals the initial amount of HF
D) [HF] = 0
E) the solution acts as a buffer

35)) Consider the amino acid lysine, shown in the neutral rather than zwitterionic form:



The pKa for the c-terminus (labeled ***)** is 2.2, the pKa for the n-terminus (**) is 9.0, and the pKa for the nitrogen of the side group (***) is 10.5.

What is the charge of lysine at pH 7?

A) -2
B) -1
C) 0
D) +1
E) +2

36) Below what temperature does the following reaction become nonspontaneous?

2 HNO_3(aq) + NO(g) → 3 NO_2(g) + H_2O(l) ΔH = +136.5 kJ; ΔS = +287.5 J/K

A) 39.2 K
B) 151 K
C) 475 K
D) This reaction is nonspontaneous at all temperatures.
E) This reaction is spontaneous at all temperatures.

37) What is the mass (in kg) of 6.89×10^{25} molecules of CO_2?

A) 3.85 kg
B) 5.04 kg
C) 2.60 kg
D) 3.03 kg
E) 6.39 kg

38.) Which of the following contains the LEAST atoms? You shouldn't need to do a calculation here.

A) 10.0 g Ne
B) 10.0 g He
C) 10.0 g Ar
D) 10.0 g Tc
E) 10.0 g Hg

39) Choose the transition (in a hydrogen atom) below that represents the **emission** of the shortest wavelength photon.

A) n = 1 to n = 2
B) n = 2 to n = 3
C) n = 4 to n = 5
D) n = 6 to n = 3
E) n = 3 to n = 1

40) Draw the Lewis structure for sulfate. How many equivalent resonance structures can be drawn?

A) 6
B) 2
C) 4
D) 3
E) 8

41) What is the maximum number of f orbitals that are possible?

A) 1
B) 3
C) 7
D) 5
E) 9

42) Electromagnetic radiation with a wavelength of 531 nm appears as green light to the human eye. Thus, a laser that emits 1.3×10^{-2} J of energy in a pulse of light at this wavelength produces __________ photons in each pulse.

A) 2.9×10^{-17}
B) 9.2×10^{-24}
C) 1.8×10^{19}
D) 3.5×10^{16}
E) 6.5×10^{13}

43) Consider the following reaction:

$$CuS(s) + O_2(g) \leftrightarrows Cu(s) + SO_2(g)$$

A reaction mixture initially contains 2.9 M O_2. Determine the equilibrium concentration of O_2 if K_c for the reaction at this temperature is 1.5.

A) 1.9 M
B) 1.7 M
C) 2.2 M
D) 1.2 M
E) 0.59 M

44) Calculate the $\Delta G°_{rxn}$ using the following information.

	$4\ HNO_3(g)$ +	$5\ N_2H_4(l)$ →	$7\ N_2(g)$ +	$12\ H_2O(l)$	$\Delta G°_{rxn} = ?$
$\Delta G°_f$ (kJ/mol)	-73.5	149.3		-237.1	

A) -3.298 x 10^3 kJ
B) -312.9 kJ
C) +2.845 x 10^3 kJ
D) +110.7 kJ
E) -954.7 kJ

45) If two electrons in the same atom have the same value of "*l*", they are
A) in the same type of orbital, but not necessarily in the same level.
B) in the same level, but different orbital types.
C) in the same orbital.
D) in different levels and in different types orbitals.
E) none of the above.

46) Determine the ammonia concentration of an aqueous solution that has a pH of 11. 00. The equation for the dissociation of NH_3 ($K_b = 1.8 \times 10^{-5}$) is

$NH_3(aq) + H_2O(l) \leftrightarrows NH_4^+(aq) + OH^-(aq)$.

A) 3.0 M
B) 0. 056 M
C) 1.8×10^{-2} M
D) 1.0×10^{-3} M
E) 0.40 M

47) Use the tabulated half-cell potentials to calculate ΔG° for the following redox reaction.

$2\ Al(s) + 3\ Mg^{2+}(aq) \rightarrow 2\ Al^{3+}(aq) + 3\ Mg(s)$

A) +4.1 x 10^2 kJ
B) +1.4 x 10^2 kJ
C) -2.3 x 10^2 kJ
D) -7.8 x 10^2 kJ
E) +6.8 x 10^2 kJ

48) Calculate the pH of a buffer that is 0.020 M HF and 0.040 M LiF. The K_a for HF is 7.2×10^{-4}.

A) 2.06
B) 4.86
C) 3.17
D) 3.46
E) 3.76

49) Calculate the molar solubility of thallium chloride in 0. 40 M NaCl at 25°C. K_{sp} for TlCl is 1.7×10^{-4}.

A) 6.8×10^{-5} M
B) 4.2×10^{-4} M
C) 8.2×10^{-3} M
D) 1.3×10^{-2} M
E) 1.7×10^{-4} M

50) A possible decay chain that could fuel a planetary object begins with thorium 232, an alpha emitter. What is the daughter nucleus of the α decay of ^{232}Th?

A) ^{232}U
B) ^{228}Th
C) ^{228}Ra
D) ^{230}Po

51) Calculate $\Delta S°_{rxn}$ for the following reaction. The S° for each species is shown below the reaction.

	$4\ NH_3(g)$	$+\ 5\ O_2(g)$	$\rightarrow$	$4\ NO(g)$	$+\ 6\ H_2O(g)$
S°(J/mol·K)	192.8	205.2		210.8	188.8

A) +287.4 J/K
B) -401.2 J/K
C) +160.0 J/K
D) -336.6 J/K
E) +178.8 J/K

52) Calculate ΔG_{rxn} at 298 K under the conditions shown below for the following reaction.

$Fe_2O_3(s) + 3\ CO(g) \rightarrow 2\ Fe(s) + 3\ CO_2(g)$ $\Delta G° = -28.0$ kJ

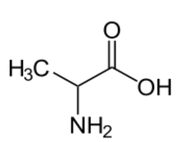
$P(CO) = 1.4$ atm, $P(CO_2) = 2.1$ atm

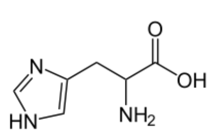
A) +31.0 kJ
B) +2.99 kJ
C) -30.7 kJ
D) +17.5 kJ
E) -25.0 kJ

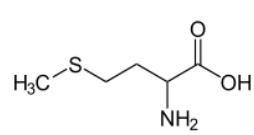
53) Give the number of valence electrons for Br^-.

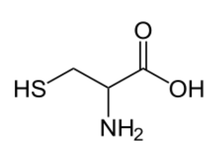
A) 16
B) 18
C) 6
D) 8
E) 7

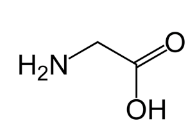
54) Which of the following amino acids is NOT chiral?

A)


B)


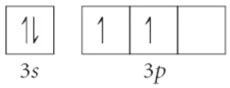
C)


D)


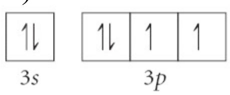
E)


55) Choose the valence orbital diagram that represents the ground state of S^{2+}.

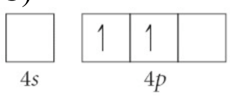
A)



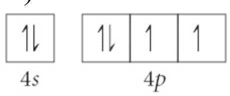
B)



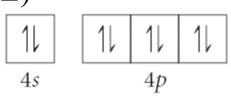
C)



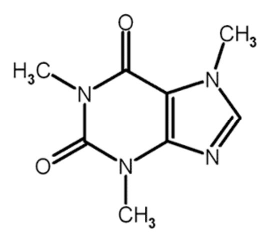
D)



E)



56) How many sigma bonds are present in the caffeine?



A) 27 B) 28 **C)25** D) 23 **E) 24**

(Poor choice of figure, it has a hidden hydrogen on rightmost carbon, either 24 or 25 were accepted)

57) Which of the following hybridizations are present in caffeine? **MARK ALL THAT APPLY.**

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

58) What is the F-Xe-F bond angle in XeF_4?

A) 60 **B) 90** C) 110 D) 120 E) 180

59) You have a galvanic cell with two solutions; Solution one is 0.3M $FeCl_2$, solution two is 1.7 M $MgCl_2$. The electrode in solution one is Fe and the electrode in solution 2 is Mg. The temperature is 85º C.

What is the spontaneous cell potential in this setup?

A) +1.94 V
B) +1.93 V
C) +1.92 V
D) +1.91 V
E) +1.90 V

60) The half-life of ^{232}Th is 1.41×10^{10} y. Through a creative and highly sophisticated experiment, scientists determine that 82% of the thorium present from the planetoid's formation is still present. What is the age of the planetary object?

A) 1.5 million years
B) 400 million years
C) 1 billion years
D) 4 billion years
E) Older than the universe itself (>13.7 billion years)