AP Chemistry 2014

$$CH_3CH_2COOH(aq) + H_2O(l) \rightleftarrows CH_3CH_2COO^-(aq) + H_3O^+(aq)$$

Propanoic acid, CH_3CH_2COOH, is a carboxylic acid that reacts with water according to the equation above. At 25°C the pH of a 50.0 mL sample of 0.20 M CH_3CH_2COOH is 2.79.

(a) Identify a Brønsted-Lowry conjugate acid-base pair in the reaction. Clearly label which is the acid and which is the base.

(b) Determine the value of K_a for propanoic acid at 25°C.

AP Chemistry 2013

Answer the following questions about the solubility of some fluoride salts of alkaline earth metals.

(a) A student prepares 100. mL of a saturated solution of MgF_2 by adding 0.50 g of solid MgF_2 to 100. mL of distilled water at 25°C and stirring until no more solid dissolves. (Assume that the volume of the undissolved MgF_2 is negligibly small.) The saturated solution is analyzed, and it is determined that $[F^-]$ in the solution is 2.4×10^{-3} M.

(i) Write the chemical equation for the dissolving of solid MgF_2 in water.

(ii) Calculate the number of moles of MgF_2 that dissolved.

(iii) Determine the value of the solubility-product constant, K_{sp}, for MgF_2 at 25°C.

AP Chemistry 2012

The equation for the dissociation reaction of HA in water is shown below.

$$HA(aq) + H_2O(l) \rightleftarrows H_3O^+(aq) + A^-(aq) \qquad K_a = 6.3 \times 10^{-5}$$

(e) Assume that the initial concentration of the HA solution (before any NaOH solution was added) is 0.200 M. Determine the pH of the initial HA solution.

AP Chemistry 2007 Form B

A sample of solid U_3O_8 is placed in a rigid 1.500 L flask. Chlorine gas, $Cl_2(g)$, is added, and the flask is heated to 862°C. The equation for the reaction that takes place and the equilibrium-constant expression for the reaction are given below.

$$U_3O_8(s) + 3\,Cl_2(g) \rightleftarrows 3\,UO_2Cl_2(g) + O_2(g) \qquad K_p = \frac{(p_{UO_2Cl_2})^3(p_{O_2})}{(p_{Cl_2})^3}$$

When the system is at equilibrium, the partial pressure of $Cl_2(g)$ is 1.007 atm and the partial pressure of $UO_2Cl_2(g)$ is 9.734×10^{-4} atm.

(a) Calculate the partial pressure of $O_2(g)$ at equilibrium at 862°C.

(b) Calculate the value of the equilibrium constant, K_p, for the system at 862°C.

AP Chemistry 2010 Form B

The two isomers exist in equilibrium as represented by the equation below.

$$n\text{-butane}(g) \rightleftarrows \text{isobutane}(g) \qquad K_c = 2.5 \text{ at } 25°C$$

Suppose that a 0.010 mol sample of pure *n*-butane is placed in an evacuated 1.0 L rigid container at 25°C.

(c) Write the expression for the equilibrium constant, K_c, for the reaction.

(d) Calculate the initial pressure in the container when the *n*-butane is first introduced (before the reaction starts).

(e) The *n*-butane reacts until equilibrium has been established at 25°C.

(i) Calculate the total pressure in the container at equilibrium. Justify your answer.

(ii) Calculate the molar concentration of each species at equilibrium.

(iii) If the volume of the system is reduced to half of its original volume, what will be the new concentration of *n*-butane after equilibrium has been reestablished at 25°C ? Justify your answer.

AP Chemistry 2008 Form B

Answer the following questions regarding the decomposition of arsenic pentafluoride, $AsF_5(g)$.

(a) A 55.8 g sample of $AsF_5(g)$ is introduced into an evacuated 10.5 L container at 105°C.

(i) What is the initial molar concentration of $AsF_5(g)$ in the container?

(ii) What is the initial pressure, in atmospheres, of the $AsF_5(g)$ in the container?

At 105°C, $AsF_5(g)$ decomposes into $AsF_3(g)$ and $F_2(g)$ according to the following chemical equation.

$$AsF_5(g) \rightleftarrows AsF_3(g) + F_2(g)$$

(b) In terms of molar concentrations, write the equilibrium-constant expression for the decomposition of $AsF_5(g)$.

(c) When equilibrium is established, 27.7 percent of the original number of moles of $AsF_5(g)$ has decomposed.

(i) Calculate the molar concentration of $AsF_5(g)$ at equilibrium.

(ii) Using molar concentrations, calculate the value of the equilibrium constant, K_{eq}, at 105°C.

AP Chemistry 2014 Solution Guide

CH_3CH_2COOH and $CH_3CH_2COO^-$ *acid* *base* OR H_3O^+ and H_2O *acid* *base*	1 point is earned for writing (or naming) either of the Brønsted-Lowry conjugate acid-base pairs with a clear indication of which is the acid and which is the base.

$[H_3O^+] = 10^{-pH} = 10^{-2.79} = 1.6 \times 10^{-3}\ M$ $[CH_3CH_2COO^-] = [H_3O^+]$ AND $[CH_3CH_2COOH] = 0.20\ M - [H_3O^+]$, OR $[CH_3CH_2COOH] \approx 0.20\ M$ (state or assume that $[H_3O^+] << 0.20\ M$) $K_a = \frac{[CH_3CH_2COO^-][H_3O^+]}{[CH_3CH_2COOH]} = \frac{(1.6 \times 10^{-3}\ M)^2}{0.20\ M} = 1.3 \times 10^{-5}$	1 point is earned for correctly solving for $[H_3O^+]$. 1 point is earned for the K_a expression for propanoic acid OR 1 point is earned for substituting values into the K_a expression. 1 point is earned for correctly solving for the value of K_a.

AP Chemistry 2013 Solution Guide

$MgF_2(s) \rightleftarrows Mg^{2+}(aq) + 2\ F^-(aq)$	1 point is earned for the correct equation.

$\frac{2.4 \times 10^{-3}\ \text{mol } F^-}{1.0\ \text{L}} \times 0.100\ \text{L} \times \frac{1\ \text{mol } MgF_2}{2\ \text{mol } F^-} = 1.2 \times 10^{-4}\ \text{mol } MgF_2$	1 point is earned for the correct calculation of moles from concentration. 1 point is earned for the correct stoichiometry.

$[Mg^{2+}] = \frac{1}{2}[F^-] = \frac{1}{2}(2.4 \times 10^{-3}\ M) = 1.2 \times 10^{-3}\ M$ $K_{sp} = [Mg^{2+}][F^-]^2 = (1.2 \times 10^{-3})(2.4 \times 10^{-3})^2$ $= 6.9 \times 10^{-9}$	1 point is earned for the correct value of $[Mg^{2+}]$ 1 point is earned for the correct setup for determining the value of K_{sp}. 1 point is earned for the correct value of K_{sp}.

AP Chemistry 2012 Solution Guide

$K_a = \frac{[H_3O^+][A^-]}{[HA]}$ $6.3\times10^{-5} = \frac{(x)(x)}{(0.200-x)}$; assume that $x << 0.200\ M$. $x = [H_3O^+] = 3.5\times10^{-3}\ M$ $pH = -\log[H_3O^+] = -\log(3.5\times10^{-3}) = 2.45$	1 point is earned for the appropriate substitution into the K_a expression. 1 point is earned for the correct $[H_3O^+]$. 1 point is earned for the calculation of pH.

AP Chemistry 2007 Form B Solution Guide

	$U_3O_8(s)$ +	$3\ Cl_2(g)$ $\rightleftarrows$	$3\ UO_2Cl_2(g)$ +	$O_2(g)$
I	---	?	0	0
C				
E		1.007 atm	9.734×10^{-4} atm	?

$$9.734 \times 10^{-4}\ \text{atm}\ UO_2Cl_2(g) \times \frac{(1\ \text{mol}\ O_2)}{(3\ \text{mol}\ UO_2Cl_2)} = 3.245 \times 10^{-4}\ \text{atm}\ O_2(g)$$

One point is earned for the correct answer.

$K_p = \frac{(p_{UO_2Cl_2})^3(p_{O_2})}{(p_{Cl_2})^3} = \frac{(9.734\times10^{-4})^3(3.245\times10^{-4})}{(1.007)^3} = 2.931 \times 10^{-13}$	One point is earned for the correct substitution. One point is earned for the correct answer.

AP Chemistry 2010 Form B Solution Guide

$K_c = \frac{[\text{isobutane}]}{[n\text{-butane}]}$	One point is earned for the correct equation.
$P = \frac{nRT}{V} = \frac{(0.010\text{ mol})(0.0821\frac{\text{L}\times\text{atm}}{\text{mol}\times\text{K}})(298\text{ K})}{1.0\text{ L}}$ $= 0.24\text{ atm}$	One point is earned for the correct substitution and numerical answer.
The total pressure in the container remains the same, 0.24 atm. As the reaction proceeds, the number of molecules in the container remains constant; one molecule of isobutane is produced for each molecule of *n*-butane consumed.	One point is earned for the correct answer with justification.
$K_c = \frac{[\text{isobutane}]}{[n\text{-butane}]} = \frac{x}{(0.010 - x)} = 2.5$ $x = 2.5(0.010 - x) = 0.025 - 2.5x$ $3.5x = 0.025 \Rightarrow x = 0.0071\ M$ isobutane $(0.010\ M - 0.0071\ M) = 0.003\ M$ *n*-butane	One point is earned for the correct setup. One point is earned for both correct numerical answers.
Halving the volume of the container at equilibrium doubles the pressure of both isobutane and *n*-butane, which has no effect on the equilibrium because the stoichiometry of the reaction is one mole of product produced for each mole of reactant consumed. Since the number of moles of each isomer is unchanged but the volume is reduced by half, concentrations of both isomers are doubled and the concentration of *n*-butane will be $2 \times 0.003\ M = 0.006\ M$.	One point is earned for the correct answer with justification.

AP Chemistry 2008 Form B Solution Guide

$\text{mol } AsF_5 = 55.8 \text{ g } AsF_5 \times \frac{1 \text{ mol } AsF_5}{169.9 \text{ g } AsF_5} = 0.328 \text{ mol}$ $[AsF_5]_i = \frac{0.328 \text{ mol } AsF_5}{10.5 \text{ L}} = 0.0313\ M$	One point is earned for the correct molar mass. One point is earned for the correct concentration.

$PV = nRT$ $P = \frac{0.328 \text{ mol} \times 0.0821 \text{ L atm mol}^{-1} \text{ K}^{-1} \times 378 \text{ K}}{10.5 \text{ L}} = 0.969 \text{ atm}$	One point is earned for the correct substitution. One point is earned for the correct pressure.

$K = \frac{[AsF_3][F_2]}{[AsF_5]}$	One point is earned for the correct equation.

$100.0\% - 27.7\% = 72.3\%$ $[AsF_5] = 0.723 \times 0.0313\ M = 0.0226\ M$	One point is earned for the correct concentration.

$[AsF_3] = [F_2] = 0.277 \times [AsF_5]_i$ $= 0.277 \times 0.0313\ M = 0.00867\ M$ $K_{eq} = \frac{[AsF_3][F_2]}{[AsF_5]} = \frac{[0.00867][0.00867]}{[0.0226]} = 0.00333$	One point is earned for setting $[AsF_3] = [F_2]$. Note: the point is not earned if the student indicates that $[AsF_3] = [F_2] = [AsF_5]$. One point is earned for the correct calculation of $[AsF_3]$ and $[F_2]$. One point is earned for the correct calculation of K_{eq}.