## CHEMISTRY 104 – Summer 2022
## Hour Exam 2 Answers

### Multiple Choice (3 points each)

| | | | |
|---|---|---|---|
| 1. | E | 14. | C |
| 2. | A | 15. | B |
| 3. | E | 16. | D |
| 4. | B | 17. | D |
| 5. | B | 18. | E |
| 6. | C | 19. | C |
| 7. | D | 20. | A |
| 8. | A | 21. | B |
| 9. | D | 22. | E |
| 10. | B | 23. | A |
| 11. | A | 24. | A |
| 12. | E | 25. | D |
| 13. | C | | |

**Written out problems – Show all work for partial credit.**

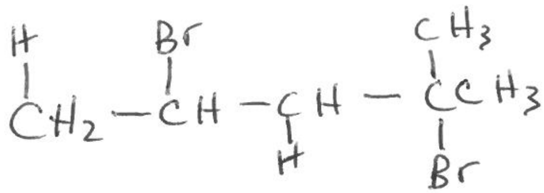
26. **Write the structural formula** for the **major** organic product in each of the following chemical reactions. For the organic product, **name** the compound.

(9)

a) $C_6H_6 \xrightarrow[FeI_3]{I_2}$

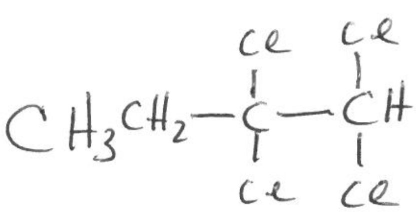
iodobenze

b) $CH_2{=}CH{-}CH{=}C(CH_3)CH_3 \xrightarrow{HBr\ (excess)}$



2,4-dibromo-2-methylpentane

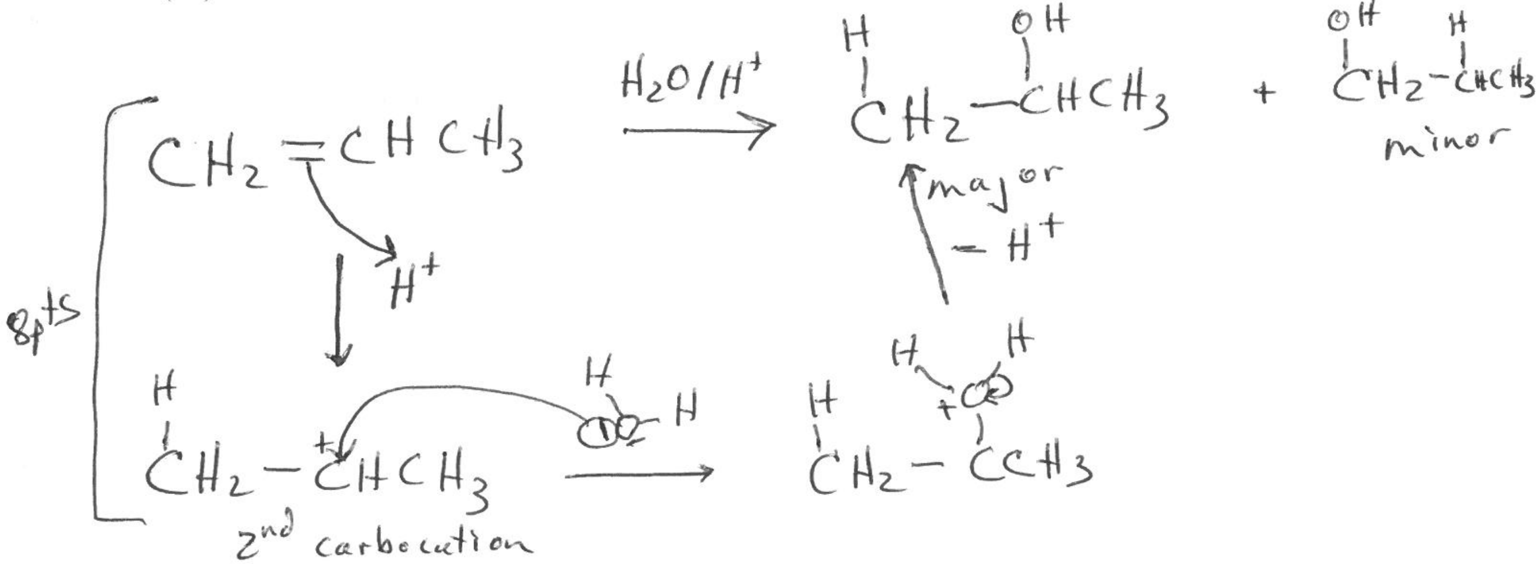
c) $CH_3CH_2{-}C{\equiv}CH \xrightarrow{Cl_2\ (excess)}$



1,1,2,2-tetrachlorobutane

27. When $H_2O$ is reacted with 1-propene in the presence of $H^+$, 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.

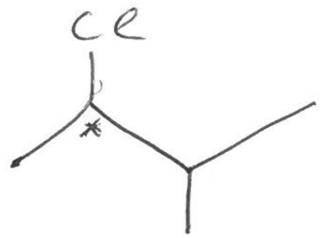
(10)




2pts A secondary carbocation is produced for the major product and a primary carbocation is produced for the minor product. Since a secondary carbocation is more stable than a primary carbocation, the major product is prefered.

28. a) One of the structural isomers of $C_5H_{11}Cl$ has a chiral carbon, i.e, is optically active. Name the structural isomer that is optically active. 3pts

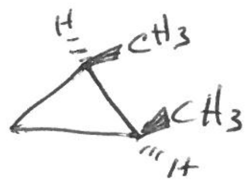
(10)



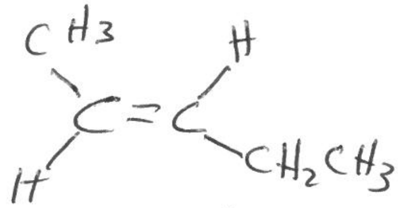

2-chloro-3-methyl butane is optically active. the 4 groups on the chiral carbon are
(1) Cl
(2) H
(3) CH
(4) isopropyl

b) Two of the structural isomers with the formula $C_5H_{10}$ exhibit geometric (cis/trans) isomerism. Name the two structural isomers.

2-pentene (2pts) and 1,2-dimethylcyclopropane (2pts) exhibit cis/trans isomerism.



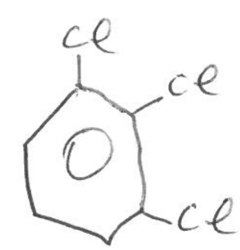

This is cis form of 1,2-dimethylcyclopropane.



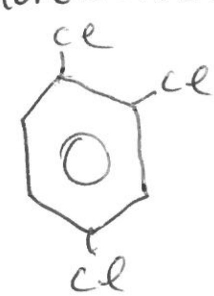

This is the trans form of 2-pentene.

c) Name the structural isomers of trichlorobenzene.

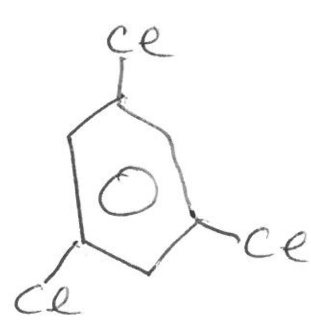
1,2,3-trichlorobenzene (1pt), 1,2,4-trichlorobenzene (1pt), and 1,3,5 trichloro benzene (1pt) are the 3 structural isomers of trichlorobenzene.




1,2,3-




1,2,4-




1,3,5-

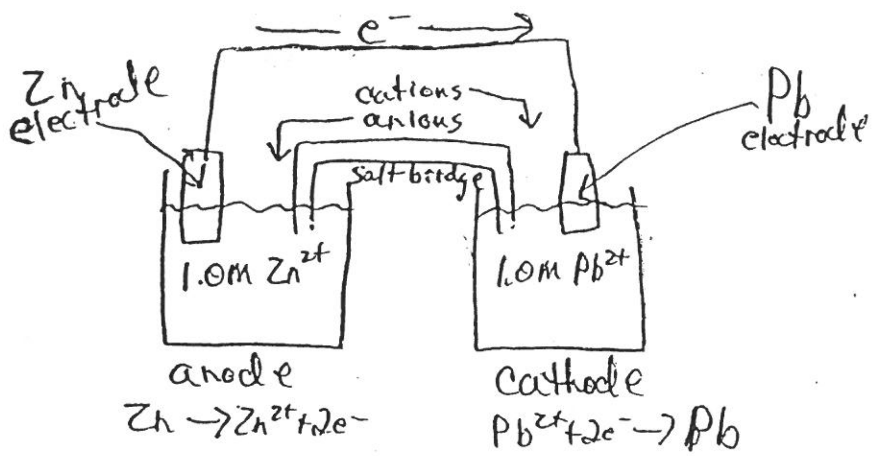
29. Consider a galvanic cell at 25°C based on the following half-reactions:
(12)

$Pb^{2+} + 2e^- \rightarrow Pb$ $E° = -0.13$ V

$Zn^{2+} + 2e^- \rightarrow Zn$ $E° = -0.76$ V

8pts

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.




$Pb^{2+} + 2e \rightarrow Pb(s)$ $E°_{Red} = -0.13V$

$Zn(s) \rightarrow Zn^{2+} + 2e^-$ $E°_{ox} = +0.76V$

$Pb^{2+} + Zn \rightarrow Pb + Zn^{2+}$ $E°_{cell} = 0.63V$

For part b.

4pts

b) To the standard cell above, $OH^-$ is added to the zinc compartment causing $Zn(OH)_2$ to precipitate. After equilibrium is reached, the measured cell potential is 1.05 V. Given the following $K_{sp}$ value for $Zn(OH)_2$:

n = 2 electrons transfered

$Zn(OH)_2(s) \longrightarrow Zn^{2+}(aq) + 2\,OH^-(aq)$ $K_{sp} = 6.5 \times 10^{-17} = [Zn^{2+}][OH^-]^2$

calculate the equilibrium $[OH^-]$ in the zinc compartment.

$$E = E° - \frac{0.0591}{n} \log Q = 0.63V - \frac{0.0591}{2} \log \frac{[Zn^{2+}]}{[Pb^{2+}]}$$

$$1.05V = 0.63V - \frac{0.0591}{2} \log \frac{[Zn^{2+}]}{1.0M} ; \log [Zn^{2+}] = \frac{-0.42(2)}{0.0591}$$

$$\log [Zn^{2+}] = -14.21 , [Zn^{2+}] = 10^{-14.21} = 6.2 \times 10^{-15} M$$

$$K_{sp} = [Zn^{2+}][OH^-]^2 , 6.5 \times 10^{-17} = (6.2 \times 10^{-15})[OH^-]^2$$

$$[OH^-]^2 = \frac{6.5 \times 10^{-17}}{6.2 \times 10^{-15}} = 0.0105 , [OH^-] = \sqrt{0.0105} = 0.10M = [OH^-]$$

30. Hydrogen-oxygen fuel cells are utilized in some cities to produce electricity. The fuel cell reaction and equilibrium constant at 25°C are:

(9)

$$2\,H_2(g) + O_2(g) \rightarrow 2\,H_2O(l) \qquad K = 1.28 \times 10^{83}$$

The oxidation state of each H atom increases from 0 to +1, with 4 mol of H in balanced rxn, n = 4(1) = 4 electrons transfered.

a) Fuel cells produce power by producing a voltage. Calculate E°, the standard cell potential, for this fuel cell reaction at 25°C.

$$E° = \frac{0.0591}{n}\log K = \frac{0.0591}{4}\log(1.28 \times 10^{83}) = 1.23\,V$$

b) This fuel cell utilizes the following half-reactions:

| | E° |
|---|---|
| $4\,H_2O(l) + 4e^- \rightarrow 2\,H_2(g) + 4\,OH^-(aq)$ | −0.83 V |
| $O_2(g) + 2\,H_2O(l) + 4e^- \rightarrow 4\,OH^-(aq)$ | ? |

Using your result from part a, and given the information above, calculate the standard reduction potential for:

$O_2(g) + 2\,H_2O(l) + 4e^- \rightarrow 4\,OH^-(aq)$ E° = 1.23 V (from part a)

$2H_2 + 4OH^- \rightarrow H_2O + 4e^-$ $\mathcal{E}^°_{ox} = 0.83\,V$

$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$ $\mathcal{E}^°_{red} = ?$

$2H_2 + O_2 \rightarrow 2H_2O$ $\mathcal{E}^°_{cell} = 0.83 + \mathcal{E}^°_{red} = 1.23\,V$

$\mathcal{E}^°_{red} = 1.23 - 0.83 = 0.40\,V$

c) The reverse reaction of this fuel cell:

$2\,H_2O(l) \rightarrow 2\,H_2(g) + O_2(g)$ 4 electrons transfered

can be used to produce hydrogen and oxygen gases in an electrolytic cell. How many moles of $O_2(g)$ can be produced if water is electrolyzed by a current of 10.0 amps for 220 minutes?

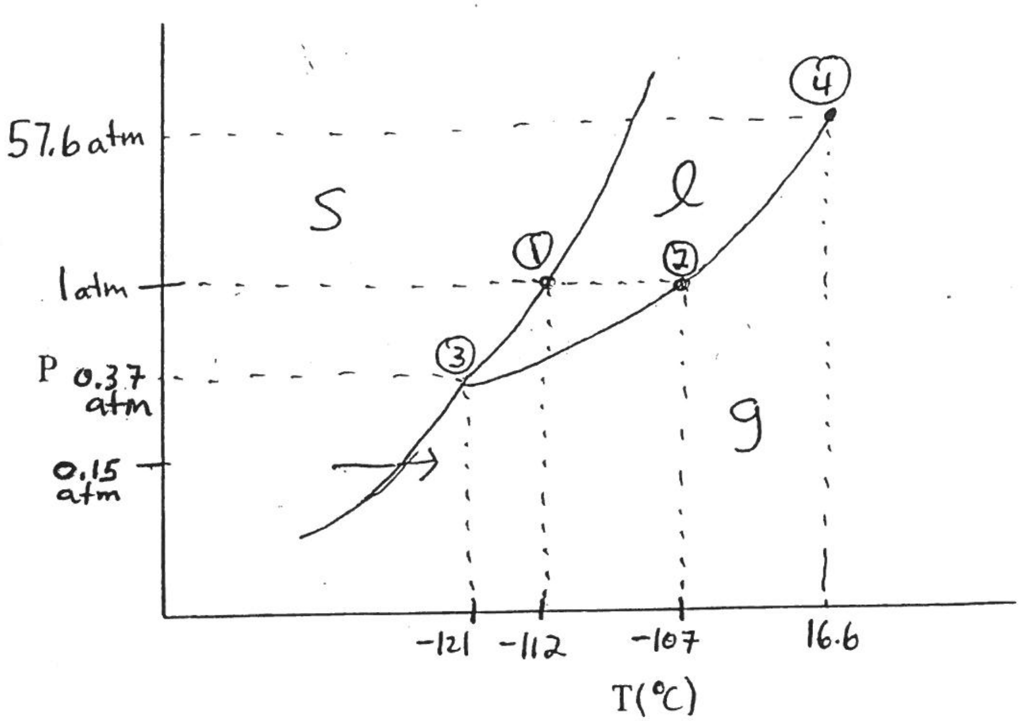
$$220\,min\left(\frac{60\,s}{1\,min}\right)\left(\frac{10.0\,C}{s}\right)\left(\frac{1\,mol\,e^-}{96{,}485\,C}\right)\left(\frac{1\,mol\,O_2}{4\,mol\,e^-}\right) = 0.34\,mol\,O_2$$

31. (12) Like most substances, xenon exists in one of three typical phases: solid, liquid and gas. Some important data points in the phase diagram for xenon are:

1. normal melting point = −112°C
2. normal boiling point = −107°C
3. triple point = −121°C and 0.37 atm
4. critical point = 17 °C and 58 atm

a) Sketch the phase diagram (P vs. T) for Xe, showing the four data points given above (label them 1-4) as well as indicating the area in which each phase is stable (label the various areas solid, liquid or gas). Your phase diagram does **not** have to be to scale. However, on your axes indicate the pressures and temperatures for the four data points given above.

8 pts




b) For the following four questions, circle the correct response.

1 pt i) Which is the denser phase, Xe(s) or Xe(l)?
From positive slope of solid-liquid equilibrium line

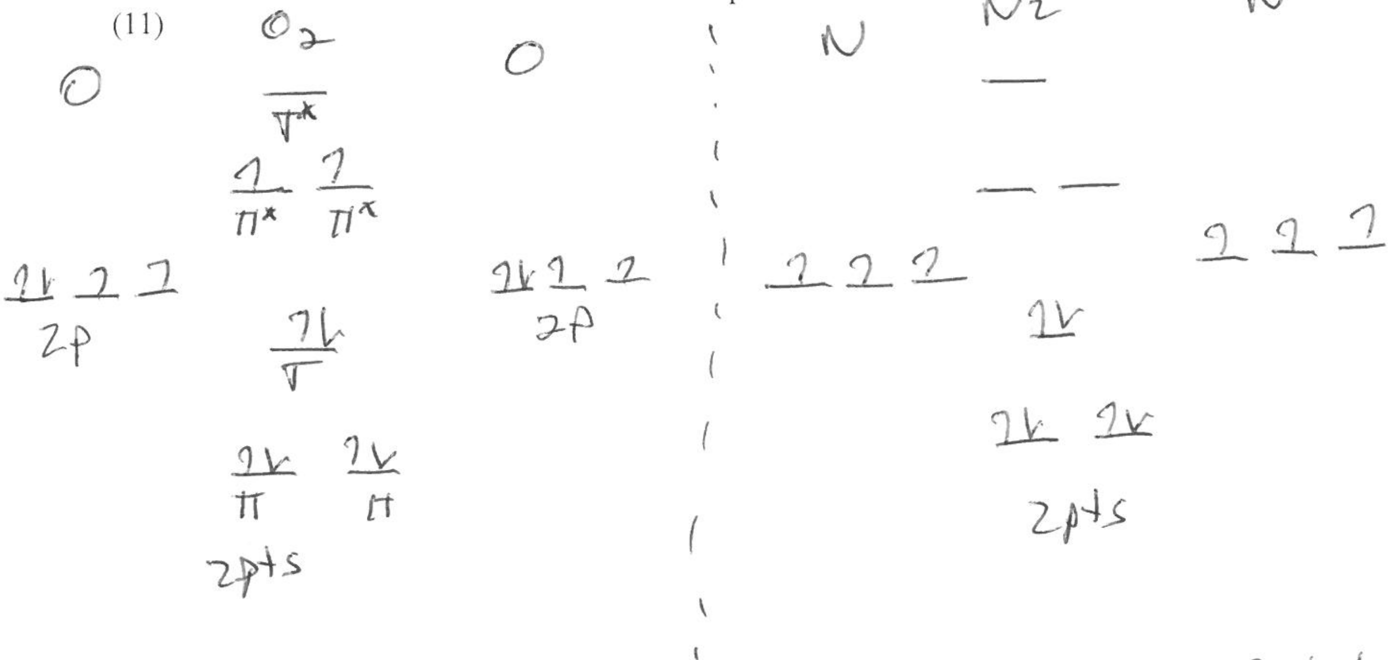
1 pt ii) As pressure increases, does the melting point of xenon increase or decrease?
From positive slope of solid-liquid equilibrium line

1 pt iii) As pressure increases, does the boiling point of xenon increase or decrease?
From positive slope of liquid-gas line.

1 pt iv) If solid xenon is heated at a constant pressure of 0.15 atm, will Xe(s) sublime or melt? See arrow at 0.15 atm. Xe(s) will sublime to form Xe(g).

32. 4pts a) Draw the molecular orbital diagrams for $O_2$ and $N_2$. Only draw the diagrams for the molecular orbitals formed from the 2p atomic orbitals.

(11)




2pts b) Is $O_2$ **paramagnetic** or **diamagnetic**? Circle your answer. Has unpaired electrons.

Is $N_2$ **paramagnetic** or **diamagnetic**? Circle your answer. All electrons are paired.

3pts c) Explain why the removal of one electron from $O_2$ strengthens the bond, while the removal of one electron from $N_2$ weakens the bond.

The bond order of $O_2$ is $(6-2)/2 = 2$. When $O_2$ loses an electron to form $O_2^+$, an antibonding electron is lost. The bond order for $O_2^+$ is $(6-1)/2 = 2.5$. When $O_2$ loses an electron, the bond order increases, so the bond strengthens. The bond order for $N_2$ is $(6-0)/2 = 3$. When $N_2$ loses an electron to form $N_2^+$, a bonding electron is lost. The bond order for $N_2^+$ is $(5-0)/2 = 2.5$. When $N_2$ loses an electron, the bond order decreases, so the bond weakens.

2pts d) Does the $O_2$ molecule have a **larger** or **smaller** ionization energy than O atoms? Circle your answer. $O_2$ loses an electron from π*, which is higher in energy than the 2p electron which is lost for O atoms. So easier to remove e⁻ from $O_2$.

Does the $N_2$ molecule have a **larger** or **smaller** ionization energy than N atoms? Circle your answer.

$N_2$ loses an electron from σ orbital, which is lower in energy than the 2p electron which is lost for N atoms. It is harder (takes more energy) to remove an electron from $N_2$ as compared to N atoms.