

BROOKLYN COLLEGE
Department of Chemistry

Chemistry 2

Final Exam

December 21, 1999
Page 1 of 10

Name: _____ Lab Instructor- Zhou, Levine, Voloshchuk

There are 200 points on this exam.

Calculators will be inspected and a card with chemistry information will be considered as evidence of cheating.

Before you begin the exam, write your name on this page and on the answer booklet. Answer questions 1-11 on the question sheet. Do questions 12-37 in the exam booklet.

You have 133 minutes. This is a long exam so do not spend too much time on any one question.

This exam has 10 pages. Make sure you have all of them.

PERIODIC CHART OF THE ELEMENTS

| IA | IIA | | | | | | | | | | | IIIA | IVA | VA | VIA | VIIA | 0 | |
|--------------------|--------------------|----------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|-------------------|
| 1 H 1.0079 | | | | | | | | | | | | | | | | | 1 H 1.0079 | 2 He 4.0026 |
| 3 Li 6.941 | 4 Be 9.0122 | | | | | | | | | | | 5 B 10.81 | 6 C 12.011 | 7 N 14.007 | 8 O 15.999 | 9 F 18.998 | 10 Ne 20.179 | |
| 11 Na 22.989 | 12 Mg 24.305 | | | | | | | | | | | 13 Al 26.981 | 14 Si 28.086 | 15 P 30.974 | 16 S 32.06 | 17 Cl 35.453 | 18 Ar 39.948 | |
| 19 K 39.098 | 20 Ca 40.08 | 21 Sc 44.956 | 22 Ti 47.88 | 23 V 50.941 | 24 Cr 51.996 | 25 Mn 54.938 | 26 Fe 55.847 | 27 Co 58.933 | 28 Ni 58.69 | 29 Cu 63.546 | 30 Zn 65.38 | 31 Ga 69.72 | 32 Ge 72.59 | 33 As 74.922 | 34 Se 78.96 | 35 Br 79.904 | 36 Kr 83.80 | |
| 37 Rb 85.468 | 38 Sr 87.62 | 39 Y 88.906 | 40 Zr 91.22 | 41 Nb 92.905 | 42 Mo 95.94 | 43 Tc (98) | 44 Ru 101.07 | 45 Rh 102.91 | 46 Pd 106.42 | 47 Ag 107.87 | 48 Cd 112.41 | 49 In 114.82 | 50 Sn 118.69 | 51 Sb 121.75 | 52 Te 127.60 | 53 I 126.90 | 54 Xe 131.29 | |
| 55 Cs 132.91 | 56 Ba 137.33 | 57 * La 138.90 | 72 Hf 178.49 | 73 Ta 180.95 | 74 W 183.85 | 75 Re 186.21 | 76 Os 190.2 | 77 Ir 192.22 | 78 Pt 195.08 | 79 Au 196.97 | 80 Hg 200.59 | 81 Tl 204.38 | 82 Pb 207.2 | 83 Bi 208.98 | 84 Po (209) | 85 At (210) | 86 Rn (222) | |
| 87 Fr (223) | 88 Ra 226.0 | 89 * Ac 227.03 | | | | | | | | | | | | | | | | |

* Lanthanides

| | | | | | | | | | | | | | |
|--------------------|--------------------|--------------------|-------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| 58 Ce 140.12 | 59 Pr 140.91 | 60 Nd 144.24 | 61 Pm (145) | 62 Sm 150.36 | 63 Eu 151.96 | 64 Gd 157.25 | 65 Tb 158.92 | 66 Dy 162.50 | 67 Ho 164.93 | 68 Er 167.26 | 69 Tm 168.93 | 70 Yb 173.04 | 71 Lu 174.97 |
|--------------------|--------------------|--------------------|-------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|

Actinides

| | | | | | | | | | | | | | |
|--------------------|--------------------|-------------------|--------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|--------------------|--------------------|--------------------|--------------------|
| 90 Th 232.03 | 91 Pa 231.03 | 92 U 238.03 | 93 Np 237.05 | 94 Pu (244) | 95 Am (243) | 96 Cm (247) | 97 Bk (247) | 98 Cf (251) | 99 Es (254) | 100 Fm (257) | 101 Md (257) | 102 No (259) | 103 Lr (260) |
|--------------------|--------------------|-------------------|--------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|--------------------|--------------------|--------------------|--------------------|

BROOKLYN COLLEGE
Department of Chemistry

Chemistry 2

Final Examination

December 31, 1999

Page 2 of 10

Name _____

Information

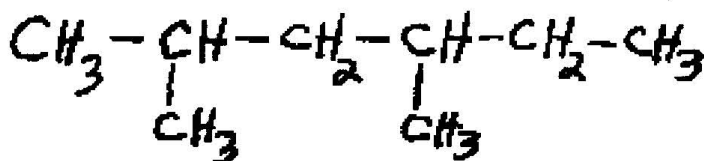
$$R = 0.08206 \text{ L-atm/mol-K} = 8.314 \text{ J/(mol-K)}$$

Answer questions 1-11 on these sheets.

1. (8 pts.) True or false? (four answers are required.)

- An atom of one chemical element can never be transformed to an atom of a different element.
- Two atoms that have different atomic numbers must be atoms of different elements.
- Two atoms that have different mass numbers must be atoms of different elements.
- Nuclear fission reactions produce nuclei with lower atomic numbers than the nucleus undergoing fission.

2. (3 pts.) Name this compound



3. (3 pts.) The functional group $\overset{\text{O}}{\parallel} \text{C-NH-}$ occurs in

- esters
- fats
- carbohydrates
- proteins
- amines

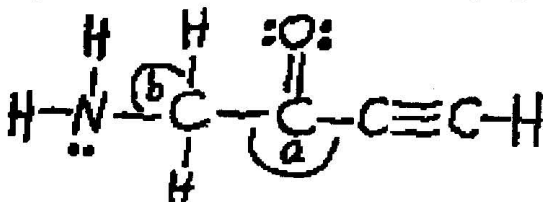
4. (3 pts.) A gene is

- a protein molecule
- a DNA molecule
- in some cases a protein and in some cases a DNA molecule
- a carbohydrate polymer

5. (3 pts.) In a certain molecule a certain atom uses sp^3d hybrid orbitals. How many sp^3d hybrid orbitals are there on that atom?

6. (3 pts.) In an unsaturated $\text{BaSO}_4(\text{aq})$ solution, is the ion product $[\text{Ba}^{2+}][\text{SO}_4^{2-}]$ less than, equal to, or greater than K_{sp} ?

7. (12 pts.) Answer the following questions for this molecule



- Give the value of the bond angle labeled a.
- How many π (pi) bonds are there in this molecule?
- How many σ (sigma) bonds are there in this molecule?
- Give the hybridization at the carbon atom that is bonded to the oxygen atom.
- Give the hybridisation at the nitrogen atom.
- Give the value of the bond angle labeled b.

8. (3 pts.) A solution is prepared by adding HCl and $\text{HC}_2\text{H}_3\text{O}_2$ to water. In the equilibrium constant

$$K_a = \frac{[\text{H}^+][\text{C}_2\text{H}_3\text{O}_2^-]}{[\text{HC}_2\text{H}_3\text{O}_2]}$$

- The $[\text{H}^+]$ in the numerator includes only the H^+ that came from the ionization of the $\text{HC}_2\text{H}_3\text{O}_2$.
- The $[\text{H}^+]$ in the numerator includes both the H^+ that comes from the ionization of the $\text{HC}_2\text{H}_3\text{O}_2$ and from the ionization of the HCl .

9. (3 pts.) Which one of the following gives a buffer solution?
- 50 mL of 0.1 M HCl(aq) mixed with 80 mL of 0.1 M NaOH(aq).
 - 80 mL of 0.1 M HCl(aq) mixed with 50 mL of 0.1 M NaOH(aq).
 - 50 mL of 0.1 M HC₂H₃O₂(aq) mixed with 50 mL of 0.1 M NaOH(aq).
 - 50 mL of 0.1 M HC₂H₃O₂(aq) mixed with 80 mL of 0.1 M NaOH(aq).
 - 80 mL of 0.1 M HC₂H₃O₂(aq) mixed with 50 mL of 0.1 M NaOH(aq).
 - None of the above.
10. (3 pts.) The gas reaction $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$ has $K_p = 0.80$ at 600 K and has $K_p = 0.15$ at 650 K. Which statement is true?
- This reaction has $\Delta H^\circ > 0$ and is exothermic.
 - This reaction has $\Delta H^\circ > 0$ and is endothermic.
 - This reaction has $\Delta H^\circ < 0$ and is exothermic.
 - This reaction has $\Delta H^\circ < 0$ and is endothermic.
11. (3 pts.) When the reaction $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$ is at equilibrium,
- The number of moles of N₂ present plus the number of moles of H₂ present must equal the number of moles of NH₃ present.
 - The number of moles of N₂ present plus three times the number of moles of H₂ present must equal two times the number of moles of NH₃ present.
 - The number of moles of NH₃ present does not change with time.
 - Both (a) and (c) are true.
 - Both (b) and (c) are true.

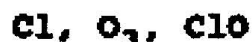
Answer questions 12-37 in the exam booklet. Show all work.

12. (8 pts.) For the mechanism

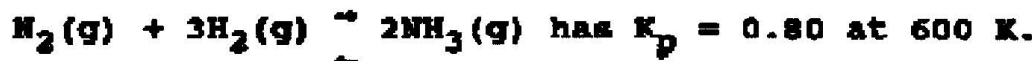


a) Write the overall reaction

b) Classify each of the following three species as a reactant, product, intermediate, catalyst, or innocent bystander:



13. (6 pts.) The gas reaction



A mixture of these three gases at EQUILIBRIUM has a partial pressure of NH_3 of 0.65 atm and a partial pressure of N_2 of 1.44 atm. Find the partial pressure of H_2 in this equilibrium mixture.

14. (6 pts.) The reaction $\text{A} + 2\text{B} \rightarrow \text{products}$ is second order with respect to A and is second order with respect to B. In a solution with $[\text{A}] = 0.30 \text{ M}$ and $[\text{B}] = 0.10 \text{ M}$ at 25°C , the rate of this reaction is $2.0 \times 10^{-4} \text{ M/s}$. Find the rate constant for this reaction at 25°C .

15. (4 pts.) For the reaction $\text{B} + \text{C} \rightarrow \text{products}$, one finds that tripling the initial concentration of B while keeping the initial C concentration constant multiplies the rate by 9. What is the order with respect to B?

16. (4 pts.) A galvanic cell at 25°C is made from a half-cell consisting of a piece of Cu dipping into $\text{CuSO}_4(\text{aq})$ and a half-cell consisting of a piece of Ag dipping into $\text{AgNO}_3(\text{aq})$, with a salt bridge.
- a) Write the balanced, spontaneous net ionic reaction for this cell. See data below.
- b) Find E° for this cell.
- For $\text{Ag}^+(\text{aq}) + \text{e}^- \rightarrow \text{Ag}$, $E^\circ = 0.80 \text{ V}$.
- For $\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cu}$, $E^\circ = 0.34 \text{ V}$.
17. (7 pts.) Given these ΔG°_f values at 600 K, find K_p at 600 K for the reaction $2\text{NO}_2(\text{g}) \rightarrow \text{N}_2\text{O}_4(\text{g})$. Note that the temperature is not 25°C. For $\text{NO}_2(\text{g})$, $\Delta G^\circ_f = 56.2 \text{ kJ/mol}$ and for $\text{N}_2\text{O}_4(\text{g})$, $\Delta G^\circ_f = 96.6 \text{ kJ/mol}$ at 600 K.
18. (7 pts.) Mr. Vincent Adams (the friendly man in charge of the stockroom) dissolves 0.60 moles of the acid HX (where X stands for some unknown group of atoms) in water and dilutes the solution to 1.00 liter. He hands a 25 mL sample of this solution in a sealed test tube to Mary Smith, a student in Chem 2 P2. Mary Smith uses a pH meter to find that the pH of her solution is 1.00.
- a) Find $[\text{H}^+]$ in Ms. Smith's solution.
- b) Find as accurately as possible the ionization constant K_a of the acid HX. Begin by writing the equation for the ionization of HX.

19. (9 pts.) Write nuclear reactions for each of these processes:
- ${}_{92}^{238}\text{U}$ emits an alpha particle (a ${}^4\text{He}$ nucleus)
 - ${}_{11}^{11}\text{C}$ emits a positron (the antiparticle of an electron)
 - ${}_{90}^{231}\text{Th}$ emits a beta particle (an electron)
20. (9 pts.) Complete and balance these reactions in the answer booklet
- $$\text{C}_6\text{H}_{14} + \text{O}_2 \rightarrow$$
- $$\text{CH}_3\text{CH}_2\text{CH}_2\overset{\text{O}}{\parallel}\text{C}-\text{OH} + \text{CH}_3\text{OH} \rightarrow$$
- $$\text{CH}_3\text{NH}_2(\text{aq}) + \text{H}_2\text{O} \rightarrow$$
21. (6 pts.) A sample of a radioactive isotope X is observed to have an activity of 400 disintegrations per minute at 10:00 AM on July 6, 1999. Twenty-four hours later (at 10:00 AM on July 7, 1999), the activity of this sample has fallen to 50 disintegrations per minute. Find the half-life of isotope X without using the formula $\ln(N_t/N_0) = -kt$. Use only the definition of half-life. You must give your reasoning.
22. (4 pts.) A certain reaction has $\Delta G^\circ = -88 \text{ kJ/mol}$ at 25°C and has $\Delta S^\circ = 18 \text{ J/(mol K)}$ at 25°C . Find ΔH° for this reaction at 25°C .
23. (3 pts.) A student carries out a reaction in which Mn^{2+} is oxidized to Mn^{4+} . The student used a 0.60 M $\text{MnCl}_2(\text{aq})$ solution. What is the normality of this solution in this reaction?

24. (7 pts.) A saturated solution of CaF_2 in water contains 0.0080 g of CaF_2 in 500 mL of solution at 25°C . Find K_{sp} for CaF_2 in water at 25°C .
25. (6 pts.) The half-life of ^{239}Pu is 2.4×10^4 years. A sample of radioactive waste contains 55.5 g of ^{239}Pu . How long will it take for only 2.48 g of ^{239}Pu to remain?
Formulas: $kt_{1/2} = 0.693$ and $\ln(N_t/N_0) = -kt$
26. (4 pts.) Draw all isomers with the formula $[\text{Co}(\text{H}_2\text{O})_4\text{Cl}_2]$.
27. (4 pts.) Find $[\text{H}^+]$ in 0.010 M $\text{Ba}(\text{OH})_2(\text{aq})$.
28. (8 pts.) Consider the $[\text{Mn}(\text{H}_2\text{O})_6]^{2+}$.
- Draw the crystal-field energy level diagram for the 3d orbitals and show the placement of d electrons assuming this is a weak-field complex ion.
 - Repeat a) assuming this is a strong-field complex ion.
29. (3 pts.) Consider the octahedral complex ion ML_6 , where M is a transition metal and L is a ligand. If this is a strong-field complex ion, what is the maximum possible number of unpaired electrons in ML_6 ? Draw an energy-level diagram with electrons to justify your answer.
Hint: Consider all possible numbers of d electrons.

30. (2 pts.) $[\text{CoF}_6]^{3-}$ is a weak-field ion, and $[\text{Co}(\text{CN})_6]^{3-}$ is a strong-field ion. Which ion absorbs higher-frequency visible light?

a) $[\text{CoF}_6]^{3-}$ b) $[\text{Co}(\text{CN})_6]^{3-}$

→ REMINDER: Answers to 30 and 31 (and all other questions after 11) go in the exam booklet.

31. (3 pts.) Give the formula of potassium diaquatetrachlorocobaltate(II).
32. (6 pts.) Draw structural formulas for all compounds with the formula C_5H_{12} . You must include the H atoms.
33. (6 pts.) Draw structural formulas for three different compounds with the formula $\text{C}_3\text{H}_6\text{O}$. Show the H atoms.
34. (9 pts.) Draw a structural formula or a condensed structural formula for
- An aldehyde with two carbon atoms.
 - An ether with three carbon atoms.
 - An amine with two carbon atoms.

Your answers must not contain the letter R.

35. (7 pts.) Do one of the following problems. Do not do both. You are not allowed to use the Henderson-Hasselbalch equation.

35 I. A student mixes 30.0 mL of 0.20 M $\text{NH}_3(\text{aq})$ with 70.0 mL of 0.30 M $\text{NH}_4\text{Cl}(\text{aq})$. Find $[\text{H}^+]$ in the final solution. $K_b = 1.8 \times 10^{-5}$ for $\text{NH}_3(\text{aq})$.
(If you do 35 I, do not do problem 35 II.)

(continued)

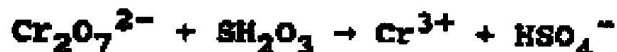
35 II. A student adds a certain number of moles of NH_3 to 100 mL of a 0.40 M $\text{NH}_4\text{Cl}(\text{aq})$ solution and finds that resulting solution has $[\text{H}^+] = 8.3 \times 10^{-10}$ M. How many moles of NH_3 were added? (Assume the final solution volume is still 100 mL.)

$$K_b = 1.8 \times 10^{-5} \text{ for } \text{NH}_3.$$

(If you do 35 II, do not do 35 I.)

36. (7 pts.) Find $[\text{H}^+]$ in 0.20 M $\text{NaC}_2\text{H}_3\text{O}_2$ given that $K_a = 1.8 \times 10^{-5}$ for $\text{HC}_2\text{H}_3\text{O}_2$.

37. (8 pts.) Balance this reaction in acidic solution. You must use the method of half-reactions. Make sure you get the number of electrons correct in each half-reaction or you will not get credit for that half-reaction.



Extra credit (put answers in the exam booklet)

EC1 (1 point) Give the first name of the lecturer in this course.

EC2 (1 point) Give the last name of the lecturer in this course. (Spelling counts).

EC3 (2 points) A reaction has the mechanism



Find the overall reaction for this mechanism. Hint: Think about the intermediate.