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Midterm exam 2016, questions and answers

Principles of Chemistry (University of Ottawa)

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1 point

At 1.00 atm and 0.0°C, for the melting of ice, $H_2O(s) \rightleftharpoons H_2O(l)$, will the entropy change in the environment, $\Delta S_{environment}$, be negative, positive, or zero? Please circle your answer.

9 points

For the reaction

$$2\ A(s) + 3\ B(g) \rightleftharpoons C(g) + D(g)$$

the equilibrium constant is 0.488 at 25.0°C and 0.177 at 75.0°C. Making the approximation that $\Delta H°$ and $\Delta S°$ do not vary with temperature, calculate the values of $\Delta H°$, $\Delta S°$, and the equilibrium contant, K, at 50.0°C. Taking into account that B, C, and D are gases, calculate the values of $\Delta U°$, Q, and W for this reaction under a constant pressure of 1.00 atm at 25.0°C.

① FIND $\Delta H°$

$$\ln\left(\frac{K_2}{K_1}\right) = -\frac{\Delta H°}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

$$\Delta H° = \frac{-R \ln\left(\frac{K_2}{K_1}\right)}{\left(\frac{1}{T_2} - \frac{1}{T_1}\right)}$$

$$= \frac{-8.3145 \ln\left(\frac{0.177}{0.488}\right)}{\left(\frac{1}{348.15} - \frac{1}{298.15}\right)}$$

$$\Delta H° = -17506\ J = \boxed{-17.5\ kJ}$$

② FIND $\Delta G°$ @ 25°C

$$\Delta G°_{25} = -RT \ln K_{25}$$

$$= -8.3145(298.15) \ln(0.488)$$

$$\Delta G°_{25} = 1179\ J$$

③ FIND $\Delta S°$

$$\Delta G° = \Delta H° - T\Delta S°$$

$$\Delta S° = \frac{\Delta H° - \Delta G°}{T}$$

$$= \frac{-17506 - 1179}{298.15}$$

$$\boxed{\Delta S° = -64.7\ J/K}$$

④ FIND $\Delta G°_{50}$

$$\Delta G_{50}° = \Delta H° - T\Delta S°$$

$$= (-17506) - (323.15)(-64.$$

$$\Delta G°_{50} = 3402\ J$$

⑤ FIND K_{50}

$$K_{50} = e^{\frac{-\Delta G°}{RT}}$$

$$= e^{-(3402)/(8.3145)(323.15)}$$

$$\boxed{K_{50} = 0.282}$$

⑥ At constant pressure, $\Delta H = \boxed{Q = -17.5\ kJ}$

⑦ FIND $\Delta U°$

$$\Delta H° = \Delta U° + RT\Delta n_{gaz}$$

$$\Delta U° = \Delta H° - RT\Delta n_{gaz}$$

$$= -17506 - (8.3145)(298.15)(-1)$$

$$= -15027\ J$$

$$\boxed{\Delta U° = -15.0\ kJ}$$

⑧ FIND W

$$\Delta U = Q + W$$

$$W = \Delta U - Q$$

$$= -15.0 - (-17.5)$$

$$\boxed{W = +2.5\ kJ}$$

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1 point

Among He(g), N_2(g), NH_3(aq), NH_4^+(aq), Na(s), Na^+(aq), NaCl(s), Cl^-(aq), Cl_2(g), and Ar(g), which is the best Bronsted-Lowry acid? Please circle your answer.

9 points

Balance the following chemical equation, in basic solution,

$$ClO_4^-(aq) + C_2H_3O_2^-(aq) \rightarrow Cl_2(g) + CO_2(g)$$

$ClO_4^- \longrightarrow Cl_2$

$2ClO_4^- \longrightarrow Cl_2$

$2ClO_4^- \longrightarrow Cl_2 + 8H_2O$

$16OH^- + 16H^+ + 2ClO_4^- \longrightarrow Cl_2 + 8H_2O + 16OH^-$

$16H_2O + 2ClO_4^- \longrightarrow Cl_2 + 8H_2O + 16OH^-$

$8H_2O + 2ClO_4^- \longrightarrow Cl_2 + 16OH^-$

$2ClO_4^- + 8H_2O + 14e^- \longrightarrow Cl_2 + 16OH^-$ $\times 4$

$C_2H_3O_2^- \longrightarrow CO_2$

$C_2H_3O_2^- \longrightarrow 2CO_2$

$2H_2O + C_2H_3O_2^- \longrightarrow 2CO_2$

$7OH^- + 2H_2O + C_2H_3O_2^- \longrightarrow 2CO_2 + 7H^+ + 7OH^-$

$7OH^- + 2H_2O + C_2H_3O_2^- \longrightarrow 2CO_2 + 7H_2O$

$7OH^- + C_2H_3O_2^- \longrightarrow 2CO_2 + 5H_2O$

$7OH^- + C_2H_3O_2^- \longrightarrow 2CO_2 + 5H_2O + 8e^-$ $\times 7$

$8ClO_4^- + 32H_2O + 56e^- \longrightarrow 4Cl_2 + 64OH^-$ (15)

$7C_2H_3O_2^- + 49OH^- \longrightarrow 14CO_2 + 35H_2O + 56e^-$ (3)

$8ClO_4^- + 7C_2H_3O_2^- \longrightarrow 14CO_2 + 3H_2O + 4Cl_2$

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1 point

Among He(g), N_2(g), NH_3(aq), NH_4^+(aq), Na(s), Na^+(aq), NaCl(s), Cl^-(aq), Cl_2(g), and Ar(g), which is the best Bronsted-Lowry base? Please circle your answer.

9 points

At a temperature of 25.0°C, we dissolve 1.22 g of an acid, HA, in enough water to produce 25.0 mL of solution. The pH of this solution is 1.55. We titrate this solution with a 0.155 M NaOH solution and we need 27.7 mL of this solution to attain the equivalence point.

(a) (3 points) What is the molar mass of HA?

(b) (4 points) What is the dissociation constant, K_A, of HA?

(b) (2 points) What would be the pH of a 1.000 M solution of NaA?

a) ① $C_A V_A = C_B V_B$

$C_A = \frac{C_B V_B}{V_A}$

$= \frac{(0.155)(27.7)}{(25.0)}$

$C_A = 0.1717\ M$

$0.1717\ mol \rightarrow 1000\ mL$

$x \rightarrow 25.0\ mL$

$x = 0,004292\ 25$

② $M = \frac{m}{n}$

$= \frac{1.22\ g}{0.004292\ 25\ mol}$

$M = 284\ g/mol$

b) $HA(aq) \rightleftharpoons H^+(aq) + A^-(aq)$

i:	0.1717	—	—
c:	$-x$	$+x$	$+x$
e:	$0.1717 - x$	x	x

① $x = [H^+] = 10^{-pH}$

$= 10^{-1.55}$

$[H^+] = [A^-] = 0,0282\ M$

② $K_A = \frac{[H^+][A^-]}{[HA]}$

$= \frac{(0.0282)(0,0282)}{(0,1717 - 0,0282)}$

$K_A = 5.5 \times 10^{-3}$

c) ① $K_B = \frac{K_{water}}{K_A}$

$= \frac{1.0 \times 10^{-14}}{5.5 \times 10^{-3}}$

$= 1.8 \times 10^{-12}$

② $A^-(aq) + H_2O(\ell) \rightleftharpoons HA(aq) + OH^-(aq)$

i:	1.00	/	—	—
c:	$-x$	/	$+x$	$+x$
e:	$1.00 - x$	/	x	x

$\Downarrow$

x is negligible

③ $K_b = \frac{[HA][OH^-]}{[A^-]}$

$1.8 \times 10^{-12} = \frac{x^2}{1.00}$

$x = 1.34 \times 10^{-6}$

④ $pOH = 5.87$

so

$pH = 8.13$

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1 point

Among He(g), N_2(g), NH_3(aq), NH_4^+(aq), Na(s), Na^+(aq), NaCl(s), Cl^-(aq), Cl_2(g), and Ar(g), which is the best reducing agent? Please circle your answer.

9 points

(a) (5 points) For the reaction 2 A(aq) ⇌ B(aq) + 2 C(aq), the equilibrium constant is 9.88. If the concentration of B(aq) is 0.244 M and the concentration of C(aq) is 0.311 M, what concentration of A(aq) would be necessary to have a value of ΔG equal to -4.00 kJ? The temperature is 25.0°C throughout.

(b) (4 points) For the reaction 3 A(g) ⇌ 2 B(g) + C(g), we start with only pure A(g). We attain equilibrium. At equilibrium, the total pressure is 7.00 atm, and the partial pressure of B(g) is 2.50 atm. What is the value of ΔG° for this reaction? The temperature is 25.0°C throughout.

a) ① FIND ΔG°

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

$= -(8.3145)(298.15)\ln(9.88)$

$\Delta G^\circ = -5678\ J$

② FIND Q

$\Delta G = \Delta G^\circ + RT\ln Q$

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

$\ln Q = \frac{\Delta G - \Delta G^\circ}{RT}$

$Q = e^{\frac{\Delta G - \Delta G^\circ}{RT}}$

$Q = e^{\frac{(-4000)+5678}{(8.3145)(298.15)}}$

$Q = 0.6769$

③ FIND [A]

$Q = \frac{[B][C]^2}{[A]^2}$

$[A] = \sqrt{\frac{[B][C]^2}{Q}}$

$[A] = \sqrt{\frac{(0.244)(0.311)^2}{1.968}}$

$[A] = 0.110\ M$

b)

$3A(g) \rightleftharpoons 2B(g) + C(g)$

i:	??	—	—
c:	$-3x$	$+2x$	$+x$
e:	??	$2x$	x

① $P_B = 2.50\ atm$

$2x = 2.50\ atm$

$x = 1.25\ atm = P_C$

② $P_t = P_A + P_B + P_C$

$P_A = P_t - P_B - P_C$

$= 7.00 - 2.50 - 1.25$

$P_A = 3.25\ atm$

③ $K = \frac{P_B^2 P_C}{P_A^3}$

$K = \frac{(2.50)^2(1.25)}{(3.25)^3}$

$K = 0.2276$

④ $\Delta G^\circ = -RT\ln K$

$= -8.3145(298.15)\ln(0.2276)$

$\Delta G^\circ = +3.67\ kJ$

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1 point

Among He(g), N_2(g), NH_3(aq), NH_4^+(aq), Na(s), Na^+(aq), NaCl(s), Cl^-(aq), Cl_2(g), and Ar(g), which is the best oxidizing agent? Please circle your answer.

9 points

(a) (5 points) For the reaction 2 A(aq) ⇌ B(aq) + C(aq), the value of $\Delta G°$ is -3.70 kJ (or kJ/mol) at 25°C. The initial concentrations of A(aq), B(aq), and C(aq) are 0.477 M, 0.311 M, and 0.233 M, respectively. What will be the concentration of A(aq) once we attain equilibrium at 25.0°C?

(b) (4 points) We have 500.0 mL of an aqueous solution of $CaCl_2$ ($CaCl_2$ is a strong electrolyte). We add an excess $AgNO_3$ so as to produce an AgCl(s) precipitate. The mass of AgCl proguced is 2.222 g. What was the original concentration of $CaCl_2$?

a) ① $K = e^{-\Delta G°/RT}$

$= e^{-(-3700)/8.3145(298.15)}$

$= 4.448$

② $2A(aq) \rightleftharpoons B(aq) + C(aq)$

i:	0.477	0.311	0.233
c:	$-2x$	$+x$	$+x$
e:	$0.477-2x$	$0.311+x$	$0.233+x$

③ $K = \frac{[B][C]}{[A]^2}$

$4.448 = \frac{(0.311+x)(0.233+x)}{(0.477-2x)^2}$

$4.448 = \frac{x^2+0.544x+0.0725}{4x^2-1.908x+0.2275}$

$0 = 16.792x^2 - 9.0308x + 0.9394$

$a = 16.792$

$b = -9.0308$

$c = 0.9394$

$x = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$

$= \frac{9.0308 \pm 4.2962}{2(16.762)}$

$x_1 = 0.3968$ impossible

$x_2 = 0.1410$

④ $[A] = 0.477 - 2x = 0.477 - 2(0.1410) = \boxed{0.195\ M}$

b) ① $n_{Cl} = n_{AgCl} = \frac{2.222\ g}{(107.9+35.45)\ g/mol}$

$= 0.015501\ mol$

② $n_{CaCl_2} = \frac{1}{2} n_{Cl}$

$= \frac{0.015501\ mol}{2}$

$n_{CaCl_2} = 0.007750\ mol$

③ $[CaCl_2] = \frac{0.007750\ mol}{0.0500\ L}$

$\boxed{= 0.1550\ mol/L}$

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