

Answers to 3.7 Paper 2

Question One

- a $K_s = [\text{Ba}^{2+}][\text{OH}^-]^2$ A
- b i Solubility products are only constant at a particular temperature (usually 298 K). A
ii Solubility products only apply to sparingly soluble ionic compounds. A
iii Solubility products only apply if the solution is in equilibrium with its solid, in other words, is saturated. A
- c $K_s = 4s^3$ (where s is the solubility of the barium hydroxide)
 $= 1.32 \times 10^{-2}$
 $s = 0.149 \text{ mol L}^{-1}$
 $= 25.52 \text{ g L}^{-1}$
 $= 6.38 \text{ g per 250 mL}$
 $> 5.10 \text{ g}$ so not saturated

OR:

$$n(\text{Ba}(\text{OH})_2) = \frac{5.10 \text{ g}}{171.3 \text{ g mol}^{-1}} = 0.0298 \text{ mol}$$
$$c(\text{Ba}(\text{OH})_2) = \frac{0.0298 \text{ mol}}{0.250 \text{ L}} = 0.119 \text{ mol L}^{-1}$$
$$K_s = 4s^3$$
$$= 1.32 \times 10^{-2}$$
$$s = 0.149 \text{ mol L}^{-1}$$
$$> 0.119 \text{ mol L}^{-1} \quad \text{so not saturated}$$

A = correct method, M = correct calculation with minor error, E = correct calculation and argument

- d A saturated solution is one which contains the maximum amount of dissolved solid at a particular temperature – in the presence of undissolved solid.
A = first part or equivalent, M = plus presence of undissolved solid

Question Two

- a $\text{pH} = -\log_{10}[\text{H}_3\text{O}^+]$
 $[\text{H}_3\text{O}^+] = 10^{-\text{pH}}$
 $= 3.16 \times 10^{-4} \text{ mol L}^{-1}$ A
- b $K_a = \frac{[\text{H}_3\text{O}^+][\text{Lac}^-]}{[\text{HLac}]}$ OR equivalent
 $[\text{HLac}] = \frac{[\text{H}_3\text{O}^+]^2}{K_a}$ because $[\text{H}_3\text{O}^+] = [\text{Lac}^-]$
 $= \frac{(3.16 \times 10^{-4})^2}{1.3 \times 10^{-4}}$
 $= 7.68 \times 10^{-4} \text{ mol L}^{-1}$

A = correct method but minor error, M = correct answer

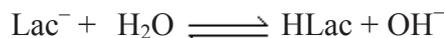
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- c Adding sodium lactate increases the lactate ion concentration which shifts the equilibrium to the left



This reduces the hydronium ion, $[\text{H}_3\text{O}^+]$, concentration, so the pH increases.

OR The lactate ion reacts with water, so the equilibrium

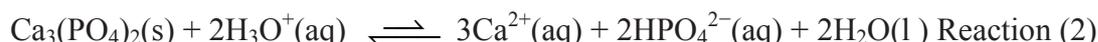
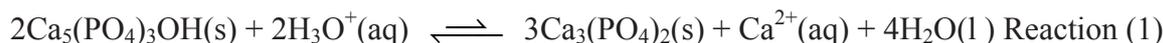


moves to the right, so the pH increases.

OR Sodium lactate is the salt of a weak acid so its solution is basic, so the pH increases.

A = correct effect on pH, M = answer backed by correct reasoning

- d i Bathing a decaying tooth in a solution containing Ca^{2+} and HPO_4^{2-} ions will reform the enamel of the tooth because this drives both reactions to the left. Increasing $[\text{Ca}^{2+}]$ and $[\text{HPO}_4^{2-}]$ causes more $\text{Ca}_3(\text{PO}_4)_2(\text{s})$ to form which in turn causes an increase in $\text{Ca}_5(\text{PO}_4)_3\text{OH}(\text{s})$, the tooth enamel.



A = mentions shift to left, M = correct reasoning

- ii Strontium is in the same group as calcium, so Sr^{2+} ions in the solution would also shift both equilibria to the left by removing $\text{HPO}_4^{2-}(\text{aq})$ ions by precipitation as $\text{Sr}_3(\text{PO}_4)_2(\text{s})$

A = mentions same group, M = plus idea of precipitation

- e A buffer solution resists changes to pH when small amounts of acid or base are added.

HCO_3^- reacts with added acid, while H_2CO_3 reacts with added base.



Added acid moves equilibrium to left and added base moves equilibrium to right.

A = mentions how a buffer works, M = explains how *this* buffer works

- f $\text{CaF}_2(\text{s}) \rightleftharpoons \text{Ca}^{2+}(\text{aq}) + 2\text{F}^-(\text{aq})$

$$K_s = [\text{Ca}^{2+}][\text{F}^-]^2$$

$$3.2 \times 10^{-11} = 1.96 \times 10^{-3} \text{ mol L}^{-1} [\text{F}^-]^2$$

$$[\text{F}^-] = \sqrt{\frac{3.20 \times 10^{-11}}{1.96 \times 10^{-3}}}$$

$$= 1.28 \times 10^{-4} \text{ mol L}^{-1}$$

A = correctly uses K_s , M = correct calculation with 1 minor error or units not given,

E = concentration correct with units

Question Three

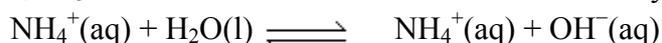
- a NH_4NO_3 is an ionic salt and completely ionises in water: $\text{NH}_4\text{NO}_3(\text{s}) + \text{water} \rightarrow \text{NH}_4^+(\text{aq}) + \text{NO}_3^-$. NH_3 , however, is a weak base and only partially ionises (dissociates) with water forming fewer ions; it has an equilibrium reaction with water: $\text{NH}_3(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{NH}_4^+(\text{aq}) + \text{OH}^-(\text{aq})$

The greater the number of charge carriers, the better the conductivity.

A = correctly identifies NH_3 as a weak base or NH_4NO_3 as a soluble salt, M = correctly identifies both compounds, E = plus links answer back to relative numbers of charge carriers

- b NH_3 is a weak base: $\text{NH}_3(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{NH}_4^+(\text{aq}) + \text{OH}^-(\text{aq}) \quad [\text{H}_3\text{O}^+] < 1 \times 10^{-7}$

NH_4NO_3 is the salt of a weak base and will be weakly acidic: $[\text{H}_3\text{O}^+] > 1 \times 10^{-7}$



HNO_3 is a strong acid: $\text{HNO}_3(\text{l}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_3\text{O}^+(\text{aq}) + \text{NO}_3^-(\text{aq}) \quad [\text{H}_3\text{O}^+] = 1 \times 10^{-1} \equiv [\text{HNO}_3]$

A = identifies the strong acid and weak base, M = correctly identifies all three, but incomplete argument, E = comprehensive answer linked to $[\text{H}_3\text{O}^+]$

Question Four

a Correct part of curve marked and labelled (outer limits 1–13 mL, inner limits 4–10 mL of HCl added). **A**

b $pK_a = 9.2 (\pm 0.1 \text{ mL})$ [$pK_a = \text{pH}$ at half-equivalence point ie. at 7.5 mL] **A**

c $\text{NH}_4^+(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{NH}_4^+(\text{aq}) + \text{OH}^-(\text{aq})$ Excess $\text{OH}^-(\text{aq})$, hence basic. **A**

d

$$\begin{aligned} V_{\text{tot}} &= 40 \text{ mL} \\ n(\text{H}_3\text{O}^+)_{\text{unreacted}} &= 0.100 \text{ mol L}^{-1} \times 10 \times 10^{-3} \text{ L} \\ &= 0.00100 \text{ mol} \\ c(\text{H}_3\text{O}^+) &= \frac{0.00100 \text{ mol}}{0.040 \text{ L}} \\ &= 0.025 \text{ mol L}^{-1} \end{aligned}$$

$$\begin{aligned} \text{pH} &= -\log_{10}[\text{H}_3\text{O}^+] \\ &= -\log_{10}(0.025 \text{ mol L}^{-1}) \\ &= 1.6 \end{aligned}$$

M = correct calculations with minor error ($V_{\text{tot}} \pm 40 \text{ mL}$), E = correct calculations

e Curve starts at $\text{pH} = 13$ and it is a flatter curve. The shape does not change after the equivalence point.

A = two parts correct, **M** = all parts correct

f The indicator changes colour on the vertical portion of the graph; pH close to pK_a , for NaOH.

For NH_3 phenolphthalein changes colour not in the vertical part of the graph, but in the buffer region.

A = one point mentioned, **M** = both points mentioned

g i NH_3 **A**

ii At $\text{pH} = 10$ only 1.5 mL of HCl so NH_3 predominates

OR $\text{pH} > pK_a$ so $[\text{base}] > [\text{conjugate acid}]$ **M**

Judgement Statement

Achievement **11 questions answered correctly.**

A minimum of $11 \times \text{A}$

Merit **13 questions answered correctly with 7 at Merit level.**

A minimum of $6 \times \text{A} + 7 \times \text{M}$

Excellence **15 questions answered correctly with 9 at Merit level and 3 at Excellence level.**

A minimum of $3 \times \text{A} + 9 \times \text{M} + 3 \times \text{E}$