CHEMISTRY 202

Hour Exam II
October 27, 2022
Dr. D. DeCoste

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	(30 pts.)	_____
22	(30 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!

$\Delta S = nR\ln(V_2/V_1)$ $\Delta S = \Delta H/T$ $C_v = (3/2)R$ $C_p = (5/2)R$

$\Delta S = nC\ln(T_2/T_1)$ $\Delta G = \Delta G° + RT\ln(Q)$ $\Delta S_{surr} = -q/T$

$w = -P\Delta V$ $q_{rev} = nRT\ln(V_2/V_1)$ $q = nC\Delta T$

$\ln(K) = -\dfrac{\Delta H°}{R}\left(\dfrac{1}{T}\right) + \dfrac{\Delta S°}{R}$ $\ln\left(\dfrac{K_2}{K_1}\right) = -\dfrac{\Delta H°}{R}\left(\dfrac{1}{T_2} - \dfrac{1}{T_1}\right)$

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1.   The enthalpy of formation of $AB_2(l)$ from $A_2(g)$ and $B_2(g)$ at 298K is –301.4 kJ/mol.
      Determine ΔE for this process at 298K in units of kJ/mol.

      a) –294.0   b) –297.7   c) –298.9   d) –303.9   e) –305.1

2.   In a coffee-cup calorimeter, a 3.000-g sample of a salt (molar mass = 65.12 g/mol) is mixed
      with 100.0 g of water at an initial temperature of 25.0°C. After the salt dissolves, the
      temperature of the solution is 27.5°C. Assume the specific heat capacity of the solution is
      constant at 4.18 J/g°C that there is no heat transfer to or out of the calorimeter. Determine
      the enthalpy change for the dissolving of the salt kJ/mol.

      a) 1.076   b) 22.68   c) –22.68   d) 23.36   e) –23.36

3.   Consider 1.00 mole of an ideal monatomic gas in a 25.0-L container at a pressure of 4.50 atm.
      The gas expands isothermally to a volume of 100.0 L at constant pressure. Determine the
      ratio of [maximum work peformed:minimum work performed] for this expansion.

      a) 1.85   b) 2.43   c) 4.00   d) 5.63   e) 7.32

4.   You carry out an acid-base reaction in a Styrofoam cup calorimeter by mixing aqueous solutions of
      baking soda and vinegar, measuring the temperature (which decreases), and determining ΔH for
      the reaction in kJ/mol. Your lab partner carries out the same reaction in a bomb calorimeter,
      measures the temperature (also decreases), and determines ΔE for the reaction in kJ/mol. Which
      of the following best describes the relationship between ΔH and ΔE? The reaction in question is:

      $$NaHCO_3(aq) + HC_2H_3O_2(aq) \rightarrow NaC_2H_3O_2(aq) + H_2O(l) + CO_2(g)$$

      a)   The values for ΔH and ΔE are both negative and the magnitude of the value for ΔH is greater
            than the value for ΔE.
      b)   The values for ΔH and ΔE are both positive and the magnitude of the value for ΔH is greater
            than the value for ΔE.
      c)   The values for ΔH and ΔE are both positive and the magnitude of the value for ΔE is greater
            than the value for ΔH.
      d)   The values for ΔH and ΔE are both negative and the magnitude of the value for ΔE is greater
            than the value for ΔH.
      e)   The values for ΔH and ΔE are both negative and the magnitudes of the values for ΔH and ΔE
            do not differ significantly.

5.   You have ice in a freezer, take it out, place it on the counter in your kitchen, and forget about
      it. In which case is the value of ΔS_{univ} greatest for the process that occurs?

      a)   The freezer is set at –15°C and room temperature is 25°C.
      b)   The freezer is set at –15°C and room temperature is 0°C.
      c)   The freezer is set at –25°C and room temperature is 25°C.
      d)   The freezer is set at –15°C and room temperature is 35°C.
      e)   At least two of the ΔS_{univ} values would be the same.

6. The reaction represented by the chemical equation $H_2(g) + F_2(g) \rightarrow 2HF(g)$ is exothermic. What does this tell us?

    a) The bond energy of HF is higher than the average bond energies of H_2 and F_2.
    b) The average bond energies of H_2 and F_2 are higher than the bond energy of HF.
    c) Nothing about average bond energies.
    d) All bond energies are endothermic.
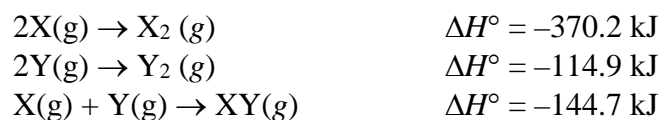   e) All bond energies are exothermic.

7. Consider the reaction between $NO_2(g)$ and $O_2(g)$ to produce $N_2O_5(g)$ at 25.0°C. Assuming $\Delta H°$ and $\Delta S°$ values are independent of temperature, determine the temperatures at which this reaction will occur spontaneously at 1 atm. Use the following data:

	$NO_2(g)$	$O_2(g)$	$N_2O_5(g)$
$\Delta H_f°$ (kJ/mol)	33.10		11.30
$S°$ (J/mol K)	240.0	205.2	346.6

    a) The process will only occur spontaneously above temperatures of about –40°C.
    b) The process will only occur spontaneously below temperatures of about –40°C.
    c) The process will only occur spontaneously above temperatures of about 40°C.
    d) The process will only occur spontaneously below temperatures of about 40°C.
    e) The process is spontaneous at any temperature.

8. In how many of the following cases is the sign of q negative?

    I.   An isothermal expansion of an ideal gas against a constant external pressure.
    II.   An isothermal reversible expansion of an ideal gas against a constant external pressure.
    III. An isothermal free expansion of an ideal gas.
    IV.   An isothermal phase change from a liquid to its vapor at its boiling point.
    V.   An isothermal spontaneous chemical reaction for which $\Delta S < 0$.

    a) 0   b) 1   c) 2   d) 4   e) 5

9. Using the following data, calculate the standard enthalpy of formation of the compound $XY(g)$ at 25°C in kJ/mol. The standard states of elements X and Y are $X_2(g)$ and $Y_2(g)$, respectively.

    $2X(g) \rightarrow X_2 (g)$ $\Delta H° = -370.2$ kJ
    $2Y(g) \rightarrow Y_2 (g)$ $\Delta H° = -114.9$ kJ
    $X(g) + Y(g) \rightarrow XY(g)$ $\Delta H° = -144.7$ kJ

    a) 48.93   b) 97.85   c) 170.2   d) 195.7   e) 340.4

10. Chloroform ($CHCl_3$) is a liquid at room temperature and has a boiling point of 61.7°C. The value of $\Delta H_{vaporization}$ for chloroform at its boiling point is 31.4 kJ/mol. Determine the value of $\Delta S_{univ} + \Delta S_{surr} + \Delta S$ for the vaporization of 1.00 mol of chloroform at 61.7°C.

    a) 0 J/K   b) 93.8 J/K   c) –93.8 J/K   d) 188 J/K   e) –188 J/K

11. A quantity of 11.50 kJ of heat is transferred to 1.000 mole of an ideal, monatomic gas in a rigid steel container at 25.0°C. Determine ΔS in J/K.

   a) 8.728   b) 11.72   c) 17.58   d) 21.82   e) 29.30

12. Determine the sign (positive, negative, or zero) for the given quantity in each of the processes described below. For how many of them is the sign positive?

   - The value of q for an isothermal compression of 1.00 mole of an ideal monatomic gas.
   - The value of ΔH for water vaporizing at 95.0°C and 1 atm.
   - The value of ΔS_{univ} for water vaporizing at 95.0°C and 1 atm.
   - The value of ΔS_{univ} for water freezing at 0°C and 1 atm.
   - The value of ΔG for the spontaneous isothermal compression of 1.00 mole of an ideal monatomic gas.
   - The value of ΔS for water freezing at 0°C and 1 atm.

   a) 0   b) 1   c) 2   d) 3   e) 4

13. A 500.0 g sample of water at 27.0°C is mixed with a 500.0 g sample of water at 73.0°C in an insulated container and allowed to come to thermal equilibrium. Assume the specific heat capacity of water is constant at 4.18 J/g°C and that there is no heat transfer to or out of the container. Determine ΔS_{univ} in J/K.

   a) 0   b) 10.62   c) 21.25   d) 30.14   e) 39.17

14-15. In lecture we looked at problem 122 from Chapter 9 to introduce the concept of entropy. In this problem, you have 2.4 moles of a gas (ideal monatomic) in a 4.0-L bulb at a temperature of 32°C. This bulb is connected to a 20.0-L sealed, initially evacuated bulb via a closed valve. The valve is opened.

14. Determine the value of ΔS_{univ} (in J/K) for the process that occurs.

   a) 0   b) 13.38   c) 14.90   d) 32.11   e) 35.75

15. Determine the value of ΔG (in kJ) for the process that occurs.

   a) 0   b) −10.90   c) −9.79   d) 9.79   e) 10.90

16-17. Consider a sample of 1.000 mol of an ideal monatomic gas taken from a condition of 3.000 atm and 20.00 L to 5.000 atm and 15.00 L in one step.

16. Determine the value of ΔH (in kJ/mol) for this process.

   a) 0   b) 2.280   c) −2.280   d) 3.799   e) −3.799

17. Determine the value of ΔE (in kJ/mol) for this process.

   a) 0   b) 2.280   c) −2.280   d) 3.799   e) −3.799

18-20.   Consider the reaction $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ at 25.0°C and the following data:

	$SO_2(g)$	$SO_3(g)$
ΔG_f° (kJ/mol)	−300.	−371

18.   You have a mixture of the three gases (SO_2, O_2, and SO_3) at equilibrium. How will the system respond to an increase in temperature?

a) Equilibrium will shift toward the left (producing more SO_2 and O_2).
b) Equilibrium will shift to the right (producing more SO_3).
c) Equilibrium will not shift.
d) Without more information there is no way to know how equilibrium will shift.

19.   Suppose you mix SO_2 and O_2 gases each at 2.00 atm in a rigid container and allow them to react to equilibrium at 25.0°C. Determine the equilibrium pressure of SO_3 gas.

a) 7.17 x 10^{-13} atm
b) 1.01 x 10^{-12} atm
c) 2.02 x 10^{-12} atm
d) 1.00 atm
e) 2.00 atm

20.   How does the value of the equilibrium constant at 50.0°C compare to the value of the equilibrium constant at 25.0°C?

a) The equilibrium constant at 50.0°C is greater than that at 25.0°C.
b) The equilibrium constant at 50.0°C is less than that at 25.0°C.
c) The equilibrium constant at 50.0°C is the same as that at 25.0°C.
d) Without more information there is no way to know how the equilibrium constant will change.

21. We discussed in the videos and in lecture about the isothermal compression and expansion of an ideal, monatomic gas. We discussed this by considering the gas in a container fitted with a piston for which a weight added to the top of the piston (causing the compression of the gas) and then the weight was removed (allowing for the expansion):

State A   →   State B   →   State C
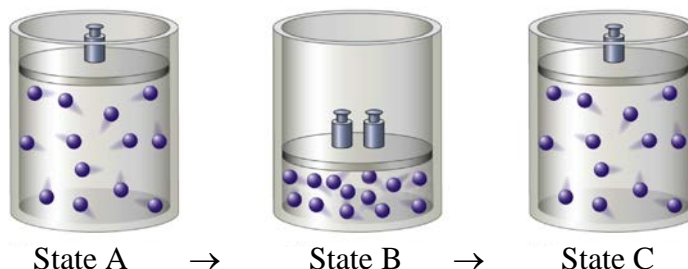
The overall goal for this question is to **show and explain/justify** whether or not the compression and/or the expansion are **spontaneous processes**.

Make sure to discuss how/if the **gas sample** and the **universe have been changed** as the gas goes from State A to State C as shown above.

Your answers (for the compression, expansion, and overall) should include:

- **Determining** and **explaining/justifying** the **signs** (positive, negative, or zero) of:
  - ΔH
  - ΔE
  - q
  - w
  - ΔS
  - ΔS_{surr}
  - ΔS_{univ}
  - ΔG

- **Determining** and **explaining/justifying** the **relative magnitudes** of q and w.
- **Determining** and **explaining/justifying** the **relative magnitudes** of ΔS and ΔS_{surr}.

Use PV diagrams like the ones discussed in the videos, textbook, and lectures, and a **discussion of w_{rev} and q_{rev}** to **support your answers**.

Full credit is reserved for a logical and systematic presentation of ideas. [30 points]

PLEASE INCLUDE YOUR ANSWERS ON THE FOLLOWING PAGES

21.   a.   Use the space below to discuss the **compression** of the gas. **[11 points]**

See lectures, videos, and the textbook.

21. b.   Use the space below to discuss the **expansion** of the gas. **[11 points}**

See lectures, videos, and the textbook.

21.   c.   Use the space below to discuss the **overall results** of the compression and expansion of
           the gas. **[8 points]**

See lectures, videos, and the textbook.

22. The overall goal for this problem is to quantitatively support the fact that the freezing of water is not spontaneous at 5.0°C and 1 atm. Suppose you are given the following information:

- ΔH_f° for $H_2O(s)$ and for $H_2O(l)$.
- Heat capacity for $H_2O(s)$ and for $H_2O(l)$.
- The melting point of water

We will make the assumption that the heat capacity values are independent of temperature, but we will not assume that the ΔH_f° values are independent of temperature.

a. Before you begin calculating anything, **explain the process** you will follow. **How will you prove spontaneity**? **Explain/justify what you will need** to determine along the way to evaluating spontaneity, **how you will get there**, and **defend your answers**.

Full credit is reserved for a logical, systematic description of the process. **[10 points]**

See lectures, videos, and the textbook.

22. b. Use the numbers given below to show that the freezing of water is not spontaneous at 5.0°C and 1 atm. **Show all work** and **explain how** your quantitative answer supports non-spontaneity. Use the following page if needed. **[20 points]**

- ΔH_f° for $H_2O(s)$ = –290.90 kJ/mol
- ΔH_f° for $H_2O(l)$ = –285.83 kJ/mol
- Heat capacity for $H_2O(s)$ = 37.5 J/Kmol
- Heat capacity for $H_2O(l)$ = 75.3 J/Kmol
- Melting point of water = 0°C, 1 atm

ΔH at 273K for $H_2O(l) \rightarrow H_2O(s)$ = **–4.125 kJ**

ΔS at 273K = **–15.11 J/K**

ΔS at 278K for $H_2O(l) \rightarrow H_2O(s)$ = **–15.80 J/K**
ΔH at 278K for $H_2O(l) \rightarrow H_2O(s)$ = **–4.314 kJ**

ΔS_{surr} at 278K = 15.52/K

ΔS_univ = **–0.28 J/K (negative so not spontaneous)**

ΔG = **+78 J (positive so not spontaneous)**

22.   b.   Use this page, if needed, for additional work.