CHM1311E - Principles of Chemistry

Mid-term Exam

Wednesday October 8th, 2014

Name: Marking Student No.: Scheme

Please keep your work covered at all times and keep your eyes on your own paper! Cheating or any appearance of cheating will result in an F in the course and possible expulsion from the university.

Guidelines:

- Non-programmable calculators are permitted.
- All communication devices are strictly prohibited.
- Do not use liquid paper.
- Only copies written in ink will be considered for re-grade.

Question No.	Points	
1		/ 10
2		/ ~~15~~ 9
3		/ 8
~~4~~		~~/ 7~~
5a		/ 10
5b		/ 8
5c		/ 4
Total		~~/ 62~~

Best of the two { 127 or 149

Question 1. Short answers. (no partial points)

a) What volume of water must be added to 1.5 mL of a 3.0 M aqueous solution of $NaHCO_3$ to reach a concentration of 2.0 M? (2 points)

(2)

$C_1V_1 = C_2V_2$

$V_2 = \frac{C_1V_1}{C_2}$

$V_2 = \frac{(3.0\,M)(1.5\,mL)}{2.0\,M} = 2.25\,mL$

$V_{added} = V_2 - V_1$

$= 2.25\,mL - 1.5\,mL$

$= 0.75\,mL$

b) What is the name or formula of the following ionic pair? (3 points)

(3)

Na_2SO_4: (1) sodium sulfate

$Pb(OAc)_2$: (1) lead (II) acetate

potassium permanganate: (1) $KMnO_4$

c) In a constant volume closed system, what change in internal energy of the system will occur if the following reaction occurs and no heat is produced or absorbed? (2 points)

$$A_{(s)} + 2B_{(g)} \rightarrow 2C_{(s)} + D_{(g)}$$

(2)

$\Delta U = q + W$

$q = 0$

$W = -P\Delta V$,

$\Delta V = 0$

$\therefore W = -P(0)$

$W = 0$

$\Delta U = 0 + 0$

$\Delta U = 0$

$\therefore$ no change

d) Provide the number of protons, neutrons and electrons for ^{65}Cu. (3 points)

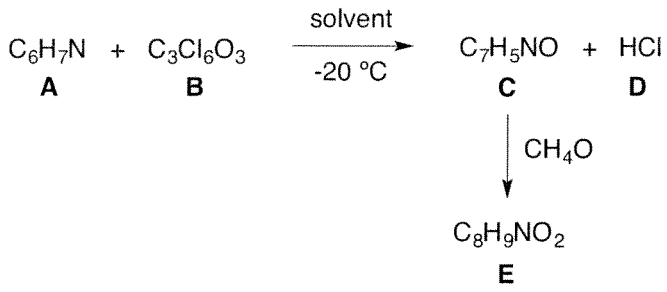
(3)

(1) protons : 29

(1) neutrons : 36

(1) electrons : 29

Question 2. Abby, a chemistry student, is performing the following reaction sequence.



The molar masses for each of the reactants and products are the following:

A: 93.07 g/mol
B: 296.73 g/mol
C: 119.07 g/mol
D: 36.45 g/mol
E: 151.09 g/mol

a) Provide a balanced equation for the *first* transformation (**A**+**B** →**C**+**D**). (2 points)

(2) $3C_6H_7N + C_3Cl_6O_3 \longrightarrow 3C_7H_5NO + 6HCl$

b) To perform the *first* reaction, Abby is following a known procedure previously reported in the scientific literature. In this publication, the authors treat 688.7 g of reactant **A** with 761.1 g of reactant **B**. If the authors report a yield of 82.5 %, what mass of product **C** should Abby expect to obtain if the results are to be reproduced exactly? (7 points)

$n_A = \frac{m_A}{MM_A} = \frac{688.7\,g}{93.07\,g/mol} = 7.400\,mol$

$n_B = \frac{m_B}{MM_B} = \frac{761.1\,g}{296.73\,g/mol} = 2.565\,mol$

$\frac{n_A}{3} = \frac{7.400}{3} = 2.467\,mol$

$\frac{n_A}{3} < n_B \therefore A$ is L.R.

$n_A = n_C = 7.400\,mol$

$m_C = 7.400\,mol \cdot 119.07\,g/mol = 881.1\,g$

$\%y = \frac{m_{C\,exp.}}{m_{C\,theo.}}$

$m_{C\,exp} = \%y \cdot m_{C\,theo.}$

$m_{C\,exp} = 0.825 \cdot 881.1\,g$

$m_{C\,exp} = 726.9\,g$

K

Question 3. Balance the following redox equation under acidic conditions. (8 points)

C_2H_6O $\qquad\qquad$ $C_2H_4O_2$

$$CH_3CH_2OH + Cr_2O_7^{2-} \longrightarrow CH_3CO_2H + Cr^{3+}$$

[O] $\qquad$ red

(2) [O] $\quad H_2O + C_2H_6O \longrightarrow C_2H_4O_2 + 4H^+ + 4e^-$ (x3)

(2) [red] $\quad 6e^- + 14H^+ + Cr_2O_7^{2-} \longrightarrow 2Cr^{3+} + 7H_2O$ (x2)

$\downarrow$

(2) [O] $\quad 3H_2O + 3C_2H_6O \longrightarrow 3C_2H_4O_2 + 12H^+ + 12e^-$

[red] $\quad 12e^- + 28H^+ + 2Cr_2O_7^{2-} \longrightarrow 4Cr^{3+} + 14H_2O$

(2) $\quad 16H^+ + 3C_2H_6O + 2Cr_2O_7^{2-} \longrightarrow 4Cr^{3+} + 3C_2H_4O_2 + 11H_2O$

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Question 5. A mixture of gaseous formaldehyde (CH_2O) and gaseous ethanol (C_2H_6O) has a total mass of 198.08 g. Combustion of the mixture is performed in the presence of excess O_2 under standard conditions. From this reaction, it was determined that 8.0 mol of CO_2 is produced. The molar mass of CH_2O is 30.01 g/mol and C_2H_6O is 46.02 g/mol and 46.02 g/mol respectively.

a) What is the mass percentage of gaseous formaldehyde (CH_2O) in the initial mixture? (10 points)

① $x\,CH_2O + O_2 \rightarrow x\,CO_2 + H_2O$

① $y\,C_2H_6O + 3O_2 \rightarrow 2y\,CO_2 + 3H_2O$

① $\therefore n_{CO_2} = x + 2y$, $x = n_{CO_2} - 2y$

① $m_{tot} = m_{CH_2O} + m_{C_2H_6O}$

① $m_{tot} = x(MM_{CH_2O}) + y(MM_{C_2H_6O})$

$m_{tot} = (n_{CO_2} - 2y)(MM_{CH_2O}) + y(MM_{C_2H_6O})$

$m_{tot} = n_{CO_2} \cdot MM_{CH_2O} - 2y(MM_{CH_2O}) + y(MM_{C_2H_6O})$

$m_{tot} - n_{CO_2} \cdot MM_{CH_2O} = y(MM_{C_2H_6O} - 2 \cdot MM_{CH_2O})$

$$\frac{m_{tot} - n_{CO_2} \cdot MM_{CH_2O}}{MM_{C_2H_6O} - 2MM_{CH_2O}} = y$$

$$\frac{198.08\,g - 8.0\,mol \cdot 30.01}{46.02 - 2(30.01)} = y$$

$$\frac{-42.}{-14.} = y$$

$3.0\,mol = y$ ①

$x = n_{CO_2} - 2y$

① $x = 8.0 - 2(3.0)$

$x = 2.0\,mol = n_{CH_2O}$

$m_{CH_2O} = n_{CH_2O} \cdot MM_{CH_2O}$

① $m_{CH_2O} = 2.0\,mol \cdot 30.01\,g/mol$

$m_{CH_2O} = 60.\,g$

① $m\% = \frac{60.02\,g}{198.08\,g} \times 100\% = 30\%$ ①

b) What is the individual enthalpy of reaction for the combustion of each of the compounds found in the initial mixture of gases? (8 points)

$CH_2O + O_2 \longrightarrow CO_2 + H_2O$

$\Delta H_r^\circ = \sum n_f \Delta H^\circ_{prod} - \sum n_f \Delta H^\circ_{react.}$

$\Delta H_r^\circ = [-393.5\,kJ/mol + (-241.826\,kJ/mol)]$

$-[-116\,kJ/mol + (0)]$ (4)

$\Delta H_r^\circ = -519\,kJ/mol$

$C_2H_6O + 3O_2 \longrightarrow 2CO_2 + 3H_2O$

$\Delta H_r^\circ = [2(-393.5\,kJ/mol) + 3(-241.826\,kJ/mol)]$

$-[-235.1\,kJ/mol - (0)]$ (4)

$\Delta H_r^\circ = -1512.5 + 235.1$

$\Delta H_r^\circ = -1277.4\,kJ/mol$

c) What is the amount of heat released from the combustion of the mixture of gases? (4 points)

$q = n_{CH_2O}(\Delta H_{r\,CH_2O}^\circ) + n_{C_2H_6O}(\Delta H_{r\,C_2H_6O}^\circ)$

$q = (2.0\,mol)(-519\,kJ/mol) + (3.0\,mol)(-1277.4\,kJ/mol$ (4)

$q = -1040\,kJ + (-3800\,kJ)$

$q = -4840\,kJ$