CHEMISTRY 204
Hour Exam III
May 1, 2025
Dr. D. DeCoste

Name **KEY**

Signature _____

T.A. _____

Section _____

This exam contains 23 questions on 9 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	(22 pts.)	_____
22	(20 pts)	_____
23	(18 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
- PV=nRT
- R = 0.08206 Latm/molK = 8.3145 J/Kmol
- K = °C + 273
- $N_A = 6.022 \times 10^{23}$

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

$\pi = iMRT$

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

K_f = 1.86 K/m for water K_b = 0.51 K/m for water

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

$G = H - TS$ $\Delta G = \Delta G° + RT\ln(Q)$

1. As we discussed in class, solids have vapor pressures. Use the thermodynamic data below to determine the vapor pressure of solid iodine at 25°C

	ΔH_f° (kJ/mol)	S° (J/Kmol)
$I_2(s)$	0	116.1
$I_2(g)$	62.42	260.7

a) 0.3110 torr b) 0.5981 torr c) 1.957 torr d) 5.981 torr e) 29.21 torr

2. Consider an ethanol-water solution at 25°C that is 10.0% ethanol by moles. You decide to "distill" it by allowing the solution to come to equilibrium with its vapor, condensing the vapor into a liquid solution, allowing the new solution to come to equilibrium with its vapor, and then condensing this vapor. Which of the following is the closest percent by moles of ethanol in this last liquid solution? The vapor pressures of ethanol and water at 25°C are 58.7 torr and 23.8 torr, respectively.

a) 10% b) 20% c) 30% d) 40% e) 60%

3-4. In Table 17.6 in the text, it is stated that the observed value of the van't Hoff factor (i) for a 0.05m aqueous solution of magnesium sulfate is 1.3.

3. Your lab partner believes the solution to behave ideally. Determine the absolute value of the percent error in your lab partner's determination of the freezing point of the solution.

a) 30.0% b) 35.0% c) 53.8% d) 65.0% e) 70.0%

4. Determine the percent of solute particles in solution that exist as ions.

a) 30.0% b) 35.0% c) 46.2% d) 65.0% e) 70.0%

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5. Suppose you have a 0.010M aqueous solution of a weak acid, HA. If we assume HA is a non-volatile solute, and we find that the i value we should use for colligative property calculations is 1.042, what is the identity of the acid?

a) HF ($K_a = 7.2 \times 10^{-4}$)
b) HOCl ($K_a = 3.5 \times 10^{-8}$)
c) $HC_2H_3O_2$ ($K_a = 1.8 \times 10^{-5}$)
d) HCN ($K_a = 6.2 \times 10^{-10}$)
e) None of the above because the acid must be a strong acid.

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

a) Ag^+ b) Cu c) Li d) Li^+ e) H_2

7. Of the metals Cu, Sn, Ni, and Na, how many will exhibit a redox reaction with 1.00M HCl(aq) but **not** with pure water?

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

8. In the reaction between methane and oxygen to produce carbon dioxide and water, how many electrons are transferred per mole of methane consumed?

a) 0 b) 2 c) 4 d) 6 e) 8

9. Consider an electrochemical cell with $Ag^+(aq)$ and $Ag(s)$ in one side, and $Cu^{2+}(aq)$ and $Cu(s)$ in the other side (the volumes are the same).

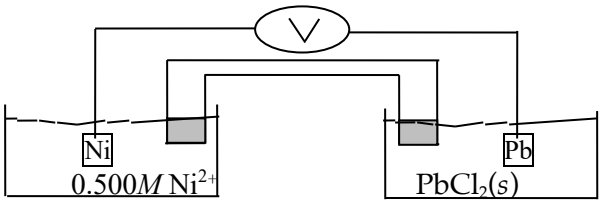
The cell begins at standard conditions and runs until 10.0% of the original $Ag^+(aq)$ ions remain. Determine the cell potential at this point.

a) 0.33V b) 0.40V c) 0.43V d) 0.46V e) 0.49V

10. Consider a silver concentration cell in which the Ag^+ concentration ratio is about 10^4. If you wish to set up a tin concentration cell which has the **same potential** as that of the silver concentration cell, what is approximate the Sn^{2+} concentration ratio?

a) 10 b) 10^2 c) 10^4 d) 10^8 e) 10^{16}

11-14. Consider the following cell, in which we have a 10.00g nickel (Ni) electrode and 0.500*M* $Ni^{2+}(aq)$ in one side, and a 10.00g lead (Pb) electrode and an excess of $PbCl_2(s)$ ($K_{sp} = 1.6 \times 10^{-5}$) in equilibrium with its ions in the other side. The volume in each side is 500.0 mL.



11. Determine the value of the standard potential, $\mathcal{E}°$, for a cell with Ni/Ni^{2+} and Pb/Pb^{2+}.

a) 0.10V b) 0.13V c) 0.18V d) 0.23V e) 0.36V

12. Determine the initial potential, $\mathcal{E}$, for the cell as shown above.

a) 0.04V b) 0.06V c) 0.10V d) 0.14V e) 0.16V

13. Determine $[Ni^{2+}]$ after the cell is run for 1.00 hour with a current flow of 1.00 A.

a) 0.425*M* b) 0.463*M* c) 0.519*M* d) 0.537 *M* e) 0.575 *M*

14. Determine the **total mass** of both electrodes after the cell is run for 1.00 hour with a current flow of 1.00 A.

a) 14.5 g b) 17.2 g c) 20.0 g d) 22.8 g e) 25.5 g

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

- methanoic acid (also known as formic acid)
- methanal (also known as formaldehyde)
- methanol
- methane

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

16. How many of the following pairs are isomers of one another?

- Propanone and propanal
- Ethanol and dimethyl ether
- Methyl ethanoate and propanoic acid
- Dimethyl amine and ethyl amine

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

17. How many of the following statements is/are **true**?

- The mono-brominated product of *n*-pentane has five isomers.
- The lightest aldehyde has the same molar mass as the lightest ketone.
- A molecule with the formula C_6H_{14} can have at least one isomer that has a correct name ending with "propane".
- Alkanes are more reactive with $Cl_2(g)$ than alkenes.

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

18. How many of the following are **incorrect** names? How many are **impossible** names? "Incorrect name" means that the correct structure can be drawn from the name, but the name is something different from what is given. "Impossible name" means a correct structure cannot be drawn from the name.

- 3-methyl-4-heptene
- 4-chlorobutane
- *trans*-1,2-dichloroethene
- methene
- 2-ethylpropane
- 3-methyl-3-hexanol

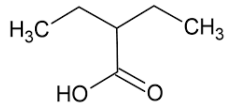
	Incorrect	Impossible
a)	3	3
b)	4	2
c)	2	1
d)	2	3
e)	3	1

19. Consider five different organic molecules each with one of the functional groups as listed below. If each of the molecules contains the **smallest possible number of carbon atoms** while still being labeled with that functional group, for how many of the molecules is the number of oxygen atoms **greater** than the number of carbon atoms?

- carboxylic acid
- ester
- ketone
- aldehyde
- alcohol

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

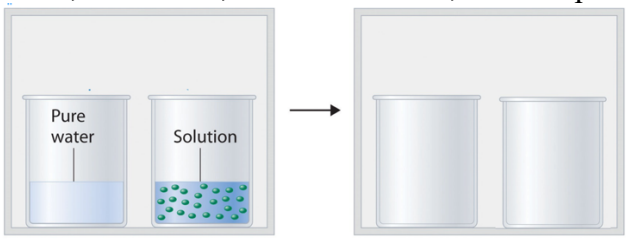
20. What is the correct name of the compound pictured below?



a) 3-ethylbutanoic acid
b) 3-methanoic pentane
c) 2-ethylbutan-ol-al
d) 1-hexanoic acid
e) 2-ethylbutanoic acid

21. **Full credit** is reserved for **showing all work** in a **logical, coherent, legible** fashion that **we can follow**.

a. Recall from the videos, the lecture, and the textbook, the set-up as shown below:



You add 1.00L of pure water to the left beaker and dissolve 5.00 mol of NaCl in 1.00 L of water in the right beaker, all at 25°C. Answer the following questions: [**11 points**]

- What does the system look like when it reaches equilibrium? **Sketch it** in the right-hand side of **the figure above**. **Justify** your sketch in **words below**.
- We discussed that we assume that there is a negligible amount of water in vapor state above the beakers. Assume that the volume of the container that is not occupied by water, a solution, or the beakers, is 10.0 liters, the density of liquid water is 1.00 g/mL, and the water vapor acts as an ideal gas, what **percentage of the total water** is in the **vapor state**? The vapor pressure of pure water at 25°C is 23.8 torr.

0.0106% of the water is in the vapor state. [1 pt]

21. b. Suppose we have the two beakers in a container, but we have water (vapor pressure = 23.8 torr) in the left-hand beaker (Beaker #1) and ethanol (vapor pressure = 58.7 torr) in the right-hand beaker (Beaker #2). The mole ratio of water:ethanol is 2:1. We let the **system come to equilibrium**. Determine the following ratios (**show all work and explain/justify your answers**): [**11 points**]

- (Number of moles of water) : (Number of moles of ethanol) in Beaker #1
- (Number of moles of water) : (Number of moles of ethanol) in Beaker #2
- (Number of moles of water in Beaker #1) : (Number of moles of water in Beaker #2)

The ratio of **water: ethanol in each beaker will have to be 2:1** at equilibrium (the amount in the vapor state is very small, as seen in part a).

The ratio of water in Beaker #1/Beaker #2 = = **4.9328**

22. Please refer to Table 11.1 (on the back of the periodic table) as needed. **Full credit** is reserved for **logical, coherent, legible** answers that **we can follow**.

a. The following is a multiple-choice question from the Practice Exam:

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 $Co(s)$.

As it turns out, mathematically there are **two possible answers** for this question. Answer the following: [**10 points**]

- **Explain why** there are two possible answers to this question.
- **Show all work** and find **both possible answers** for the standard reduction potential for $Co^{2+}(aq) + 2e^- \rightarrow Co(s)$.

Because we do not know the standard reduction potential for $Co^{2+}(aq)$, we do not know if the reaction that occurs is:

$$Sn(s) + Co^{2+}(aq) \rightarrow Sn^{2+}(aq) + Co(s)$$

SRP of $Co^{2+}(aq)$ = 0.24V

$$Co(s) + Sn^{2+}(aq) \rightarrow Co^{2+}(aq) + Sn(s)$$

SRP of $Co^{2+}(aq)$ = –0.28V

22. b. A popular stoichiometry lab (one that you did in Chemistry 203) involves adding solid iron (Fe) to an aqueous solution of Cu^{2+} ions to determine if the reaction produces $Fe^{2+}(aq)$ *or* $Fe^{3+}(aq)$ by measuring the mass of copper produced and using stoichiometry. Of course, thermodynamics tells us that both $Fe^{2+}(aq)$ *and* $Fe^{3+}(aq)$ are produced. Were you lied to in Chemistry 203? Electrochemistry to the rescue!

Suppose you add excess iron to 100.0 mL of 0.100*M* $Cu^{2+}(aq)$. Answer the following:

- **Determine the concentrations** of $Fe^{2+}(aq)$ and $Fe^{3+}(aq)$ at equilibrium
- **Discuss why it is reasonable** to conclude that the iron product was purely $Fe^{2+}(aq)$.

[Note: don't worry about the possible formation of $Cu^{+}(aq)$ for this problem –it is negligible]. [**10 points**]

$[Fe^{2+}] = 0.100\ M$

$[Fe^{3+}] = 9.82 \times 10^{-23}\ M$

Ratio of $Fe^{2+}/Fe^{3+} = 1.02 \times 10^{21}$; **essentially all $Fe^{2+}(aq)$**

Note:
We have ~0.01 mol of $Fe^{2+}(aq)$ (100 mL of 0.100*M*) = (0.01)(6.022×10^{23}) = 6.022×10^{21} Fe^{2+} ions

$6.022 \times 10^{21}/Fe^{3+} = 1.02 \times 10^{21}$; number of Fe^{3+} ions ≈ 6, which can be neglected

23. You and a friend are in the stockroom and find a compound labeled "C_4H_8". Please answer the following questions. You may find it worthwhile to **sketch structures** of molecules **on scratch paper** before answering. Full credit is reserved for **legible, correctly spelled** answers. [**18 points**]

a. List **all** of the possible names of this compound (including any **isomers**).

- 1-butene (or 1-butylene)
- 2-butene (cis and trans)
- 2-methylpropene (or isobutylene)
- Cyclobutane
- Methylcyclopropane

b. Of the compounds you listed in part "a", consider any alkenes which could react with water to produce an alcohol. **List the names** of the alkenes from part a that could make an alcohol (don't name the alcohols … yet). If none, write, "none" and **justify**.

- 1-butene
- 2-butene (cis/trans)
- 2-methylpropene

c. **Name** any compounds from part "b" that could react with water to form a primary (1°) alcohol and **match** it with the alcohol produced (that is, name the primary alcohol as well). If none, write, "none" and **justify**.

- 1-butene 1-butanol
- 2-methylpropene 2-methyl-1-propanol

d. **Name** any compounds from part "b" that could react with water to form a secondary (2°) alcohol and **match** it with the alcohol produced (that is, **name** the secondary alcohol as well). If none, write, "none" and **justify**.

- 1-butene 2-butanol (both)
- 2-butene (cis/trans)

e. **Name** any compounds from part "b" that could react with water to form a tertiary (3°) alcohol and **match** it with the alcohol produced (that is, **name** the tertiary alcohol as well). If none, write, "none" and **justify**.

- 2-methylpropene 2-methyl-2-propanol