

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	$\Delta H_f^\circ$ kJ/mol	$S^\circ$ J/mol K
Br <sub>2</sub> (ℓ)	—	152
Br <sub>2</sub> (g)	31	245
C <sub>3</sub> H <sub>8</sub> (g)	-104	270
C <sub>5</sub> H <sub>12</sub> (ℓ)	-174	263
Cl <sub>2</sub> (g)	—	223
HNO <sub>3</sub> (aq)	-207	146
H <sub>2</sub> O (ℓ)	-286	70
H <sub>2</sub> O (g)	-242	189
NH <sub>4</sub> NO <sub>3</sub> (s)	-366	151
NO <sub>2</sub> (g)	33	240
NO (g)	90	211
N <sub>2</sub> H <sub>4</sub> (ℓ)	51	12
N <sub>2</sub> O (g)	82	220
O <sub>2</sub> (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 <sub>2</sub> O	CH <sub>3</sub> OH
density	g/mL	1.000	0.792
$C_{s,\text{solid}}$	J/g K	2.09	—
$C_{s,\text{liquid}}$	J/g K	4.184	2.533
$C_{s,\text{gas}}$	J/g K	2.03	—
$\Delta H_{\text{fus}}$	J/g	334	102
$\Delta H_{\text{vap}}$	J/g	2022	1226
$T_{\text{mp}}$	°C	0	-98
$T_{\text{bp}}$	°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.

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**001 4.0 points**

Which one of the processes listed below (if any) have a positive value for  $\Delta S$  ?

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  $\Delta S$ .
4. The formation of ice crystals from water in a freezer compartment.

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**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.

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**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 ( $\Delta U$ ) of the

reaction?

1. -50.4 kJ
2. -79.0 kJ
3. 50.4 kJ
4. 90.4kJ
5. 79.0 kJ

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**004 2.0 points**

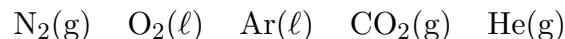
A system that can exchange energy but not matter with the surroundings is termed:

1. Isolated
2. Closed
3. Open

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**005 4.0 points**

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



1.  $\text{N}_2(\text{g})$ ,  $\text{CO}_2(\text{g})$ , and  $\text{He}(\text{g})$
2.  $\text{N}_2(\text{g})$  and  $\text{He}(\text{g})$
3.  $\text{Ar}(\ell)$  and  $\text{He}(\text{g})$
4.  $\text{O}_2(\ell)$  and  $\text{Ar}(\ell)$
5.  $\text{N}_2(\text{g})$ ,  $\text{O}_2(\ell)$ ,  $\text{Ar}(\ell)$  , and  $\text{He}(\text{g})$

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**006 4.0 points**

Calculate the approximate boiling point of chloroform,  $\text{CHCl}_3$ , given the following data:

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

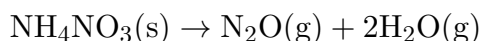
$$\Delta S_{\text{vap}} = 93.6 \text{ J mol}^{-1} \text{ K}^{-1}$$

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  $\Delta G^\circ$  for the following reaction at 298 K.

1. -169 kJ

2. -113 kJ

3. -130 kJ

4. +169 kJ

5.  $-1.33 \times 10^5$  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  $q_{\text{sys}}$  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 ( $\text{C}_5\text{H}_{12}\text{O}(\ell)$ , 88.15 g/mol) is carried out in a bomb calorimeter. The calorimeter's hardware has a heat capacity of 1.540 kJ/ $^\circ\text{C}$  and is filled with exactly 2.022 L of water. The initial temperature was 26.336 $^\circ\text{C}$ . After the combustion, the temperature was 29.849 $^\circ\text{C}$ . Analyze this calorimeter data and determine the molar internal energy of combustion ( $\Delta U$ ) 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 ( $\Delta S$ ) for the heating of 20.0 grams of methanol ( $\text{CH}_3\text{OH}$ , liquid) from 34 $^\circ\text{C}$  to 62 $^\circ\text{C}$ ?

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  $S^\circ$  ?

1.  $\text{H}_2\text{O}_2(\ell)$ 2.  $\text{Ar}(\text{g})$ 3.  $\text{C}_6\text{H}_{14}(\ell)$ 4.  $\text{CH}_3\text{F}(\text{g})$ 5.  $\text{CH}_4(\text{g})$ 

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**014 4.0 points**

An important reaction that takes place in the atmosphere is



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

reaction  $\Delta H^\circ$  (kJ)

$\text{O}_2(\text{g}) \rightarrow 2\text{O}(\text{g})$  +498.4

$\text{NO}(\text{g}) + \text{O}_3(\text{g}) \longrightarrow \text{NO}_2(\text{g}) + \text{O}_2(\text{g})$  -200.0

$\frac{3}{2}\text{O}_2(\text{g}) \longrightarrow \text{O}_3(\text{g})$  +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

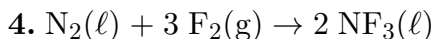
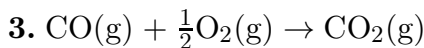
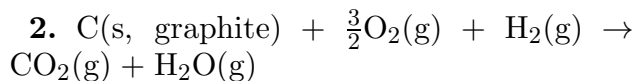
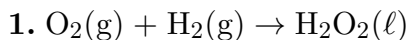
6. +38.1 J/K

7. -11.5 J/K

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**017 4.0 points**

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




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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  $\Delta S_{\text{sys}}$ , respectively?

1.  $-$ ,  $+$ ,  $+$

2.  $-$ ,  $+$ ,  $-$

3.  $+$ ,  $+$ ,  $+$

4.  $+$ ,  $-$ ,  $-$

5.  $+$ ,  $+$ ,  $-$

6.  $+$ ,  $-$ ,  $+$

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**020 4.0 points**

Calculate the  $\Delta S_{\text{surr}}$  for the following reaction at  $25^\circ\text{C}$  and 1 atm.



1.  $-104 \text{ J/K}$

2.  $-93 \text{ J/K}$

3.  $+93 \text{ J/K}$

4.  $+104 \text{ J/K}$

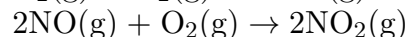
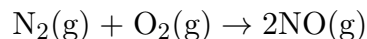
5.  $+124 \text{ J/K}$

6.  $-124 \text{ J/K}$

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**021 4.0 points**

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



1.  $\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{NO}(\text{g})$

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

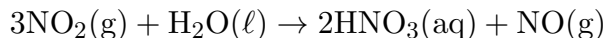
3.  $2\text{NO}(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{NO}_2(\text{g})$

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

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**022 4.0 points**

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



1.  $-137 \text{ kJ}$

2.  $-304 \text{ kJ}$

3.  $-104 \text{ kJ}$

4.  $-370 \text{ kJ}$

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<sub>2</sub>H<sub>5</sub>OH, with a specific heat of 2.46 J/g°C and the other is benzene, C<sub>6</sub>H<sub>6</sub>, 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?

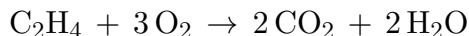
- I)  $\Delta S_{\text{univ}}$  is negative at all temperatures.  
 II) This reaction will reach equilibrium when  $T = \Delta H / \Delta S$ .  
 III) The reaction is spontaneous only at relatively high temperatures.  
 IV)  $\Delta G$  is positive at all temperatures.

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<sub>2</sub>H<sub>4</sub>)



assume all reactants and products are gases, and calculate the  $\Delta H_{\text{rxn}}^0$  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.  $-680 \text{ kJ/mol}$

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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.