

Printed **Last** Name: | | | | | | | | | | | | | | |

Printed **First** Name: | | | | | | | | | | | | | | |

Social Security # | | | | | | | | | |

School: | | | Barnard | | | College | | | Engineering | | | General Studies
Chemistry C1404y Exam 3 April 22, 2003

INSTRUCTIONS

Be certain you have the NINE (9) pages of the exam and a BUBBLE SHEET

On the EXAM, fill in your name and CUID number as indicated above.

On the BUBBLE SHEET:

- 1) On Side 2 of the Bubble Sheet print your **first and last NAME** in the box provided.
- 2) Fill in your **Social Security IDENTIFICATION #** in the space provided.
- 3) Using a soft lead pencil, blacken the one response that best answers the question or completes the statement. There is only one correct answer to each question. **Questions with more than one answer will not be counted.**
- 4) **Your score will be the total number of correct answers**; therefore, it is to your advantage to answer every question.
- 5) **There are 25 QUESTIONS. They are equally weighted.**

UNDER NO CIRCUMSTANCES are you to make marks on the bubble sheet except in the appropriate *bubbles* for marking an answer you believe to be correct.
You may write on the exam sheets themselves for the purpose of doing calculations.

DATA SHEET IS PROVIDED ON PAGES 6 AND 7

PERIODIC TABLE OF THE ELEMENTS can be found on **PAGE 8.**

SCRATCH SHEET is provided on **PAGE 9.**

Check the front blackboard for **TIME REMAINING, LAST-MINUTE CORRECTIONS** and **ADDITIONAL INFORMATION.**

You will be given 90 MINUTES to complete the exam.

WHEN YOU HAVE FINISHED THE EXAM or at the end of the allowed time, deposit the **exam** and the **bubble sheet** in the **separate** boxes provided at the front of the room.

DO NOT FORGET! Print your first and last names in the box provided (1) on the bubble sheet, and (2) on the front page of the 9-page exam.

REMEMBER! It is your responsibility to ensure that your bubble sheet and exam sheets are properly identified.

1. Calculate the standard entropy change at 298 K for the reaction $\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{NO}(\text{g})$

- a) **24.77 J K⁻¹ mol⁻¹** b) 185.88 J K⁻¹ mol⁻¹ c) 210.65 J K⁻¹ mol⁻¹
 d) 229.80 J K⁻¹ mol⁻¹ e) 421.30 J K⁻¹ mol⁻¹

This question requires use of the formula relating ΔS to S_f° given on Slide 15, Lecture 18, and is just like one-half of Problem 33, Chapter 11.

2. Calculate ΔG_r° for the reaction $\text{H}(\text{g}) + \text{I}(\text{g}) \rightarrow \text{HI}(\text{g})$.

- a) - 1.72 kJ mol⁻¹ b) - 70.28 kJ mol⁻¹ c) - 135.91 kJ mol⁻¹
 d) - 203.26 kJ mol⁻¹ **e) - 271.82 kJ mol⁻¹**

See Slide 17, Lecture 8, and note that this is just like Problem 35, Chapter 11.

3. A sample of $\text{H}_2(\text{g})$ is held at a constant temperature of 300 K while it expands reversibly doing 100 J of PV work. During this expansion the $\text{H}_2(\text{g})$ absorbs 30 J of heat from the reservoir to which it is connected. What is ΔS for this process?

- a) 0.00 J K⁻¹ **b) 0.10 J K⁻¹** c) 0.23 J K⁻¹ d) 0.33 J K⁻¹ e) 0.70 J K⁻¹

See Slides 5 and 10, Lecture 6, which show that $\Delta S = q_{\text{rev}}/T$.

4. A Stirling heat engine is operated with a hot reservoir at a temperature $T_H = 400$ K, and a cold reservoir at $T_C = 300$ K. The maximum possible efficiency of this engine is:

- a) 0.125 **b) 0.250** c) 0.333 d) 0.375 e) 0.750

See Slide 11, Lecture 11 and Slide 2, Lecture 6, which show that $e = 1 - T_C/T_H$.

5. A system consisting of 4.0×10^{23} Xe(g) atoms is calculated to have $\ln W_{\text{most prob.}} = 2.8 \times 10^{23}$. What is the molar entropy of this Xe(g)?

- a) 2.5 J K⁻¹ mol⁻¹ b) 3.7 J K⁻¹ mol⁻¹ c) 4.7 J K⁻¹ mol⁻¹
d) 5.5 J K⁻¹ mol⁻¹ e) 7.1 J K⁻¹ mol⁻¹

This is exactly the example problem solved on Slide 2, Lecture 8.

6. The reaction $\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}(\text{s}) + 2\text{NH}_4\text{NO}_3(\text{s}) \rightarrow \text{Ba}(\text{NO}_3)_2(\text{s}) + 2\text{NH}_3(\text{aq}) + 10\text{H}_2\text{O}(\text{l})$ has $\Delta S_r = + 430 \text{ J K}^{-1} \text{ mol}^{-1}$ at 400 K and $\Delta H_r = + 66.0 \text{ kJ mol}^{-1}$ at 400 K. What is ΔG_r for this reaction at 400 K?

- a) - 172 kJ mol⁻¹ **b) - 106 kJ mol⁻¹** c) - 62.0 kJ mol⁻¹
 d) + 66.0 kJ mol⁻¹ e) + 172 kJ mol⁻¹

This is exactly the example problem solved on Slides 14-16, Lecture 8.

7. A thermodynamic calculation shows that when 2 moles of a particular pure crystalline solid is taken by some irreversible process from $T_i = 27 \text{ K}$ to $T_f = 0 \text{ K}$ the entropy change for the process is -34 J K^{-1} . What is the entropy of the solid at the end of the process?

a) -34 J K^{-1} b) -17 J K^{-1} **c) 0 J K^{-1}** d) $+34 \text{ J K}^{-1}$ e) $+68 \text{ J K}^{-1}$

See Slide 24, Lecture 7, which gives the Third Law that says S goes to zero as T goes to zero.

8. For the reaction $2\text{NO}_2(\text{g}) \rightarrow \text{N}_2\text{O}_4(\text{g})$ $\Delta G_r^\circ = -4.76 \text{ kJ mol}^{-1}$ at 298 K . Calculate ΔG_r at 298 K when the partial pressures are $\text{NO}_2(\text{g}) = 0.667 \text{ atm}$ and $\text{N}_2\text{O}_4(\text{g}) = 0.333 \text{ atm}$.

a) $-0.314 \text{ kJ mol}^{-1}$ b) $-0.476 \text{ kJ mol}^{-1}$ c) $-4.04 \text{ kJ mol}^{-1}$
d) $-5.48 \text{ kJ mol}^{-1}$ e) $-6.48 \text{ kJ mol}^{-1}$

See Slide 24, Lecture 8 and Slides 5 and 6, Lecture 9. This system appeared in Problem 63, Chapter 11.

9. For an unknown ionic compound the reaction $\text{AB}(\text{s}) \rightarrow \text{A}^+(\text{aq}) + \text{B}^-(\text{aq})$ has $\Delta S^\circ = -44.17 \text{ J K}^{-1} \text{ mol}^{-1}$ at 298 K . The reaction is spontaneous at 298 K . What is ΔH° for this reaction at 298 K ?

a) $< -13.16 \text{ kJ mol}^{-1}$ b) $-13.16 \text{ kJ mol}^{-1}$ c) 0 kJ mol^{-1}
d) $+13.16 \text{ kJ mol}^{-1}$ e) $> +13.16 \text{ kJ mol}^{-1}$

See Slides 13 and 16, Lecture 8. This question also derives from Problems 23 and 33 in Chapter 11.

10. Calculate the equilibrium constant for the reaction $\text{H}(\text{g}) + \text{HCl}(\text{g}) \rightarrow \text{H}_2(\text{g}) + \text{Cl}(\text{g})$ at 298 K . For this reaction: $\Delta H_r^\circ = -3.97 \text{ kJ mol}^{-1}$, $\Delta S_r^\circ = -5.74 \text{ J K}^{-1} \text{ mol}^{-1}$, $\Delta G_r^\circ = -2.25 \text{ kJ mol}^{-1}$. The equilibrium constant is:

a) 0.202 b) 0.403 c) 0.690 **d) 2.48** e) 4.96

See Slide 20, Lecture 8. This question is a simplified example of Problems 49 and 51 in Chapter 11.

11. The oxygen molecule $^{16}\text{O}^{18}\text{O}$ is made from one ^{16}O atom and one ^{18}O atom. A sample consisting of $100 \text{ } ^{16}\text{O}^{18}\text{O}$ molecules in a crystalline solid is prepared in which every $^{16}\text{O}^{18}\text{O}$ molecule has exactly the same energy but each molecule can take one of two different orientations in the crystal, the ^{16}O end up and the ^{18}O end down, or the ^{18}O end up and the ^{16}O end down. What is the number of possible microstates for this sample?

a) 2 **b) 2^{+100}** c) 2^{-100} d) $\ln 2^{100}$ e) $2 \ln 100$

This is part (b) of Problem 79 in Chapter 11, changing N_2O to O_2 .

12. A gas expands reversibly at a constant temperature of 300 K against an external pressure and the PV work done in the process is $w = -30 \text{ J}$. During the process the gas absorbs heat and $q = +30 \text{ J}$. Then the gas is compressed irreversibly back to its original pressure, volume, and temperature and $q = -50 \text{ J}$ for the compression. What is the entropy change for the compression?
- a) $< -0.17 \text{ J K}^{-1}$ **b) -0.10 J K^{-1}** c) 0 J K^{-1} d) $+0.10 \text{ J K}^{-1}$ e) $> +0.17 \text{ J K}^{-1}$

See Slides 5 and 6, Lecture 6. We use the fact that S is a state function, and that ΔS can be computed for a reversible process. Note that the temperature is not specified as constant for the irreversible step, so you have no way of computing ΔS for it directly, not even setting a limit on it.

13. You are given three identical blocks of aluminum, each with a mass of 1.000 g. Each block is initially at 0 K. Block A is connected to a heat source and 10.00 J of energy is transferred to it. Block B is connected to a different heat source and 15.00 J of energy is transferred to it. Block C is connected to a third heat source and 20.00 J of energy is transferred to it. All three blocks are removed from their heat sources. Then Block A and Block B are brought into contact, isolated from everything else, and allowed to come to equilibrium. Then Blocks A and B are separated and Blocks B and C are brought into contact, isolated from everything else, and allowed to come to equilibrium. What is the final energy content of Block C?
- a) 12.50 J b) 15.00 J **c) 16.25 J** d) 17.50 J e) 18.75 J

See Slide 21, Lecture 6. This question involves two successive applications of that result.

14. The reaction $2\text{HCl(g)} \rightarrow (\text{HCl})_2(\text{g})$ has an equilibrium constant of 1.82 at 150 K and 9.83 at 100 K. What is ΔH_r for this reaction at 100 K assuming that ΔH_r and ΔS_r are temperature independent over the range 100 K to 150 K?
- a) $-4.21 \text{ kJ mol}^{-1}$ b) $-1.90 \text{ kJ mol}^{-1}$ c) $-0.745 \text{ kJ mol}^{-1}$
d) $-0.506 \text{ kJ mol}^{-1}$ e) $+0.462 \text{ kJ mol}^{-1}$

This question is the same as Problem 63, Chapter 11.

15. Which of the following will react with teflon at 450 K?
- a) Li(s)** b) $\text{Na}^+(\text{aq})$ c) $\text{O}_2(\text{g})$ d) $\text{H}_2\text{O}_2(\text{aq})$ e) $\text{I}_2(\text{s})$

See Slide 4, Lecture 4.

16. What is the standard cell voltage of the cell:
 $\text{Ni(s)}|\text{Ni}^{2+}(\text{aq}, 1\text{M})::\text{Ag}^+(\text{aq}, 1\text{M})|\text{Ag(s)}$?

- a) - 0.529 V b) - 0.257 V c) + 0.543 V d) + 0.800 V **e) +1.057 V**

See Slide 29, Lecture 10.

17. Balance the half-reaction for the reduction of hydrogen peroxide ($\text{H}_2\text{O}_2(\text{aq})$) to water ($\text{H}_2\text{O}(\text{l})$) in acidic solution. The equation is $\text{H}_2\text{O}_2(\text{aq}) + b\text{H}^+ + c\text{e}^- \rightarrow d\text{H}_2\text{O}(\text{l})$. In this equation b, B, c, C, and d are, in order:
 a) 1, H^+ , 2, e^- , 2 **b) 2, H^+ , 2, e^- , 2** c) 2, OH^- , 2, O_2 , 2
 d) 1, OH^- , 2, e^- , 1 e) 2, H_2O , 2, OH^- , 2

See Slides 14 and 15, Lecture 9. The answer is given on p. 572 of your text.

18. In the cell $\text{Zn}(\text{s})|\text{Zn}^{2+}(\text{aq}, 1\text{M})::\text{H}^+(\text{aq}, 1\text{M})|\text{H}_2(\text{g}, 1\text{atm})|\text{Pt}(\text{s})$ what is the cathode?
 a) $\text{Zn}(\text{s})$ b) $\text{Zn}^{2+}(\text{aq})$ c) $\text{H}^+(\text{aq})$ d) $\text{H}_2(\text{g})$ **e) $\text{Pt}(\text{s})$**

This question comes from Problem 25 in Chapter 12.

19. What is ΔG_r° for the reaction $\text{Mg}^{2+}(\text{aq}) + 2\text{K}(\text{s}) \rightarrow 2\text{K}^+(\text{aq}) + \text{Mg}(\text{s})$?
 a) + 228 kJ mol^{-1} b) + 116 kJ mol^{-1} c) + 53.9 kJ mol^{-1}
d) - 108 kJ mol^{-1} e) - 283 kJ mol^{-1}

See Slide 30, Lecture 10. This question comes from Problem 5 in Chapter 13.

20. What is the equilibrium constant for the reaction $\text{Pb}^{2+}(\text{aq}) + \text{Sn}(\text{s}) \rightarrow \text{Pb}(\text{s}) + \text{Sn}^{2+}(\text{aq})$ at 298 K?
 a) 0.40 b) 0.94 c) 1.3 d) 1.6 **e) 2.5**

See Slide 31, Lecture 10. This question comes from Problem 43 in Chapter 13.

21. The anode in a particular galvanic cell operating in basic solution involves the reaction of cadmium. Which one of the following is a description of that anode?
 a) $\text{Cd}(\text{s}) \rightarrow \text{Cd}^{2+}(\text{aq}) + \text{e}^-$ b) $\text{Cd}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cd}(\text{s})$
 c) $\text{Cd}(\text{s}) + \text{OH}^-(\text{aq}) \rightarrow \text{Cd}(\text{s}) + 1/2\text{H}_2\text{O}(\text{l}) + 1/2\text{O}_2(\text{g}) + \text{e}^-$
d) $\text{Cd}(\text{s}) + 2\text{OH}^-(\text{aq}) \rightarrow \text{Cd}(\text{OH})_2(\text{s}) + 2\text{e}^-$
 e) $\text{Cd}(\text{s}) + \text{H}_2(\text{g}) \rightarrow \text{Cd}^{2+}(\text{aq}) + 2\text{H}^+(\text{aq}) + 4\text{e}^-$

See Slide 24, Lecture 9.

22. A galvanic cell is constructed from a strip of metallic $\text{Zn}(\text{s})$ in contact with a solution that is 0.75 M in $\text{Zn}^{2+}(\text{aq})$ and a strip of metallic $\text{Cu}(\text{s})$ in contact with a 1.50 M solution of $\text{Cu}^{2+}(\text{aq})$. What is the initial voltage generated by this cell at 298 K?
 a) 1.059 V b) 1.098 V **c) 1.116 V** d) 1.125 V e) 1.142 V

See Slide 31, Lecture 10. This question comes from Problem 27 in Chapter 13.

23. The label on a battery states that its capacity is 700mAhours, meaning that it can deliver a current of 0.700 A for 1 hour. How many moles of $\text{Mn}^{3+}(\text{aq})$ can be reduced to $\text{Mn}^{2+}(\text{aq})$ by this battery.
- a) 0.000435 mole b) 0.0131 mole **c) 0.0261 mole**
d) 2.52 mole e) 38.3 mole

See Slide 27, Lecture 9 and Slide 18, Lecture 10. This question comes from Problem 29 in Chapter 12.

24. The hydrogen fuel cell has the overall reaction $\text{H}_2(\text{g}) + 1/2\text{O}_2(\text{g}) \rightarrow \text{H}_2\text{O}(\text{l})$. What is the maximum amount of electrical work that this cell can perform if it utilizes oxygen from the air around it and hydrogen from a high-pressure tank containing 1.50 kilograms of $\text{H}_2(\text{g})$?
- a) $1.50 \times 10^3 \text{ J}$ b) $2.37 \times 10^3 \text{ J}$ c) $3.16 \times 10^5 \text{ J}$
d) $1.78 \times 10^8 \text{ J}$ e) $3.56 \times 10^8 \text{ J}$

See Slide 17, Lecture 10. This question comes from Problem 7 in Chapter 13.

25. Which of the following is NOT required in a galvanic cell?
- a) anode b) cathode c) anions d) electrons **e) salt bridge**

See Lectures 9 and 10. Note that batteries do not have salt bridges.

Physical Constants

Constant	Value
Avogadro's Number (N_0)	$6.0221420 \times 10^{23} \text{ mol}^{-1}$
Faraday Constant (F)	$96,485.342 \text{ C mol}^{-1}$
Universal Gas Constant (R)	$8.31447 \text{ J K}^{-1} \text{ mol}^{-1}$
Boltzmann Constant (k)	$1.308630 \times 10^{-23} \text{ J K}^{-1}$

Standard Chemical Thermodynamic Properties

Data at 298 K

Substance	$\Delta H_f^\circ (\text{kJ mol}^{-1})$	$S^\circ (\text{J K}^{-1} \text{ mol}^{-1})$	$\Delta G_f^\circ (\text{kJ mol}^{-1})$
$\text{C}_3\text{F}_8(\text{g})$	-1,784.7	321.0	-1,633.6
$\text{Cl}_2(\text{g})$	0.00	222.96	0.00
$\text{Cl}(\text{g})$	121.68	165.09	105.71
$\text{H}_2(\text{g})$	0.00	130.57	0.00
$\text{H}(\text{g})$	217.96	114.60	203.26
$\text{HCl}(\text{g})$	-92.31	186.80	-95.30
$\text{HI}(\text{g})$	26.48	206.48	1.72
$\text{H}_2\text{O}(\text{l})$	-285.83	69.91	-237.18
$\text{H}_2\text{O}(\text{g})$	-241.82	188.72	-228.59
$\text{H}_2\text{O}_2(\text{aq})$	-191.17	143.9	-134.03
$\text{I}_2(\text{s})$	0.00	116.14	0.00
$\text{I}_2(\text{g})$	62.44	260.58	19.36
$\text{I}(\text{g})$	106.84	180.68	70.28
$\text{Li}(\text{s})$	0.00	29.12	0.00
$\text{Na}(\text{s})$	0.00	51.21	0.00
$\text{Na}^+(\text{aq})$	-240.12	59.0	-261.90
$\text{N}_2(\text{g})$	0.00	191.50	0.00
$\text{N}(\text{g})$	472.70	153.19	455.58
$\text{NO}(\text{g})$	90.25	210.65	86.55
$\text{NO}_2(\text{g})$	33.18	239.95	51.29
$\text{N}_2\text{O}_4(\text{g})$	9.16	304.18	97.82
$\text{O}_2(\text{g})$	0.00	205.03	0.00
$\text{O}(\text{g})$	249.17	160.95	231.76

Standard Reduction Potentials
Aqueous Solution at 298 K

Half-Reaction	E° (V)
$\text{Pt}^{2+}(\text{aq}) + 2 \text{e}^- \rightarrow \text{Pt}(\text{s})$	+1.18
$\text{Ag}^+(\text{aq}) + \text{e}^- \rightarrow \text{Ag}(\text{s})$	+0.800
$\text{Cu}^{2+}(\text{aq}) + 2 \text{e}^- \rightarrow \text{Cu}(\text{s})$	+0.345
$2\text{H}^+(\text{aq}) + 2 \text{e}^- \rightarrow \text{H}_2(\text{g})$	0.000
$\text{Pb}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Pb}(\text{s})$	-0.126
$\text{Sn}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Sn}(\text{s})$	-0.138
$\text{Ni}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Ni}(\text{s})$	-0.257
$\text{Cd}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cd}(\text{s})$	-0.403
$\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Zn}(\text{s})$	-0.762
$\text{Mg}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Mg}(\text{s})$	-2.372
$\text{K}^+(\text{aq}) + \text{e}^- \rightarrow \text{K}(\text{s})$	-2.931
$\text{Li}^+(\text{aq}) + \text{e}^- \rightarrow \text{Li}(\text{s})$	-3.040