Part 1: Multiple Choice.
(4 pts each, 44 pts total)

Instructions: Bubble in the correct answer on your Scantron™ form AND circle the answer on your exam. Each question has one correct answer.

1.) The answer to question 1 is **A**. Bubble in **A** on your Scantron™ form.

2.) Consider the sublimation of dry ice:

$$CO_2\ (s) \rightleftharpoons CO_2\ (g)$$

If K_1 is the equilibrium constant at 300 K, and K_2 is the equilibrium constant at 400 K, which of the following inequalities must be true?

A.) $K_1 = K_2$ B.) $K_1 = K_2^{-1}$ C.) $K_1K_2 = 0$ D.) $K_1 > K_2$ E.) $K_1 < K_2$

3.) For the vaporization of methanol

$$CH_3OH\ (l) \rightleftharpoons CH_3OH\ (g),$$

$\Delta H^\circ = 38.0$ kJ mol^{-1} and $\Delta S^\circ = 112.9$ J K^{-1} mol^{-1}. What is the boiling point of methanol at sea level? Assume ΔH° and ΔS° are independent of T.

A.) 64 K B.) 237 K C.) 273 K D.) 337 K E.) 373 K

4.) Consider the reaction:

$$N_2\ (g) + 3H_2\ (g) \rightleftharpoons 2NH_3\ (g)$$

at equilibrium. What would be the reaction quotient immediately following the reduction of volume by two at constant temperature before any reaction occurs?

A.) $Q = \frac{1}{4}K$ B.) $Q = \frac{1}{2}K$ C.) $Q = K$ D.) $Q = 2K$ E.) $Q = 4K$

5.) One mole of an ideal gas expands *isothermally* against a constant pressure of 1 atmosphere. Which of the following inequalities is true?

A.) $\Delta P > 0$ B.) $q > 0$ C.) $\Delta S < 0$ D.) $\Delta V < 0$ E.) $\Delta T < 0$

6.) One mole of an ideal gas expands *adiabatically* against a constant pressure of 1 atmosphere. Which of the following inequalities is true?

A.) $\Delta P > 0$ B.) $q > 0$ C.) $\Delta S < 0$ D.) $\Delta V < 0$ E.) $\Delta T < 0$

7.) At what temperature does $K = 1$, $\Delta G^\circ = 0$ for the reaction $H_2O\ (l) \rightleftharpoons H_2O\ (g)$?

A.) –273 °C B.) 0 °C C.) 100 °C D.) 273 °C E.) 373 °C

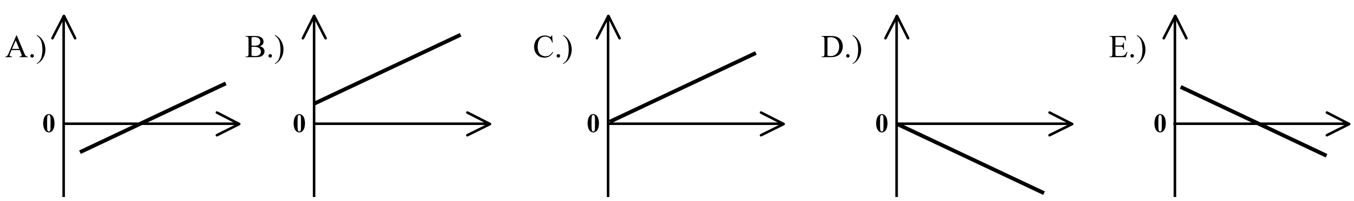
8.) How many different ways can you distribute six distinguishable stones between two boxes with five in the first box and one in the second box?

A.) 1 B.) 3 C.) 6 D.) 9 E.) 15

9.) The caloric content of 10 little cookies can heat up 10 kg of water by 10 °C. What would be the change in temperature if 1 little cookie was used to heat up 1 kg of water?

A.) 0.1 °C B.) 1.0 °C C.) 10 °C D.) 100 °C E.) 1000 °C

For each of the problems **10-12**, select the graph that best describes the behavior listed.



10.) $P_{N_2O_4}$ as a function of $(P_{NO_2})^2$ for $N_2O_4\ (g) \rightleftharpoons 2NO_2\ (g)$, at constant T.

11.) $\ln(K)$ as a function of $\frac{1}{T}$ for a the combustion of liquid methanol (CH_3OH).

12.) ΔG° as a function of T for the vaporization of water, $H_2O\ (l) \rightleftharpoons H_2O\ (g)$.

 Name:____________________________________

Part 2: Short Answer Problems (101 pts total)
Instructions: Enter answers in the boxes provided. Show your work. Explain your answer when requested in 15 words or less.

(30 pts)
1.) The reaction

$$SO_2Cl_2\ (g) \rightleftharpoons SO_2\ (g) + Cl_2\ (g)$$

is endothermic with $\Delta H = 4.6$ kJ/mol. SO_2Cl_2 (g) and SO_2 (g) are placed in a bulb at a fixed temperature with partial pressures of 3.0 atm each.

a) Write the expression for reaction quotient (Q) and calculate its value before any reaction occurs.

Answers:

b) After equilibrium is reached in the bulb at the same fixed temperature, the partial pressure of Cl_2 (P_{Cl_2}) is found to be 1.0 atm. What are the partial pressures of SO_2Cl_2 and SO_2 ($P_{SO_2Cl_2}$ and P_{SO_2})?

Answers:

c) Calculate the value of the equilibrium constant for the reaction in part b).

Answer:

d) If some Cl_2 is added to the equilibrium mixture, will the pressure of SO_2 increase, decrease, or stay constant as the system approaches the new equilibrium state? Circle the answer and explain.

Decrease Same Increase

Explanation:

 Name:____

(18 pts)

2.) Consider the reaction of silver chloride (AgCl) dissolving in water.

$$AgCl\ (s) \rightleftharpoons Ag^{+}\ (aq)\ +\ Cl^{-}\ (aq)$$

a) Dissolving 14.3 g of AgCl (s) consumes 6.5 kJ of heat. What is the temperature change if 14.3 g of AgCl(s) totally dissolves in 1.00 L of water initially at 20 °C?

Answer:

b) In actuality the equilibrium constant (K) for this reaction is very small (1.6×10^{-10} at 25.0 °C). How will this affect the temperature change predicted in part (a)? Explain.

Answer:

(23 pts)

3.) A study of the geology of the earth shows that rocks older than 2 billion years contain iron in the form of FeS_2. In rocks less than 2 billion years old, iron appears mostly as the oxide Fe_2O_3 (hematite).

$$4\ FeS_2\ (s) + 8\ H_2O\ (l) + 15\ O_2\ (g) \longrightarrow 2\ Fe_2O_3\ (s) + 8\ H_2SO_4\ (l)$$

a) Calculate $\Delta H°$ for the above reaction.

Answer:

b) Calculate $\Delta S°$ for the above reaction.

Answer:

c) Over what temperature range is this reaction spontaneous? As always, show your calculations.

Answer:

 Name:____

(23 pts)
4.) Consider the hydrogenation of formaldehyde ($H_2C{=}O$) to form methanol (CH_3OH).

$$CH_2O + H_2 \longrightarrow CH_3OH$$

Average Bond Energy (kJ/mol)			
H-H	436	C-O	360
H-C	413	C=O	743
H-O	463	C-C	348
O-O	146	C=C	612
O=O	497	C C	838

a) Estimate ΔH^o for this reaction.

Answer:

b) The *formation* of which species, formaldehyde or methanol, is more exothermic (i.e. has the lower $\Delta H_f°$)?

Answer:

c) The *combustion* of which species, formaldehyde or methanol, produces more heat per mole?

Answer: