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School: ☐ Barnard    ☐ College    ☐ Engineering    ☐ General Studies

Chemistry 1404 y

# FINAL EXAM

May 9, 2003

## INSTRUCTIONS

**Be certain you have FIFTEEN (15) pages of the exam, and a BUBBLE SHEET**

**Fill in your name and CUID number as indicated above.**

**On the BUBBLE SHEET:**

- 1) On Side 2 print your first and last NAME in the box provided.
- 2) Fill in your Social Security IDENTIFICATION # in the space provided.
- 3) Using a soft lead pencil, blacken the one response that best answers the question or completes the statement. There is only one correct answer to each question. Questions with more than one answer will not be counted.
- 4) Your score will be the total number of correct answers; therefore, it is to your advantage to answer every question.
- 5) All 41 QUESTIONS are equally weighted.
- 6) You will be given 180 minutes to complete the exam.
- 7) Physical Constants – PAGE 12
- 8) Standard Reduction Potentials – PAGE 13
- 9) Periodic Table – PAGE 14
- 10) Scratch Sheet – PAGE 15

**CHECK THE FRONT BOARD** for time remaining, last minute corrections and additional information.

**WHEN YOU HAVE FINISHED THE EXAM** or at the end of the allowed time, deposit the exam and the bubble sheet in the separate boxes provided at the front of the room.

**DO NOT FORGET!** Print your first and last names in the box provided (1) on the bubble sheet, and (2) on the front page of the 10-page exam.

**REMEMBER!** It is your responsibility to ensure that your bubble sheet and exam sheets are properly identified.

1. Which of the following molecules has the largest dipole moment?
  - a)  $\text{CH}_4$
  - b)  $\text{CO}_2$
  - c)  $\text{NC-CN}$
  - d)  $\text{CO}$**
  - e)  $\text{O}_2$
  
2. Infrared spectroscopy provides definitive fingerprints of molecules comprised of vibrational modes. The expected number of vibrational modes in formaldehyde ( $\text{HCHO}$ ) is....
  - a) 1
  - b) 3
  - c) 4
  - d) 6**
  - e) 9
  
3. Comparing C-O to C=O bonds and C-O to C-S bonds in otherwise identical molecules, as one shifts from C-O to C=O the force constant shifts (higher, lower) with bond stiffness while the C-O and C-S stretching frequencies shift (higher, lower) as one shifts from lighter to heavier atoms:
  - a) higher, higher
  - b) higher, lower**
  - c) lower, lower
  - d) lower, higher
  - e) because they are in otherwise identical molecules, they are the same.
  
4. The sun is a 6000 K photoflood lamp, warming us with the glow of its radiation. This middle-aged star is spilling all its seemingly endless energy from the thin outer layer of the solar atmosphere known as the PHOTOSPHERE that is roughly composed of H atoms at a density of  $10^{-7} \text{ g/cm}^3$ . The pressure of the solar atmosphere known as the photosphere is ...
  - a)  $10^{-5} \text{ atm}$
  - b)  $10^{-2} \text{ atm}$**
  - c)  $10^0 \text{ atm}$
  - d)  $10^2 \text{ atm}$
  - e)  $10^5 \text{ atm}$
  
5. Based on the data in the problem above, the best estimate of the rms speed of a photospheric hydrogen atom is .....
  - a)  $3.00 \times 10^8 \text{ m/s}$
  - b)  $1.22 \times 10^4 \text{ m/s}$**
  - c)  $6.0 \times 10^3 \text{ m/s}$
  - d)  $3.89 \times 10^2 \text{ m/s}$
  - e)  $6.65 \times 10^{-1} \text{ m/s}$

6. The density of an unknown monoxide is found to be 0.2398g/L at the same temperature and pressure at which the density of oxygen ( $O_2$ ) is found to be 0.2579 g/L. Therefore, the unknown monoxide must be
- a) BeO
  - b) CO
  - c) **NO**
  - d) ClO
  - e) BrO
7. Ethanol and methanol form a solution that is very nearly ideal. The vapor pressure of ethanol is 44.5 torr and that of methanol is 88.7 torr at 20°C. For a solution of methanol and ethanol obtained by mixing 46 g of ethanol with 32 g of methanol, calculate the mole fraction of methanol in the vapor phase above the solution (at 20°C)
- a) .250
  - b) .333
  - c) .500
  - d) **.667**
  - e) .750
8. Members of one class of water-soluble proteins are called albumins. If an 1.50 g sample of a particular albumin in 100 mL of solution had an osmotic pressure of 47.0 torr at 25°C, what must be the molecular weight of the albumin?
- a) 150
  - b) 1000
  - c) 5000
  - d) **6000**
  - e) 10,000
9. The equilibrium constant for the reaction  $Cl_2 \rightleftharpoons 2 Cl$  is known to be 0.004 at 2000°C. If the concentration of chlorine molecules is 0.001 mol/L, then the concentration of chlorine atoms (in mol/L) must be....
- a)  $4.0 \times 10^{-6}$
  - b)  $4.0 \times 10^{-3}$
  - c)  **$2.0 \times 10^{-3}$**
  - d) 0.25
  - e) 2.0

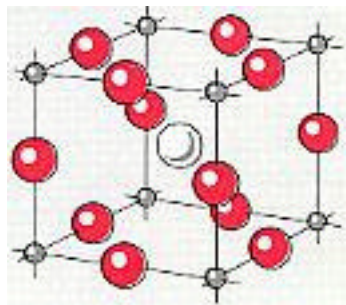
10. Consider the following chemical equilibrium at 25°C which is exothermic and has an equilibrium constant  $K_p=0.0172$ :



If a vessel contains  $p(\text{BrCl})=0.400$  atm,  $p(\text{Br}_2)=0.050$  atm, and  $p(\text{Cl}_2)=0.050$  atm, then the reaction...

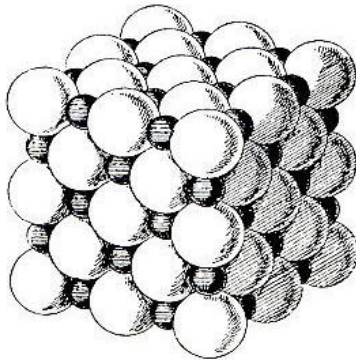
- a) **will proceed by forming products at the expense of reactants.**
  - b) will proceed by forming reactants at the expense of products.
  - c) will proceed by forming BrCl and Br<sub>2</sub>
  - d) will proceed by forming BrCl and Cl<sub>2</sub>
  - e) will produce no net reaction as the system is at equilibrium
11. The alkaline oxide among the following molecules is....
- a) CO<sub>2</sub>
  - b) SO<sub>2</sub>
  - c) NO<sub>2</sub>
  - d) ClO<sub>2</sub>
  - e) **None of the above**
12. The experimental observation that aqueous 0.10M potassium acetate solutions have lower pH values than 0.10M potassium cyanide solutions leads one to most logically conclude that...
- a) cyanide salts are less soluble.
  - b) acetate salts are more completely ionized.
  - c) **acetic acid is a stronger acid than cyanic acid**
  - d) cyanic acid is a stronger acid than acetic acid.
  - e) acetate ion is amphoteric.
13. A sample of barium fluoride (BaF<sub>2</sub>) was suspended in water and after equilibrium with undissolved solid was established the barium ion concentration in solution was found to be  $7.6 \times 10^{-3}$  M:
- $$\text{BaF}_2\text{(s)} \rightleftharpoons \text{Ba}^{2+}\text{(aq)} + 2 \text{F}^{-}\text{(aq)}$$
- Therefore, the  $K_{sp}$  of BaF<sub>2</sub> must be ...
- a)  $7.6 \times 10^{-3}$
  - b)  $1.5 \times 10^{-5}$
  - c)  $5.8 \times 10^{-5}$
  - d)  **$1.8 \times 10^{-6}$**
  - e)  $4.4 \times 10^{-7}$

14. Cabbage juice can be used as a universal indicator of sorts. It tends to be green on the basic side and pink on the acidic side of its neutral purple color. When the indicator is added to dilute solutions of HCl,  $(\text{NH}_4)_2\text{SO}_4$ , NaOH and  $\text{Na}_2\text{CO}_3$ , the respective colors observed are
- a) green, red, red, green
  - b) green, green, red, red
  - c) **red, red, green, green**
  - d) green, red, red, red
  - e) red, green, green, red.
15. The  $K_a$  for formic acid, a monoprotic acid, is  $1.8 \times 10^{-4}$ . If 100 mL of 1.0M HCl is added (carefully) to 900 mL of a solution prepared by dissolving 0.35 mole of sodium formate ( $\text{HCOONa}$ ) and 0.65 mole of formic acid ( $\text{HCOOH}$ ) in water, then the final pH of the resulting liter of solution must be.....
- a) **3.27**
  - b) 3.57
  - c) 3.74
  - d) 3.92
  - e) 4.22
16. Given the sketch below for the unit cell of a mineral consisting of barium (corner), titanium (center) and oxygen (edge) atoms, the general formula must be.....
- a)  $\text{BaTiO}$
  - b)  $\text{BaTi}_8\text{O}_{12}$
  - c)  $\text{BaTi}_4\text{O}_6$
  - d)  $\text{BaTi}_2\text{O}_3$
  - e)  **$\text{BaTiO}_3$**



17. A segment of the sodium chloride lattice is pictured below. If the distance **a** along the edge of the unit cell is known from diffraction data to be  $4.7\text{\AA}$ , then the ionic radius of the chloride ion (in  $\text{\AA}$  units;  $1\text{\AA}=10^{-10}\text{m}$ ) must be...

- a) 4.7
- b) 2.4
- c) **1.7**
- d) 1.0
- e) 0.8



18. With respect to Bragg Law experiments and the scattering of X-rays, the most fitting of the following statements is .....

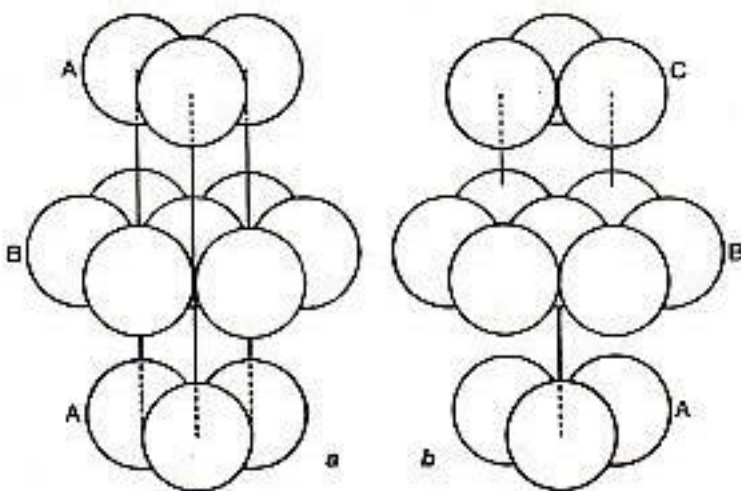
- a) If two X-rays scattered from adjacent atoms are to reinforce each other, the path length difference between them must be equal to the X-ray wavelength or some integral multiple of the wavelength.
- b) Planes of atoms will only reflect the incident X-rays when their orientation is such that  $\sin \theta = n\lambda/2d$ .
- c) X-rays are the wavelength of choice to obtain diffraction patterns because they are on the order of the spacing between the planes of atoms in crystals.
- d) **All of the above are correct statements.**
- e) None of the above are correct statements.

19. Perhaps three-quarters of all the elements are metallic. Nickel is typically metallic, has a density of  $8.90\text{g cm}^{-3}$  and a unit cell structure that is face-centered cubic (FCC). Calculate the distance along an edge of the unit cell in the Ni crystal lattice. ( $1\text{\AA} = 10^{-8}\text{ cm}$ ):

- a)  $1.0\text{\AA}$
- b)  $1.6\text{\AA}$
- c)  $3.2\text{\AA}$
- d)  **$3.6\text{\AA}$**
- e)  $4.7\text{\AA}$

20. Which of the following is true about metallic elements in the solid state?

- a) They have structures of high coordination number, high electrical resistance and thermal conductivity, are typically lustrous, and can often be hammered into sheets.
- b) The properties of the metallic can be explored by regarding them as a close-packed array of positive ions held in equilibrium positions by the interactions with delocalized valence electrons supplied by the atoms of the element.**
- c) The ABA (left) structure depicted below consists of equal spheres with coordination number 12 and cubic symmetry (FCC).
- d) The ABC (right) structure depicted below consists of equal spheres in a hexagonal close-packed array with coordination number 12.
- e) All of the above are true.



21. A gas is compressed at a constant pressure of  $1.2 \times 10^5$  Pa from a volume of  $2.5 \times 10^{-4} \text{ m}^3$  to a volume of  $1.3 \times 10^{-4} \text{ m}^3$  raising its temperature from 273K to 350K under conditions such that no heat is transferred to or from the gas. Then the gas is cooled back down to 273K and allowed to expand to a volume of  $2.5 \times 10^{-4} \text{ m}^3$  without any work being done on it. What is  $q$  for the overall process?
- a. - 30 J      b. -16 J      **c. -14 J**      d. +18 J      e. + 26 J

22. For the reaction  $\text{NO(g)} + 1/2\text{O}_2\text{(g)} \rightarrow \text{NO}_2\text{(g)}$  calculate the enthalpy change,  $\Delta H_r$ , when 18.0 g of  $\text{O}_2\text{(g)}$  is consumed in this reaction.
- a. - 256 kJ      b. - 128 kJ      **c. - 64.2 kJ**      d. - 32.1 kJ      e. 0.00 kJ

23. What is the standard enthalpy of reaction for  $2\text{H}_2\text{O}_2(\text{l}) \rightarrow 2\text{H}_2\text{O}(\text{l}) + \text{O}_2(\text{g})$ ?  
a.  $-572 \text{ kJ mol}^{-1}$       b.  $-384 \text{ kJ mol}^{-1}$       **c.  $-196 \text{ kJ mol}^{-1}$**   
d.  $-98 \text{ kJ mol}^{-1}$       e.  $+90 \text{ kJ mol}^{-1}$
24. 2.50 g of graphite (C(s, graphite), specific heat =  $0.686 \text{ J K}^{-1} \text{ g}^{-1}$ ) at 350 K is dropped into a perfectly insulated styrofoam cup calorimeter containing 2.50 g of water (specific heat =  $4.184 \text{ J K}^{-1} \text{ g}^{-1}$ ) at 300 K. What is the temperature of the water and the graphite when thermal equilibrium is reached, assuming that the heat capacity of the calorimeter is equal to the heat capacity of the water in it?  
**a. 307 K**      b. 315 K      c. 327 K      d. 335 K      e. 343 K
25.  $5.00 \times 10^{-3} \text{ m}^3$  of a gas is confined at a pressure of  $2.02 \times 10^5 \text{ Pa}$  and a temperature of 273K. The confining pressure is reduced to zero and the gas is heated to 373K, causing the gas to expand to a final volume of  $8.50 \times 10^{-3} \text{ m}^3$ . Determine the work done on the gas during the expansion.  
a.  $-707 \text{ J}$       b.  $-354 \text{ J}$       **c.  $0.00 \text{ J}$**       d.  $+540 \text{ J}$       e.  $+1,010 \text{ J}$
26. A gas expands reversibly at a constant temperature of 500 K against an external pressure, and the PV work done in the process is  $w = -60 \text{ J}$ . During the process the gas absorbs heat and  $q = +50 \text{ J}$ . Then the gas is compressed irreversibly back to its original pressure, volume, and temperature and  $q = -70 \text{ J}$  for the compression. What is the entropy change for the compression?  
a.  $< -0.14 \text{ J K}^{-1}$       **b.  $-0.10 \text{ J K}^{-1}$**       c.  $0 \text{ J K}^{-1}$   
d.  $+0.12 \text{ J K}^{-1}$       e.  $> +0.14 \text{ J K}^{-1}$

27. The hydrogen fuel cell has the overall reaction  $\text{H}_2(\text{g}) + 1/2\text{O}_2(\text{g}) \rightarrow \text{H}_2\text{O}(\text{l})$ . What is the maximum amount of electrical work that this cell can perform if it utilizes oxygen from the air around it and hydrogen from a high-pressure tank containing 125 grams of  $\text{H}_2(\text{g})$ ?
- a.  $1.19 \times 10^5 \text{ J}$       b.  $2.37 \times 10^5 \text{ J}$       c.  $7.40 \times 10^6 \text{ J}$   
**d.  $1.48 \times 10^7 \text{ J}$**       e.  $2.96 \times 10^7 \text{ J}$
28. Calculate  $\Delta G_r^\circ$  for the reaction  $\text{H}_2(\text{g}) + 2\text{Cl}(\text{g}) \rightarrow 2\text{HCl}(\text{g})$ .
- a.  $-605.28 \text{ kJ mol}^{-1}$       **b.  $-402.02 \text{ kJ mol}^{-1}$**       c.  $-306.72 \text{ kJ mol}^{-1}$   
d.  $-296.31 \text{ kJ mol}^{-1}$       e.  $-190.60 \text{ kJ mol}^{-1}$
29. Calculate the equilibrium constant for the reaction  $\text{H}(\text{g}) + \text{HI}(\text{g}) \rightarrow \text{H}_2(\text{g}) + \text{I}(\text{g})$  at 298 K. For this reaction:  $\Delta H_r^\circ = -137.60 \text{ kJ mol}^{-1}$ ,  $\Delta S_r^\circ = -98.30 \text{ J K}^{-1} \text{ mol}^{-1}$ ,  $\Delta G_r^\circ = -108.31 \text{ kJ mol}^{-1}$ . The equilibrium constant is:
- a. 1.04      b.  $1.36 \times 10^5$       c.  $1.70 \times 10^{17}$   
**d.  $9.68 \times 10^{18}$**       e.  $1.32 \times 10^{24}$
30. Which of the following is NOT required in an electrolytic cell?
- a. anode      b. cathode      c. oxidation      d. reduction      **e. porous membrane**
31. A Stirling heat engine is operated with a hot reservoir at a temperature  $T_H = 500 \text{ K}$ , and a cold reservoir at  $T_C = 300 \text{ K}$ . The maximum possible efficiency of this engine is:

- a. **0.400**      b. 0.550      c. 0.600      d. 0.667      e. 0.750

32. When 3 moles of a particular pure crystalline solid is taken by some irreversible process from  $T_i = 33 \text{ K}$  to  $T_f = 0 \text{ K}$  the entropy change for the process is  $-33 \text{ J K}^{-1}$ . What is the molar entropy of the solid at the end of the process?  
 a.  $-33 \text{ J K}^{-1} \text{ mol}^{-1}$       b.  $-11 \text{ J K}^{-1} \text{ mol}^{-1}$       **c.  $0 \text{ J K}^{-1} \text{ mol}^{-1}$**   
 d.  $+27 \text{ J K}^{-1} \text{ mol}^{-1}$       e.  $+37 \text{ J K}^{-1} \text{ mol}^{-1}$
33. What is  $\Delta G_r^\circ$  for the reaction  $\text{Zn}^{2+}(\text{aq}) + 2\text{Li}(\text{s}) \rightarrow 2\text{Li}^+(\text{aq}) + \text{Zn}(\text{s})$ ?  
 a.  $-587 \text{ kJ mol}^{-1}$       **b.  $-440 \text{ kJ mol}^{-1}$**       c.  $-220 \text{ kJ mol}^{-1}$   
 d.  $-147 \text{ kJ mol}^{-1}$       e.  $-73.5 \text{ kJ mol}^{-1}$
34. A galvanic cell is constructed from a strip of metallic  $\text{Zn}(\text{s})$  in contact with a solution that is  $1.25 \text{ M}$  in  $\text{Zn}^{2+}(\text{aq})$  and a strip of metallic  $\text{Cu}(\text{s})$  in contact with a  $0.50 \text{ M}$  solution of  $\text{Cu}^{2+}(\text{aq})$ . What is the initial voltage generated by this cell at  $298 \text{ K}$ ?  
 a.  $1.083 \text{ V}$       **b.  $1.095 \text{ V}$**       c.  $1.107 \text{ V}$       d.  $1.119 \text{ V}$       e.  $1.131 \text{ V}$
35. The decomposition reaction,  $\text{C}_2\text{H}_5\text{Br}(\text{g}) \rightarrow \text{C}_2\text{H}_4(\text{g}) + \text{HBr}(\text{g})$ , obeys first-order kinetics. A measurement of the instantaneous rate of the reaction gives  $\text{Rate} = 2.50 \times 10^{-5} \text{ mol L}^{-1} \text{ s}^{-1}$  at a  $\text{C}_2\text{H}_5\text{Br}(\text{g})$  concentration of  $0.0100 \text{ mol L}^{-1}$ . What is the rate constant of this reaction?  
 a.  $2.50 \times 10^{-5} \text{ mol L}^{-1} \text{ s}^{-1}$       b.  $2.50 \times 10^{-5} \text{ s}^{-1}$       c.  $2.50 \times 10^{-3} \text{ mol L}^{-1} \text{ s}^{-1}$   
**d.  $2.50 \times 10^{-3} \text{ s}^{-1}$**       e.  $1.00 \times 10^{-2} \text{ mol L}^{-1} \text{ s}^{-1}$
36. The reaction  $\text{CH}_3 + \text{CH}_3 \rightarrow \text{C}_2\text{H}_6$  is second order in  $\text{CH}_3$  in hexane solution, with a rate constant  $k = 7.50 \times 10^8 \text{ L mol}^{-1} \text{ s}^{-1}$ . If the initial concentration of  $\text{CH}_3$  is  $1.50 \times 10^{-4} \text{ mol L}^{-1}$ , what is the concentration of  $\text{CH}_3$  after  $9.00 \times 10^{-7} \text{ s}$ ?  
 a.  $1.26 \times 10^{-5} \text{ mol L}^{-1}$       b.  $2.53 \times 10^{-5} \text{ mol L}^{-1}$       **c.  $1.25 \times 10^{-4} \text{ mol L}^{-1}$**   
 d.  $1.36 \times 10^{-4} \text{ mol L}^{-1}$       e.  $1.75 \times 10^{-4} \text{ mol L}^{-1}$

37. The reaction  $\text{Ar(g)} + \text{O}_2\text{(g)} \rightarrow \text{Ar(g)} + \text{O(g)} + \text{O(g)}$  has a rate constant of  $5.49 \times 10^6 \text{ L mol}^{-1} \text{ s}^{-1}$  at 5,000K and  $9.86 \times 10^8 \text{ L mol}^{-1} \text{ s}^{-1}$  at 10,000K. What is the activation energy of this reaction?
- a.  $3.35 \times 10^3 \text{ J mol}^{-1}$       b.  $2.13 \times 10^4 \text{ J mol}^{-1}$       c.  $5.05 \times 10^4 \text{ J mol}^{-1}$   
 d.  $2.13 \times 10^5 \text{ J mol}^{-1}$       **e.  $4.31 \times 10^5 \text{ J mol}^{-1}$**
38. A first-order reaction has an activation energy of  $161 \text{ kJ mol}^{-1}$ . At 600 K the rate constant is  $0.41 \text{ s}^{-1}$ . What is the Arrhenius pre-exponential factor, A, for this reaction?
- a.  $1.1 \times 10^{12} \text{ s}^{-1}$       b.  $3.1 \times 10^{12} \text{ s}^{-1}$       **c.  $4.3 \times 10^{13} \text{ s}^{-1}$**       d.  $5.9 \times 10^{14} \text{ s}^{-1}$   
 e.  $1.1 \times 10^{15} \text{ s}^{-1}$
39. Acetone is oxidized in the troposphere by OH radicals,  $\text{CH}_3\text{COCH}_3\text{(g)} + \text{OH(g)} \rightarrow \text{H}_2\text{O(g)} + \text{CH}_3\text{COCH}_2\text{(g)}$ . The reaction is second order overall, first order in acetone and first order in OH, with a rate constant of  $1.10 \times 10^8 \text{ L mol}^{-1} \text{ s}^{-1}$  at 300K. If the OH concentration in the troposphere is constant and equal to  $1.4 \times 10^{-15} \text{ mol L}^{-1}$  and the temperature of the troposphere is taken to be 300K what is the half-life of acetone in the troposphere?
- a. 2.2 days      b. 26 days      **c. 52 days**      d. 75 days      e. 130 days
40. Which species are responsible for absorption of uv light in the atmosphere?
- a. OH and  $\text{HO}_2$       **b.  $\text{O}_2$  and  $\text{O}_3$**       c.  $\text{CO}_2$  and  $\text{H}_2\text{O}$       d. NO and  $\text{NO}_2$   
 e. CFC's
41. Which of the following is NOT part of the reason that CFC's attack the ozone in the stratosphere?
- a. CFC's are not soluble in water.      b. CFC's are not oxidized by OH.  
**c. CFC's are photolyzed in the troposphere.**      d. Cl atoms react with ozone.  
 e. CFC's are photolyzed in the stratosphere.

### Physical Constants

| Constant                    | Value                                                                                          |
|-----------------------------|------------------------------------------------------------------------------------------------|
| Avogadro's Number ( $N_0$ ) | $6.0221420 \times 10^{23} \text{ mol}^{-1}$                                                    |
| Faraday Constant (F)        | $96,485.342 \text{ C mol}^{-1}$                                                                |
| Universal Gas Constant (R)  | $0.08205 \text{ L-atm mol}^{-1} \text{ K}^{-1}$<br>$8.31447 \text{ J K}^{-1} \text{ mol}^{-1}$ |
| Boltzmann Constant (k)      | $1.380630 \times 10^{-23} \text{ J K}^{-1}$<br>$\text{J} = \text{kg m}^2 \text{s}^{-2}$        |

### Standard Chemical Thermodynamic Properties

Data at 298 K

| Substance                        | $\Delta H_f^\circ (\text{kJ mol}^{-1})$ | $S^\circ (\text{J K}^{-1} \text{ mol}^{-1})$ | $\Delta G_f^\circ (\text{kJ mol}^{-1})$ |
|----------------------------------|-----------------------------------------|----------------------------------------------|-----------------------------------------|
| $\text{Cl}_2(\text{g})$          | 0.00                                    | 222.96                                       | 0.00                                    |
| $\text{Cl}(\text{g})$            | 121.68                                  | 165.09                                       | 105.71                                  |
| $\text{H}_2(\text{g})$           | 0.00                                    | 130.57                                       | 0.00                                    |
| $\text{H}(\text{g})$             | 217.96                                  | 114.60                                       | 203.26                                  |
| $\text{HCl}(\text{g})$           | -92.31                                  | 186.80                                       | -95.30                                  |
| $\text{HI}(\text{g})$            | 26.48                                   | 206.48                                       | 1.72                                    |
| $\text{H}_2\text{O}(\text{l})$   | -285.83                                 | 69.91                                        | -237.18                                 |
| $\text{H}_2\text{O}(\text{g})$   | -241.82                                 | 188.72                                       | -228.59                                 |
| $\text{H}_2\text{O}_2(\text{l})$ | -187.78                                 | 109.6                                        | -120.42                                 |
| $\text{I}_2(\text{s})$           | 0.00                                    | 116.14                                       | 0.00                                    |
| $\text{I}_2(\text{g})$           | 62.44                                   | 260.58                                       | 19.36                                   |
| $\text{I}(\text{g})$             | 106.84                                  | 180.68                                       | 70.28                                   |
| $\text{N}_2(\text{g})$           | 0.00                                    | 191.50                                       | 0.00                                    |
| $\text{NO}(\text{g})$            | 90.25                                   | 210.65                                       | 86.55                                   |
| $\text{NO}_2(\text{g})$          | 33.18                                   | 239.95                                       | 51.29                                   |
| $\text{N}_2\text{O}_4(\text{g})$ | 9.16                                    | 304.18                                       | 97.82                                   |
| $\text{O}_2(\text{g})$           | 0.00                                    | 205.03                                       | 0.00                                    |
| $\text{O}(\text{g})$             | 249.17                                  | 160.95                                       | 231.76                                  |

**Standard Reduction Potentials**  
**Aqueous Solution at 298 K**

| <b>Half-Reaction</b>                                                       | <b><math>E^\circ</math> (V)</b> |
|----------------------------------------------------------------------------|---------------------------------|
| $\text{Pt}^{2+}(\text{aq}) + 2 \text{e}^- \rightarrow \text{Pt}(\text{s})$ | +1.18                           |
| $\text{Ag}^+(\text{aq}) + \text{e}^- \rightarrow \text{Ag}(\text{s})$      | +0.800                          |
| $\text{Cu}^{2+}(\text{aq}) + 2 \text{e}^- \rightarrow \text{Cu}(\text{s})$ | +0.345                          |
| $2\text{H}^+(\text{aq}) + 2 \text{e}^- \rightarrow \text{H}_2(\text{g})$   | 0.000                           |
| $\text{Pb}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Pb}(\text{s})$  | -0.126                          |
| $\text{Sn}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Sn}(\text{s})$  | -0.138                          |
| $\text{Ni}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Ni}(\text{s})$  | -0.257                          |
| $\text{Cd}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cd}(\text{s})$  | -0.403                          |
| $\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Zn}(\text{s})$  | -0.762                          |
| $\text{Mg}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Mg}(\text{s})$  | -2.372                          |
| $\text{K}^+(\text{aq}) + \text{e}^- \rightarrow \text{K}(\text{s})$        | -2.931                          |
| $\text{Li}^+(\text{aq}) + \text{e}^- \rightarrow \text{Li}(\text{s})$      | -3.040                          |

**PERIODIC TABLE**

## SCRATCH PAPER