2021학년도 2학기 화학2 중간고사 답안

1. (a) $\Delta E = q + w$

$= q - P\Delta V$

$= q_p - P\Delta V$ (at const. P)

$\therefore q_p = \Delta E + P\Delta V$

$H = E + PV$

$\therefore \Delta H = \Delta E + P\Delta V + V\Delta P$ ($\Delta P = 0$ at const. P)

$\Delta H = \Delta E + P\Delta V$

$\therefore \underline{\Delta H = q_p \text{ (at const. P)}}$

(b) $G = H - TS$

$\therefore \Delta G = \Delta H - T\Delta S - S\Delta T$ ($\Delta T = 0$ at const. T)

$= \Delta H - T\Delta S$

$\therefore -\frac{\Delta G}{T} = -\frac{\Delta H}{T} + \Delta S$

$= -\frac{q_p}{T} + \Delta S$

$= \Delta S_{surr}$

$= \Delta S_{surr} + \Delta S_{sys} = \Delta S_{univ}$

$\therefore \underline{\Delta S_{univ} = -\frac{\Delta G}{T}}$

자발적 과정에서 $\Delta S_{univ} > 0 \Longrightarrow$ 자발적 과정에서 $\Delta G < 0$.

T는 항상 양수 (T: Kelvin 온도)

2. ① $H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$ $\quad \Delta H_{for}^{\circ} = -285.8\ kJ/mol$

② $\frac{1}{2}N_2O_5(g) + \frac{1}{2}H_2O(l) \rightarrow HNO_3(l)$ $\quad \Delta H_{rxn}^{\circ} = -38.3\ kJ/mol$

③ $\frac{1}{2}N_2(g) + \frac{3}{2}O_2(g) + \frac{1}{2}H_2(g) \rightarrow HNO_3(l)$ $\quad \Delta H_{for}^{\circ} = -174.1\ kJ/mol$

$2\times③ - ① - 2\times②$

$= N_2(g) + \frac{5}{2}O_2(g) \rightarrow N_2O_5(g)$

$\therefore N_2O_5$의 생성 엔탈피 (ΔH_{for}°)

$2\times(-174.1\ kJ/mol) - (-285.8\ kJ/mol) - 2\times(-38.3\ kJ/mol)$

$= \underline{14.2\ kJ/mol}$

3.

$$2N_2O_5(g) \longrightarrow 4NO_2(g) + O_2(g)$$

(a) $\text{Rate} = -\frac{\Delta[N_2O_5]}{\Delta t} = k[N_2O_5]$

(b) $-\frac{d[N_2O_5]}{dt} = k[N_2O_5]$

$$-\frac{d[N_2O_5]}{[N_2O_5]} = k\,dt$$

$$d(\ln[N_2O_5]) = -k\,dt$$

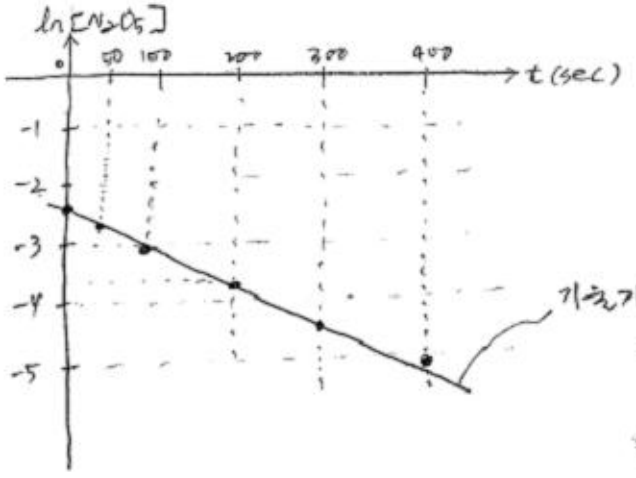
$$\ln[N_2O_5]\Big|_{[N_2O_5]_0}^{[N_2O_5]} = -kt\Big|_0^t$$

$$\ln[N_2O_5] - \ln[N_2O_5]_0 = -kt$$

$$\therefore \ln[N_2O_5] = -kt + \ln[N_2O_5]_0$$

(c)

$[N_2O_5]$ (M)	시간 (sec)	$\ln[N_2O_5]$
0.100	0	−2.30
0.0707	50	−2.65
0.0500	100	−3.00
0.0250	200	−3.69
0.0125	300	−4.38
0.00625	400	−5.08



기울기 $= -k$

$= \frac{-5.08-(-2.30)}{(400-0)\,\text{sec}}$

$= -6.95\times10^{-3}\,\text{sec}^{-1}$

$\therefore k = 6.95\times10^{-3}\,\text{sec}^{-1}$

(d) 반감기 $= 100$ sec

4. (a) Arrhenius Eq.

$$k = A e^{-Ea/RT}$$

$$\ln k_1 = \ln A - \frac{Ea}{RT_1} \quad \cdots ①$$

$$\ln k_2 = \ln A - \frac{Ea}{RT_2} \quad \cdots ②$$

① − ②

$$\ln\left(\frac{k_1}{k_2}\right) = -\frac{Ea}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

(b) $T_1 = 20°C = 293K$, $k_1 = 2.00 \times 10^{-5}\ sec^{-1}$

$T_2 = 50°C = 323K$, $k_2 = 9.10 \times 10^{-4}\ sec^{-1}$

$$Ea = \frac{-\ln\left(\frac{k_1}{k_2}\right) R}{\frac{1}{T_1} - \frac{1}{T_2}} = -\frac{\ln\left(\frac{2.00 \times 10^{-5}}{9.10 \times 10^{-4}}\right) \times 8.3145\ J/K \cdot mol}{\frac{1}{293K} - \frac{1}{323K}}$$

$$= 1.00 \times 10^5\ J/mol$$

5. $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$, $K = 6.12 \times 10^{-2}$

(a) $$Q = \frac{[NH_3]_0^2}{[N_2]_0[H_2]_0^3} = \frac{(1.00 \times 10^{-5})^2}{(1.00 \times 10^{-3})(2.00 \times 10^{-3})^3} = 12.5$$

(b) $Q > K$ ∴ 역반응이 자발적

6.

(a) 정반응

(b) 역반응

(c) 정반응

(d) 무변화

(e) 역반응

(f) 정반응

17. (a)

	CH_3COOH	$\rightleftharpoons$ H^+	+ CH_3COO^-
처음	1.00 M	0 M	0 M
평형	(1.00 − x) M	x M	x M

$$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]} = \frac{x^2}{1.00 - x \simeq 0}$$

$\therefore x = [H^+] = \sqrt{K_a}$ — ①

$pH = -\log[H^+] = 2.37$ $\therefore [H^+] = 10^{-2.37} = 4.26 \times 10^{-3}$ M — ②

②→①

$$K_a = [H^+]^2 = (4.26 \times 10^{-3})^2 = 1.82 \times 10^{-5}$$

(b)

$CH_3COONa \rightarrow CH_3COO^- + Na^+$ 완전해리

1.00 M → 1.00 M 1.00 M

	CH_3COOH	$\rightleftharpoons$ H^+	+ CH_3COO^-
처음	1.00 M	0 M	1.00 M
평형	(1.00 − x) M	x M	(1.00 + x) M

$$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]} = \frac{x \cdot (1.00 + x \simeq 0)}{1.00 - x \simeq 0} = 1.82 \times 10^{-5}$$

$\therefore x = [H^+] = 1.82 \times 10^{-5}$ M

$\therefore pH = -\log[H^+] = -\log(1.82 \times 10^{-5}) = 4.74$

(c)

NaOH의 양 = 0.0100 M × 10 mL = 0.000100 mol = 1.00×10^{-4} mol

전체 부피 = 500 mL

$$\therefore [NaOH] = \frac{1.00 \times 10^{-4}\ \text{mol}}{500\ \text{mL}} = \frac{2.00 \times 10^{-4}\ \text{mol}}{1000\ \text{mL}} = 2.00 \times 10^{-4}\ \text{M}$$

$NaOH \rightarrow Na^+ + OH^-$ 완전해리

$\therefore [OH^-] = 2.00 \times 10^{-4}$ M

$$[H^+] = \frac{K_w}{[OH^-]} = \frac{10^{-14}}{2.00 \times 10^{-4}} = 0.5 \times 10^{-10}\ \text{M}$$

$\therefore pH = -\log[H^+] = 10.3$

7 · (cont'd)

(d) $CH_3COOH + OH^- \longrightarrow CH_3COO^- + H_2O$ (NaOH) 완전 반응

	CH_3COOH	OH^-	CH_3COO^-
반응전	1.00 M (×490 mL) = 490 mmol	0.200 M (×10 mL) = 2.0 mmol	1.00 M (×490 mL) = 490 mmol
반응후	488.9 mmol ≃ 490 mmol	0 mmol	490.1 mmol ≃ 490 mmol

$$CH_3COOH \rightleftharpoons H^+ + CH_3COO^-$$

	CH_3COOH	H^+	CH_3COO^-
처음	490 mmol	0 mmol	490 mmol
평형	(490−x) mmol	x mmol	(490+x) mmol

$$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]} = \frac{\frac{x}{500}\ \frac{490+x}{500}\ (\simeq 0)}{\frac{490-x}{500}\ (\simeq 0)} = 1.82\times10^{-5}$$

$\therefore x = 1.82\times10^{-5} \times 500$ (mmol)

$\therefore [H^+] = \frac{x \text{ mmol}}{500 \text{ mL}} = 1.82\times10^{-5}$ M

$\therefore$ pH $= -\log[H^+] = -\log(1.82\times10^{-5}) = 4.74$

8 (a) NaOH의 몰수 $= \frac{\text{질량}}{\text{분자량}} = \frac{20.0\text{ g}}{(23.0+16.0+1.0)\text{ g/mol}} = 0.500$ mol

$[NaOH] = \frac{\text{몰수}}{\text{부피}} = \frac{0.500 \text{ mol}}{1.00 \text{ L}} = 0.500$ M

(b) $NV = N'V'$ (HF, NaOH)

$\therefore N = \frac{N'V'}{V} = \frac{0.500\text{M} \times 200\text{mL}}{100\text{ mL}} = 1.00$ M

$\therefore [HF] = 1.00$ M

8. (cont'd)

(c)

$$HF + OH^- \xrightarrow{NaOH} F^- + H_2O \quad \text{완전 반응}$$

	HF	OH^-	F^-
반응전	1.00 M (×100 mL) = 100 m mol	0.500 M (×200 mL) = 100 m mol	0 m mol
반응후	0 m mol	0 m mol	100 m mol

$$F^- + H_2O \longrightarrow HF + OH^-$$

	F^-	HF	OH^-
처음	100 m mol	0 m mol	0 m mol
평형	(100 − x) m mol	x m mol	x m mol

$$\therefore K_b = \frac{[HF][OH^-]}{[F^-]} = \frac{\frac{x}{300}\cdot\frac{x}{300}}{\frac{100-x}{300}} \approx \frac{K_w}{K_a} = \frac{10^{-14}}{7.2\times10^{-4}} = 1.39\times10^{-11}$$

$$\therefore x^2 = 1.39\times10^{-11}\times 30{,}000 = 4.17\times10^{-7}$$

$$\therefore x = 6.46\times10^{-4}\ \text{m mol}$$

$$\therefore [OH^-] = \frac{6.46\times10^{-4}\ \text{m mol}}{300\ \text{mL}} = 2.15\times10^{-6}\ \text{M}$$

$$\therefore [H^+] = \frac{K_w}{[OH^-]} = \frac{10^{-14}}{2.15\times10^{-6}} = 4.65\times10^{-9}\ \text{M}$$

$$\therefore pH = -\log[H^+] = -\log(4.65\times10^{-9}) = 8.33$$