Tooth enamel solubility

Education in Chemistry
August 2019
rsc.li/33xB7BY

This resource is targeted at students in the 16–18 year age range and aims to provide a context for questions about solubility and some extension material.

Questions

1. What is the definition of 'solubility'?

2. (a) Write down the chemical equation for the equilibrium between solid calcium carbonate and its dissolved ions.

(b) Write an equation for the solubility product K_{sp} of calcium carbonate.

(c) The solubility of calcium carbonate in water is 0.67 mg per 100 ml, use this to calculate the solubility product K_{sp}.

3. Researchers have measured the solubility product of hydroxyapatite (HAP) $Ca_{10}(PO_4)_6(OH)_2$ using a variety of different methods.

(a) Given the equation below, write an expression for the solubility product of HAP.

$Ca_{10}(PO_4)_6(OH)_2 \rightleftarrows 10Ca^{2+} + 6PO_4^{3-} + 2OH^-$

(b) When the concentration of calcium is low (less than 30 mM), the hydroxyapatite demineralises (ie it dissolves). Explain why this occurs, with reference to the equilibrium above. How might you promote remineralisation (ie precipitation of the hydroxyapatite)?

(c) [Extension question] The solubility product for $Ca_3(PO_4)_2$ is 2.07×10^{-33} M. Show that the concentration of calcium at equilibrium is 3.4×10^{-7} M.

4. When you eat sugary foods, some oral bacteria produce lactic acid.

(a) What effect might this have on the pH of your saliva?

(b) Saliva contains bicarbonate ions. What effect will this have on the pH of saliva in the presence of bacteria?

(c) Saliva also contains a protein called statherin, which has stretches of glutamate or aspartate amino acids. How might these amino acid side chains interact with calcium ions?

(d) It is thought that the presence of statherin allows the calcium ions to become supersaturated in saliva. What effect would you expect this to have on the mineralisation or demineralisation of the tooth enamel?

Answers

1. Solubility is the amount of a solid that can dissolve into a unit volume of solution.

2. (a) $CaCO_{3(s)} \rightleftarrows Ca^{2+}_{(aq)} + CO_3^{2-}{}_{(aq)}$

(b) $K_{sp} = [Ca^{2+}][CO_3^{2-}]$

(c) The relative formula mass of $CaCO_3$ is 100.

0.67 mg / 100 ml = 6.7 x 10-5 $mol.dm^{-3}$

$[Ca^{2+}][CO_3^{2-}] = 6.7 \times 10^{-5} \times 6.7 \times 10^{-5} = 4.5 \times 10^{-9}\ mol^2.dm^{-6}$

3. (a) $K_{sp} = [Ca^{2+}]^{10}[PO_4^{3-}]^6[OH]^2$

(b) When the concentration of calcium is low the hydroxyapatite dissolves to re-establish the equilibrium.

(c) Let the concentration of Ca^{2+} be $3x$ and the concentration of PO_4^{3-} be $2x$.

$$K_{sp} = [Ca^{2+}]^3[PO_4^{3-}]^2 = (3x)^3(2x)^2$$

$$2.07 \times 10^{-33} = 108x^5$$

$$1.92 \times 10^{-35} = x^5$$

$$1.14 \times 10^{-7} M = x$$

The concentration of Ca^{2+} is $3 \times 1.14 \times 10^{-7} = 3.42 \times 10^{-7}\ mol.dm^{-3}$ and the concentration of PO_4^{3-} is $2 \times 1.14 \times 10^{-7} = 2.28 \times 10^{-7}\ mol.dm^{-3}$.

4. (a) Lactic acid is a weak acid so the pH will decrease.

(b) Bicarbonate ions (HCO_3^-) will buffer the pH and mean that the effect of lactic acid is less (ie the pH stays higher). $H^+ + HCO_3^- \rightleftarrows H_2CO^{3-}$

(c) Glutamate and aspartate contain carboxylic acid side groups $–COO^-$. The negative charges on these side chains will form electrostatic interactions with the positively charged calcium Ca^{2+}.

(d) Keeping the calcium concentration high means that mineralisation is promoted over demineralisation.