Chemistry 112-2018 Name: Answers, Version A

Exam # 4a Vining

**1.** For each pair, choose the species with the greater entropy: $N_2O_4(g)$ or $2\ NO_2(g)$

$H_2O(g)$ or $H_2O(l)$

**2.** In which temperature range will the following reaction be thermodynamically most favored:

favored by $\Delta S$ → $2\ MgO(s) \rightarrow 2\ Mg(s) + O_2(g)$ reaction is endothermic ← disfavored by $\Delta H$

a. at all temperatures b. at no temperatures c. at high temperatures d. at low temperatures

**3.** Consider the reaction: $2\ H_2(g) + O_2(g) \rightarrow H_2O(l)$ ← disfavored by $\Delta S$

The reaction occurs at room temperature. What can be said about thermodynamic control of the reaction?

a. it is disfavored and enthalpy controlled

b. it is disfavored and entropy controlled

c. it is favored and enthalpy controlled ← favored overall

d. it is favored and entropy controlled

**4.** For a reaction to actually occur, it must be favored by:

a. thermodynamics

b. kinetics

c. either thermodynamics or kinetics

d. both thermodynamics and kinetics

**5.** You have a saturated solution of AgCl that has solid AgCl at the bottom of the solution. Some NaCl solution is added to the AgCl solution. What happens?

a) nothing

b) more AgCl precipitates

c) NaCl precipitates

d) solid AgCl dissolves

favored overall

**6.** NaOH is highly soluble and when solid NaOH dissolves, the solution gets warm. What can you tell from this information: (A)

exothermic, so favored by ΔH, enthalpy

| | | | |
|---|---|---|---|
| In terms of enthalpy, dissolution is: | favored | disfavored | can't tell |
| In terms of entropy, dissolution is: | favored | disfavored | can't tell |
| In terms of $\Delta G^\circ$, dissolution is: | favored | disfavored | can't tell |
| In terms of kinetics, dissolution is: | favored | disfavored | can't tell |

**7.** A chemical system has an equilibrium constant of $4.4 \times 10^6$. What is $\Delta G^\circ$ for the reaction?

$$\Delta G^\circ = -RT \ln K$$

$$= -8.314 \frac{J}{K \cdot mol} \times 298\,K \times \ln(4.4 \times 10^6) = -37{,}900\ J/mol$$

$\Delta G^\circ =$ -37.9 kJ/mol

**8.** Will $Cu_3(PO_4)_2$ be more soluble in pure water, or in water in which $Na_3PO_4$ has been dissolved?

$Cu_3(PO_4)_2(s) \rightleftarrows 3\ Cu^{2+}(aq) + 2\ PO_4^{3-}(aq)$

a) pure water  b) $Na_3PO_4$ solution

Is $Fe(OH)_2$ more soluble in:

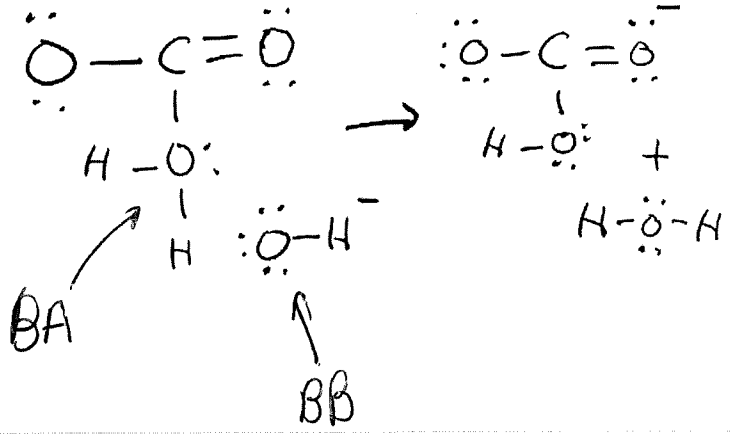
a) pure water  b) 0.1 M HCl  c) 0.1M NaOH

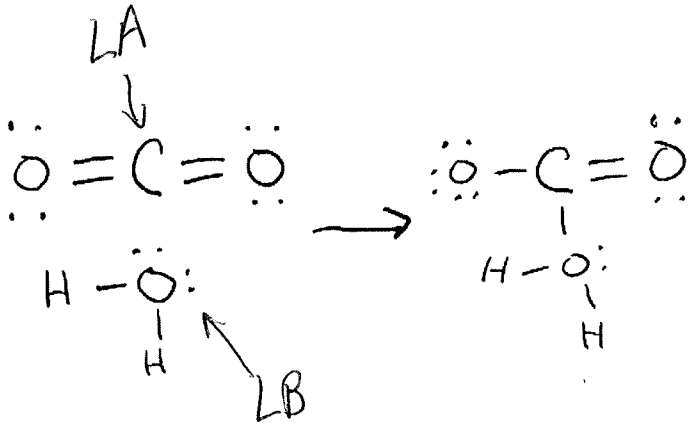
**9.** Write the equilibrium reaction **and** the $K_{sp}$ equilibrium expression for dissolution of:

$Al_2(CO_3)_3(s) \rightleftharpoons 2\ Al^{3+}(aq) + 3\ CO_3^{2-}(aq)$

$$K_{sp} = [Al^{3+}]^2 [CO_3^{2-}]^3$$

**10.** Label any species that are acting as Lewis acids (LA), Lewis bases (LB), Bronsted acids (BA), or Bronsted bases (BB).




In which of the following ways can a water molecule act? Choose all that apply.

Lewis acid | Lewis base | Bronsted acid | Bronsted base

**11.** What is the solubility of $Cd_3(PO_4)_2$, in *moles per liter*? $K_{sp} = 2.2 \times 10^{-32}$

$$Cd_3(PO_4)_2(s) \rightleftharpoons 3Cd^{2+}(aq) + 2PO_4^{3-}(aq)$$

$x \rightarrow 3x \quad 2x$

$$K_{sp} = 2.2\times10^{-32} = (3x)^3(2x)^2 = 108x^5$$

$$x = \sqrt[5]{\frac{2.2\times10^{-32}}{108}} = 4.7\times10^{-7}$$

1.8 ~~1.8~~ $\times 10^{-7}$ mol/L

(A)

**12.** Use the following reaction and the data given to calculate $\Delta G^\circ$ at 328 K.

$2NO(g) + 2H_2(g) \longrightarrow N_2(g) + 2H_2O(l)$

$\Delta H^\circ = -752.2$ kJ and $\Delta S^\circ = -351.6$ J/K

$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ = -752.2\,kJ - 328\,K\,(-0.3516\ kJ/K) =$

$\Delta G^\circ =$ **−636.9** kJ/mol

Is the reaction favored at 328 K: (yes) or no

In what temperature range is the reaction favored?

favored by $\Delta H$ } favored at low T
& favored by $\Delta S$

all temperatures

no temperatures

above _____ K

below **2140** K

$T_{cutoff} = \frac{\Delta H}{\Delta S} = \frac{-752.2\ kJ}{-0.3516\ kJ/K} =$

2140K

**13.** Methanol boils at 65 °C with an enthalpy of vaporization of 35.2 kJ/mol.

What is the entropy change for the vaporization of methanol at 65 °C?

$\Delta S_{\text{phase change}} = \frac{-\Delta H_{vap}}{T} = \frac{-35{,}200\ J/mol}{(65+273)\,K} =$

**+104** J/K·mol

**14.** What is the solubility of $PbBr_2$ is a 0.15 M solution of NaBr, in grams per liter?

Molar mass $PbBr_2$ = 367 g/mol. $K_{sp} = 6.6 \times 10^{-6}$

$PbBr_2(s) \rightleftharpoons Pb^{2+}(aq) + 2Br^-$

| | | |
|---|---|---|
| I | 0 | 0.15 |
| C | +x | +2x |
| E | x | 0.15+2x |

$6.6\times10^{-6} = (x)(0.15+2x)^2$

$\approx (x)(0.15)^2$

$x = 2.93\times10^{-4}$ mol/L

$2.93\times10^{-4}\frac{mol}{L} \times \frac{367\,g}{mol} = 0.108\frac{g}{L}$

_____ g/L

(A)

**15.** $Cu^{2+}$ forms a complex ion with ammonia:

$Cu^{2+}(aq) + 4\ NH_3(aq) \text{ ===== } [Cu(NH_3)_4]^{2+}(aq)$ $\quad K_f = 2.1 \times 10^{13}$

Formation of the complex ion is: highly favored moderately favored not favored

What is the value of $K_d$, the dissociation constant for the complex ion, $[Cu(NH_3)_4]^{2+}$?

$K_d = \frac{1}{K_f} = 4.8 \times 10^{-14}$

$K_d =$ $4.8 \times 10^{-14}$

**16.** Determine $\Delta H°$, $\Delta S°$, $\Delta G°$ for the following reaction at 298 K.

$SF_6(g) + 3\ H_2(g) \rightarrow S(s) + 6\ HF(g)$

| | $\Delta H_f°$(kJ/mol) | $\Delta G_f°$ (kJ/mol) | S°(J/K·mol) |
|---|---|---|---|
| $SF_6(g)$ | -1209 | -1105 | 292 |
| $H_2(g)$ | 0 | 0 | 131 |
| S(s) | 0 | 0 | 32 |
| HF(g) | -271 | -273 | 174 |

$\Delta H° = [0 + 6(-271)] - [-1209 + 3(0)]$ kJ/mol $= -417$ kJ/mol

$\Delta S° = [32 + 6(174)] - [292 + 3(131)]$ J/K·mol $= +391$ J/K·mol

$\Delta G° = [0 + 6(-273)] - [-1105 + 3(0)]$ kJ/mol

$= -533$ kJ/mol

$\Delta H° = -417$ kJ/mol

$\Delta S° = +391$ J/K·mol

$\Delta G° = -533$ kJ/mol

Chemistry 112-2018 Name: Answer Key Version B

Exam # 4b Vining

**1.** For each pair, choose the species with the greater entropy:

$H_2O(g)$ or $H_2O(l)$

$2\ NO_2(g)$ or $N_2O_4(g)$

**2.** In which temperature range will the following reaction be thermodynamically most favored:

$\Delta S$ negative $2\ Mg(s) + O_2(g) \rightarrow 2\ MgO(s)$ reaction is exothermic

a. at all temperatures b. at no temperatures c. at high temperatures d. at low temperatures

**3.** Consider the reaction: $2\ H_2(g) + O_2(g) \rightarrow H_2O(l)$ $\Delta S$ negative ← not favored by entropy

The reaction occurs at room temperature. What can be said about thermodynamic control of the reaction?

a. it is disfavored and enthalpy controlled — favored overall

b. it is disfavored and entropy controlled

c. it is favored and enthalpy controlled

d. it is favored and entropy controlled

**4.** For a reaction to actually occur, it must be favored by:

a. thermodynamics

b. kinetics

c. either thermodynamics or kinetics

d. both thermodynamics and kinetics

**5.** You have a saturated solution of AgCl that has solid AgCl at the bottom of the solution. Some NaCl solution is added to the AgCl solution. What happens?

a) nothing

b) more AgCl precipitates

c) NaCl precipitates

d) solid AgCl dissolves

favored overall (by $\Delta G^\circ$ + kinetics)

**6.** NaOH is highly soluble and when solid NaOH dissolves, the solution gets warm. What can you tell from this information:

↳ exothermic, ∴ enthalpy favored

| | | | |
|---|---|---|---|
| In terms of enthalpy, dissolution is: | favored | disfavored | can't tell |
| In terms of entropy, dissolution is: | favored | disfavored | can't tell |
| In terms of $\Delta G^\circ$, dissolution is: | favored | disfavored | can't tell |
| In terms of kinetics, dissolution is: | favored | disfavored | can't tell |

**7.** A chemical system has an equilibrium constant of $2.4 \times 10^4$. What is $\Delta G^\circ$ for the reaction?

$$\Delta G^\circ = -RT \ln K = -8.314\ J/K\cdot mol \times 298\ K \times \ln(2.4\times10^4)$$

$$= -25{,}000\ J/mol$$

$\Delta G^\circ =$ −25.0 kJ/mol

**8.** Will $Cu_3(PO_4)_2$ be more soluble in pure water, or in water in which $Na_3PO_4$ has been dissolved?

$$Cu_3(PO_4)_2(s) \rightleftarrows 3\ Cu^{2+}(aq) + 2\ PO_4^{3-}(aq)$$

a) pure water  b) $Na_3PO_4$ solution

Is $Fe(OH)_2$ more soluble in:

a) pure water  b) 0.1 M HCl  c) 0.1M NaOH

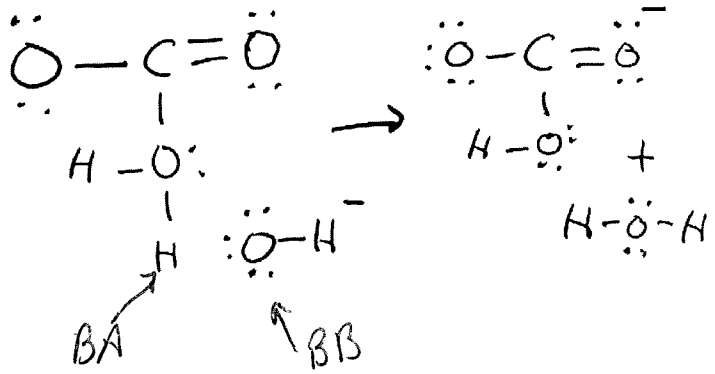
**9.** Write the equilibrium reaction **and** the $K_{sp}$ equilibrium expression for dissolution of:

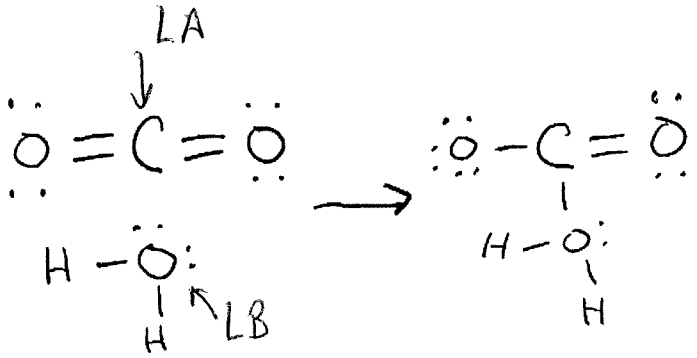
$$Al_2(CO_3)_3(s) \rightleftarrows 2\ Al^{3+}(aq) + 3\ CO_3^{2-}(aq)$$

$$K_{sp} = [Al^{3+}]^2 [CO_3^{2-}]^3$$

**10.** Label any species that are acting as Lewis acids (LA), Lewis bases (LB), Bronsted acids (BA), or Bronsted bases (BB).

B




In which of the following ways can a water molecule act? Choose all that apply.

~~Lewis acid~~ Lewis base Bronsted acid Bronsted base

**11.** What is the solubility of $Ba_3(PO_4)_2$, in *moles per liter*? $K_{sp} = 1.3 \times 10^{-29}$

$Ba_3(PO_4)_2(s) \rightleftharpoons 3\,Ba^{2+}(aq) + 2\,PO_4^{3-}(aq)$

| | | |
|---|---|---|
| I | 0 | 0 |
| C | +3x | +2x |
| E | 3x | 2x |

$K_{sp} = 1.3 \times 10^{-29} = [Ba^{2+}]^3 [PO_4^{3-}]^2 = (3x)^3 (2x)^2 = 108x^5$

$x = \sqrt[5]{\frac{1.3 \times 10^{-29}}{108}} = 6.5 \times 10^{-7}$

$6.5 \times 10^{-7}$ mol/L

(B)

**12.** Use the following reaction and the data given to calculate $\Delta G°$ at 328 K.

$$2NH_3(g) + 2O_2(g) \longrightarrow N_2O(g) + 3H_2O(l)$$

$\Delta H° = -683.1$ kJ and $\Delta S° = -365.6$ J/K

$\Delta G° = \Delta H° - T\Delta S° = -683.1\,kJ - 328\,K(-0.3656\,kJ/K) =$

$\Delta G°$ = −563.2 kJ/mol

Is the reaction favored at 328 K: (yes) or no

In what temperature range is the reaction favored?

Both $\Delta H$ & $\Delta S$ negative, so favored at low temperatures

all ~~temperatures~~

no ~~temperatures~~

above ~~_____~~ K

below 1868 K

$T_{cutoff} = \frac{\Delta H°}{\Delta S°} = \frac{-683.1\,kJ}{-0.3656\,kJ/K} = 1868\,K$

**13.** Ethanol boils at 78 °C with an enthalpy of vaporization of 38.6 kJ/mol.

What is the entropy change for the vaporization of methanol at 78 °C?

$\Delta S° = -\frac{\Delta H_{vap}}{T} = \frac{38{,}600\,J/mol}{(273+78)\,K} =$

+110.0 J/K·mol

**14.** What is the solubility of $PbI_2$ is a 0.25 M solution of NaI, in grams per liter?

Molar mass $PbI_2$ = 461 g/mol. $K_{sp} = 8.7 \times 10^{-9}$

| | $PbI_2(s) \rightleftharpoons$ | $Pb^{2+}$ | + | $2I^-$ |
|---|---|---|---|---|
| I | | 0 | | 0.25 |
| C | x → | +x | | +2x |
| E | | x | | 0.25+2x |

$8.7\times10^{-9} = (x)(0.25+2x)^2 \approx (x)(0.25)^2$

$x = 1.39\times10^{-7}$ mol/L

$1.39\times10^{-7}\,mol/L \times \frac{461\,g}{mol} =$

$6.4\times10^{-5}$ g/L

(B)

**15.** $Cu^{2+}$ forms a complex ion with ammonia:

$Cu^{2+}(aq) + 4\ NH_3(aq) \text{ ===== } [Cu(NH_3)_4]^{2+}(aq)$ $\quad K_f = 2.1 \times 10^{13}$

Formation of the complex ion is: highly favored moderately favored not favored

What is the value of $K_d$, the dissociation constant for the complex ion, $[Cu(NH_3)_4]^{2+}$?

$K_d = \frac{1}{K_f} = 4.8 \times 10^{-14}$

$K_d =$ $4.8 \times 10^{-14}$

**16.** Determine $\Delta H°$, $\Delta S°$, $\Delta G°$ for the following reaction at 298 K.

$S(s) + 6\ HF(g) \rightarrow SF_6(g) + 3\ H_2(g)$

| | $\Delta H_f°$(kJ/mol) | $\Delta G_f°$ (kJ/mol) | S°(J/K·mol) |
|---|---|---|---|
| $SF_6(g)$ | -1209 | -1105 | 292 |
| $H_2(g)$ | 0 | 0 | 131 |
| S(s) | 0 | 0 | 32 |
| HF(g) | -271 | -273 | 174 |

$\Delta H° = [-1209 + 3(0)] - [0 + 6(-271)]\ kJ/mol = +417\ kJ/mol$

$\Delta S° = [292 + 3(131)] - [32 + 6(174)]\ J/K \cdot mol = -391\ J/K \cdot mol$

$\Delta G° = [\cancel{-1209}\ -1105\ kJ/mol + 3(0)] - [0 + 6(-273)]\ kJ/mol = +533\ kJ/mol$

$\Delta H° = +417\ kJ/mol$

$\Delta S° = -391\ J/K \cdot mol$

$\Delta G° = +533\ kJ/mol$