CHEMISTRY 104
Prof. J.W. Moore
EXAM III
April 28, 2000

Name Key

Sec: ________ **TA:** ________________

FORM A
(Pink)

Instructions

1. This exam consists of 9 pages and periodic table. If a page is missing, raise your hand and ask a TA to give you a replacement. Print your name in the space at the top of each page; do it now!

2. The periodic table contains constants and conversion factors that may be useful. Some possible useful formulas are found on the last page of the exam (just before the periodic table). Tables of data are at the end of the exam; these may be useful for answering non-numeric questions as well as for numeric problems. **(Do not use the table of E° values that is on the back of the periodic table-use the one on page 8.)**

3. You will have 50 minutes to work on the exam.

4. Many of the questions are multiple-choice; answer multiple-choice questions inside the test and **transfer your answers to the spaces provided below. A penalty of 4 points will be assessed if this is not done.**

5. There is no need to show work on multiple-choice questions. Show your work clearly on open-ended questions so that graders can understand how you arrived at the solution. Round answers to the correct number of significant figures; include appropriate units.

6. Communicating in any way with another student during this exam will be considered to be one form of cheating.

Answers to Multiple-Choice Questions

1.____ B
2.____ E
3.____ F or B(1)
4.____ C
5.____ B
6.____ B
7.____ B
8.____ E
9.____ A
10.____ D
11.____ A
12.____ B
13.____ D
14.____ C
15.____ C

Page	**Score**
2-4	_____/ 45
5	_____/ 13
6	_____/ 12
7	_____/ 10
TOTAL	_____/ 80

Multiple-Choice Questions. There is *one* best response to each question. Read *all* responses, choose the *best* one, circle it on this page, and **write the letter corresponding to that response in the appropriate numbered space on page one of the exam.** (4 point penalty if this is not done.) Each multiple-choice question is worth three points.

1. Which is a strong enough reducing agent to reduce $I_2(s)$ to $I^-(aq)$?

A. $Ni^{2+}(aq)$
[✓ B.] $Cu(s)$
C. $Br^-(aq)$
D. $Ag(s)$
E. None of these will reduce I_2 to I^-.

2. Balance the following redox equation

$$2\,\mathrm{MnO_4^-(aq)} + \overset{5}{\mathrm{Ni(s)}} + \overset{16}{\mathrm{H_3O^+(aq)}} \longrightarrow \overset{5}{\mathrm{Ni^{2+}(aq)}} + \overset{2}{\mathrm{Mn^{2+}(aq)}} + \overset{24}{\mathrm{H_2O}(\ell)}$$

In the balanced equation, the coefficient of Ni(s) is

A. 1
B. 2
C. 3
D. 4
[✓ E.] 5
F. 6
G. 7
H. 8
I. 9
J. 10
K. 11
L. 12
M. 13
N. 14
O. 15

3. Which of the half-reactions listed below would take place at the cathode in an electrolytic cell to which 9.0 V is applied?

A. $6\,H_2O(\ell) \longrightarrow O_2(g) + 4\,H_3O^+(aq) + 4e^-$
✓B. $Hg_2^{2+}(aq) + 2e^- \longrightarrow 2\,Hg(\ell)$
✓C. $Fe^{3+}(aq) + e^- \longrightarrow Fe^{2+}(aq)$
D. $Pb(s) + SO_4^{2-}(aq) \longrightarrow PbSO_4(s) + 2e^-$
E. Both A and D.
[✓ F.] Both B and C.

4. Which of the groups of elements below accounts for the largest percentage of atoms in the human body?

A. C, H, Ni
B. C, N, Mo
[✓ C.] C, O, H
D. N, O, K
E. O, Fe, Mg

5. Suppose that you are designing a synthetic polymer that needs to be strong and tough. Which of the characteristics below would be most important?

A. more branching in the polymer chain
[✓ B.] greater cross linking
C. lower molecular weight
D. addition polymerization

6. Which oxide is the strongest Lewis acid?

A. CaO
[✓ B.] SO_3
C. SiO_2
D. Fe_2O_3
E. TeO_2

7. An electrolysis cell operates for 30. minutes and plates 0.35 mol Zn(s) onto an electrode from a solution of $ZnSO_4$. How long would it take for the same current to plate 0.70 mol Ag(s) onto an electrode from a solution of $AgNO_3$?

A. 60. min
[✓ B.] 30. min
C. 15 min
D. 49 min
E. 25 min

$Zn^{2+} + 2e^- \longrightarrow Zn$

$Ag^+ + e^- \longrightarrow Ag$

$\frac{0.35 \text{ mol Zn}}{30 \text{ min}} \times \frac{2 \text{ mol } e^-}{\text{mol Zn}} \times \frac{1 \text{ mol Ag}}{1 \text{ mol } e^-} = 0.02333 \text{ mol Ag/min}$

$0.70 \text{ mol Ag} \times \frac{\text{min}}{0.2333 \text{ mol Ag}} = 30 \text{ min.}$

8. Which of these substances is important in the reactions that take place in an automobile battery?

A. H_2SO_4(aq)
B. Pb(s)
C. PbO_2(s)
D. $PbSO_4$(s)
[✓ E.] All of these substances are important.

9. Which solution has the greatest electrical conductivity?

[✓ A.] 0.20 M NaOH(aq)
B. 0.20 M NH_3(aq)
C. 0.20 M CH_3COOH(aq)
D. tap water
E. 0.020 M HCl(aq)

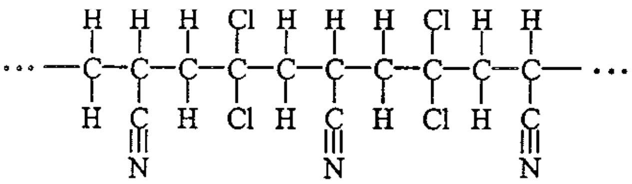
10. Which of the following is least likely to be able to cross a lipid bilayer?

A. CH_3HgCl
B. H_2O
C. N_2
[✓ D.] cellulose
E. CO_2

11. Which statement is true?

[✓ A.] Household cleaners containing strong bases are more dangerous to people than those containing strong acids.
B. NaOH and KOH can neutralize lots of stomach acid, so they are used as antacids.
C. CaO and $NaHSO_4$ can both be used to "sweeten" (raise the pH of) soil.
D. Chlorine-containing household bleaches are extremely safe and no precautions are needed when using them.

12. The polymer structure shown is



A. an addition polymer with a single monomer.
[✓ B.] an addition copolymer of two monomers.
C. a condensation polymer with a single monomer.
D. a condensation $\overset{co}{\wedge}$polymer of two monomers.

13. Which is **not** a drawback of disposing of waste plastics by incineration?

A. Aldehydes and ketones are produced when some plastics burn.
B. HCl is produced when some plastics burn.
C. Chlorinated hydrocarbons are produced when some plastics burn.
[✓ D.] The energy produced by burning plastics is not as easy to use as energy from fossil fuels.

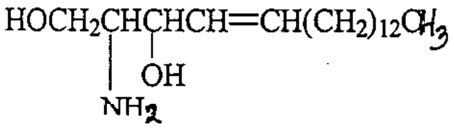
14. Which of these is a monosaccharide?

A. lactose
B. sucrose
[✓ C.] glucose
D. cellulose
E. olestra

15. Which molecule is not an amphiphile?

A. lauric acid, $CH_3(CH_2)_{10}COOH$

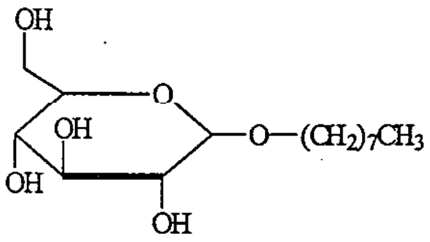
B. sphingosine,



$HOCH_2\underset{NH_2}{CH}\underset{OH}{CH}CH{=}CH(CH_2)_{12}CH_3$

[✓ C.] hexane

D. octyl glucoside,



Open-Ended Questions. Show all work, use correct numbers of significant figures, and write answers in the spaces provided.

16. 6 (~~7~~ *pts.)* Equal numbers of moles of Na_2SO_4 and $CaCl_2$ are added to water in a beaker. A precipitate forms. The mixture is allowed to stand for 2 days and then the solid is filtered off. To the clear liquid filtate is added a solution of $BaCl_2$. A precipitate forms.

A. Write balanced, net ionic equations for the equilibria involved.

$$SO_4^{2-}(aq) + Ca^{2+}(aq) \rightleftharpoons CaSO_4(s)$$

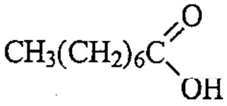
$$SO_4^{2-}(aq) + Ba^{2+}(aq) \rightleftharpoons BaSO_4(s)$$

B. Explain why a precipitate formed when the $BaCl_2(aq)$ was added. What does this observation imply about the relative sizes of K_{sp} for $CaSO_4$ and $BaSO_4$?

Even though $CaSO_4$ precipitates, some Ca^{2+} and SO_4^{2-} ions remain in solution. When Ba^{2+} is added the concentration of SO_4^{2-} is large enough to form a ppt. Ksp must be larger for $CaSO_4$ than for $BaSO_4$. The smaller Ksp is the less soluble a compound is. Because $BaSO_4$ precipitated, it must be less soluble than $CaSO_4$.

17. 7 (~~8~~ *pts.)* Which fatty acid has the highest melting point? (Circle the correct letter.) Explain clearly why the other two have lower melting points.

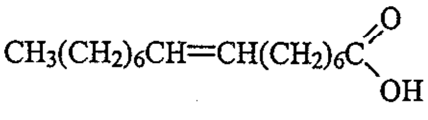
A.



$CH_3(CH_2)_6COOH$

lower because the molecule is smaller (shorter tail)

B.

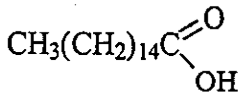


$CH_3(CH_2)_6CH{=}CH(CH_2)_6COOH$

(cis isomer)

lower because the double bond requires a bend in the tail and the molecules cannot pack together as well.

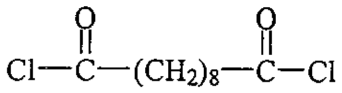
[✓ C.]



$CH_3(CH_2)_{14}COOH$

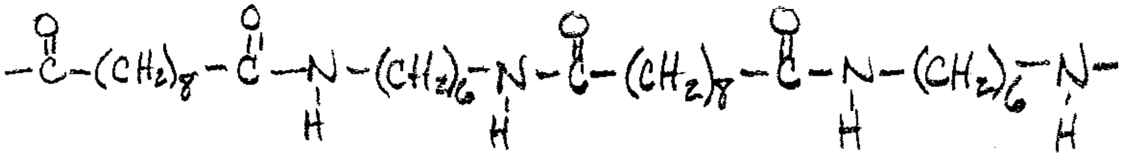
18. *(6 pts.)* Draw at least two repeating units of the polymer formed by

A. condensation polymerization of



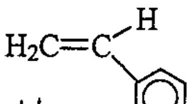
$Cl-\overset{O}{\overset{\|}{C}}-(CH_2)_8-\overset{O}{\overset{\|}{C}}-Cl$

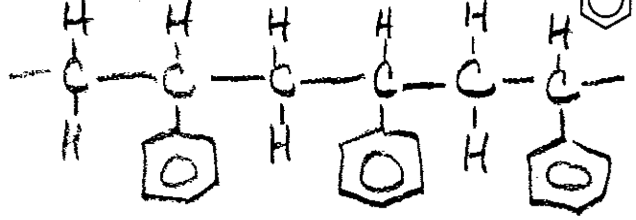
and $H_2N-(CH_2)_6-NH_2$



$-\overset{O}{\overset{\|}{C}}-(CH_2)_8-\overset{O}{\overset{\|}{C}}-\underset{H}{\underset{|}{N}}-(CH_2)_6-\underset{H}{\underset{|}{N}}-\overset{O}{\overset{\|}{C}}-(CH_2)_8-\overset{O}{\overset{\|}{C}}-\underset{H}{\underset{|}{N}}-(CH_2)_6-\underset{H}{\underset{|}{N}}-$

B. addition polymerization of





19. *(6 pts.)* For a cell based on the reaction

$$Fe^{2+}(aq) + Cu(s) \longrightarrow Cu^{2+}(aq) + Fe(s)$$

A. Calculate the voltage under standard conditions.

$Fe^{2+} + 2e^- \longrightarrow Fe \quad E^\circ_{red} = -0.44V$

$Cu \longrightarrow Cu^{2+} + 2e^- \quad E^\circ_{ox} = -(0.337V)$

$E^\circ_{cell} = (-0.44-0.337)V$

$= -0.777V = -0.78V$

B. Calculate ΔG° for the reaction.

$$\Delta G^\circ = -nFE^\circ = -2\,mole\,e^- \times \frac{96,500\,C}{1\,mole\,e^-} \times (-0.777V)$$

$$= +1.500\times10^5\,VC = 1.50\times10^2\,kJ$$

C. Is the reaction product-favored? Explain.

No $\Delta G^\circ > 0$ $E^\circ < 0$

20. *(10 pts.)* The figure below represents an electrochemical cell based on the product-favored reaction.

$$2\,Ce^{4+}(aq) + Co(s) \longrightarrow 2\,Ce^{3+}(aq) + Co^{2+}(aq)$$

The cell has one electrode made of platinum (Pt) and a salt bridge containing KCl(aq). Label the diagram showing each of the following:

- Ce^{4+}(aq)
- Ce^{3+}(aq)
- Co^{2+}(aq)
- Co electrode
- Pt electrode
- salt bridge
- direction of electron flow in wire
- direction of K^+ ion movement in salt bridge
- anode
- cathode

Make sure that you label the cell so that the meter reading is positive.

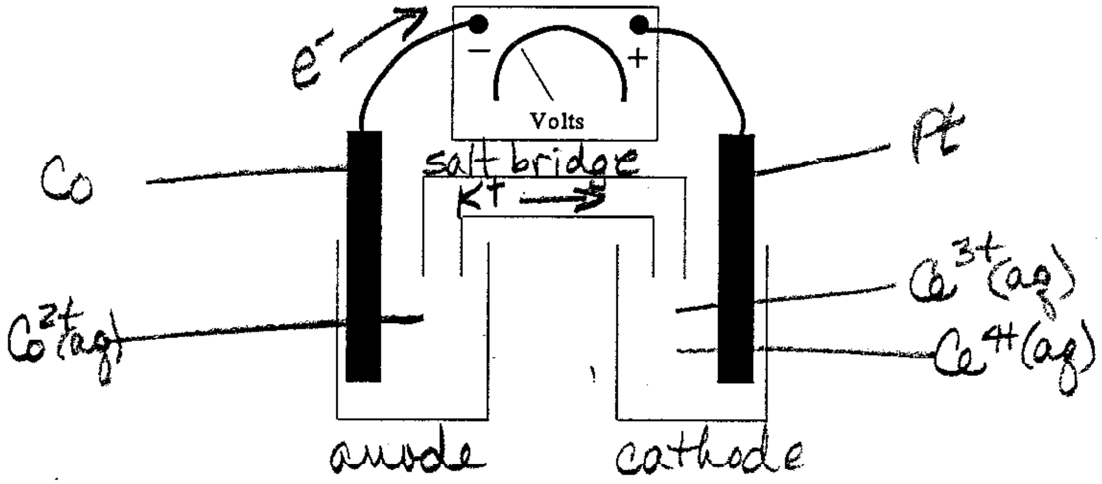


TABLE 18.1 **Standard Reduction Potentials in Aqueous Solution at 25 °C***

Increasing Strength of Oxidizing Agents

Increasing Strength of Reducing Agents

Reduction Half-Reaction		$E°$ (V)
$F_2(g) + 2\ e^-$	$\longrightarrow 2\ F^-(aq)$	2.87
$H_2O_2(aq) + 2\ H_3O^+(aq) + 2\ e^-$	$\longrightarrow 4\ H_2O(\ell)$	1.77
$PbO_2(s) + SO_4^{2-}(aq) + 4\ H_3O^+(aq) + 2\ e^-$	$\longrightarrow PbSO_4(s) + 6\ H_2O(\ell)$	1.685
$MnO_4^-(aq) + 8\ H_3O^+(aq) + 5\ e^-$	$\longrightarrow Mn^{2+}(aq) + 12\ H_2O(\ell)$	1.52
$Au^{3+}(aq) + 3\ e^-$	$\longrightarrow Au(s)$	1.50
$Cl_2(g) + 2\ e^-$	$\longrightarrow 2\ Cl^-(aq)$	1.360
$Cr_2O_7^{2-}(aq) + 14\ H_3O^+(aq) + 6\ e^-$	$\longrightarrow 2\ Cr^{3+}(aq) + 21\ H_2O(\ell)$	1.33
$O_2(g) + 4\ H_3O^+(aq) + 4\ e^-$	$\longrightarrow 6\ H_2O(\ell)$	1.229
$Br_2(\ell) + 2\ e^-$	$\longrightarrow 2\ Br^-(aq)$	1.08
$NO_3^-(aq) + 4\ H_3O^+ + 3\ e^-$	$\longrightarrow NO(g) + 6\ H_2O$	0.96
$OCl^-(aq) + H_2O(\ell) + 2\ e^-$	$\longrightarrow Cl^-(aq) + 2\ OH^-(aq)$	0.89
$Hg^{2+}(aq) + 2\ e^-$	$\longrightarrow Hg(\ell)$	0.855
$Ag^+(aq) + e^-$	$\longrightarrow Ag(s)$	0.80
$Hg_2^{2+}(aq) + 2\ e^-$	$\longrightarrow 2\ Hg(\ell)$	0.789
$Fe^{3+}(aq) + e^-$	$\longrightarrow Fe^{2+}(aq)$	0.771
$I_2(s) + 2\ e^-$	$\longrightarrow 2\ I^-(aq)$	0.535
$O_2(g) + 2\ H_2O(\ell) + 4\ e^-$	$\longrightarrow 4\ OH^-(aq)$	0.40
$Cu^{2+}(aq) + 2\ e^-$	$\longrightarrow Cu(s)$	0.337
$Sn^{4+}(aq) + 2\ e^-$	$\longrightarrow Sn^{2+}(aq)$	0.15
$2\ H_3O^+(aq) + 2\ e^-$	$\longrightarrow H_2(g) + 2\ H_2O(\ell)$	0.00
$Sn^{2+}(aq) + 2\ e^-$	$\longrightarrow Sn(s)$	−0.14
$Ni^{2+}(aq) + 2\ e^-$	$\longrightarrow Ni(s)$	−0.25
$PbSO_4(s) + 2\ e^-$	$\longrightarrow Pb(s) + SO_4^{2-}(aq)$	−0.356
$Cd^{2+}(aq) + 2\ e^-$	$\longrightarrow Cd(s)$	−0.40
$Fe^{2+}(aq) + 2\ e^-$	$\longrightarrow Fe(s)$	−0.44
$Zn^{2+}(aq) + 2\ e^-$	$\longrightarrow Zn(s)$	−0.763
$2\ H_2O(\ell) + 2\ e^-$	$\longrightarrow H_2(g) + 2\ OH^-(aq)$	−0.8277
$Al^{3+}(aq) + 3\ e^-$	$\longrightarrow Al(s)$	−1.66
$Mg^{2+}(aq) + 2\ e^-$	$\longrightarrow Mg(s)$	−2.37
$Na^+(aq) + e^-$	$\longrightarrow Na(s)$	−2.714
$K^+(aq) + e^-$	$\longrightarrow K(s)$	−2.925
$Li^+(aq) + e^-$	$\longrightarrow Li(s)$	−3.045

*In volts (V) versus the standard hydrogen electrode.

Possibly useful formulas (most constants are on the back of the periodic table):

$T_F = T_C + (9^\circ F/5^\circ C) + 32^\circ F$ $T_K = T_C + 273.15$ $d = m/V$

$N_A = 6.022 \times 10^{23}\ mol^{-1}$ % yield = (actual yield/theoretical yield) x 100%

mass % = (mass of element per mole compound)/(mass per mole compound) x 100%

c = molarity = $n_{solute}/V_{solution}$ = amount solute/volume solution

moles solute after dilution = moles solute before dilution M_m = molar mass

$PV = nRT$ $P = F/A$ $P = P_A + P_B + P_C + \ldots$

$P = g\,d\,h$ PV = constant (at const. T, n) mole fraction of A = $n_A/n = P_A/P$

$V = n\,V_m$ V/T = constant (at const. P, n) $P = mRT/VM_m$ $P = dRT/M_m$

$u_{rms} = \frac{\sqrt{(3RT)}}{M_m}$ rate of effusion = $\frac{1}{\sqrt{M_m}}$ $(P + a\frac{n^2}{V^2})(V - bn) = nRT$

energy of emitted photon = $E_i - E_f = h\nu$ $E = h\nu$ $c = \lambda\nu$ $\lambda = h/mv$

$E = mc^2$ $E = hc/\lambda$ $\Delta x\ .\ \Delta(mv) \geq h/4\pi$ $H\psi = E\psi$

$n = 1, 2, 3, \ldots$ $l = 0, 1, 2, \ldots, (n-1)$ $m_l = -l, -l+1, \ldots, 0, \ldots, l-1, l$ $m_s = \pm 1/2$

$E = -2.178 \times 10^{-18}\ J\,(Z^2/n^2)$ $n = 1, 2, 3, 4, \ldots$

$\Delta E = q + w$ $w = -P\Delta V$ $H = E + PV$ $\Delta H = H_{prod} - H_{react}$

$q = C\Delta T = mc\Delta T = nC_m\Delta T$ $\Delta H = \Sigma(a\Delta H_f^o(\text{products})) - \Sigma(b\Delta H_f^o(\text{reactants}))$

$\Delta H = \Sigma$(bonds broken) $- \Sigma$(bonds formed) $\Delta S = \Sigma(aS^o(\text{products})) - \Sigma(bS^o(\text{reactants}))$

$\Delta S_{universe} = \Delta S_{system} + \Delta S_{surroundings}$ $\Delta S_{surroundings} = -\Delta H_{system}/T$

$\Delta G = \Delta H - T\Delta S$ $\Delta G^o = -RT\ln K_{th} = \Delta H^o - T\Delta S^o$

$j\,A + k\,B \Leftrightarrow l\,C + m\,D$ $K_c = [C]^l[D]^m/[A]^j[B]^k$ $Q = [C]_0^l[D]_0^m/[A]_0^j[B]_0^k$

$E = E^o - (RT/nF)\ln Q = -(0.0592V/n)\log Q$ $pH = pKa + \log([\text{base}]/[\text{conjugate acid}])$

$P = cRT$ $c = P/RT$ $K_p = K_c(RT)^{\Delta n}$

Solubility of gas = $k_H P$ $\Delta T_b = K_b c_m i$ $\Delta T_f = K_f c_m i$ $\Pi V = nRTi$ $\Pi = cRTi$

mass % = (mass solute)/(mass solution) x 100% molality = c_m = (moles solute)/(kg solvent)

mole fraction = (moles solute)/(total moles solution)

For an equation: $ax^2 + bx + c = 0$, *the roots are:* $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$\ln(N/N_0) = -kt = -(0.693/t_{1/2})\,t$ $\Delta E = \Delta mc^2$

0th order reaction Rate = $k[A]^0 = k$ $[A] = -kt + [A]_0$

1st order reaction Rate = $k[A]$ $\ln[A] = -kt + \ln[A]_0$

2nd order reaction Rate = $k[A]^2$ $1/[A] = kt + 1/[A]_0$