CHEMISTRY 204
Hour Exam III
April 25, 2024
Dr. D. DeCoste

Name **KEY**

Signature ______________________________

T.A. ______________________________

Section ______________________________

This exam contains 23 questions on 11 numbered pages. Check now to make sure you have a complete exam. You have two hours to complete the exam. Determine the **best** answer to the first 20 questions and enter these on the special answer sheet. Also, circle your responses in this exam booklet. **Show all of your work and provide complete answers to questions 21, 22 and 23.**

1-20	(60 pts.)	______________
21	(20 pts.)	______________
22	(20 pts)	______________
23	(20 pts.)	______________
Total	(120 pts)	______________

Useful Information:

- Unless otherwise noted, all solutions referred to on this exam are aqueous solutions at 25°C.
- Unless otherwise noted, assume all solutions act ideally.
- 760 torr = 1.00 atm
- R = 0.08206 Latm/molK = 8.3145 J/Kmol
- K = °C + 273
- $N_A = 6.022 \times 10^{23}$

$P_{soln} = \chi_{solvent}P°_{solvent}$ $\quad$ $P_{total} = P_A + P_B = \chi_A P°_A + \chi_B P°_B$

$\pi = iMRT$

$\Delta T = iK_f m_{solute}$ $\quad$ $\Delta T = iK_b m_{solute}$

K_f = 1.86 K/m for water $\quad$ K_b = 0.51 K/m for water

$\varepsilon = \varepsilon° - \frac{0.0591}{n}\log(Q)$ $\quad$ F = 96,485 coulombs $\quad$ 1 Ampere = 1C/s

1. Consider a solution made by mixing liquid A with liquid B at constant temperature in a closed container. At equilibrium the vapor above the solution has a mole fraction of A that is three times as great as the mole fraction of A in the solution. The vapor pressure of pure liquid A is six times as great as the vapor pressure of pure liquid B. Determine the mole fraction of A in the **solution**.

a) 0.100 b) 0.167 c) 0.200 d) 0.250 e) 0.333

2. We discussed how the different vapor pressures of liquids can be used to distill liquid mixtures, such as ethanol and water. Suppose we start with an ethanol-water mixture that is 50% water by moles. After allowing this solution to come to equilibrium with its vapor at 25°C, the vapor is condensed and is found to be about 35% water by moles. What is the vapor pressure of ethanol at 25°C? The vapor pressure of water at 25°C is 24 torr.

a) 18 torr b) 31 torr c) 37 torr d) 44 torr e) 58 torr

3. You dissolve 10.0 g of NaCl in 250.0 g water and the resulting solution has a freezing point of –2.42°C. Determine the percent ion-pairing for the NaCl.

a) 0% b) 5.00% c) 9.90% d) 20.0% e) 95.0%

4. Assume that when solid $AlCl_3$ dissolves in water, some of it remains un-ionized (that is, produces $AlCl_3$(*aq*)), and the remainder forms a 1:3 ratio of Al^{3+}(a*q*) and $Cl^–$(*aq*). What percent of the aluminum chloride remains un-ionized if the van't Hoff factor, *i*, is equal to 3.14?

a) 21.5% b) 28.7% c) 31.8% d) 71.3% e) 78.5%

5. None of the following solutions would be perfectly ideal. Which of the solutions is expected to have the **smallest positive deviation** from Raoult's law?

a) ethanol and water
b) 1-butanol and water
c) hexane and water
d) octane and water
e) acetone and water

6. Assuming an aqueous solution of NaCl is dilute enough that its concentration in molality is essentially the same as the concentration in molarity, what is the expected freezing point of a solution for which the osmotic pressure is equal to 3.14 atm at 25°C?

a) –0.0655°C b) –0.120°C c) –0.131°C d) –0.239°C e) –0.478°C

7. Which of the following is the best reducing agent?

a) Na b) Na^+ c) $F^–$ d) Cl_2 e) Fe

8. How many of the following would result in a redox reaction?

A piece of _______ metal is placed in an aqueous solution of _____ nitrate.

I. copper; silver
II. copper; zinc
III. iron; lead(II)
IV. magnesium; silver

a) 0 b) 1 c) 2 d) 3 e) 4

9. A solution of $M(NO_3)_2(aq)$ is electrolyzed. The time required for a current of 3.14 amperes to deposit 3.14 g of metal, M(*s*), on the cathode is 54.8 minutes. Determine the identity of the metal.

a) Ag b) Zn c) Cr d) Sn e) Ni

10. Cobalt, of course, is our favorite metal, but, for some reason, it does not appear on our table of standard reduction potentials (at least not as a solid metal). Consider a galvanic cell at 25°C made by placing a tin electrode in 1.00*M* $Sn^{2+}(aq)$ in one side and a cobalt electrode in the other side with 1.00×10^{-4} *M* $Co^{2+}(aq)$. The potential for this cell is 0.26V. Determine the standard reduction potential for $Co^{2+}(aq)$ to Co(*s*).

a) 0.52 V b) –0.52 V c) –0.24 V d) 0.28 V e) –0.28 V

11. Consider an electrochemical cell with a tin electrode immersed in 1.00*M* $Sn^{2+}(aq)$ and a nickel electrode immersed in 0.100*M* $Ni^{2+}(aq)$. Calculate $[Sn^{2+}(aq)]$ at equilibrium.

a) 9.0×10^{-4} *M* b) 9.9×10^{-4} *M* c) 1.8×10^{-3} *M* d) 0.0314 *M* e) 0.999 *M*

12, 13. An excess of finely divided iron (Fe) is stirred with a solution that contains $Cu^{2+}(aq)$. Once the system reaches equilibrium, all solid material is filtered off.

12. Determine the order of magnitude of the ratio of $[Fe^{2+}(aq)]/[Cu^{2+}(aq)]$

a) 10^{3} b) 10^{20} c) 10^{-20} d) 10^{26} e) 10^{-26}

13. Solid electrodes of iron and copper are inserted into the solution. Determine the measured potential.

a) 0 V b) 0.10 V c) 0.60 V d) 0.78 V e) Cannot be determined.

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14. Given the following two standard reduction potentials, taken from Table 11.1:

$Cr^{3+} + e^- \rightarrow Cr^{2+}$ –0.50 V
$Cr^{3+} + 3e^- \rightarrow Cr$ –0.73 V

Solve for the standard reduction potential of the following half-reaction: $Cr^{2+} + 2e^- \rightarrow Cr$.

a) 0.23 V b) –0.23 V c) –0.85 V d) –1.23 V e) –1.35 V

15. Consider the **smallest possible** molecule that contains the given functional group. Which of the following ranks the **number of carbon atoms** in the molecules, from **greatest to smallest**?

a) carboxylic acid > ketone > alcohol (any) > aldehyde > amine (any)
b) carboxylic acid = ketone > 1° alcohol > aldehyde > amine (any)
c) ketone > aldehyde > 2° alcohol > carboxylic acid = 1° amine
d) ester > ketone > carboxylic acid = aldehyde > 1° alcohol
e) 3° alcohol > ketone = 2° alcohol > 2° amine > aldehyde

16. How many of the following names require the *cis*- or *trans*- designation to be correct?

I. 1,1-dichloroethene
II. 1,4-dichloro-2-butene
III. 2-pentene
IV. 2,3-dimethyl-2-butene

a) 0 b) 1 c) 2 d) 3 e) 4

17. How many of the following have a carbon atom with an oxidation state equal to zero?

I. 1-propanol
II. methanal
III. propanone
IV. ethanoic acid (also called acetic acid)
V. hexane

a) 1 b) 2 c) 3 d) 4 e) 5

18. The substance 3-methyl-1,4-hexadiene is reacted with an excess of $Cl_2(g)$. What is the name of the product of this reaction?

a) 1,2,4,5-tetrachloro-3-methylhexane
b) 2,5-dichloro-3-methylhexane
c) 1,4-dichloro-3-methylhexane
d) 1,4-dichloro-3-methyl-4-hexadiene
e) 2,5-dichloro-3-methyl-4-hexadiene

19. The following names may be incorrect (although not necessarily), but correct structures can be drawn from them. How many different molecules are represented among the following five names? Assume all of them have the same orientation around the double bond (that is, *cis*- or *trans*-, so this is not an issue).

- 3-methyl-4-heptene
- 5-methyl-3-heptene
- 2-methyl-4-heptene
- 2-ethyl-3-hexene
- 5-ethyl-3-hexene

a) 1 b) 2 c) 3 d) 4 e) 5

20. How many of the following organic compounds cannot exist? How many of these cannot exist because they exceed the octet rule around a carbon atom?

- 2-chloro-2-butyne
- 2-methyl-2-propanone
- 2-pentanal
- 3-hexanoic acid
- 1,1-dimethylbenzene

	Cannot exist	Octet rule exceeded
a)	3	3
b)	4	2
c)	4	4
d)	5	5
e)	5	3

21. We discussed that colligative properties can best be explained by using the concept of vapor pressure. Consider this in your answers.

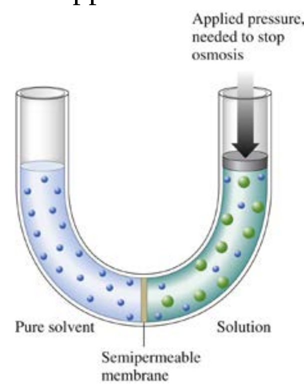
a. When dissolving a solute in a liquid, the solution has a lower freezing point than the pure liquid. Address this idea by providing answers to the following:

- On one graph, **sketch plots** of vapor pressure vs. temperature for a substance as a pure liquid and as a pure solid and **explain** it. **Label the freezing point** on the graph, and **support your answer**.
- **Explain how** adding a solute to a liquid results in a solution with a lower freezing point than the pure liquid. **Explain how** this can be shown in your graph of vapor pressure vs temperature.

Please limit your answer to this page. [**12 points**]

See lectures, videos, and textbook.

21. b. In the textbook we offer a couple definitions of osmotic pressure. In this problem we will focus on the following definition: osmotic pressure is equal to the applied pressure that just stops osmosis (see the figure from the text).



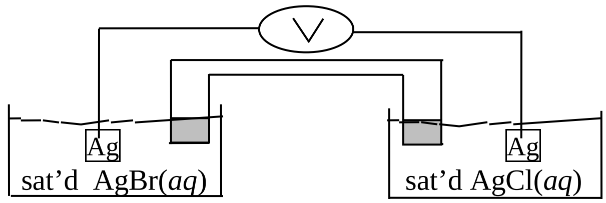
Address this idea by providing answers to the following:

- **Briefly explain** what osmosis is and **why** it takes place across a semipermeable membrane when pressure is not applied.
- **Explain why** applying pressure on the solution as shown in the figure to the right would stop osmosis from happening.

Please limit your answer to this page. [**8 points**]

See lectures, videos, and textbook.

22. Suppose we have the following cell, in which we have a silver (Ag) electrode in each half. In one side of the cell we have a saturated of silver bromide, AgBr(*aq*), and in the other side we have a saturated solution of silver chloride, AgCl(*aq*). These solutions were made by dissolving an excess of each salt in water, allowing the salts to come to equilibrium with their ions, and then filtering out the remaining solid:



The overall goal for this problem is to **determine the standard reduction potential** of the half-reaction: **AgBr(*s*) + e^- → Ag(*s*) + Br^-(*aq*)**.

Here is some useful information:

- The salts AgBr and AgCl would be labeled as "insoluble" in a list of solubility rules, but we know this means that they are "not very soluble."
- AgBr is less soluble than AgCl.
- The potential for the cell as described above (with saturated solutions of the salts in separate half-cells) is 0.0745 V.
- For your convenience, **potentially** relevant standard reduction potentials are taken from Table 11.1 and listed below. You **may not need** all of these (that is for you to decide), but they include all of the relevant species present:
  - $Ag^+(aq) + e^- \rightarrow Ag(s)$, $\varepsilon° = 0.80V$
  - $Br_2(l) + 2e^- \rightarrow 2Br^-(aq)$, $\varepsilon° = 1.09V$
  - $Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$, $\varepsilon° = 1.36V$
  - $AgCl(s) + e^- \rightarrow Ag(s) + Cl^-(aq)$, $\varepsilon° = 0.22V$

As always, **think before you start writing**. In your solution, you will be asked to **include answers to the following**:

I. What is the **driving force** for the cell? That is, **why is there a potential** at all? **Support your answer**.
II. What is the **relevant half-reaction** in each half-cell? In which side is oxidation happening, and in which side is reduction occurring? **Support your answer**.
III. What is the **value of $\varepsilon°$** for the cell? **Support your answer**.
IV. **Which direction** are the electrons flowing? **Support your answer**.

22. a. Please **address the following questions** as you think about how to solve this problem. **Do not provide calculations** for this problem on this page (that is for the next page)/

I. What is the **driving force** for the cell? That is, **why is there a potential** at all? **Support your answer**.

II. What is the **relevant half-reaction** in each half-cell? In which side is oxidation happening, and in which side is reduction occurring? **Support your answer**.

III. What is the **value of $\mathcal{E}°$** for the cell? **Support your answer**.

IV. **Which direction** are the electrons flowing? **Support your answer**.

Please limit your answer to this page. [**10 points**]

See lectures, videos, and textbook.

22. b. **Calculate** the standard reduction potential for $AgBr(s) + e^- \rightarrow Ag(s) + Br^-(aq)$.

Show all work, and please limit your answer to this page. [**10 points**]

$AgCl(s) \rightarrow Ag^+(aq) + Cl^-(aq)$, **$\varepsilon°$ = –0.58V**

K_{sp} (AgCl): **= 1.535 x 10^{-10}**.

$[Ag^+]_{AgCl}$ = 1.239 x 10^{-5} *M*.

$[Ag^+]_{AgBr}$ = 6.800 x 10^{-7} *M* = $[Br^-]_{AgBr}$

K_{sp} (AgBr) = $[Ag^+]^2$ = 4.624 x 10^{-13}

$AgBr(s) \rightarrow Ag^+(aq) + Br^-(aq)$, **$\varepsilon°$ = –0.7290V**

For $AgBr(s) + e^- \rightarrow Ag(s) + Br^-(aq)$, **$\varepsilon°$ = 0.071V**

See lectures, videos, and textbook.

23. Recall the following question from the Discussion worksheet last week:

Each of the following names is missing at least one of the numbers to make it a complete name. For which of the following names is there the greatest number of potential structures you could draw?

a) dibromobenzene
b) dibromopropane
c) chloro-2,4-dimethylpentane
d) bromopentane
e) At least two of the above (a-d) have an equally great number of possible structures.

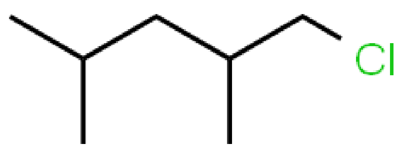
a. Your roommate's friend, visiting from "another university", reads the question and says, "Well, we know that the molecule in 'c' has seven carbon atoms, so there are seven potential structures."

Is your roommate's friend correct? **Are there seven** potential structures for the molecule "chloro-2,4-dimethylpentane"? If so**, draw these structures** and **name them**. If not, **how many are there**? **Draw these** and **name them**. [**8 points**]

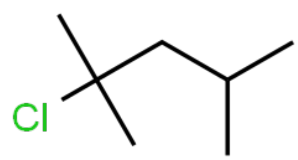
The roommate's friend is **not correct**.

There are **three structures**:

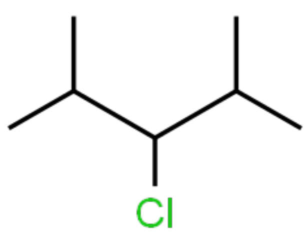
1-chloro-2,4-dimethylpentane:



2-chloro-2,4-dimethylpentane:



3-chloro-2,4-dimethylpentane:



23. b. **How many** structures can be drawn for each of "dibromobenzene", "dibromopropane", and "bromopentane"? **Do not draw** these structures below (feel free to use scratch paper to check your answers), but **provide the names** for each.

Write the names in the table provided. Note: there may be more spaces available than required.

Also, **what is the correct answer to the worksheet question**? **Write the letter** of the answer in the space provided. [**12 points**]

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dibromobenzene	**dibromopropane**	**bromopentane**
1,2-dibromobenzene (ortho)	1,1-dibromopropane	1-bromopentane
1,3-dibromobenzene (meta)	1,2-dibromopropane	2-bromopentane
1,4-dibromobenzene (para)	1,3-dibromopropane	3-bromopentane
	2,2-dibromopropane	

The correct answer to the worksheet question is "b".