The Advanced Placement Examination in Chemistry

Part II - Free Response Questions & Answers 1970 to 2006

Redox

Compiled for the Macintosh and PC by:

Harvey Gendreau *(ret.)*
Framingham High School
Framingham, MA 01701-4195
419-735-4782 (fax)

508-877-8723 (home office)
www.apchemistry.com
apchemtchr@aol.com
hgendreau@rcn.com

Requests for copies of these questions and answers as e-mail attachments for either the Macintosh or the PC (MS-Office files) should be sent to:

apchemtchr@aol.com.

Please include your name, school, school phone, name of principal/headmaster and school website address. Don't forget to include the file format you want, Mac or PC.

1971

Permanganate ion, MnO_4^-, oxidizes sulfite ions to sulfate ion. The manganese product depends upon the pH of the reaction mixture. The mole ratio of oxidizing to reducing agent is two to five at pH 1, and is two to one at pH 13. For each of these cases, write a balanced equation for the reaction, and indicate the oxidation state of the manganese in the product containing manganese.

Answer:

$2\ MnO_4^- + 5\ SO_3^{2-} + 6\ H^+ \rightarrow 2\ Mn^{2+} + 3\ H_2O + 5\ SO_4^{2-}$ (oxidation state Mn = +2)

$2\ MnO_4^- + SO_3^{2-} + 2\ OH^- \rightarrow 2\ MnO_4^{2-} + H_2O + SO_4^{2-}$ (oxidation state Mn = +6)

1981 B

A 1.2516 gram sample of a mixture of $CaCO_3$ and Na_2SO_4 was analyzed by dissolving the sample and completely precipitating the Ca^{2+} as CaC_2O_4. The CaC_2O_4 was dissolved in sulfuric acid and the resulting $H_2C_2O_4$ was titrated with a standard $KMnO_4$ solution.

(a) Write the balanced equation for the titration reaction, shown unbalanced below.

$MnO_4^- + H_2C_2O_4 + H^+ \rightarrow Mn^{2+} + CO_2 + H_2O$

Indicate which substance is the oxidizing agent and which substance is the reducing agent.

(b) The titration of the $H_2C_2O_4$ obtained required 35.62 milliliters of 0.1092 molar MnO_4^- solution. Calculate the number of moles of $H_2C_2O_4$ that reacted with the MnO_4^-

(c) Calculate the number of moles of $CaCO_3$ in the original sample.

(d) Calculate the percentage by weight of $CaCO_3$ in the original sample.

Answer:

(a) $2\ MnO_4^- + 5\ H_2C_2O_4 + 6\ H^+ \rightarrow 2\ Mn^{2+} + 10\ CO_2 + 8\ H_2O$

oxidizing agent: MnO_4^-, reducing agent: $H_2C_2O_4$

(b) $0.03562\ \text{L} \times \dfrac{0.1092\ \text{mol}}{\text{L}} \times \dfrac{5\ \text{mol}\ H_2C_2O_4}{2\ \text{mol}\ MnO_4^-} = 9.72\times10^{-3}\ \text{mol}\ H_2C_2O_4$

(c) moles of $H_2C_2O_4$ = moles $CaCO_3$, therefore, 9.72×10^{-3} mol $H_2C_2O_4$ = 9.72×10^{-3} mol $CaCO_3$

(d) $\dfrac{9.72\times10^{-3}\ \text{mol}\ CaCO_3 \times \dfrac{100.1\ \text{g}\ CaCO_3}{1\ \text{mol}\ CaCO_3}}{1.2516\ \text{g sample}} \times 100 = 77.7\%\ CaCO_3$

1986 D

(a) Describe what you would see if you added

1. a piece of zinc metal to a test tube that contains 6 molar hydrochloric acid.
2. a piece of copper metal to another test tube that contains 6 molar hydrochloric acid.

(b) Write balanced equations for any reactions that occur.

(c) Explain how you could use the table of standard reduction potentials [attached] to predict the observed results.

(d) In a separate experiment, concentrated nitric acid is added to a test tube containing a piece of copper metal.

1. Describe what you would see.
2. Explain any differences between the results obtained in this experiment and those obtained with copper metal in part (a).

Answer:

(a) 1. Bubbling or dissolving of Zn

2. No reaction

(b) $Zn + 2\ H^+ \rightarrow Zn^{2+} + H_2$ **or** $Zn + 2\ HCl \rightarrow ZnCl_2 + H_2$

(c) The table shows that Zn is a better reducing agent than H_2, so Zn can reduce H^+ in HCl to H_2. Cu is a weaker reducing agent than H_2, so no reaction occurs when Cu is added to HCl.

(d) 1. A reaction occurs in which a brown gas is given off **OR** the solution turns blue or green OR copper dissolves.

2. Nitric acid is an oxidizing acid and hydrochloric acid is not. **OR** Nitric acid is a better oxidizing agent than Cu^{2+} is. OR equivalent explanation.

1994 D (Required)

Discuss the following phenomena in terms of the chemical and physical properties of the substances involved and general principles of chemical and physical change.

(c) What will be observed on the surfaces of zinc and silver strips shortly after they are placed in separate solutions of $CuSO_4$, as shown on the right? Account for these observations.

Answer:

(c) No reaction in the Ag | Cu^{2+} beaker because Ag^+ is easier to reduce than Cu^{2+}.

The zinc will go into solution as Zn^{2+} while the Cu^{2+} will reduce to Cu, forming on the surface of the zinc.

$Zn_{(s)} + Cu^{2+} \rightarrow Zn^{2+} + Cu_{(s)}$ $E^\circ_{cell} = +\ 1.10$ v

1998 D

Answer each of the following using appropriate chemical principles.

(d) Identify a chemical species that is

(i) capable of oxidizing $Cl^-_{(aq)}$ under standard conditions

(ii) capable of reducing $Cl_{2(aq)}$ under standard conditions.

In each case, justify your choice.

Answer

(d) (i) $2\ Cl^- - 2\ e^- \rightarrow Cl_2$, $E^\circ = -1.36$v Any species that has a reduction potential greater than +1.36v, such as Au^{3+} or Co^{3+} or F_2, will oxidize the chloride ion.

(ii) $Cl_2 + 2\ e^- \rightarrow 2\ Cl^-$, $E^\circ = +1.36$v Any species that has an oxidation potential greater than -1.36v, such as Li, Cs, K, will cause chlorine to be reduced.