ANSWERS: NCEA past exam questions on buffer solutions

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| **2018** | **Evidence** | **Achieve** | **Merit** | **Excellence** |
| (i)  (ii)  (iii) | The solution will function as a buffer over a pH range 2.74 – 4.74  (p*K*a + / – 1).    Since the pH of the solution falls within the buffer zone (2.74 –  4.74), it will function as a buffer. However, as the pH > p*K*a, / this  means [HCOO–] > [HCOOH], so the buffer will be more effective  against added strong acid. | • Identifies pH range for buffer.  • Determines *n*(HCOO–).  OR  Correct substitution into *K*a expression.  • Buffer is more effective against acid. | • Correct pH.  Evaluates ability of solution to function as a buffer (could have an incorrect pH). | Correct calculation of the buffer’s pH.  AND  A full evaluation of the ability of the solution to function as a buffer. |

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| **2017** | **Evidence** | **Achieve** | **Merit** | **Excellence** |
|  | [H3O+] = √ (Ka × Kw ÷ [NH3])  [H3O+] = √ (5.75 ×10-10 × 1.00 ×10-14 ÷ 0.105)  [H3O+] = 7.40 ×10-12 molL–1  pH = -log (7.40 ×10-12) = 11.1    The solution will function as a buffer (as it contains a weak base and conjugate acid in a 5:1 ratio / within a 1:10 ratio / within a pH range of 8.24 – 10.24).  Since the [NH3] > [NH4+] / pH > pKa, the buffer will be more effective at neutralizing added strong acid. | • One step correct.  Correct process for determining pH.  OR  Buffer use / concept | Correct answer, with minor error e.g. significant figures.  Correct pH.  OR  Correct evaluation of the buffer. | Correct answer, including three significant figures.  Correct pH, including three significant figures.  AND  Correct evaluation of the buffer. |
| **2015** | **Evidence** | **Achieve** | **Merit** | **Excellence** |
|  | pH = p*K*a + log [F–] / [HF]  = 3.17 + log 0.5  = 2.87  [H3O+] = 2 × 10–3.17 = 1.35 × 10–3 mol L–1  pH = –log (1.35 × 10–3) = 2.87.  Since there are significant concentrations of the weak acid and its conjugate base the solution can resist added acid or base.  However, since the pH of the buffer solution is less than the p*K*a, / [HF] > [F–], it is more effective against added base than acid. | * Correct process for determining the pH. * Recognises solution is more effective against added base.   OR  Describes function of a buffer by resisting added acid and base. | * Correct pH   OR  Evaluates the function of the buffer. | * Correct pH and full evaluation. |

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| **2014** | **Evidence** | **Achievement** | **Merit** | **Excellence** |
|  |  | * Writes correct *K*a or pH expression. OR   Calculates *K*a or [H3O+].  • Correct ‘n’ and ‘m’ step with  incorrect [F¯]. | * Correct method but error in calculation / units missing / unit incorrect. | Correct answer with units. |

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| **2013** | **Evidence** | **Achievement** | **Merit** | **Excellence** |
| (i)  (ii) | *Candidates should not be penalised for using ratio of volume and getting correct answer.*  When a small amount of acid (H3O+) ions are added, they will react with the CH3NH2(*aq*) molecules to form CH3NH3+(*aq*) ions.  CH3NH2(*aq*) + H3O+(*aq*) → CH3NH3+(*aq*) + H2O()  The added acid (H3O+), is mostly consumed, and the pH of the solution changes very little. | * Correct *K*a expression.   OR   * pH = p*K*a + log   OR  Correct concentrations or number of moles.   * Correct equation.   OR  Shows understanding that CH3NH2(*aq*) reacts with added acid.  OR  Discusses minor reaction of  OH– + H3O+. | * Correct process with minor error. * Correct equation.   AND  Shows understanding that  CH3NH2(*aq*) reacts with added  acid. | * Correct answer.   Correct equation and correct discussion of reaction. |

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| **2012** | **Evidence** | **Achievement** | **Merit** | **Excellence** |
| (a)  (b) | A buffer is a solution that undergoes a minimal change of pH when small  amounts of acid or base are added.  Added acid will react with NH3 so that there is almost no change in  [H3O+]: NH3 + H3O+ → NH4 + + H2O  Added base will react with NH4+ so that there is almost no change in  [OH–]:NH4 + + OH– → NH3 + H2O  (These equations show that the ratio of NH3: NH4+ changes slightly, but this does not significantly affect the pH.)  Since the pH of the buffer is lower than the p*K*a of NH4+, the [NH4+] will  be higher than the [NH3]. This means the buffer will be more effective  against added base. | Either:  Recognises acid will react  with added base and base will  react with added acid  OR  Describes the function of a  buffer. | Explains buffer action, writes  appropriate equations and  refers to the fact that there is  almost no change in [H3O+] /  [OH-]. | Correct answer with units.  Complete discussion of  buffer action and its  effectiveness at pH 8.60. |

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| **2011** | **Evidence** | **Achievement** | **Merit** | **Excellence** |
|  |  |  |  | Correct answer to 3 sig figs. |

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| **2010** | **Evidence** | **Achievement** | **Merit** | **Excellence** |
| (a)  (b) | A solution which will maintain its pH / resist change of pH.   * HCOO– / HCOOH is a conjugate weak base / acid pair. * Any acid that is added to the buffer system will react with HCOO– thus maintaining the pH / removing H3O+. * Any base that is added to the buffer system will react with the HCOOH, thus maintaining the pH / removing OH–.   HCOOH + OH– → HCOO– + H2O  HCOO– + H3O+ → HCOOH + H2O | • Correct answer.   * Recognises acid / base pair AND the acid will react with added base + base will react with added acid.   (Specific naming of species **not** required.)  OR  Writes BOTH equations.  (may be back to front compared to convention) | EITHER  Writes equations for BOTHspecies.  OR  Links buffer action to the **specific** species present. | Recognises conjugate acid base pair AND writes equations linking buffer action to the species present. |

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| **2009** | **Evidence** | **Achievement** | **Merit** | **Excellence** |
|  | A buffer is a solution containing a weak acid and its conjugate base (or a weak base and its conjugate acid). It is able to resist changes in pH.  When 9.80 mL of base has been added, some of the benzoic acid has been converted to the benzoate ion (the conjugate base). There is still unreacted benzoic acid in the reaction vessel, so both acid and conjugate base are present together in reasonable / sufficient amounts. Hence the solution has buffering properties.  When 25 mL of base has been added, the acid molecules have been converted to the conjugate base. The amount of benzoic acid is too low to have buffering properties. | * Defines a buffer   **OR**   * Identifies presence of reasonable amounts of (benzoic) acid and conjugate base (benzoate) when 9.80 mL base added   **OR**   * Identifies lack of (benzoic) acid when 25.0 mL base added | * Defines a buffer and correct discussion for 9.80 mL **or** 25.0 mL.   **OR**  Reasonably correct  discussion for 9.80 mL  **and** 25.0 mL without  defining a buffer | * Defines a buffer and correctly compares  9.80 mL **and** 25.0 mL in (b) |

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| **2008** | **Evidence** | **Achievement** | **Merit** | **Excellence** |
|  | (i) Both solutions A and B can act as buffers because both contain reasonable amounts of a weak acid and its conjugate base/ NH4+ and NH3. The ammonium ion can absorb added base and the ammonia can absorb added acid (or equations) thereby minimising changes in pH.  (ii) Sodium hydroxide is a strong base and will accept H+ from the NH4+ ions in solution.  OH– + NH4+ → NH3 + H2O.  and so the pH will only increase very slightly as the effect of added OH– ions is minimised.  The lower amount / concentration / number of NH4+ ions in solution B limit the buffering properties as these would be used up more rapidly, so the pH will increase / change faster than with Solution A.  Accept evidence for part (i) and (ii) from either section. | Recognises that a buffer solution exists in A and B (can be implied)  OR  recognises A or B is a buffer with some more detail.  eg contains a weak acid and its conjugate base  resists changes in pH  gives the correct equation. | Recognises A and B are buffers.  Identifies the presence of a weak acid and its conjugate base by name or formula in both A and B.  Explains the function of a buffer. | Effect of adding the strong base discussed for each solution.  Answer includes comparison of buffering effect of solutions A and B.  Correct equation included for buffer solutions. |

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