RECOGNISING ACHIEVEMENT

UNIFYING CONCEPTS IN CHEMISTRY

Mark Scheme 2816/01
June 2002

1. (a)(i) $K_c = \frac{[NO_2(g)]^2}{[N_2O_4(g)]}$ [1]

(ii) $K_c = \frac{(0.0150)^2}{(0.0390)} = 5.77 \times 10^{-3}$ ✓ $mol\ dm^{-3}$ ✓ accept 5.76923 to $5.8 \times 10^{-3}$

If (i) is upside down: $\frac{[N_2O_4(g)]}{[NO_2(g)]^2}$, then ans = 173 ✓ $dm^3\ mol^{-1}$ ✓ accept 173.33333.....to 170

if no square in (i): $\frac{[NO_2(g)]}{[N_2O_4(g)]}$, then ans = 0.384615.. ✓ no units ✓ (must be stated)

if no square in (i) and inverse: $\frac{[N_2O_4(g)]}{[NO_2(g)]}$, 2.6 ✓ no units ✓ (must be stated)

[2]

(b) $\Delta H$ = (2 x 33) −(9) ✓ = (+)57 kJ $mol^{-1}$ ✓

***common errors***: −57 ✓ x +24 ✓ x +75 ✓ x −24 x x

[2]

(c) *change* more $NO_2$ / less $N_2O_4$ ✓

*explanation* equilibrium position ⟶ right or forwards / $K_c$ increases ✓

reaction is endothermic ✓

*THIS ANSWER IS CONSEQUENTIAL ON SIGN OF THE ANSWER TO (i)*

*BUT, a candidate interpreting a '+' enthalpy change as 'exothermic' (or vice versa) will lose the 3rd mark but the 2 'logic marks' before are still consequentially available.*

[3]

(d) 1 mol $N_2O_4$ reacts with 2 mol NaOH ✓

amount of NaOH required = 0.00930 mol ✓

volume NaOH = 1000 x 0.0093/0.300 = 31.0 $cm^3$ / 0.0310 $dm^3$ ✓

***Common errors***

*3.1 x $10^x$ (where x is incorrect)* ✓✓x

*15.5 $cm^3$ / 0.0155 $dm^3$* ✓✓x

*1.55 x $10^x$ (where x is incorrect)* ✓xx

62 $cm^3$ / 0.062 $dm^3$ ✓✓x

6.2 x $10^x$ (where x is incorrect) ✓xx [3]

**[Total: 11]**

**2. (a)** $k = \frac{\text{rate}}{[H_2(g)][NO(g)]^2}$ ✓

$k = 8.3 \times 10^4$ ✓ $dm^6\ mol^{-2}\ s^{-1}$ ✓ calculator value: 8.33333.... x $10^4$

If [NO] is not squared: $\frac{\text{rate}}{[H_2(g)][NO(g)]}$ ×, ans = 250 ✓ units: $dm^3\ mol^{-1}\ s^{-1}$ ✓

If the expression is upside down: $\frac{[H_2(g)][NO(g)]^2}{\text{rate}}$ ×, ans = $1.2 \times 10^{-5}$ ✓ units: $mol^2\ s\ dm^{-6}$ ✓

upside down and not squared: $\frac{[H_2(g)][NO(g)]}{\text{rate}}$ ××, ans = 0.004 $mol\ s\ dm^{-3}$ ✓ [3]

**(b)(i)** *effect on rate* x 2 ✓

*reason* 1st order wrt $H_2(g)$ ✓ [2]

**(ii)** *effect on rate* x 1/4 ✓

*reason* 2nd order wrt NO(g) ✓

[2]

**(iii)** *effect on rate* x 27 ✓

[1]

**(c)(i)** slowest step ✓

[1]

**(ii)** step 1 (RDS) $H_2(g) + 2\,NO(g)$ ✓ $\longrightarrow N_2O(g) + H_2O(l)$

step 2 $H_2(g) + N_2O(g) \longrightarrow N_2(g) + H_2O(l)$ rest of equations ✓

[2]

**(d)(i)** $NH_3$, –3 ✓

NO, +2 ✓

$HNO_3$ +5 ✓ [3]

**(ii)** $4NH_3(g) + 5O_2(g) \longrightarrow 4NO(g) + 6H_2O(l)$

products + reactants ⟶ 1 mark; balancing ⟶ 1 mark ✓ ✓

[2]

**(iii)** molar masses $NH_3$ = 17; $HNO_3$ = 63 ✓

mass = 700 000 x 17/63 = $1.89 \times 10^5$ tonnes ✓ calc value 1.888888.... x $10^5$

*ans: mark could be consequential on incorrect molar masses.* [2]

**[Total: 18]**

3. (a) Empirical formula = C : H : O = 40.0/12 : 6.7/1 : 53.3/16 = 3.33 : 6.7 : 3.33 ✓

= $CH_2O$ ✓

mass $CH_2O$ = 30; $M_r$ = 90 ∴ molecular formula = $C_3H_6O_3$ ✓ [3]

(b)

$$K_a = \frac{[H^+(aq)]\,[A^-(aq)]}{[HA(aq)]} \;/\; \frac{[H^+(aq)]^2}{[HA(aq)]}$$ ✓

$$\therefore 1.2 \times 10^{-5} = \frac{[H^+(aq)]^2}{1.5}$$

$[H^+(aq)] = \sqrt{\{(1.2 \times 10^{-5}) \times (1.5)\}} = 4.2 \times 10^{-3}$ mol dm$^{-3}$ ✓

pH = $-\log[H^+(aq)]$ ✓ = $-\log 4.2 \times 10^{-3}$ = 2.4 / 2.37 ✓

***4 marks***: $K_a$ expression✓;

$[H^+]$✓;

pH expression✓;

calculation of pH from $[H^+]$ (ecf) ✓

***Common error***: Without square root, answer is 4.7/ 4.7447... ✓✓✓x

[4]

(c)(i) A solution that minimises changes/resists change in pH after addition of acid/alkali ✓

**NOT** 'maintains constant pH' or 'cancel out' [1]

(ii) $CH_3COOH \rightleftharpoons H^+ + CH_3COO^-$ / $CH_3COOH + H_2O \rightleftharpoons H_3O^+ + CH_3COO^-$ [1]

(iii) The weak acid or $CH_3COOH$ reacts with added alkali / added alkali reacts with $H^+$ ✓

The base or $CH_3COO^-$ reacts with added acid ✓

Direction of movement indicated for one change / indication of the products formed for one change ✓ [3]

(d) *effect on pH* increases ✓

*explanation* equilibrium ⟶ left ✓

$H^+$ removed by $CH_3COO^-$ ✓ [3]

**[Total: 15]**

4. (a) ***Pressure: 3 marks***

high pressure ✓ fewer gaseous moles on right ✓

***Compromise:*** pressure used but too much is requires too much energy/high costs/causes safety issues/thick pipes ✓

***Temperature: 4 marks***

low temperature ✓ reaction is exothermic ✓

Increased temperature needed to increase the rate/low temperature gives a slow rate ✓

***Compromise:*** idea of a compromise between rate and equilibrium amount ✓

7 marking points ⟶ 6 max

***Clear, well-organised, using specialist terms*** ✓

[7]

(b)(i)

***what citric acid does:*** citric acid dissociates ✓

$H^+$ released / $H_2O$ accepts $H^+$/behaves as a base ✓

***equation:*** $H_3A + 3H_2O \longrightarrow 3H_3O^+ + A^{3-}$

*or* $H_3A \longrightarrow 3H^+ + A^{3-}$

*or* $H_3A + H_2O \longrightarrow H_3O^+ + H_2A^-$

*or* $H_3A \longrightarrow H^+ + H_2A^-$ ✓ (or other intermediate dissociation)

*The equation alone will also score the 2 'what citric acid does' marks.*

***how $H^+$ reacts:*** $H^+$ now reacts with $HCO_3^-$ ions/$NaHCO_3$ ✓

***equation:*** $H^+ + HCO_3^- \longrightarrow H_2O + CO_2$ ✓

*The equation alone will also score the 'how $H^+$ reacts' mark.*

5 marks ⟶[4] max

(ii) Molar mass of $NaHCO_3$ = 84.0 ✓

amount of $NaHCO_3$ = 0.5/84.0 = 5.95 x $10^{-3}$ mol ✓

3 mol $NaHCO_3$ reacts with 1 mol citric acid ✓

amount of citric acid = 5.95 x $10^{-3}$/3 = 1.98 x $10^{-3}$ mol ✓

mass of citric acid required = 1.98 x $10^{-3}$ x 192 = 0.380 g ✓

*(allow 0.4 g)*

***Answer of 0.127g / 0.12698 g from dividing by 3 twice*** ⟶ ✓✓✓✓x

[5]

**[Total: 16]**