Name ________________________________

CH302H **Exam 1** Spring 2013

Multiple Choice Neatly write your choice in the blank provided. (3 pts each)

__E__ **1.** The heat for this reaction at constant temperature and pressure
$CO_2\ (g) \rightarrow C\ (s, \text{graphite}) + O_2\ (g)$

(a) is equal to half the bond energy of a C–O bond.
(b) is equal to but opposite in sign to the bond energy of a C=O bond.
(c) is equal to twice the bond energy of a C=O bond.
(d) is equal to the enthalpy of formation of CO_2.
(e) is equal to but opposite in sign to the enthalpy of formation of CO_2.

__B__ **2.** Which of the following values of K_p most strongly favors the reactants assuming the same type of reaction for each?

(a) 6.9×10^{2} (b) 9.3×10^{-2} (c) 9.3×10^{0} (d) 1.8×10^{-1}

__A__ **3.** When Q > K a reaction will do the following:

(a) go backwards (b) go forwards (c) no change (d) go back and forth

__C__ **4.** What is the role of time on a chemical reaction that is already at equilibrium?

(a) As time increases a chemical reaction will favor the direction that is exothermic.
(b) As time increases a chemical reaction will favor the direction that is endothermic.
(c) Time is not a factor in systems at equilibrium.
(d) Longer times will yield more products as the reactants are consumed.

__D__ **5.** Equilibrium in a chemical reaction can be attained by

(a) starting with products only
(b) starting with a combination of reactants and products
(c) starting with reactants only
(d) all the choices are correct

__C__ **6.** Knowing that $\Delta H_f°$ for Fe_2O_3 (s) is -826 kJ/mol, what would you predict about the spontaneity of the following reaction: $2\ Fe_2O_3\ (s) \rightarrow 4\ Fe\ (s) + 3\ O_2\ (g)$

(a) it would be spontaneous at all temperatures
(b) it would never be spontaneous at any temperature
(c) it would be spontaneous only at high temperatures
(d) it would be spontaneous only at low temperatures
(e) there is not enough information to predict spontaneity of this reaction

E 7. Consider the reaction: Ni (s) + 4 CO (g) → $Ni(CO)_4$ (g)
Assuming the gases are ideal, calculate the work done on the system at a constant pressure of 1 atm at 75°C for the conversion of 2.50 mole of Ni to $Ni(CO)_4$.

(a) 11.6 kJ (c) 23.8 kJ (e) 21.7 kJ
(b) 28.9 kJ (d) 8.68 kJ (f) 7.24 kJ

B 8. The formation of chemical bonds from separated atoms

(a) is always endothermic. (c) could be endothermic or exothermic
(b) is always exothermic. (d)is never spontaneous

B 9. Calculate the change in molar entropy when the pressure of argon is allowed to double isothermally. Assume ideal behavior.

(a) +1.39 J/mol K (c) -4.16 J/mol K (e) +5.76 J/mol K
(b) -5.76 J/mol K (d) -1.39 J/mol K (f) +4.16 J/mol K

D 10. Which of the following has the highest entropy?

(a) 1 mol H_2 gas at 300K occupying 1 L
(b) 1 mol N_2 gas at 300K occupying 1 L
(c) 1 mol H_2 gas at 300K occupying 10 L
(d) 1 mol N_2 gas at 300K occupying 10 L

True or False For each of the following statements write "T" for true, or "F" for false in the blanks provided. (2 pts each)

F 11. It is impossible for a real process to result in an increase in the entropy of the system.

F 12. Heat transfer to a substance always causes the temperature to increase.

T 13. At constant pressure, exothermic reactions increase the entropy of the surroundings.

F 14. The enthalpy for the following reaction is the enthalpy of formation of CO (*g*)
C (*g*) + O (*g*) → CO (*g*)

T 15. If $\Delta G°$ for a given reaction is large and positive, the equilibrium constant (K) will be very small and favor the reactants

T 16. $\Delta S°$ is greater than zero for the following reaction: $2\ H_2O\ (l) \rightarrow 2\ H_2\ (g) + O_2\ (g)$

F 17. If ΔH and ΔS are independent of temperature then ΔG is independent of temperature

F 18. The equilibrium constant for any reaction is independent of temperature

T 19. 1 mole of an ideal gas at constant temperature is compressed from 1 atm to 10 atm.
For this process $w > 0$, $q < 0$, and $\Delta U = 0$

F 20. All endothermic reactions are spontaneous at extremely high temperatures.

21. 2.460 g of pentane, C_5H_{12} (g), is burned in a bomb calorimeter with an excess of oxygen gas. The calorimeter is filled with 4520 g of water and has a heat capacity for the hardware of 2.350 kJ/°C. Before ignition the temperature was 27.500°C. After ignition the temperature stabilized at 33.170°C.

(a) Write out the entire balanced reaction for this combustion. Make sure you include the state of each substance in the reaction. Also, make sure the coefficient on the pentane is a one. (3 pts)

$\mathbf{C_5H_{12}(\mathit{g}) + 8\ O_2(\mathit{g}) \rightarrow 5\ CO_2(\mathit{g}) + 6\ H_2O(\mathit{l})}$

(b) How much total heat (in kJ) was evolved/released during the reaction for the amount given? (3 pts)

$\mathbf{\Delta T = 33.170\ °C - 27.500°C = 5.670\ °C}$
$\mathbf{q_{cal} = q_{H2O} + q_{hardware} = m\ C_s\ \Delta \mathit{T} + C\ \Delta \mathit{T}}$ **(water + hardware)**
$\mathbf{q_{cal} = (4520\ g)(4.184\ J\ g^{-1}\ °C^{-1})(5.670\ °C) + (2350\ J\ °C^{-1})(5.670\ °C) = 120.6\ kJ}$
$\mathbf{q_{rxn} = -q_{cal} = -120.6\ kJ}$

(c) What is ΔU_{rxn} for this reaction in kJ/mol of pentane? (3 pts)

$\mathbf{q_{rxn} = q_v = \Delta \mathit{U}_{rxn}}$
$\mathbf{2.460\ g\ C_5H_{12} \times 1\ mol \div 72.17\ g\ C_5H_{12} = 0.03409\ mol}$
$\mathbf{-120.6\ kJ \div 0.03409\ mol = -3537\ kJ\ mol^{-1} = \Delta \mathit{U}_{rxn}}$

(d) What is ΔH_{rxn} for the reaction? (also in kJ/mol of pentane) (3 pts)

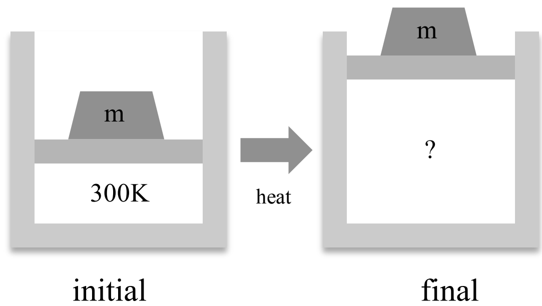
$\mathbf{\Delta \mathit{U} = \Delta \mathit{H} - \Delta(\mathit{PV}) = \Delta \mathit{H} - \Delta(\mathit{nRT})}$
$\mathbf{-3537\ kJ\ mol^{-1} = \Delta \mathit{H_{rxn}} - (4\ mol)(0.008314\ kJ\ mol^{-1}\ K^{-1})(5.67\ K)}$
$\mathbf{\Delta \mathit{H_{rxn}} = -3547\ kJ\ mol^{-1}}$

(e) Given the data below what is the heat of formation of pentane? (3 pts)

$\Delta H°_f\ H_2O(l) = -285.8\ kJ\ mol^{-1}$
$\Delta H°_f\ CO_2(g) = -393.5\ kJ\ mol^{-1}$

$\mathbf{\Delta \mathit{H_{rxn}} = 6\ \Delta \mathit{H}°_f\ H_2O(\mathit{l}) + 5\ \Delta \mathit{H}°_f\ CO_2(g) - 8\ \Delta \mathit{H}°_f\ O_2(\mathit{g}) - \Delta \mathit{H}°_f\ C_5H_{12}}$
$\mathbf{-3547\ kJ\ mol^{-1} = 6(-285.8\ kJ\ mol^{-1}) + 5(-393.5\ kJ\ mol^{-1}) - 0 - \Delta \mathit{H}°_f\ C_5H_{12}}$
$\mathbf{-3547\ kJ\ mol^{-1} = -3682\ kJ\ mol^{-1} - \Delta \mathit{H}°_f\ C_5H_{12}}$
$\mathbf{\Delta \mathit{H}°_f\ C_5H_{12} = -135\ kJ\ mol^{-1}}$

22. 2.00 moles of an unknown ideal gas are put into a piston/cylinder system at an initial temperature of 300K (see diagram). The piston has a mass on top of it that supplies a constant pressure and is free to move. The system is then gently heated which causes the gas to both expand and change temperature. The work for this process is found to be, w = -3.325 kJ. What must be the temperature that the system was heated up to? (10 pts)

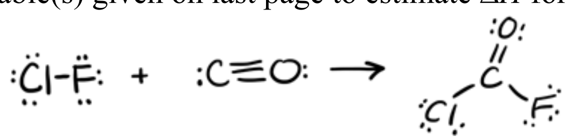


$\boldsymbol{w = -P\Delta V = -P(V_f - V_i)}$
$\boldsymbol{w = -P(nRT_f / P - nRT_i / P)}$
$\boldsymbol{w = -nR(T_f - T_i)}$
$\mathbf{-3325\ J = -(2.0\ mol)(8.314\ J\ mol^{-1}\ K^{-1})(T_f - 300K)}$
$\mathbf{-3325\ J = (-16.628\ J\ K^{-1})T_f + 4988.4\ J}$
$\mathbf{-8313.4\ J = (-16.628\ J\ K^{-1})T_f}$
$\mathbf{T_f = 500\ K}$

23. Chlorine monofluoride (ClF) will react with carbon monoxide (CO) to give carbonyl chlorofluoride (COClF):

$$ClF + CO \rightarrow COClF$$

Use bond energies from the table(s) given on last page to estimate ΔH for this reaction. (8 pts)



$\boldsymbol{\Delta H \cong \sum BE_{reactants} - \sum BE_{products}}$
$\boldsymbol{\Delta H \cong [253\ kJ\ mol^{-1} + 1072\ kJ\ mol^{-1}] - [732\ kJ\ mol^{-1} + 485\ kJ\ mol^{-1} + 339\ kJ\ mol^{-1}]}$
$\boldsymbol{\Delta H \cong -231\ kJ\ mol^{-1}}$

24. For the following reaction: $CH_4(g) + H_2O(g) \rightarrow CO(g) + 3H_2(g)$
an equilibrium mixture at 600 K is found to have the following partial pressures:

P_{CH4} = 1 atm P_{H2O} = 1 atm P_{H2} = 0.010 atm P_{CO} = 0.18 atm

(a) What is the equilibrium constant (K) for this reaction at 600 K? (4 pts)

$K = P_{CO}\, P_{H2}^3 / P_{CH4}\, P_{H2O}$
$K = (0.18)(0.01)^3 / (1)(1) = 1.8 \times 10^{-7}$

(b) What is $\Delta G°$ for this reaction at 600 K? (3 pts)

$\Delta G° = -RT \ln K = -(8.314 \text{ J mol}^{-1} \text{ K}^{-1})(600 \text{ K}) \ln 1.8 \times 10^{-7} = 77.5 \text{ kJ mol}^{-1}$

(c) Is the reaction endothermic or exothermic? Explain how you know. (3 pts)

$\Delta G = \Delta H - T\,\Delta S$ where ΔG and ΔS are both positive. This reaction is endothermic because ΔG is positive even when the entropy is increasing. Thus, ΔH has to be a large positive number in order for ΔG to be positive.

25. Calculate the standard enthalpy of reaction for the reaction: $NO_2\ (g) \rightarrow NO\ (g) + O\ (g)$
Given the following reactions and their standard enthalpy changes: (7 pts)

a)	$O_2\ (g) \rightarrow 2O\ (g)$	$\Delta H° = +498.4$ kJ
b)	$NO\ (g) + O_3\ (g) \rightarrow NO_2\ (g) + O_2\ (g)$	$\Delta H° = -200$ kJ
c)	$3\ O_2\ (g) \rightarrow 2\ O_3\ (g)$	$\Delta H° = +285.4$ kJ

$NO_2\ (g) + O_2\ (g) \rightarrow NO\ (g) + O_3\ (g)$ **$\Delta H°_1 = +200$ kJ**

$O_3\ (g) \rightarrow 3/2\ O_2\ (g)$ **$\Delta H°_2 = -142.7$ kJ**

$1/2\ O_2\ (g) \rightarrow O\ (g)$ **$\Delta H°_3 = +249.2$ kJ**

$\Delta H°_1 + \Delta H°_2 + \Delta H°_3 = \Delta H°_{total} = 306.5$ kJ

Periodic Table of the Elements

1A 1	2A 2	3B 3	4B 4	5B 5	6B 6	7B 7	8B 8	8B 9	8B 10	1B 11	2B 12	3A 13	4A 14	5A 15	6A 16	7A 17	8A 18
1 **H** 1.01																	2 **He** 4.00
3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.87	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.41	31 **Ga** 69.72	32 **Ge** 72.64	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57 **La** 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.84	75 **Re** 186.21	76 **Os** 190.23	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.20	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89 **Ac** (227)	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (266)	107 **Bh** (264)	108 **Hs** (277)	109 **Mt** (268)	110 **Ds** (281)	111 **Rg** (272)	112 **Cn** (285)						

58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.36	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.04	71 **Lu** 174.97
90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (262)

Some Average Singe Bond Energies (kJ/mol)

	H	C	N	O	F	Cl	Br
H	436	413	391	463	565	432	366
C	413	346	305	358	485	339	285
N	391	305	163	201	283	192	—
O	463	358	201	146	—	218	201
F	565	485	283	—	155	253	249
Cl	432	339	192	218	253	242	216
Br	366	285	—	201	249	216	193

Single and Multiple Bond Energies (kJ/mol)

Single Bonds		Double Bonds		Triple Bonds	
C–C	346	C=C	602	C≡C	835
N–N	163	N=N	418	N≡N	945
O–O	146	O=O	498		
C–N	305	C=N	615	C≡N	887
C–O	358	C=O	732*	C≡O	1072