

Solutions

Original marking guidance: M1 method, A1 accuracy, B1 explanation.

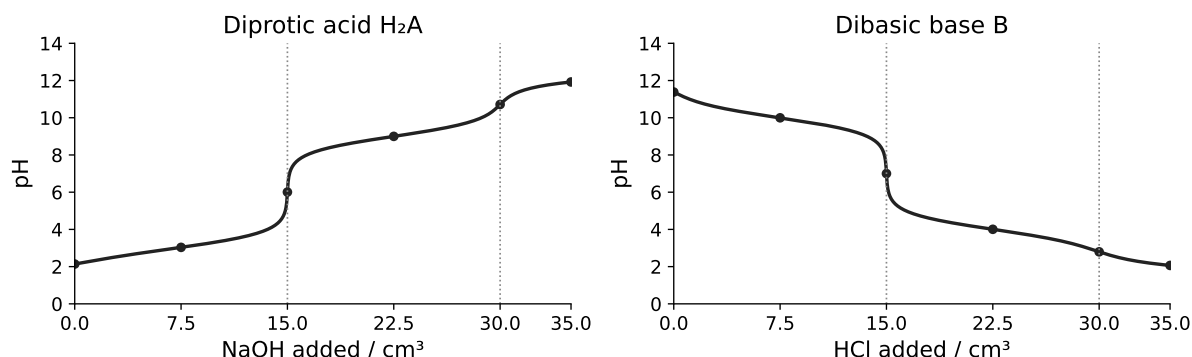
2.1 HCl rises by 1, 2 and 3 pH units relative to the original. HA rises by 0.51, 1.02 and 1.57, near but increasingly above the 0.50, 1.00 and 1.50 predictions. At factor 1000, $c = 0.100/1000 = 1.00 \times 10^{-4} \text{ mol dm}^{-3}$, $[H^+] = 10^{-4.57} = 2.69 \times 10^{-5} \text{ mol dm}^{-3}$. Dissociation is approximately $100[H^+]/c = 26.9\%$, too large to replace equilibrium HA by initial c . Water is not the main explanation at this pH.

2.2 $[H^+] = 10^{-5}$ and $[A^-]/[HA] = 2.00$. $3[HA] = 0.120$ gives final HA = 0.0400 and $A^- = 0.0800 \text{ mol dm}^{-3}$. Acid stock = $0.0400(250.0/40.0) = 0.250 \text{ mol dm}^{-3}$. Salt stock = $0.0800(250.0/60.0) = 0.333 \text{ mol dm}^{-3}$. Dilute the mixed aliquots to the stated final volume; do not add 250 cm^3 of water.

2.3 BH^+ is the conjugate acid. Initial B = 0.00250 mol; at 12.5 cm^3 H^+ added is 0.00125 mol, leaving equal B/ BH^+ . Hence $pK_a(BH^+) \approx 9.25$, $K_a = 10^{-9.25} = 5.62 \times 10^{-10} \text{ mol dm}^{-3}$. At 20.0 cm^3 , B = 0.000500 and $BH^+ = 0.00200 \text{ mol}$; $pH = 9.25 + \log_{10}(0.000500/0.00200) = 8.65$. Added acid converts B to BH^+ ; the ratio changes moderately while appreciable quantities of both remain, rather than leaving the added H^+ free.

3.1 Completed ideal-model curves through the supplied points:

25.0 cm^3 of 0.0600 M solute + 0.100 M titrant, 298 K
Illustrative aqueous models; dotted lines mark 15.0 and 30.0 cm^3



For each curve: B1 for axes/direction and appropriate end regions; B1 for plotting all six points with a smooth curve; B1 for first equivalence 15.0 cm^3 ; B1 for second total equivalence 30.0 cm^3 . $n = 0.0600(0.0250) = 0.00150 \text{ mol}$; one and two titrant equivalents require 0.00150 and 0.00300 mol. Do not require a discontinuity: finite-concentration curves are continuous. Model constants are illustrative and supplied data, not a claim about every diprotic substance.

3.2 $HCO_3^- + H^+ \rightarrow H_2CO_3$; $H_2CO_3 + OH^- \rightarrow HCO_3^- + H_2O$. Limiting pH changes helps maintain enzyme activity/cell conditions. Food buffering can limit pH changes from microbial activity, but does not kill or exclude microbes and cannot alone establish safety/sterility. Added reagent consumes a component; once too little remains, capacity is exceeded. Blood also relies on respiratory/renal regulation, so buffering is not permanent unlimited acid disposal.

3.3 Weigh an accurately known mass m , dissolve completely, transfer/rinse quantitatively and make up to known volume V in a volumetric flask; $c = m/(MV)$ with V in dm^3 . Calibrate the meter with suitable standard buffers and maintain stated temperature/rinse the electrode between solutions. Measure equilibrium pH; $x = 10^{-\text{pH}}$, $[HA] = c - x$, $K_a = x^2/(c - x)$ when HA is the sole significant H^+ source. Repetition improves random scatter but does not correct a biased calibration, contaminated standard or wrong final volume. This is assessed method knowledge, not certification of practical performance.