Chemistry 1210 Spring 2024 Test 2

Friday, March 1, 2024

Time: 1 hour 50 minutes

Name: ANSWERS

Student #: _____

*This test consists of **six** pages of questions, the formula sheet, and a periodic table. Please ensure that you have a complete test and, if you do not, obtain one from me **immediately**. There are **37.5** marks available. Good luck!*

1) **[2 marks]** A certain reaction has $\Delta H° = 65.0$ kJ/mol and $K = 50.0$ at 25°C. What will be its value of K at 50°C?

a) 50.1
b) 380.1
c) 3.09×10^{8}
d) 1.25×10^{88}
e) None of these

2) **[2 marks]** The normal boiling point of hexane is 68.75°C, and its enthalpy of vaporization is 31 kJ/mol. It's vapour pressure at 22°C will be:

a) 7.33×10^{-73} torr
b) 6.78×10^{-48} torr
c) 7.51×10^{-3} torr
d) 135.1 torr
e) 758.7 torr

3) **[5 marks total]** A 10-litre flask was charged with 5 moles of H_2, 5 moles of Cl_2, and 10 moles of HCl, and the equilibrium

$H_2(g) + Cl_2(g) \rightleftharpoons 2HCl(g)$ $\quad K_p = 0.25$ @ 27.53°C

established.

a) **[1 mark]** In which direction did the reaction shift to attain equilibrium? How do you know? (No marks for guessing. 😊)

$K_p + K_c$ are equal, so work problem in []s:

$Q = \frac{1^2}{0.5^2} = 4$

Q too big, rxn ← to make it smaller.

b) **[4 marks]** What were the equilibrium pressures of all species?

	H_2	+ Cl_2	$\rightleftharpoons$	$2HCl$
i	0.5M	0.5		1
c	+x	+x		toi −2x
e	0.5+x	0.5+x		1−2x

$[HCl]_e = 1-2x = 0.4M$

$[H_2]_e = [Cl_2]_e = 0.8M$

$\frac{(1-2x)^2}{(0.5+x)^2} = 0.25$

$\frac{1-2x}{0.5+x} = 0.5$

$1-2x = 0.25 + 0.5x$

$2.5x = 0.75$

$x = 0.3$

Since $P = [] \cdot RT$:

$P_{H_2,e} = P_{Cl_2,e} = 20$ bar

$P_{HCl,e} = 10$ bar

4) **[4 marks]** A flask was charged with 4.0×10^{-4} bar of CO_2 and the equilibrium

$CO_2(g) \rightleftharpoons CO(g) + \frac{1}{2}O_2(g)$ $\quad K_p = 4.0 \times 10^{-26}$

established. Calculate the equilibrium pressures of all species.

Double the reaction to get rid of fractions:

$2CO_2 \rightleftharpoons 2CO + O_2 \quad K_p = 1.6 \times 10^{-51}$

	$2CO_2$	$2CO$	O_2
i	4×10^{-4}	0	0
c	$-2x$	$+2x$	$+x$
e	$4 \times 10^{-4} - 2x$	$2x$	x

$$\frac{(2x)^2(x)}{(4 \times 10^{-4} - 2x)^2} = 1.6 \times 10^{-51}$$

$$\frac{4x^3}{(4 \times 10^{-4})^2} = 1.6 \times 10^{-51}$$

$$x^3 = 6.4 \times 10^{-59}$$

$$x = 4 \times 10^{-20}$$

So...

$P_{CO_2,e} = 4 \times 10^{-4}$ bar

$P_{CO,e} = 8 \times 10^{-20}$ bar

$P_{O_2,e} = 4 \times 10^{-20}$ bar

5) **[6 marks]** The K_{sp} of Ag_2SO_4 is 1.2×10^{-5}. How many grams of Ag_2SO_4 (311.8 g/mol) will dissolve in **half a litre** of:

a) water

$Ag_2SO_4 \rightleftharpoons 2Ag^+ + SO_4^{2-}$

		$2Ag^+$	SO_4^{2-}
i		0	0
c		$+2x$	$+x$
e		$2x$	x

$(2x)^2 \cdot x = 1.2 \times 10^{-5}$

$\Rightarrow x = 0.01442\ M$

So 2.248 g will dissolve

b) a solution with $[AgNO_3] = 0.100$ M

$Ag_2SO_4 \rightleftharpoons 2Ag^+ + SO_4^{2-}$

		$2Ag^+$	SO_4^{2-}
i		0.1	0
c		$+2x$	$+x$
e		$0.1+2x$	x

$(0.1+2x)^2 \cdot x = 1.2 \times 10^{-5} \Rightarrow$

$\rightarrow x = 1.2 \times 10^{-3}\ M$

So 0.187 g will dissolve

6) **[3 marks]** You have a solution with $[CO_3^{2-}] = 3.28 \times 10^{-3}$ M and $[Cl^-] = 1.7 \times 10^{-5}$ M. You choose to separate these two anions by adding solid $AgNO_3$. The K_{sp} of Ag_2CO_3 is 8.2×10^{-12}, and the K_{sp} of AgCl is 1.7×10^{-10}. At the point of maximum separation, what percent of the first of the two anions to precipitate will remain in solution?

Check Ag_2CO_3: $[Ag^+]_e^2 \cdot (3.28 \times 10^{-3}) = 8.2 \times 10^{-12}$

$\Rightarrow [Ag^+]_e = 5 \times 10^{-5}\ M$

Check AgCl: $[Ag^+]_e \cdot (1.7 \times 10^{-5}) = 1.7 \times 10^{-10}$

$\Rightarrow [Ag^+]_e = 1.0 \times 10^{-5}$

So Cl^- precipitates first.

At PoMS: $(5 \times 10^{-5})[Cl^-]_e = 1.7 \times 10^{-10}$

$\Rightarrow [Cl^-]_e = 3.4 \times 10^{-6}\ M$

$\rightarrow \frac{3.4 \times 10^{-6}}{1.7 \times 10^{-5}} \times 100 = 20\%$

7) **[4 marks]** Give the oxidation number of oxygen in the following molecules or ions:

a) O_2 0 b) HOF 0 c) OF_2 +2 d) H_2O_2 -1

8) **[5.5 marks]** Given the following redox reaction, occurring in **basic** solution:

$Al + ClO_4^{-1} \longrightarrow Al(OH)_4^{-1} + Cl^{-1}$

a) **[4 marks]** Balance the reaction.

$(4H_2O + Al \longrightarrow Al(OH)_4^- + 4H^+ + 3e^-) \times 8$

$(8H^+ + 8e^- + ClO_4^- \longrightarrow Cl^- + 4H_2O) \times 3$

$32H_2O + 8Al + 24H^+ + 24e^- + 3ClO_4^- \longrightarrow 8Al(OH)_4^- + 32H^+ + 24e^- + 3Cl^- + 12H_2O$

$20H_2O + 8Al + 3ClO_4^- \longrightarrow 8Al(OH)_4^- + 8H^+ + 3Cl^-$

$8H^+ + 8OH^- \longrightarrow 8H_2O$

$12H_2O + 8Al + 3ClO_4^- + 8OH^- \longrightarrow 8Al(OH)_4^- + 3Cl^-$

b) **[0.5 marks]** Which species is oxidized?

Al

c) **[0.5 marks]** Which species is the reducing agent?

Al

d) **[0.5 marks]** How many electrons are transferred in the overall reaction?

24

9) **[3 marks]** Given the half-reactions:

$NO_2 + H^+ + e^{-1} \rightleftharpoons HNO_2$ $\quad \varepsilon° = 1.07\ V$
$2HNO_2 + 4H^+ + 4e^{-1} \rightleftharpoons N_2O + 3H_2O$ $\quad \varepsilon° = 1.297\ V$

calculate $\varepsilon°$ for:

$2NO_2 + 6H^+ + 6e^{-1} \rightleftharpoons N_2O + 3H_2O$

$2NO_2 + 2H^+ + 2e^- \rightleftharpoons 2HNO_2$ $\quad 2 \cdot 1 \cdot (1.07)$

$2HNO_2 + 4H^+ + 4e^- \rightleftharpoons N_2O + 3H_2O$ $\quad + \ 1 \cdot 4 \cdot (1.297)$

$2NO_2 + 6H^+ + 6e^- \rightleftharpoons N_2O + 3H_2O$ $\quad 7.328$

$6 \cdot \varepsilon° = 7.328 \Rightarrow \boxed{\varepsilon° = 1.221\ V}$

10) **[3 marks]** Given the half-reactions:

$MnO_2 + 4H^+ + 2e^{-1} \rightleftharpoons Mn^{2+} + 2H_2O$ $\quad \varepsilon° = 1.23\ V$
$MnO_4^{-1} + 4H^+ + 3e^{-1} \rightleftharpoons MnO_2 + 2H_2O$ $\quad \varepsilon° = 1.70\ V$

Will MnO_2 disproportionate? Calculate $\varepsilon°$ for the disproportionation to prove your answer.

$3 \times (MnO_2 + 4H^+ + 2e^- \rightleftharpoons Mn^{2+} + 2H_2O)$ $\quad \varepsilon° = 1.23\ V$

$2 \times (MnO_2 + 2H_2O \rightleftharpoons MnO_4^- + 4H^+ + 3e^-)$ $\quad \varepsilon° = -1.70\ V$

$3MnO_2 + \cancel{12}_{4}H^+ + \cancel{6e^-} + 2MnO_2 + \cancel{4H_2O} \rightleftharpoons 3Mn^{2+} + \cancel{6}_{2}H_2O + 2MnO_4^- + \cancel{8H^+} + \cancel{6e^-}$

$5MnO_2 + 4H^+ \rightleftharpoons 3Mn^{2+} + 2MnO_4^- + 2H_2O$

$6 \cdot \varepsilon°_{TOT} = \cancel{3 \times 2} \times (1.23) + \cancel{2 \times 3} \times (-1.70)$

$= \boxed{-0.47\ V}$

$\varepsilon° < 0$, so NO_2 will not disproportionate