# AP Chemistry
# 2000 Student Samples



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A1

3. Answer the following questions about $BeC_2O_4(s)$ and its hydrate.

(a) Calculate the mass percent of carbon in the hydrated form of the solid that has the formula $BeC_2O_4 \cdot 3\ H_2O$

(b) When heated to 220.°C, $BeC_2O_4 \cdot 3\ H_2O(s)$ dehydrates completely as represented below.

$$BeC_2O_4 \cdot 3\ H_2O(s) \rightarrow BeC_2O_4(s) + 3\ H_2O(g)$$

If 3.21 g of $BeC_2O_4 \cdot 3\ H_2O(s)$ is heated to 220.°C, calculate

(i) the mass of $BeC_2O_4(s)$ formed, and,

(ii) the volume of the $H_2O(g)$ released, measured at 220.°C and 735 mm Hg.

(c) A 0.345 g sample of anhydrous $BeC_2O_4$, which contains an inert impurity, was dissolved in sufficient water to produce 100. mL of solution. A 20.0 mL portion of the solution was titrated with $KMnO_4(aq)$. The balanced equation for the reaction that occurred is as follows.

$$16\ H^+(aq) + 2\ \overset{+7}{Mn}O_4^-(aq) + 5\ \overset{+3}{C_2}O_4^{2-}(aq) \rightarrow 2\ Mn^{2+}(aq) + 10\ \overset{+4}{C}O_2(g) + 8\ H_2O(l).$$

The volume of 0.0150 *M* $KMnO_4(aq)$ required to reach the equivalence point was 17.80 mL.

(i) Identify the reducing agent in the titration reaction.

(ii) For the titration at the equivalence point, calculate the number of moles of each of the following that reacted.

- $MnO_4^-(aq)$
- $C_2O_4^{2-}(aq)$

(iii) Calculate the total number of moles of $C_2O_4^{2-}(aq)$ that were present in the 100. mL of prepared solution.

(iv) Calculate the mass percent of $BeC_2O_4(s)$ in the impure 0.345 g sample.

a) $MM_{hydrate} = 9.01\frac{g}{mol} + 2(12.01\frac{g}{mol}) + 4(16.00\frac{g}{mol}) + 3(2(1.01\frac{g}{mol}) + 16.00\frac{g}{mol})$

$= 151.09\ \frac{g}{mol}$

$\%\ carbon = 100 * \frac{2(12.01\ \frac{g}{mol})}{151.09\ g/mol} =$ **15.90 %**

b) 3.21 g $BeC_2O_4 \cdot 3H_2O$ $\quad MM_{BeC_2O_4} = 97.03\ \frac{g}{mol}$

i) $3.21\ g\ BeC_2O_4 \cdot 3H_2O * \frac{mol\ BeC_2O_4 \cdot 3H_2O}{151.09\ g\ BeC_2O_4 \cdot 3H_2O} * \frac{mol\ BeC_2O_4}{mol\ BeC_2O_4 \cdot 3H_2O} * \frac{97.03\ g\ BeC_2O_4}{mol\ BeC_2O_4}$

$=$ **2.06 g $BeC_2O_4$**

ii) $2.06\ g\ BeC_2O_4 * \frac{3\ mol\ H_2O}{mol\ BeC_2O_4} * \frac{mol\ BeC_2O_4}{97.03\ g\ BeC_2O_4} = 0.0637\ mol\ H_2O$

$PV = nRT \quad T = 220.\ °C = 493\ K \quad P = 735\ mm\ Hg * \frac{atm}{760\ mmHg} = 0.967\ atm$

$(0.967\ atm)V = (0.0637\ mol)(0.08206\ \frac{L\ atm}{mol\ K})(493\ K)$

$V =$ **2.66 L $H_2O$**

**GO ON TO THE NEXT PAGE.**

A2

ADDITIONAL PAGE FOR ANSWERING QUESTION 3.

c) 0.345 g $BeC_2O_4$ w/ impurity

100. mL soln.

20.0 mL sdn. = 17.80 mL 0.0150 M $KMnO_4$

i) $C_2O_4^{2-}$ is the reducing agent.

ii) $17.80\ mL * 0.0150\ M = 0.267\ mmol\ MnO_4^- = \boxed{2.67 * 10^{-4}\ mol\ MnO_4^-}$

$2.67 * 10^{-4}\ mol\ MnO_4^- * \frac{5\ mol\ C_2O_4^{2-}}{2\ mol\ MnO_4^-} = \boxed{6.68 * 10^{-4}\ mol\ C_2O_4^{2-}}$

iii) $\frac{6.68\ mol\ C_2O_4^{2-}}{20.0\ mL\ sdn} * \frac{n}{100.\ mL\ sdn}$ $\quad n = \boxed{3.34 * 10^{-3}\ mol\ C_2O_4^{2-}}$

iv) $m_{BeC_2O_4} = 3.34 * 10^{-3}\ mol\ C_2O_4^{2-} * \frac{mol\ BeC_2O_4}{mol\ C_2O_4^{2-}} * \frac{97.03\ g\ BeC_2O_4}{mol\ BeC_2O_4}$

$= 0.324\ g\ BeC_2O_4$

$\%_{BeC_2O_4} = 100 * \frac{0.324\ g}{0.345\ g} = \boxed{93.9\ \%}$

**S T O P**

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(iv) Calculate the mass percent of $BeC_2O_4(s)$ in the impure 0.345 g sample.

a) MW C = 24
MW $BeC_2O_4 \cdot 3H_2O$ = 119 $\%C = \frac{24.02}{119} \times 100 =$ 20.2%

b) (i) $3.21\ g\ BeC_2O_4 \cdot 3H_2O \times \frac{1\ mole}{119\ g} =$ .0270 moles

∴ .0270 moles $BeC_2O_4 \times \frac{97.09}{mole} =$ 2.62 g

(ii) $V = \frac{nRT}{P} = \frac{(.0810)(.0821)(492)}{\left(\frac{735}{760}\ atm\right)} =$ 3.39 L

GO ON TO THE NEXT PAGE.

B2

ADDITIONAL PAGE FOR ANSWERING QUESTION 3.

c) ~~$C_2O_4^{-2}$~~ Specifically, the Carbon was the red. agent b/c the ox. oxidation state of carbon went from +3 to +4.

(ii) (.01780 L)(.0150 M) = .000267 moles $MnO_4^-$

.000267 moles $MnO_4^-$ × $\frac{5 \text{ moles } C_2O_4^{-2}}{2 \text{ moles } MnO_4^-}$ = .00668 moles $C_2O_4^{-2}$

(iii) .345 g × $\frac{1 \text{ mole}}{97 \text{ g}}$ = .00356 moles $BaC_2O_4$

= .00356 moles $C_2O_4^-$

(iv) .00356 − .00668 = .00259 impure moles

$\frac{.00259 \text{ moles}}{.00356 \text{ moles}} \times 100$

= 78% impurity

# S T O P

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C1

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(iii) Calculate the total number of moles of $C_2O_4^{2-}(aq)$ that were present in the 100. mL of prepared solution.

(iv) Calculate the mass percent of $BeC_2O_4(s)$ in the impure 0.345 g sample.

a) % mass C in $BeC_2O_4 \cdot 3H_2O$:

$$\frac{24\ g\ C}{151\ g\ BeC_2O_4 \cdot 3H_2O} \times 100 = \boxed{16\%\ C}$$

b) (i) mass of $BeC_2O_4(s)$ formed

$$3.21\ g\ BeC_2O_4 \cdot 3H_2O \left| \frac{1\ mol}{151\ g\ BeC_2O_4 \cdot 3H_2O} \right| \frac{1\ mol\ BeC_2O_4}{1\ mol\ BeC_2O_4 \cdot 3H_2O} \left| \frac{9\ g\ BeC_2O_4}{1\ mol\ BeC_2O_4} \right| =$$

$$\boxed{0.191\ g\ BeC_2O_4(s)\ formed}$$

(ii) volume $H_2O(g)$ released

$$3.21\ g\ BeC_2O_4 \cdot 3H_2O \left| \frac{1\ mol}{151} \right| \frac{3\ mol\ H_2O}{1\ mol} \left| \frac{22.4\ L}{1\ mol\ H_2O} \right| = \boxed{1.42\ L\ H_2O(g)}$$

GO ON TO THE NEXT PAGE.

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c) $16\,H^+ + 2\,MnO_4^- + 5\,C_2O_4^{2-} \rightarrow 2\,Mn^{2+} + 10\,CO_2 + 8\,H_2O$

0.0150 M — 1000 mL

17.8 mL @ eq. pt.

(i) Identify reducing agent → oxidized

$2\,MnO_4^- \rightarrow 2\,Mn^{2+} + 4H_2O + e^-$

$MnO_4^-$ is the reducing agent, because it causes the substance to be oxidized.

(ii) Number of moles at eq. pt.?

- $MnO_4^-(aq)$

~~$17.8\text{ mL } MnO_4^- \left| \frac{1\text{ mol}}{22.4\text{ L}} \right. = 0.794\text{ mol } MnO_4^-$~~

- ~~$C_2O_4^{2-}(aq)$~~

$17.8\text{ mL } MnO_4^- \left( \frac{.0150\text{ mol}}{1000\text{ mL}} \right) = 2.67 \times 10^{-4}\text{ mol}$

- $C_2O_4^{2-}$

(iii) $0.345\text{ g } BeC_2O_4 \left| \frac{1\text{ mol}}{97\text{ g } BeC_2O_4} \right| \frac{1\text{ mol } C_2O_4^{2-}}{1\text{ mol}} = 0.00356\text{ mol } C_2O_4^{2-}$

(iv) % $BeC_2O_4$

**STOP**

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