Problem Session - October 5, 2014 - Sunday

1. Calculate the change in total internal energy for a system that releases 2.11×10^4 kJ of heat and does 5.50×10^4 kJ of work on the surroundings.

$\Delta U = q + w$

$\Delta U = -2.11 \times 10^4 \text{ kJ} + (-5.50 \times 10^4 \text{ kJ})$

$\boxed{\Delta U = -7.61 \times 10^4 \text{ kJ}}$

2. In a gas expansion, 91 J of heat is absorbed by the system, and the energy of the system decreases by 134 J. Calculate the work done.

$\Delta U = q + w$

$-134 \text{ J} = 91 \text{ J} + w$

$-134 \text{ J} - 91 \text{ J} = w$

$\boxed{-225 \text{ J} = w}$

3. Calculate q, and determine whether heat is absorbed or released when a system does work on the surroundings equal to 64.0 J and ΔU = -218.0 J.

$\Delta U = q + w$

$-218.0 \text{ J} = q + (-64.0)$

$-154 \text{ J} = q$ (Heat is released into surroundings.)

4. Given the thermochemical equation for photosynthesis:

$6H_2O(l) + 6CO_2\,(g) \rightarrow C_6H_{12}O_6 + 6O_2\,(g)$

$\Delta H = +2803$ KJ/mol

Calculate the solar energy required to produce 6459g of $C_6H_{12}O_6$. Enter your result in scientific notation.

$$6459g\ C_6H_{12}O_6 \times \frac{1\ mol\ C_6H_{12}O_6}{180.16g\ C_6H_{12}O_6} = 35.85\ mol\ C_6H_{12}O_6$$

$$35.85\ mol\ C_6H_{12}O_6 \times \frac{2803\ KJ}{1\ mol\ C_6H_{12}O_6} = \boxed{1.005 \times 10^5\ kJ}$$

5. What volume of each of the following acids will react completely with 50.00 mL of 0.100M NaOH?

a. 0.100 M HCl

b. 0.100 M H_2SO_4

c. 0.200M H_3PO_4

$$50.00\,mL \times \frac{0.100\,mmol\,NaOH}{1\,mL} = 5.00\,mmol\,NaOH$$

ⓐ $NaOH + HCl \longrightarrow NaCl + H_2O$

$$5.00\,mmol\,NaOH \times \frac{1\,mmol\,HCl}{1\,mmol\,NaOH} \times \frac{1\,mL\,HCl}{0.1\,mmol\,HCl} = 50.0\,mL\,HCl$$

ⓑ $H_2SO_4 + 2NaOH \longrightarrow Na_2SO_4 + 2H_2O$

$$5.00\,mmol\,NaOH \times \frac{1\,mmol\,H_2SO_4}{2\,mmol\,NaOH} \times \frac{1\,mL\,H_2SO_4}{0.100\,mmol\,H_2SO_4} = 25\,mL\,H_2SO_4$$

ⓒ $H_3PO_4 + 3NaOH \longrightarrow Na_3PO_4 + 3H_2O$

$$5.00\,mmol\,NaOH \times \frac{1\,mmol\,H_3PO_4}{3\,mmol\,NaOH} \times \frac{1\,mL\,H_3PO_4}{0.200\,mmol\,H_3PO_4} = 8.33\,mL\,H_3PO_4$$

6. How do you prepare 2.00L of a 0.100M K_2CrO_4 solution from a 1.75M K_2CrO_4 stock?

$$2.00L\ K_2CrO_4 \times \frac{0.100\,Mol}{1\ L\ K_2CrO_4\ soln} = 0.200\ mol\ K_2CrO_4\ \text{needed.}$$

$$0.200\ mol\ K_2CrO_4\ \text{needed} \times \frac{L}{1.75\ mol\ K_2CrO_4} = 0.114\ L\ \text{of stock solution needed.}$$

Add 0.114L of 1.75M K_2CrO_4 stock to a 2L volumetric flask + make the solution up to the 2L line.

7. Calculate the sodium ion concentration when 70.0 mL of 3.0M sodium carbonate is added to 30 mL of 1.0M sodium bicarbonate.

Sodium carbonate = Na_2CO_3 Sodium bicarbonate = $NaHCO_3$

$$70.0mL \times \frac{3.0\,mmol\ Na_2CO_3}{1mL} \times \frac{2\ mmol\ Na^+}{1\ mmol\ Na_2CO_3} = 420\,mmol\ Na^+\ ion$$

$$30.0mL \times \frac{1.0\,mmol\ NaHCO_3}{1mL\ NaHCO_3} \times \frac{1.0\,mmol\ Na^+}{1.0\,mmol\ NaHCO_3} = 30\ mmol\ Na^+\ ion$$

$$420\ mmol\ Na^+\ ion + 30\,mmol\ Na^+\ ion = 450\ mmol\ Na^+\ ion\ \text{total.}$$

$$\frac{450\,mmol\ Na^+\ ion}{100mL} = \frac{4.5\ mmol\ Na^+}{mL} = \boxed{4.5M\ Na^+}$$

70.0mL + 30.0mL

Be sure to answer all parts.

Balance the following skeleton reaction and identify the oxidizing and reducing agents:

Include the states of all reactants and products in your balanced equation. You do not need to include the states with the identities of the oxidizing and reducing agents.

$Zn(s) + NO_3^-(aq) \rightarrow Zn(OH)_4^{2-}(aq) + NH_3(g)$ [basic]

This homework question was answered at a students request.

The oxidizing agent is

See the Next pages for the Solution.

The reducing agent is

(From Homework #7 CHAPTER 4-2 #33)

Balance the following skeleton reaction and identify the oxidizing and reducing agents:

Include the states of all reactants and products in your balanced equation. You do not need to include the states with the identities of the oxidizing and reducing agents.

$\mathbf{Zn}(s) + \mathbf{NO_3}^{-}(aq) \rightarrow \mathbf{Zn(OH)_4}^{2-}(aq) + \mathbf{NH_3}(g)$ **[basic]**

Step 1:

Start by breaking the reaction into its half–reactions.

The oxidation half–reaction is:

$Zn(s) \longrightarrow Zn(OH)_4^{2-}(aq)$

Zn is oxidized and is, thus, the reducing agent.

Step 2:

The reduction half–reaction is:

$NO_3^{-}(aq) \longrightarrow NH_3(g)$

NO_3^{-} is reduced and is, thus, the oxidizing agent.

Step 3:

Balance one half–reaction at a time. We'll start with the oxidation half–reaction:

We start by examining all atoms other than oxygen and hydrogen. In this case, the zinc atoms are already balanced.

Now, we balance oxygen atoms by adding 4 H_2O molecules to the left–hand side of the equation.

$4H_2O(l) + Zn(s) \longrightarrow Zn(OH)_4^{2-}(aq)$

Step 4:

Now we balance hydrogen atoms by adding 4 hydrogen ions to the right–hand side of the equation.

$4H_2O(l) + Zn(s) \longrightarrow Zn(OH)_4^{2-}(aq) + \mathbf{4}H^{+}(aq)$

Step 5:

Now, we balance the charge by adding electrons. The overall charge on the left–hand side of the equation is 0, and the overall charge on the right–hand side of the equation is **+2**, so we add 2 electrons to the right–hand side of the equation (electrons are always added to more positive side of the equation).

$4H_2O(l) + Zn(s) \longrightarrow Zn(OH)_4{}^{2-}(aq) + 4H^+(aq) + 2e^-$

The oxidation half–reaction is now balanced.

Step 6:

Let's move on to the reduction half–reaction.

We start by examining all atoms other than oxygen and hydrogen. In this case, the nitrogen atoms are already balanced.

Now, we balance oxygen atoms by adding 3 H_2O molecules to the right–hand side of the equation.

$NO_3{}^-(aq) \longrightarrow NH_3(g) + 3H_2O(l)$

Step 7:

Now we balance hydrogen atoms by adding 9 hydrogen ions to the left–hand side of the equation.

$9H^+(aq) + NO_3{}^-(aq) \longrightarrow NH_3(g) + 3H_2O(l)$

Step 8:

Now, we balance the charge by adding electrons. The overall charge on the left–hand side of the equation is +8, and the overall charge on the right–hand side of the equation is 0, so we add 8 electrons to the left–hand side of the equation (electrons are always added to more positive side of the equation).

$8e^- + 9H^+(aq) + NO_3{}^-(aq) \longrightarrow NH_3(g) + 3H_2O(l)$

The reduction half–reaction is now balanced.

Step 9:

In order to balance the number of electrons in the two half–reactions, we multiply the oxidation half–reaction by 4:

Oxidation half–reaction:

$16H_2O(l) + 4Zn(s) \longrightarrow 4Zn(OH)_4{}^{2-}(aq) + 16H^+(aq) + 8e^-$

Step 10:

Reduction half–reaction:

$8e^- + 9H^+(aq) + NO_3{}^-(aq) \longrightarrow NH_3(g) + 3H_2O(l)$

Step 11:

We now add the half–reactions and reduce where possible:

Step 11

$13\,H_2O$

$\cancel{16H_2O}_{(l)} + 4Zn_{(s)} \longrightarrow 4Zn(OH)_4^{2-}{}_{(aq)} + \cancel{16H^+}_{(aq)} + \cancel{8e^-}$ $7H^+$

$+ \quad \cancel{8e^-} + \cancel{9H^+}_{(aq)} + NO_3^-{}_{(aq)} \longrightarrow NH_{3(g)} + \cancel{3H_2O}_{(l)}$

$$13\,H_2O_{(l)} + 4Zn_{(s)} + NO_3^-{}_{(aq)} \longrightarrow 4Zn(OH)_4^{2-}{}_{(aq)} + NH_{3(g)} + 7H^+_{(aq)}$$

Step 12:

Because the reaction is balanced in basic solution, we add 7 hydroxide ions to both sides of the equation to react with the hydrogen ions (the hydrogen and hydroxide ions combine to make water) and then reduce where possible:

$$7OH^-(aq) + 6H_2O(l) + 4Zn(s) + NO_3^-(aq) \longrightarrow 4Zn(OH)_4^{2-}(aq) + NH_3(aq)$$

The equation is now balanced.

Enter your answer in the provided box.

Acetic acid ($HC_2H_3O_2$) is an important ingredient of vinegar. A sample of 50.0 mL of a commercial vinegar is titrated against a 1.00 *M* NaOH solution. What is the concentration (in *M*) of acetic acid present in the vinegar if 5.75 mL of the base is needed for the titration?

[ ] *M*

By request.
(Homework #9 ch.4-4 #11)

See the next pages for solution

Acetic acid ($HC_2H_3O_2$) is an important ingredient of vinegar. A sample of 50.0 mL of a commercial vinegar is titrated against a 1.00 M NaOH solution. What is the concentration (in M) of acetic acid present in the vinegar if 5.75 mL of the base is needed for the titration?

Step 1:

In this question, we are asked to calculate the molarity of acetic acid in a vinegar sample. We will need to write an equation for the titration reaction. Next, we will multiply the volume and concentration of base to obtain the moles of base used. From the reaction equation, we will use the ratio of moles of base to acid to calculate the moles of acid used. Finally, the moles of acid will be divided by the volume of vinegar, giving the molarity of acid.

Step 2:

$HC_2H_3O_2(aq) + NaOH(aq) \rightarrow NaC_2H_3O_2(aq) + H_2O(l)$

$$x \text{ mL NaOH} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{1.00 \text{ mol NaOH}}{\text{L}} \times \frac{1 \text{ mol } HC_2H_3O_2}{1 \text{ mol NaOH}} = y \text{ mol } HC_2H_3O_2$$

$$\frac{y \text{ mol } HC_2H_3O_2}{50.0 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = z\ M\ HC_2H_3O_2$$

Step 3:

$$5.75 \text{ mL NaOH} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{1.00 \text{ mol NaOH}}{\text{L}} \times \frac{1 \text{ mol } HC_2H_3O_2}{1 \text{ mol NaOH}}$$

$$= 0.00575 \text{ mol } HC_2H_3O_2$$

Step 4:

$$\frac{0.00575 \text{ mol } HC_2H_3O_2}{50.0 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 0.115\ M\ HC_2H_3O_2$$

Be sure to answer all parts.

What volume of a 0.500 M HCl solution is needed to neutralize each of the following:

(a) 10.0 mL of a 0.300 M NaOH solution

[ ] **mL**

(b) 18.0 mL of a 0.200 M $Ba(OH)_2$ solution

[ ] **mL**

By request.

(Homework #9 ch. 4-4 #12)

What volume of a 0.500 M HCl solution is needed to neutralize each of the following:

(a) 10.0 mL of a 0.300 M NaOH solution

(b) 18.0 mL of a 0.200 M $Ba(OH)_2$ solution

Step 1:

In this question, we are asked to neutralize basic solutions with a given strength of acid solution.

To determine the volume of acid required, we need to calculate the moles of base (OH^-) present in each solution. We will then find the volume of acid that corresponds to the equivalent number of moles of H^+ ions.

Step 2:

We can obtain the moles of OH^- in each solution by multiplying the volume (mL), the concentration (mmol/mL), and the ratio of OH^- per molecule. A solution of NaOH will produce one mole of OH^- for each mole of NaOH, whereas a solution of $Ba(OH)_2$ will produce two moles of OH^- for each mole of $Ba(OH)_2$.

Step 3:

$$y \text{ mmol } OH^-_{NaOH} = x \text{ mL NaOH} \times 0.300\ M \times \frac{1 \text{ mmol } OH^-}{1 \text{ mmol NaOH}}$$

$$y' \text{ mmol } OH^-_{Ba(OH)_2} = x' \text{ mL } Ba(OH)_2 \times 0.200\ M \times \frac{2 \text{ mmol } OH^-}{1 \text{ mmol } Ba(OH)_2}$$

Step 4:

HCl produces one mole of H^+ per mole of HCl, and H^+ and OH^- react in a 1:1 ratio. Therefore, the millimoles of OH^- are divided by the concentration of acid to give the volume of HCl required for neutralization:

Step 5:

$$z \text{ mL HCl} = y \text{ mmol } OH^- \times \frac{1 \text{ mmol } H^+}{1 \text{ mmol } OH^-} \times \frac{1 \text{ mmol HCl}}{1 \text{ mmol } H^+} \times \frac{\text{mL}}{0.500 \text{ mmol HCl}}$$

Step 6:

Think of this last step another way:

$M \times V = \text{mmol}$ where M is the molarity (mmol/mL) and V is the volume (mL).

$$\text{mmol } OH^- = \text{mmol } H^+ = M_{acid} V_{acid}$$

Rearrange to solve for V_{acid}:

$$\frac{\text{mmol } OH^-}{M_{acid}} = V_{acid}$$

(a) $10.0 \text{ mL NaOH} \times 0.300\ M \times \frac{1 \text{ mmol OH}}{1 \text{ mmol NaOH}} = 3.00 \text{ mmol OH}^{-}{}_{\text{NaOH}}$

Step 7:

$$V_{\text{acid}} = \frac{3.00 \text{ mmol OH}^{-}{}_{\text{NaOH}}}{0.500\ M \text{ HCl}} = 6.00 \text{ mL HCl}$$

Step 8:

(b) $18.0 \text{ mL Ba(OH)}_2 \times 0.200\ M \times \frac{2 \text{ mmol OH}^{-}}{1 \text{ mmol Ba(OH)}_2} = 7.20 \text{ mmol OH}^{-}{}_{\text{Ba(OH)}_2}$

Step 9:

$$V_{\text{acid}} = \frac{7.20 \text{ mmol OH}^{-}{}_{\text{Ba(OH)}_2}}{0.500\ M \text{ HCl}} = 14.4 \text{ mL HCl}$$