Answers to exam questions for Chapter 11 Acids and bases

Question 1

$$HLac + H_2O \rightleftharpoons Lac^- + H_3O^+ \qquad \text{(write the equation)}$$

$$K_a = \frac{[Lac^-][H_3O^+]}{[HLac]} \qquad \text{(write the expression for } K_a\text{)}$$

$[H_3O^+]^2 = 1.38 \times 10^{-4} \times 0.100 \text{ mol L}^{-1}$ (rearrange and substitute known values)

$[H_3O^+] = 3.71 \times 10^{-3} \text{ mol L}^{-1}$ (square root both sides)

    pH = 2.43   (pH $= -\log_{10}[H_3O^+]$)

A = correct method used with minor error, M = correct value

Question 2

Part A

a   A weak acid is one that is only partially dissociated or ionised, or one that transfers protons to a limited extent.   **A**   (Definition, bookwork must be learned)

b CH_3COOH, CH_3COO^-, H_3O^+/H^+, OH^- (In the aqueous solution the following equilibria exist:

     A = all correct $CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$ and

                                  $2H_2O \rightleftharpoons H_3O^+ + OH^-$; gives species present.)

c   Sodium ethanoate dissociates completely in solution and therefore has more ions (charge carriers) and is a better electrolyte. Ethanoic acid only dissociates partly, so not as many ions, so does not conduct as well.

    A = some mention of relative amounts of dissociation, M = correctly linked to charge carriers and conduction

Part B

    Equation 1: $CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$

    Equation 2: $H_2CO_3(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + H_3O^+(aq)$

    As carbon dioxide escapes from the bottle of soda water that has been left open the equilibrium in equation 1 shifts to the left, $[H_2CO_3]$ is reduced. The equilibrium in equation 2 also shifts to the left and $[H_3O^+]$ is thus reduced, hence reducing the pH.   (shift in equilibria linked to loss in reactants)

    A = some mention of shift in equilibrium, M = both shifts in equilibria correctly mentioned, E = plus links this back to pH

Question 3

a $H_2PO_4^-(aq) + H_2O(l) \rightleftharpoons H_2PO_4^-(aq) + H_3O^+(aq)$ ($H_2PO_4^-$ behaving as an acid with H_2O)

$$K_a = \frac{[HPO_4^{2-}][H_3O^+]}{[H_2PO_4^-]}$$ A

b   The species present in higher concentration if the pH in urine is 6.6 is $H_2PO_4^-$.   A
Justification: The pK_a value for the $H_2PO_4^-/HPO_4^{2-}$ conjugate pair is 7.2, so at pH = 7.2
$[H_2PO_4^-] = [HPO_4^{2-}]$. At lower pH values the acid form of the buffer predominates as it is less than half
neutralized. Hence, $[H_2PO_4^-] > [HPO_4^{2-}]$.   (acid form greater when pH < pK_a)
M = concentration difference understood, E = buffer formation understood

c   The stronger base is PO_4^{3-} A
Justification: PO_4^{3-} is the base in the conjugate pair with the smaller K_a , larger pK_a
          Or PO_4^{3-} is the base with the larger K_b , smaller pK_b.   M   (larger K_a stronger acid)

d   The formula for the cleaning product that would not leave a residue is NH_3.   A
Justification: Ammonia is a soluble gas. M (both soluble and gas needed)