**Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Chemical Thermodynamics Quiz (88 points)**

**Multiple Choice 2pts each**

1. Which reaction has the largest positive entropy change per mole of CO formed?

(A) CO2*(g)*  CO*(g)* + 1/2O2*(g)*

(B) CH3OH*(g)* CO*(g)* + 2H2*(g)*

(C) CO2*(g)* + NO*(g)*  CO*(g)* + NO2*(g)*

(D) CO2*(g)* + H2*(g)*  CO*(g)* + H2O*(l)*

2. When Al2O3*(s)* is formed from the elements at standard conditions, the values of Δ*H*0 and Δ*G*0 at 298 K are

-1617 kJ·mol–1 and –1577 kJ·mol–1, respectively. The standard entropy of formation per mole, in joules per degree, will be

(A) –135

(B) –157

(C) –93.3

(D) –0.0933

(E) +15.7

3. Vaporization of a liquid is an example of a process for which

(A) Δ*H*, Δ*S*, and Δ*G* are positive at all temperatures.

(B) Δ*H* and Δ*S* are positive.

(C) Δ*G* is negative at low temperatures, positive at high temperatures.

1. Δ*H* = Δ*S*

4. A particular chemical reaction has a negative Δ*H* and negative Δ*S*. Which statement is correct?

(A) The reaction is spontaneous at all temperatures.

(B) The reaction is nonspontaneous at all temperatures.

(C) The reaction becomes spontaneous as temperature increases.

(D) The reaction becomes spontaneous as temperature decreases.

5. The hydrolysis of ATP in the body: ATP + H2O ⇔ ADP + H2PO4-1

is a source of energy. For this reaction the K = 2.23 x 105. Which reaction quotient for this reaction would be found in a system capable of doing the most work?

(A) Q = 5.0 x 10 5

(B) Q = 5.0 x 10 15

(C) Q = 5.0 x 10-5

(D) Q = 1

6. A spontaneous reaction will occur at ***any*** temperature when

(A) Δ*H* is positive and Δ*S* is positive.

(B) Δ*H* is negative and Δ*S* is negative.

(C) Δ*H* is positive and Δ*S* is negative.

(D) Δ*H* is negative and Δ*S* is positive.

7. For this process at 25 °C: H2O*(g)* H2O*(l)*

(A) Δ*H* is negative and Δ*S* is negative.

(B) Δ*H* is negative and Δ*S* is positive.

(C) Δ*H* is positive and Δ*S* is positive.

(D) Δ*H* is positive and Δ*S* is negative.

8. Which change is likely to be accompanied by the greatest increase in entropy?

(A) N2*(g)* + 3H2*(g)* 2NH3*(g)* (at 25 °C)

(B) Ag+*(aq)* + Cl–*(aq)* AgCl*(s)* (at 25 °C)

(C) CO2*(s)* CO2*(g)* (at –70 °C)

(D) H2O*(g)* H2O*(l)* (at 100 °C)

9. Under which conditions does nitrogen have the largest entropy per mole?

(A) N2*(s)* at 50 K and l atm

(B) N2*(l)* at 70 K and l atm

(C) N2*(g)* at 80 K and 1 atm

(D) N2*(g)* at 80 K and 0.5 atm

10. What is the standard enthalpy of combustion of C2H6 in kJ·mol–1?

Thermochemical Data

H2*(g)* + 1/2O2*(g)* H2O*(l)* Δ*H*0=  –286 kJ

C2H4*(g)* + H2*(g)* C2H6*(g)* Δ*H*0=  –137 kJ

C2H4*(g)* + 3O2*(g)* 2CO2*(g)* + 2H2O*(l)*  Δ*H*0= –1412 kJ

(A) –1275 kJ

(B) –1561 kJ

(C) –31561 kJ

(D) +1834 kJ

11. More heat is derived from cooling one gram of steam at 100 °C to water at 50 °C than from cooling one gram of liquid water at 100 °C to 50 °C because

(A) water is a poor thermal conductor.

(B) the steam is hotter than the water.

(C) the steam occupies a greater volume than the water.

(D) the density of water is greater than that of steam.

(E) the heat of condensation is evolved.

12. Copper is more reactive chemically than is gold. What is the best ***experimental*** evidence for this?

(A) The copper atom may lose as many as two electrons, whereas the gold atom may lose as many as three electrons.

(B) Gold is alloyed with copper.

(C) The copper ion has less tendency to lose electrons than has the gold ion.

(D) Gold oxide requires less heat per gram mole for decomposition than does copper oxide.

(E) Copper loses electrons more easily than does gold.

13. For which process is the entropy change per mole the largest at constant temperature?

(A) H2O*(l)* H2O*(g)*

(B) H2O*(s)* H2O*(g)*

(C) H2O*(s)* H2O*(l)*

(D) H2O*(l)* H2O*(s)*

14. Consider ice in equilibrium with liquid water at 273 K. Which of the following relationships is correct for *G(s)*, the free energy per mole of ice and *G(l)*, the free energy per mole of the liquid?

(A) *G(s)* is less than *G(l)*

(B) *G(s)* is greater than *G(l)*

(C) *G(s)* equals 0, *G(l)* equals 0

(D) *G(s)* equals *G(l)*; neither equals 0

**AP Questions (5 points each part)**

**Problem A**

2 NO*(g)* + O2*(g)* → 2 NO2*(g) ΔH*°= -114.2 kJ, Δ*S*°= -146.5 J K-1

The reaction represented above is one that contributes significantly to the formation of photochemical smog.

(a) Calculate the quantity of heat released when 72.1 g of NO*(g)* is converted to NO2*(g)*.

(b) For the reaction at 25°C, the value of the standard free-energy change, Δ*G*°, is -70.4 kJ.

(i) Calculate the value of the equilibrium constant, *Keq*, for the reaction at 25°C.

(ii) Indicate whether the value of Δ*G*° would become more negative, less negative, or remain unchanged as the temperature is increased. Justify your answer.

(c) Use the data in the table below to calculate the value of the standard molar entropy, S°, for O2*(g)* at 25°C.

|  |  |
| --- | --- |
|  | Standard Molar Entropy, *S*° (J K-1 mol-1) |
| NO*(g)* | 210.8 |
| NO2*(g)* | 240.1 |

**Problem B**

(a) When liquid water is introduced into an evacuated vessel at 25°C, some of the water vaporizes. Predict the sign for the enthalpy, entropy, free energy, and temperature change in the system during this process. Explain the basis for each of your predictions.

1. When a large amount of ammonium chloride is added to water at 25°C, some of it dissolves and the temperature of the system decreases. Predict the sign for the enthalpy, entropy, and free energy change in the system during this process. Explain the basis for each of your predictions.
2. If the temperature of the aqueous ammonium chloride system in part (b) were to be increased to 30°C, predict how the solubility of the ammonium chloride would be affected. Explain the basis for each of your predictions.

**Problem C**

Ehtylene oxide, C2H4O, is a hydrocarbon commonly used in the production of plastics.

1. The heat of combustion of ethylene oxide is –1300.5 kJ for 1.00 mol C2H4O. Calculate the heat of formation, ΔHf°, of ethylene oxide given that ΔHf° =of H2O (l) = - 283.3 kJ/mol and ΔHf° of CO2(g) = -393.5 kJ/mol.
2. Assume that all of the heat evolved in burning 30.0 grams of ethylene oxide is transferred to 8.00 kilograms of water (specific heat = 4.18 J/g• K) at 25.0 °C, calculate the final temperature of the water.

**Short Answer (5 pts each)**

1. What is the normal boiling point for formic acid, HCOOH?

ΔHf° (kJ/mol) S° (J/mol K)

HCOOH (l) -410 130

HCOOH (g) -363 251

1. Consider the following reaction at 800K. N2(g) + 3F2(g) → 2 NF3(g)  An equilibrium mixture contains the following partial pressures: PN2 = 0.021 atm, PF2 = 0.063 atm, PNF3 = 0.48 atm. Calculate the ΔG° at 800 K
2. Given the following reactions and ΔH values

P4(s) + 6Cl2(g) → 4 PCl3(g) ΔHa = -1225.6 kJ

P4(s) + 5O2(g) → P4O10(s)  ΔHb = -2967.3 kJ

PCl3(g) + Cl2(g) → PCl5(g) ΔHc = - 84.2 kJ

PCl3(g) + ½ O2(g) → Cl3PO(g) ΔHd = - 285.7 kJ

Calculate ΔH for: P4O10(s) + 6PCl5(g) → 10 Cl3PO(g)

1. The enthalpy change for the conversion of white phosphorous to red phosphorus is –17.6 kj/mol. Will one mole of red phosphorous or one mole of white phosphorus give off more heat when burned?