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ANSWER KEY

CHEMISTRY F14O3 THIRD EXAM 12/8/99
PROFESSOR J. MORROW

PRINT NAME, LAST: _____

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I.D.# : _____

MAXIMUM POINT VALUE IS IN PARENTHESES

1. _____ (10)	7. _____ (10)	13. _____ (20)
2. _____ (20)	8. _____ (10)	14. _____ (10)
3. _____ (15)	9. _____ (10)	15. _____ (15)
4. _____ (15)	10. _____ (10)	16. _____ (20)
5. _____ (20)	11. _____ (10)	17. _____ (20)
6. _____ (20)	12. _____ (10)	18. _____ (20)

COLUMN TOTALS (MAXIMUM):

_____(100) _____(60) _____(105)

EXAM TOTAL (205 pts) _____ _____
OUT OF 1OO

1) Given the following table of thermodynamic data for the indicated species. All of the following species are in the gaseous state at 298 K.

SPECIES	S^o $(\frac{J}{mol \cdot K})$	ΔH^o_f $(\frac{kJ}{mol})$
CO_2	213.79	-393.51
NO^-	214.86	?
CO_2^-	218.70	-441.4O
NO	21O.76	9O.29

For the following reaction, $K_P = 2.189 \times 1O^{-7}$

$$CO_2^- + NO \rightleftharpoons CO_2 + NO^-$$

Calculate ΔG^o_{rxn} (in kJ) at 298 K for this reaction. (10 pts)

$\Delta G^o = - RT \ln K_p = -(8.314x10^{-3})(298)\ln(2.189 \times 1O^{-7}) = 38.00$ kJ

$\Delta G^o_{rxn} =$ _____

2) Calculate ΔH^o_f (in kJ) for NO^- at 298 K for the reaction using the data from problem 1. (20 pts) SHOW WORK

$$CO_2^- + NO \rightleftharpoons CO_2 + NO^-$$

$T\Delta S_{rxn} = (298)(214.86 + 213.79 - 218.70 - 210.76)(10^{-3}) = -0.241$ kJ (FROM TABLE)

$\Delta H_{rxn} = (\Delta H^o_f + (-393.51) - (-441.40) - (90.29)) = \Delta H^o_f - 42.40$ kJ (FROM TABLE)

$\Delta G_{rxn} = \Delta H_{rxn} - T\Delta S_{rxn}$ $\therefore$ $38.00 = \Delta H^o_f - 42.40$ kJ $- (-0.241)$

$\Delta H^o_f = 80.2$ kJ

$\Delta H^o_f =$ _____

3) Using the ion-electron method, balance the following reaction under the conditions given. Show the balanced oxidation and reduction half reactions where indicated. Write your answers in the space provided.

$$C_3H_4O_4 + S_2O_6^{2-} \longrightarrow CH_3OH + 2\,CO_{2(g)} + SO_{2(g)} \quad \text{(acidic)}$$

oxidation half reaction: (5 pts)

$$C_3H_4O_4 + H_2O \longrightarrow CH_3OH + 2\,CO_2 + 2\,H^+ + 2\,e^-$$

reduction half reaction: (5 pts)

$$2\,e^- + 4\,H^+ + S_2O_6^{2-} \longrightarrow 2\,SO_2 + 2\,H_2O$$

ANSWER: (5 pts) Subscripts need NOT be shown in final answer.

BAL EQ. $C_3H_4O_4 + S_2O_6^{2-} + 2\,H^+ \longrightarrow CH_3OH + 2\,CO_2 + 2SO_2 + H_2O$

4) $MnO_{4\,(aq)}^- + S^{2-}_{(aq)} \longrightarrow MnS_{2(S)} + S^o_{(S)}$ (basic)

oxidation half reaction: (5 pts)

$$S^{2-}_{(aq)} \longrightarrow S^o_{(S)} + 2\,e^-$$

reduction half reaction: (5 pts)

$$3\,e^- + 8\,H^+ + MnO_4^- + 2\,S^{2-} \longrightarrow MnS_2 + 4\,H_2O$$

ANSWER: (5 pts) Subscripts need NOT be shown in final answer.

$16\,H^+ + 2\,MnO_4^- + 7\,S^{2-} \longrightarrow 2\,MnS_2 + 3\,S^o + 8\,H_2O$ (ACIDIC)

$8\,H_2O + 2\,MnO_4^- + 7\,S^{2-} \longrightarrow 2\,MnS_2 + 3\,S^o + 16\,OH^-$ (BASIC SOL'N)

5) The vapor pressure of water at 298 K is O.O3132 atm. The standard free energy of formation of $H_2O_{(\ell)}$, ΔG^o_f, is -237.2 kJ/mol also at 298 K. Using this information, calculate the standard free energy of formation, ΔG^o_f (in kJ), of $H_2O_{(g)}$. BE CAREFUL USING THE DEFINITION OF EACH TERM! (20 pts) SHOW WORK

GIVEN: For the reaction, $H_2O_{(\ell)} \rightleftharpoons H_2O_{(g)}$, $\Delta G_{rxn} = -RT\,\ln P_{(atm)}$

a) - 224.3 b) - 232.9 c) - 245.8 d) - 228.6

$H_2O_{(\ell)} \rightleftharpoons H_2O_{(g)}$ $\Delta G_{rxn} = \Delta G^o_{f(g)} - \Delta G^o_{f(\ell)} = -RT\,\ln P = -(8.314)(298)\ln(0.03132)$

$\Delta G_{rxn} = \Delta G^o_{f(g)} - (-237.2\ kJ/mol) = 8581\ J/mol = 8.581\ kJ/mol$

$\Delta G^o_{f(g)} = 8.581 - 237.2 = -228.6\ kJ/mol$

ANSWER IS: d

6) The equilibrium constant for the reaction

$$I_2 + \underset{\text{cyclopentene}}{C_5H_8} \rightleftharpoons HI + \underset{\text{iodocyclopentene}}{C_5H_7I}$$

was measured spectrophotometrically in the gas phase between 175°C and 415°C. The following equation was obeyed:

$$\log_{10}K_{p(atm)} = -\frac{2611.4}{T} + 7.55$$

Calculate ΔH^o and ΔS^o for this reaction (20 pts) SHOW WORK

a) ΔH^o= 25.0 kJ ΔS^o= 78 J b) ΔH^o= 50.0 kJ ΔS^o= 145 J c) ΔH^o= 21.7 kJ ΔS^o= 63.0 J d) ΔH^o= 25.0 kJ ΔS^o= 145.0J e) ΔH^o= 50.0 kJ ΔS^o= 63.0 J

$$\ln K = -\frac{\Delta G^o}{RT} \quad \log_{10} K = -\frac{\Delta G^o}{2.303RT} = -\frac{\Delta H^o}{2.303RT} + \frac{\Delta S^o}{2.303R}$$

$$-\frac{\Delta H^o}{2.303RT} = -\frac{2611.4}{T} \quad \text{AND} \quad \frac{\Delta S^o}{2.303R} = 7.55$$

ΔH^o = 50.0 kJ AND ΔS^o = 145 J

(15 pts) ANSWER IS: b

7) If equal pressures (1 atm each) of I_2 and cyclopentene (see question 6) are mixed at 300°C, what will be the equilibrium partial pressure of HI (in atm)? (10 pts) SHOW WORK

a) 0.21 b) 0.044 c) 0.46 d) 0.12 e) 0.34

$$\log_{10}K_{p(atm)} = -\frac{2611.4}{300} + 7.55 \therefore K_P = 0.0700 = \frac{x^2}{(1-x)^2}$$

$x = 0.209$ atm = P_{HI} (= 0.21 atm)

(15 pts) ANSWER IS: 0.21

8) If an ideal gas is expanded at constant temperature, then ; (10 pts)

a) $\Delta E > 0$ and $\Delta S > 0$ b) $\Delta E = 0$ and $\Delta S = 0$ c) $\Delta E = 0$ and $\Delta S < 0$
d) $\Delta E < 0$ and $\Delta S > 0$ e) $\Delta E = 0$ and $\Delta S > 0$

ANSWER IS: e

9) If $\Delta G^{o}_{f}(HI_{(g)}) = 1.70$ kJ what is the equilibrium constant at 25°C for the reaction, $2\ HI_{(g)} \rightleftharpoons H_{2(g)} + I_{2(s)}$? (10 pts)

a) 3.9 b) 2.0 c) 0.69 d) 0.50 e) 0.25

ANSWER IS: a

10) For the reaction, $H_2O_{(\ell)} \rightleftharpoons H_2O_{(g)}$ at 100°C and 1 atm pressure, which of the following is true ; (10 pts)

a) $\Delta H = 0$ b) $\Delta S = 0$ c) $\Delta H = \Delta E$ d) $\Delta H = T\Delta S$ e) $\Delta H = \Delta G$

ANSWER IS: d

11) For the gas phase decomposition, $PCl_{5(g)} \rightleftharpoons PCl_{3(g)} + Cl_{2(g)}$ (10 pts)

a) $\Delta H < 0$ and $\Delta S < 0$ b) $\Delta H > 0$ and $\Delta S > 0$ c) $\Delta H > 0$ and $\Delta S < 0$
d) $\Delta H < 0$ and $\Delta S > 0$ e) $\Delta H = 0$ and $\Delta S > 0$

ANSWER IS: b

12) You are given four reactions along with their equilibrium constants and heats of reaction: (10 pts)

REACTION	K	ΔH_{rxn}
1.	K_1	ΔH_1
2.	K_2	ΔH_2
3.	K_3	ΔH_3
4.	K_4	ΔH_4

You want to combine these four reactions to obtain a fifth reaction.

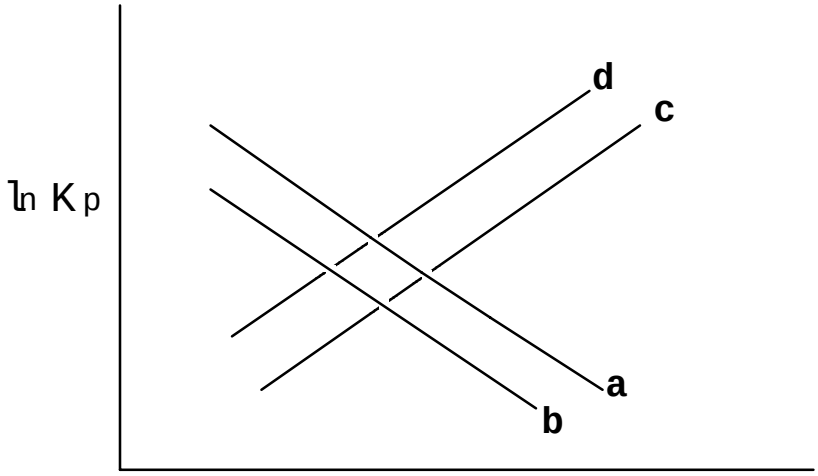
If for the fifth reaction, $K_5 = \dfrac{K_2 K_4^3}{K_1 K_3^2}$, then $\Delta H_5 =$

a) $\Delta H_2 + 2\Delta H_4 - \Delta H_1 - 3\Delta H_3$ b) $\Delta H_2 + 3\Delta H_4 - \Delta H_1 - 2\Delta H_3$
c) $\Delta H_1 + 2\Delta H_3 - \Delta H_2 - 3\Delta H_4$ d) $3\Delta H_2 + \Delta H_4 - \Delta H_1 - 2\Delta H_3$

ANSWER IS: b

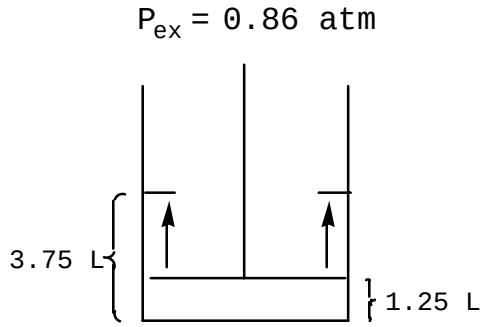
13) Correlate each of the curves in the figure with the appropriate reaction.
20 pts - 5 pts each answer

HINT: $\ln K_p = -\frac{\Delta H}{RT}$ + constant (y = mx + b), and, $\Delta G^o = -RT \ln K_p$



	ΔG^o (kJ)	ΔH^o (kJ)	ANSWERS
Reaction I	- 16.4	- 41	b
Reaction II	- 9.8	+ 2O	c
Reaction III	- 14.8	+ 20	d
Reaction IV	- 24.6	- 41	a

GIVEN THE FOLLOWING PISTON FOR USE IN QUESTIONS 14 and 15.



14) A 1.25 L sample of a gas is heated and expands against a constant pressure of 0.86 atm to a final volume of 3.75 L. Calculate the work done by this gas during the expansion in joules. THIS IS QUESTION 54 FROM YOUR TEXTBOOK.
(10 pts)

$$W = -P_{ex}\Delta V = -(0.86)(3.75 - 1.25)(101.3)$$

$$W = -217.8 \text{ J}$$

ANSWER IS: _____

15) The above piston contains 0.50 mol of an inert gas at an initial temperature of 300 K. An adiabatic expansion now occurs with the volume changing from 1.25 L to 3.75 L at a constant external pressure of 0.86 atm.

Calculate the final temperature, T_f (in Kelvin), in the piston at the end of this expansion. Given: $C_{v,m} = 12.47 \frac{J}{deg \cdot mol}$. (15 pts)

$\Delta E = nC_{v,m}\Delta T = W \quad \therefore \Delta T = \frac{W}{nC_{v.m}} = \frac{-217.8}{(0.5)(12.47)} = -34.9^o (= -35^o)$

$\therefore T_f = 265\ K$

ANSWER IS: 265 K

16) 5O.O g of ice at O°C are mixed with 4O.O g of liquid (water) at O°C and an unknown mass of liquid (water) at 75°C. At equilibrium the final temperature of the entire system is 1O°C. Calculate the starting mass of liquid at 75°C. (20 pts)

SHOW WORK

GIVEN: specific heat of liquid = 4.18 J/g·deg ; heat of fusion = 333 J/g .

a) 15.O g b) 75.1 g c) 25.5 g d) 5O.1 g e) 3O.2 g

$$H_2O_{(S)} \xrightarrow{q_1} H_2O_{(\ell)} \xrightarrow{q_2} H_2O_{(\ell)}$$

5Og, O°C 5Og, O°C 5Og, 1O°C

$$H_2O_{(\ell)} \xrightarrow{q_3} H_2O_{(\ell)} \qquad H_2O_{(\ell)} \xrightarrow{q_4} H_2O_{(\ell)}$$

4Og, O°C 4Og, 1O°C m, 75°C m, 1O°C

$q_1 + q_2 + q_3 + q_4 = O$

$(5O)(333) + (5O)(4.18)(1O) + (4O)(4.18)(1O) + (m)(4.18)(-65) = O$

$m = 75.1\ g$

ANSWER IS: b

17) BOND ENTHALPIES (kJ/mole)

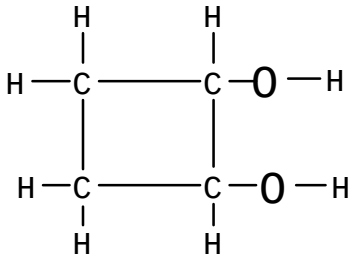
C-C 348 , C=C 61O , C≡C 835 , C-Cl 339 ,
C-H 412 , H-H 431 , O-O 146 , O=O 494 ,
C-O 358 , C=O 745 , C≡O 1O7O , O-H 463 ,
N-H 391 , P-H 322 , S-H 347 , Se-H 276 ,
Te-H 239 , N≡N 945 , H-Cl 431 , N-N 163 ,

Using the above table of bond enthalpies, calculate the heat of reaction, ΔH_{rxn}, for the gaseous reaction, (20 pts) SHOW WORK

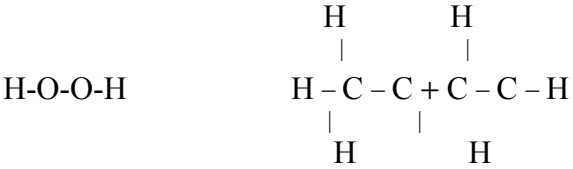
$$H_2O_2 + C_4H_6 \longrightarrow C_4H_6(OH)_2$$

2-butyne cyclobutadiol

where C_4H_6 is CH_3CCCH_3 (one triple bond) and cyclobutadiol (all single bonds) is,



HINT: FIRST WRITE THE LEWIS STRUCTURE FOR EACH MOLECULE.



H-O-O-H

BONDS BROKEN (+)		BONDS FORMED (-)	
2 H-O	2(463)	2 H-O	2(-463)
2 C– C	2(348)	2 C-O	2(-358)
6 C-H	6(412)	6 C-H	6(-412)
1 O-O	1(146)	4 C-C	4(-348)
1 C+C	1(835)		
	+ 5075 kJ		- 5506 kJ

ANSWER IS: -431 kJ

18) Use the following data,

	ΔH^o(kJ)
1. $Fe_2O_{3(S)} + 3\ CO_{(g)} \longrightarrow 2\ Fe_{(S)} + 3CO_{2(g)}$	-3O.O

2. $3\ Fe_2O_{3(S)} + CO_{(g)} \longrightarrow 2\ Fe_3O_{4(S)} + CO_{2(g)}$ -57.O

3. $Fe_3O_{4(S)} + CO_{(g)} \longrightarrow 3\ FeO_{(S)} + CO_{2(g)}$ +42.O

to determine the heat of reaction, ΔH^o_{rxn}, for the reduction of ferrous oxide by carbon monoxide according to; (20 pts) SHOW WORK

$$FeO_{(S)} + CO_{(g)} \longrightarrow Fe_{(S)} + CO_{2(g)}$$

a) -6.O kJ b) +27.O kJ c) +6.O kJ d) -27.O kJ

e) -19.5 kJ f) +19.5 kJ g) +3.O kJ h) -3.O kJ

$(\frac{1}{3})(-3)$ $FeO_{(S)} + \frac{1}{3}\ CO_{2(g)} \longrightarrow \frac{1}{3}\ Fe_3O_{4(S)} + \frac{1}{3}\ CO_{(g)}$ $(\frac{1}{3})(-42.O)$

$(\frac{1}{2})(1)$ $\frac{1}{2}\ Fe_2O_{3(S)} + \frac{3}{2}\ CO_{(g)} \longrightarrow Fe_{(S)} + \frac{3}{2}\ CO_{2(g)}$ $(\frac{1}{2})(-3O.O)$

$(\frac{1}{6})(-2)$ $\frac{1}{3}\ Fe_3O_{4(S)} + \frac{1}{6}\ CO_{2(g)} \longrightarrow \frac{1}{2}\ Fe_2O_{3(S)} + \frac{1}{6}\ CO_{(g)}$ $(\frac{1}{6})(+57.O)$

$$FeO_{(S)} + CO_{(g)} \longrightarrow Fe_{(S)} + CO_{2(g)} \qquad \Delta H^o_{rxn} = -19.5\ kJ$$

ANSWER IS: e