ANSWERS: Relative concentrations of dissolved species

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| **2019** | **Evidence** | **Achievement** | **Merit** | **Excellence** |
| (i)  (ii) | CH3COOH has the smaller p*K*a / larger *K*a, so it will be a stronger acid than NH4+.  This means CH3COOH will dissociate to a greater extent to produce a higher [H3O+] than NH4+, so CH3COOH will have a lower pH.  The electrical conductivity of a solution depends upon [ions]. NH4Cl is an acidic salt, so it completely dissociates / dissolves to produce a relatively high [NH4+] and [Cl–]. This makes NH4Cl a good electrical conductor.  NH4Cl ⇌ NH4+ + Cl–  However, CH3COOH is a weak acid and only partially dissociates to produce a relatively low [CH3COO–] and [H3O+]. This makes CH3COOH a poorer electrical conductor than NH4Cl.  CH3COOH + H2O ⇌ CH3COO– + H3O+ | Recognises p*K*a is a measure of the extent of dissociation of a weak acid.  Recognises electrical conductivity in a solution requires ions. | Links magnitude of p*K*a (or *K*a) to degree of dissociation, [H3O+] and pH.  OR  Links the [ions] to the electrical  conductivity of BOTH solutions. | Full explanation of the pH and  electrical conductivity of BOTH  solutions,  i.e. links degree of dissociation to BOTH [H3O+]  AND pH  AND [ions]  AND electrical conductivity, including supporting equations. |

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| **2017** | **Evidence** | **Achievement** | **Merit** | **Excellence** |
| (i)  (ii) | HF + H2O  **⇌** F– + H3O+  HBr + H2O → Br– + H3O+  To conduct a current, a substance requires mobile charged particles / ions. HF and HBr solutions have ions in solution, so both will conduct electricity.  HBr is a strong acid, and therefore completely dissociates to produce a high [Br–] and [H3O+]. In contrast, HF is a weak acid and therefore only partially dissociates to produce a lower [ions], i.e. F– and H3O+.  So, HF is a poorer electrical conductor / weaker electrolyte. | ONE correct equation.  Mobile charged particles/ ions.  Relates electrical conductivity to the  degree of dissociation / ion concentration.  TWO species related to concentration. | Links the degree of dissociation to the amount of ions for both  HBr and HF.  (*Correct follow on accepted from incorrect equations*) | Links the degree of dissociation to the amount of ions for both HBr and HF.  (*Correct follow on accepted from incorrect equations*) |

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| **2016** | **Evidence** | **Achievement** | **Merit** | **Excellence** |
|  | Cl– > CH3CH2NH3+ > H3O+ > CH3CH2NH2 > OH–  OR  Cl– > CH3CH2NH3+ > H3O+ = CH3CH2NH2 > OH–  CH3CH2NH3Cl → CH3CH2NH3+ + Cl–  CH3CH2NH3Cl completely dissociates.  (*The chloride ion does not react further with water and so will be in the greatest concentration.*)  The ethanamine ion will react further with water, but only partially, leaving it the next in the series.  CH3CH2NH3+ + H2O  CH3CH2NH2 + H3O+  For every mole of CH3CH2NH3+ that reacts with water, 1 mole of CH3CH2NH2 and H3O+ are formed.  (However, H3O+ is slightly more concentrated than CH3CH2NH2, as there is a small contribution from water).  OH– is present in the lowest concentration as this comes from the dissociation of water only. | * FOUR species in the correct order. * ONE correct equation.   OR  ONE correct justification. | * All species in their correct order.   AND  TWO correct equations / justifications. | * All species in their correct order.   AND  TWO correct equations.  AND  Correct justifications. |

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| **2015** | **Evidence** | **Achievement** | **Merit** | **Excellence** |
| (i)  (ii)  (iii) | H2O  CH3NH3Cl(*s*) → CH3NH3+(*aq*)+ Cl–(*aq*)  CH3NH3+ + H2O ⇌ CH3NH2 + H3O+  Cl– > CH3NH3+ > H3O+ = CH3NH2 > OH–  OR  Cl– > CH3NH3+ > H3O+ > CH3NH2 > OH- | One correct equation.  OR  Four species identified. | Correct order, all species. |  |
| (b) | **pH:**  The pH of a solution is calculated from its [H3O+].  NaOH is an ionic solid that is a strong base and dissociates completely to produce a high OH– concentration (low [H3O+]).  Since [OH–] is high / [H3O+] is low, the pH is high.  NaOH → Na+ + OH–  CH3NH2 is a weak base that partially reacts / dissociates / ionises with H2O producing a lower concentration of OH–,  Therefore it has a lower pH than NaOH:  CH3NH2 + H2O ⇌ CH3NH3+ + OH–  The CH3COONa is an ionic solid that dissociates completely in H2O. The CH3COO– ion is a weak base that partially reacts / dissociates / ionises with H2O producing a lower concentration of OH–.  CH3COO– + H2O ⇌ CH3COOH + OH–  The pH is closer to 7, showing it is the weakest base.  Therefore it has a lowest pH  **Electrical conductivity:**  Electrical conductivity is determined by the concentration of ions.  NaOH completely dissolves to produce a high concentration of Na+ and OH– ions in solution.  NaOH → Na+ + OH–  Therefore it is a good conductor.  Since CH3NH2 is a weak base, it only partially reacts with water to produce a low concentration of ions in solution so it is a poor electrical conductor.  CH3NH2 + H2O ⇌ CH3NH3+ + OH–  CH3COONa is also an ionic solid. It dissolves completely to produce a high concentration of Na+ and CH3COO– ions:  CH3COONa → Na+ + CH3COO–  Therefore it is a good conductor. | * Recognises that pH depends upon [H3O+] / [OH–] ratio.   OR  States that NaOH is a strong base whereas CH3COONa and CH3NH2 form weakly basic solutions.   * Recognises that electrical conductivity depends upon concentration / amount of ions in solution.   OR  Relates conductivity to the degree of dissociation. | * Links the pH of each solution to its strength and degree of dissociation.   Links the ion concentration / amount of each solution to the degree of dissociation and its electrical conductivity. | * Compares and contrasts the pH of each solution.   Compares and contrasts the electrical conductivity of each solution. |

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| **2014** | **Evidence** | **Achievement** | **Merit** | **Excellence** |
| (i)  (ii) | HOCl + H2O **⇌** OCl– + H3O+  HOCl > H3O+ > OCl– > OH– or HOCl > H3O+ = OCl– > OH–  HOCl partially dissociates, and so the equilibrium lies to the LHS/favours the reactants; therefore HOCl is present in the greatest amounts.  H3O+ and OCl– are produced in equal amounts / there is a small contribution to H3O+ from water therefore H3O+ > OCl–  Because there is a relatively high [H3O+], the [OH–] is very low (or links to *K*w). | * Equation correct.   OR  FOUR species correctly identified.   * Recognises HOCl partially dissociates.   OR  One correct justification. | * ALL species and order correct AND partial explanation to support the order of the species. | ALL species and order correct AND complete justification. |

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| **2013** | **Evidence** | **Achievement** | **Merit** | **Excellence** |
| (a) | HCl < CH3NH3Cl < CH3NH2  HCl, a strong acid, reacts completely with water to form 1 mol L–1 H3O+ and hence a low pH.  HCl + H2O → H3O+ + Cl–  CH3NH3Cl dissociates completely in water to form CH3NH3+ and Cl–. CH3NH3+, a weak acid, partially reacts with water to form less than 1 mol L–1 H3O+ and hence a higher pH than HCl.  CH3NH3Cl → CH3NH3+ + Cl–  CH3NH3+ + H2O ⇌ CH3NH2 + H3O+  CH3NH2, a weak base, partially reacts with water to form OH– ions. So there are more OH– ions than H3O+ ions and the pH is thus high.  CH3NH2 + H2O ⇌ CH3NH3+ + OH– | * Correct order. * TWO equations correct. * Recognises that HCl dissociates completely in water.   OR  Recognises that CH3NH3+ OR  CH3NH2 only partially react with  water. | * THREE correct equations. * Recognises that HCl dissociate completely in water.   AND  Recognises that CH3NH3+ or CH3NH2 only partially react with water. | * Discusses all the reactions correctly including concentrations of OH– and H3O+ ions. |
| (b) | HCl = CH3NH3Cl > CH3NH2  CH3NH3Cl and HCl will dissociate completely in water to produce 2 mol L–1 ions.  CH3NH2 will only partially react with water to produce less than 1 mol L–1 of ions. | * CH3NH2 written last. * Links concentration of ions to degree of conductivity | * CH3NH2 written last and discusses HCl / CH3NH3Cl AND CH3NH2.  Links concentration of ions to degree of conductivity. | * Correct order with valid discussion. Links concentration of ions to degree of conductivity. |

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| **2012** | **Evidence** | **Achievement** | **Merit** | **Excellence** |
|  |  | Any TWO of:  Any TWO equations correct.  All species correct for TWO solutions identified.  Either:  Recognises reasons for pH  variation are due to production of H3O+ / OH–  OR  Recognises conductivity is related to the number of ions in solution. | All FOUR equations correct.  OR  ALL species and order  correct for TWO solutions.  AND  Either:  Recognises reasons for variations in pH and conductivity AND makes a valid comparison between one pair.  OR  Difference in pH correctly  discussed for ALL 3 solutions.  OR  Difference in conductivity  correctly discussed for ALL 3 solutions. | ONE answer to merit level.  AND  Discussion addresses variation in BOTH pH (including whether acidic or basic) and conductivity  using correct reasons for ALL 3 solutions. |
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|  | HCl is a strong acid, so fully reacts with water to produce a high [H3O+]. pH < 7.  NH4Cl is an acidic salt that completely dissociates into its ions producing NH4+ and Cl–.  NH4+ is a weak acid, so only partially reacts with water to produce H3O+. pH < 7, but higher than HCl since NH4+ has a lower [H3O+] than HCl.  CH3NH2 is a weak base, so only partially reacts with water to produce OH– ions. pH > 7.  Electrical conductivity relates to the concentration of mobile charged particles present. In the case of solutions, conductivity relates to the number of ions present.  Both HCl and NH4Cl completely react with water to produce a high concentration of ions, so their conductivity will be high (and equal).  Since CH3NH2 is a weak base, it partially reacts with water to produce only a few ions in the solution, making it a poor electrical conductor. |

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| **2011** | **Evidence** | **Achievement** | **Merit** | **Excellence** |
| (a) | NH3 weak base  NaCl neutral  NH4Cl weak acid  HF weak acid | THREE from part (a) correct.  Correct equation.  OR  Correct rank for b(i) or b(ii) | THREE from part (a) correct.  AND  Correct equation AND correct order of species for BOTH (b)(i) and (b)(ii)  OR  Correct equation, order of species  AND full explanation (all four species) for EITHER (b)(i) or (b) (ii) | ONE explanation to Merit level.  AND  ONE full explanation. (all 4 species). |
| (b) (i) | NH3 + H2O ⇌ NH4 + + OH–  Equilibrium is to the left, so the greatest concentration of a species is NH3. For each NH3 that reacts equal amounts of NH4+ and OH– are formed and are greater than the OH– and H3O+ formed by the dissociation of water.  NH3 > OH– ≥ NH4 + > H3O+ |
| (ii) | HF + H2O ⇌ F– + H3O+  Equilibrium is to the left, so the greatest concentration of a species is HF. For each HF that reacts equal amounts of F– and H3O+ are formed and are greater than the OH– and H3O+ formed by the dissociation of water.  HF > H3O+ ≥ F– > OH– |

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| **2010** | **Evidence** | **Achievement** | **Merit** | **Excellence** |
| (a) (i)  (ii)  (b) | NH4Cl(*s*) → NH4+ (*aq*)+ Cl–(*aq*)  NH4+ + H2O → NH3 + H3O+  **A** = Cl– **B** = NH4+ **C** / **D** = H3O+ / NH3 **E** = OH–   * NH4+ and Cl– form in equal amounts from dissociation of salt in water. * Some NH4+ reacts further with water so [NH4+ ] < [Cl–]. * H3O+ and NH3 formed in equal amounts from the reaction of NH4+ with water. * [NH3] « [NH4+], since only small amount of NH4+ reacts (NH4+ is a weak acid / small dissociation constant). * [OH–] « [H3O+] since solution is acidic. * [H3O+] × [OH–] = 1 × 10–14.   • [H3O+] = [NH3] from NH4+ dissociating. | Any TWO of:  Both equations correct.  OR  One Equation and *K*a.  Correctly identifies THREE out of A to E.  *Note that identification could be in justification.* | Correctly identifies FOUR out of A to E with justification of each. | Correctly identifies A to E with justification for ALL.  This **must** include:  [H3O+] = [NH3] from NH4+ dissociation  AND  explanation of OH– < H3O+in terms of Kw= 1 x 10–14. Stating that [OH-] is from H2O dissociation negates to ‘m’.Specific use of word amount / concentration when discussing species is required for ‘e’. |