CHEMISTRY 202
Hour Exam II
October 31, 2019
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Name KEY
Signature
T.A.

This exam contains 22 questions on 11 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/or provide complete answers to questions 21 and 22.**

1-20	(60 pts.)	
21	(32 pts.)	
22	(28 pts.)	
Total	(120 pts.)	

Useful Information:

- Always assume ideal behavior for gases (unless explicitly told otherwise).
- 760 torr = 1.00 atm
- R = 0.08206 Latm/molK = 8.314 J/Kmol
- K = °C + 273
- $N_A = 6.022 \times 10^{23}$

$\Delta E = q + w$

$H = E + PV$

$\Delta S = q_{rev}/T$

$G = H - TS$

Here are some of the formulas we used/derived in studying thermodynamics. An individual formula may or may not apply to a specific problem. This is for you to decide!

$\Delta S = nR\ln(V_2/V_1)$

$\Delta S = \Delta H/T$

$C_v = (3/2)R$

$C_p = (5/2)R$

$\Delta S = nC\ln(T_2/T_1)$

$\Delta G = \Delta G^\circ + RT\ln(Q)$

$\Delta S_{surr} = -q/T$

$w = -P\Delta V$

$q_{rev} = nRT\ln(V_2/V_1)$

$q = nC\Delta T$

$$\ln(K) = -\frac{\Delta H^\circ}{R}\left(\frac{1}{T}\right) + \frac{\Delta S^\circ}{R}$$

$$\ln\left(\frac{K_2}{K_1}\right) = -\frac{\Delta H^\circ}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

1. We discussed in lecture how we often assume ΔH for a process/reaction is independent of temperature, even though this is not technically correct. Consider the vaporization of water and methanol. The standard enthalpy of vaporization values for both of these are approximately the same (around 40 kJ/mol). Given the following data, decide for which substance the enthalpy of vaporization at the boiling point is closer to the standard enthalpy of vaporization (at 25°C). That is, for which substance is the assumption that $\Delta H_{\text{vaporization}}$ is independent of temperature more accurate?

	Boiling point (1 atm)	**Heat capacity of liquid (J/mol°C)**	**Heat capacity of vapor (J/mol°C)**
water	100°C	75	33
methanol	65°C	81	44

[✓ a) The assumption is more accurate for methanol.]
b) The assumption is more accurate for water.
c) The assumption is equally accurate for both water and methanol.
d) No assumption is necessary – $\Delta H_{\text{vaporization}}$ is independent of temperature for every substance.

2. Consider the reaction $4NO_2(g) + O_2(g) \rightleftharpoons 2N_2O_5(g)$ at 25.0°C and the following data:.

	ΔH_f° (kJ/mol)
$NO_2(g)$	33.20
$N_2O_5(g)$	11.30

Determine the value of ΔE° for the reaction as written.

[✓ a) –102.8 kJ/mol]
b) –105.2 kJ/mol
c) –110.2 kJ/mol
d) –112.7 kJ/mol
e) –117.6 kJ/mol

3. A sample of water is placed in a coffee cup calorimeter. When an ionic solid is added, the temperature of the water decreases from 21.5°C to 20.8°C as the solid dissolves. For the dissolving of the solid how many of the following **must** be true for the dissolving of the solid?

- $\Delta H < 0$
- $\Delta S_{\text{univ}} > 0$
- $\Delta S_{\text{sys}} < 0$
- $\Delta S_{\text{surr}} > 0$

a) 0 [✓ b) 1] c) 2 d) 3 e) 4

4. Recall in the video on calorimetry that we mentioned that because of similar structures, metals have similar molar heat capacities (all about 25 J/mol°C). Given this value, determine the identity of a "mystery" metal if a 31.4 g sample of the metal is heated to 100.0°C, placed in a calorimeter containing 150.0 g of 25.0°C water (4.184 J/g°C), and the final temperature of the water is 26.7°C.

a) Sodium b) Aluminum [✓ c) Iron] d) Zinc e) Silver

5. Given: $2Cu_2O(s) + O_2(g) \rightarrow 4CuO(s)$ $\Delta H° = -288$ kJ
$Cu_2O(s) \rightarrow Cu(s) + CuO(s)$ $\Delta H° = +11$ kJ

Calculate the standard enthalpy of formation of CuO(s).

a) –299 kJ/mol b) +299 kJ/mol c) –310. kJ/mol d) +310. kJ/mol [✓ e) –155 kJ/mol]

6. Consider the reaction as described by the equation $2H(g) \rightleftharpoons H_2(g)$. What can we say about its spontaneity?

a) We cannot predict how temperature affects its spontaneity.
b) The reaction is spontaneous at all temperatures above 0K.
[✓ c) The reaction becomes more spontaneous as we lower the temperature.]
d) The reaction becomes more spontaneous as we raise the temperature.
e) The reaction is never spontaneous at any temperature.

7. For the reaction $2AB(g) \rightleftharpoons A_2(g) + B_2(g)$, $\Delta G° = 38.3$ kJ. If the initial pressures are 400.0 atm $AB(g)$, 0.500 atm $A_2(g)$, and 0.200 atm $B_2(g)$ (all at 25°C), how will the reaction shift to reach equilibrium?

[✓ a) Some AB will be formed (from A_2 and B_2).]
b) Some AB will decompose (to yield A_2 and B_2).
c) The system is at equilibrium with the initial conditions.

8, 9. Consider the process of heating 1.00 mole of an ideal monatomic gas from a temperature of 25°C to 75°C. Determine the following values at the specified condition.

8. Determine ΔH when the temperature is changed at constant volume.

a) 1.93 J b) 3.22 J c) 416 J d) 624 J [✓ e) 1040 J]

9. Determine ΔE when the temperature is changed at constant pressure.

a) 1.93 J b) 3.22 J c) 416 J [✓ d) 624 J] e) 1040 J

10-14. In the first lecture on thermodynamics, we discussed how the principles of thermodynamics could verify that if placed at room temperature, hot coffee would always cool and ice cream would always melt, and both would end up at room temperature. Let's verify something similar now. Imagine we have about 2 cups of hot water (473 g) at 85°C and 250.0 g of ice at 0°C. Room temperature is constant at 25°C. Use the following information (assume both heat capacity and ΔH_{fusion} are independent of temperature):

Heat capacity of liquid water = 4.184 J/g°C

Heat of fusion of water = 6.02 kJ/mol

10. Determine ΔS_{univ} for the process of the hot water cooling to room temperature.

a) –363 J/K
[✓ b) 35.4 J/K]
c) 363 J/K
d) 398 J/K
e) 761 J/K

11. Determine ΔS_{univ} for the process of the ice melting.

a) 0 J/K
b) 20.2 J/K
c) 22.1 J/K
[✓ d) 25.7 J/K]
e) 42.3 J/K

12. Determine ΔS_{univ} for the process of the water from the ice that melted becoming room temperature.

a) –91.7 J/K
[✓ b) 3.90 J/K]
c) 87.8 J/K
d) 91.7 J/K
e) 179 J/K

13. Which of the following statements is true concerning the relative **magnitudes (NOT signs)** of ΔS and ΔS_{surr}?

a) For the hot water cooling to room temperature, $\Delta S > \Delta S_{\text{surr}}$.
b) For the ice melting, $\Delta S = \Delta S_{\text{surr}}$.
c) For the ice melting, $\Delta S_{\text{surr}} > \Delta S$.
[✓ d) For the water from the melted ice to reach room temperature, $\Delta S > \Delta S_{\text{surr}}$.]
e) For the total process (all H_2O becoming room temperature), $\Delta S = \Delta S_{\text{surr}}$.

14. Imagine a situation in which, while the room remained at 25°C, the temperature of the hot water reached 26°C and the ice eventually became liquid water at 24°C. How would ΔS_{univ} for this situation compare to ΔS_{univ} for all of the water reaching 25°C?

a) ΔS_{univ} would be negative because this process would not be spontaneous.
b) ΔS_{univ} would be the same because it is a state function.
[✓ c) ΔS_{univ} would still be positive but its value would be lower because reaching different temperatures would be less spontaneous.]
d) ΔS_{univ} would be positive but its value would be higher because according to the second law, ΔS_{univ} tends toward a maximum.
e) ΔS_{univ} would be zero.

15-20. Recall the videos in which we discussed the isothermal expansion of an ideal monatomic gas against a constant pressure, followed by its isothermal compression to the same conditions of pressure and volume.

15. Which of the following best describes the value of ΔH for the expansion?

a) Because the expansion is isothermal, $q = 0$, and because the gas expands against a constant pressure, $q = \Delta H$, so $\Delta H = 0$.
b) If this were a free expansion, ΔH would equal zero. But because work is done by the system, ΔH must be less than zero.
c) By expanding, the gas is doing work, and in order to do work, heat must flow into the system, meaning $q > 0$. Because $q > 0$, and because $\Delta H = q$ (since external pressure is constant), $\Delta H > 0$.
d) We know $H = E + PV$. Because the expansion is isothermal, $\Delta E = 0$, and because the gas is expanding, $P\Delta V > 0$, so $\Delta H > 0$.
e) Because the expansion is isothermal, ΔH must equal zero, even though the value of q is not zero.

16. Which of the following is the best response to a person who says, "I know that the value of ΔS for the compression is zero, but I can't figure out why"?

a) It is because the expansion is isothermal, which means $\Delta H = 0$. And because $\Delta S = \Delta H/\mathrm{T}$, $\Delta S = 0$.
b) It is because $\Delta S = \mathrm{nC_p ln(T_2/T_1)}$. Since the process is isothermal, $\mathrm{T_2 = T_1}$, and because $\ln(1) = 0$, $\Delta S = 0$.
c) It is because $\Delta S = \mathrm{nRln(V_2/V_1)}$ and because $\mathrm{P_1V_1 = P_2V_2}$. So, $\Delta S = \mathrm{nRln(P_1/P_2)}$. Since the gas is being compressed under a constant pressure, $\mathrm{P_2 = P_1}$, and because $\ln(1) = 0$, $\Delta S = 0$.
d) You are incorrect. The entropy decreases for the compression ($\Delta S < 0$) because the volume is decreasing.
e) You are incorrect. The entropy increases ($\Delta S > 0$) for every part of this process since each step is spontaneous.

17. Which of the following best describes the values of ΔG for the expansion, compression, and overall?

a) For the expansion, $\Delta G = 0$, for the compression $\Delta G = 0$, and for the overall process, $\Delta G = 0$.
b) For the expansion, $\Delta G < 0$, for the compression $\Delta G > 0$, and for the overall process, $\Delta G < 0$.
c) For the expansion, $\Delta G > 0$, for the compression $\Delta G < 0$, and for the overall process, $\Delta G < 0$.
d) The signs for can vary for the compression and expansion, but for the overall process, $\Delta G < 0$.
e) For the expansion, $\Delta G < 0$, for the compression $\Delta G > 0$, and for the overall process, $\Delta G = 0$.

18. Consider that we carry out this process as a one-step isothermal expansion followed by a one-step isothermal compression of an ideal gas (again, to the original conditions of pressure and volume). What is the ratio (R) of work during the compression to work during the expansion?

That is, $\dfrac{\textit{work during the compression}}{\textit{work during the expansion}} = \mathrm{R}$

[✓ a) $\mathrm{R} < -1$] b) $\mathrm{R} = -1$ c) $-1 < \mathrm{R} < 1$ d) $\mathrm{R} = 1$ e) $\mathrm{R} > 1$

19. Which of the following two quantities have different magnitudes from each other for both the expansion and compression, but have the same signs and magnitudes as each other for the overall process of expansion and compression?

a) q and w
b) ΔE and ΔH
c) ΔS_{univ} and ΔG
[✓ d) ΔS_{surr} and ΔS_{univ}]
e) ΔS and ΔS_{univ}

20. How many of the following quantities are zero for the overall process of expansion and compression, but nonzero for the expansion and nonzero for the compression?

q, w, ΔE, ΔH, ΔS, ΔS_{surr}, ΔS_{univ}, and ΔG

a) 0 [✓ b) 2] c) 4 d) 6 e) 8