CH301 Practice Exam 3

1. Theory: First Law of Thermodynamic
Which of the following statements is/are true concerning the first law of thermodynamics?

I. The internal energy of the universe may increase, decrease, or stay the same for a given process, depending on the changes in enthalpy and entropy.

II. Chemists often consider the universe to be made up of two things: the system and the surroundings (aka everything in existence other than the system)

III. If the energy of a system increases, then the energy of the surroundings must also increase to compensate.

1. I only
2. II only
3. III only
4. I and II
5. I and III
6. II and III
7. I, II and III

2. Definition: Enthalpy
Which of the following is **not** a correct description of enthalpy or change in enthalpy?

1. In the absence of gas, $\Delta H \sim \Delta E$.
2. $\Delta H = q$ in a closed system.
3. Enthalpy is an indirect measure of the change in entropy of the surroundings.
4. In an open system, $\Delta H = q$ so the change in enthalpy is a path function, not a state function.

3. Signs for thermodynamic quantities
Ice melts at 50 °C, changing from ice (s) to water (l). Which of the following statements about the signs of the process are true?

I. Work w is positive (but small).
II. Heat q is positive.
III. The change in free energy is positive.
IV. The change in entropy is positive.

1. I only
2. III only
3. IV only
4. I and II
5. III and IV
6. I, II and IV

4. Definition: state functions
Which of the following quantities is **not** a path function? Choose the **best** answer.

1. Both enthalpy (H) and pressure (P).
2. work (w)
3. enthalpy (H)
4. pressure (P)
5. Both heat (q) and work (w).
6. heat (q)
7. Both enthalpy (H) and heat (q).

5. Definition: Heats of formation

Which of the following reactions **is** an enthalpy of formation reaction?

1. $2K(s) + F_2(g) \rightarrow 2KF(s)$
2. $K(g) + 1/2F_2(g) \rightarrow KF(s)$
3. $K(s) + 1/2F_2(g) \rightarrow KF(s)$
4. $KF(s) \rightarrow K(s) + 1/2F_2(g)$

6. Definition: Heat capacity

It will take ____ (more/less) energy to raise the temperature of 10 g of water than 1 g of nickel because _____________?

1. more; it has a higher specific heat capacity and more mass
2. more; it has a higher specific heat capacity
3. less; it has a lower specific heat capacity and more mass
4. less; it has more mass

7. Calculation: Bomb calorimeter

You set up a bomb calorimetry experiment using 2 liter of water as your heat sink and combust a 12.2122 g sample of benzoic acid (C_6H_5COOH). If the initial and final temperature are 10.00 °C and 48.57 °C respectively, what is the molar enthalpy of combustion of benzoic acid? (Assume the calorimeter itself absorbs no heat [aka the heat capacity of the calorimeter is zero] and assume the density of water is 1 g·mL). Remember that the specific heat capacity of water is 4.184 $J\ g^{-1}\ K^{-1}$.

1. $-3{,}228\ J{\cdot}mol^{-1}$
2. $-322.8\ kJ{\cdot}mol^{-1}$
3. $-322.8\ J{\cdot}mol^{-1}$
4. $-3{,}228\ kJ{\cdot}mol^{-1}$
5. $-32.28\ kJ{\cdot}mol^{-1}$

8. Calculation: Hess' Law and heats of formation

Which of the following correctly mathematically describe how to calculate ΔH_{rxn} for the following generalized reaction?

$A + 2B \square 3C + D$

1. $\Delta H_{rxn} = [\Delta H_f(C) + \Delta H_f(D)] - [\Delta H_f(A) + \Delta H_f(B)]$
2. $\Delta H_{rxn} = [1*\Delta H_f(C) + 2*\Delta H_f(D)] - [3*\Delta H_f(A) + 1*\Delta H_f(B)]$
3. $\Delta H_{rxn} = [3*\Delta H_f(A) + 1*\Delta H_f(B)] - [1*\Delta H_f(C) + 2*\Delta H_f(D)]$
4. $\Delta H_{rxn} = [1*\Delta H_f(A) + 2*\Delta H_f(B)] - [3*\Delta H_f(C) + 1*\Delta H_f(D)]$
5. $\Delta H_{rxn} = [3*\Delta H_f(C) + 1*\Delta H_f(D)] - [1*\Delta H_f(A) + 2*\Delta H_f(B)]$

9. Calculation: Hess's Law and combined reaction enthalpies

Given the following data:

$CH_2CO(g) + 2O_2(g) \square 2CO_2(g) + H_2O(g)$ $\Delta H = -981.1\ kJ{\cdot}mol^{-1}$
$CH_4(g) + 2\ O_2(g) \square CO_2(g) + 2H_2O(g)$ $\Delta H = -802.3\ kJ{\cdot}mol^{-1}$

calculate ΔH for the reaction

$2CH_4(g) + 2O_2(g) \square CH_2CO(g) + 3H_2O(g)$

1. $-623.5\ kJ{\cdot}mol^{-1}$
2. $623.5\ kJ{\cdot}mol^{-1}$
3. $-1783.4\ kJ{\cdot}mol^{-1}$
4. $1783.4\ kJ{\cdot}mol^{-1}$
5. $178.8\ kJ{\cdot}mol^{-1}$

10. Calculation: Statistical mechanics determination of internal energy
How much energy would be associated with the motion of 2.5 moles of methane (CH_4)?

1. 3.75RT
2. 3.75kT
3. 18.75RT
4. 18.75kT
5. 7.5kT

11. Calculation: Bond energies
You will need the following data
C-C 348 kJ mol^{-1}
C-H 413 kJ mol^{-1}
O=O 498 kJ mol^{-1}
C=O 728 kJ mol^{-1}
O-H 463 kJ mol^{-1}
Using bond enthalpy data, calculate the change in enthalpy for the following reaction.

$C_3H_8(g) + 5O_2(g)$ ☐ $3CO_2(g) + 4H_2O(g)$

1. -1322 kJ mol^{-1}
2. 1322 kJ·mol^{-1}
3. -496 kJ·mol^{-1}
4. 496 kJ·mol^{-1}
5. 1582 kJ·mol^{-1}
6. -1582 kJ·mol^{-1}

12. Calculation: Work calculation
Consider the hypothetical reaction below and approximate the value of the work function at room temperature.

$18A(l) + 5B(g)$ ☐ $6C(g) + 14D(l)$

1. 2.5 kJ
2. 5 kJ
3. -2.5 kJ
4. -5 kJ
5. 0 kJ

13. Definition: Internal Energy
Which of the following is **not** a definition of internal energy or change in internal energy?

1. An intensive path function.
2. $\Delta U = q_V$
3. The difference between the final and initial internal energy of a system.
4. $\Delta U = q + w$

14. Theory: Calorimetry
Which of the following statements concerning calorimetry is/are true?
I. One calorie is the same thing as one Calorie.
II. Calorimetry is done at constant volume.
III. In real life, we must compensate for heat lost to the calorimeter.

1. I only
2. II only
3. III only
4. I and II
5. I and III
6. II and III only

15. Calculation: Internal Energy calculation (q and w)
If the car from the Jetsons does 11000 kJ of work and absorbs 10 kJ of heat (it's the FUTURE, anything could happen…), what is the change in internal energy for the car?

   1. -10990 kJ
   2. +11010 kJ
   3. 10990 kJ
   4. -11010 kJ

16. Ranking: Predicting entropy change in a chemical reaction
Rank the following reactions from least to greatest in terms of change in entropy (ΔS_{rxn}):

a. $2H_{2(g)} + O_{2(g)}$ ☐ $2H_2O_{(s)}$
b. $2Na_{(s)} + O_{2(g)}$ ☐ $2NaO_{(s)}$
c. $C_6H_{12}O_{6(s)} + 6O_{2(g)}$ ☐ $6H_2O_{(g)} + 6CO_{2(g)}$
d. $MgCO_{3(s)}$ ☐ $MgO_{(s)} + CO_{2(g)}$

   1. a<c<b<d
   2. a<b<d<c
   3. c<d<b<a
   4. d<b<c<a

17. Calculation: Entropy change at a phase transition
An unknown compound X was discovered on mars. The standard molar entropy is 300 $J\cdot mol^{-1}\cdot K^{-1}$ for X(g), 100 $J\cdot mol^{-1}\cdot K^{-1}$ for X(l), and 30 $J\cdot mol^{-1}\cdot K^{-1}$ for X(s),. What is the change in entropy for the melting of X?

1. 70 $J\cdot mol^{-1}\cdot K^{-1}$
2. -100 $J\cdot mol^{-1}\cdot K^{-1}$
3. -80 $J\cdot mol^{-1}\cdot K^{-1}$
4. -500 $J\cdot mol^{-1}\cdot K^{-1}$

18. Theory: Second and Third Laws of Thermodynamic
Which of the following statements concerning the second and third laws of thermodynamics is/are true?

I. Entropy can be zero at a certain temperature
II. $\Delta G_{sytem} = -T\Delta S_{universe}$
III. The universe is getting less ordered because $\Delta S_{universe}$ is always negative.

   1. I
   2. II only
   3. III only
   4. I and II only
   5. I and III only
   6. II and III only
   7. I, II and III

19. Theory: Statistical thermodynamics and entropy
When calculating the positional entropy of a system using the Boltzmann formula ($S = k\ln(W)$, which of the following statements is/are true?

I. Presence of intermolecular force decreases the complexity (W) of the system.
II. The absolute entropy can be negative.
III. Two water molecules would have twice the positional entropy as a single water molecule.

   1. I
   2. II only
   3. III only
   4. I and II only

5. I and III only
6. II and III only
7. I, II and III

20. Calculation: Statistical thermodynamics and entropy
What is the positional entropy of 5 moles of CH_3F at absolute zero?
1. 57.6 $J{\cdot}K^{-1}$
2. 10.1 $J{\cdot}K^{-1}$
3. $9.56x10^{-23}$ $J{\cdot}K^{-1}$
4. $3.03x10^{-23}$ $J{\cdot}K^{-1}$

21. Ranking: Statistical thermodynamics, ranking molar entropy in a compound
Rank the following compounds in terms of decreasing molar entropy: CO_2(g), CO_2(l), CO_2(s), CO(l).
1. CO_2 (g) > CO_2 (l)> CO (l)> CO_2 (s)
2. CO_2 (l) > CO_2 (g)> CO (l)> CO_2 (s)
3. CO_2 (s) > CO (l)> CO_2 (l)> CO_2 (g)
4. CO_2 (g) > CO (l)> CO_2 (l)> CO_2 (s)

22. Problem: Non-ideality and absolute entropy
Assuming you have one mole of each of the following, rank them in terms of decreasing value of the term W in the Boltzmann equation: HCl, HF, CN.
1. CN > HCl > HF
2. HCl > CN > HF
3. HF > HCl>CN
4. HF > HCl >CN

23. Calculation of ΔS from heat transfer
If a system at 1000 °C absorbs 1000 J of heat, what is its change in entropy?
1. -0.79 $J{\cdot}K^{-1}$
2. -1 $J{\cdot}K^{-1}$
3. 0.79 $J{\cdot}K^{-1}$
4. 1 $J{\cdot}K^{-1}$

24. Calculation involving the second law equation
An unknown compound Y was found on Mars. The S°m for Y(s) and Y(g) are 300 $J{\cdot}mol^{-1}{\cdot}K^{-1}$ and 100 $J{\cdot}mol^{-1}{\cdot}K^{-1}$, respectively. Y naturally sublimes at 100K. But what is $\Delta S_{universe}$ for the sublimation of Y at 50K?
1. -200 $J{\cdot}mol^{-1}{\cdot}K^{-1}$
2. 200 $J{\cdot}mol^{-1}{\cdot}K^{-1}$
3. 150 $J{\cdot}mol^{-1}{\cdot}K^{-1}$
4. 175 $J{\cdot}mol^{-1}{\cdot}K^{-1}$

25. Calculation involving the second law equation
If a given process increases the entropy of the universe by 5,000 $J{\cdot}K^{-1}$ while the entropy of the system decreases by 3,000 $J{\cdot}K^{-1}$, what must the change in entropy of the surroundings?
1. 10,000 $J{\cdot}K^{-1}$
2. 8,000 $J{\cdot}K^{-1}$
3. -10,000 $J{\cdot}K^{-1}$
4. -8,000 $J{\cdot}K^{-1}$

26. Calculation of phase transition temperature using the Gibbs equation at equilibrium
Compound Z has ΔH°_{fusion} = 10 kJ·mol^{-1} and ΔS°_{fusion} = 80 J·mol^{-1}·K^{-1}. What is the normal melting point of Z expressed in centigrade?

1. 125 °C
2. -125 °C
3. 148 °C
4. -148 °C

27. Theory: The temperature dependence of ΔGro
For a given reaction, if ΔH°_{rxn} is positive and ΔS°_{rxn} is negative, then the value of ΔG°_{rxn} will always ___ as you decrease the temperature.

1. Decrease
2. Increase
3. Both of the above
4. Undetermined

28. Problem: temperature dependence of reaction spontaneity for a chemical reaction
Which of the following reactions ONLY occurs at low temperature?

I. H_2O (l) ☐ H_2O (s)
II. CO_2(s) ☐ CO_2(g)
III. C_3H_8(g) + $5O_2$(g) ☐ $3CO_2$(g) + $4H_2O$(g)

1. I only
2. II only
3. III only
4. I, II, and III.

29. Problem: predicting compound stability from ΔGro
Consider the reaction below:

X(s) + Y(g) ☐ Z(s) ΔG°_{rxn} = -100 kJ·mol^{-1} at room temperature.

How would you characterize the stability of Z at room temperature?

1. Stable
2. Not Stable
3. Not enough information

30. Calculation: ΔGro from table values of ΔHfo and Sfo
Exam
Consider the reaction below:

A + B ☐ C + D

Using the provided table values, calculate ΔG°_{rxn} if it is performed under standard conditions.

	ΔH°_f (kJ·mol^{-1})	ΔS°_m (J·mol^{-1}·K^{-1})
A	-100	200
B	-400	150
C	100	200
D	200	250

1. 773 kJ·mol^{-1}
2. 750 kJ·mol^{-1}
3. 800 kJ·mol^{-1}
4. -1000 kJ·mol^{-1}