

3 (a) (i) Define conjugate acid–base pair.

.....  
 ..... [1]

(ii) Give the formulas of the conjugate acid and the conjugate base of the hydrogen phosphate ion,  $\text{HPO}_4^{2-}$ .

conjugate acid of  $\text{HPO}_4^{2-}$  .....  
 conjugate base of  $\text{HPO}_4^{2-}$  ..... [1]

(b) The  $K_a$  of propanoic acid,  $\text{CH}_3\text{CH}_2\text{COOH}$ , is  $1.35 \times 10^{-5} \text{ mol dm}^{-3}$  at 298 K.

Solution C is a solution of  $\text{CH}_3\text{CH}_2\text{COOH}$  with a pH of 3.60 at 298 K.

(i) Calculate the concentration of  $\text{CH}_3\text{CH}_2\text{COOH}$  in solution C.

$[\text{CH}_3\text{CH}_2\text{COOH}] = \dots\dots\dots \text{ mol dm}^{-3}$  [2]

(ii) Calculate the concentration of hydroxide ions in solution C.

$[\text{OH}^-] = \dots\dots\dots \text{ mol dm}^{-3}$  [1]

(iii) Calculate the concentration of a solution of hydrochloric acid with the same pH as solution C.

concentration =  $\dots\dots\dots \text{ mol dm}^{-3}$  [1]

(iv) Table 3.1 shows three possible values of the  $K_a$  of dimethylpropanoic acid,  $(\text{CH}_3)_3\text{CCOOH}$ .

Place a tick in Table 3.1 to show the correct value. Explain your answer.

Table 3.1

value of $K_a$ / $\text{mol dm}^{-3}$	place <b>one</b> tick (✓) in this column
$9.33 \times 10^{-6}$	
$1.35 \times 10^{-5}$	
$3.35 \times 10^{-5}$	

explanation .....  
 .....  
 .....  
 .....  
 ..... [3]

(c) Solution D is made by mixing  $100 \text{ cm}^3$  of  $0.100 \text{ mol dm}^{-3}$   $\text{CH}_3\text{CH}_2\text{COOH}$  and  $100 \text{ cm}^3$  of  $0.100 \text{ mol dm}^{-3}$   $\text{NaCl}$ .

The pH of solution D is measured as small amounts of  $\text{H}_2\text{SO}_4(\text{aq})$  are added to it, and when small amounts of  $\text{NaOH}(\text{aq})$  are added to it.

Solution D only acts as a buffer solution when **one** of these solutions is added to it.

(i) Complete the sentence and write an equation for the reaction that occurs.

Solution D acts as a buffer when ..... is added to it.  
 equation ..... [1]

(ii) Complete the sentence and explain why solution D does **not** act as a buffer when the other solution is added.

Solution D does **not** act as a buffer when ..... is added to it.  
 explanation ..... [1]

(d) Manganese(II) hydroxide,  $\text{Mn}(\text{OH})_2$ , is only slightly soluble in water.

The solubility of  $\text{Mn}(\text{OH})_2$  in water is  $3.28 \times 10^{-3} \text{ g dm}^{-3}$  at 298 K.

(i) Calculate the concentration of a saturated solution of  $\text{Mn}(\text{OH})_2$  at 298 K.

$[\text{Mn}(\text{OH})_2] = \dots\dots\dots \text{ mol dm}^{-3}$  [1]

(ii) Write an expression for the  $K_{sp}$  of  $\text{Mn}(\text{OH})_2$ . Give the units of  $K_{sp}$ .

$K_{sp} = \dots\dots\dots$   
 units = ..... [2]

(iii) Use your answers to (d)(i) and (d)(ii) to calculate the value of  $K_{sp}$  of  $\text{Mn}(\text{OH})_2$  at 298 K.

$K_{sp} = \dots\dots\dots$  [1]