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Acid-Base and Redox Exam - Solutions

Exercise #1

The reaction table is:

	$NH_3 + H_2O \rightleftharpoons$	$NH_4^+ +$	OH^-
c init	0.025	-	-
c change	$-0.025\ \alpha$	$0.025\ \alpha$	$0.025\ \alpha$
c equil	$0.025\ (1-\alpha)$	$0.025\ \alpha$	$0.025\ \alpha$

a) The dissociation percent

From the dissociation constant we get the dissociation percent:

$$K_b = 1.8*10^{-5} = \frac{[NH_4^+]\,[OH^-]}{[NH_3]} = 0.025\ \frac{\alpha^2}{1-\alpha} \xrightarrow[1-\alpha=1]{\text{approximation}}$$

$$\alpha = \sqrt{\frac{1.8*10^{-5}}{0.025}} = 0.0268 \rightarrow \text{Approximation correct} \rightarrow \alpha = 2.68\ \%$$

b) The number of moles of hydroxide ions

$$n\,(OH^-) = [OH^-] * V = (0.025\ \alpha) * 0.1\ L$$

$$n\,(OH^-) = 6.7 * 10^{-5}\ \text{mol}\ OH^-$$

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c) pH

First, we will calculate pOH and then pH:

$pOH = -\log (0.025\ \alpha) = 3.17$

$pH = 14 - pOH =$ **10.83**

d) The volume of HCl in neutralization

The reaction is: $NH_3 + HCl \rightarrow NH_4Cl$

1 mol 1 mol

36.5 g

Mm (HCl) = 1 + 35.5 = 36.5 g/mol

The amount of ammonia neutralized is:

$$n\ (NH_3) = 0.025\ \frac{mol}{L} * 0.1\ L = 2.5 * 10^{-3}\ mol\ NH_3$$

The volume of HCl will be:

$$V\ (HCl) = 2.5*10^{-3}\ mol\ NH_3 * \frac{1\ mol\ HCl}{1\ mol\ NH_3} * \frac{36.5\ g\ HCl}{1\ mol\ HCl} * \frac{1\ L}{25\ g\ HCl} = 3.65*10^{-3}\ L$$

V = 3.65 mL HCl solution

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Exercise #2

a) Molarity

We are going to transform one way to express concentrations into another:

$$Mm\ (HNO_3) = 1 + 14 + (3*16) = 63\ g/mol$$

$$[HNO_3] = \frac{40\ g\ HNO_3}{100\ g\ sol} * \frac{1250\ g\ sol}{1\ L\ sol} * \frac{1\ mol}{63\ g\ HNO_3} = 7.94\ M$$

b) pH

This acid is strong; it means that it is fully dissociated. Thus:

$$pH = -\log (7.94) = -0.9$$

The acid is so concentrated that the pH is negative.

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Exercise #2

c) Concentration of ammonia The reaction is: $NH_3 + HNO_3 \rightarrow NH_4NO_3$

1 mol 1 mol

63 g

The concentration of NH_3 will be:

$$n\,(NH_3) = 0.028\ L\ HNO_3 * \frac{7.94\ mol\ HNO_3}{1\ L} * \frac{1\ mol\ NH_3}{1\ mol\ HNO_3} = 0.222\ mol\ NH_3$$

$$[NH_3] = \frac{0.222\ mol\ NH_3}{0.125\ L} = 1.78\ M$$

d) pH The pH depends on the hydrolysis reactions:

$$NO_3^- + H_2O \rightarrow \text{no reaction}$$

$$NH_4^+ + H_2O \rightarrow NH_3 + H_3O^+$$

The pH at the equivalente point will be less than 7.

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Exercise #3

a) Mass 96500 C are the equivalent of 1 mole of electrons.
Magnesium is reduced according to this half-reaction:

$$Mg^{2+} + 2\ e^- \rightarrow Mg$$

The charge that passes through the cell in 3.5 days is:

$$q = 6.20\ \frac{C}{s} * 3.5\ days * \frac{24\ hr}{1\ day} * \frac{3600\ s}{1\ hr} = 1\ 874\ 880\ C$$

The mass of Mg formed:

$$m = 1\ 874\ 880\ C * \frac{1\ mol\ e^-}{96\ 500\ C} * \frac{1\ mol\ Mg}{2\ mol\ e^-} * \frac{24\ g\ Mg}{1\ mol\ Mg} = 233.15\ g\ Mg$$

b) Time (in minutes) The time needed:

$$t = 10\ g\ Mg * \frac{1\ mol\ Mg}{24\ g\ Mg} * \frac{2\ mol\ e^-}{1\ mol\ Mg} * \frac{96\ 500\ C}{1\ mol\ e^-} * \frac{1\ s}{4.5\ C} * \frac{1\ min}{60\ s} = 297.8\ min$$

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Exercise #4

a) Balancing the equation

$2^* (MnO_4^- + 8\ H^+ + 5\ e^- \rightarrow Mn^{2+} + 4\ H_2O)$

$5^* (S^{2-} \rightarrow S + 2\ e^-)$

$2\ MnO_4^- + 16\ H^+ + 5\ S^{2-} \rightarrow 5\ S + 2\ Mn^{2+} + 8\ H_2O$

$2\ KMnO_4 + 6\ HCl + 5\ H_2S \rightarrow 5\ S + 2\ MnCl_2 + 2\ KCl + 8\ H_2O$

b) The species

Oxidant: MnO_4^- Reduced: Mn^{2+}

Reductant: S^{2-} Oxidized: S

c) d) The voltaic cell

Cathode: $2^* (MnO_4^- + 8\ H^+ + 5\ e^- \rightarrow Mn^{2+} + 4\ H_2O)$ $E^0 = 1.51$ V

Anode: $5^* (S^{2-} \rightarrow S + 2\ e^-)$ $E^0 = -0.14$ V

$2\ MnO_4^- + 16\ H^+ + 5\ S^{2-} \rightarrow 5\ S + 2\ Mn^{2+} + 8\ H_2O$ $E^0_{cell} = 1.37$ V

$$Pt\ (s)\ |\ S(s)\ |\ S^{2-}\ (aq)\ \|\ MnO_4^-\ (aq),\ Mn^{2+}\ (aq)\ |\ Pt\ (s)$$

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Exercise #5

a) Natural acidic rain

It is the acidic rain produced by CO_2 in the atmosphere. It is weakly acidic (pH = 5.6)

b) Gas emissions

Nitrogen (NOx) and sulfur oxides (SOx) are the gases responsible for the acid rain.

c) Effects in lakes

It kills living organisms (pH is acidic) and liberates heavy metal ions from rocks.

d) Prevention

Catalytic converters (eliminates NOx) and combustion of fuels with low content in sulfur.