CHEMISTRY 204
Hour Exam III
April 27, 2023
Dr. D. DeCoste

Name ________**KEY**______________

Signature ______________________________

T.A. ___________________________________

Section ________________________________

This exam contains 23 questions on 14 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
- $N_A = 6.022 \times 10^{23}$

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

$\pi = i\text{MRT}$

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

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

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

1. Consider a solution made by mixing liquid A with liquid B at constant temperature in a closed container. Liquid A has a vapor pressure of 200.0 torr and the liquid mixture is 40% liquid A by moles. At equilibrium the vapor above the solution is about 70% B. Which of the following is the best estimate of the vapor pressure of liquid B?

   a) 100 torr b) 150 torr c) 200 torr d) 250 torr e) 300 torr

2. Consider a solution at a given temperature consisting of equal moles of benzene (vapor pressure = 745 torr) and toluene (vapor pressure = 290 torr). You distill this mixture in two steps; that is, you place the mixture in a closed container, allow the solution and vapor to come to equilibrium, collect and condense the vapor, and then allow that solution to come to equilibrium with its vapor. What is the mole fraction of benzene in the vapor in this second step?

   a) 0.28 b) 0.50 c) 0.72 d) 0.87 e) 0.93

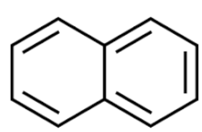
3. Which of the following is expected to have the **highest** vapor pressure (all at the same temperature)?

   a) butane
   b) formic acid (also called methanoic acid)
   c) 2-propanol (also called isopropyl alcohol)
   d) acetone (also called propanone)
   e) water

4. When solid $MgCl_2$ dissolves in water, some of it remains un-ionized (that is, produces $MgCl_2$(*aq*)), some forms the ions $MgCl^+$(*aq*) and Cl^-(*aq*), and some forms a 1:2 ratio of Mg^{2+}(a*q*) and Cl^-(*aq*). Suppose you dissolve 1.000 mole of $MgCl_2$(*s*) in 1.000 kg of water, and find that the freezing point is –4.557°C. If we know that all of the magnesium chloride dissolved in the water, and that 15.00% of it is un-ionized, determine the number of moles of Mg^{2+}(a*q*) in the solution.

   a) 0.1500 mol b) 0.3000 mol c) 0.6000 mol d) 0.7000 mol e) 0.9000 mol

5. Naphthalene is the traditional ingredient in mothballs, which are used when storing clothing (to keep moths away). The structure can be represented as follows:



   Benzene has a freezing point of 5.51°C and a freezing point constant (K_f) of 5.12 K/m. What mass of naphthalene must be dissolved in 1.00 kg of benzene to give the solution the same freezing point as pure water?

   a) 111 g b) 119 g c) 127 g d) 138 g e) 147 g

6. Suppose you have a 1.00*M* aqueous solution of HF (K_a = 7.2 x 10^{-4}). If we assume HF is a non-volatile solute, what is the *i* value we should use for colligative property calculations, rounded to the hundredths place?

a) 1.00 b) 1.03 c) 1.05 d) 1.09 e) 1.50

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

a) Cl_2 b) Fe c) Na d) Na^+ e) F^-

8. Consider a galvanic cell at 25°C made by placing a tin electrode in 500.0 mL of 1.00*M* Sn^{2+}(*aq*) in one side and a lead electrode in 500.0 mL of 1.00*M* Pb^{2+}(*aq*) in the other side. Determine the concentration of Sn^{2+}(*aq*) when the cell is "dead".

a) 0.629 *M* b) 0.808 *M* c) 1.19 *M* d) 1.37 *M* e) 2.00*M*

9. Each of the following cells has 1.0 x 10^{-7} *M* Cu^{2+}(*aq*) in one side. Which of the following cells has the **lowest** potential?

a) A cell made with copper and zinc such that the "copper side" has a copper electrode and 1.0 x 10^{-7} *M* Cu^{2+}(a*q*), and the "zinc side" has a zinc electrode and 1.0 *M* Zn^{2+}(a*q*).
b) A cell made with copper and silver such that the "copper side" has a copper electrode and 1.0 x 10^{-7} *M* Cu^{2+}(a*q*), and the "silver side" has a silver electrode and 1.0 *M* Ag^+(a*q*).
c) A copper concentration cell which has two copper electrodes, 1.0 *M* Cu^{2+}(a*q*) in one side, and 1.0 x 10^{-7} *M* Cu^{2+}(a*q*) in the other side.
d) A cell made with copper and cadmium such that the "copper side" has a copper electrode and 1.0 x 10^{-7} *M* Cu^{2+}(a*q*), and the "cadmium side" has a cadmium electrode and 1.0 *M* Cd^{2+}(a*q*).
e) At least two of the above (a-d) have the same lowest potential.

10. Consider the reaction between Ni(*s*) and HCl(*aq*). If we react an excess of nickel metal in a solution of hydrochloric acid, what is the ratio of $[H^+]/[Ni^{2+}]$ when the system reaches equilibrium?

a) 1.6 x 10^{-8} b) 1.3 x 10^{-4} c) 7.8 x 10^{3} d) 6.07 x 10^{7} e) Cannot be determined.

11, 12. Recall the demonstration in which we placed a piece of copper metal in an aqueous solution of silver nitrate. Suppose instead we placed a 6.000 g piece of copper in a beaker with 100.0 mL of 0.1000*M* $Au(NO_3)_3$(*aq*).

11. Determine the concentration of Cu^{2+}(a*q*) at equilibrium.

a) 1.2 x 10^{-7} *M* b) 3.5 x 10^{-4} *M* c) 0.050*M* d) 0.10*M* e) 0.15*M*

12. Determine the concentration of Cu^+(a*q*) at equilibrium.

a) 1.2 x 10^{-7} *M* b) 3.5 x 10^{-4} *M* c) 0.050*M* d) 0.10*M* e) 0.15*M*

13, 14. Consider a galvanic cell at 25°C made by placing a zinc electrode in 500.0 mL of 0.100*M* $ZnCl_2$(*aq*) in one side, and a copper electrode in 500.0 mL of 0.0100*M* $CuSO_4$(*aq*) in the other side.

13. Determine the potential of the cell.

a) 1.04 V b) 1.07 V c) 1.10 V d) 1.13 V e) 1.16 V

14. Calculate [Cu^{2+}(a*q*)] after this cell was allowed to produce an average current of 1.00 amp for 3 minutes and 14 seconds.

a) 0.0040*M* b) 0.0060*M* c) 0.0080*M* d) 0.0120*M* e) 0.0140*M*

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15. The substance with the formula $H_2CCHCH_2N(CH_3)_2$ is

a) An alkene and a secondary amine.
b) An alkane and a tertiary amine.
c) An alkene and a tertiary amine.
d) An alkyne and a primary amine.
e) An alkane and a secondary amine.

16. You are visiting a friend at another university and sitting in on a chemistry lecture. The instructor writes "2,3-dimethyl-2,3-diethylpropane" on the board. What should you say to this person?

a) "Actually, the name is 1,2-dimethyl-1,2-diethylpropane"
b) "Actually, the name is 3,4,4-trimethylhexane."
c) "Actually, the name is 3,4-dimethylheptane."
d) "Actually, the name is 3,3,4-trimethylhexane."
e) "Actually, the name is 2,3-dimethyl-2-ethylpentane."

17. How many of the following require a number in the name in order to correctly identify it?

I. chloropropane
II. propanone
III. propene
IV. propanoic acid

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

18. You wish to synthesize methyl ethanoate. Which of the following should be your staring materials?

a) ethanoic acid and methanol
b) methanoic acid and ethanol
c) ethanal and methanal
d) methanoic acid and ethane
e) ethanoic acid and methane

19. Consider the following alcohols and amine. How many of them are “secondary”?

I. 2-methyl-2-butanol
II. 2,2-dimethyl-1-butanol
III. 2-methyl-2-propanol
IV. ethylmethylamine

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

20. For which of the following molecules is the oxidation state of carbon closest to zero; that is, the absolute value of the oxidation state is the smallest?

a) propane
b) ethyl methyl ether
c) 2-propanol
d) propanal
e) propanoic acid

21. When discussing solutions, we talked about the colligative properties of freezing-point depression, boiling-point elevation, and osmotic pressure. Let's look at each of these.

a. First, let's consider freezing-point depression. Suppose we have an ice cube at 0°C in a beaker of pure water at 0°C. We can melt the ice cube by either increasing the temperature of the water, or by adding salt to the water at 0°C. Even if we lower the temperature of this salt-ice-water system a bit, the water does not freeze. Answer the following questions:

- Why does increasing the temperature of the pure water result in the melting of the ice?
- Why does adding salt to the water (keeping the temperature at 0°C) result in the melting of the ice?
- Why are we able to lower the temperature of the ice-cube/salt-water solution without additional water freezing, and why does it eventually freeze if we lower the temperature enough?

Explain your answers using the concept of **vapor pressure**. Make sure to **describe what is meant** by the **freezing-point** of a liquid. **[7 points]**

Please see videos, textbook, and lectures

21. b. Now let's consider boiling-point elevation. If you've ever made pasta by boiling it in water, you may have been told to add table salt (NaCl) to the water first. But why? If you look to the internet for answers, you will find many sites offer a reason that seems scientific – because adding salt to water increases the boiling point, we can boil the pasta at a higher temperature, therefore reducing the cooking time. But is this really the reason? That is, answer the following question: **is it reasonable to say that we add salt to water when cooking pasta because we will reduce the cooking time**?

Here are our givens:

- The K_{sp} value for NaCl is about 38.
- The K_b value for water is 0.51 K/m.
- The boiling point of pure water is 100°C at 1 atm.
- It takes about 10 minutes to cook pasta at 100°C.

Provide **quantitative support** for your answer, **list and explain any assumptions**, and **show all work**. **[8 points]**

- **No, it is not reasonable**. You will not appreciably save cooking time, and is way too much salt.

Please see videos, textbook, and lectures

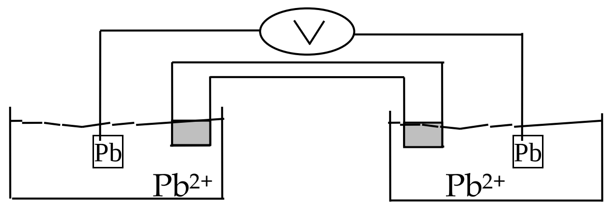
21. c. Finally, let's look at osmotic pressure. Suppose that you predict (that is, determine by calculation) the osmotic pressure of an aqueous solution of NaCl from its concentration, but you failed to take into account that, in reality, 31.4% of the salt dissolves without dissociating into ions. Is your predicted (determined) osmotic pressure **higher or lower** than the actual value? **Why**?

Calculate the percent error in your determination of osmotic pressure. **Show and explain all work. [5 points]**

Please see videos, textbook, and lectures

18.6% error

22. A concentration cell is one for which we have the same components in each side of the cell. For this problem, consider a lead concentration cell as shown below:



a. Answer the following questions concerning this cell:

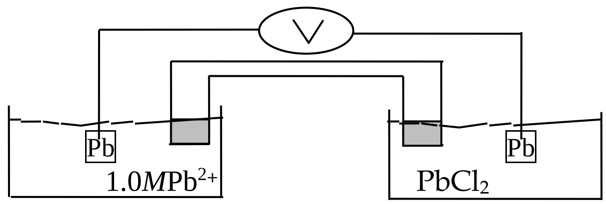
- What is the value of ε° for this cell? Why?
- How do we make a concentration cell like the one above that has a potential? What is the driving force for the cell?
- To have a cell potential of at least 0.1V, what must be true about the relative concentrations of the Pb^{2+} in each side? Provide **quantitative support**.
- Write the half-reaction that occurs in each side of the cell and explain how they correspond to the relative concentration of Pb^{2+} in each side.

Show/explain all work. **[8 points]**

Please see videos, textbook, and lectures

- The higher concentration must be about 2400 times as great as the low concentration (the ratio is either 4.13×10^{-4} or 2422).

22. b. Suppose we have the following cell, in which we have lead (Pb) electrodes, 1.0*M* Pb^{2+} in one side, and an excess of $PbCl_2$(s) in equilibrium with its ions in the other side:



You measure the cell potential and find it to be 0.053V. Determine:

- The concentration of Pb^{2+} in the right side of the cell. (in molarity).
- The K_{sp} value for $PbCl_2$.
- The standard reduction potential of $PbCl_2(s) + 2e^- \rightarrow Pb(s) + 2Cl^-(aq)$

Show all work. **[7 points]**

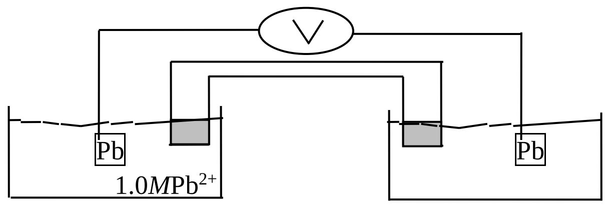
Please see videos, textbook, and lectures

$[Pb^{2+}]$ = 0.016085 *M*.

K_{sp} = 1.6648 x 10^{-5} .

$PbCl_2(s) + 2e^- \rightarrow Pb(s) + 2Cl^-(aq)$ $\varepsilon° = -0.27$ V

22. c. We saw in lecture, the videos, and the textbook that concentration affects the potential of a cell. If we increase the concentration of the reactant and decrease the concentration of the product, our knowledge of equilibrium tells us that the potential will be increased. Because we cannot get a lower concentration than 0*M*, consider the following cell in which we have lead (Pb) electrodes, 1.0*M* Pb^{2+} in one side, and distilled water in the other side:



Given that to measure a potential we need a flow of electrons through the wire from one side of the cell to the other, **determine the maximum measured potential** of this cell. Assume the volume of each side is 1.00L. **Show all work. [5 points]**

Please see videos, textbook, and lectures

ε = = **0.70 V**

23. In lecture I did a demonstration showing that water does not mix well with what I called hexane. It turns out that when you purchase "hexane" you can do so less expensively by purchasing what is called "hexanes," which is a mixture of hexane isomers. Answer the following questions concerning hexane isomers and their derivatives. **[20 points]**

a. **Write the names of all the hexane isomers below**. Do not include their structures (you probably should draw these on scratch paper, but that is up to you) – just list the names (legibly, please) on the lines below. You have been given at least as many lines as you need (you may not need all of them – that is for you to decide).

__Hexane (or n-hexane)____

_____2,3-dimethylbutane___

_____2,2-dimethylbutane___

______2-methylpentane_____

_______3-methylpentane____

23. b. Now consider what happen when you brominate the hexanes (that is, you replace at least one of the hydrogen atoms with a bromine atom). In answering these questions, the same isomer from part a may be used once, twice, or all three times and, like in part a, you have been given at least as many lines as you need.

i. When replacing one hydrogen atom with one bromine atom, which hexane isomer from part a has the **fewest** isomers? Name the mono-brominated isomers.

The isomer with the fewest mono-brominated isomers is _2,3-dimethylbutane_

The names of the isomers are:

____1-bromo-2,3-dimethylbutane_

____2-bromo-2,3-dimethylbutane_

____

____

23. b. ii. When replacing two hydrogen atoms with two bromine atoms, which hexane isomer from part a has the **fewest** isomers? **Note: only consider those isomers for which the bromine atoms are bonded to the carbon atoms in the longest carbon chain.** Name the di-brominated isomers.

The isomer with the fewest di-brominated isomers is _2,3-dimethylbutane

The names of the isomers are:

____1,1-dibromo-2,3-dimethylbutane_

____1,2-dibromo-2,3-dimethylbutane_

____1,3-dibromo-2,3-dimethylbutane_

____1,4-dibromo-2,3-dimethylbutane_

____2,3-dibromo-2,3-dimethylbutane_

23. b. iii. When replacing three hydrogen atoms with three bromine atoms, which hexane isomer from part a has the **fewest** isomers? **Note: only consider those isomers for which the bromine atoms are bonded to the carbon atoms in the longest carbon chain.** Name the tri-brominated isomers.

The isomer with the fewest tri-brominated isomers is __2,3-dimethylbutane_

The names of the isomers are:

____1,1,1-tribromo-2,3-dimethylbutane_

____1,1,2-tribromo-2,3-dimethylbutane_

____1,1,3-tribromo-2,3-dimethylbutane_

____1,1,4-tribromo-2,3-dimethylbutane_

____1,2,3-tribromo-2,3-dimethylbutane_

____1,2,4-tribromo-2,3-dimethylbutane_