CHEMISTRY 104 – Summer 2023
Hour Exam II Answers

True-False

1. B (false)
2. B (false)
3. A (true)
4. B (false)
5. B (false)
6. A (true)
7. A (true)
8. B (false)
9. B (false)
10. A (true)

Multiple Choice (3 points each)

11. D
12. A
13. D
14. A
15. B
16. C
17. C
18. E
19. B
20. E
21. B
22. C
23. D
24. E
25. E
26. A
27. B
28. D
29. C
30. D
31. A
32. B
33. C

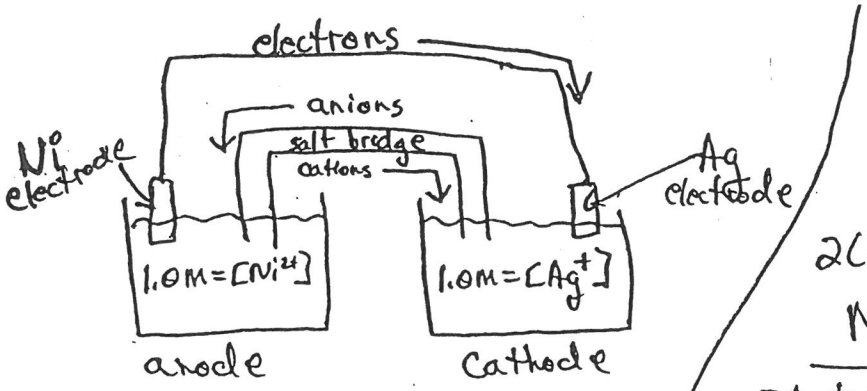
WRITTEN OUT PROBLEMS – Show all work for partial credit.

34. Consider a standard cell based on the following half-reactions:
12 pts.

$Ag^+ + e^- \rightarrow Ag(s)$ $E° = 0.80\ V$ ← cathode rxn

$Ni^{2+} + 2\,e^- \rightarrow Ni(s)$ $E° = -0.23\ V$ ← reverse is the anode rxn

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



For part b

$2(Ag^+ + e^- \rightarrow Ag)$ $E^0_{red} = 0.80V$

$Ni \rightarrow Ni^{2+} + 2e^-$ $E^0_{ox} = 0.23V$

$2Ag^+ + Ni \rightarrow 2Ag + Ni^{2+}$ $E^0_{cell} = 1.03V$

$Q = \frac{[Ni^{2+}]}{[Ag^+]^2}$

b) 1.0 *M* HCl is added to the silver compartment of the standard cell constructed above. The Cl^- reacts with some of the Ag^+ present to produce AgCl(s). After all the precipitate has formed, the $[Cl^-]_e = 1.0\ M$. Given:

$$AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq) \qquad K_{sp} = 1.6 \times 10^{-10}$$

calculate the cell potential, E, at 25°C. Note: the same anode and cathode reactions occur as in the standard cell.

$K_{sp} = 1.6 \times 10^{-10} = [Ag^+][Cl^-] = [Ag^+](1.0M)$, $[Ag^+] = 1.6 \times 10^{-10} M$

$E = E^0 - \frac{0.0591}{n} \log Q = 1.03V - \frac{0.0591}{2} \log \frac{(1.0M)}{(1.6 \times 10^{-10} M)^2}$

$E = 1.03V - \frac{0.0591}{2} \log (3.91 \times 10^{19}) = 1.03V - 0.58V$

$E = 0.45\ V$

35. Consider the electrolysis of a molten metal chloride having the general formula MCl_2. A current of 5.00 amps is applied for 748 seconds. This results in 0.471 g of the metal M plating out at the cathode. Identify the metal M. MCl_2 composed of M^{2+} + Cl^- ions

6 pts.

$M^{2+} + 2e^- \rightarrow M$

$$\text{molar mass} = \frac{0.471\ \text{g M}}{?\ \text{mol M}}$$

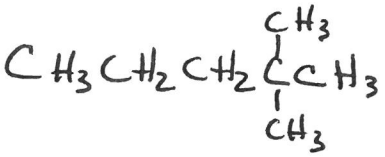
$$\text{mol M} = \frac{748\ \text{s}}{} \left| \frac{5.00\ \text{C}}{\text{s}} \right| \frac{1\ \text{mol e}^-}{96{,}485\ \text{C}} \left| \frac{1\ \text{mol M}}{2\ \text{mol e}^-} \right. = 0.01938\ \text{mol M}$$

$$\text{Molar mass} = \frac{0.471\ \text{g M}}{0.01938\ \text{mol M}} = 24.3\ \text{g/mol}$$

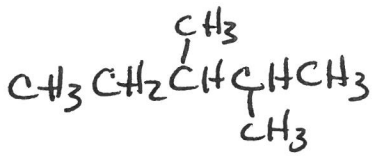
From periodic table, M = Mg.

36. There are 9 structural isomers having the C_7H_{16} formula. Name the structural isomers of C_7H_{16} that have a base name of pentane.

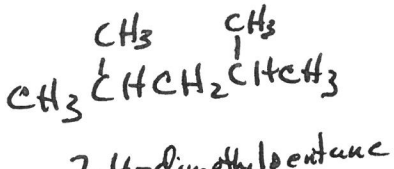
10 pts. 5 total isomers with base name of pentane,



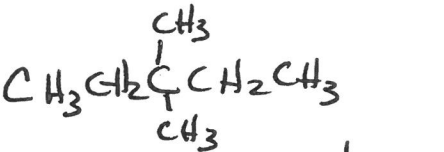
2,2-dimethylpentane



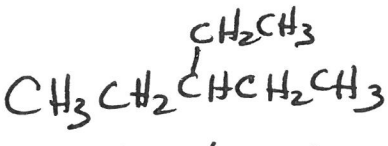
2,3-dimethylpentane



2,4-dimethylpentane



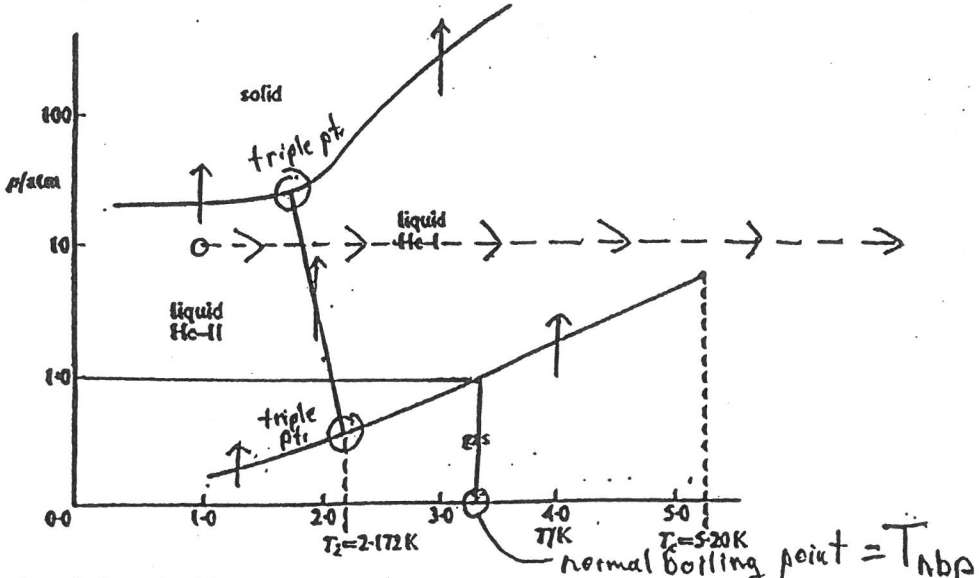
3,3-dimethylpentane



3-ethylpentane

37. The phase diagram for helium shows four phases: solid, gas, and two liquid phases (I and II). Using the phase diagram for helium given below, answer the following questions. The phase diagram is plotted P (in atm) vs. T (in K)

10 pts



2pts a) Circle the triple point(s) on the phase diagram.

2 triple points - see phase diagram

2pts b) Place the four phases in order of increasing density (smallest to largest).

Arrows (↑) indicate increase in pressure. As pressure increases, the various phases convert to the more dense phase. From arrows:

$He(g) < He(\ell, II) < He(\ell, I) < He(s)$

least dense — most dense

2pts c) What is the approximate normal boiling point for helium?

Temperature where gas and liquid phases are in equilibrium at 1 atm. From plot: $T_{nbp} \approx 3.3\,K$

2pts d) A sample of helium is heated at a constant pressure of 10 atm from 1 K to 273 K. What phase changes will occur when the helium is heated? Note: 5.20 K is the critical temperature. See dashed line (→ - - → - -), when the temperature reaches higher than the critical temperature, only the gas phase can exist. The phase changes are:

liquid He-II → liquid He-I → gas

2pts e) Can helium gas at 3.0 K sublime? Explain.

NO. Sublimation process is a solid converting directly to gas (bypasses liquid phase). From the phase diagram, the solid and gas phases are never in equilibrium together. Therefore, He cannot sublime.

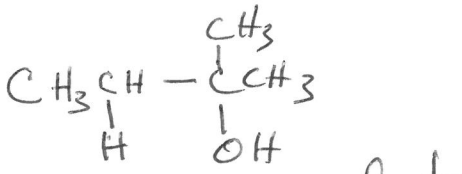
Both reactions use Markovnikov's rule to predict the major product.

38. Write the structural formula for the major organic product in each of the following chemical reactions.

9 pts.

a) $CH_3CH{=}CCH_3$ (with CH_3 on the C) + H_2O $\xrightarrow{H^+}$

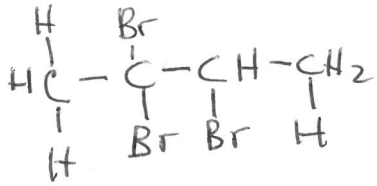
addition rxn



major product

b) $HC{\equiv}C{-}CH{=}CH_2$ $\xrightarrow{HBr\ (excess)}$

addition rxn
- react all of the π bonds



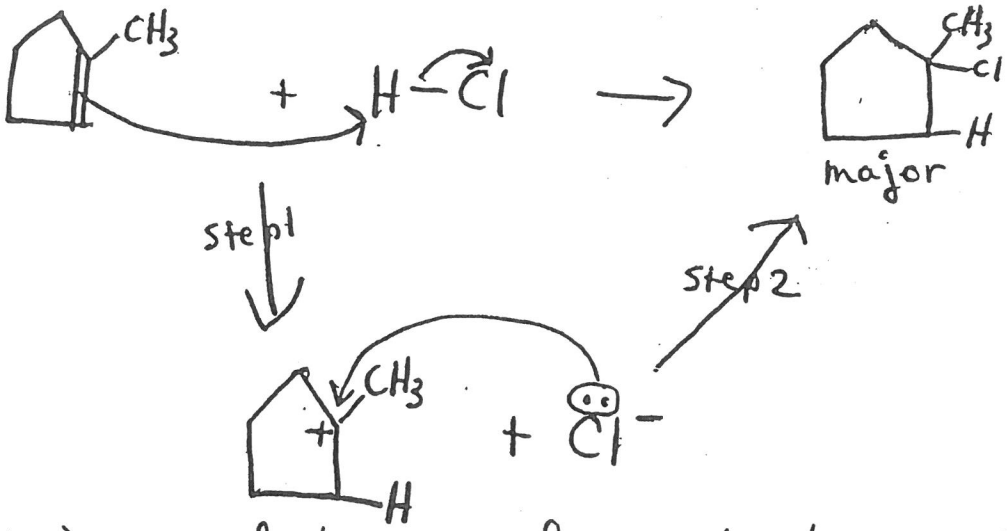
major product

c) Name the major product in part b.

2,2,3-tribromobutane

39. When HCl is reacted with 1-methyl-1-cyclopentene, two products are obtained. Propose a detailed mechanism for the major product formed from this reaction. Explain why the major product is preferred over the minor product.

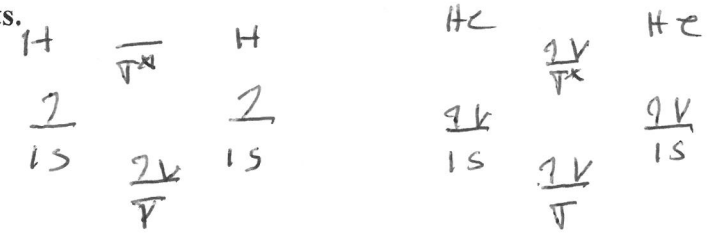
6 pts.



For the minor product, a secondary carbocation is the intermediate. This intermediate is not as stable as the 3° carbocation formed for the major product.

40. a) How does MO theory explain that H_2 is stable while He_2 is not stable?

12 pts.



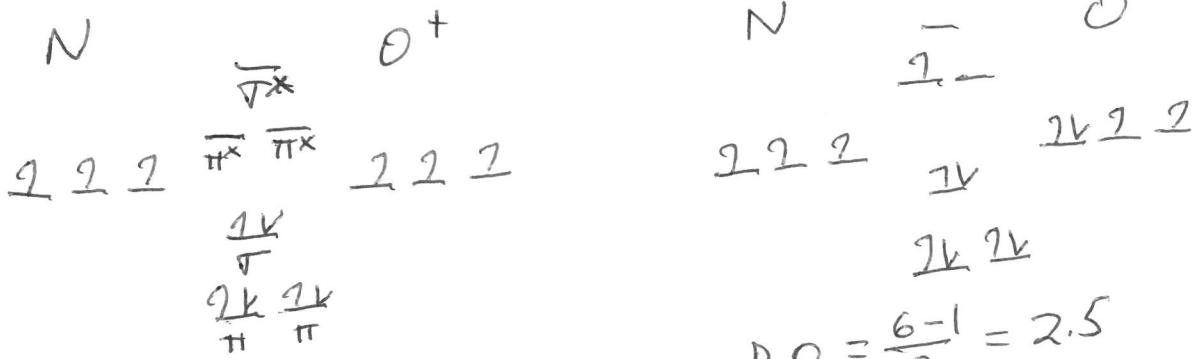
$B.O. = \frac{2-0}{2} = 1$ $B.O. = \frac{2-2}{2} = 0$; B.O. = bond order

Because H_2 has a bond order greater than zero it should be a stable species. Because He_2 has a bond order equal to zero, it is not a stable species.

b) How does MO theory explain that the H_2 molecule has a larger ionization energy than an H atom? See above for the H_2 MO diagram.

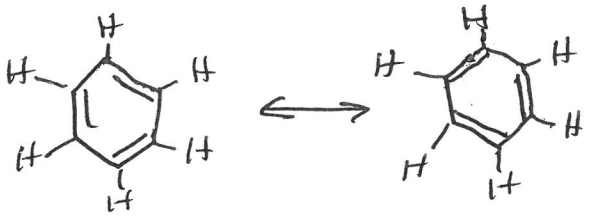
H_2 loses an electron in the lower energy σ bonding orbital as compared to the energy of the 1s electron of an H atom. It takes more energy to remove the lower energy electron in H_2, hence H_2 has the larger ionization energy.

c) How does MO theory explain that NO^+ is more stable than NO^-?



$B.O. = \frac{6-0}{2} = 3$ $B.O. = \frac{6-1}{2} = 2.5$

Because NO^+ has a larger bond order than NO, NO^+ is the more stable species.



Benzene resonance structures.

41. Give a detailed explanation of the bonding in benzene, C_6H_6. In your explanation, indicate the orbitals that overlap to form the various bonds and the type of bond formed (σ or π). Why are the carbon-carbon bonds in the ring equivalent in length and in strength?

6 pts.

Each carbon in the ring exhibits 120° bond angles; so each carbon is sp^2 hybridized with 1 unhybridized p atomic orbital perpendicular to the plane of the ring.

The six C-H σ (sigma) bonds are formed from overlap of an sp^2 hybrid orbital from carbon with a 1s atomic orbital from hydrogen. The six C-C σ (sigma) bonds in the ring are formed from overlap of sp^2 hybrid orbitals from each carbon.

The π bonding system in benzene is formed from overlap of the six unhybridized p atomic orbitals. The result is that the π electrons in benzene are delocalized above and below the entire ring surface. Since the π electrons are delocalized, this results in equivalent carbon-carbon bonds in the ring.