|  |  |  |  |
| --- | --- | --- | --- |
| Substance |  **ΔHof kJ/mol)** |  **ΔGof (kJ/mol)** |  **So (J/mol K)** |
| C6H6 |  49.0 |  124.5 |  172.8 |
| SO2(g) |  −296.9 |  −300.4 |  248.5 |
| C2H4(g) |  52.30 |  68.11 |  219.4 |
| C2H5OH(*l*) |  -277.7 |  -174.76 |  160.7 |
| H2(g) |  0 |  0 |  130.58 |
| Br2(g) |  30.71 |  3.14 |  245.3 |
| CO2(g) | -393.5 | -394.4 | 213.6 |
| H2O(g) | –241.82 | –228.57 | 188.83 |
| H2O(*l*) |  -285.83 |  -237.13 |  69.96 |

Constants: ℱ = 96500 coulombs per mole of electrons. R = 8.31 joule/ mol K.

 *E* = *E*0 - 0.0592 log Q

 n

**Assume that all reactions in this exam take place at 298.15K**

**Thermodynamic Quantities. (At 298.15 K )**

Selected Ksp Values: Some Standard Reduction Potentials in Water at 25oC.

BaSO4  1.1x10–10 Potential (V) Reduction half reaction

AgCl 1.8 x 10–10 +2.76 F2(g) + 2 e– ➞ 2 F–(aq)

BaF2 1.7 x 10–6 +1.36 Cl2(g) + 2e– ➞ 2 Cl–(aq)

Co(OH)2 1.3 x 10–15 +0.80 Ag+(aq) + e– ➞ Ag(s)

**Ka values** +0.77 Fe3+(aq) + e– ➞ Fe2+(aq)

HC2H3O2 1.8 x 10–5 0.44 Fe2+(aq) + 2 e– ➞ Fe(s)

 +0.34 Cu2+(aq) + 2 e– ➞ Cu(s)

HBrO 2.5 x 10–9 -0.13 Pb2+ (aq) + 2 e- → Pb(s)

 –0.28 Ni2+(aq) + 2 e– ➞ Ni(s)

HF 6.8 x 10−4 –0.76 Zn2+(aq) + 2 e– ➞ Zn(s)

**Kb values** –1.66 Al3+(aq) + 3 e– ➞ Al(s)

NH3 1.8 x 10–5

HONH2 1.1 x 10–8

Questions 1 - 7 are based on the following chemical system: 1.25 pts each except as noted.

For the reaction of SO2 gas with O2 gas, 2 SO2(g) + O2(g) ⇄ 2 SO3(g),

ΔH° = −196.6 kJ at 298 K

Predict the effect of each of the following changes on the equilibrium quantity of O2(g)

(Increased, decreased, or unchanged) (I, D, or U)

\_\_D\_\_\_\_1. Temperature is decreased

\_\_\_D\_\_\_2. Container volume is decreased

\_\_\_I\_\_\_3. Some SO2 is removed from the system

\_\_\_U\_\_\_4. A catalyst is added to the equilibrium system

\_\_\_-395.2 kJ\_\_\_\_\_\_\_5. Using the given ΔH for the reaction, and the information on your data sheets, find ΔH ̊*f*  of SO3(g).

\_-190J/molK\_\_or 0.190 kJ/molK 6. ΔG° for the reaction above is −140 kJ/mol at 298 K. Find ΔS° for the reaction at that temperature. (-.5 if unit is wrong or omitted)

\_\_\_C\_\_\_\_\_\_\_7. Based on the value of ΔG° we could conclude that the value of the equilibrium constant K for the reaction is A) negative B) positive, and less than one

 C) positive, and greater than one

 D) no prediction can be made about the magnitude of K

At high temperatures, the solid NH4Cl decomposes to form NH3 and HCl gases

 NH4Cl(s) ➞ NH3(g) + HCl(g)

\_\_81\_\_\_\_\_\_\_\_\_\_\_\_8. A sample of NH4Cl is heated until, at equilibrium, pNH3 is 9.00 atm.

 What is Kp for the reaction at that temperature?

\_\_0.0156\_\_\_\_\_\_\_\_\_\_\_\_9. At a certain high temperature, with the reaction N2(g) + 3 H2(g) D 2 NH3(g) at equilibrium, it is found that the pressure of each of the three gases is 8.00 atm. What is the value of the Kp for the reaction at that temperature?

7.2\_\_\_\_\_\_\_\_\_\_\_10. Suppose that in the reaction 2 SO2(g) + O2(g) D 2 SO3(g), the initial pressures of the SO2(g) and O2(g) are each 2.00 atm. At equilibrium, at the same temperature, the

pressure of the SO3 is found to be 1.50 atm. What is the value of Keq at that temperature?

\_D\_\_\_\_11. Which of the following acids has the **weakest**  conjugate base?

 A) HF B) HC2H3O2 C) HBrO D) HNO3

\_\_\_1.085\_\_\_\_\_\_\_\_12. What is the pH of 0.0823 molar HCl ? (-.5 for 1.0 or 1.1)

A chemist prepares three aqueous solutions; their properties are summarized in the table below. Solution A is dilute HCl. Solution B is dilute NH3 Solution C is a solution of a weak acid, but he can't remember which. He has a pH meter, but it is accurate only for pH values of less than 7. Here is his data:

|  |  |  |
| --- | --- | --- |
| Solution | Solute | pH |
| A ? molar | HCl | 1.90 |
| B 0.200 molar | NH3 | ?? |
| C 0.200 molar | ?? | 3.12 |

0.013\_\_\_\_\_\_\_\_\_\_\_13. What is the molarity of the HCl solution? full credit for 0.0126 or 0.012

\_\_11.278\_\_\_\_\_\_\_\_\_14. What is the pH of the NH3 solution? accept 11.3, or 11.28, -1 pt for 11

\_\_\_2.9 x 10-6\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_15. What is the Ka of the acid in solution C?

\_\_D\_\_\_\_\_\_\_\_\_16. What is the molar solubility of BaF2 ?

 A) 1.7 x10–6 M B) 1.19 10–2 M C) 1.3 x 10–4 M D) 7.5 x10–3 M

\_8.1 x 10-8\_\_\_\_17. If the Co2+ concentration is 0.200 molar, what is the minimum [OH−] needed

 for a precipitate of Co(OH)2 to form?

\_\_6.91\_\_\_\_\_\_\_\_\_18. What is the pH of the solution in question 17 ?

\_A\_\_\_\_\_\_\_\_19. Which metal reacts spontaneously with Fe2+(aq) ? A) Al B) Ag

 C) Cl2 D) Ni

\_\_\_\_1.08 v\_\_\_\_\_21. Find ℰ ° for the reaction Ni(s) + 2Ag+ (aq) ➞ Ni2+(aq) + 2Ag(s)

\_\_\_2−\_\_\_\_\_\_22. What is the charge on the ion with the name tetrachloroferrate (II) ?

\_\_4\_\_\_\_\_\_\_ 23. What is the coordination number of the metal ion called

 bis(ethylenediamine)nickel(II) ?

\_11\_\_\_\_\_\_\_\_\_24. How many carbons are there in the molecule with the name

 3–ethyl,2,2–dimethylheptane?

\_\_\_12\_\_\_\_\_\_\_25. How many hydrogen atoms are there on the molecule called 2-methyl butane?

Indicate the hybridization (sp3,sp2, sp, sp3d2, sp3d) for each of the following atoms:

\_\_sp2\_\_\_\_\_\_\_\_26. The carbon in a molecule of methanal. (formaldehyde)

\_\_sp\_\_\_\_\_\_\_\_27. The middle carbon atom in 2-pentyne

\_\_\_\_sp3\_\_\_\_\_\_28. The carbon in a molecule of methanol

\_\_\_\_sp2\_\_\_\_\_\_\_\_\_\_30. The middle carbon atom in propanone

\_\_−0.34 v\_\_\_\_\_\_\_31. What is ℰ ̊ for the reaction Cu(s) + 2 H+(aq) ➞ Cu2+ (aq) + H2(g)

\_B\_\_\_\_\_\_33. A voltaic cell is constructed using Nickel metal in a 1.0 molar solution of Ni2+ ions

 at one pole, and Aluminum metal, in a 1.0 molar solution of Al3+ ions at the other.

 The electron flow in such a cell would be A) from Ni to Al B) from Al to Ni

 C) from Al to Al3+ D) from Ni2+ to Ni

\_\_6\_\_\_\_\_\_\_34. A chemist wishes to use the equation ΔG° = −nFℰ° to calculate the value of

 ΔG° for the reaction 2 Al + 3 Ni2+ ➞ 2 Al3+ + 3 Ni . What value should be used for the term "n" in the equation ?

\_\_\_B\_\_\_\_\_\_35. In the reaction 2Fe2+ (aq) + Cl2(aq) ➞ 2 Cl–(aq) + 2 Fe3+(aq) the oxidizing

 agent is the A) Fe B) Cl2 C) Fe2+ D) Cl-

 \_\_\_+6\_\_\_\_\_36. What is the oxidation state of the sulfur in the sulfate ion, SO42– ?

37. Assume that the reaction 2 H2O2 → 2 H2O + O2 is first order. Determine for each of the following statements, whether the statement is true or false. ( 1 pt each)

i. the reaction proceeds at a constant rate \_\_F\_\_\_\_\_\_\_\_\_\_\_\_\_\_

ii. the reaction has a constant half life if the temperature is constant \_\_\_\_\_\_T\_\_

iii. a graph of Ln[H2O2] versus time produces a straight line. \_\_\_\_\_T\_\_\_\_\_\_\_\_

 \_4.44\_\_\_\_\_\_\_\_\_38. A buffer is prepared by mixing 2.00 moles of HC2H3O2 with 1.00 mole of NaC2H3O2 in a total volume of 1.00 liter. What is the pH of this buffer?

\_\_\_\_\_4.05\_\_\_\_\_39. What is the pH of the solution prepared in question 43 after the addition of 100. mL of 5.00 molar HCl ? (accept 4.04, 4.045, 4.0 or 4.1)

\_\_\_B\_\_\_\_\_40. When 2.00 molar HCl is titrated with 1.00 molar NH3, the pH at the equivalence

 point is closest to A) 4.6 B) 7 C) 9.6 D) 12

\_\_\_\_B\_\_\_41. When 2.00 molar HCl is titrated with 1.00 molar NH3 the concentration of Cl− ion

 at the equivalence point is A) 1.20 M B) 0.667 M C) .500 M D) 5.00 M

\_\_\_\_A\_\_\_\_\_\_42 Which of the following salts, in aqueous solution, will have the highest pH?

 A) 1 M NaBrO B) 1 M Al(NO3)3 C) 1 M CuSO4 D)1 M KCl

\_\_1.5x10−11\_\_\_\_\_\_\_\_\_\_\_\_43. What is the Kb of a fluoride ion, F− ?

\_\_B\_\_\_\_\_\_\_\_\_44. Suppose that the decomposition of gaseous substance X is first order.

 If the initial pressure of X is 4.00 atm, and the pressure after 15.0 seconds is

 1.00 atm, what is the rate constant for the decomposition? (sec-1)

 A) 0.0462 B) 0.092 C) 0.20 D) 0.075

\_\_A\_\_\_\_45. The rate constant of the exothermic reaction N2(g) + 3 H2(g) ➞ 2 NH3(g) can be increased by A) increasing the temperature B) increasing the hydrogen concentration

 C) Decreasing the size of the reaction vessel D) all of these

Organic: Use the list of substances, A through H. (questions 46 to 51) (*Choice F is no longer covered.)*

A. 2 -pentanol B. 3–ethyloctane C. pentanoic acid

D. Pentanal E. 2 - pentyne F. butyl ethanoate G. Hexane

\_F\_\_\_\_\_\_46. Which of these substances is an isomer of hexanoic acid?

\_F\_\_\_\_\_\_47. Which is formed by the reaction of acetic acid with an alcohol?

\_E\_\_\_\_\_\_48. Which of these substances has the **fewest** hydrogens?

\_E\_\_\_\_\_\_49. Which is an isomer of 1,3-pentadiene? ( hint: diene means two double bonds)

\_\_B\_\_\_\_\_50. Which of the following molecules is an isomer of substance B?

 A) 2-methyl octane B) 2,2-dimethyloctane C) 3,4-dimethyl decane D) 2-octene

\_\_A\_\_\_\_51. **Which** of these molecules contains a chiral carbon?

\_\_C\_\_\_\_\_52. Which molecule contains **only** σ bonds? A) butanone B) propene

 C) 2-methyl,2-butanol D) ethyl methanoate

\_A\_\_\_\_\_\_\_53. What is the expected product of the reaction between Cl2 gas and

 1-butene? A) 1,2-dichlorobutane B) 1,1--dichlorobutane

 C) 2,3-dichlorobutane D) 1,3--dichlorobutane

 \_A\_\_54. The formation of PbCl2(s) , Pb(s) + Cl2(g)➞ PbCl2(s) , is spontaneous at room

 temperature. At temperatures above 2370 K, the **reverse** reaction becomes theoretically

 spontaneous. From this information, we can tell that for the formation of lead(II) chloride,

 A) ΔH and ΔS are both - B) ΔH and ΔS are both +

 C) ΔH is − while ΔS is D) ΔH is +, while ΔS is −

55. to 57. The reaction (all gases) 2 NO + 2 H2 ➞ N2 + 2 H2O is found to obey the rate law:

 Rate = k[NO]2[H2]. It is found that at 300 K, when the intitial concentrations of NO

 and H2 are both 2.00 molar, the initial rate of formation of N2 is 2.00 x 10−2 M/sec.

\_0.00250 M-2/sec\_55. What is the rate constant of the reaction at 300 K? Include the correct unit.

 ( -.5 for incorrect unit)

\_0.16\_\_\_\_\_\_\_\_\_\_56. What is the initial rate of reaction if the H2 is initially 1.00 molar, while the

 NO is 8.00 molar ? (in M/sec) A) 4.00 x 10−2 B) 8.00 x 10−2 C) 0.16

 D) 4.00 x 10−3

Suppose the following mechanisms are suggested for this reaction:

Mechanism I: step 1. 2 NO → N2O2 (fast, equilibrium)

 step 2. N2O2 + H2 → H2O + N2O (slow, rate determining)

 step 3. H2 + N2O → H2O + N2 (fast)

Mechanism II. step 1. NO + H2 → H2O + N (fast, equilibrium)

 step 2. N + NO → N2O ( slow, rate determining)

 step 3. H2 + N2O → H2O + N2 (fast)

Mechanism III. step 1. 2 H2 + NO → NH4 O ( fast, equilibrium)

 step 2. NH4O + NO → N2 + 2 H2O (slow)

\_A\_\_\_\_\_57. Which of these mechanisms is/are consistent with the given rate law?

 A) I only B) I and II only C) II and III only D) all of them

The following is a possible mechanism for the decomposition of ozone, O3

 1. Cl2(g) + O3(g) ➞ Cl2O(g) + O2(g) (slow)

 2. Cl2O(g) + O3(g) ➞ Cl2(g) + 2 O2 (g)(fast)

\_B\_\_\_\_\_\_\_58 The best description of the Cl2(g) in this reaction is A) intermediate

 B) catalyst C) reactant D) product.

\_\_\_\_\_\_\_\_\_\_Rate = k[Cl2][O3]\_\_59. Write the rate law, based on the mechanism above.

\_0.25 atm\_\_\_\_\_\_60. Assume that at a certain temperature the decomposition of iodine vapor,

 I2(g) ➞ 2 I(g) is first order with a half life of 8 minutes. If the initial pressure of the I2(g)

 is 4.00 atm., what is the pressure of the I2(g)  after 32 minutes?

\_\_\_HSO4-\_\_\_\_\_\_\_\_\_\_\_\_\_\_61. What is the formula for the conjugate acid of a sulfate ion?

\_\_\_\_\_B\_\_\_\_\_\_\_\_\_\_\_\_62. A ligand can be best described as A) an Arrhenius acid

 B) a Lewis base C) a Bronsted acid D) an electron pair receiver

I. Draw a diagram that clearly shows the difference between cis tetraaquadichloroiron (III) ion, and trans tetraaquadichloroiron(III) ion (4 pts)

B. Both of the ions above are **high spin** complexes. How many unpaired electrons are there on the iron (III) ions? (1 pt) 5

C. The hexacyanoferrate (II) complex is a low spin complex. How many unpaired electrons are there on the iron (II) ion? (1 pt) 0

II. Draw and name three **different**  substances that have the formula C3H8O. (6 pts)

 Ans: You could draw 1-propanol and 2- propanol. The other structure would be an ether,

 ( CH3-O-C2H5) not covered this term.

III. Draw the structures of the following molecules. You must show all hydrogen atoms. (8 pts)

 A. butanoic acid B. 2 - pentanol

 C. 2,3-dichloro,2-butene.



 D. Which of these molecules contains a chiral (optically active) carbon? Explain. (2)

 2-pentanol. The second carbon has four different attachments.

 E. Which of these molecules would demonstrate cis-trans isomerism? Explain. (2)

 2,3-dichloro,2-butene. There is no free rotation about the double bond, so the chlorines can be either opposite or adjacent.