

CHEM 103—Spring 2006
Exam 2
15 May 2006

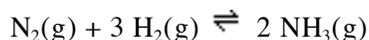
Name _____

Multiple Choice (5 points each)

Write the letter of the choice that best completes the statement or answers the question in the blank provided

- A 1. Which process is reactant-favored?
- decomposition of iron ore into pure iron
 - the melting of ice at 25 C
 - diffusion of the odor of cooking food
 - the freezing of water at -5 C
 - burning a candle
- C 2. Nature favors exothermic reactions because after such a reaction
- energy previously concentrated in a few particles is now dispersed over more particles in the system.
 - energy previously concentrated in a few particles is now dispersed over more particles in the surroundings.
 - energy previously concentrated in a few particles is now dispersed over more particles in both the system and the surroundings.
 - energy previously held in many particles is now concentrated in a few, resulting in a temperature rise.
 - energy previously held in many particles is now concentrated in a few, resulting in a temperature fall.
- D 3. The boiling point of tin is 232 C. The heat of vaporization of tin at its boiling point is 247 kJ. The entropy of vaporization is
- 2045 J/K.
 - 1065 J/K.
 - 939 J/K.
 - 489 J/K.
 - 2.04 J/K.
- E 4. Which has the highest entropy at a given temperature?
- SO₂(s)
 - S(s)
 - O₂(g)
 - SO₂(l)
 - SO₂(g)
- E 5. For a particular reaction, the value of $H = +98.8$ kJ and $S = +141.5$ J/K. This reaction is
- product-favored, because S_{universe} is positive.
 - reactant-favored, because S_{universe} is positive.
 - reactant-favored, because S_{universe} is negative.
 - product-favored, because S_{universe} is negative.
 - either reactant- or product-favored; cannot determine without further information.

A 6. Calculate the value of S for the reaction shown:



At 25 C the values of entropy in $\text{J K}^{-1} \text{mol}^{-1}$ are nitrogen, 191.61; hydrogen, 130.68 ; and ammonia, 192.77.

- a. -198.11 J/K
- b. -259.03 J/K
- c. -390.88 J/K
- d. -393.20 J/K
- e. -969.19 J/K

B 7. Use the data given to calculate the value of G_{rxn} at 25 C for the reaction given below. G_f for $\text{CO}(\text{g})$ is -137.16 kJ/mol.

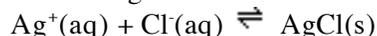


- a. -274.32 kJ
- b. -137.16 kJ
- c. -68.58 kJ
- d. +137.16 kJ
- e. +274.32 kJ

C 8. A certain reaction has $H_{\text{rxn}} = +177.8 \text{ kJ}$, and $S_{\text{rxn}} = +160.5 \text{ J/K}$. Above what temperature does it become product-favored ?

- a. 384 C
- b. 630 C
- c. 835 C
- d. 1108 C
- e. 1381 C

B 9. Use the data given to calculate the value of K for the reaction at 5 C



	$\text{AgCl}(\text{s})$	$\text{Ag}^+(\text{aq})$	$\text{Cl}^-(\text{aq})$
$S (\text{J K}^{-1} \text{mol}^{-1})$	96.2	72.68	56.4
$H_f (\text{kJ/mol})$	-127.07	105.58	-167.2

- a. 1.9×10^{12}
- b. 3.7×10^{10}
- c. 5.7×10^9
- d. 1.3×10^6
- e. 1.0

D 10. Which set of conditions describes a reaction that is most likely to proceed?

- a. endothermic, decreasing entropy, high activation energy
- b. exothermic, decreasing entropy, high activation energy
- c. exothermic, increasing entropy, high activation energy
- d. exothermic, increasing entropy, low activation energy
- e. endothermic, decreasing entropy, low activation energy

- A 11. Combustion of wood is exothermic, with $S < 0$. A campfire, once lit, is self-sustaining because some of the heat produced warms up more wood
- and decreases its kinetic stability.
 - and increases its kinetic stability.
 - and decreases its thermodynamic stability.
 - both a and c.
 - both b and c.
- E 12. In the reaction shown below, _____ is the oxidizing agent and _____ the reducing agent.
- $$\text{Zn(s)} + \text{H}_2\text{SO}_4(\text{aq}) \rightarrow \text{H}_2(\text{g}) + \text{ZnSO}_4(\text{aq})$$
- Zn^{2+} ; H_2
 - Zn ; H^+
 - H_2 ; Zn^{2+}
 - H^+ ; Zn^{2+}
 - H^+ ; Zn
- B 13. If cadmium metal and the Fe(III) ion are mixed in aqueous solution, a solution containing Cd(II) and Fe(II) results. The balanced equation for this process is
- $\text{Cd(s)} + \text{Fe}^{3+}(\text{aq}) \rightarrow \text{Fe}^{2+}(\text{aq}) + \text{Cd}^{2+}(\text{aq})$.
 - $\text{Cd(s)} + 2 \text{Fe}^{3+}(\text{aq}) \rightarrow 2 \text{Fe}^{2+}(\text{aq}) + \text{Cd}^{2+}(\text{aq})$.
 - $2 \text{Cd(s)} + \text{Fe}^{3+}(\text{aq}) \rightarrow \text{Fe}^{2+}(\text{aq}) + 2 \text{Cd}^{2+}(\text{aq})$.
 - $2 \text{Cd(s)} + \text{Fe}^{3+}(\text{aq}) \rightarrow 2 \text{Fe}^{2+}(\text{aq}) + \text{Cd}^{2+}(\text{aq})$.
 - $2 \text{Cd(s)} + \text{Fe}^{3+}(\text{aq}) \rightarrow \text{Fe}^{2+}(\text{aq}) + 2 \text{Cd}^{2+}(\text{aq})$.
- A 14. In the anode compartment of an electrochemical cell, the electrode is being _____, and _____ are flowing in from the salt bridge.
- oxidized; anions
 - oxidized; cations
 - oxidized; electrons
 - reduced; cations
 - reduced; anions

Exhibit 19-1

Use this list of half-reactions to answer the following question(s).

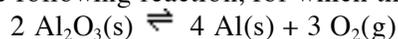
$\text{MnO}_4^-(\text{aq}) + 8\text{H}^+(\text{aq}) + 5\text{e}^- \rightarrow \text{Mn}^{2+}(\text{aq}) + 4\text{H}_2\text{O}(\text{l})$	+1.51 V
$\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 6\text{e}^- \rightarrow 2\text{Cr}^{3+}(\text{aq}) + 7\text{H}_2\text{O}(\text{l})$	+1.33 V
$\text{Pt}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Pt}(\text{s})$	+1.20 V
$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cu}(\text{s})$	+0.34 V
$\text{Pb}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Pb}(\text{s})$	-0.13 V
$\text{Al}^{3+}(\text{aq}) + 3\text{e}^- \rightarrow \text{Al}(\text{s})$	-1.66 V

- A 15. Refer to Exhibit 19-1. The strongest reducing agent in the table is
- $\text{Al}(\text{s})$.
 - $\text{Al}^{3+}(\text{aq})$.
 - $\text{H}^+(\text{aq})$.
 - $\text{MnO}_4^-(\text{aq})$.
 - $\text{Mn}^{2+}(\text{aq})$.

- D 16. Refer to Exhibit 19-1. Which of these combinations would result in reaction?
- $\text{Al}^{3+}(\text{aq})$ and $\text{Cr}^{3+}(\text{aq})$
 - $\text{Al}^{3+}(\text{aq})$ and $\text{Cu}(\text{s})$
 - $\text{Cr}_2\text{O}_7^{2-}(\text{aq})$ and $\text{MnO}_4^{-}(\text{aq})$
 - $\text{Cu}(\text{s})$ and $\text{MnO}_4^{-}(\text{aq})$
 - $\text{Pt}(\text{s})$ and $\text{Pb}^{2+}(\text{aq})$
- A 17. The value of E_{cell} for an aluminum-nickel electrochemical cell is +1.41 V at 25 C. Calculate the value of G for this cell under standard conditions.
- 816 kJ
 - 680 kJ
 - 272 kJ
 - +403 kJ
 - +680 kJ
- C 18. The value of E_{cell} at 25 C for the cell shown below is +1.27 V. What is the value of E_{cell} ?
- $\text{Cd}(\text{s}) \mid \text{Cd}^{2+}(\text{aq}), 2.0 \text{ M} \parallel \text{Ag}^{+}(\text{aq}), 2.0 \text{ M} \mid \text{Ag}(\text{s})$
- 1.57 V
 - 1.28 V
 - 1.26 V
 - 1.23 V
 - 0.97 V
- D 19. For a zinc-platinum electrochemical cell, calculate the value of E_{cell} when the concentration of $\text{Pt}^{2+}(\text{aq})$ is 0.050 M and the concentration of $\text{Zn}^{2+}(\text{aq})$ is 1.1 M. $E_{\text{cell}} = 1.96 \text{ V}$ under standard conditions. Pt is the less active metal.
- 2.04 V
 - 2.00 V
 - 1.96 V
 - 1.92 V
 - 1.88 V
- E 20. Calculate the mass of cobalt that will be deposited when a current of 2.00 A is passed through a solution of CoSO_4 for 10.0 hours.
- $6.11 \times 10^{-3} \text{ g}$
 - 0.366 g
 - 4.40 g
 - 8.72 g
 - 22.0 g

Short Answer

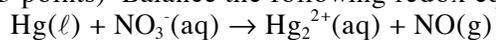
21. (25 points) Recovering aluminum directly from its ore, which is primarily aluminum oxide, involves the following reaction, for which thermodynamic data is tabulated below:



	aluminum	aluminum oxide	oxygen
H_f (kJ/mole)	0	-1676.0	0
S ($\text{J K}^{-1} \text{mol}^{-1}$)	28.28	50.96	205.15

- Calculate H_{rxn} and S_{rxn} .
 - Explain how you could have predicted the signs of H_{rxn} and S_{rxn} without any calculations.
 - Without performing any further calculations, predict whether this reaction will be product-favored only above a certain temperature, or only below a certain temperature. Explain your answer.
 - Calculate the temperature alluded to in part c.
 - Calculate G at this temperature.
- a. $H_{\text{rxn}}^{\circ} = 4(0.00) + 3(0.00) - 2(-1676.0) = 3352.0 \text{ kJ}$
 $S_{\text{rxn}}^{\circ} = 4(28.28) + 3(205.15) - 2(50.96) = 626.65 \text{ J/K}$
- b. Without looking at any number for enthalpies of formation or standard entropies, we know that H_{rxn} will be positive because in order to form products, we must break a total of 4 double bonds and 4 single bonds in the reactants, and form only 3 double bonds in the products. Thus, we must put in more energy than we get out, and the reaction is endothermic. We know S_{rxn} is positive because we form 3 moles of gas phase product from solid reactants.
- c. $G^{\circ} = H^{\circ} - T S^{\circ}$. Since both H_{rxn}° and S_{rxn}° are positive, G_{rxn}° can be negative (product-favored) only at higher temperatures when the second term dominates the expression.
- d. When $G_{\text{rxn}}^{\circ} = 0$, $T = H_{\text{rxn}}^{\circ} / S_{\text{rxn}}^{\circ} = 3,352,000 \text{ J} / 626.65 \text{ J/K} = 5350 \text{ K}$
- e. $G_{\text{rxn}}^{\circ} = 0$

22. (25 points) Balance the following redox equation using acidic conditions.

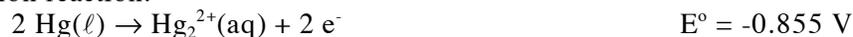


The standard reduction potential for the Hg_2^{2+} reaction is 0.855 V and for the NO_3^- reaction is 0.96 V.

Determine the equilibrium constant for the balanced electrochemical reaction assuming a temperature of 298 K.

Faraday's constant = 96,485 C/mol

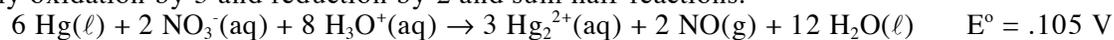
Oxidation reaction:



Reduction reaction:



Multiply oxidation by 3 and reduction by 2 and sum half-reactions:



$$G^\circ = -RT \ln K_{\text{eq}}$$

$$G^\circ = -nFE^\circ$$

$$\therefore RT \ln K_{\text{eq}} = nFE^\circ$$

$$K_{\text{eq}} = \exp\{nFE^\circ/RT\} = \exp\{(6)(96485 \text{ C/mol})(.105 \text{ J/C}) / (8.314 \text{ J/mol K})(298 \text{ K})\}$$
$$= 4.5 \times 10^{10}$$

Exam 2 2006
Answer Section

MULTIPLE CHOICE

- | | |
|------------|---|
| 1. ANS: A | OBJ: 18.1 Reactant-Favored and Product-Favored Processes |
| 2. ANS: C | OBJ: 18.2 Chemical Reactions and Dispersal of Energy |
| 3. ANS: D | OBJ: 18.3 Measuring Dispersal of Energy: Entropy |
| 4. ANS: E | OBJ: 18.3 Measuring Dispersal of Energy: Entropy |
| 5. ANS: E | OBJ: 18.5 Entropy and the Second Law of Thermodynamics |
| 6. ANS: A | OBJ: 18.4 Calculating Entropy Changes |
| 7. ANS: B | OBJ: 18.6 Gibbs Free Energy |
| 8. ANS: C | OBJ: 18.6 Gibbs Free Energy |
| 9. ANS: B | OBJ: 18.7 Gibbs Free Energy Changes and Equilibrium Constants |
| 10. ANS: D | OBJ: 18.11 Thermodynamic and Kinetic Stability |
| 11. ANS: D | OBJ: 18.11 Thermodynamic and Kinetic Stability |
| 12. ANS: E | OBJ: 19.1 Redox Reactions |
| 13. ANS: B | OBJ: 19.2 Using Half-reactions to Understand Redox Reactions |
| 14. ANS: A | OBJ: 19.3 Electrochemical Cells |
| 15. ANS: A | OBJ: 19.5 Using Standard Cell Potentials |
| 16. ANS: D | OBJ: 19.5 Using Standard Cell Potentials |
| 17. ANS: A | OBJ: 19.6 E° and Gibbs Free Energy |
| 18. ANS: C | OBJ: 19.7 Effect of Concentration on Cell Potential |
| 19. ANS: D | OBJ: 19.7 Effect of Concentration on Cell Potential |
| 20. ANS: E | OBJ: 19.12 Counting Electrons |

SHORT ANSWER

21. ANS:

- a. $H_{\text{rxn}} = (4 \times 0 + 3 \times 0) - (2 \times (-1676.0)) = +3352.0 \text{ kJ}$.
 $S_{\text{rxn}} = (4 \times 28.28 + 3 \times 205.15) - (2 \times (50.96)) = +626.65 \text{ J/K}$.
- b. Since the reaction is the exact reverse of a combustion reaction (which is invariably exothermic), it is endothermic, i.e., H_{rxn} is positive. Since the reaction produces 3 mol of gas per mol of reaction, S_{rxn} is also expected to be positive.
- c. Now $S_{\text{universe}} = S_{\text{rxn}} + S_{\text{surroundings}} = S_{\text{rxn}} + (-H_{\text{rxn}}/T)$. The Second Law of Thermodynamics states that the reaction will be product-favored if S_{universe} is > 0 . For large T, the second (negative) term will be small and the first (positive) term will dominate, so reaction will be product-favored. For small T, the second term will dominate and reaction will be reactant-favored. Reaction will be product-favored only above a certain temperature.
- d. At that certain temperature, G is on the cusp between negative and positive values; clearly, therefore, it is zero. Thus,

$$G = H_{\text{rxn}} - T S_{\text{rxn}} = 0$$

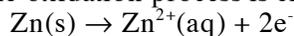
=>

$$S_{\text{rxn}} = H_{\text{rxn}}/T \Rightarrow T = H_{\text{rxn}} / S_{\text{rxn}} = \frac{3.3520 \times 10^6 \text{ J}}{626.65 \text{ J/K}} = 5349.1 \text{ K}$$

e. See d. $G = 0 \text{ J}$.

22. ANS:

The oxidation process is clearly

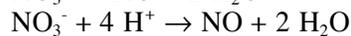


The reduction can be balanced as follows:

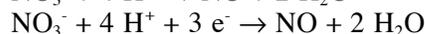
(balance O atoms using H_2O)



(balance H atoms using H^+)



(balance charge using e^-)



Now multiply oxidation process by 3, reduction by 2, so that e^- cancel, and add:

