Chemistry 1A, Spring 2009

Final Exam
May 16, 2009
(180 min, closed book)

Name:___________________

SID:_____________________

TA Name:________________

- There are 40 Multiple choice questions worth 6 points each.
- There are 3, multi-part short answer questions.
- For the multiple choice section, fill in the Scantron form AND circle your answer on the exam.
- Put your written answers in the boxes provided. Full credit cannot be gained for answers outside the boxes provided.
- The lecture, homework, chemquizzes, discussion or experiment that each question is based upon is listed after the question e.g. [L3, HW 1.13, CQ 7.3]

Question	Points	Score
Multiple Choice Section	240	
Question 41 Buffer	18	
Question 42 Thermo.	22	
Question 43 Electrochem.	20	
Total	300	

Quantum:

$E = h\nu$

$\lambda\nu = c$

$\lambda_{deBroglie} = h / p = h / mv$

E_{kin} (e-) $= h\nu - \Phi = h\nu - h\nu_0$

$$E_n = -\frac{Z^2}{n^2}R_\infty$$

$\Delta x\, \Delta p \sim h$

$p = mv$

Particle in a box (1-D Quantum):

$E_n = h^2n^2/8mL^2$; n = 1, 2, 3...

Vibrational:

$E_v = (v + ½)\, hA/2\pi$; $A =(k/m)^{½}$

Rotational:

$E_n = n(n + 1)\, hB$; $B = h/8\pi^2I$; $I = 2mr^2$

$m = m_Am_B/(m_A + m_B)$

Ideal Gas:

$PV = nRT$

$$E_{kin} = \frac{3}{2}RT$$

$$v_{rms} = \sqrt{\frac{3RT}{M}}$$

Constants:

$N_0 = 6.02214 \times 10^{23}\ mol^{-1}$

$1\ eV = 1.60218\times10^{-9}$ J

$1 Ci = 3.7\times10^{10}$ disintegrations/sec

$R_\infty = 3.289\times10^{15}$ Hz or 2.179×10^{-18} J

$k = 1.38066\times10^{-23}\ J\ K^{-1}$

$h = 6.62608\times10^{-34}$ J s

$m_e = 9.101939\times10^{-31}$ kg

$c = 2.99792\times10^{8}\ m\ s^{-1}$

T (K) = T (C) + 273.15

F = 96,485 C / mol

1 V = 1 J / C

Gas Constant:

$R = 8.31451\ J\ K^{-1}\ mol^{-1}$

$R = 8.20578\times10^{-2}\ L\ atm\ K^{-1}\ mol^{-1}$

$1\ nm = 10^{-9}$ m   1 kJ = 1000 J

1 atm = 760 mm Hg = 760 torr ≈ 1 bar

1 L atm ≈ 100 J

Thermodynamics:

$\Delta G° = \Delta H° - T\Delta S°$

$\Delta H° = \sum \Delta H°_f$ (products) $- \sum \Delta H°_f$ (reactants)

$\Delta S° = \sum S°$ (products) $- \sum S°$ (reactants)

$\Delta G° = \sum \Delta G°_f$ (products) $- \sum \Delta G°_f$ (reactants)

$S = k_B \ln W$

$\Delta S = q_{rev}/T$

$\Delta E = q + w$

$w = - P_{ext}\Delta V$

for $aA + bB \rightleftarrows cC + dD$

$$Q = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$ At equilibrium, Q = K

$\Delta G = \Delta G° + RT \ln Q$

$G = G° + RT\ln(a)$; a = activity = $\gamma P/P°$ or $\gamma[A]/[A]°$

$\Delta G° = - RT\ln K$

$\Delta G° = - nF\Delta Є^o$

$\Delta Є = \Delta Є^o - (RT/nF) \ln Q$

$$\ln K = -\frac{\Delta H°}{R}\frac{1}{T} + \frac{\Delta S°}{R}$$

$\Delta T = ik_{b,f}\, m$

$\Pi = iMRT$

$P_{total} = P_A + P_B = X_AP_A° + X_BP_B°$

Acid Base:

$pH = - \log[H_3O^+]$

$pX = - \log X$

$$pH = pK_a + \log\frac{[A^-]}{[HA]}$$

Decay Kinetics:

$[A]_t = [A]_0e^{-kt}$ or $N_t = N_0e^{-\lambda t}$

(in book $k = \lambda$)

$\ln(N_t / N_0) = -\lambda t$

$t_{1/2} = \ln2/k$ or $t_{1/2} = \ln2/\lambda$

MULTIPLE CHOICE

1) After the reaction of 2 moles of H_2 and 2 moles of O_2 to form H_2O, which species has the greater number of moles? [CQ 2.1]

A) H_2
B) O_2
C) H_2O
D) they all have an equal number of moles after the reaction

2) Radon has seventeen isotopes ranging from ^{210}Rn to ^{226}Rn. What do all of these isotopes have in common? [HW B11]

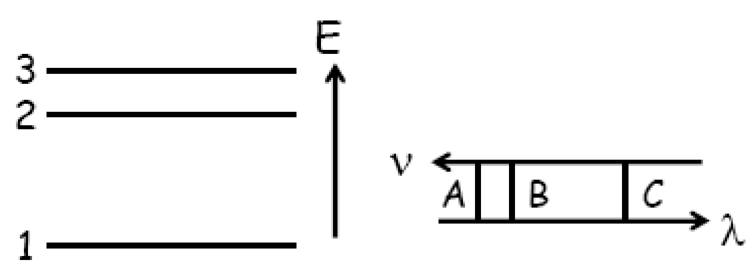
A) the same number of electrons
B) the same number of protons
C) the same number of neutrons
D) a and b
E) b and c

3) In the photoelectric effect, increasing the intensity of the monochromatic light will ____. [L4]

A) ensure that electrons will be emitted from all metals.
B) cause more electrons to be emitted from the metal if the frequency is sufficiently high.
C) cause the electrons to be emitted with higher kinetic energy if the frequency is sufficiently high.
D) have no effect on the experiment.
E) both b and c

4) The energy level diagram for an atom is shown below along with its corresponding emission spectrum. Which transition corresponds to line C? [CQ 6.1, HW 1.36]

A) 2 to 3
B) 1 to 3
C) 2 to 1
D) 3 to 1
E) 3 to 2



Currently, the human population is largely concerned with global warming and increased concentrations of Greenhouse Gases.

5) Given that human noses are best equipped to smell polar molecules, which of the following Greenhouse Gases would be the MOST DIFFICULT for us to detect by smell?

A) Water
B) Methane
C) Nitrous oxide
D) Ozone
E) Chlorofluorocarbons

6) All of the P-O bond lengths in PO_4^{3-} have been determined experimentally. Which statement best describes the type of bonds that we observe in the ion? (Assume formal charge is minimized.)

A) One double bond and three single bonds
B) Two single bonds and two double bonds
C) Four single bonds
D) Four double bonds
E) None of the above

7) Which of the following reactions would result in energy released? [Disc 4]

A) $Na^+ (g) + e^- \rightarrow Na (g)$
B) $F^+ (g) + e^- \rightarrow F (g)$
C) Both A and B
D) Neither A nor B

8) Which of the following species have the smallest ionization energy? [CQ11.2]

A) K^+
B) Ar
C) Cl^-
D) They have equal ionization energy

9) Which of the following is the best explanation for your response to the previous question? [L11, Disc 4]

A) Noble gases are stable. All atoms want noble gas configurations.
B) The greater the number of protons, the greater the effective nuclear charge.
C) Removing the second electron from an atom always requires more energy than the first.
D) They are isoelectronic. All the atoms and ions have the same number of electrons.

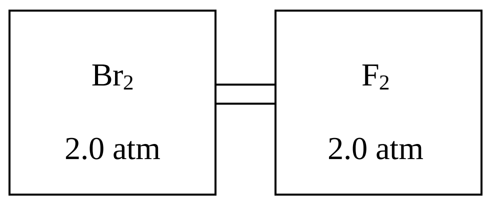
10) Arrange the following molecules in order of increasing bond angle. [CQ15.1]

CH_4, NH_3, AlF_2^-, BF_3, H_2S

A) $BF_3 < AlF_2^- < CH_4 < NH_3 < H_2S$
B) $CH_4 < NH_3 < BF_3 < AlF_2^- < H_2S$
C) $CH_4 < AlF_2^- < H_2S < NH_3 < BF_3$
D) $H_2S < AlF_2^- < BF_3 < NH_3 < CH_4$
E) $H_2S < NH_3 < CH_4 < AlF_2^- < BF_3$

You have two closed 1.0 L containers, one with 2.0 atm of Br_2 (g) and the other with 2.0 atm of F_2 (g). When the containers are connected and the gases are allowed to mix, Br_2 (g) and F_2 (g) react to form BrF_5 (g). Assume that the reaction goes to completion and that the initial and final temperatures are equal.

$$Br_2\,(g) + 5\,F_2\,(g) \rightarrow 2\,BrF_5\,(g)$$



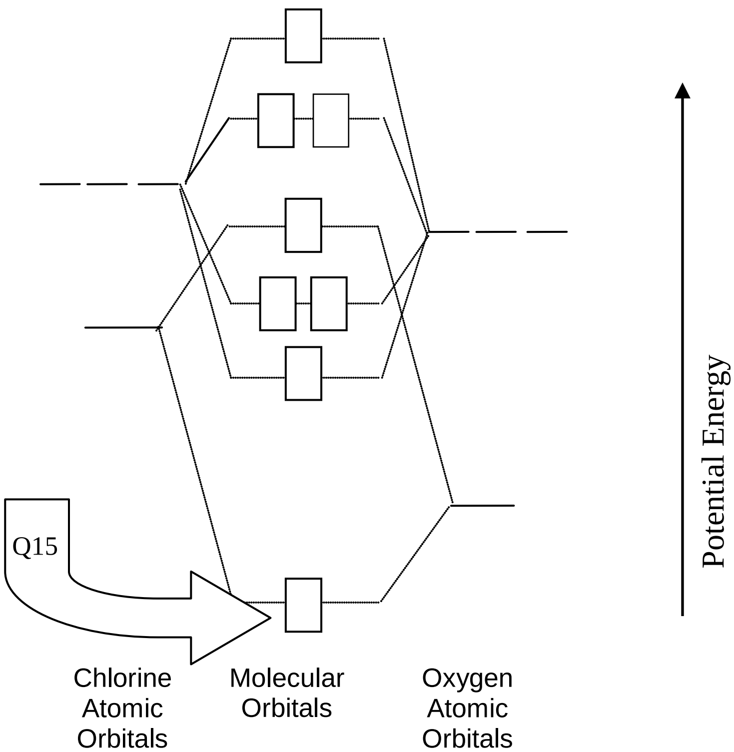
11) What is the final pressure in the system after the reaction has taken place? [CQ18.4]

A) 1.0 atm
B) 1.2 atm
C) 2.0 atm
D) 0.6 atm
E) 2.4 atm

Given the atomic orbitals and the molecular orbitals shown complete the following tasks. Use the completed diagram to answer the next four questions.

a. Fill in the s and p electrons for oxygen and chlorine atomic orbitals.

b. Fill in the electrons for the molecule, ClO, on the molecular orbital diagram.



12) Of the atoms shown, which is more electronegative?

A) chlorine

$\boxed{\text{B)}}$ oxygen

C) they have the same electronegativity

D) not enough information provided

13) What is the bond order for the ClO molecule?

A) 0

B) 1.0

$\boxed{\text{C)}}$ 1.5

D) 2.0

E) 2.5

(ClO MO Continued)

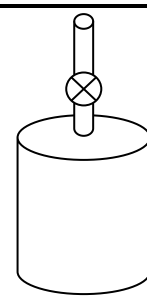
14) Based on the molecular orbital diagram, would you expect the molecule ClO to be attracted to a magnetic field?

A) yes
B) no
C) not enough information provided

15) Pictured below are cross sectional diagrams of atomic orbitals. Which two orbitals overlap to generate the σ molecular orbital indicated by the arrow on the MO diagram? (Mark two answers on your scantron.)

A) B) C) D) E)

One mole each of gaseous He, CO_2 and NH_3 are placed in a sealed container. The volume of the container is initially 20 L and the temperature is 298K.



16) The valve on the container is opened and the gases expand adiabatically. The temperature of the gas _______ because ______? [CQ 23.1, HW 6.6]

A) Increases, the gases are traveling faster
B) Increases, the internal energy of the gas is increasing
C) Stays the same, adiabatic means that temperature is constant
D) Decreases, the system loses heat to the surroundings
E) Decreases, the system does work

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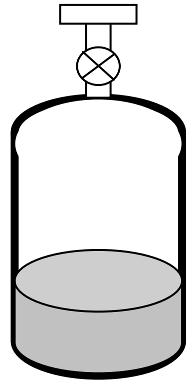
17) Given the following reaction:
$Na\ (g) \rightarrow Na^+\ (g) + e^-$
This process:

A) Requires energy to overcome the electron's attraction to the Na nucleus.
B) Requires enough energy to provide the electron with kinetic energy.
C) Releases energy because the Na^+ ion is more stable than the Na atom.
D) Releases energy because the electron has more kinetic energy outside of the atom.
E) Is energetically neutral because the charges balance.

A CO_2 cylinder for carbonating beverages contains carbon dioxide liquid coexisting at equilibrium with carbon dioxide gas according to the following chemical equation:

$CO_2\ (l) \leftrightarrows CO_2\ (g)$ $\quad$ $K = 56$ atm (298K)

The system is the CO_2 inside the tank.



18) At room temperature (298 K) and standard conditions, which is true for the system?

$\boxed{\text{A)}\ Q < K}$ $\quad$ B) $Q = K$ $\quad$ C) $Q > K$

19) If the tank were cooled to 250K, which is true for the pressure inside the tank?

A) $P_{298} < P_{250}$ $\quad$ B) $P_{298} = P_{250}$ $\quad$ $\boxed{\text{C)}\ P_{298} > P_{250}}$

20) If the tank were cooled to 250K, which is true for the equilibrium constant?

A) $K_{298} < K_{250}$ $\quad$ B) $K_{298} = K_{250}$ $\quad$ $\boxed{\text{C)}\ K_{298} > K_{250}}$

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21) If you have a 2-liter plastic bottle filled with ice and water sitting out on a sunny day, how much energy will be required for all the water to come to room temperature, 298 K?

A) Exactly 209 kJ of energy given that water has a specific heat capacity of 4.184 J/g·°C.

B) Less than 209 kJ of energy because there is ice present and ice is less dense than water.

C) Less than 209 kJ of energy because there is energy transfer from the light from the sun.

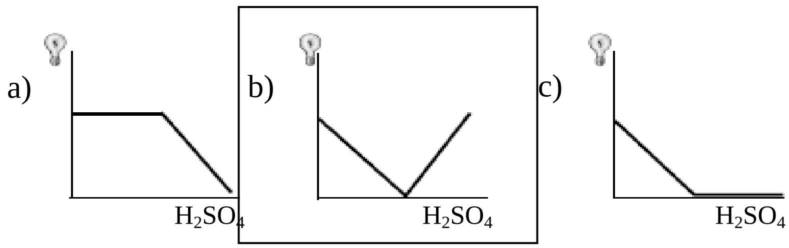
$\boxed{\text{D)}}$ More than 209 kJ of energy because there is no temperature change as long as ice is present.

E) Less than 209 kJ of energy because some of the heat has to be transferred to the bottle containing the water in addition to the water inside the bottle.

22) An excess amount of $BaCO_3$ (s) is added to an aqueous solution. Which of the following solutions will dissolve the most $BaCO_3$ (*s*)? [CQ 32.3]

A) 0.1 M H_2CO_3
B) 0.01 M $BaCl_2$
C) 0.1 M $Ba(OH)_2$
D) H_2O
E) Both (a) and (c)

23) For the titration of $Ca(OH)_2$ solution with H_2SO_4, which is the correct plot of conductance vs. added H_2SO_4? [CQ 32.4]

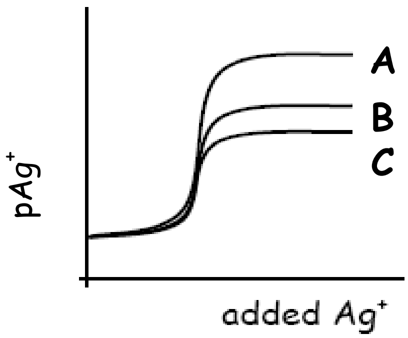


24) Select the best explanation for your answer to the previous question.
A) As precipitate is formed, the conductance decreases.
B) Strong acids completely dissociate.
C) After equivalence the concentration of ions approaches zero
D) Both (a) and (b)
E) Both (a) and (c)

25) Rank the following solutions from lowest to highest pH: [CQ 33.1]
i. 10^{-1}M HCl ii. 10^{-4}M NaOH iii. 10^{-1}M H_2SO_4 iv. 10^{-12}M HCl

A) iii < i < ii < iv
B) i = iii < ii < iv
C) i = iii < iv < ii
D) i < iii < ii < iv
E) iii < i < iv < ii

The stock room made 3 solutions: NaCl, NaBr, and NaI all in 0.1 M concentration, but forgot to label the solutions. In order to determine the identities, each solution was titrated with $AgNO_3$ to yield the following titration curves. ($pAg^+ = -\log [Ag^+]$)



Compound	K_{sp} for AgX (s) $\leftrightarrows$ Ag^+ + X^-
AgCl (s)	1.6×10^{-10}
AgBr (s)	7.7×10^{-13}
AgI (s)	8×10^{-17}

26) Given the data and K_{SP} values, what is the identity of solution A? [CQ 33.1]
A) NaCl
B) NaBr
$\boxed{\text{C)}}$ NaI

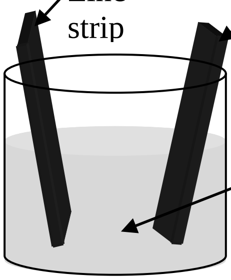
27) Which of the following 0.1 M solutions has the highest pH? [CQ 34.3]

Acid	pKa
cyanic acid, HOCN	3.46
hydrocyanic acid, HCN	9.40

A) 0.1 M HOCN
B) 0.1 M HCN
C) 0.1 M NaOCN
$\boxed{\text{D)}}$ 0.1 M NaCN

28) A 10 mL solution of a weak acid, HF, has a pH of exactly 2.0. If 90 mL of water is added to the solution bringing the total volume to 100 mL, the pH of the resulting solution will be_____. [CQ 35.3b]
A) less than 2.0
B) exactly 2.0
$\boxed{\text{C)}}$ between 2.0 and 3.0
D) exactly 3.0
E) greater than 3.0

Reduction Reaction	Standard Reduction Potential, ε°
Cu^{2+} + 2e- → Cu	+0.34 V
2 H^+ + 2e- → H_2	0.00 V
Zn^{2+} + 2e- → Zn	-0.76 V



29) What forms when a strip of zinc metal, Zn (*s*), and a strip of copper metal, Cu (*s*), are placed in a solution of 1.0 M sulfuric acid, H_2SO_4 (*aq*)? [CQ 38.1]

A) Zn^{2+} only
B) Cu^{2+} only
C) $Zn^{2+}$and H_2
D) Cu^{2+} and H_2
E) Cu^{2+}, Zn^{2+}, and H_2

30) How much energy (in electron volts, eV) is released when a positron and electron annihilate each other? [CQ 40.4]

$$\text{Annihilation: } {}^{0}_{+1}e + {}^{0}_{-1}e \rightarrow 2\gamma$$
$$1\text{ eV} = 1.60217646 \times 10^{-19}\text{ J}$$

A) ~10^{-13} eV
B) ~ 1 eV
C) ~ 10^3 eV
D) ~ 10^6 eV
E) ~10^{13} eV

31) Which of the following nuclides produces ^{235}U when it undergoes alpha decay? [CQ 40.2]

A) ^{239}U
B) ^{239}Pu
C) ^{239}Np
D) ^{237}U
E) ^{237}Pu

32) A watch that is made today will have approximately 0.1% of its original tritium in which year? The half-life of tritium is 12 years. [CQ41.5]

A) 2033
B) 2069
$\boxed{\text{C)}}$ 2129
D) 2249
E) 2309

33) What would be the iodate concentration of a saturated solution of $Cr(IO_3)_3$? Chromium (III) iodate has a Ksp of 5.0×10^{-6}.

A) 4.7×10^{-2} M
B) 5.0×10^{-2} M
$\boxed{\text{C)}}$ 2.1×10^{-2} M
D) 6.2×10^{-2} M
E) 1.7×10^{-2} M

Positron emission tomography (PET) is a nuclear medicine imaging technique that utilizes the short-lived β^+ nuclides such as C-11 ($t_{1/2}$ = 20.38 minutes) to scan body tissue.

34) If a patient was injected with 100 mCi of C-11, approximately how much would remain 1 hour later?

A) 33 mCi
B) 0.1 mCi
$\boxed{\text{C)}}$ 13 mCi
D) 1 mCi
E) 20 mCi

35) Assume the minimum detectable amount of C-11 is 1 μCi. How long would a patient treated with 100 mCi have to wait until reach this detection limit?

A) 57 days
B) 5.7 days
C) 57 hours
D) 5.7 hours
E) 57 minutes

36) Who was the principle discoverer of the element plutonium?

A) Lise Meitner
B) Otto Hahn
$\boxed{\text{C)}}$ Glenn Seaborg
D) Ernest Lawrence
E) Marie Curie

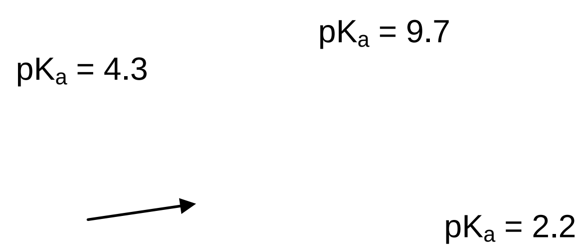
37) You have a 1.0 M solution of a strong acid, HCl, and you have a 1.0 M solution of a weak acid, HF. Which solution would require more 0.10 M NaOH to be titrated to its equivalence point?

A) HCl
B) HF
$\boxed{\text{C)}}$ They would require the same amount of NaOH
D) Unable to determine from the data given

38) Select the ***BEST*** reason that supports your answer to the previous question.

A) HCl is a strong acid and fully hydrolyzes to give more H_3O^+ in solution.
B) HF is a weak acid and fully hydrolyzes to give more H_3O^+ in solution.
$\boxed{\text{D)}}$ The concentration of HF is equal to the concentration of HCl.
E) HF is a weak acid and partially hydrolyzes to leave more HF in solution.

Glutamic acid is an amino acid
with the following fully-protonated structure:



39) The two carboxylic acid groups have a pK_a of 2.2 and 4.3 and the amino group has a pK_a of 9.7. What will the charge on the majority of glutamic acid molecules be in a pH = 7 solution?

A) +1
B) 0
$\boxed{\text{C)}}$ -1
D) -2
E) Not enough information to tell.

40) What is the hybridization on the carbon atom indicated by the arrow on the glutamic acid structure?

$\boxed{\text{A)}}$ sp^3
B) sp^2
C) sp
D) sp^3d
E) sp^3d^2

41) TRIS Buffer (18 points)

In order to determine the molarity of a strong acid, HCl, in lab this semester, you used a weak base, TRIS. It is commonly used as a buffer in the field of biochemistry. TRIS and a salt of its conjugate acid are shown below.

a) If the pKa of TRIS-H^+ is 8.075, what is the Ka?

Ka = $10^{-8.075}$ = 8.41×10^{-9}

b) What is the pH of a solution prepared by dissolving 12.43 g TRIS and 4.67 g TRIS-H^+Cl^- in 1.00 L of water?

$$12.43 g TRIS \times \frac{mol TRIS}{121.14 g} = 0.1026 mol TRIS$$

$$4.67 g TRIS \times \frac{mol TRIS}{157.59 g} = 0.02963 mol TRIS - HCl$$

$$pH = pK_a + \log\frac{[A^-]}{[HA]} \qquad pH = 8.075 + \log\frac{0.1026}{0.02963} \quad = \quad 8.614$$

c) If 12.00mL of 1.00M HCl was added to the buffer solution above, what will be the new pH?

the added acid reacts with the basic form of TRIS

12.00mL of 1.00M HCl = 0.01200 moles H_3O^+

	TRIS	+	H_3O^+	⇆	TRIS-H^+	+	H_2O
initial	0.1026 mol		0.01200 mol		0.02963 mol		
change	-0.01200 mol		-0.01200 mol		+0.01200 mol		
equilibrium	0.0906 mol		~0		0.04163 mol		

$$pH = 8.075 + \log\frac{0.0906}{0.04163} \quad = \quad 8.412$$

pH = ___________

42) Thermodynamics (22 points)

Consider the formation of chlorine monoxide (ClO) gas molecules from the elements.

$$Cl_2\,(g) + O_2\,(g) \leftrightarrows 2ClO\,(g) \qquad \Delta H_{rxn}° = +203.6\text{ kJ}$$

a) Draw the Lewis structures for the reactants and products.

a. Cl_2 $\qquad$ O_2 $\qquad$ ClO

or

b) Given the bond energy data on the back of your periodic table and the data above, calculate the bond energy for the chlorine-oxygen bond in ClO.

$$\Delta H° = \Sigma n\Delta H°_{\text{bonds broken}} - \Sigma n\Delta H°_{\text{bonds formed}}$$

$$+203.6\text{ kJ} = [\,1(\Delta H\text{ Cl-Cl}) + 1(\Delta H\text{ O=O})\,] - [2(\Delta H\text{ ClO})]$$

$$203.6\text{ kJ} = [\,243\text{ kJ} + 498\text{ kJ}\,] - [2(\Delta H\text{ ClO})]$$

$$\Delta H\text{ ClO} = 269\text{ kJ}$$

The value of $\Delta S_{rxn}° = +24.79$ J/mol·K.

c) The change in entropy is a positive number. Explain why.

The product is a mixture of Cl and O atoms, so it has more disorder than the pure Cl_2 and O_2. There are more ways to make ClO than ways to make Cl_2 and O_2.

(Note: Arguments about the relative strengths of the bonds are enthalpy explanations.)

d) The change in entropy is a small number. Explain why in terms of the numbers of molecules.

There are two moles of gas in the reactants and products, so the change in entropy will not be large and only dependent on the relative molecular complexity.

e) What is the minimum temperature in Kelvin at which this reaction becomes product favored?

$0 = \Delta H - T\Delta S \quad T = \Delta H/\Delta S \;\; (203.6\text{kJ})/(0.02479\text{kJ/molK}) = 8212$ K

$T = 8212 \text{ K}$

43) Electrochemistry (20 points)

Ozone (O_3 (g)) will undergo a reduction reaction to form oxygen (O_2 (g)) and water with a standard reduction potential of E° = 2.07 V. Hydrogen peroxide (H_2O_2 (aq)) will undergo a reduction reaction to form water with a standard reduction potential of E° = 1.78 V.

a) Write a balanced half reaction for each of these reactions in acidic solution.

$O_3 \rightarrow O_2 + H_2O$ $\qquad$ $H_2O_2 \rightarrow H_2O$

$O_{3\,(g)} + 2\,H^+_{(aq)} + 2\,e^- \rightarrow O_{2\,(g)} + H_2O_{(l)}$ $\qquad$ $H_2O_{2\,(aq)} + 2\,H^+_{(aq)} + 2\,e^- \rightarrow 2\,H_2O_{(l)}$

b) Which is a stronger oxidizer? $\boxed{\text{ozone}}$ hydrogen peroxide

c) What is $\Delta E°_{rxn}$ for O_3 (g) + H_2O (l) ⇆ O_2 (g) + H_2O_2 (aq)?

$\Delta E°_{rxn}$ = 2.07 V - 1.78 V = 0.29 V

d) Calculate the equilibrium constant for the reaction at standard conditions and 25°C. Be sure to show all your work.

$\Delta G° = -nF\,\Delta E°$; and $\Delta G° = -RT \ln K$, thus $\ln K = (nF\,\Delta E°)/RT$

K = e^((2 * 9.6485e4 C/mol * 0.29 V) / (8.314 J/molK * 298 K)) = 6.45e9

$\boxed{K = 6.45\times10^{9}}$