CHEMISTRY 104 – Summer 2024
Hour Exam II Answers

Multiple Choice (3 points each)

1.	D	12.	A
2.	E	13.	A
3.	C	14.	C
4.	A	15.	A
5.	B	16.	B
6.	C	17.	D
7.	B	18.	C
8.	E	19.	C
9.	D	20.	B
10.	E	21.	B
11.	D	22.	E

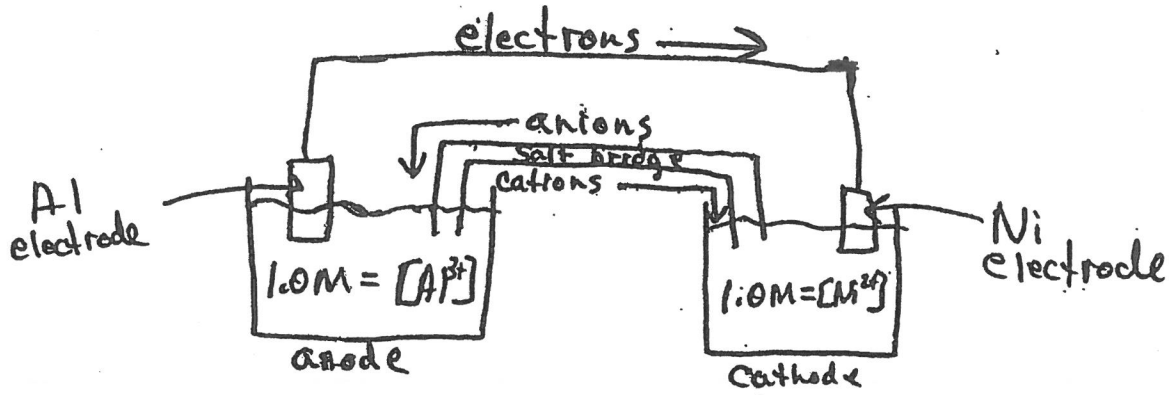
Written out problems – Show all work for partial credit.

23. Consider a galvanic cell at 25°C based on the following half-reactions: **(12 pts)**

$Al^{3+} + 3e^- \rightarrow Al$ $\quad E° = -1.66$ V ← anode reaction

$Ni^{2+} + 2e^- \rightarrow Ni$ $\quad E° = -0.23$ V ← cathode reaction

a) Draw the cell under **standard** conditions labeling the anode, the cathode, the direction of electron flow, the concentration of ions, the electrodes, and the direction of flow of cations and anions through the salt bridge.



For part b.

$(Ni^{2+} + 2e^- \rightarrow Ni) \times 3$ $\quad E°_{red} = -0.23$ V

$(Al \rightarrow Al^{3+} + 3e^-) \times 2$ $\quad E°_{ox} = 1.66$ V

$3Ni^{2+}(aq) + 2Al(s) \rightarrow 2Al^{3+}(aq) + 3Ni(s)$ $\quad E°_{cell} = 1.43$ V

$n = 6e^-$ $\quad Q = \frac{[Al^{3+}]^2}{[Ni^{2+}]^3}$

b) To the standard cell above, OH^- is added to the aluminum compartment causing $Al(OH)_3(s)$ to precipitate. After precipitation of $Al(OH)_3(s)$ has ceased, the concentration of OH^- is 1.0×10^{-4} *M* and the measured cell potential is 1.82 V. Calculate the K_{sp} value for $Al(OH)_3(s)$. $K_{sp} = [Al^{3+}][OH^-]^3 = [Al^{3+}](1.0 \times 10^{-4})^3$

$Al(OH)_3(s) \rightleftharpoons Al^{3+}(aq) + 3\ OH^-(aq)$ $\quad K_{sp} = ?$

$E = E° - \frac{0.0591}{n} \log Q$, $\quad 1.82V = 1.43V - \frac{0.0591}{6} \log \frac{[Al^{3+}]^2}{(1.0)^3}$

$\log [Al^{3+}]^2 = \frac{(1.43 - 1.82)6}{0.0591} = -39.59$

$[Al^{3+}]^2 = 10^{-39.59} = 2.57 \times 10^{-40}$, $\quad [Al^{3+}] = 1.6 \times 10^{-20}$ M

$K_{sp} = (1.6 \times 10^{-20})(1.0 \times 10^{-4})^3 = 1.6 \times 10^{-32} = K_{sp}$

24. Consider an aqueous solution of copper nitrate, $Cu(NO_3)_2$. It took 1380 seconds using a current of 2.00 A to plate out all the copper from 25.0 mL of the copper nitrate solution. What was the original concentration of copper nitrate in the solution? Calculate the concentration in units of molarity (= mol/L).

(6 pts)

$$[Cu(NO_3)_2] = \frac{\text{mol } Cu(NO_3)_2}{\text{Vol. solution}} = \frac{\text{mol } Cu^{2+}}{\text{Vol. soln}} \quad ; \quad Cu^{2+} + 2e^- \rightarrow Cu(s)$$

$$\text{Mol } Cu^{2+} = \text{mol Cu produced} = 1380\,s\left(\frac{2.00\,C}{s}\right)\left(\frac{1\,\text{mol } e^-}{96{,}485\,C}\right)\left(\frac{1\,\text{mol Cu}}{2\,\text{mole}^-}\right) = 1.43 \times 10^{-2}\,\text{mol Cu}$$

$$\text{Molarity} = \frac{1.43 \times 10^{-2}\,\text{mol } Cu(NO_3)_2}{0.0250\,L} = \boxed{0.572\,M}$$

25. The boiling points of 5 organic compounds are 9.5°C, 36°C, 76°C, 117°C, and 141°C.
The structures of three of the compounds are: The molar masses of these compounds
(5 pts) are all very close to each other, so all have similar strength LDFs.

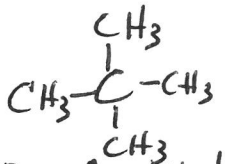
polar
$CH_3CH_2CH_2CHO$
LDF + dipole

polar
$CH_3CH_2C(=O)OH$
LDF + dipole + H-bonding

$CH_3CH_2CH_2CH_2OH$
LDF + H-bonding

The other three compounds are pentane and 2,2-dimethylpropane. Match the boiling points to the 5 compounds.

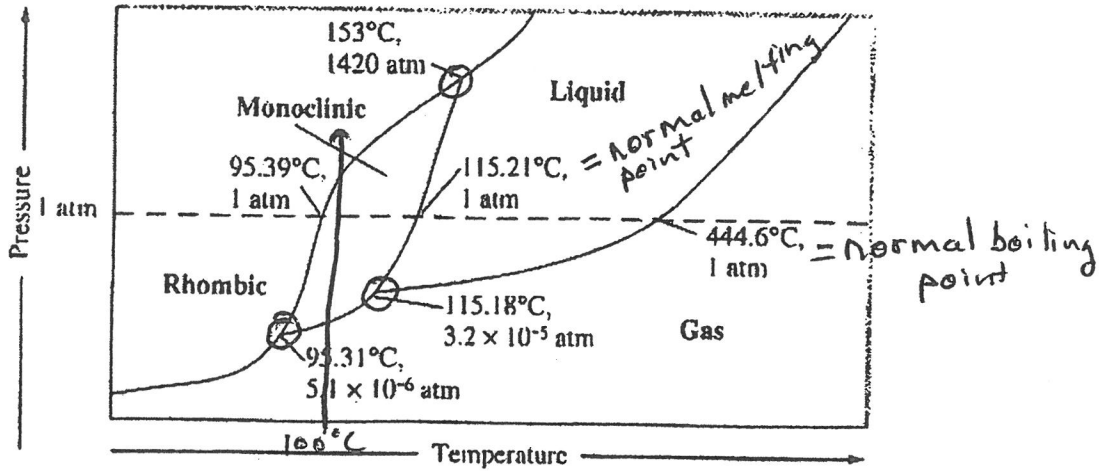
$CH_3CH_2CH_2CH_2CH_3$
Pentane only has LDF since nonpolar.


2,2-dimethyl propane only exhibits LDF. With its more spherical structure, this compound has weaker LDFs than pentane.

9.5°C 36°C 76°C 117°C
2,2-dimethyl butane < pentane < $CH_3CH_2CH_2CHO$ < $CH_3CH_2CH_2CH_2OH$ <
weakest IMF → $CH_3CH_2C(=O)OH$ 141°C strongest IMF

26. Sulfur exhibits two solid forms, rhombic and monoclinic. The complete phase diagram for sulfur is shown below. Consider the phase diagram when answering the following questions.

(10 pts)



a. What is the normal melting point of monoclinic sulfur?

solid → liquid phase change at 1 atm.
From plot, (nmp = 115.21°C.)

b. How many triple points are in the phase diagram?

(3) - see circles on plot

c. Which is the densest phase? (Rhombic) is densest phase.
From slopes of rhombic/monoclinic line, rhombic is more dense. From slope of rhombic/liquid line, rhombic is more dense. And rhombic more dense than gas.

d. At a pressure of 1.0×10^{-5} atm, can rhombic sulfur sublime? (NO)

From phase diagram, rhombic and gas phase are only in equilibrium with each other at pressures at or below 5.1×10^{-6} atm, so rhombic cannot convert directly to gas at a pressure greater than 5.1×10^{-6} atm.

e. The pressure on a sample of sulfur at 100°C is increased from 0 atm to 2000 atm. What phase changes will occur in this sample of sulfur as the pressure is increased?

See the arrow in the phase diagram representing this process.

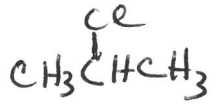
Phase Changes:

(gas → monoclinic → rhombic)

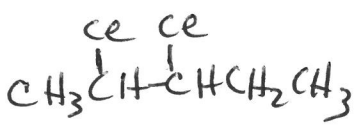
27. The following compounds can be produced in a single step reaction. Indicate which reactants (including catalysts) are necessary to make the desired products. Only major products should be produced. For the organic reactant compound, **draw the structural formula and name it.** Make sure your structural formulas contain all hydrogen atoms, e.g., butane should be drawn as $CH_3CH_2CH_2CH_3$ or $CH_3–CH_2–CH_2–CH_3$, not C–C–C–C or line notation.

(12 pts)

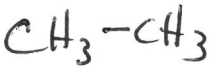
a. $CH_2=CHCH_3 + HCl$ (propene or 1-propene) → 2-chloropropane (major product)



b. $CH_3CH=CHCH_2CH_3 + Cl_2$ (2-pentene) → 2,3-dichloropentane



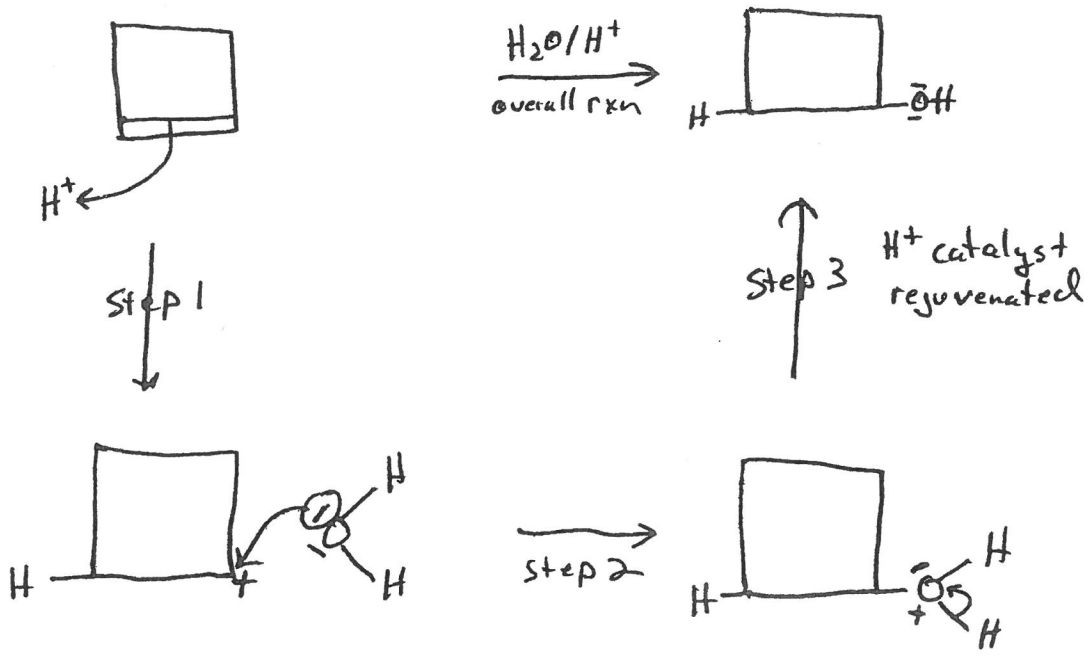
c. $CH_2=CH_2 + H_2/Pt$ (ethene) → ethane



d. $CH_2=CHCH_2CH_2CH_2CH_3 + H_2O/H^+$ (1-hexene) → $CH_3CH(OH)CH_2CH_2CH_2CH_3$ (major product)

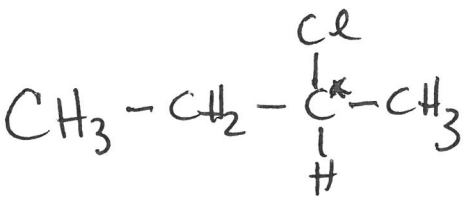
28. Propose a detailed mechanism for the reaction of H_2O and cyclobutene (in the presence of an H^+ catalyst).

(9 pts)

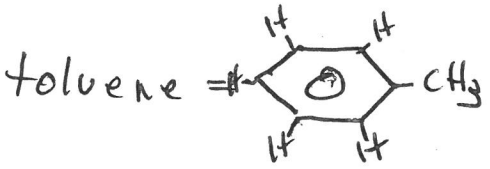


29. a. Draw the structural formula(s) for the isomer(s) of C_4H_9Cl which is/are optically active. Place an asterisk by the chiral carbon(s). Name the isomer(s).

(12 pts)

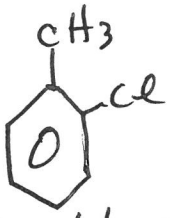


Only 1 optically active isomer is possible.

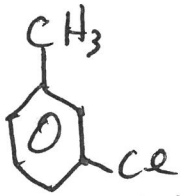


substitution rxn for benzene ring H atoms.

b. Consider the reaction of toluene ($C_6H_5CH_3$) with $Cl_2(g)$ in the presence of $FeCl_3$ as the catalyst. Draw the structural formula(s) for the possible monochlorinated product(s) of this reaction. Name the product(s).



2-chlorotoluene
or
ortho-chlorotoluene



3-chlorotoluene
or
meta-chlorotoluene

4-chlorotoluene
or
para-chorotoluene

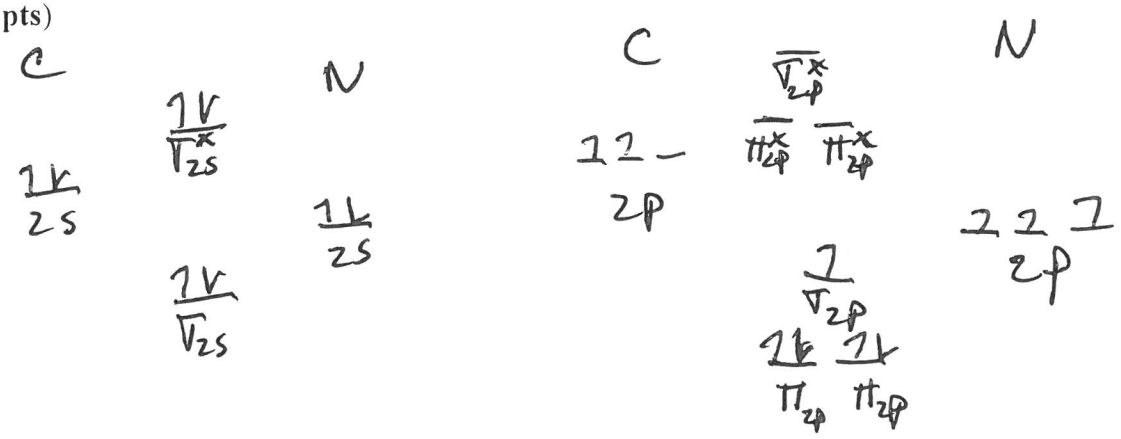
substitution rxn with CH_3 group.

c. Consider the reaction of toluene ($C_6H_5CH_3$) with $Cl_2(g)$ in the presence of ultraviolet light as the catalyst. Draw the structural formula(s) for the possible monochlorinated product(s) of this reaction.

C: $1s^2 2s^2 2p^2$
N: $1s^2 2s^2 2p^3$

30. a. Draw the molecular orbital diagram for CN. In your diagram, include the 2s and 2p MO diagrams.

(12 pts)



b. What is the bond order for the CN molecule? Is CN expected to be paramagnetic or diamagnetic?

$BO = \frac{5-0}{2} = 2.5$ or $\frac{7-2}{2} = 2.5$

CN has an unpaired electron, so it is paramagnetic

c. Is CN^- expected to have a stronger or weaker bond than CN. Explain. Is CN^- expected to be paramagnetic or diamagnetic? Add 1 electron to CN diagram to get CN^-.

CN^-: $(\sigma_{2s})^2(\sigma^*_{2s})^2(\pi_{2p})^4(\sigma_{2p})^2$ $B.O = \frac{6-0}{2} = 3.0$ or $\frac{8-2}{2} = 3.0$

Since CN^- has a larger bond order than CN, CN^- will have a stronger bond. Since all electrons are paired, CN^- is diamagnetic

d. Is CN^+ expected to have a shorter or longer bond length than CN. Explain. Is CN^+ expected to be paramagnetic or diamagnetic? Remove 1 electron from CN diagram to get CN^+.

CN^+: $(\sigma_{2s})^2(\sigma^*_{2s})^2(\pi_{2p})^4$ $B.O = \frac{4-0}{2} = 2$ or $\frac{6-2}{2} = 2.0$

CN^+ has a weaker bond than CN, so the bond length will be longer in CN^+ than in CN. Since all electrons are paired in the CN^+ MO diagram, CN^+ is diamagnetic.