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version

last name ______ first name ______ signature ______

McCord CH301
49970 / 49975

Exam 4

Fall 2016

Remember that the bubble sheet has the periodic table on the back.

Thermodynamic Data at 25°C

Substance	ΔH_f° kJ/mol	S° J/mol K
Br_2 (ℓ)	—	152
Br_2 (g)	31	245
C_3H_8 (g)	-104	270
C_5H_{12} (ℓ)	-174	263
Cl_2 (g)	—	223
HNO_3 (aq)	-207	146
H_2O (ℓ)	-286	70
H_2O (g)	-242	189
NH_4NO_3 (s)	-366	151
NO_2 (g)	33	240
NO (g)	90	211
N_2H_4 (ℓ)	51	12
N_2O (g)	82	220
O_2 (g)	—	205

Single Bond Energies (kJ/mol)

	H	C	N	O	S	Br
H	436					
C	413	346				
N	391	305	163			
O	463	358	201	146		
S	347	272	—	—	226	
Br	366	285	—	201	217	193

Multiple Bond Energies (kJ/mol)

C=C 602	C=N 615	C=O 799
C≡C 835	C=S 577	C≡O 1072
N=N 418	O=O 498	N≡N 945

Some Physical Properties

property		H_2O	CH_3OH
density	g/mL	1.000	0.792
$C_{s,solid}$	J/g K	2.09	—
$C_{s,liquid}$	J/g K	4.184	2.533
$C_{s,gas}$	J/g K	2.03	—
ΔH_{fus}	J/g	334	102
ΔH_{vap}	J/g	2022	1226
T_{mp}	°C	0	−98
T_{bp}	°C	100	65

NOTE: Please keep your Exam copy intact (all pages still stapled). You must turn in your exam copy, bubble sheet, and scratch paper.

This print-out should have 27 questions. Multiple-choice questions may continue on the next column or page – find all choices before answering.

001 4.0 points

Which one of the processes listed below (if any) have a positive value for ΔS ?

1. The condensation of water droplets on an ice cold drink.

2. Rubbing alcohol (isopropanol) evaporating from your skin.

3. None of the choices here have a positive ΔS.

4. The formation of ice crystals from water in a freezer compartment.

002 2.0 points

Which of the following statements is true?

1. The standard molar entropy of an element in its standard state is zero.

2. The change in the entropy of the system is always positive for a spontaneous process.

3. The magnitude of the entropy change of the system will always equal the magnitude of the entropy change for the surroundings for all phase changes.

4. The Gibb′s free energy change of the system must be positive for a spontaneous process.

5. The magnitude of the heat released by the system will equal the magnitude of the heat absorbed by the surroundings.

003 4.0 points

A student runs a reaction in a closed system. In the course of the reaction, 64.7 kJ of heat is released to the surroundings and 14.3 kJ of work is done on the system. What is the change in internal energy (ΔU) of the reaction?

1. -50.4 kJ

2. -79.0 kJ

3. 50.4 kJ

4. 90.4kJ

5. 79.0 kJ

004 2.0 points

A system that can exchange energy but not matter with the surroundings is termed:

1. Isolated

2. Closed

3. Open

005 4.0 points

Which of the following have standard Gibbs free energy of formation values equal to zero?

$N_2(g)$ $O_2(\ell)$ $Ar(\ell)$ $CO_2(g)$ $He(g)$

1. $N_2(g)$, $CO_2(g)$, and $He(g)$

2. $N_2(g)$ and $He(g)$

3. $Ar(\ell)$ and $He(g)$

4. $O_2(\ell)$ and $Ar(\ell)$

5. $N_2(g)$, $O_2(\ell)$, $Ar(\ell)$, and $He(g)$

006 4.0 points

Calculate the approximate boiling point of chloroform, $CHCl_3$, given the following data:

$\Delta H_{\text{vap}} = 31.4$ kJ mol^{-1}

$\Delta S_{\text{vap}} = 93.6$ J mol^{-1} K^{-1}

1. 665 K

2. 59.3 K

3. 298 K

4. 335 K

5. 0.34 K

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007 4.0 points

Calculate $\Delta G°$ for the following reaction at 298 K.

$$NH_4NO_3(s) \rightarrow N_2O(g) + 2H_2O(g)$$

1. −169 kJ

2. −113 kJ

3. −130 kJ

4. +169 kJ

5. -1.33×10^5 kJ

6. +97.2 kJ

7. +130 kJ

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008 4.0 points

What is responsible for the solubility of substances that dissolve endothermically?

1. The decrease in the entropy of the system.

2. The negative value of q_{sys} for the dissolution process.

3. The increase in entropy of the system.

4. The large amount of heat absorbed by the surroundings for the process.

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009 4.0 points

Consider a system where 2.50 L of ideal gas expands to 6.25 L against a constant external pressure of 330 torr. Calculate the work (w) for this system.

1. −1.63 J

2. +1.63 J

3. +165 J

4. −165 J

5. −1238 J

6. +1238 J

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010 4.0 points

Methyl tert-butyl ether or MTBE is an octane booster for gasoline. The combustion of 0.9211 grams of MTBE ($C_5H_{12}O(\ell)$, 88.15 g/mol) is carried out in a bomb calorimeter. The calorimeter's hardware has a heat capacity of 1.540 kJ/°C and is filled with exactly 2.022 L of water. The initial temperature was 26.336°C. After the combustion, the temperature was 29.849°C. Analyze this calorimeter data and determine the molar internal energy of combustion (ΔU) for this octane booster.

1. -4293 kJ/mol

2. -3362 kJ/mol

3. -2748 kJ/mol

4. -3120 kJ/mol

5. -3560 kJ/mol

6. -2286 kJ/mol

7. -1957 kJ/mol

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011 4.0 points

What is the change in entropy (ΔS) for the heating of 20.0 grams of methanol (CH_3OH, liquid) from 34°C to 62°C?

1. 168.81 J/K

2. 0 J/K

3. -30.42 J/K

4. 0.22 J/K

5. 1418 J/K

6. 4.42 J/K

7. 30.42 J/K

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012 4.0 points

2.26 g of liquid water at 23.5 °C was completely converted to ice at 0 °C. How much heat was (absorbed/released) by the system during this process?

1. 755 J; absorbed

2. 755 J; released

3. 1478 J; absorbed

4. 977 J; released

5. 977 J; absorbed

6. 1478 J; released

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013 4.0 points

Which of the following compounds would you expect to have the highest S° ?

1. $H_2O_2(\ell)$

2. Ar(g)

3. $C_6H_{14}(\ell)$

4. CH_3F(g)

5. CH_4(g)

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014 4.0 points

An important reaction that takes place in the atmosphere is

$$NO_2(g) \longrightarrow NO(g) + O(g)$$

which is brought about by sunlight. Calculate the standard enthalpy of the reaction from the following information

reaction	ΔH° (kJ)
$O_2(g) \rightarrow 2\,O(g)$	+498.4
$NO(g) + O_3(g) \longrightarrow NO_2(g) + O_2(g)$	−200.0
$\frac{3}{2}O_2(g) \longrightarrow O_3(g)$	+142.7

1. 106.5 kJ

2. 963.8 kJ

3. 306.5 kJ

4. 820.5 kJ

5. 555.7 kJ

6. 449.2 kJ

7. 320.2 kJ

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015 0.0 points

Extra Point Question: Bubble in choice 1 and you might just get some extra points on this exam if we decide to grant them.

1. Correct!

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016 4.0 points

Calculate the change in entropy when 3.28 moles of an ideal gas are compressed isothermally such that the volume changes from 14.4 L to 3.6 L.

1. −37.8 J/K

2. −32.2 J/K

3. +24.7 J/K

4. −56.7 J/K

5. −16.4 J/K

6. +38.1 J/K

7. −11.5 J/K

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017 4.0 points

For which of the following chemical equations would $\Delta H^\circ_{\text{rxn}} = \Delta H^\circ_{\text{f}}$?

1. $O_2(g) + H_2(g) \rightarrow H_2O_2(\ell)$

2. C(s, graphite) + $\frac{3}{2}O_2(g) + H_2(g) \rightarrow CO_2(g) + H_2O(g)$

3. $CO(g) + \frac{1}{2}O_2(g) \rightarrow CO_2(g)$

4. $N_2(\ell) + 3\ F_2(g) \rightarrow 2\ NF_3(\ell)$

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018 4.0 points

The oxidation of sugar to carbon dioxide and water is a spontaneous chemical reaction. Since we know that reactions that occur spontaneously in one direction cannot occur spontaneously in the reverse direction, how can we understand photosynthesis?

1. Thermodynamics does not apply to living systems.

2. Thermodynamics deals only with closed systems; photosynthesis is an open system.

3. It is not a spontaneous chemical reaction; it is driven by an external source of energy – light.

4. Thermodynamics does not apply to photochemical reactions.

5. This reaction is characterized by an energy change so close to zero that it is essentially reversible.

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019 4.0 points

When water condenses, what are the signs for q, w, and ΔS_{sys}, respectively?

1. $-, +, +$

2. $-, +, -$

3. $+, +, +$

4. $+, -, -$

5. $+, +, -$

6. $+, -, +$

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020 4.0 points

Calculate the ΔS_{surr} for the following reaction at 25°C and 1 atm.

$Br_2(\ell) \rightarrow Br_2(g)$ $\qquad \Delta H^\circ_{\text{rxn}} = +31$ kJ

1. −104 J/K

2. −93 J/K

3. +93 J/K

4. +104 J/K

5. +124 J/K

6. −124 J/K

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021 4.0 points

The two reactions shown below are both endothermic. For which reaction is $\Delta H < \Delta U$?

$N_2(g) + O_2(g) \rightarrow 2NO(g)$

$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$

1. $N_2(g) + O_2(g) \rightarrow 2NO(g)$

2. Both reactions have $\Delta H < \Delta U$.

3. $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$

4. Neither reaction has $\Delta H < \Delta U$.

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022 4.0 points

Calculate the standard reaction enthalpy ($\Delta H^\circ_{\text{rxn}}$) for the final stage in the production of nitric acid, when nitrogen dioxide dissolves in and reacts with water:

$$3NO_2(g) + H_2O(\ell) \rightarrow 2HNO_3(aq) + NO(g)$$

1. −137 kJ

2. −304 kJ

3. −104 kJ

4. −370 kJ

5. +136 kJ

6. +70 kJ

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023 4.0 points

The absolute entropy of a system (S measured in J/K) is related to the number of microstates in that system. Consider the three processes listed below. Which one(s) will result in an increase in the number of microstates in the system?

I) The temperature of a gas is raised by 3°C.

II) A fixed amount of gas is allowed to expand to a slightly larger volume.

III) The total number of gas molecules in a system is reduced to a smaller number.

1. I only

2. II and III only

3. I and II only

4. III only

5. I, II, and III

6. I and III only

7. II only

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024 4.0 points

You have two liquids of identical mass, and both with initial temperatures of 15°C. One is ethanol, C_2H_5OH, with a specific heat of 2.46 J/g°C and the other is benzene, C_6H_6, with a specific heat of 1.74 J/g°C. If both liquids absorb the same amount of heat, which one will have the highest final temperature? Assume that neither liquid reaches its boiling point.

1. Cannot tell without more information given.

2. ethanol

3. benzene

4. Both liquids will have the same final temperature.

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025 4.0 points

Consider a chemical reaction that is endothermic and has a negative change in entropy. Which of the following is/are true?

I) ΔS_{univ} is negative at all temperatures.

II) This reaction will reach equilibrium when $T = \Delta H/\Delta S$.

III) The reaction is spontaneous only at relatively high temperatures.

IV) ΔG is positive at all temperatures.

1. I and II only

2. III only

3. I, III, and IV only

4. I and IV only

5. I, II, III, and IV

6. II and III only

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026 4.0 points

For the combustion reaction of ethylene (C_2H_4)

$$C_2H_4 + 3\,O_2 \rightarrow 2\,CO_2 + 2\,H_2O$$

assume all reactants and products are gases, and calculate the ΔH^0_{rxn} using bond energies.

1. 251 kJ/mol

2. 0 kJ/mol

3. −1300 kJ/mol

4. 680 kJ/mol

5. −251 kJ/mol

6. 1300 kJ/mol

7. −680 kJ/mol

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027 4.0 points

Consider a thermodynamic system that is simultaneously releasing heat and doing work. The internal energy of this system will:

1. Increase

2. Decrease

3. Increase, decrease, or stay the same depending on the magnitudes of heat and work

4. Stay exactly the same.